TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

AGENDA

Day 1: October 31, 2000

GSFC Introduction	Wolff	15 Minutes	8:00 - 8:15	Page 4
Program Management	Grant	45	8:15 - 9:00	Page 14
Science	Yee	45	9:00 - 9:45	Page 97
BREAK		**15**	**9:45 - 10:00**	
System	Kusnierkiewicz	90	10:00 -11:30	Page 128
Software	Chu	60	11:30 - 12:30	Page 195
LUNCH		**45**	**12:30 - 1:15**	
R&QA	Ali	30	1:15 - 1:45	Page 231
<u>SPACECRAFT</u>				
IEM	Marth	30	1:45 - 2:15	Page 261
Processors	Perschy	15	2:15 - 2:30	Page 274
SSR	Bogdanski	15	2:30 - 2:45	Page 308
Cdm/Tlm I/F	Oden	15	2:45 - 3:00	Page 319
C&DH Software	S. Williams	30	3:00 - 3:30	Page 330
BREAK		**15**	**3:30 - 3:45**	
RF Comm	DeBoy	15	3:45 - 4:00	Page 526
GNS	Heins	60	4:00 - 5:00	Page 466
GNS Software	Chacos	45	5:00 - 5:45	Page 394

AGENDA

Day 3: November 2, 2000

SPACECRAFT CONTINUED

IEM (CONT'D)

Boot Code	Schneider	45 Minutes	8:00 - 8:45	Page 359
RIU	Reiter	15	8:45 - 9:00	Page 1004
DC/DC Converters	Temkin	15	9:00 - 9:15	Page 1014
Power System	Butler	60	9:15 - 10:15	Page 1030
BREAK		**15**	**10:15 - 10:30**	
G&C	Radford	15	10:30 - 10:45	Page 1070
G&C Software	Wilson	60	10:45 - 11:45	Page 918
Autonomy	Harvey	60	11:45 - 12:45	Page 786
LUNCH		**45**	**12:45 - 1:30**	
Mission Operations	Knopf	60	1:30 - 2:30	Page 715
Ground System	Rodberg	60	2:30 - 3:30	Page 682
BREAK		**15**	**3:30 - 3:45**	
MOC	Mitnick	30	3:45 - 4:15	Page 610
Ground Station	Gemeny	30	4:15 - 4:45	Page 578
MDC	Lafferty	30	4:45 - 5:15	Page 545

AGENDA

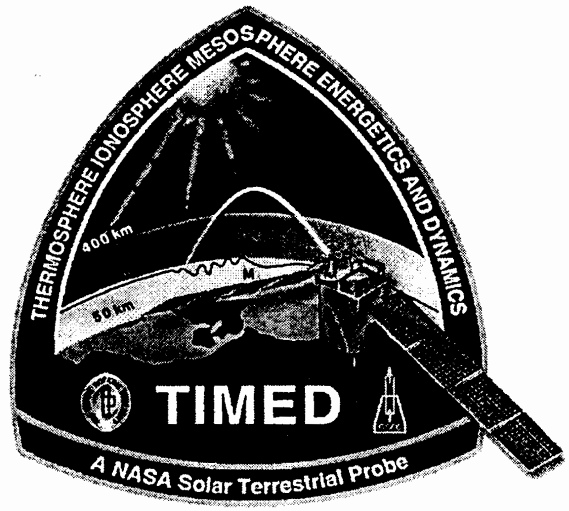
Day 4: November 3, 2000

Mechanical	Vernon	30 Minutes	8:00 - 8:30	Page 869
Solar Array Deployments	Vernon	30	8:30 - 9:00	Page 892
Launch Vehicle Interfaces	Vernon	30	9:00 - 9:30	Page 984
Alignments/Error Budget	Sadilek	30	9:30 - 10:00	Page 970
BREAK		**15**	**10:00 - 10:15**	
Thermal	B. Williams	45	10:15 - 11:00	Page 836
FMEA, FTA, PRA	Farmer, STi	60	11:00 - noon	
Safety	Dion	30	Noon - 12:30	Page 1014
Conclusion/Wrap-up	ALL			

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000



Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) Project

Overview to Red Team Committee

John Wolff- NASA/GSFC

Introduction/Background

The TIMED Mission is the first science mission in the Solar Terrestrial Probe Program. The TIMED Mission will explore the Earth's Mesosphere and Lower Thermosphere/Ionosphere (MLTI) region. (60 to 180 km)

A Science Definition Team (SDT) was established in December 1990, by NASA's Space Physics Division to develop a satellite program for exploration of the MLTI region, which resulted in the TIMED Mission. Phases A/B Definition Studies were conducted by GSFC's Flight Projects Directorate (FPD) during 1991, to develop the mission concept defined by the SDT.

The original TIMED Mission consisted of two identical spacecraft carrying nine instruments each. The operation lifetime of each spacecraft would be 2 years with a design goal of 5 years.

The TIMED Mission was removed from GSFC, and through a restructuring process was downsized to one spacecraft and four instruments. In 1994, NASA HQ assigned responsibility for performing the Phase C/D effort to the JHU/APL.

The JHU/APL assumed overall management of the mission definition, including the preliminary design of the spacecraft, the development of four science investigations, and development of mission operations concept.

Introduction/Background Continued

• In August 1996, Dr. Wes Huntress, the AA at NASA HQ OSSA, designated the GSFC as the contracting center for NASA tasks to be implemented with JHU/APL. This effort was previously funded by NASA HQ under the Navy SPARWAR/NAVSEA contract.

• Two contracts were planned for JHU/APL:
- •TIMED Mission NAS5-97179
- •Agency-Wide General Aerospace Contract (GAC) NAS5-97271

•In June 1997 a letter contract for TIMED was issued to JHU/APL and was definitized in December 1997.

• The GAC was awarded to JHU/APL in October 1997.

• The GAC is task order type contract and has a soft contract value of $500 Million.

• In December 1996, NASA HQ's co-manifested the Code Y Jason-1 Mission and TIMED on a Delta 2920 to be launched from VAFB in January 2000. Later changed to May 2000 then to October, then to December, then to February 2001, and finally March 7, 2001.

Milestones/Reviews

PDR ....February 1997
NAR.....................................February 1997
CDR....................................December 1997
PCA.....................................March 1998
IAR......................................July 1998
Post T & E Review................February 2000
MOR....................................June 2000
RED TEAM.........................October – November 2000
FOR.....................................November 2000
PRESHIP............................November 29, 2000

TIMED Project Management

NASA Project Manager	John J. Wolff
NASA Program Scientist	Dr. Mary M. Mellot
NASA Project Scientist	Dr. Richard A. Goldberg
JHU/APL Project Manager	Dave G. Grant
JHU/APL Project Scientist	Dr. J. H. Yee

TIMED Mission Science Team

Instrument Principal Investigators

A. B. Christensen	Aerospace Corporation	GUVI Instrument
T. L. Killeen*	University of Michigan	TIDI Instrument
J. J. Russell III	Hampton University	SABER Instrument
T. N. Woods	University of Colorado	SEE Instrument

*Now Director of NCAR

Interdisciplinary Investigators

Interdisciplinary Investigators

A. Smith	NCAR
J. M. Forbes	University of Colorado
D. C. Fritts	University of Colorado
J. U. Kozyra	University of Michigan
H. G. Mayr	NASA/GSFC
S. C. Solomon	NCAR

Ground-based Community Representatives

J. W. Meriwether	Clemson University
J. Thayer	SRI, International

TIMED Management Philosophy

TIMED to be managed in a "lite touch" mode.

- JHU/APL to manage the TIMED Mission for the GSFC.
- GSFC to exercise minimum oversight of JHU/APL.
- GSFC TIMED Project staffed with approximately 2 - 3 FTE's.
- JHU/APL internal policies a procedures to be used where applicable.

JHU/APL responsible for managing the instruments:

- SABER GFE from LaRC.
- SEE and TIDI under contract to JHU/APL.
- GUVI build and tested at JHU/APL.

JHU/APL responsible for MO & DA.

NASA/GSFC TIMED Project Organization

GSFC TIMED Project Manager
John Wolff
Project Administrative Assistant
Terri Hynson

Project System engineer (PT)
Bruce Campbell

Flight Assurance Manager (PT)
Ron Perison

Business Manager (PT)
Phil Shimkaveg

Contract Manager (PT)
James Debelius

Project Scientist
Dr. Richard Goldberg

-------Co-Location

GSFC Project Manager's Assessment

Assessment

- Project in good shape to meet a March 2001 Launch.
- JHU/APL has done a good job.

TIMED PROJECT OFFICE

David G. Grant
Project Manager
Tel: 240-228-5297
FAX: 240-228-5297
e-mail: david.grant@jhuapl.edu

The Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20723-6099

APL Organization

R. T. Roca	Director
I. M. Blatstein	Strategic Planning
J. C. Hagan	Chief of Staff
E. J. Hinman	Programs
R. E. Nimmo	Business Operations
E. M. Portner	Laboratory Operations

Executive Council
Operations Council
Science & Technology Council

Air Defense Systems Department
R. W. Constantine

Power Projection Systems Department
D. V. Kalbaugh

Space Department
S. M. Krimigis

Strategic Systems Department
D. L. Eddins

Submarine Technology Department
G. D. Tyler

Joint Warfare Analysis Department
R. E. Gingras

Research and Technology Development Center
J. C. Sommerer

Institute for Adv. Science & Technology in Medicine
V. L. Pisacane

Business & Information Services Department
L. C. Kohlenstein

Technical Services Department
R. A. Fletcher

Human Resources & Services Department
A. E. Kujawa

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The Space Department

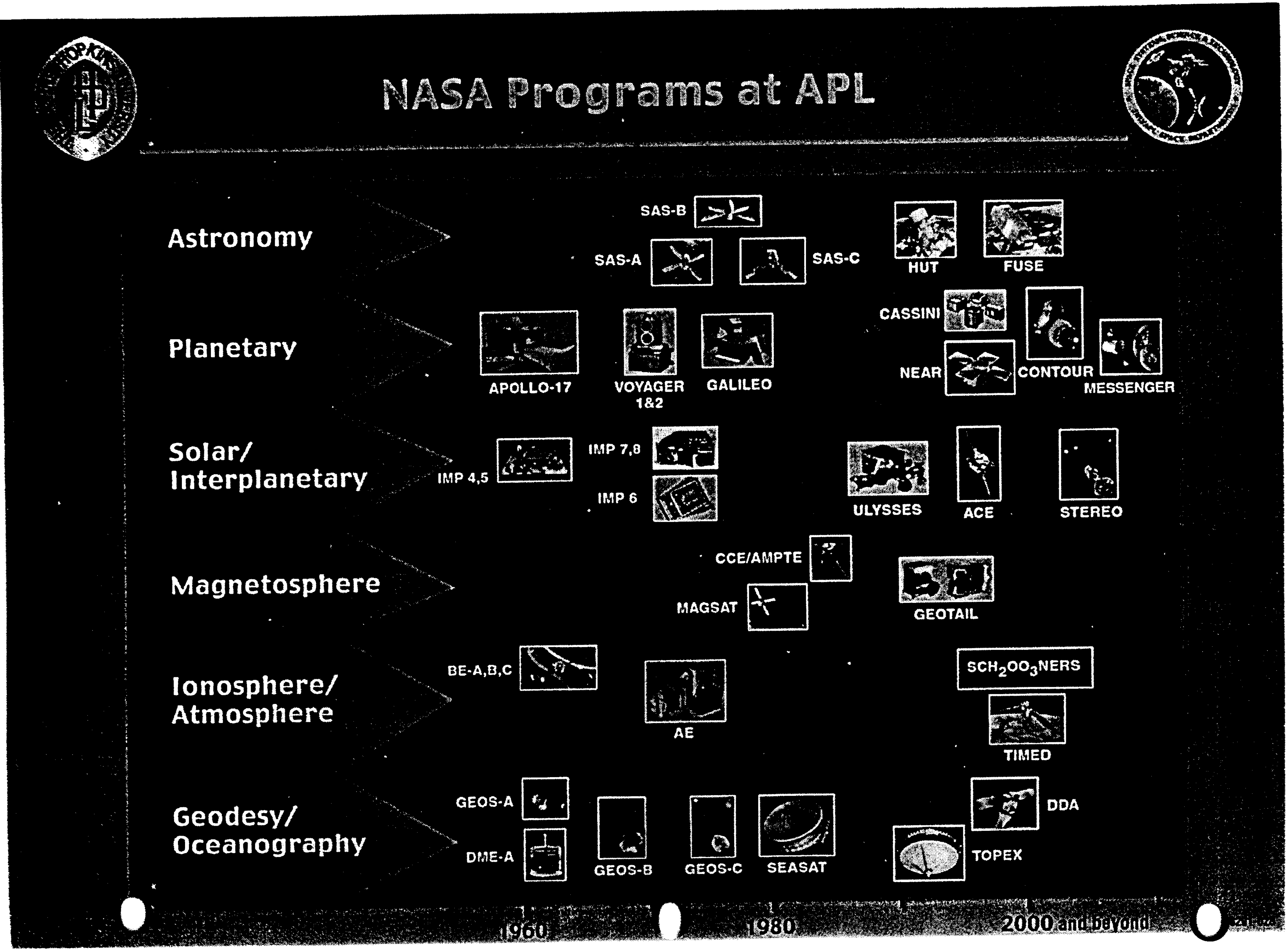
... creating innovative space systems for space physics, planetary exploration, navigation, oceanography, and environmental studies, including rapid, low-cost, end-to-end development.

Areas of Expertise

- End-to-End Definition, Design, and Implementation of Space Missions
- Space Science and Instrumentation
- Satellite Tracking & Navigation; Ultrastable Oscillators

Selected Programs

- MSX (Midcourse Space Experiment)
- NEAR (Near Earth Asteroid Rendezvous)
- ACE (Advanced Composition Explorer)
- FUSE (Far Ultraviolet Spectroscopic Explorer)
- TIMED (Thermosphere, Ionosphere, & Mesosphere Energetics and Dynamics)
- CONTOUR (Comet Nucleus Tour)
- MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging)
- STEREO (Solar TErrestrial Relations Observatory)


NASA Programs at APL
Astronomy
SAS-B
SAS-A
SAS-C
HUT
FUSE
Planetary
APOLLO-17
VOYAGER 1&2
GALILEO
CASSINI
NEAR
CONTOUR
MESSENGER
Solar/ Interplanetary
IMP 4,5
IMP 7,8
IMP 6
ULYSSES
ACE
STEREO
Magnetosphere
CCE/AMPTE
MAGSAT
GEOTAIL
Ionosphere/ Atmosphere
BE-A,B,C
AE
SCH$_2$OO$_3$NERS
TIMED
Geodesy/ Oceanography
GEOS-A
DME-A
GEOS-B
GEOS-C
SEASAT
DDA
TOPEX
1960
1980
2000 and beyond

Space Department

Space Department Head
S. M. Krimigis
Asst. Dept. Head for Business
L. J. Crawford
Asst. Dept. Head for Operation
W. L. Ebert
Program Manager
T.B. Coughlin
Chief Engineer
E. J. Hoffman

- **SOR**
  Reliability and Quality Assurance
  S. R. Purwin
  S. W. Ali
- **SOM**
  Management Systems Support
  S. L. Quinn
  A. Eisner
- **Office of Education and Outreach**
  K. B. Beisser
- **SE**
  Engineering and Technology Branch
  G. H. Fountain
  R. E. Gold
  - **SEA**
    Space Systems Applications
    W. S. Devereux
  - **SEE**
    Electronic Systems
    A. L. Lew
  - **SEI**
    Integration and Operations
    R. K. Huebschman
    E. H. Rodberg
  - **SEM**
    Mechanical Systems
    W. E. Skullney
  - **SER**
    RF Engineering
    M. L. Edwards
- **SR**
  Science and Analysis Branch
  C.-I. Meng
  - **SRA**
    Atmospheric and Ionospheric Remote Sensing
    R. A. Greenwald
  - **SRI**
    Space Science Instrumentation
    R. M. Henshaw
    R. L. McNutt
  - **SRM**
    Mission Concept and Analysis
    T. E. Strikwerda
    A.D. Goldfinger
  - **SRO**
    Ocean Remote Sensing
    R. F. Gasparovic
    R. K. Raney
  - **SRP**
    Space Physics
    R. W. McEntire
  - **SRS**
    Software and Data Systems
    L. L. Suther
    K. J. Heeres
    M. I. Chu
- **Program Development Managers**
  J. F. Appleby
  R. E. Dove
  D. J. McMorrow
- **Program Managers**
  M. C. Chiu
  D. G. Grant
  J. T. Mueller
  C. T. Pardoe
  M. R. Peterson
  J. J. Suter
  B. E. Tossman

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The Technical Services Department

... providing mechanical and electrical engineering, design, fabrication, and test capabilities for a broad spectrum of APL programs.

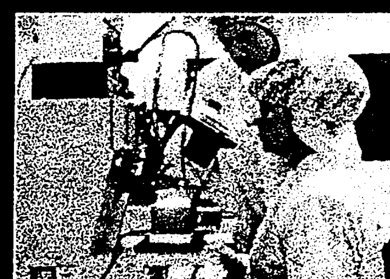
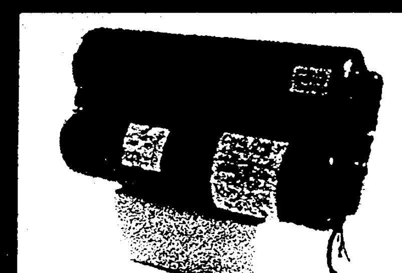
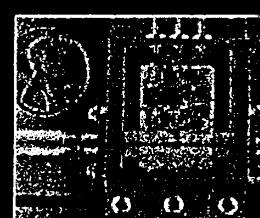
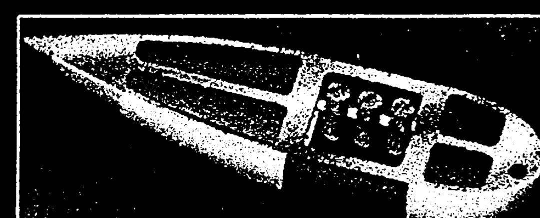
Areas of Expertise

Electronic & Integrated Circuit Design
Electronic Fabrication, Assembly, & Test
Mechanical Design & Analysis
Mechanical Fabrication & Assembly
Composite Design & Fabrication
Materials Characterization, Analysis, Testing, & Qualification

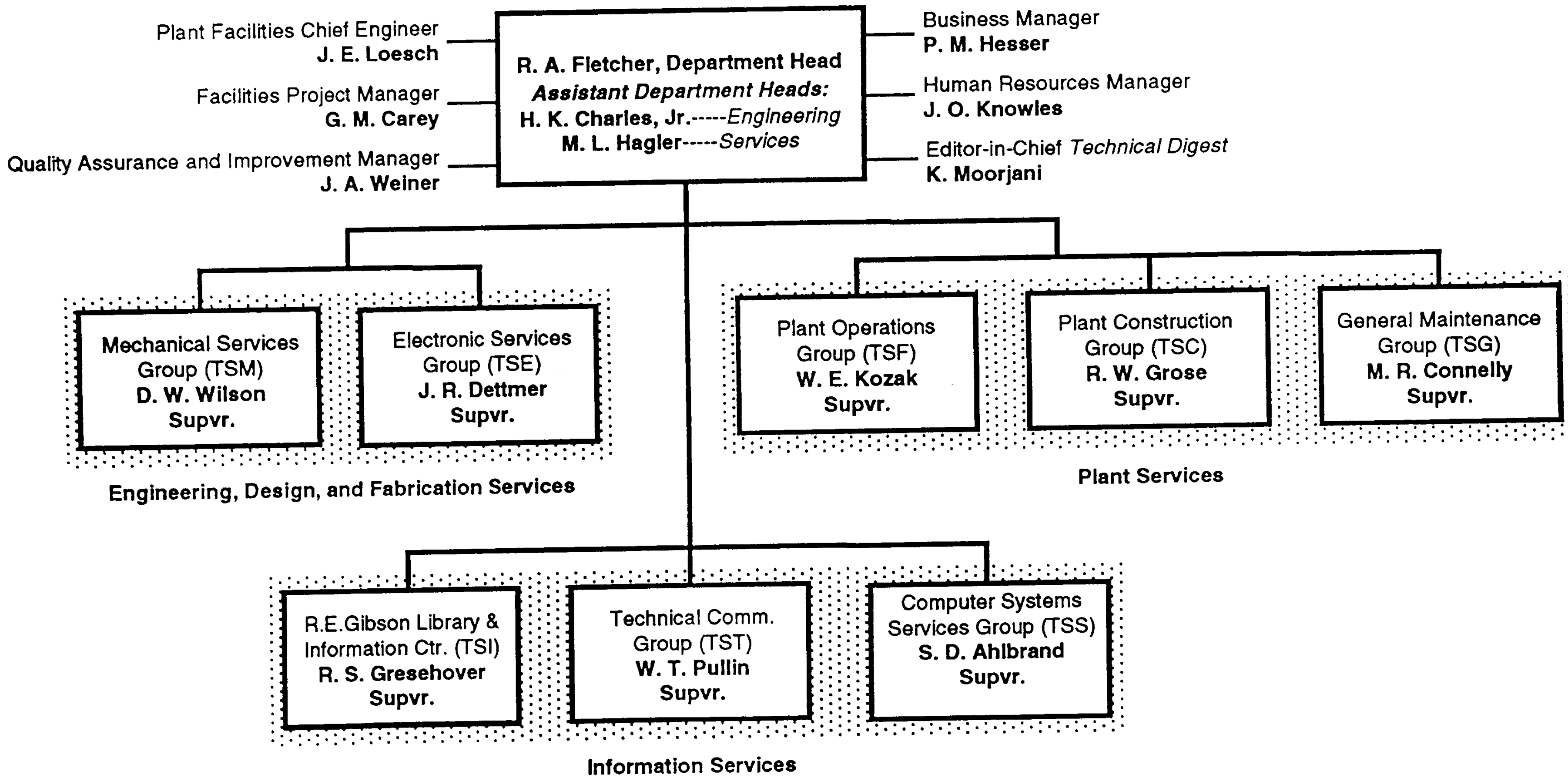
Selected Application Areas

Space Systems & Instruments
Shipboard Instrumentation & Underwater Devices
Sensors & Sensor Systems
Biomedical Devices, Components, & Systems
Advanced Materials
Advanced Electronic Packaging
Reengineering, Technology Transfer & Insertion



TSD Organization Chart



- TIMED Is A Design To Cost Mission

TIMED Management Approach

- Based Upon NEAR Program "B, F, C" Paradigm
- Streamlined Management
  - APL/SD Allows Program Managers Wide Decision Making Latitude
- Seasoned System Engineers, Major Program Element Leads
  - Delegation of Technical Authority, Responsibility
- Subsystem Lead Engineer Empowerment
  - Experience
  - Stability
  - End-to-End Commitment

TIMED Program

Roles and Responsibilities

NASA
TIMED Program Office
Program Executive: V. Elsbernd (HQ)
Program Manager: J. Wolff (GSFC)
Program Scientist: M. Mellott (HQ)

JHU/APL Space Department
Department Head: S. M. Krimigis
Programs Manager: T. Coughlin

Product Assurance
S. Ali
H. Utterback

Resource Manager
D. Bennett

JHU/APL
TIMED Project Office
Project Manager: D. Grant
Project Scientist: S. Yee
Project Administrator: M. A. Haug

Science Working Group
Project Scientist: S. Yee
A. Smith/A. Christensen/J. Forbes/D. Fritts/
T. Killeen/J. Kozyra/H. Mayr/J. Russell/
S. Solomon/T. Woods

Ground Based Science Teams

Mission System Engineer
D. Kusnierkiewicz
Mission Software Engineer
M. Chu

Mission Autonomy Engineer
R. Harvey

Mission Ops. Mgr.
W. Knopf

Mission Ops. Team
R. Nordeen
M. Packard (SS)
R. Dragonette (SS)
P. Boie (SS)
C. Kowal
D. Tady
G. Chiu
PJ Clark
D. Wichard
S. Lundfelt

Int. & Test Director
S. Kozuch

I&T Engineers
M. Colby
M. Hill
H. Nguyen
R. Bachtell
V. Bailey
S. Dion (Safety)
J. Coopersmith (Contam.)

Ground Sys. Eng.
P. Grunberger
E. Rodberg
H. Winters (SW)

Mission Ops. Center
E. Rodberg
W. Mitnick (LSE)

Ground Station
S. Gemeny

Mission Data Center
P. Lafferty

Payload Ops. Centers
SABER - R. Grube
TIDI - D. Gell
GUVI - B. Ogorzalek
SEE - G. Tate

S/C Sys. Eng.
D. Kusnierkiewicz
Flight Software
M. Chu

Mechanical - S. Vernon
Structure - E. Schaefer
Power - G. Dakermanji
G&C - W. Radford
- D. Wilson (LSE)
RF Comm. - R. Bokulic
Navigation - W. Devereux
- A. Chacos (LSE)
C&DH - J. Perschy
- S. Williams (LSE)
Thermal - B. Williams
IEM - P. Marth
EMC - G. Seylar
Mfg. - R. Stanford
- J. Hogan
- J. Weiner

Payload Manager
E. Prozeller
Payload Sys. Eng.
K. Heffernan
Payload Software
R. Gary

SABER - D. Fort (TDA)
GUVI - B. Ogorzalek (SE)
SEE - A. El Dinary (TCM)
TIDI - D. Mehoke (TCM)

Q6

TIMED Management Approach

- Use Proven APL Technical Practices and Procedures. Strong NASA Heritage. Value Added Requirement. P&P are Simplified and Accessible.
  - Reviews
  - Tests
  - R&QA
  - Documentation

TIMED Management Approach

– RFA's

- Peer Reviews; Closure of Action Items Responsibility of Subsystem Lead Engineer. Formal Documentation or Tracking Not Required at Project Level.

- System Level Reviews; Closure Indicated Via Subsystem Lead Engineer Memo. Spacecraft System Engineer Delegated RFA Review/Approval Authority. Documentation/Tracking Via PA Office.

TIMED Management Approach

- PFR's, SPR's
  - PFR Process Starts at Subsystem Level Acceptance Testing
  - SPR Process Starts Upon Delivery of Software
  - Spacecraft System Engineer , Spacecraft SW Engineer Delegated Review/Approval Authority
  - Anomaly Goes Through Reporting, Analysis, Corrective Action, Verification, Concurrence of CCB (HW/SW)
  - Documentation, Tracking via PA Engineering

TIMED Management Approach

– Waiver
  - Performance Does Not Meet Specifications
  - Subsystem Lead Engineer Submits Written Request
  - Spacecraft System Engineer, Spacecraft SW Engineer Granted Review/Approval Authority
  - Documentation, Tracking via PA Office

Note: All RFA, PFR, SPR or Waiver Closures with Implicit Changes in System Level Performance, Substantial Risk or Major Cost/Schedule Impact are Processed Through the Project Office.

TIMEDManagement Approach

- Communications
  - Spacecraft Status Meetings
    - Weekly, Ph.B Start Through I&T Start
    - Spacecraft System Eng. Chair, Full Design Team, PA, Mfg, etc.
    - Present Mechanical Status, Other Subsystem by Turn, Weight and Power Margins, Status All, Problems
    - Published Minutes

TIMED Management Approach

- Communications
  - Staff Meeting
    - Weekly, PHB Start Through I&T Start
    - Project Manager, Project Scientist, System Engineering Office, Program Element Leads
    - System Concerns, Schedule, Staffing
    - Top Five Problem List

TIMED Management Approach

- Communications
  - I&T Planning Meeting
    - Daily, I&T Start Through Launch
    - I&T Director Chair, I&T Team, MO Team, Ground System, Instruments
    - Assignments, milestones for Day, Near Team Schedule
    - Daily Update of I&T Plan

TIMED Management Approach

- Communications
  - MO Forum, Biweekly
  - Software Segment Leads, Biweekly
  - IEM Team, Weekly
  - G&C Team, Weekly
  - GNS Team, Weekly
  - R. F. Comm. Team, Weekly
  - Instruments
  - Etc.

TIMED Management Approach

- Oversight
  - Hands on Lightly
  - APL
    - Weekly Meeting with SD Programs Manager
    - Quarterly Status Brief with SD Head, SD MAC
  - NASA/GSFC
    - Weekly Status Brief with Program Manager
    - Monthly Status Brief with Program Manager
    - Immediate, Complete Disclosure of Serious Problems

Instrument Management Approach

- Consistent with "B, F, C"
- Small Oversite Team
- Fully Integrated Interaction (Engineer-to-Engineer)

TIMED Program

NASA TIMED Program Office
Program Executive – V. Elsbernd
Program Manager – J. Wolff NASA/GSFC
Program Scientist – M. Mellott NASA/HQ

JHU/APL TIMED Project Office
Project Manager – D. Grant
Project Scientist – S. Yee
Project Administrator – M. A. Haug

TIMED
Science Working Group

Payload Manager – Ed Prozeller
Payload System Engineer – Kevin Heffernan
Software Engineer – R. Gary

Product Assurance
L. Mastracci

Technical Direction
Agent
Dennis Fort

NASA 506

SABER
Jim Miller (PM)
Langley Research
Center

Langley Contract

Loren Zollinger
(PM)
Utah State Univ.
(SDL)

Technical Contract
Representative
Ashruf El-Dinary

APL Contract

SEE
Mike Anfinson
(PM)
Univ. of Colorado
(LASP)

Technical Direction
Representative
Doug Mehoke

APL Contract

TIDI
Chas. Edmonson (PM)
Univ. of Michigan
(SPRL)

Technical Direction
Agent
Bernie Ogorzalek

NASA Contract

GUVI
Tom Pardoe (PM)
APL/Aerospace

Ad-Hoc Technical
Support
Mechanical – Steve Vernon
Thermal – Bruce Williams
Structures – Ed Schaeffer
Optics – Keith Peacock
Detectors – Hugo Darlington
Alignment – Al Sadilek
Flight S/W – Steve Williams
Processors – Joe Bogdansky
+
GSFC Staff (for Reviews)
Joe Wonsever et. al

TIMED Instrument Management Organization

Instrument Management Approach

- Documentation
  - Product Assurance Implementation Plan (PAIP)
  - Software Development Plan (SDP)
  - Interface Control Document (ICD)
  - Instrument Calibration Plan (ICP)
  - Technical Requirements Specification (TRS)
  - Acceptance Test Plan (ATP)
- Reviews
  - CODR, PDR, CDR, PSR

Instrument Management Approach

Communications

- Weekly Telecons
- Monthly Management Updates
- Quarterly Technical Interchange Meetings (TIMs)
- Six-Month Management Reviews
- Instrument Accommodation Workshops

Instrument Milestones

	CoDR	IAW	PDR	CDR	ITW	PSR	Spacecraft Integration 1	2	3
SABER	Apr-95	Aug-96	Dec-96	Oct-97	May-98	Aug-99	Sep-99		
GUVI	May-95	Oct-96	Jan-97	Jan-98	Jun-98	May-99	May-99	Sep-99	Aug-00
SEE	Jul-95	Aug-96	Feb-97	Feb-98	Jul-98	May-99	Jun-99	Sep-99	Jul-00
TIDI	Oct-95	Aug-96	Jan-97	Apr-98	Jul-98	Oct-99	Oct-99	Jul-00	

Post integration activities

GUVI: 6/1/99: first Photek detector tube failure
2/10/00: second Photek detector tube failure
6/8/00: 1553 board failure

SEE: 7/27/99: SEE EGS planned removal for calibration at SURF
8/26/99: EGS vacuum door failure while at SURF
11/4/99: EGS HV control failure

TIDI: 6/8/00: Electronics unit removed for DC/DC converter rework and Cal lamp temp calibration.

TIMED Program Chronology of Significant Events

- TIMED Kickoff - 20 May 94
- Instrument Downselect - 5 Oct 94
- Systems Requirements Review - 14 Oct 94 HQ (R. Howard) Chair
- TIMED Conceptual Design Review - 14 Dec 94 APL (M. Chiu) Chair
- Instrument Design Phase - Feb 95
- Technology Insertion Assessment - Feb 95
- Technology Insertion Review - May 96
  - Integrated Electronic Module
  - Low Cost Mission Operations

Q1, Q2

TIMED Program Chronology of Significant Events

- Initiate TIMED Phase B - 10 Jun 96
- Preliminary Design Review - 18, 19 Feb 97
  APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair
- Non-Advocate Review - 20, 21 Feb 97
  HQ (P. Evanich) Chair
- Program Management Council Review - 21 Apr 97
  HQ (J. Dailey) Chair, Initiate Phase C/D
- Critical Design Review - 2, 3, 4 Dec 97
  APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair

TIMED Program Chronology of Significant Events

- Concept of Missions Operations Review - 14 May 98 APL/GSFC (E.Hoffman, J. Wonsover) Co-Chair
- Independent Annual Review - 7 Jul 98 HQ (P. Evanich), LaRC (J. Schick) Co-Chair
- Pre-Environmental Review - 26 Oct 99 APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair
- Post-Environmental Review - 29 Feb 00 APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair, Commence Spacecraft Controlled Storage

TIMED Program Chronology of Significant Events

- Exit Spacecraft Storage, Commence Testing - 1 Jun 00
- Mission Ops Review - 8 Jun 00
  APL/GSFC (E. Hoffman W. Mack) Co-Chair
- Red Team Review - 31 Oct 00, 1, 2, 3 Nov 00
  HQ (W. Taylor) Chair
- Flight Operations Review - 8, 9 Nov 00
  GSFC (W. Mack) Chair
- Pre-Ship Review - 29 Nov 00
  APL/GSFC Co-Chair
- Ship to Vandenberg - 11 Dec 00

TIMED Program Chronology of Significant Events

- Flight Readiness Review - TBD
  NASA Chair
- Mission Readiness Review - TBD
  NASA/GSFC Director Chair
- Launch Readiness Review - TBD
  NASA Chair
- Launch - 7 Mar 01

TIMED Program Chronology of Significant Events

- Initiate Phase C/D - 21 Apr 97
- APL/GSFC TIMED Letter Contract - 16 Jun 97
  Launch Date Jan 00
- Launch Date Revision Notification - 2 Feb 98
  Launch Date 15 May 00
- Launch Date Revision Notification - 27 Mar 00
  Launch Date 18 Oct 00
- Launch Date Revision Rumor - Apr 00
  Launch Date 15 Dec 00
- Launch Date Revision Notification - 31 Aug 00
  Launch Date 7 Mar 01

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program)
MANAGEMENT					
D. Grant (MS)	Princ. Prof. Staff	Staff	Project Manager	41	TOPAZ, ALTAIR, Polar BEAR
E. Prozeller (MS)	Princ. Prof. Staff	Staff	Payload Manager	36	NTBMD, MSX
SCIENCE					
S. Yee (PhD)	Princ. Prof. Staff	Dir. Atmospheric Sensing Technologies, JHU/APL	Project Scientist	27	UARS, MSX
A. Christensen (PhD)		Princ. Director, Space and Environment Technology Center, Aerospace Corp.	GUVI Principal Inv.		
T. Woods (PhD)	Sr. Research Scientist	Laboratory for Atmospheric and Space Physics, Univ. of Colorado.	SEE Principal Inv.		
J. Russell (PhD)	Professor	Co-Director, Center for Atmospheric Sciences, Hampton Univ.	SABER Principal Inv.		
T. Killeen (PhD)		Dir. National Center for Atmospheric Research	TIDI Principal Inv.		
SYSTEM ENGINEERING					
D. Kusnierkiewicz (MS)	Princ. Prof. Staff	Assistant Group Supervisor	Mission System Engineer	24	MSX,NEAR
M. Chu (PhD)	Sr. Prof. Staff	Assistant Group Supervisor	Mission Software Engineer	31	Hubble, GRO,EUVE, XTE, TRMM
R. Harvey (BS)	Sr. Prof. Staff	Section Supervisor	Autonomy System Eng.	16	Delta, MSX
P. Grunberger (BS)	Princ. Prof. Staff	Staff	Ground System Syst. Eng.	33	MSX, AGRE
R. Nordeen (BS)	Princ. Prof. Staff	Staff	Mission Operations Syst. Eng.	38	MSX, FUSE, Delta
K. Heffernan (MS)	Princ. Prof. Staff	Section Supervisor	Payload System Engineer	25	MSX, CONTOUR

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program
FLIGHT SUBSYS. DEV.					
Mechanical/Structural					
S. Vernon (BS)	Sr. Prof. Staff	Staff	Mechanical Lead	8	Cassini, MSX, EPIC
E. Schaefer (MS)	Sr. Prof. Staff	Staff	Structures Lead	30	NEAR, MSX
Thermal					
B. Williams (MS)	Sr. Prof. Staff	Staff	Thermal Lead	16	NEPSTEP, ACE
Power					
G. Dakermanji (PhD)	Princ. Prof. Staff	Section Supervisor	Power System Lead	31	NEAR, ACE, SAMPEX
M. Butler (MS)	Sr. Prof. Staff	Staff	Power Test, Solar Arrays	14	MSX, TOPAZ, NEAR
D. Temkin (MS)	Sr. Prof. Staff	Staff	Power Converters	17	NEAR, SAMPEX
Guidance and Control (G&C)					
W. Radford (BS)	Princ. Prof. Staff	Staff	G&C Lead	39	ACE, MSX, NEAR
W. Dellinger (PhD)	Sr. Prof. Staff	Staff	G&C Analyst	18	CONTOUR
L. Kennedy (MS)	Sr. Prof. Staff	Staff	G&C Test	25	Delta, MSX, NEAR
D. Wilson (BS)	Sr. Prof. Staff	Section Supervisor	G&C Software Lead	26	MSX, NEAR
RF Communications					
R. Bokulic (MS)	Princ. Prof. Staff	Assistant Group Supervisor	RF Communications Lead	18	MSX, NEAR
S. Cheng (MS)	Senior Prof. Staff	Staff	Downlink Board	18	Technology Development
C. Deboy (MS)	Sr. Prof. Staff	Staff	Uplink Board	10	MSX
R. Stilwell (MS)	Sr. Prof. Staff	Staff	Antennas	27	ACE, MSX
J. Goldman (MS)	Assoc. Prof. Staff	Staff	RF Communications Test	5	CONTOUR

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program
GPS Navigation System (GNS)					
W. Devereux (MS)	Princ. Prof. Staff	Group Supervisor	GNS Lead	20	Brilliant Pebbles
R. Heins (MS)	Princ. Prof. Staff	Staff	GNS Test	36	NEAR, MSX
R. DeBolt (MS)	Assoc. Prof. Staff	Staff	GNS Engineer	2	TOPEX, ACE
A. Chacos (MS)	Princ. Prof. Staff	Section Supervisor	GNS Software Lead	26	NEAR, MSX
Command and Data Handling (C&DH)					
J. Perschy (MS)	Princ. Prof. Staff	Staff	C&DH Lead	42	CONTOUR, ACE, NEAR, TOPEX
S. Oden (BS)	Princ. Prof. Staff	Staff	Crit. Cmd. Decoder	38	TOPEX, NEAR
J. Bogdanski (MS)	Sr. Prof. Staff	Staff	Solid State Recorder	24	ACE, NEAR, MSX
R. Reiter (BS)	Sr. Prof. Staff	Staff	Remote Interface Unit	22	MSX, ACE, NEAR, CONTOUR
S. Williams (MS)	Princ. Prof. Staff	Staff	C&DH Software Lead	25	MSX,NEPSTEP, ACE
S. Schneider (MS)	Sr. Prof. Staff	Staff	Boot Code Software Lead	26	NEAR, MESSENGER
Integrated Elec. Mod.					
P. Marth (MS)	Princ. Prof. Staff	Section Supervisor	Integrated Electronics Mod. Lead	39	TOPEX, DSRFS, CONTOUR
EMI/EMC					
G. Seylar (BS)	Sr. Prof. Staff	Staff	EMC Engineer	37	NEAR, MSX, ALTAIR, TOPEX
Product Assurance					
S. Ali (MS)	Prin. Prof. Staff	Assistant Group Supervisor	Product Assurance Lead	39	ACE,NEAR,FUSE,CASSINI
Manufacturing					
R. Stanford	Assoc.Prof.Staff	Staff	Mechanical Mfg. Lead	22	MSX,TOPEX,CASSINI,NEAR
J. Hogan	Assoc.Prof.Staff	Staff	Electronic Mfg. Lead	37	MSX,ACE,NEAR,CASSINI
J. Weiner (MS)	Prin.Prof.Staff	Staff	Mfg. Qual.Assur. Lead	29	MSX,NEAR

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (Yrs.)	Exp. (Program)
INTEGRATION AND TEST					
S. Kozuch (BS)	Sr. Prof. Staff	Staff	I&T Director	37	Delta, MSX, NEAR, MESSENGER
H. Nguyen (MS)	Assoc. Prof. Staff	Staff	Test Conductor	9	MSX, NEAR, ACE, CONTOUR
M. Hill (BS)	Sr. Prof. Staff	Staff	Test Conductor	9	MAP, FUSE, ACE, SOHO
M. Colby (BS)	Professional	Resident Subcontract Engineer	Test Conductor	24	MSX, NEAR, CONTOUR
V. Bailey (BS)	Professional	Resident Subcontract Engineer	Test Conductor	17	NEAR
R. Bachtell	Professional	Resident Subcontract Engineer	Test Engineer	15	Delta, NEAR, MSX, ACE
GROUND SYSTEM DEV.					
E. Rodberg (MS)	Princ. Prof. Staff	Assistant Group Supervisor	Ground System Lead	18	AMPTE, TOPEX, ACE
W. Dove (BS)	Sr. Prof. Staff	Staff	Mission Ops Center Lead	11	ACE, NEAR, MSX
W. Mitnick (BS)	Sr. Prof. Staff	Section Sup.	Mission Ops Center Software Lead	25	MSX, NEAR, ACE, CONTOUR
P. Lafferty (BS)	Sr. Prof. Staff	Staff	Mission Data Center Lead	13	MSX, Galileo, Cassini, NEAR
S. Gemeny	Sr. Prof. Staff	Staff	Ground Station Lead	20	INMARSAT, OSC, COMSAT
MISSION OPERATIONS					
W. Knopf (MS)	Sr. Prof. Staff	Staff	Mission Operations Manager	19	MSX, NEAR, Delta
M. Packard (MS)	Sr. Prof. Staff	Staff	Spacecraft Specialist (G&C)	10	MSX, NEPSTP, NEAR
R. Dragonette (MS)	Sr. Prof. Staff	Staff	Spacecraft Specialist (GNS)	13	MSX, NMD
P. Boie (BS)	Professional	Resident Subcontract Engineer	Spacecraft Specialist (C&DH)	7	MSX

SOR Management for the program

Stan Purwin

- BSEE, MSME, MBA
- 34 yrs professional experience in Engineering And Quality
- ASQ Certified Quality Manager

Syed Ali

- M.S. QA Engineering
- 27 yrs of Q.A.P.A. experience
- 20 yrs in Aerospace Fabrication process

Kim Cooper

- M.S. in Technical Management
- 19 yrs EEE reliability physics, & quality engineering
- 8 yrs NASA related projects

Heara Lee

- B.S. in Business Management
- 24 yrs experience in Materials Management
- 12 yrs experience on BMDO & NASA programs

Jim Kinnison

- B.S., M.S., Physics
- 13 yrs experience in Radiation Effects
- 13 yrs expereience for NASA & BMDO

SOR Key Staff for the program

Carlos Castillo

- B.S. in Engineering Technology
- 20+ yrs Quality Assurance experience
- 10 yrs NASA related

Jonathan Coopersmith

- BA Physics, University of Virginia, 1986.
- 13 yrs experience in clean room operations
- 13 yrs experience in scientific contamination control

John Farnan

- B.S. Business Management
- 17 yrs experience in Materials Management
- 17 yrs experience in DoD, BMDO and NASA programs

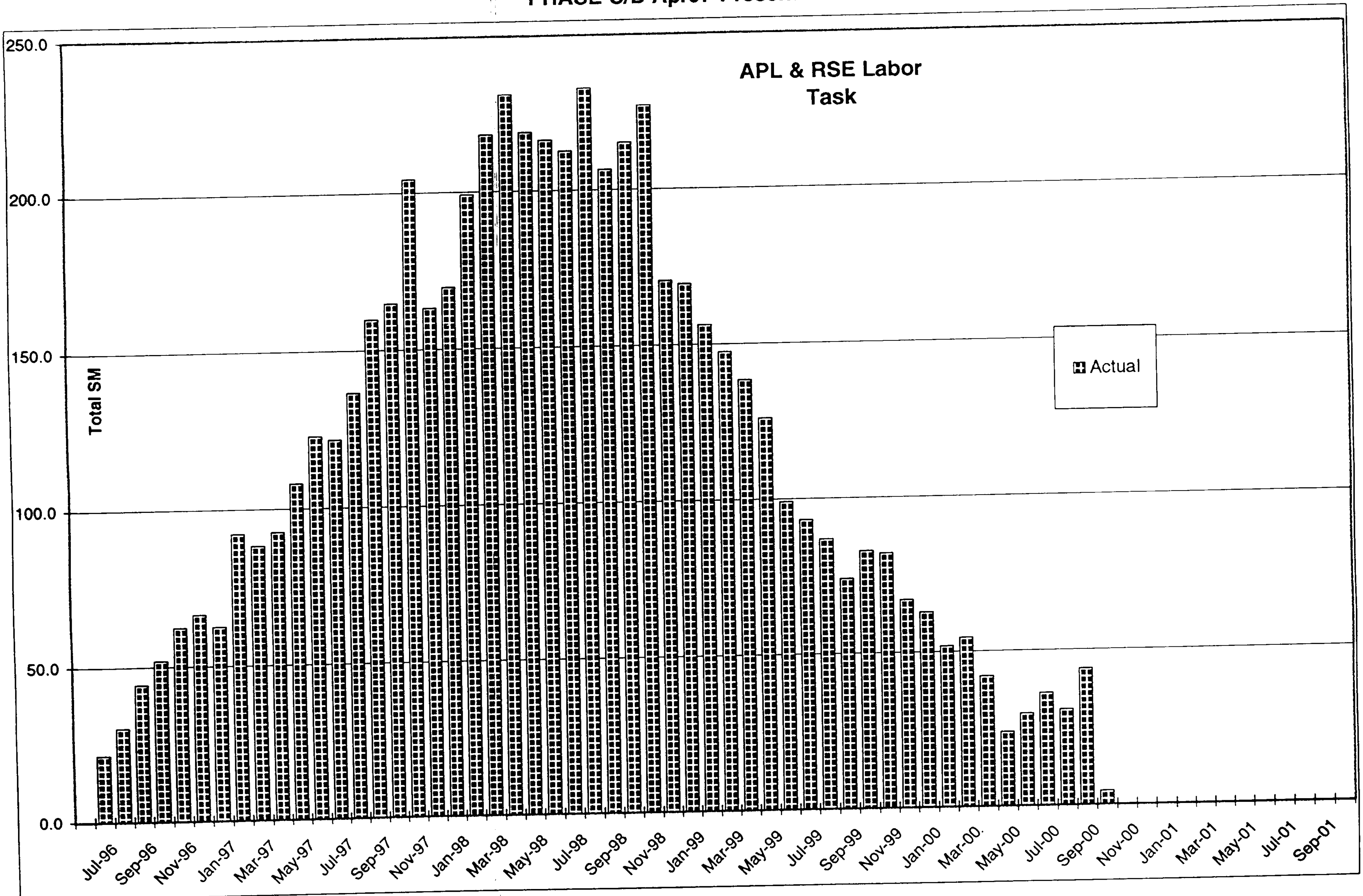
Juan Lander

- M.S. in Computer Science
- 17 yrs experience in component testing
- 14 yrs NASA related projects

Andy Moor

- M.S. Engineering Management
- 13 yrs experience space reliability parts engineering
- 10 yrs NASA based program

TIMED (ICR)
Manpow... ...ctuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



Program Plots LaborMMAll

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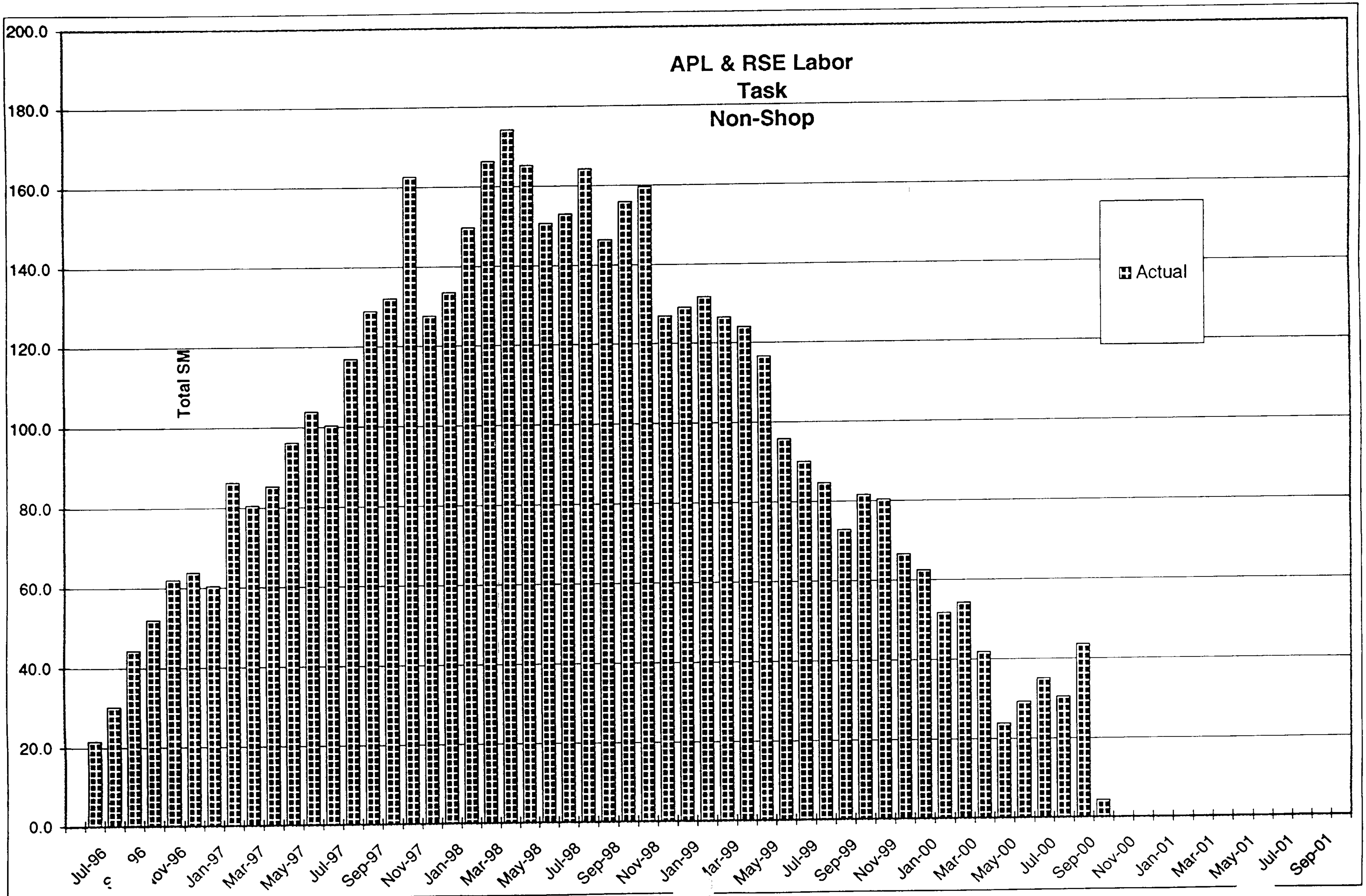
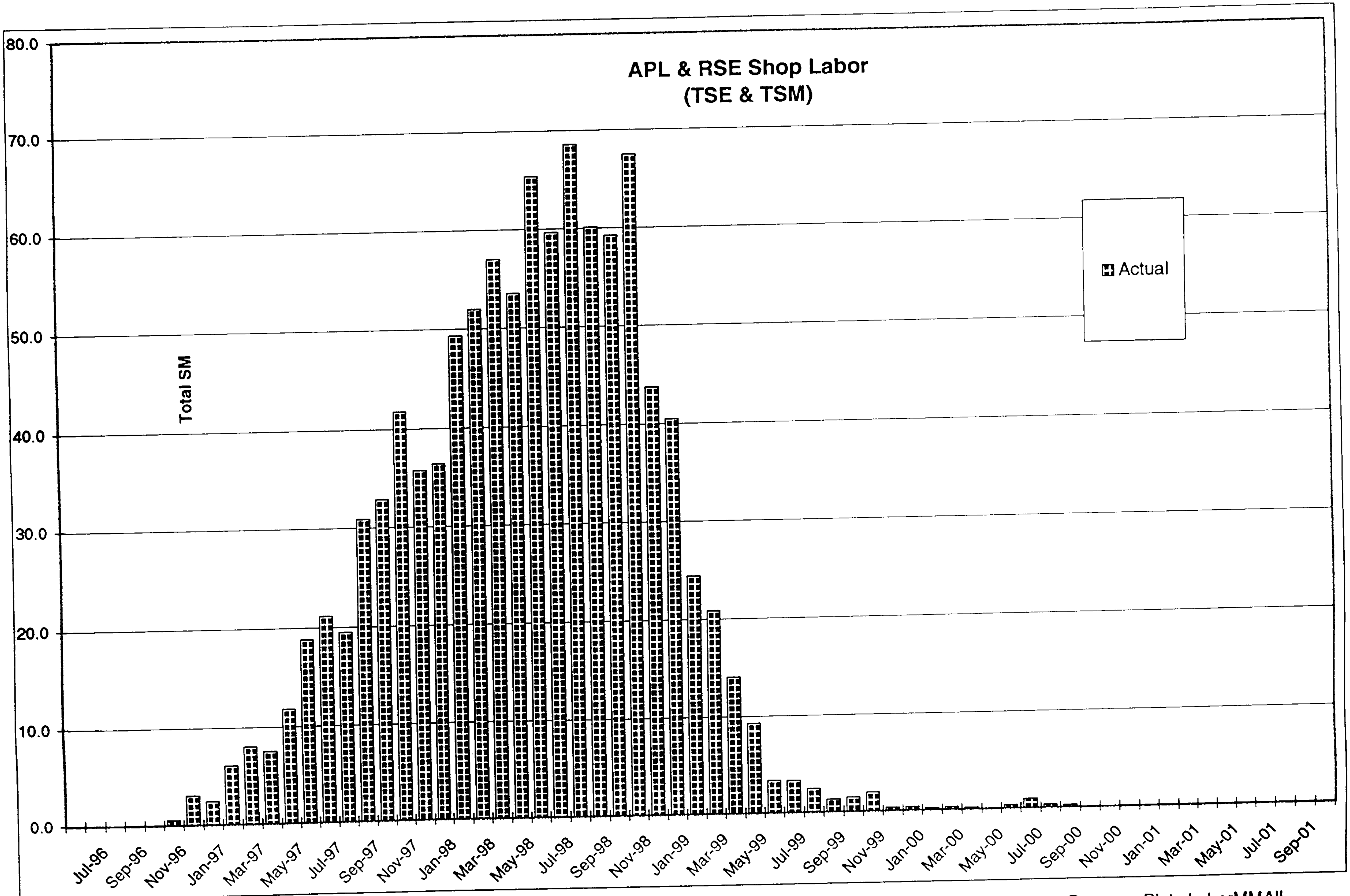
TIMED (ICR)
Manpower Actuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



TIMED (CR)
Manpower Actuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



Program Plots LaborMMAll

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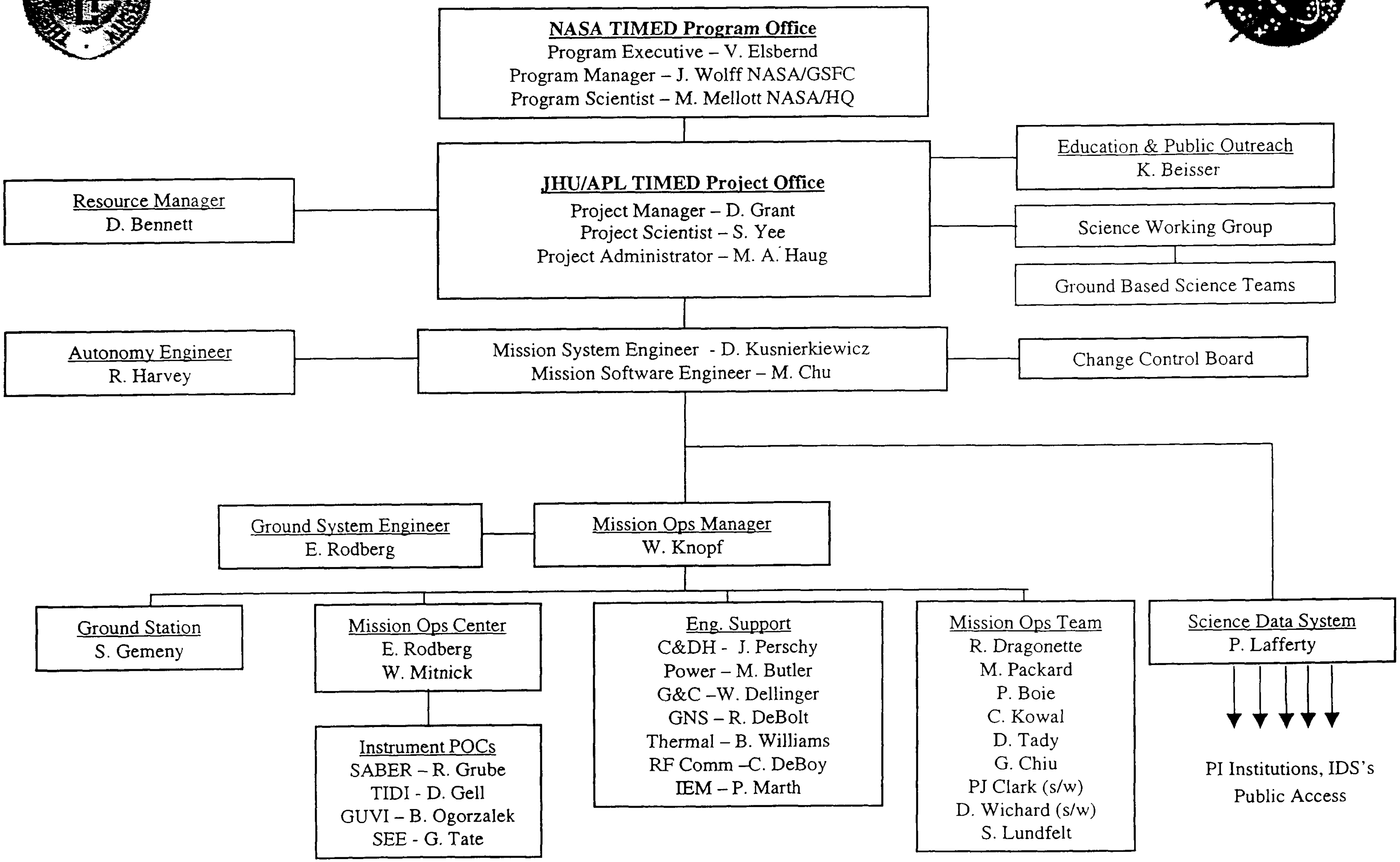
TIMED Management Approach

- What Are We About
  - Test, Test, Test, Test, Test!

TIMED Program - Phase E



TIMED Program – Phase E
Change Control Board

Chairman
D. Kusnierkiewicz
Mission System Engineer

NASA/GSFC
Program Office

Sam Yee – Project Scientist
Instrument Principal Investigators
M. Chu – Mission Software Engineer
W. Knopf – Mission Operations Manager
R. Harvey – Autonomy Engineer

TIMED PROJECT OFFICE

David G. Grant
Project Manager
Tel: 240-228-5297
FAX: 240-228-5297
e-mail: david.grant@jhuapl.edu

The Johns Hopkins University
Applied Physics Laboratory
Laurel, MD 20723-6099

APL Organization

0013MK
Oct 2000

The Space Department

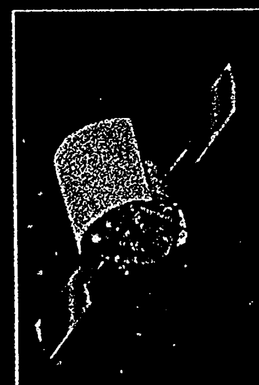
... creating innovative space systems for space physics, planetary exploration, navigation, oceanography, and environmental studies, including rapid, low-cost, end-to-end development.

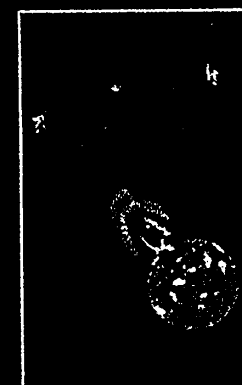
Areas of Expertise

- End-to-End Definition, Design, and Implementation of Space Missions
- Space Science and Instrumentation
- Satellite Tracking & Navigation; Ultrastable Oscillators

Selected Programs

- MSX (Midcourse Space Experiment)
- NEAR (Near Earth Asteroid Rendezvous)
- ACE (Advanced Composition Explorer)
- FUSE (Far Ultraviolet Spectroscopic Explorer)
- TIMED (Thermosphere, Ionosphere, & Mesosphere Energetics and Dynamics)
- CONTOUR (Comet Nucleus Tour)
- MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging)
- STEREO (Solar TErrestrial Relations Observatory)





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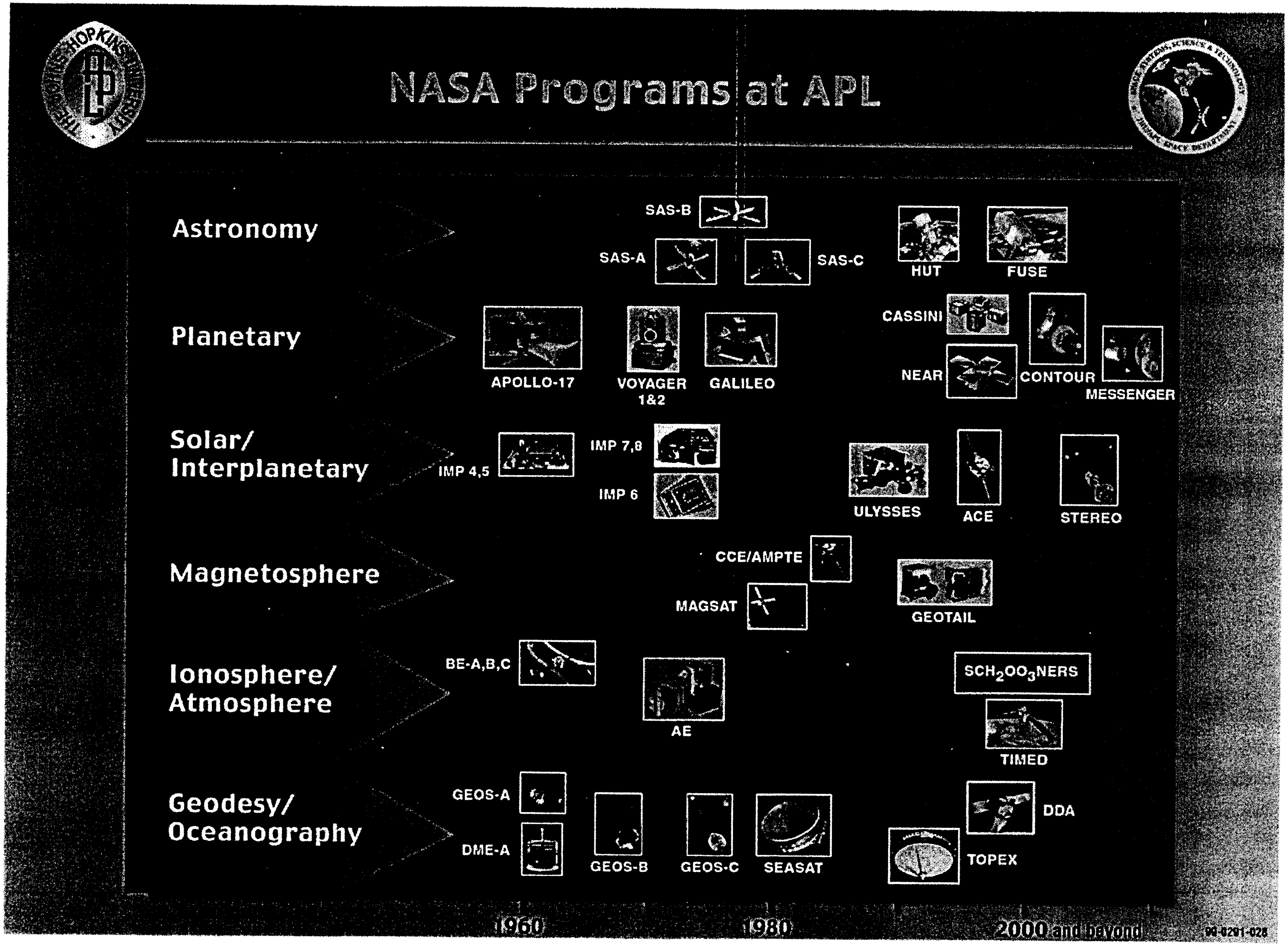
Apr 2000


NASA Programs at APL
Astronomy
SAS-B
SAS-A
SAS-C
HUT
FUSE
Planetary
APOLLO-17
VOYAGER 1&2
GALILEO
CASSINI
NEAR
CONTOUR
MESSENGER
Solar/ Interplanetary
IMP 4,5
IMP 7,8
IMP 6
ULYSSES
ACE
STEREO
Magnetosphere
CCE/AMPTE
MAGSAT
GEOTAIL
Ionosphere/ Atmosphere
BE-A,B,C
AE
SCH$_2$OO$_3$NERS
TIMED
Geodesy/ Oceanography
GEOS-A
DME-A
GEOS-B
GEOS-C
SEASAT
DDA
TOPEX
1960
1980
2000 and beyond

Space Department

Space Department Head
S. M. Krimigis
Asst. Dept. Head for Business
L. J. Crawford
Asst. Dept. Head for Operation
W. L. Ebert
Program Manager
T.B. Coughlin
Chief Engineer
E. J. Hoffman

- **SOR**
  Reliability and Quality Assurance
  S. R. Purwin
  S. W. Ali
- **SOM**
  Management Systems Support
  S. L. Quinn
  A. Elsner
- **Office of Education and Outreach**
  K. B. Beisser
- **SE**
  Engineering and Technology Branch
  G. H. Fountain
  R. E. Gold
  - **SEA**
    Space Systems Applications
    W. S. Devereux
  - **SEE**
    Electronic Systems
    A. L. Lew
  - **SEI**
    Integration and Operations
    R. K. Huebschman
    E. H. Rodberg
  - **SEM**
    Mechanical Systems
    W. E. Skullney
  - **SER**
    RF Engineering
    M. L. Edwards
- **SR**
  Science and Analysis Branch
  C.-I. Meng
  - **SRA**
    Atmospheric and Ionospheric Remote Sensing
    R. A. Greenwald
  - **SRI**
    Space Science Instrumentation
    R. M. Henshaw
    R. L. McNutt
  - **SRM**
    Mission Concept and Analysis
    T. E. Strikwerda
    A.D. Goldfinger
  - **SRO**
    Ocean Remote Sensing
    R. F. Gasparovic
    R. K. Raney
  - **SRP**
    Space Physics
    R. W. McEntire
  - **SRS**
    Software and Data Systems
    L. L. Suther
    K. J. Heeres
    M. I. Chu
- **Program Development Managers**
  J. F. Appleby
  R. E. Dove
  D. J. McMorrow
- **Program Managers**
  M. C. Chiu
  D. G. Grant
  J. T. Mueller
  C. T. Pardoe
  M. R. Peterson
  J. J. Suter
  B. E. Tossman

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The Technical Services Department

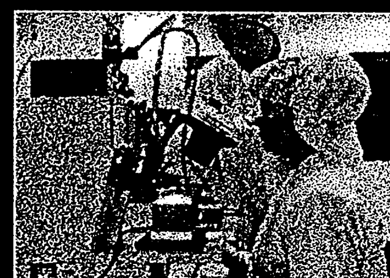
... providing mechanical and electrical engineering, design, fabrication, and test capabilities for a broad spectrum of APL programs.

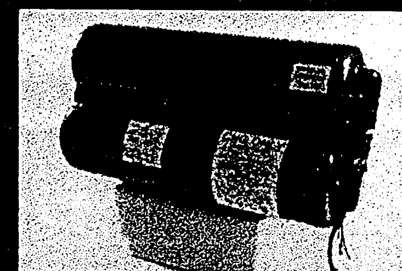
Areas of Expertise

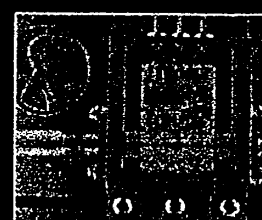
Electronic & Integrated Circuit Design
Electronic Fabrication, Assembly, & Test
Mechanical Design & Analysis
Mechanical Fabrication & Assembly
Composite Design & Fabrication
Materials Characterization, Analysis, Testing, & Qualification

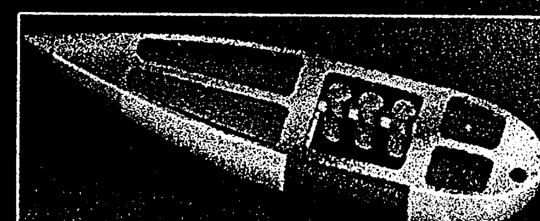
Selected Application Areas

Space Systems & Instruments
Shipboard Instrumentation & Underwater Devices
Sensors & Sensor Systems
Biomedical Devices, Components, & Systems
Advanced Materials
Advanced Electronic Packaging
Reengineering, Technology Transfer & Insertion



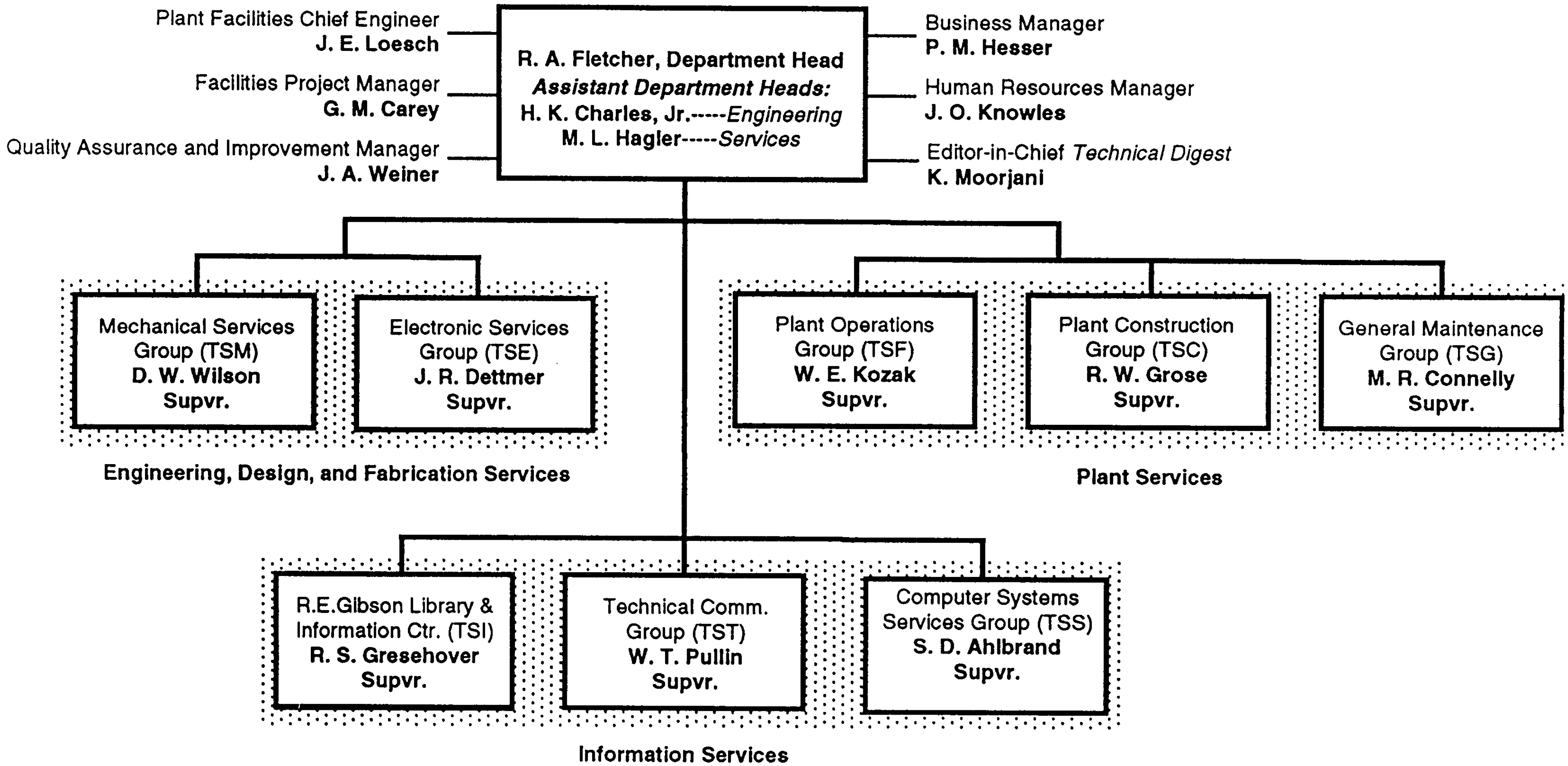






0020MK
Mar 2000

TSD Organization Chart

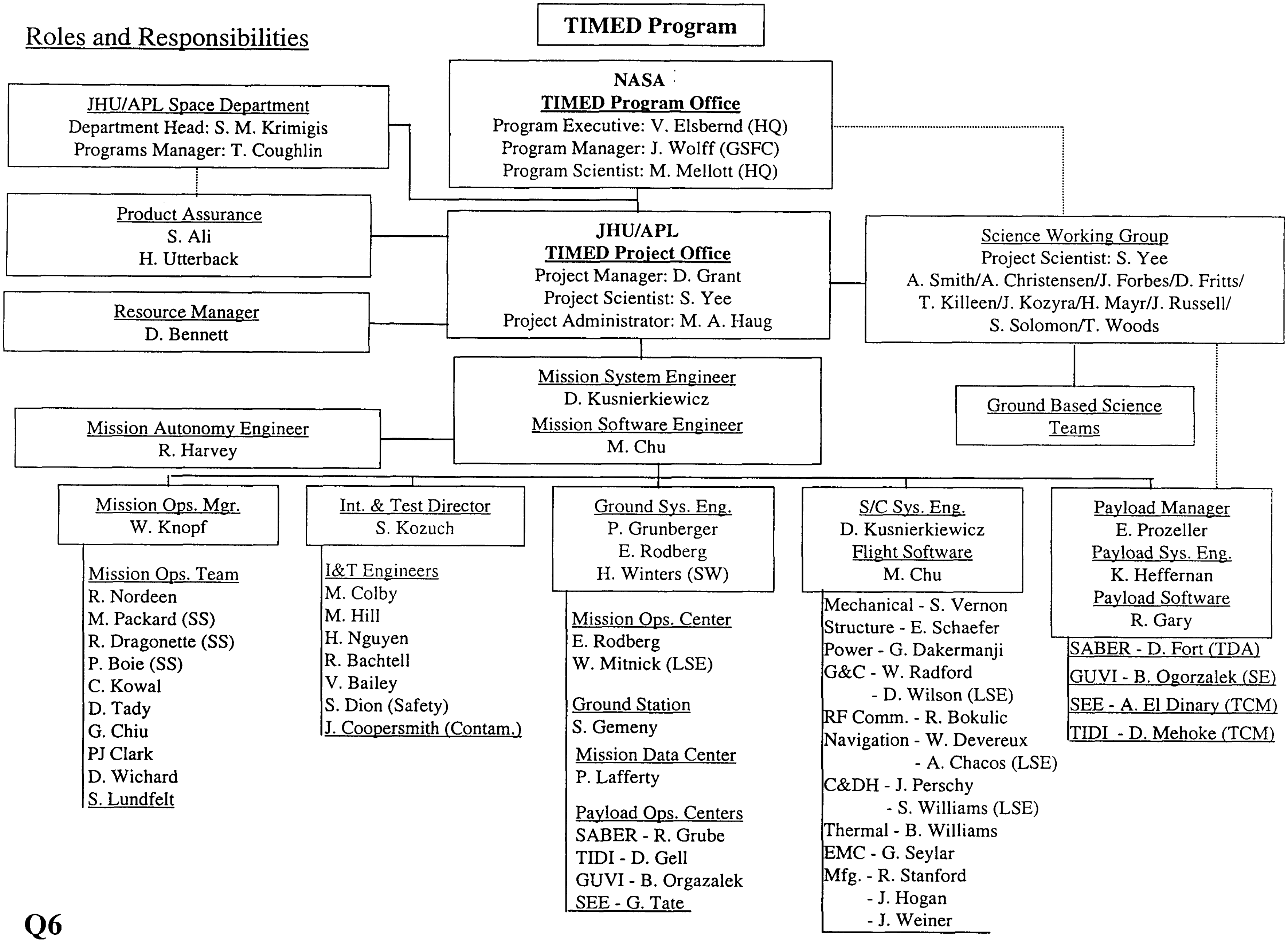


- TIMED Is A Design To Cost Mission

TIMED Management Approach

- Based Upon NEAR Program "B, F, C" Paradigm
- Streamlined Management
  - APL/SD Allows Program Managers Wide Decision Making Latitude
- Seasoned System Engineers, Major Program Element Leads
  - Delegation of Technical Authority, Responsibility
- Subsystem Lead Engineer Empowerment
  - Experience
  - Stability
  - End-to-End Commitment

Roles and Responsibilities



Q6

TIMED Management Approach

- Use Proven APL Technical Practices and Procedures. Strong NASA Heritage. Value Added Requirement. P&P are Simplified and Accessible.
  - Reviews
  - Tests
  - R&QA
  - Documentation

TIMED Management Approach

– RFA's

- Peer Reviews; Closure of Action Items Responsibility of Subsystem Lead Engineer. Formal Documentation or Tracking Not Required at Project Level.

- System Level Reviews; Closure Indicated Via Subsystem Lead Engineer Memo. Spacecraft System Engineer Delegated RFA Review/Approval Authority. Documentation/Tracking Via PA Office.

TIMED Management Approach

- PFR's, SPR's
  - PFR Process Starts at Subsystem Level Acceptance Testing
  - SPR Process Starts Upon Delivery of Software
  - Spacecraft System Engineer , Spacecraft SW Engineer Delegated Review/Approval Authority
  - Anomaly Goes Through Reporting, Analysis, Corrective Action, Verification, Concurrence of CCB (HW/SW)
  - Documentation, Tracking via PA Engineering

TIMED Management Approach

– Waiver

- Performance Does Not Meet Specifications
- Subsystem Lead Engineer Submits Written Request
- Spacecraft System Engineer, Spacecraft SW Engineer Granted Review/Approval Authority

Note: All RFA, PFR, SPR or Waiver Closures with Implicit Changes in System Level Performance, Substantial Risk or Major Cost/Schedule Impact are Processed Through the Project Office.

TIMEDManagement Approach

- Communications
  - Spacecraft Status Meetings
    - Weekly, Ph.B Start Through I&T Start
    - Spacecraft System Eng. Chair, Full Design Team, PA, Mfg, etc.
    - Present Mechanical Status, Other Subsystem by Turn, Weight and Power Margins, Status All, Problems
    - Published Minutes

TIMED Management Approach

- Communications
  - I&T Planning Meeting
    - Daily, I&T Start Through Launch
    - I&T Director Chair, I&T Team, MO Team, Ground System, Instruments
    - Assignments, milestones for Day, Near Team Schedule
    - Daily Update of I&T Plan

TIMED Management Approach

- Communications
  - MO Forum, Biweekly
  - Software Segment Leads, Biweekly
  - IEM Team, Weekly
  - G&C Team, Weekly
  - GNS Team, Weekly
  - R. F. Comm. Team, Weekly
  - Instruments
  - Etc.

TIMED Management Approach

- Oversight
  - Hands on Lightly
  - APL
    - Weekly Meeting with SD Programs Manager
    - Quarterly Status Brief with SD Head, SD MAC
  - NASA/GSFC
    - Weekly Status Brief with Program Manager
    - Monthly Status Brief with Program Manager
    - Immediate, Complete Disclosure of Serious Problems

Instrument Management Approach

- Consistent with “B, F, C”
- Small Oversite Team
- Fully Integrated Interaction (Engineer-to-Engineer)

TIMED Program

NASA TIMED Program Office
Program Executive – V. Elsbernd
Program Manager – J. Wolff NASA/GSFC
Program Scientist – M. Mellott NASA/HQ

JHU/APL TIMED Project Office
Project Manager – D. Grant
Project Scientist – S. Yee
Project Administrator – M. A. Haug

TIMED
Science Working Group

Payload Manager – Ed Prozeller
Payload System Engineer – Kevin Heffernan
Software Engineer – R. Gary

Product Assurance
L. Mastracci

Technical Direction Agent
Dennis Fort

NASA 506

SABER
Jim Miller (PM)
Langley Research Center

Langley Contract

Loren Zollinger (PM)
Utah State Univ. (SDL)

Technical Contract Representative
Ashruf El-Dinary

APL Contract

SEE
Mike Anfinson (PM)
Univ. of Colorado (LASP)

Technical Direction Representative
Doug Mehoke

APL Contract

TIDI
Chas. Edmonson (PM)
Univ. of Michigan (SPRL)

Technical Direction Agent
Bernie Ogorzalek

NASA Contract

GUVI
Tom Pardoe (PM)
APL/Aerospace

Ad-Hoc Technical Support
Mechanical – Steve Vernon
Thermal – Bruce Williams
Structures – Ed Schaeffer
Optics – Keith Peacock
Detectors – Hugo Darlington
Alignment – Al Sadilek
Flight S/W – Steve Williams
Processors – Joe Bogdansky
+
GSFC Staff (for Reviews)
Joe Wonsever et. al

TIMED Instrument Management Organization

Instrument Management Approach

- Documentation
  - Product Assurance Implementation Plan (PAIP)
  - Software Development Plan (SDP)
  - Interface Control Document (ICD)
  - Instrument Calibration Plan (ICP)
  - Technical Requirements Specification (TRS)
  - Acceptance Test Plan (ATP)
- Reviews
  - CODR, PDR, CDR, PSR

Instrument Management Approach

Communications

- Weekly Telecons
- Monthly Management Updates
- Quarterly Technical Interchange Meetings (TIMs)
- Six-Month Management Reviews
- Instrument Accommodation Workshops

Instrument Milestones

	CoDR	IAW	PDR	CDR	ITW	PSR	Spacecraft Integration 1	2	3
SABER	Apr-95	Aug-96	Dec-96	Oct-97	May-98	Aug-99	Sep-99		
GUVI	May-95	Oct-96	Jun-97	Jan-98	Jun-98	May-99	May-99	Sep-99	Aug-00
SEE	Jul-95	Aug-96	Feb-97	Feb-98	Jul-98	May-99	Jun-99	Sep-99	Jul-00
TIDI	Oct-95	Aug-96	Jan-97	Apr-98	Jul-98	Oct-99	Oct-99	Jul-00	

Post integration activities

GUVI: 6/1/99: first Photek detector tube failure
2/10/00: second Photek detector tube failure
6/8/00: 1553 board failure

SEE: 7/27/99: SEE EGS planned removal for calibration at SURF
8/26/99: EGS vacuum door failure while at SURF
11/4/99: EGS HV control failure

TIDI: 6/8/00: Electronics unit removed for DC/DC converter rework and Cal lamp temp calibration.

TIMED Program Chronology of Significant Events

- TIMED Kickoff - 20 May 94
- Instrument Downselect - 5 Oct 94
- Systems Requirements Review - 14 Oct 94 HQ (R. Howard) Chair
- TIMED Conceptual Design Review - 14 Dec 94 APL (M. Chiu) Chair
- Instrument Design Phase - Feb 95
- Technology Insertion Assessment - Feb 95
- Technology Insertion Review - May 96
  - Integrated Electronic Module
  - Low Cost Mission Operations

Q1, Q2

TIMED Program Chronology of Significant Events

- Initiate TIMED Phase B - 10 Jun 96
- Preliminary Design Review - 18, 19 Feb 97
  APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair
- Non-Advocate Review - 20, 21 Feb 97
  HQ (P. Evanich) Chair
- Program Management Council Review - 21 Apr 97
  HQ (J. Dailey) Chair, Initiate Phase C/D
- Critical Design Review - 2, 3, 4 Dec 97
  APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair

TIMED Program Chronology of Significant Events

- Concept of Missions Operations Review - 14 May 98 APL/GSFC (E.Hoffman, J. Wonsover) Co-Chair
- Independent Annual Review - 7 Jul 98 HQ (P. Evanich), LaRC (J. Schick) Co-Chair
- Pre-Environmental Review - 26 Oct 99 APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair
- Post-Environmental Review - 29 Feb 00 APL/GSFC (E. Hoffman, J. Wonsover) Co-Chair, Commence Spacecraft Controlled Storage

TIMED Program Chronology of Significant Events

- Exit Spacecraft Storage, Commence Testing - 1 Jun 00
- Mission Ops Review - 8 Jun 00
  APL/GSFC (E. Hoffman W. Mack) Co-Chair
- Red Team Review - 31 Oct 00, 1, 2, 3 Nov 00
  HQ (W. Taylor) Chair
- Flight Operations Review - 8, 9 Nov 00
  GSFC (W. Mack) Chair
- Pre-Ship Review - 29 Nov 00
  APL/GSFC Co-Chair
- Ship to Vandenberg - 11 Dec 00

TIMED Program Chronology of Significant Events

- Flight Readiness Review - TBD
  NASA Chair
- Mission Readiness Review - TBD
  NASA/GSFC Director Chair
- Launch Readiness Review - TBD
  NASA Chair
- Launch - 7 Mar 01

TIMED Program Chronology of Significant Events

- Initiate Phase C/D - 21 Apr 97
- APL/GSFC TIMED Letter Contract - 16 Jun 97
  Launch Date Jan 00
- Launch Date Revision Notification - 2 Feb 98
  Launch Date 15 May 00
- Launch Date Revision Notification - 27 Mar 00
  Launch Date 18 Oct 00
- Launch Date Revision Rumor - Apr 00
  Launch Date 15 Dec 00
- Launch Date Revision Notification - 31 Aug 00
  Launch Date 7 Mar 01

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program)
MANAGEMENT					
D. Grant (MS)	Princ. Prof. Staff	Staff	Project Manager	41	TOPAZ, ALTAIR, Polar BEAR
E. Prozeller (MS)	Princ. Prof. Staff	Staff	Payload Manager	36	NTBMD, MSX
SCIENCE					
S. Yee (PhD)	Princ. Prof. Staff	Dir. Atmospheric Sensing Technologies, JHU/APL	Project Scientist	27	UARS, MSX
A. Christensen (PhD)		Princ. Director, Space and Environment Technology Center, Aerospace Corp.	GUVI Principal Inv.		
T. Woods (PhD)	Sr. Research Scientist	Laboratory for Atmospheric and Space Physics, Univ. of Colorado.	SEE Principal Inv.		
J. Russell (PhD)	Professor	Co-Director, Center for Atmospheric Sciences, Hampton Univ.	SABER Principal Inv.		
T. Killeen (PhD)		Dir. National Center for Atmospheric Research	TIDI Principal Inv.		
SYSTEM ENGINEERING					
D. Kusnierkiewicz (MS)	Princ. Prof. Staff	Assistant Group Supervisor	Mission System Engineer	24	MSX,NEAR
M. Chu (PhD)	Sr. Prof. Staff	Assistant Group Supervisor	Mission Software Engineer	31	Hubble, GRO,EUVE, XTE, TRMM
R. Harvey (BS)	Sr. Prof. Staff	Section Supervisor	Autonomy System Eng.	16	Delta, MSX
P. Grunberger (BS)	Princ. Prof. Staff	Staff	Ground System Syst. Eng.	33	MSX, AGRE
R. Nordeen (BS)	Princ. Prof. Staff	Staff	Mission Operations Syst. Eng.	38	MSX, FUSE, Delta
K. Heffernan (MS)	Princ. Prof. Staff	Section Supervisor	Payload System Engineer	25	MSX, CONTOUR

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program
FLIGHT SUBSYS. DEV.					
Mechanical/Structural					
S. Vernon (BS)	Sr. Prof. Staff	Staff	Mechanical Lead	8	Cassini, MSX, EPIC
E. Schaefer (MS)	Sr. Prof. Staff	Staff	Structures Lead	30	NEAR, MSX
Thermal					
B. Williams (MS)	Sr. Prof. Staff	Staff	Thermal Lead	16	NEPSTEP, ACE
Power					
G. Dakermanji (PhD)	Princ. Prof. Staff	Section Supervisor	Power System Lead	31	NEAR, ACE, SAMPEX
M. Butler (MS)	Sr. Prof. Staff	Staff	Power Test, Solar Arrays	14	MSX, TOPAZ, NEAR
D. Temkin (MS)	Sr. Prof. Staff	Staff	Power Converters	17	NEAR, SAMPEX
Guidance and Control (G&C)					
W. Radford (BS)	Princ. Prof. Staff	Staff	G&C Lead	39	ACE, MSX, NEAR
W. Dellinger (PhD)	Sr. Prof. Staff	Staff	G&C Analyst	18	CONTOUR
L. Kennedy (MS)	Sr. Prof. Staff	Staff	G&C Test	25	Delta, MSX, NEAR
D. Wilson (BS)	Sr. Prof. Staff	Section Supervisor	G&C Software Lead	26	MSX, NEAR
RF Communications					
R. Bokulic (MS)	Princ. Prof. Staff	Assistant Group Supervisor	RF Communications Lead	18	MSX, NEAR
S. Cheng (MS)	Senior Prof. Staff	Staff	Downlink Board	18	Technology Development
C. Deboy (MS)	Sr. Prof. Staff	Staff	Uplink Board	10	MSX
R. Stilwell (MS)	Sr. Prof. Staff	Staff	Antennas	27	ACE, MSX
J. Goldman (MS)	Assoc. Prof. Staff	Staff	RF Communications Test	5	CONTOUR

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (yrs)	Exp. (Program
GPS Navigation System (GNS)					
W. Devereux (MS)	Princ. Prof. Staff	Group Supervisor	GNS Lead	20	Brilliant Pebbles
R. Heins (MS)	Princ. Prof. Staff	Staff	GNS Test	36	NEAR, MSX
R. DeBolt (MS)	Assoc. Prof. Staff	Staff	GNS Engineer	2	TOPEX, ACE
A. Chacos (MS)	Princ. Prof. Staff	Section Supervisor	GNS Software Lead	26	NEAR, MSX
Command and Data Handling (C&DH)					
J. Perschy (MS)	Princ. Prof. Staff	Staff	C&DH Lead	42	CONTOUR, ACE, NEAR, TOPEX
S. Oden (BS)	Princ. Prof. Staff	Staff	Crit. Cmd. Decoder	38	TOPEX, NEAR
J. Bogdanski (MS)	Sr. Prof. Staff	Staff	Solid State Recorder	24	ACE, NEAR, MSX
R. Reiter (BS)	Sr. Prof. Staff	Staff	Remote Interface Unit	22	MSX, ACE, NEAR, CONTOUR
S. Williams (MS)	Princ. Prof. Staff	Staff	C&DH Software Lead	25	MSX,NEPSTEP, ACE
S. Schneider (MS)	Sr. Prof. Staff	Staff	Boot Code Software Lead	26	NEAR, MESSENGER
Integrated Elec. Mod.					
P. Marth (MS)	Princ. Prof. Staff	Section Supervisor	Integrated Electronics Mod. Lead	39	TOPEX, DSRFS, CONTOUR
EMI/EMC					
G. Seylar (BS)	Sr. Prof. Staff	Staff	EMC Engineer	37	NEAR, MSX, ALTAIR, TOPEX
Product Assurance					
S. Ali (MS)	Prin. Prof. Staff	Assistant Group Supervisor	Product Assurance Lead	39	ACE,NEAR,FUSE,CASSINI
Manufacturing					
R. Stanford	Assoc.Prof.Staff	Staff	Mechanical Mfg. Lead	22	MSX,TOPEX,CASSINI,NEAR
J. Hogan	Assoc.Prof.Staff	Staff	Electronic Mfg. Lead	37	MSX,ACE,NEAR,CASSINI

TIMED Key Personnel

Name (Degree)	Classification	Supervisory Position	Program Position	Exp. (Yrs.)	Exp. (Program)
INTEGRATION AND TEST					
S. Kozuch (BS)	Sr. Prof. Staff	Staff	I&T Director	37	Delta, MSX, NEAR, MESSENGER
H. Nguyen (MS)	Assoc. Prof. Staff	Staff	Test Conductor	9	MSX, NEAR, ACE, CONTOUR
M. Hill (BS)	Sr. Prof. Staff	Staff	Test Conductor	9	MAP, FUSE, ACE, SOHO
M. Colby (BS)	Professional	Resident Subcontract Engineer	Test Conductor	24	MSX, NEAR, CONTOUR
V. Bailey (BS)	Professional	Resident Subcontract Engineer	Test Conductor	17	NEAR
R. Bachtell	Professional	Resident Subcontract Engineer	Test Engineer	15	Delta, NEAR, MSX, ACE
GROUND SYSTEM DEV.					
E. Rodberg (MS)	Princ. Prof. Staff	Assistant Group Supervisor	Ground System Lead	18	AMPTE, TOPEX, ACE
W. Dove (BS)	Sr. Prof. Staff	Staff	Mission Ops Center Lead	11	ACE, NEAR, MSX
W. Mitnick (BS)	Sr. Prof. Staff	Section Sup.	Mission Ops Center Software Lead	25	MSX, NEAR, ACE, CONTOUR
P. Lafferty (BS)	Sr. Prof. Staff	Staff	Mission Data Center Lead	13	MSX, Galileo, Cassini, NEAR
S. Gemeny	Sr. Prof. Staff	Staff	Ground Station Lead	20	INMARSAT, OSC, COMSAT
MISSION OPERATIONS					
W. Knopf (MS)	Sr. Prof. Staff	Staff	Mission Operations Manager	19	MSX, NEAR, Delta
M. Packard (MS)	Sr. Prof. Staff	Staff	Spacecraft Specialist (G&C)	10	MSX, NEPSTP, NEAR
R. Dragonette (MS)	Sr. Prof. Staff	Staff	Spacecraft Specialist (GNS)	13	MSX, NMD
P. Boie (BS)	Professional	Resident Subcontract Engineer	Spacecraft Specialist (RF Comm)	7	MSX

SOR Management for the program

Stan Purwin
- BSEE, MSME, MBA
- 34 yrs professional experience in Engineering And Quality
- ASQ Certified Quality Manager

Syed Ali
- M.S. QA Engineering
- 27 yrs of Q.A.P.A. experience
- 20 yrs in Aerospace Fabrication process

Kim Cooper
- M.S. in Technical Management
- 19 yrs EEE reliability physics, & quality engineering
- 8 yrs NASA related projects

Heara Lee
- B.S. in Business Management
- 24 yrs experience in Materials Management
- 12 yrs experience on BMDO & NASA programs

Jim Kinnison
- B.S., M.S., Physics
- 13 yrs experience in Radiation Effects
- 13 yrs expereience for NASA & BMDO

SOR Key Staff for the program

Carlos Castillo
- B.S. in Engineering Technology
- 20+ yrs Quality Assurance experience
- 10 yrs NASA related

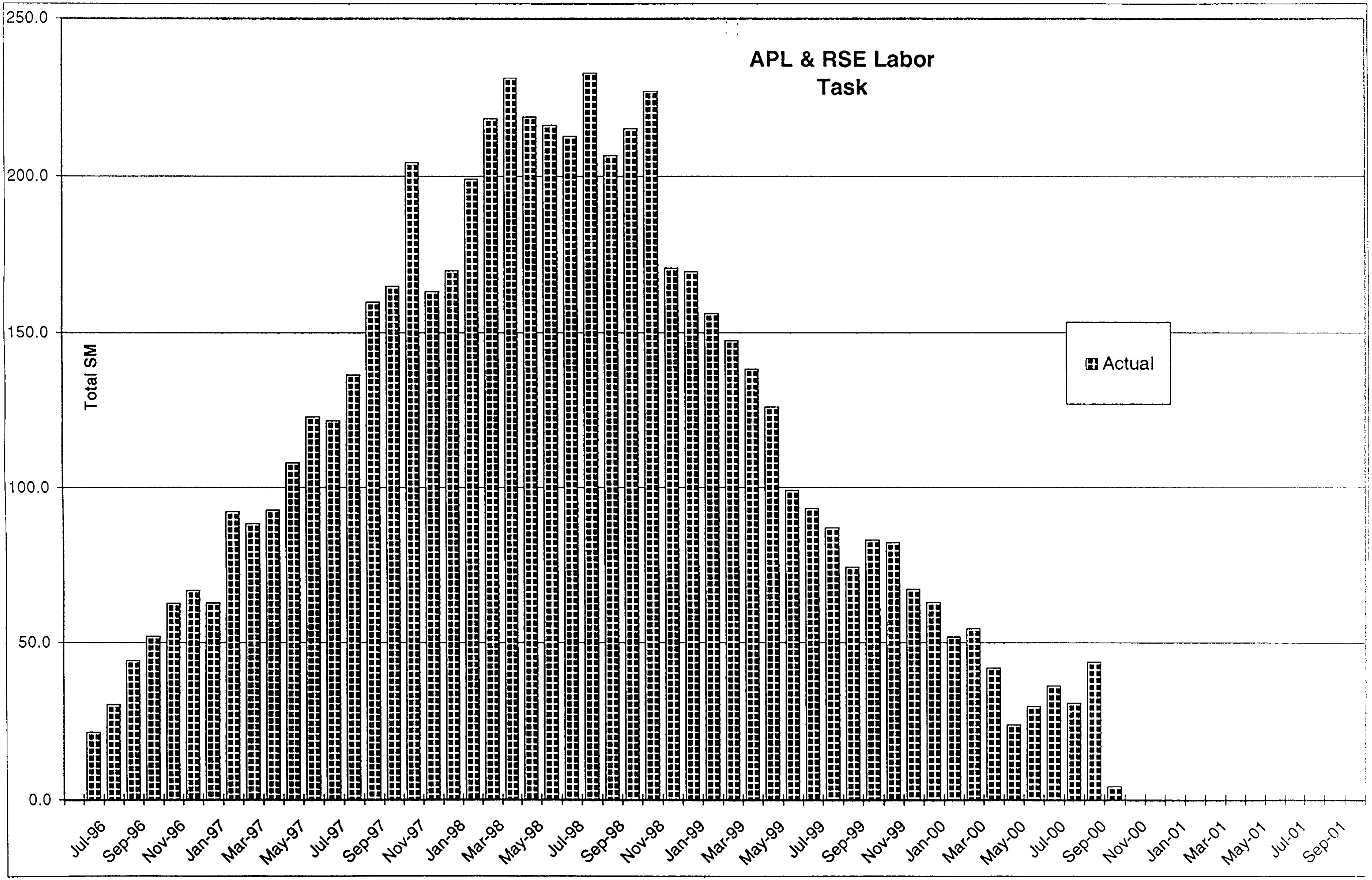
Jonathan Coopersmith
- BA Physics, University of Virginia, 1986.
- 13 yrs experience in clean room operations
- 13 yrs experience in scientific contamination control

John Farnan
- B.S. Business Management
- 17 yrs experience in Materials Management
- 17 yrs experience in DoD, BMDO and NASA programs

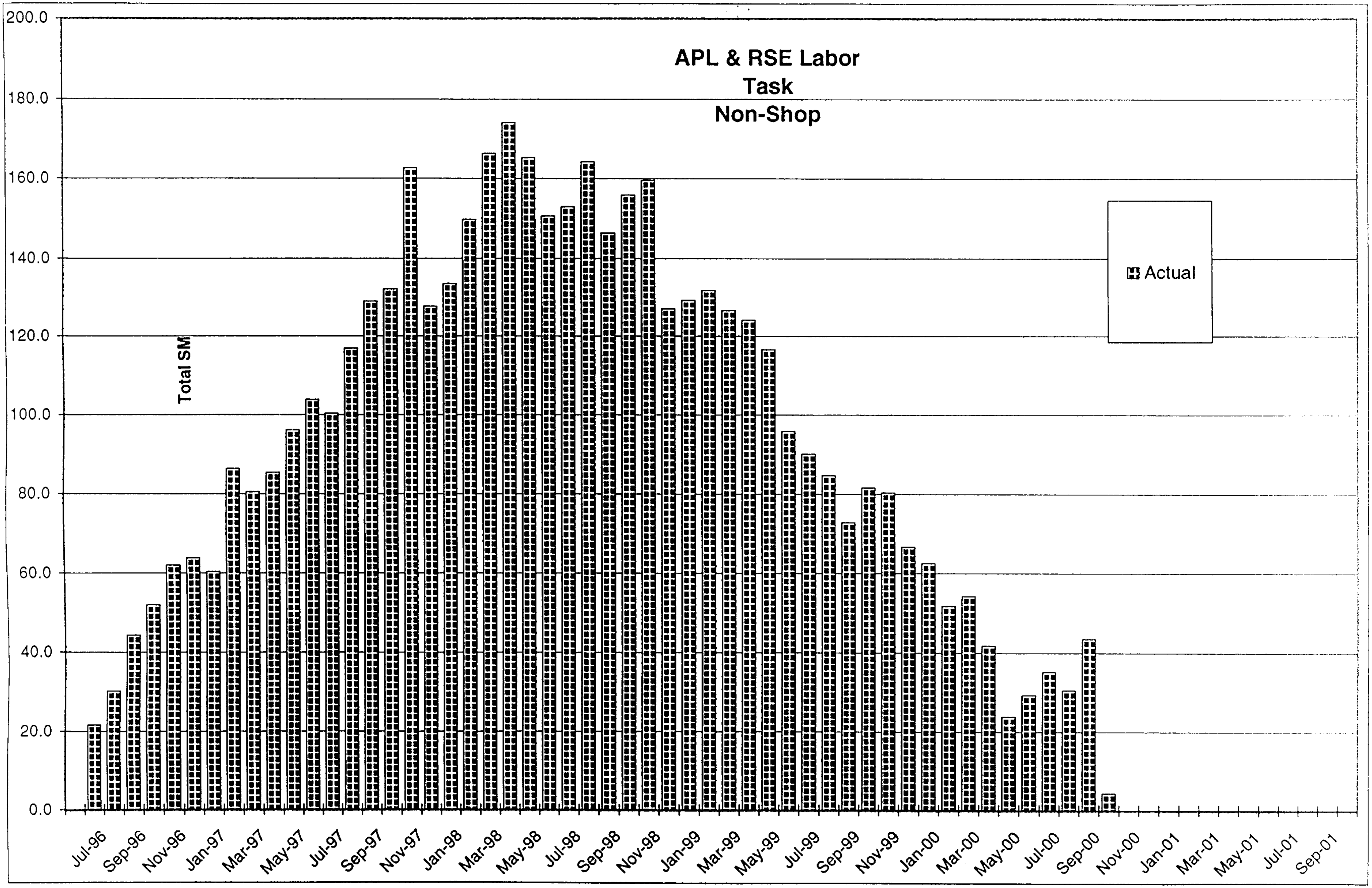
Juan Lander
- M.S. in Computer Science
- 17 yrs experience in component testing
- 14 yrs NASA related projects

Andy Moor
- M.S. Engineering Management
- 13 yrs experience space reliability parts engineering
- 10 yrs NASA based program

TIMED (ICR)
Manpower Actuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



TIMED (ICR)
Manpower Actuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



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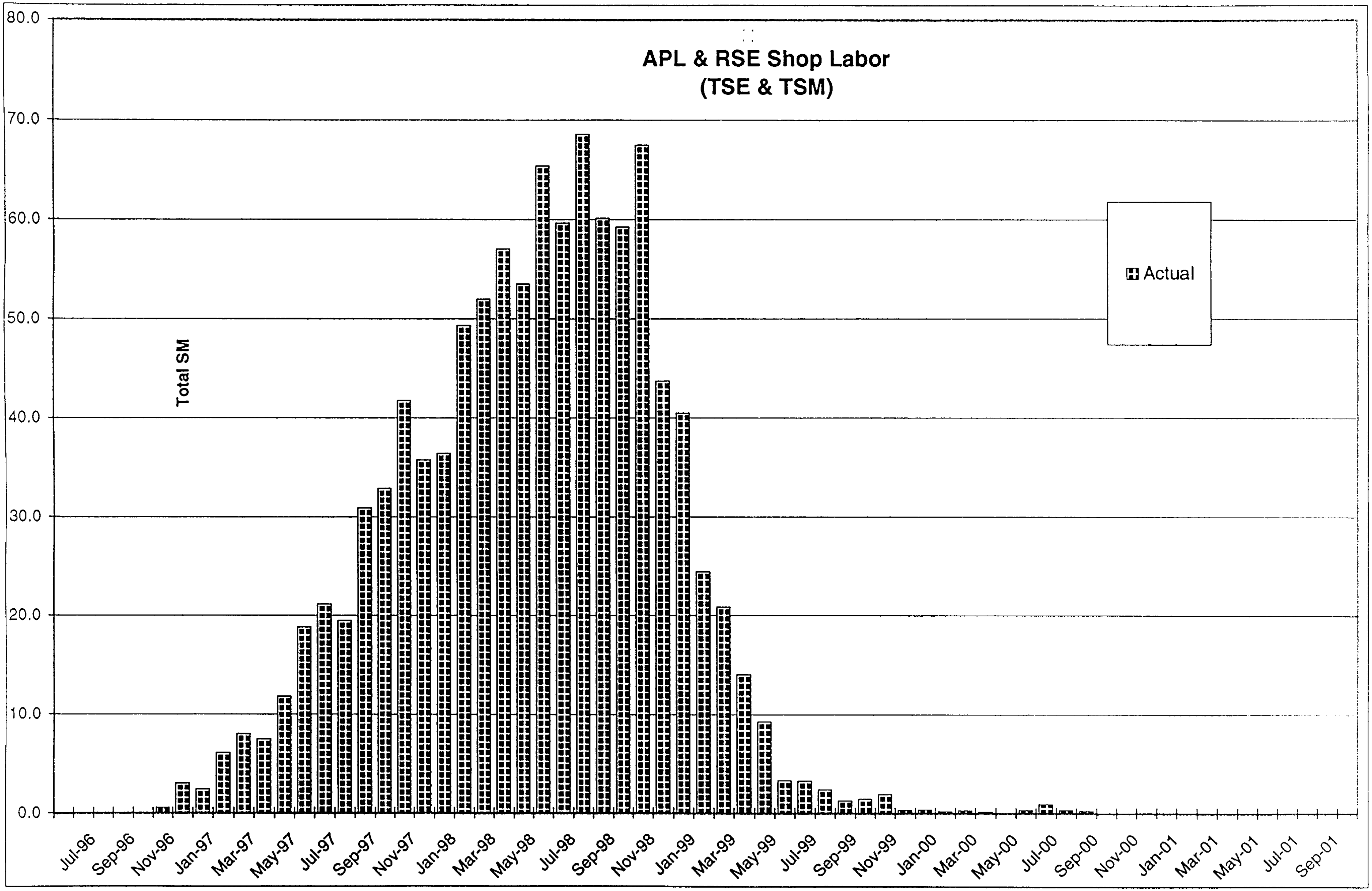
Program Plots LaborMMAll

Manpower Actuals
PHASE B Jun96-Mar97
PHASE C/D Apr97-Present



TIMED Management Approach

- What Are We About
  - Test, Test, Test, Test, Test!

TIMED Program – Phase E

NASA TIMED Program Office
Program Executive – V. Elsbernd
Program Manager – J. Wolff NASA/GSFC
Program Scientist – M. Mellott NASA/HQ

JHU/APL TIMED Project Office
Project Manager – D. Grant
Project Scientist – S. Yee

Resource Manager
D. Bennett

Education & Public Outreach
K. Beisser

Science Working Group

Ground Based Science Teams

Autonomy Engineer
R. Harvey

Mission System Engineer - D. Kusnierkiewicz
Mission Software Engineer – M. Chu

Change Control Board

Ground System Engineer
E. Rodberg

Mission Ops Manager
W. Knopf

Ground Station
S. Gemeny

Mission Ops Center
W. Dove
W. Mitnick

Instrument POCs
SABER – R. Gurbe
TIDI - D. Gell
GUVI – B. Orgazalek
SEE - G. Tate

Eng. Support
C&DH - J. Perschy
Power – M. Butler
G&C –W. Dellinger
GNS – R. DeBolt
Thermal – B. Williams
RF Comm –C. DeBoy
IEM – P. Marth

Mission Ops Team
R. Dragonette
M. Packard
P. Boie
C. Kowal
D. Tady
G. Chiu
PJ Clark (s/w)
D. Wichard (s/w)
S. Lundfelt

Science Data System
P. Lafferty

PI Institutions, IDS's
Public Access

Q6

TIMED Program – Phase E
Change Control Board

Chairman
D. Kusnierkiewicz
Mission System Engineer

NASA/GSFC
Program Office

Sam Yee – Project Scientist
Instrument Principal Investigators
M. Chu – Mission Software Engineer
W. Knopf – Mission Operations Manager
R. Harvey – Autonomy Engineer
Subsystem Lead Engineers
E. Rodberg – Ground System Lead
P. Lafferty – Science Data System

SCIENCE

Jeng-Hwa Yee

TIMED Project Scientist

Applied Physics Laboratory

Johns Hopkins University

Laurel, Maryland

Tel: (301)-953-6206

Fax: (301)-953-6670

e-mail: jeng-hwa_yee@jhuapl.edu

Outline

- Science Overview
- Mission Science Objectives and Success Criteria
- TIMED Science Implementation: Roles, Responsibilities and Communications
- Mission Requirements and Instrument/Spacecraft Performance
- Science Recovery Plan
- Summary

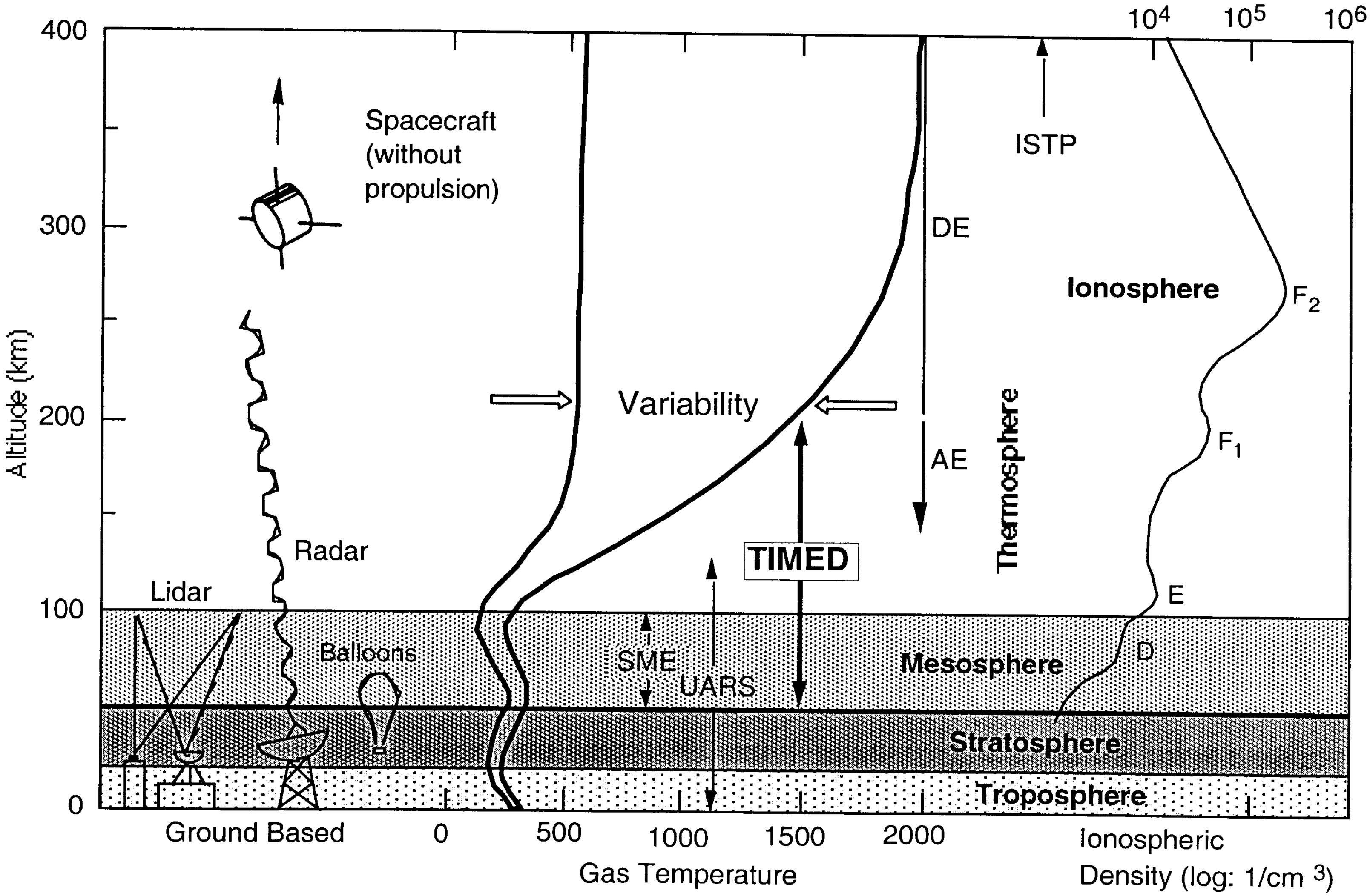
- Thermosphere, Ionosphere, Mesosphere, Energetics, Dynamics (TIMED)

  TIM: Region of Interest (60-180 km);

  ED: Scientific Interest (Energetics, Dynamics).

- The first in the Solar Terrrestrial Probe Mission
  - a mission dedicated to understand the interface between the atmosphere and space.

TIMED: Atmospheric Regions of Study



- TIMED Core Region of Interest (60-180 km)
  - a critical part of Earth's Ionosphere, Thermosphere, and Mesosphere (ITM) region
  - the least-explored and least-understood region of the Earth's atmosphere:
    - only limited data sets existed from rocket and groundbased experiments
      - spatial limitation: limited in geographic location;
      - temporal limitation: limited in time and duration of the observations.
    - AE, DE, SME and UARS provided the first glimpse of region
      - lack of comprehensive and complete global data set to examine the basic structure and energy balance

Characteristics of ITM region

- ITM is a transition region between the atmosphere we live in and the space. It blocks out the harmful EUV radiation and energetic charged particles from the Sun and prevents them from reaching the lower atmosphere.
- Energy from the Sun in the forms of electromagnetic radiation and charged particles keeps the ITM chemical and dynamical engines running.
- In addition, it is also affected by external electric fields and waves propagating upward from the lower atmosphere.
- As a result, ITM region exhibits
  - short-term (daily) weather-like and mid-term (seasonal) climate-like variability --- similar to the lower part of the atmosphere, the Troposphere;
  - strong long-term (11-year) solar cycle variability; and
  - to our best theoretical knowledge, long-term climate change due to human-induced activities.
- Many theoretical models, 1-D, 2-D, and 3-D, have been developed and used to study the chemical, dynamical, and radiative processes taking place in the region and how they couple together spatially.
- These models have been used to interpret a temporally and spatially limited observational data set. Continuous global observations of atmospheric state parameters (i.e. pressure, temperature, and winds), and simultaneous energy inputs and outputs of the system are needed to constrain the models to improve our understanding of the importance of various processes governing the structure and changes of the ITM region.

Basic Structure Parameters

- **State Variables:**
  - p (pressure), n (density), T(temperature) *Equation of State*
- **Motion Variables:**
  - u (zonal wind), v(meridional wind), w (vertical wind) *Equation of Motion*

Energetic Parameters

- **Energy Inputs:** *Equation of Energy*
  - solar radiation: X-ray, EUV, FUV, MUV;
  - magnetospheric inputs: energetic electrons, protons, neutrals;
  - electrodynamics inputs: Joule heating;
  - waves: tides, planetary and gravity waves;
- **Energy Outputs:** *Equation of Energy*
  - CO_2 15.4 μm radiation;
  - NO 5.3 μm radiation;
  - O_3 9.6 μm radiation, and others.
- **Energy Redistribution:** *Equation of Energy*
  - chemical energy release: O+O+M, O+O_2+M, H+O_3, etc.
- **Energy Deposition Profiles:** *Equation of Energy*
  - Absorber Concentrations (e.g. O_2, O_3, etc.).

Science Objectives

- **To determine the MLTI Basic Structure (primary)**
  - To determine the temperature, density, and wind structure in the Mesosphere, Lower thermosphere, and Ionosphere (MLTI) region (60-180 km), including the seasonal and latitudinal variations;
- **To understand the MLTI Energy Balance (secondary)**
  - To determine the relative importance of the various radiative, chemical, electrodynamical, and dynamical sources and sinks of energy for the thermal structure of MLTI region

Mission Full Success Criteria

Over the 2-year prime mission,

- Provide global scale measurements in the MLTI region (between 60 and 180 km) of:
  - temperature from emission of CO_2 at 15.4 μm, O_2 at 762 nm, or O at 630 nm
  - N_2 density from the Lyman-Birge-Hopfield bands emission of N_2, and O density from the 130.4 nm, 135.6 nm or 844.6 nm emission of oxygen
  - horizontal wind velocity, and
  - infrared emissions of CO_2 at 15.4 μm and 4.3 μm, O_3 at 9.6 μm, NO at 5.3 μm, and OH at 1.6 and 2.0 μm

  with a vertical resolution of at least 1/2 of a scale height
- Provide daily measurements of the solar extreme ultraviolet (EUV) irradiance from approximately 0.1 nm to 200 nm
- The local time drift rate of the orbits allows approximately 24 hour local time measurement within a season

Mission Minimum Success Criteria

- For one season, provide global scale measurements in the MLTI region (between 60 and 180 km) of:
  - temperature from emission of CO_2 at 15.4 μm, O_2 at 762 nm, or O at 630 nm
  - O density from the 130.4 nm, 135.6 nm or 844.6 nm emission of oxygen
  - horizontal wind velocity

  with a vertical resolution of at least a scale height
- The local time drift rate of the orbits allows approximately 24 hour local time measurement within a season

TIMED Science Implementation Approach

In order to maximize the scientific returns of the TIMED MLTI research program, TIMED science investigation

- uses a space platform (TIMED space component) to obtain global observations of basic atmospheric state parameters and energy inputs and outputs, and -- implemented since 1993
- collaborates with an existing ground-based observational and modeling program (TIMED ground-based component) to provide supplementary and complimentary observational data and models. -- implemented since June 2000

In addition, TIMED will collaborate with other MLT research and study programs supported by NASA and other government agencies (i.e. UARS, IMAGE, DMSP, etc.) and by other international space missions (i.e. Envi-sat, Odin) and ground-based observational investigators (i.e. European and Japanese). ------ informal agreement

TIMED/CEDAR Synergy

- There have been two major government agencies, NASA and NSF, supporting the MLT research during the past few decades.
- Currently under these two agencies:
  - NASA/TIMED
    - A space program dedicated to the study of global spatial and temporal variabilities of basic structures in the Mesosphere, Lower Thermosphere and Ionosphere (60-180 km) and its energy balance
  - NSF/CEDAR
    - CEDAR: Coupling, Energetics, Dynamics of Atmospheric Regions
    - A ground-based observational and theoretical modeling program dedicated to the study of energy transfer processes between atmospheric regions.
- The joint TIMED/CEDAR effort combines the resources and infrastructures of the two programs and consequently will maximize scientific returns

Science Implementation and TIMED SWG (I)

- To ensure the TIMED mission science objectives are met, we have conducted Science Working Group (SWG) meetings about every 3-4 months since 1994.
- The SWG meetings are attended by NASA program offices, APL project office, mission System Engineer, instrument PIs, Inter-Disciplinary Scientists (IDSs), and ground-based instruments representatives
- SWG meetings have been the avenue for communication between instrument development teams, the science team, the mission implementation team at APL, and the NASA program office.

TIMED Science Working Group (SWG)

- APL Project Scientist: J. H. Yee
- Instrument PIs:
  - Andy Christensen (GUVI),
  - Timothy Killeen (TIDI),
  - James Russell (SABER),
  - Thomas Woods (SEE)
- Inter-Disciplinary Scientists (IDSs):
  - Jeffery Forbes: Large-scale Wave Dynamics (tides and waves)
  - Dave Fritts: Small-scale Wave Dynamics (gravity waves)
  - Janet Kozyra Ionosphere/Magnetosphere Coupling
  - Hans Mayr Wave Dynamics and Wave Energetics
  - Anne Smith: Middle Atmosphere Energetics and Dynamics
  - Stan Solomon Lower Thermosphere Energetics

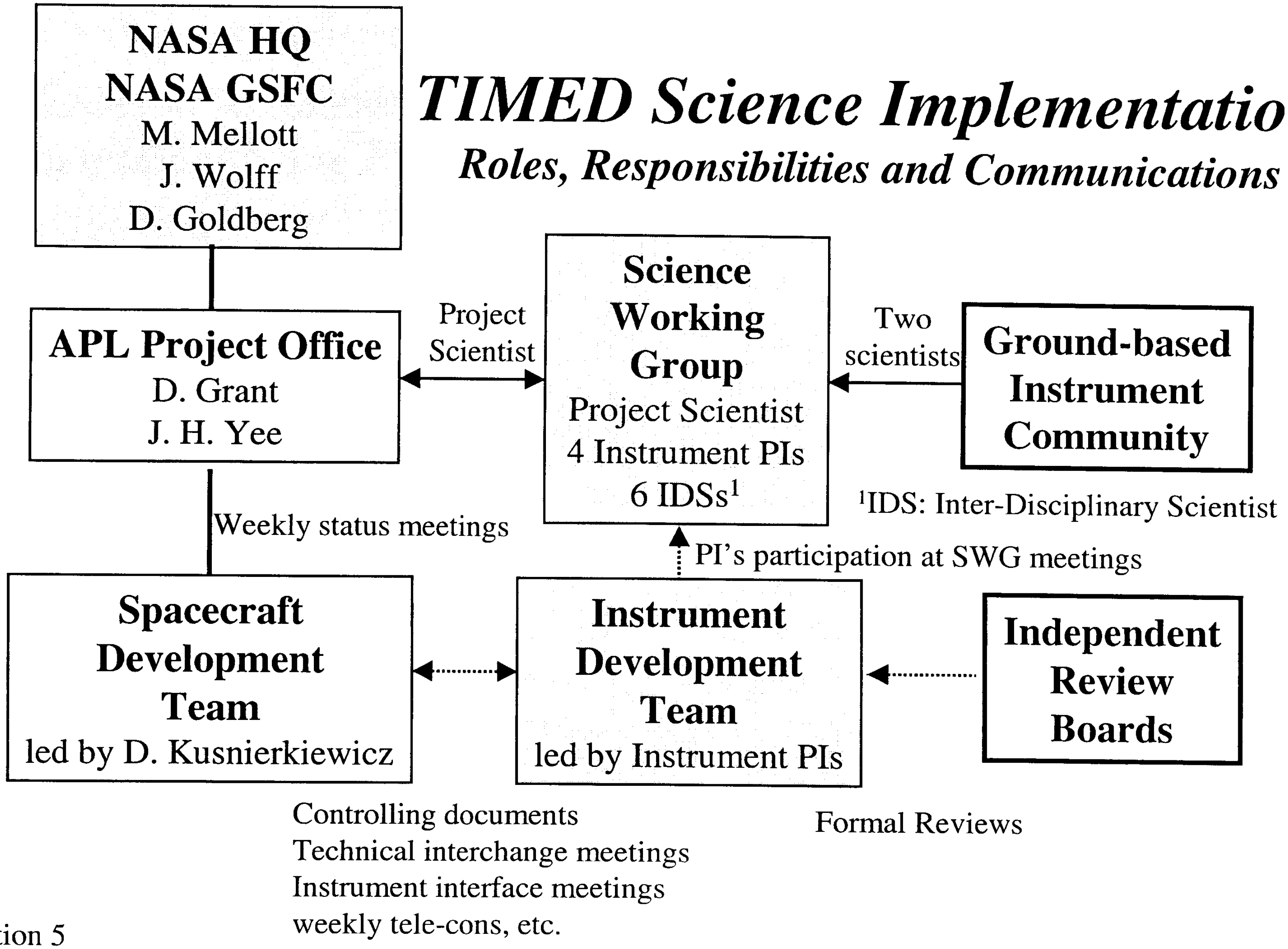
TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

TIMED Science Implementation

Roles, Responsibilities and Communications



Question 5

Science Implementation and TIMED SWG (II)

- The participation of the project scientist at the spacecraft status meetings will ensure that the needs of the science team are implemented;
- The participation of PIs at the SWG meetings will inform the science team and NASA program offices the progress of their instrument development efforts, including waiver requests, and ensure that their special requests are scientifically justified and, if implemented, do not adversely impact the design and operations of spacecraft and other instruments.
- The participation of the IDSs at the SWG meetings will provide critical inputs to the planning of instrument operations and the analysis/ interpretation of instrument observational data.
- The participation of the ground-based instruments representatives at the SWG meetings will ensure optimum implementation of the ground-based observation component of the TIMED science investigation.

Ground-based Instrument Investigators

The TIMED ground-based investigators were officially selected in June 2000 through a competitive peer-review process:

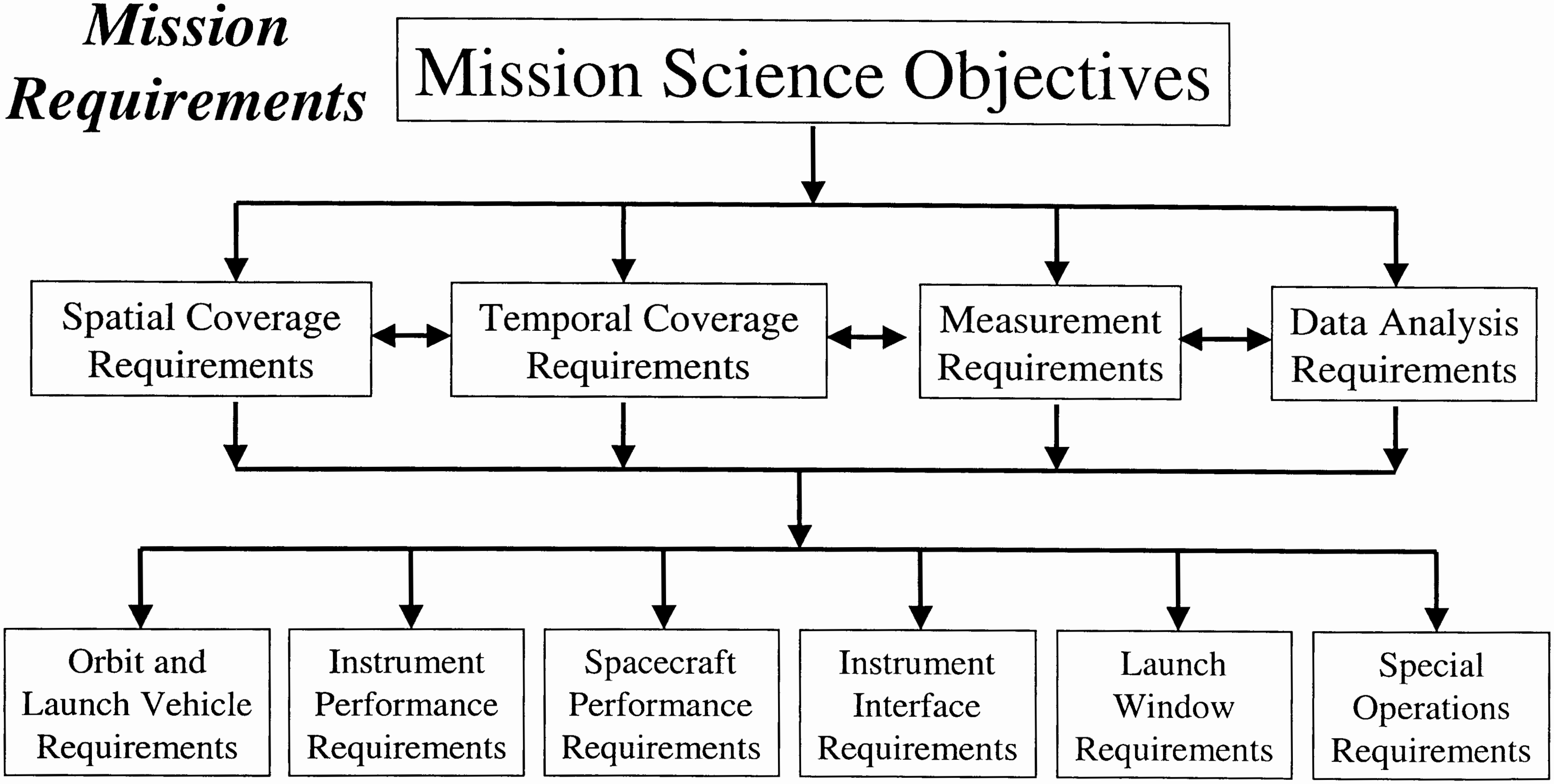
Susan Avery	Radars, Winds, Temperature, Antarctic, Basic Structure
Geoff Crowley	Data Assimilation Model, Joule Heating, Energy Balance
Mark Conde	Optical, Winds, Basic Structure
Ray Greenwald	Radar, Ion and Neutral Winds, Joule Heatings, Energy Balance
Maura Hagen	Basic structure, models
James Hecht	Opticals, Composition, auroral particle inputs
Ruth Lieberman	Radars, Winds, Basic Structure
Scott Palo	Radars, Winds, Mid-high latitudes, Basic Structure
Joseph Salah	Radar, Winds and Temperature, Mid-high latitudes, Basic Structure
Brad Sandor	Microwave Sounder, Composition and Chemistry
Joe She	Lidars, Winds and Temperature, Basic Structure
Abas Sivjee	Fabry-Perot, Spectrometers, Wind, Temperature, Basic Structure
Gary Swenson	Lidar & Imagers, Mid-latitudes, Small Scale Waves, Momentum Balance
Michael Taylor	Imagers, Mid-latitudes,Small Scale Waves, Momentum and Energy Balance

⟹ Providing supplementary/complimentary observational data and modeling expertise to the TIMED investigation team

Major Responsibilities of TIMED SWG

- Develop strategy and implementation plans to meet TIMED Science Objectives
  - Determine Important Mission Requirements
    - Orbits and Mission Lifetime
    - Measurement Requirements and Priorities
    - Mission System Requirements
    - Launch Window Requirements
  - Develop TIMED ground-based investigation plan
- Work with Mission/Spacecraft development teams to meet the needs of the investigators (instrument developers, IDS, and others);

Mission Requirements



TIMED Science Implementation Requirements/Goals Flowdown
I. Measurement Requirements/Goals

TIMED Mission Science Objectives →

- life time[1]: > 6 months
- measurements[1]: global
- measurements[1]:
  - density (pressure)
  - temperature
  - winds
  - energy inputs
  - energy outputs
- data analysis/ interpretation[1,2]
  - spatial coverage: 60-180 km
  - spatial resolution ~2 (V) x 500 (H) km
  - temporal coverage all local time
  - temporal resolution
  - ability to resolve tides[1,2]
  - ability to observe at similar local time at same latitude during each seasons[3]
- special requirements[1,2]:
  - measurements at summer high-latitudes

→ Instrument Requirements → Mission System Engineering Requirements

[1]Science Definition Documents
[2]SWG meeting notes

TIMED Science Implementation Requirements/Goals Flowdown
2. Instrument Requirements

TIMED Mission Science Objectives →

- life time[1]: > 6 months
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- measurements[1]:
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  - temporal resolution
  - ability to resolve tides[1,2]
  - ability to observe at similar local time at same latitude during each seasons[3]
- special requirements[1,2]:
  - measurements at summer high-latitudes

→

- Four spaceborne remote sensing instruments operated at 100% duty cycle with performance requirements[1,3]
- Groundbased program to provide supplimentary and complimentary data for[4]
  - •cross-validation
  - •resolving tides
  - •small-scale waves
  - •ion-neutral coupling

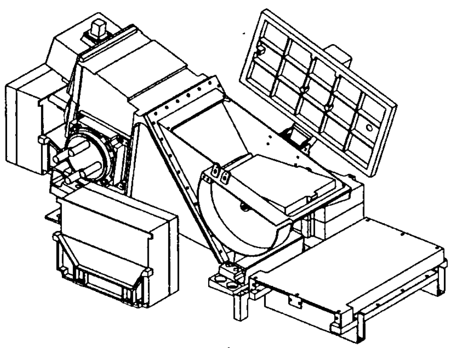
→ Mission System Engineering Requirements

[1]Science Definition Documents
[2]SWG meeting notes
[3]Instrument Requirements Documents
[4]Groundbased Implementation Plan

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

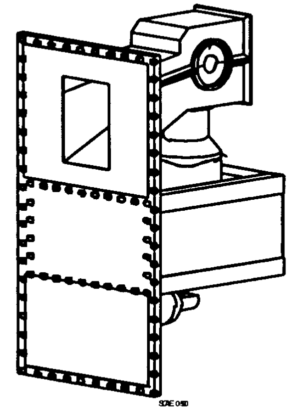
Red Team Review 31 Oct. - 3 Nov. 2000



GUVI
(Aerospace Corp.
APL/JHU)

* composition
* temperature
* auroral inputs
* electron density

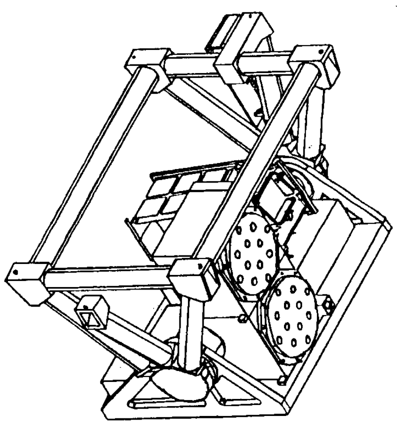
Global Ultra-Violet Imager



SABER
(NASA Langley,
SDL/Utah State)

* pressure
* temperature
* infrared cooling rates
* composition

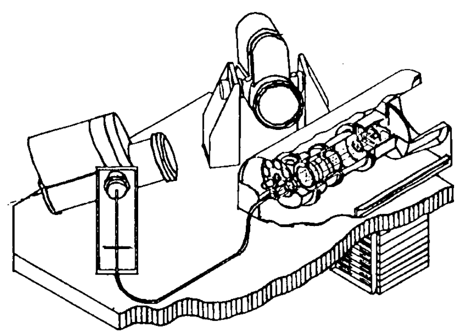
Sounding of Atmosphere using Broadband Emission Radiometry



SEE
(Univ. of Colorado)

* solar EUV irradiance
* composition

Solar EUV Experiment



TIDI
(Univ. of Michigan)

* vector winds
* temperature
* composition

TIMED Doppler Interferometer

TIMED Instruments

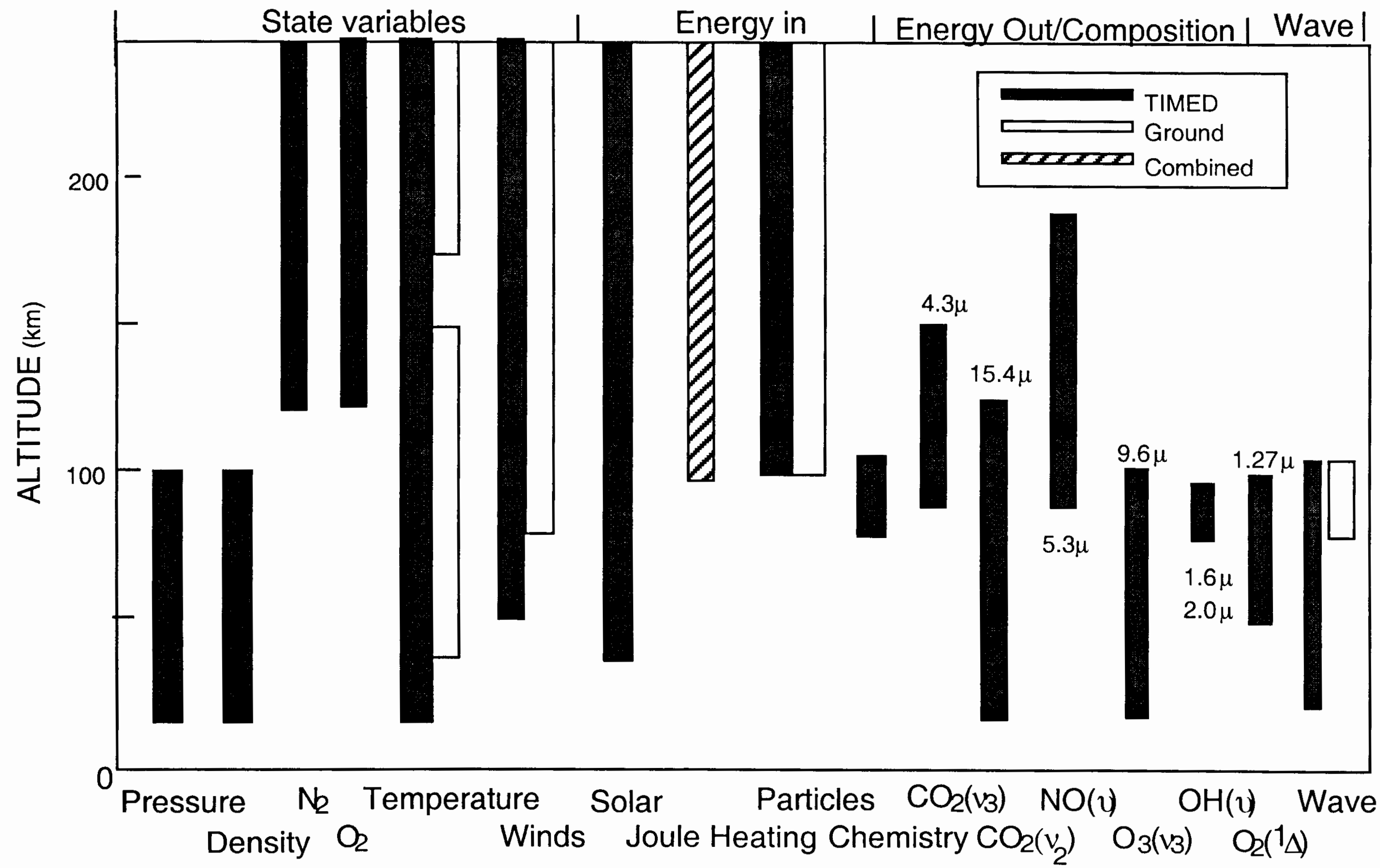
- **SEE (Solar EUV Experiment):** -- Energy Input
  - A suite of photometers and spectrometer designed to measure the solar X-ray, UV and FUV irradiance.
- **SABER (Sounding of the Atmosphere using Broadband Emission Radiometry):** ----------------- State Variables, Minor Species, and Energy Output
  - A multichannel radiometer designed to measure the pressure, temperature, minor species and infra-red cooling rates.
- **GUVI (Global Ultraviolet Imager):** ------------ State Variables and Energy Inputs
  - A spatial scanning UV spectrograph designed to measure the composition and temperature profiles, and auroral energy inputs.
- **TIDI (TIMED Doppler Interferometer):** ---------------------------- State Variables
  - A Fabry-Perot Interferometer designed to measure the winds and temperature profiles.
- **Groundbased Instrument Network:** ----------------- State Variables and Energy Inputs
  - A network of groundbased instruments to provide measurement validation and supplementary atmospheric parameters.

Ground-based Investigator Contributions

- TIMED ground-based component will provide supplementary and complimentary data for
  - providing necessary cross-validation;
  - aiding the study of large-scale tidal and planetary waves (i.e. tides,
  - providing important measurements of momentum and energy inputs from small-scale gravity waves
  - understanding the neutral-ion coupling and joule heating

TIMED Ground-based Investigation Plan, 1997

TIMED Measurement Capabilities



	Instruments				
Measurements	**GUVI**	**SABER**	**SEE**	**TIDI**	**SM***
State Parameters					
Temperature	P	P		P	C
Density	P	P	C	C	C
Wind Velocity		C		P	C
Composition	P	P	C	C	C
Energy Inputs					
Solar	C	P	P	P	C
Auroral	P		C		P
Tides/Waves		P		P	P
Energy Outputs		P		C	

P: Primary Measurement; C: Contributing Measurement

*SM: Supporting Measurements (ground-based and other space missions)
Ground-based investigators are to be selected.

Science Recovery Plan

- TIMED mission has been implemented with single-string instrument payload.
- Although we do not believe that any instrument will potentially suffer catastrophic failure on orbit, contingency plans have been developed to recover some of the lost data which are important for the TIMED investigation if it happens.
  > we will increase the efforts of contributing and supporting measurements to recover the data loss:
    - GUVI failure: recovered by using SUSSI/DMSP (a similar instrument providing identical measurements, to be launched in 1/01) data, and SEE, IMAGE and POLAR data;
    - SEE failure: recovered by using SNOE and SOHO data, and by increasing GUVI efforts to obtain EUV integrated flux; and by increasing the number of supporting SEE rocket experiments to validate GUVI EUV proxy algorithms.
    - TIDI failure: recovered by increasing the ground-based observation efforts, and by deriving wind vectors from SABER temperature fields with NCEP or UKMO stratospheric wind data.
    - SABER failure: recovered by using Envi-sat and Odin data, and by increasing the ground-based observation efforts, and by implementing an optimized TIDI temperature mode
- TIMED and other supporting measurements will be used to constrain models and further our understanding of processes taking place in MLT region. The science recovery plan ensures that useful measurements will be available and viable science will be returned.

Questions 4, 11

TIMED Science Implementation Requirements/Goals Flowdown
3. Spacecraft and Mission Requirements

TIMED Mission Science Objectives →

- life time[1]: > 6 months
- measurements[1]: global
- measurements[1]:
  - density (pressure)
  - temperature
  - winds
  - energy inputs
  - energy outputs
- data analysis/ interpretation[1,2]
  - spatial coverage: 60-180 km
  - spatial resolution ~2 (V) x 500 (H) km
  - temporal coverage all local time
  - temporal resolution
  - ability to resolve tides[1,2]
  - ability to observe at similar local time at same latitude during each seasons[3]
- special requirements[1,2]:
  - measurements at summer high-latitudes

→

- Four spaceborne remote sensing instruments operated at 100% duty cycle with performance requirements[1,3]
- Ground-based program to provide supplimentary and complimentary data for[4]
  - •cross-validation
  - •resolving tides
  - •small-scale waves
  - •ion-neutral coupling

→

- Orbit[5]
  - type: circular
  - altitude: 625 km
  - inclination: 74.1°
- life time[5]: 2 years
- instrument performance[3]
- spacecraft performance[6]
- instrument interface[7]
- ground-based program[4]
- special requirements
  - launch window: favorable beta angles to permit measurements at summer high latitudes[2]
  - yaw maneuvering[5]
  - SABER stray light calibration[7]

[1]Science Definition Documents
[2]SWG meeting notes
[3]Instrument Requirements Documents
[4]Groundbased Implementation Plan
[5]Mission System Engineering Requirements
[6]Spacecraft Performance Requirements
[7]General and Specific Interface Documents

TIMED Mission Science Objectives → Requirements ← Performances

Requirements

- Orbit[5]
  - type: circular
  - altitude: 625 km
  - inclination: 74.1°
- life time[5]: 2 years
- instrument performance[3]
- spacecraft performance[6]
- instrument interface[7]
- ground-based program[4]
- special requirements
  - launch window: favorable beta angles to permit measurements at summer high latitudes[2]
  - yaw maneuvering[5]
  - SABER stray light calibration[7]

Performances

- Orbit[7]
  - type: circular
  - altitude: 625 km
  - inclination: 74.1°
  - launch vehicle: Delta II
- life time[7]: 2 years
- instrument performance[7]
- instrument interface[7]
- spacecraft performance[7]
- ground-based based program
  - 14 PIs selected on 6/2000
- special requirements
  - launch window: favorable beta angles to permit measurements at summer high latitudes[8]
  - yaw maneuvering[7]:-every ~60 days
  - SABER stray light calibration
    - implemented for early operations

[3]Instrument Requirements Documents
[4]Groundbased Implementation Plan
[5]Mission System Engineering Requirements
[6]General and Specific Interface Documents

[7]Instrument and Spacecraft Performance (RTR materials)
[8]requirement is still met for 3/01 launch

Questions 7, 12

Summary

- TIMED investigation plan is developed at the SWG meetings. It implements a joint space (NASA/TIMED) and ground-based (NSF/CEDAR) collaborative studies program to achieve the TIMED mission science objectives.
- SWG meetings have been the avenue for communication between instrument development teams, the science team, the mission implementation team at APL, and the NASA program offices.
- Most of the instrument/spacecraft interface requirements have been met (waiver requests have been granted) and the spacecraft performance meets all science requirements.
- Most of the instrument performance requirements have been met. For those which have not been met, waivers have been granted and the impacts on the science have been found to be minimal.
- Mission science objectives will be met with the instrument and spacecraft performance as-tested.
- The entire science investigation team (both space and ground-based components) is eagerly awaiting the launch of TIMED.

Red Team Review

October 31, November 1-3, 2000

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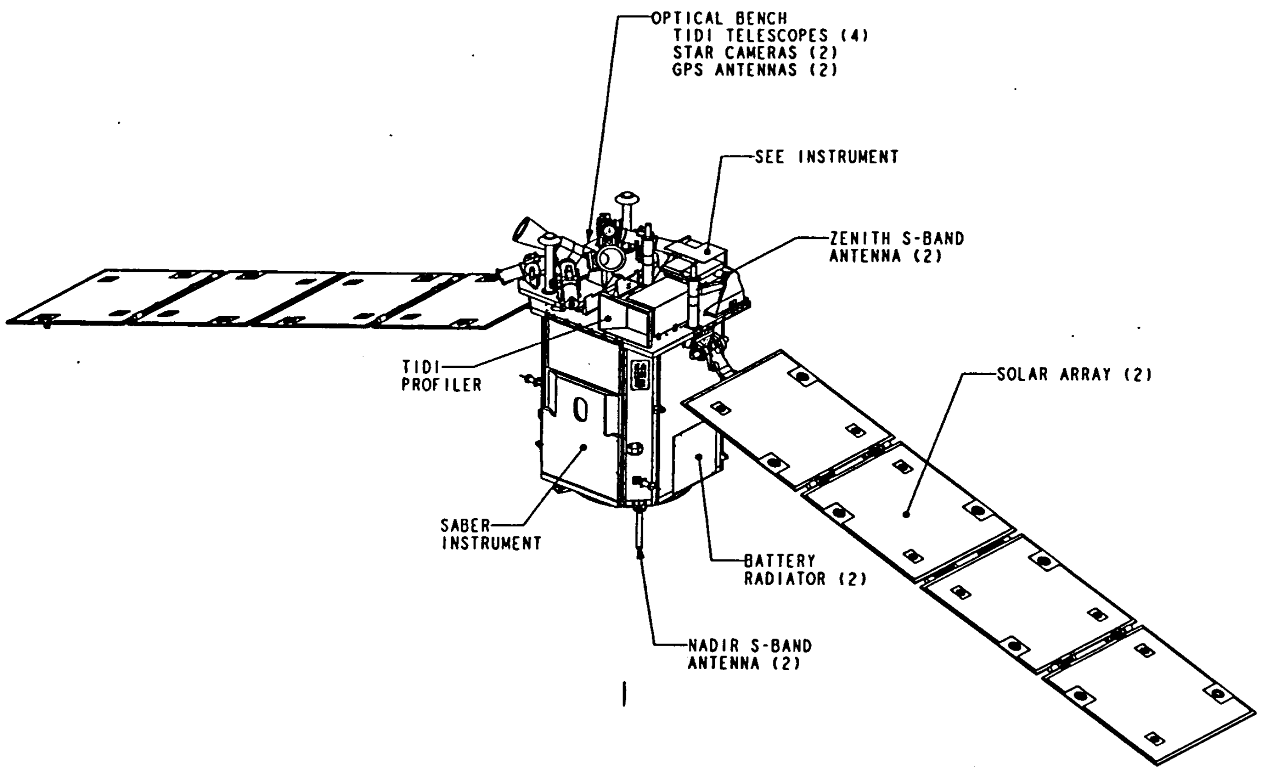
TIMED Mission Overview

- **TIMED is an atmospheric remote sensing mission sponsored by the NASA Office of Space Science; TIMED is the first *Solar Connections* program**
- **TIMED is a <u>two-year mission</u> intended to launch in March 2001 on a Delta II co-manifested with JASON**
- **TIMED will launch into a 625-km circular orbit inclined 74.1° with a 720° per year nodal regression**
- **The four TIMED instruments (GUVI, SABER, SEE, and TIDI) operate on a 100% duty-cycle**
- **The TIMED instruments, spacecraft and ground system incorporate advanced autonomy features and use a decoupled operations concept intended to lower the cost of Mission Operations and Data Analysis**

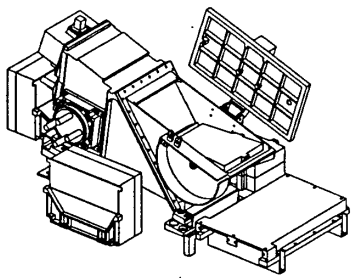
TIMED Mission Overview

- Program Conceptual Design Review in December, 1994
- 18 month delay before restart with full team in June, 1996
- The baseline design for the TIMED spacecraft was re-defined after June 1996 start
  - Therefore, this review will address processes beginning with June 1996 start
    - CoDR review, RFAs, etc. will not be covered
    - PDR represents baseline of the TIMED spacecraft as realized today
- Redundancy in spacecraft subsystems was not a requirement, but a goal
- No one instrument is considered mission critical
  - Instrument single string design acceptable

TIMED Spacecraft



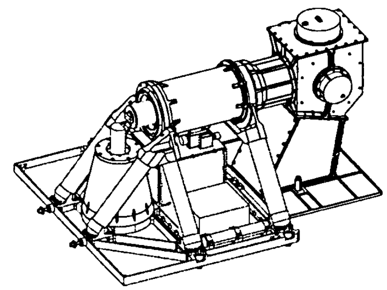
TIMED Instruments



GUVI
(Aerospace/APL)

- COMPOSITION
- TEMPERATURE
- AURORAL INPUTS
- ELECTRON DENSITY

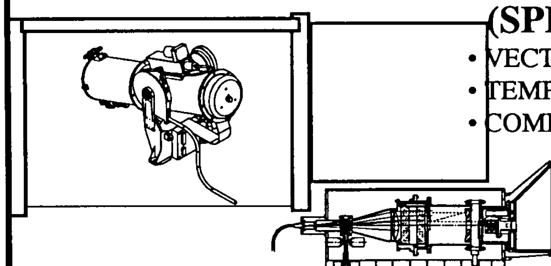
Global Ultra-Violet Imager



SABER
(LaRC/SDL)

- PRESSURE
- TEMPERATURE
- INFRARED COOLING
- COMPOSITION

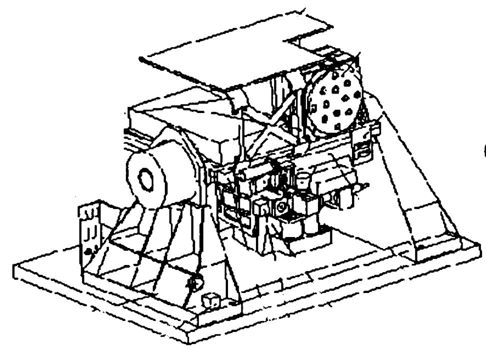
Sounding of the Atmosphere using Broadband Emission Radiometry



TIDI
(SPRL/APL)

- VECTOR WINDS
- TEMPERATURE
- COMPOSITION

TIMED Doppler Interferometer



SEE
(LASP)

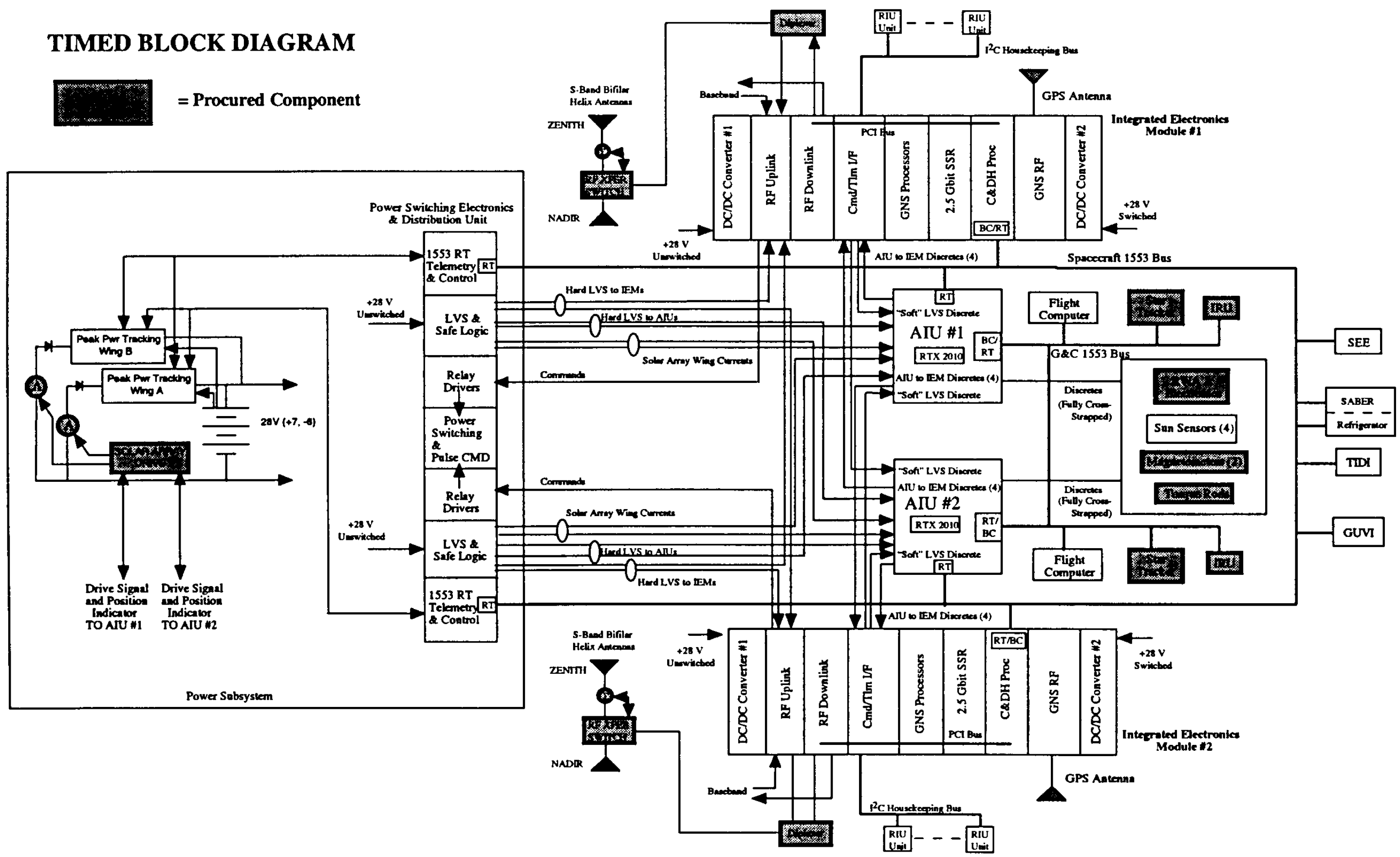
OLAR EUV
OMPOSITION

Solar EUV Experiment

TIMED Spacecraft Parameters

• Mass:	587 kg	(Allocation from LV is 660 kg)
• Power:	426 W	(Array output, EOL, 1 failed string, Beta 0 orbit average)
• SSR Capacity	2.5 Gbit	(1.9 Gbit required)
• Uplink Data Rate (S-Band)	2 kbps	
• Downlink Rate (S-Band)	4.59 Mbps, 2.295 Mbps, 10.361 kbps, 5 kbps (TDRSS comm)	
• Attitude Control	0.5°, each axis, 3σ	
• Attitude Knowledge	0.03°, each axis, 3σ	
• Position Knowledge	300 m, each axis, 3σ	
• Velocity Knowledge	0.25 m/sec, each axis, 3σ	
• Time Accuracy	10 ms	

Spacecraft Block Diagram



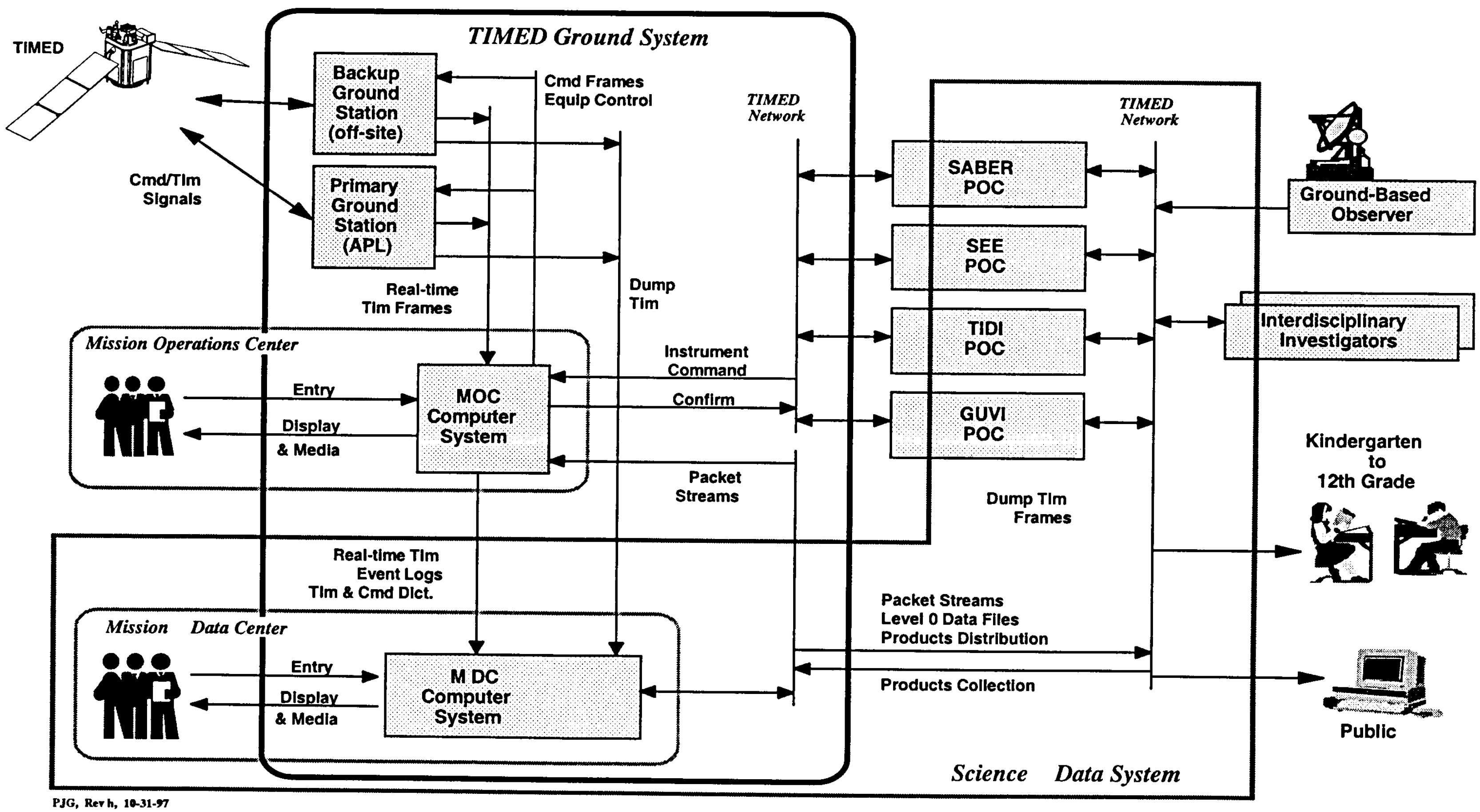
Spacecraft Description

- **Aluminum Structure, Al Honeycomb Panels**
  - **Composite Optical Bench for TIDI, Star Cameras**
  - **Aluminum Face Sheets on Solar Panels**
- **Three Axis stabilized; no propulsion**
  - **One side of spacecraft always cold (180° yaw maneuver every 60 days)**
- **On-board Autonomous GPS Navigation**
- **S-Band Communications**
- **Two solar panel wings (GaAs Cells) with single axis drive**
- **22 cell Individual Pressure Vessel Nickel Hydrogen battery**
- <u>Most</u> **Spacecraft relay commands executable without software through Critical Command Decoder (CCD, located on Uplink Card in IEM; always powered)**

Spacecraft Description (Cont'd)

- **Fully redundant spacecraft bus (Both Star Trackers Needed to meet Attitude Knowledge Requirement)**
- **Two 1553 Bus Architecture (Similar to NEAR)**
  - **C&DH/Spacecraft 1553 Bus**
  - **G&C 1553 Bus**
    - **AIUs are RTs on C&DH 1553, BC/RT for G&C 1553**
    - **<u>AIUs are responsible for safing spacecraft</u>**
- **Instruments are on C&DH 1553 Bus**
  - **Instrument Discretes Only for S/C Monitored Temperatures**
    - **Interface through RIUs**
  - **Each IEM is a single-string C&DH processor, 2.5 Gbit SSR, GPS Navigation System (GNS), and RF Communications "Subsystem" (Similar to ACE)**
  - **No Discrete (non-1553) Cross-Strapping Between IEMs**

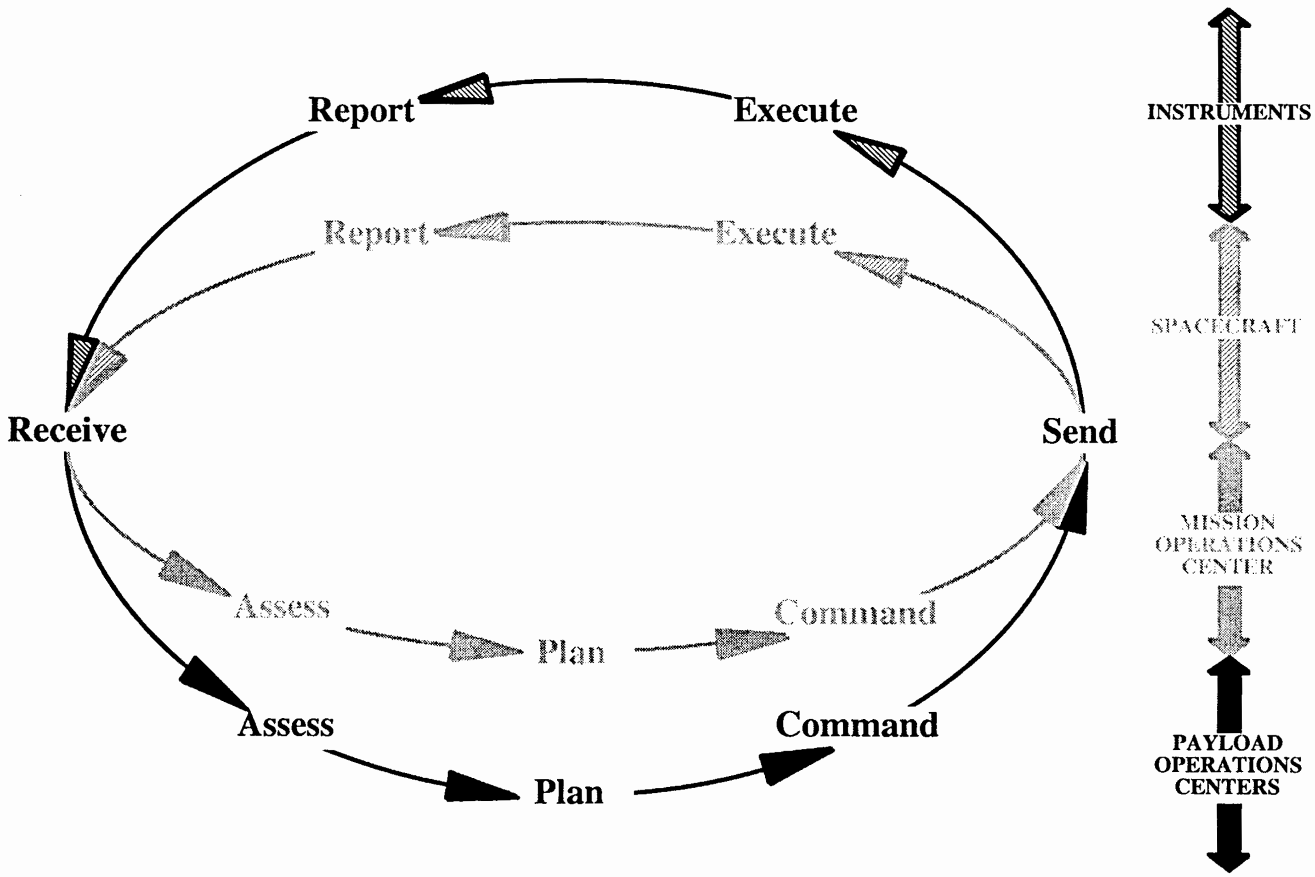
Ground System Architecture



TIMED Mission Operations Concept

- TIMED spacecraft has a high degree of autonomy to enable inexpensive Mission Operations with a small Mission Operations Team
  - Greyhound™ Bus Paradigm
    - Spacecraft is the "bus", instruments are the "passengers"
    - Instrument operations are "decoupled" from spacecraft operations
    - Spacecraft provides sufficient resources for unconstrained, independent instrument operations
- Operations are single-shift, seven days/week
  - Six Mission Ops Team members, including the Mission Ops Manager

TIMED Operations Concept (cont'd)



TIMED Mission Operations Concept (cont'd)

- **Mission Ops Team (MOT) is responsible for operating <u>spacecraft</u> from the Mission Operations Center (MOC)**
  - **MOC is responsible for DELIVERING instrument commands to spacecraft, NOT responsible for instrument command CONTENT**
- **Instrument Teams are responsible for operating <u>instruments</u> from flight Payload Operations Centers (POCs)**
  - **Each POC prepares command uploads and forwards them via FTP to MOC for transmission to the spacecraft**
  - **Each instrument stores and executes its own commands, time-tags its own data, which is then stored on the SSR for later downlink**

TIMED Mission Operations Concept (cont'd)

- MOC, Mission Data Center (MDC), Science Data System (SDS), Ground Station, GUVI POC at APL
  - USN for back-up ground stations
- TIDI POC at SPRL Ann Arbor, MI
- SEE POC at LASP, Boulder, CO
- SABER POC at NASA Langley
- POCs connect to MOC via Internet or modem
  - Back-up POCs at APL

TIMED Mission Operations Concept (cont'd)

- "Event based" commanding replaces time-tagged command loads for repetitive events
  - GPS Navigation System (GNS) provides on-board knowledge of position, velocity and time
    - On-board notification provided to instruments of events of interest:
      - Terminator crossings
      - Polar region
      - SAA
    - Downlinks autonomously initiated in the course of normal operations

System Engineering

- **APL process characterized by small, highly motivated and skilled team of experienced engineers and scientists**
- **High degree of experience of lead technical people and the APL culture fosters system level thinking and perspective at the subsystem level**
- **Small size of organization and project team enables open, frequent communications**
  - **Openness of environment encourages rapid problem identification and resolution**
- **Historically, APL has a very low turnover rate**
  - **Continuity of key personnel (design engineers) throughout the life of the project**
    - **Reduces need for excessive documentation**

System Engineering (Cont'd)

- **Key to the success of the APL "process" is the role of the Lead Engineer**
  - **Experienced engineer with "cradle to grave" responsibility;**
    - **That is, one individual who is responsible for a given component, subsystem, or activity from program start through the end of Phase C/D**
    - **Has responsibility for design, implementation, testing at sub-assembly and assembly level, flight qualification testing, spacecraft level I&T support, documentation, etc.**
    - **This level of responsibility and involvement helps cultivate the system level perspective throughout the technical team**

System Engineering (Cont'd)

- Strong APL emphasis on testing
  - Testing at all levels:
    - Piece Part
      - Radiation
    - Subassembly
    - Assembly
    - Subsystem
    - Spacecraft/Ground System/Operations
  - Simulation Testing at subsystem level
    - Mini-MOCs, Spacecraft emulators
      - "Test it as you fly it"

System Engineering (Cont'd)

- Simulation Testing at subsystem level (cont'd)
  - Simulations
    - G&C, GPS, Power system
- Simulation Testing at spacecraft level
  - Mission simulations supported by G&C, GPS, and solar array simulators
- Exhaustive spacecraft autonomy testing
- Operations contingency testing

- TOPS Simulator
  - TIMED OperationS Simulator
    - Engineering models of spacecraft subsystems (single string), with G&C and GPS Simulators
    - Test software uploads, anomaly investigations, etc.

System Engineering (Cont'd)

- Launch pad tests
  - JASON RF compatibility testing

- <u>Even within the context of faster, better, cheaper, and design-to-cost, the technical staff at APL considers thorough testing to be essential to mission success</u>

Requirements Flowdown

- Science requirements flowed down into high level mission requirements in "TIMED System Requirements Document", 7363-9001.
  - Covers Spacecraft, Ground System, Launch Vehicle, Integration and Test, Mission Operations and Data System Requirements at the top level
- Subsystem level requirements derived by lead engineers, reviewed and iterated with system engineer
  - Documented by lead engineer
- Instrument requirements derived by APL instrument managers working with instrument teams
  - APL instrument leads perform interface functions between instrument development teams and system engineer

Question 5

Requirements Flowdown (Cont'd)

- **Instrument interface requirements:**

7363-9050	**TIMED Spacecraft General Instrument Interface Specification (GIIS) (Includes MOC-POC I/F)**
7363-9046	**GUVI Instrument Specific Instrument Interface Specification (SIIS)**
7363-9047	**SABER Instrument Specific Instrument Interface Specification (SIIS)**
7363-9048	**SEE Instrument Specific Instrument Interface Specification (SIIS)**
7363-9049	**TIDI Instrument Specific Instrument Interface Specification (SIIS)**
7363-9010	**TIMED Component Environmental Specification**
7363-9038	**TIMED EMC Requirements Document**

Question 5

Documentation

- Mission level requirements documents, spacecraft level integration and test plans and procedures are formal program documents (7363-XXXX)
- Instrument interface documents are formal program documents
- Subsystem level requirements documents, test plans and procedures may be either formal program documents or informal memos (left to discretion of lead engineers)
- All APL hardware drawing packages under Level 2 Configuration Control (Formal change notice required)
  - Spacecraft harness and instruments (GUVI) Level 2a; red lined drawings permitted

Resource Management

- **All resource reserves (mass, power, data rate, etc.) are held at the system level by the system engineer**
  - **No distinction is made between margin and reserves**
  - **Subsystems are not given allocations of either**
  - **Component/subsystem resources are tracked and updated regularly (either as best known estimate or actuals)**
    - **Holding all margin/reserves at system level allows for more flexible, efficient allocation across the entire system**
    - **For example, subsystem power was allowed to grow as needed, causing growth in solar arrays, which was allowed because mass margin was comfortable**
  - **Reserves were allocated to instruments so as not to overly constrain their design efforts**

Margins

Parameter	Margin	Comment
Mass	12.4%	CDR margin = 10%
Power	4.90 %	CDR margin = 11%
Battery DOD @ separation	24.5%	Against nameplate capacity
Battery DOD after detumble	49.7%	Assumes no solar input
Uplink	43.5 dB 31.2 dB	Nadir Omni
Downlink: 4 Mbps 2 Mbps 10 kbps	13.9 dB 17.7 dB 38.2 dB	

Processor Margins

Subsystem	Throughput Margin (Peak)	Processor
C&DH	80%	Mongoose V, 12 MHz
GNS Tracking	19% (40% Average)	Mongoose V, 12 MHz
GNS Navigation	66%	Mongoose V, 12 MHz
AFC	55%	Mongoose V, 12 MHz
AIU	70%	RTX 2010, 6 MHz
GUVI	80%	80C186, 8 MHz
SEE	98% Idle 70% Observations 25% Worst Case	GEC Plessey 13750 (Mil-Std-1750) 16 MHz
TIDI	52%	80C51

Memory Margins

Subsystem	Memory Margin	Memory Capacity
C&DH	48% RAM 44% Flash	2M SRAM 4M Flash
GNS Tracking	87% RAM	2M SRAM
GNS Navigation	34% RAM 56% Flash	2M SRAM 4M Flash
AFC	53% RAM 69% Flash	2M SRAM 4M Flash
AIU	1.5% RAM 69% PROM 22% EEPROM	128 Kbytes 16 Kbytes 128 Kbytes
GUVI	57% RAM 69% EEPROM 67% PROM	320 Kbytes 256 Kbytes 48 Kbytes
SEE	55% ROM 17% RAM 44% EEPROM	8 Kwords 448 Kwords 128 Kwords
TIDI	26% PROM 3% EEPROM 6% RAM	

Risk Management

- Risks managed through close, open team communications (weekly status meetings) and "top ten list" tracking
  - Weekly spacecraft status meetings, ground system forums, more frequent meetings with smaller teams to resolve issues as needed
  - Weekly telcons and quarterly TIMs with instruments
  - Emphasis on solving problems, not assigning blame encourages openness, rapid identification of risks, problems
    - Facilitates timely resolution

Risk Management (Cont'd)

- **Example: Early risk identified in development of Integrated Electronics Module (card cage with RF, C&DH/SSR, and GPS Navigation subsystems)**
  - **Decision to build engineering model IEM; Environmental qualification of first flight unit delayed until after spacecraft level compatibility tests**
- **Example: Early risk identified in use of Mongoose V**
  - **Decision to provide engineering model processor to all software development teams**
  - **Fall back option (Mongoose IV) maintained until Mongoose V success was clear**

Risk Management (Cont'd)

- **Example: Remote Interface Units/ RIO ASIC**
  - **Actel implementation baselined, fall forward option maintained, not exercised**
- **Example: IEM backplane bus choice: PCI or IEEE 1394**
  - **PCI chosen; no development required vs. 1394 ASIC**
- **Example: Use of plastic parts**
  - **Development of discipline, dry box storage in labs**

Risk Management (Cont'd)

- **Risks also identified from outside program**
  - **Many system engineers reside within same section in the line organization**
    - **Close proximity physically, promoting frequent communications**
    - **Lessons learned easily passed between projects**
  - **Access to NASAs Lessons Learned Web page**
- **FMEA, FTA, PRA performed in response to Red Team Review Requirements**
  - **FTA developed early in program by Autonomy System Engineer and Spacecraft System Engineer to aid in design of autonomy rules**

APL Hardware Design/Development Process

- Spacecraft and GUVI development
- Formal weekly status meetings
  - Ongoing informal team meetings as required
- Requirements Definition and review
- Engineering Design Review (EDR)
- Fabrication Feasibility Review
- Drawing sign-off
  - Level 2 Configuration Control
- Discrepancy Reports generated at subassembly level
  - Reviewed and signed off by Material Review Board: lead engineer, technical services representatives, space department reliability, and spacecraft system engineer (others as needed: thermal, mechanical, EMC, etc.)

Configuration Control Boards

- **Different boards for different phases of program, different disciplines**
  - **Fabrication phase**
    - **Spacecraft system engineer, lead engineer, R&QA, technical services representatives, others as required**
  - **Hardware CCB**
    - **Spacecraft system engineer, lead engineer, R&QA, others as required (for example, the software system engineer may be brought in if it is decided to fix a hardware problem in software**
  - **Software CCB**
    - **Mission system engineer, Mission software system engineer, software segment engineer, software subsystem lead, software QA, others (I&T, Mission Ops) as required**

Configuration Control Boards (Cont'd)

- Operations CCB
  - Mission system engineer, software system engineer, mission ops manager, others as required

Hardware Test Program
Board Level (Typical)

- **Verify discrete component values, power consumption**
- **Ambient Bench Testing**
  - **Vary power supply voltages**
- **Thermal Test in Air (optional)**
  - **-29° to +65° C**
  - **Voltage variation**
- **Environmental Stress Screening 20 cycles -34° to + 90° C (typical)**
- **Three powered thermal test cycles -29° to +65° C**
- **Conformal Coat**
- **Ambient & Thermal Card Test**
  - **-29° to +65° C**
  - **Voltage variation**
- **Delivery for integration with higher assembly**

Hardware Test Program
Box Level (Typical)

- Defined in TIMED Component Environmental Specification, 7363-9010
  - Also imposed on instruments and procured items
- Bench Ambient & Thermal Test
  - -29° to +55° C
- Powered Vibration
  - Sine Survey, 3 axis
  - Sine, 3 axis
  - Random, 3 axis
- Thermal Vacuum
  - One unpowered survival cycle
  - Six operational cycles -29 C to +55 C
    - Cold and hot turn-on, min and max temp
    - Complete test procedure at plateaus, 1st and 6th cycle
- Baseline Test
- Problem Failure Reporting Process begins with box level acceptance testing

Question 3

Hardware Test Program

Spacecraft Level

- Baseline Performance Test of integrated spacecraft
  - Full performance test of all subsystems (Pre/Post TV)
- Simulations, special tests, system end-to-end tests
  - Includes testing of cross-strapped configurations (Pre/Post TV)
- Environmental Test Program as detailed in 7363-XXXX
  - Sine survey
  - Random vibration
  - Acoustics
  - Pyro/shock
  - Thermal vacuum
    - Suvival (1 cycle), balance (1 cycle), and operational cycles (4)

Summary Test Matrix

	Pre-Vib	Post-Vib	Post-Acoustic Tests	Thermal Vacuum	Post-TV	VAFB
Baseline Performance (BPT)	X	X	X	X	X	X
Functional Tests		X (each axis)	X			
Event Driven Sims	X	X	X	X	X	X
Launch/Separation Sim	X	X	X	X	X	X
Orbit Simulations				X	X	
Cold Turn-On				X		
Hot Turn-On				X		
Hard LVS	X			X	X	X
GNS RF Threshold	X			X	X	
GNS 1PPS Offset	X			X	X	X
System Time Accuracy			X	X	X	
Survival Heaters				X		
Torque Rod Detumble Test				X		
AST TEC Set Point				X		
Autonomy	X	X	X	X	X	X
Alignments	X	X			X	X
S/C Configuration for Vibration, Acoustic and Shock Tests: Launch Configuration						

Question 3

Deployment Testing

Mechanism		Pre-Enviromental	Shock/Pyro	TV	Post-TV	VAFB
Solar Wing Deployment		Wing Level, Not on	S/C Pop & Catch		Wing Level, Not o	S/C Level, Not c
Solar Array Pyros		Tested with fuses	Actual pyros fired	Tested w/ fuses	Tested with Fuses	Test with Fuses
TIDI Telescope Pyros		Tested with fuses	Actual pyros fired			Test with Fuses
GUVI Cover Release Pin Puller		Tested with fuses	Actual pyros fired	Tested w/ fuses	Tested with Fuses	Test with Fuses
SABER Telescope Cover (Wax Actuator)				T		
Clamband Separation			T; initiated sep sequence			

Question 3

EMC Testing

- Component Level EMC Testing performed to the requirements of 7363-9010, "TIMED Component Environmental Specification" and 7363-9038, "TIMED EMC Control Plan and EMI Performance Requirements Specification"
  - Component Level Tests Waived on some units that could be qualified by similarity to previously tested designs
- Spacecraft level tests limited to self compatibility
  - Subsystems configured to "noisiest" modes
  - GNS performance of particular concern

EMC Verification

Subsystem	Component	Verification by Test (T) or Similarity (S)
IEM	IEM 1,2	T
	IEM #1, 2 RIU 1-7	T
G&C	AST 1,2	T
	IRU 1,2	S
	RWA 1-4	S
	AFC 1,2	S
	AIU 1,2	T
	Magnetometers 1,2	S
	Torque Rods 1-3	N/A
	Sun Sensors 1-4	N/A
	Solar Array Drives	S
	Solar Array Drive Electronics	S
Power	Battery	T
	PSE/DU	T
	PPT	T
	Solar Array	N/A
GUVI	ECU	S
	SIS	S
	SIS Electronics	S
	FPE 1,2	S
	HVPS 1,2	S
SABER		T
SEE		T
TIDI	Electronics	T
	Profiler	T
	Telescopes 1-2	T

Question 3

Contamination Control

- GSFC resources were used to develop a rigorous process for meeting TIMED cleanliness requirements
- Contamination model was developed
  - Vent added to spacecraft design
    - Component outgassing requirements were quantified
      - Requirements for interior, and exterior components
- Process was to quantify outgassing rate (via TQCM) at end of TV test (if applicable)
  - Bakeout added if required
  - Bakeouts performed by vendors, instrument teams, and APL

Contamination Control Results

TQCM position	Requirement (Hz/hr)	Final Rate (Hz/hr)
SABER (vent)	715	4
GUVI	75	17
Above top deck	5	1
Side	1	0.1

Results indicate a successful program of contamination modeling which yielded bakeout requirements and successful bakeouts of individual components. This included both spacecraft and instrument hardware. (We were also able to waive bakeouts of some of the electronics, apparently with no adverse effects.)

The TIMED spacecraft will NOT have an outgassing problem on-orbit

Requirements Verification Matrix

			Verification	Pre-Vib	Post-Vib	Post-Acoustic Tests	Thermal Vacuum	Post-TV	VAFB
Mechanical									
	Envelope/ I/F to Launch Vehicle		Design, Analysis, check			T			
	Mass		Mass properties	T					
	Vib		Vibration						
	Shock		Pyro/Shock Test				T		
	Acoustic		Acoustic						
	Alignments		Alignment	T	T			T	T
	Subsystem Interface Requirements								
		Clear FOV	Design/Analysis						
		Stability (Optical Bench)	Component Level Test	T	T			T	T
C&DH									
	Uplink Command processing		BPT	T	T	T	T	T	T
	Stored Command Management		BPT	T	T	T	T	T	T
	Telemetry Data collection and Processing		BPT	T	T	T	T	T	T
	Mass Storage of science and engineering data		BPT	T	T	T	T	T	T
	Subsystem Communication		BPT	T	T	T	T	T	T
	Implement Peak Power Tracking and Coulometry		BPT	T	T	T	T	T	T
	Support uploading of new code to flash memory		Loads	T	T	T	T	T	
	Support uploading of data structures (autonomy rules, command macros) to flash memory		BPT	T	T	T	T	T	T
CCD									
	Receive CCSDS compatible commands RF or Baseband		BPT	T	T	T	T	T	T
	Forward to C&DH Processor		BPT	T	T	T	T	T	T
	Send all uplinked locally addressed relay commands to PSU		BPT	T	T	T	T	T	T
	Decode and implement several internal CCD non-relay commands		BPT	T	T	T	T	T	T
	Send C&DH Processor generated relay commands to PSU; return verification to Processor		BPT	T	T	T	T	T	T
	Implement Hard LVS		Hard LVS	T	T	T	T	T	T
	RF Watchdog timer (reset CCD and CDU digital circuits, send flag to processor)		Watchdog Timer	T	T	T	T	T	T
	Provide stable clock to C&T I/F board		BPT	T	T	T	T	T	T

Question 12

Requirements Verification Matrix

								Verification	Pre-Vib	Post-Vib	Post-Acoustic Tests	Thermal Vacuum	Post-TV
Communications													
	Fully Redundant							BPT	T	T	T	T	T
	Compatible with APL, backup, and contingency ground stations							BPT, Special Compatibility Tes	T	T	T	T	T
	Compatible with NTIA emission requirements							BPT	T	T	T	T	T
	Compatible with CCSDS recommendations							Design/Analysis					
	Uplink	2 kbps			Margin: 6 dB	(Pe = 1E-07)		BPT	T	T	T	T	T
	Downlink	4 Mbps (RS)	Realtime + SSR Playback		Margin 3 dB	(Pe = 1E-06)		BPT	T	T	T	T	T
		10 kbps (RS)	Realtime			(Pe = 1E-06)		BPT	T	T	T	T	T
	BER	Packets w/ detected and flagged		errors:	1.00E-03			BPT	T	T	T	T	T
		Packets w/ undetected errors:			1.00E-10			BPT	T	T	T	T	T
	Availability	95% of instrument sourc packets must be collec by spacecraft bus and delivered to POCs (MD						BPT	T	T	T	T	T
Antenna Coverage:	Uplink	Sufficient Link Margin over 95% of s						Antenna Range Te	Component Test				
	Downlink, 4 Mbps	Sufficient Link Margin over +/- 66 deg. Cone centered on Nadir						Antenna Range Te	Component Test				
	Downlink, 10 kbps	Sufficient Link Margin over 95% of s						Antenna Range Te	Component Test				
	GPS Receive	Sufficient Link Margin over +/- 80 deg. Cone centered on zenith						Antenna Range Te	Component Test				
Timing		10 ms						Time Verification	T			T	T

Question 12

Requirements Verification Matrix

Requirement		Verification	Pre-Vib	Post-Vib	Post-Acoustic Tests	Thermal Vacuum	Post-TV	VAFB
Broadcast Message to instruments		BPT, Sims	T	T	T	T	T	T
Attitude								
Nadir Pointing, 1 RPO pitch, 0 Roll ar		Sims	T	T	T	T	T	T
180 deg. Yaw as required		Sims	T	T	T	T	T	T
Control: 0.5 deg, each axis, 3 sigma		Sims	T	T	T	T	T	T
Knowledge: 0.03 deg., each axis, 3 sigma		Sims	T	T	T	T	T	T
Jitter/Stability less than 0.005 deg p-p @ 0.5 to 10 Hz		Design/Analysis						
Constraint: Sun vector greater than 90 deg from +Y panel during normal ops		Sims	T	T	T	T	T	T
Navigation								
Position Knowledge	300 m, each axis, 3 sigma	Sims	T	T	T	T	T	T
Velocity Knowledge	0.25 m/s, each axis, 3 sigma	Sims	T	T	T	T	T	T
Estimate Earth-Sun Vector		Sims	T	T	T	T	T	T
Perform event detection and prediction								
Primary and Backup Ground Station Rise and set times		Sims	T	T	T	T	T	T
SAA Entry/exit		Sims	T	T	T	T	T	T
Polar PCA		Sims	T	T	T	T	T	T
Terminator crossings		Sims	T	T	T	T	T	T
Perform autonomous orbit determination and generate orbital element sets		Sims	T	T	T	T	T	T
support on-orbit software uploading and reprogramming		BPT, Sims	T	T	T	T	T	T

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

Requirements Verification Matrix

	Requirement		Value	Verification	Pre-Vib	Post-Vib	Post-Acoustic Test	Thermal Vacuum	Post-TV	VAFB
Power										
	Orbit Ave Load Power		410 W	Sim				T		
	Max Cycle Life		12,000 eclipses (7,500)							
			Solar Array	Solar Array Qu	Component Test					
			Battery	Battery by Design/Analy						
	Bus voltage and regulation		22-35 V	BPT, Survival	T	T	T	T	T	T
	Redundant or non-critical Subsytems switched and fused			BPT	T	T	T	T	T	T
	Fusing for non-switched loads			S/C Power Syst Test	T				T	T
	Low Voltage protection Required			Soft, Hard LVS	Test Hard	Test Soft		Test Hard, Soft	Test Hard, Soft	Test Hard, S
	Bus Current telemetry for all subsystems			BPT	T	T	T	T	T	T
	"Flowdown" Requirements:									
		Single fault tolerant		S/C Power Syst Test	T				T	T
		SA not obstruct instrument FOVs		Design/Analysis						
		Survive any IEM Processor faults		Hard LVS	T			T	T	T
		Maintain S/A and Battery Health in Safe Mode		Sims, Soft, Hard LVS	T	T	T	T	T	T
EMC										
	22 to 35 V (24 - 35 V for instruments)			BPT						
	Survival 0 to 22V, 35 to 40 V			Component Level						
	Conducted Susceptibility (CS01 - 02; 2 v p-p 10 Hz to 400 MHz, CS06 56 V for 10 uS)			Component Level						
	Conducted Emissions (CE01-03 per 7363-9038, tailored for TIMED)			Component Level						
	Inrush Current 2.5 A after first 10uS			Component Level						

Question 12

Requirements Verification Matrix

								Verification	Pre-Vib	Post-Vi	Post-Acoustic T	Thermal Va	Post-TV	VAFB
Thermal														
	Subsystem Interface Requirements							TV						
	Temperature reporting to +/-		2 deg. C.					TV				T		
Radiation								Analysis/Piec Test						
Autonomous Fault Protection and Safing								Autonomy	T	T	T	T	T	T
Mission Lifetime:		2 years						Analysis						

Question 12

Subsystem Engineering Design Reviews (Peer Reviews)

• Solar Array	July 19, 1997
• Uplink Card	October 15, 1997
– CCD	October 15, 1997
• Structure	October 14, 1997
• Power	November 21, 1997
• Harness	November 19, 1997
• Downlink Card	April 12, 1998
– Downlink Modulator	October 17, 1997
– Downlink Framer	November 20, 1997
• Antennas	July 13, 1998
• RF Cable/Switch Assembly	March 12, 1998
• Battery	March 26, 1998

Subsystem Engineering Design Reviews (Cont'd) (Peer Reviews)

- **IEM**

– C&DH	November 20, 1997
– SSR	November 20, 1997
– PCI	November 20, 1997
– RIUs	November 20, 1997
– GNS	April 10, 1997
– CMD&TLM I/F	March 17, 1997
– DC/DC Converter Cards	November 25, 1997

Subsystem Engineering Design Reviews (Cont'd) (Peer Reviews)

- G&C
  - AIU — November 21, 1997
  - FC — November 20, 1997
  - ST — December 11, 1997
  - Gyro — December 18, 1997
  - Rods — November 4, 1997
  - Wheels — November 4, 1997
  - Solar Array Drive — November 13, 1997

(Note: Procured units were not "reviewed" in the strict sense)

Question 1

System Level Reviews

Preliminary Design Review

Held at APL on February 18 - 19, 1997

Member	Expertise	Institution
Eric J. Hoffman (Chairman)	Chair, Systems	APL
Mary C. Chiu	Systems	APL
Laurence J. Frank	C&DH, Systems	APL
Dr. Edward Gaddy	Power	GSFC
Dr. Robert E. Gold	Instrumentation	APL
Richard K. Huebschman	RF, Systems	APL
Thomas H. Stengle, III		GSFC
John J. Wolff	Program Mgmt	GSFC
James W. Woods	Mechanical-Structures	GSFC

Summary Documentation

SDO-10775, dated February 25, 1997, by E.J. Hoffman

"Minutes of TIMED Preliminary Design Review, 18-19 February, 1997"

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

PDR RFA Status

AI #	Description	Assignee/Date	Closed By	Closure Date
1	99% Data Recovery	Yee	7363-9001 Rev. B	12/1/1997
2	2 kbps command uplink sufficient?	Nordeen	SEI-97-068	6/24/1997
3	Justify not pinning SEE	Heffernan	SRI-97-059	10/14/1997
4	Account for distance separating phase centers of GPS antennas and CG of S/C	Duven	SRM-97-016	5/1/1997
5	Consider common oscillator for GNS & C&DH	Perschy/05/01/97	SER-97-0076	4/28/1997
6	Sequence RF transmitter voltages	Bokulic	SER-97-048	5/20/1997
7	Add SA deployment test while attached to S/C	Vernon	SEM-2-779	10/30/1997
8	IEM Cross-strapping reliability trade study	Kusnierkiewicz	SEA-97-0065	7/2/1997
9	Latching relays in series with battery	Kusnierkiewicz	SEA-97-0037	4/11/1997
10	Update S/C Redundancy chart	Kusnierkiewicz	SEA-97-0038	4/11/1997
11	Plot Mass and Power growth	Kusnierkiewicz	SEA-97-0039	4/11/1997
12	Reconsider 750 req't to include launch effects	Cameron	GEC-97-09	10/31/1997
13	Consider RIU cal channel and external ID straps	Reiter	SRI-97-041	6/5/1997
14	Consider using NASA std fuse topology	Dakermanji/Kozuch	SEE-97-0069	4/24/1997
15	Attitude knowledge vs. science impact	Heffernan/Sadilek	SRI-00-030	10/18/2000
16	Demonstrate the separation attitude capture sequence works	Radford	SEE-97-0091	5/29/1997
17	Will power-up of wheels react with LV	Mosher	SEM-1-1509	9/9/1997
18	Does IEM test bed fully support testing IEM redundancy	LeFevere	SEE-97-0087	5/14/1997
19	Clean up orbit determination accuracy req't	Cameron	GEC-97-09	10/31/1997
20	Does Safe mode work in eclipse; does sun vector ambiguity affect thermal state of S/C	Harvey	SEI-97-121	11/3/1997
21	Perform a complete glint analysis	Vernon/Yee	SEM-2-778	10/30/1997

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Question 9

System Level Reviews

Critical Design Review

Held at APL on December 2-4, 1997

Member	Expertise	Institution
Eric J. Hoffman	Co-chair; Systems	APL
Josef A. Wonsever	Co-chair; Flight Assurance	GSFC
Richard F. Conde	C&DH	APL
John H. Day	Power	GSFC
Ward L. Ebert	Systems	APL
Laurence J. Frank	Systems, C&DH	APL
Robert W. Jenkens, Jr.		GSFC
Robert W. Ross		GSFC
Andrew G. Santo	Systems	APL
James W. Woods	Mechanical-Structures	GSFC

Summary Documentation

SDO-10840, dated December 11, 1997, by E.J. Hoffman and J.A. Wonsever

"Minutes of TIMED Critical Design Review, 2-4 December 1997"

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

CDR RFA Status

AI #	Description	Assignee/Date	Closed By	Closure Date
1	Autononmy/safing issues	Harvey	SEI-98-091	17-Nov-98
2	Detumble/Capture/Battery DOD trades	Dellinger	SRM-98-045	30-Apr-98
3	Define autonomy rules enabled at launch	Wanagas	SEI-00-035	21-Jun-00
4	Reconsider having all instruments on @ B=0	Cameron	GEC-99-08	1-Oct-99
5	Updating Test Matrix	Kozuch	SEI-00-037	22-Jun-00
6	Define quantitatively instrument solar illumination restrictions	Heffernan	SRI-00-029	10/17/2000
7	Software documentation	Cameron	GEC-99-08	1-Oct-99
8	Telemetry for diagnosing LVS	Kusnierkiewicz	SEA-98-0029	15-May-98
9	Checkout of redundant units	Kusnierkiewicz	SEA-98-0014	2-Mar-98
10	Flight software reviews and configuration management	Chu	SRS-98-129	30-Jul-98
11	Common software considerations	Chu	SRS-98-0029	2-Mar-98
12	GTA backup with Actels	Devereux	SEA-98-0016	27-Feb-98
13	LVS trips	Dakermanji/Oden	SEE-98-0028	24-Feb-98
14	Optical bench pyro releases	Vernon	SEM-98-1-1518	5-Feb-98
15	Autonomy rule priority	Harvey	SEI-98-091	17-Nov-98
16	Uploading to processors	Cameron	GEC-99-08	1-Oct-99
17	Thermal constraints on MOPS	Williams/Kusnierkiewicz	SEM-98-4-345	26-Mar-98
18	RWA power/heat pipe trade	Williams/Kusnierkiewicz	SEM-98-4-345	26-Mar-98
19	SSR Low Power Mode	Kusnierkiewicz	SEA-98-0013	26-Feb-98
20	Tim performance summary	Cameron	GEC-99-08	1-Oct-99
21	Composite structure/long term storage/preload	Persons	SEM-98-1-1518	5-Feb-98
22	Solar array hinge performance	Vernon	Email From SRVernon	28-Feb-00
23	Sun safe algorithm using minimum of sensors	Dellinger	SRM-98-046	4-May-98
24	POC disaster recovery plan	Nordeen	SEI-98-038	28-May-98
25	POC security	Heffernan	SEA-2000-0061	17-Oct-00
26	"Dynamic Interaction " test	Kozuch	SEI-98-023	13-Mar-98
27	Panel level acoustic test	Schaefer	SEM-98-1-1518	5-Feb-98
28	Solar array deployment design/review	Vernon	Email From SRVernon	28-Feb-00
29	Multi-layer board quality assurance	Mastracci	SOR-98010	10-Feb-98
30	Design reviews of FPGA	Kusnierkiewcz/Hoffman	SEA-98-030	15-May-98
31	PPT EMC concerns	Kozuch	SEI-98-022	10-Mar-98
32	Battery temp during discharge/load shedding	Dakermanji	SEE-98-0027	24-Feb-98
33	Solar array harness temperature	Dakermanji	SEE-98-0027	24-Feb-98
34	Battery cell life tests	Dakermanji	SEE-98-0027	24-Feb-98
35	2 mil Kapton on solar arrays	Dakermanji	SEE-98-007	24-Feb-98
36	Config control for TOPS and TINTS	Rodberg	SEI-00-012	28-Feb-00
37	Deployment from Delta/power generation	Mosher	SEM-98-1-1520	23-Mar-98

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Question 9

System Level Reviews

Pre-Environmental Review

Held at APL October 26, 1999

Member	Expertise	Institution
Eric J. Hoffman	Co-chair; Systems	APL
Josef A. Wonsever	Co-chair; Flight Assurance	GSFC
Harry L. Culver	Electrical Systems	GSFC
Andrew G. Santo	Systems	APL
Thomas J. Spitzer		GSFC
Robert J. Vernier		GSFC
Judi von Mehlem	RF/Systems	APL
James W. Woods	Mechanical-Structures	GSFC

Summary Documentation

SDO-11006, dated October 29, 1999, by E.J. Hoffman and J.A. Wonsever
"Minutes of TIMED Pre-Environmental Review, 26 October 1999"

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

Pre -Environmental Review RFA Status

AI #	Description	Assignee/Date	Closed By	Closure Date
1	Solar array hinge damper heaters	B. Williams/11/18/99	SEM-00-4-371	7/7/00
2	Spacecraft -level SW testing vs. unit level regression testing	M. Chu 11/25/99	SRS-00-033	2/25/00
3	TIDI Profiler waiver	D. Grant 11/11/99	GSFC Memo	10/5/00
4	System time recovery spec	Kusnierkiewicz 11/25/99	SEA-99-0074	12/22/99
5	Solar array contamination bakeouts	Kusnierkiewicz 11/11/99	SEA-99-0061	11/15/99
6	Plan for GSE crashes	S. Kozuch 11/11/99	Email from Hien Nguyen, dated 06/02/00	Procedure developed early Nov. '99
7	Pyro bus fuse margin	Kusnierkiewicz 11/11/99	SEA-99-0064	11/18/99
8	Autonomy to support environmental testing	R. Harvey 11/25/99	SEI-00-034	6/16/00
9	Autononmy interaction testing	R. Harvey 11/25/99	SEI-00-034	6/16/00
10	Verification Matrix	Kusnierkiewicz 11/25/99	Presented at Post-ER	2/29/00
11	Antenna performance	C. Deboy 11/18/99	SER-99-036	11/19/99
12	AIU margin	D. Wilson 11/18/99	SEA-2000-0020	6/13/00

Question 9

System Level Reviews

Post-Environmental Review

Held at APL February 29, 2000

Member	Expertise	Institution
Eric J. Hoffman	Co-chair, Systems	APL
Josef A. Wonsever	Co-chair, Flight Assurance	GSFC
Harry L. Culver	Electrical Systems	GSFC
James W. Woods	Mechanical-Structures	GSFC

Summary Documentation

NASA Goddard Memo from 301/Chief, Systems Review Office, and APL/Chief Engineer, Space Department, dated April 7, 2000 "TIMED Post Environmental Test Review Report"

Post -Environmental Review RFA Status

AI #	Description	Assignee/Date	Closed By	Closure Date
1	Classify "Autonomy Rule Init" command as critical	Dragonette	SEA-2000-0024	22-Jun-00
2	Waiver for SABER out-of-spec conditions	Ali	SEA-2000-0024	22-Jun-00
3	Correlate thermal model	B. Williams	SEA-2000-0024	22-Jun-00
4	ACS Bias Error	Dellinger	SRM-00-052	22-Jun-00
5	Identify and trend parameters	Kusnierkiewicz	SEA-2000-0024	22-Jun-00
6	Revisit disposition of PFR TSC-092, battery differential heater on/off sense	Butler	SEA-2000-0024	22-Jun-00

Question 9

Mission Ops Review #1

- **Held at APL May 1998**
- **Review Team:**
- Madeleine Marshall (ICS) (Chairperson)
- Andy Good (APL)
  - MSX Planning Team Lead
- Mark Holdridge (APL)
  - NEAR Mission Operations Manager
- Dan Ossing (APL)
  - MSX Performance Assessment Team
- Keith Kalinowski (GSFC)
  - HST, NGST Operations
- Alex Herz (Omnitron)
  - VCL Operations
- Chris Silva (Allied Signal)
  - FUSE Operations
- 7 RFAs generated, all closed (Covered in Mission Operations Presentation)

Mission Ops Review #2

- **Held at APL June 8, 2000**
- **Eric Hoffman (APL) (Co-chairman)**
- **William Mack (GSFC) (Co-chairman)**
- **John Catena (GSFC)**
- **Mark Holdridge (APL)**
  - **NEAR Mission Operations Manager**
- **Eric Holmes (GSFC)**
- **Eric Isaac (GSFC)**
- **James Joyce (JHU)**
  - **FUSE Mission Operations Manager**
- **Hector Zayas (GSFC)**

- **Summary Documentation: SDO-11047, June 20, 2000, E.J.Hoffman and W.F.Mack, "Minutes of TIMED Mission Operations Review, 8 June 2000"**

RFA Status from Mission Ops Review #2

TIMED Mission Operations Review Action Items

AI #	Description	Assignee	Due Date	Status
1	Assessment Plan, Config control	Knopf	6/30/2000 for assessment plan, 9/1/00 for config control	Assessment plan closed. Config control closed per SEI-00-049, Sep 15 '00
2	Delta Review	Knopf	Launch - 5 months (October 7)	Closed, SEI-00-050, Sept 15, '00
3	Launch critical facilities and functions	Knopf	Launch - 4 months (November 7)	Closed, SEI-00-051, Sept 15, '00
4	Back-up to MOC/POCs	Rodberg	FOPS Review	Open
5	MOM, Phase E Staffing	Grant	7/31/00	Closed
6	Ground test commands in flight datab	Dragonette	7/31/00	Closed per SEI-00-047, Aug 31, '00
7	USN/TDRSS coordination	Knopf	FOPS Review	Open
8	Realistic schedule and staffing plan	Knopf	FOPS Review	Closed, SEI-00-052, Sept 15, 00
9	Automated tool for trending	Ossing/Campbell	6/30/00	Closed per PTS-00-009, Sept 20, '00
10	Auto-promote capability	Harvey	7/31/00	Closed; SEI-00-044, 04 Aug 2000
11	MOC firewall safeguards	Knopf	7/31/00	Closed, SEI-00-056, Sept 18, '00
12	GNS backup	Kusnierkiewicz	7/31/00	NORAD response pending; I was working directly with someone at Cheyenne Mountain on this. Then I was referred back to fill out a form formally requesting the information from NORAD. I filled out the form and submitted it through Carl Smith at GSFC. Aw
13	Assessment on orbit-by orbit basis	Ossing	FOPS Review	Closed per PTS-00-009, Sept 20, '00
14	2-person review of commands	Knopf	FOPS Review	Closed, SEI-00-053, Sept 15, '00

Total Operating Hours (Pre- and Post- S/C Integration)

	Pre Env 10/17/99	Post Env 2/15/2000	Post-Can 9/22/2000		Pre Env 10/17/99	Post Env 2/15/2000	Post-Can 9/22/2000
• IEM#1 Receiver	1325 Hrs	2566 Hrs	4229 Hrs	• IEM#2 Receiver	1418 Hrs	2673 Hrs	4046 Hrs
• IEM#1 C&DH,SSR,GNS	937 Hrs	1947 Hrs	3180 Hrs	• IEM#2 C&DH,SSR,GNS	886 Hrs	1703 Hrs	2445 Hrs
• Xmtr#1	266 Hrs	528 Hrs	913 Hrs	• Xmtr#2	474 Hrs	656 Hrs	711 Hrs
• Riu's for IEM#1	978 Hrs	1961 Hrs	2866 Hrs	• Riu's for IEM#2	623 Hrs	1384 Hrs	1865 Hrs
• PSE Interface #1	734 Hrs	1976 Hrs	2987 Hrs	• PSE Interface #2	746 Hrs	1877 Hrs	3173 Hrs
• Battery On-Line	100 Hrs	1110 Hrs	1572 Hrs*				
• AIU#1	1013 Hrs	2129 Hrs	3230 Hrs	• AIU#2	752 Hrs	1552 Hrs	2285 Hrs
• Flight Computer#1	232 Hrs	815 Hrs	1498 Hrs	• Flight Computer#2	108 Hrs	464 Hrs	585 Hrs
• IRU (Gyro) #1	449 Hrs	778 Hrs	1504 Hrs	• IRU (Gyro) #2	181 Hrs	331 Hrs	910 Hrs
• Magnetometer #1	336 Hrs	695 Hrs	1522 Hrs	• Magnetometer #2	338 Hrs	669 Hrs	1492 Hrs
• Primary Torque Rods	68 Hrs	110 Hrs	477 Hrs	• Secondary Torque Rods	36 Hrs	52 Hrs	423 Hrs
• SAD #1	77 Hrs	89 Hrs	499 Hrs	• SAD #2	67 Hrs	76 Hrs	436 Hrs
• Star Tracker #1	7 Hrs	772 Hrs	1534 Hrs	• Star Tracker #2	8 Hrs	771 Hrs	1531 Hrs
• Reaction Wheel #1	662 Hrs	1290 Hrs	2100 Hrs	• Reaction Wheel #3	556 Hrs	1194 Hrs	1904 Hrs
• Reaction Wheel #2	663 Hrs	1301 Hrs	2109 Hrs	• Reaction Wheel #4	547 Hrs	1184 Hrs	1995 Hrs
• GUVI Instrument	1186 Hrs	1702 Hrs	2101 Hrs	• SEE Instrument	110 Hrs	701 Hrs	1175 Hrs
• SABER Instrument	739 Hrs	1433 Hrs	1902 Hrs	• TIDI Instrument	108 Hrs	787 Hrs	1239 Hrs

* Flight Battery removed 2/11/2000 and stored, battery simulator used and number reflects Peak Power trackers usage.
•PSE/DU has 843 hours since rework to correct single point failure
•SEE has 296 hours since EGS rework
•GUVI has 231 hours since 1553/tube rework
•TIDI has 260 hours since Interpoint Converter rework/Cal lamp intensity variation tests

Residual Risk

- After a successful comprehensive testing program, the TIMED mission is ready to proceed to launch and operations

- The largest concern is the TIDI profiler
- The GUVI Photek tube is a concern, but the concern is mitigated by the redundant GUVI detector from Siegmund Scientific

- See Table below

TIMED Residual Risk Assessment

System/Component	Risk 1= low 5= high	Rationale	Concern	Mitigation
Mission	1	Extensive testing of spacecraft and ground system, mission simulations and mission operations team training, Spacecraft redundancy		
Spacecraft	1	Extensive testing, redundancy (No one instrument is mission critical)		
Instruments				
GUVI	2	Detector problem, intra-instrument harness cables replaced late in program	Photek tube	GUVI has redundant detectors
SABER	1	Successful testing program		
SEE	1	Successful testing program	EGS failure at S/C environmental testing	Modifications made, successfully requalified
TIDI	3	Likely degradation from launch	Etalon bonds	Likely degradation has been quantified, degraded performance within specification
Spacecraft Subsystems				
IEM				
RF Communications	1	Redundancy, successful testing program		
C&DH	1	Redundancy, successful testing program		
GPS Navigation	1	Redundancy, extensive testing and analysis program		
Remote Interface Units	1	Redundancy, successful testing program		
Guidance and Control				
Attitude Interface Unit	1	Redundancy, NEAR heritage, successful testing program		
Attitude Flight Computer	1	Redundancy, successful testing program		
LM Star Trackers	2	Two required to meet attitude knowledge requirement	Relatively little heritage	Successfully completed qualification program, Interpoint converter fix implemented

TIMED Residual Risk Assessment (Cont'd)

System/Component	Risk 1= low 5= high	Rationale	Concern	Mitigation
Spacecraft Subsystems				
Honeywell Inertial Reference Units	2	Known limited lifetime of ring laser gyro	Known limited lifetime of ring laser gyro	Redundancy, heritage, lifetime is 19,000 hours; TIMED requirement is 17,520
Ithaco Reaction Wheels	1	Heritage, 4 for 3 redundancy		
Ithaco Torque Rods	1	Passive, redundant coils, heritage		
SAIC/Ideas Magnetometers	1	Redundant, heritage		
APL Sun Sensors	1	Simple, passive design, redunancy		
Schaefer/Moog Solar Array Drives	1	Heritage, Redundancy, successful test program		
Power Subsytem				
Power System Electronics	1	Redundancy, successful testing program		
Peak Power Trackers	1	Successful testing program, graceful degradation		
Battery	1	Heritage, bypass circuitry, testing		
Solar Arrays	1	Successful requalification	Cell debonding experienced post-delivery	Successful failure analysis and corrective action implemented, successful requalification
Thermal	1	Succesful Testing Program		
Ground system	2	Dependence on Internet and network configuration/stability, PROC-L rewrite	Implementation of APL network security firewalls; late rewrite of critical S/W	Risk to launch/early ops only; effort to minimize impact to TIMED; POCS have modem access. PROC-L will have IV&V, TOPS testing

Launch Early Ops Risk

- Additional Risk Item:
  - Availability of HBK for early ops support
  - HBK will provide first high rate downlink (only) contact
    - Initial uplink/downlink capability through TDRSS at low data rate
      - Drop-outs expected due to spacecraft tumble
  - APL has listed HBK support as a requirement for early ops support
    - Availability has not been assured
    - No interface testing has been performed

System Software Overview

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Laurel, Maryland 20723

Software System Engineering (1 of 3)

- Key to success of the APL "software process" is the relationship between the Lead Engineer and Lead Software Engineer
  - Experienced subsystem software engineer with software "cradle to grave" responsibility
    - That is, one individual who is responsible for a given subsystem software from program start through the end of mission
    - This person reports to subsystem lead engineer that facilitates the communication and delivers the "hardware box" (hardware with software running inside) with the lead engineer
    - Has responsibility for software requirements, design, coding, testing at unit, software integration, acceptance, spacecraft level I&T support and mission simulation, software maintenance, documentation, etc.
    - The relationship and integration of hardware and software promote "box" level success.

Q4,Q5

TIMED Organization Chart

Q4,Q5

Roles and Responsibilities

TIMED Program

NASA
TIMED Program Office
Program Executive: V. Elsbernd (HQ)
Program Manager: J. Wolff (GSFC)
Program Scientist: M. Mellott (HQ)

JHU/APL Space Department
Department Head: S. M. Krimigis
Programs Manager: T. Coughlin

Product Assurance
S. Ali
H. Utterback

Resource Manager
D. Bennett

JHU/APL
TIMED Project Office
Project Manager: D. Grant
Project Scientist: S. Yee
Project Administrator: M. A. Haug

Science Working Group
Project Scientist: S. Yee
A. Smith/A. Christensen/J. Forbes/D. Fritts/
T. Killeen/J. Kozyra/H. Mayr/J. Russell/
S. Solomon/T. Woods

Ground Based Science Teams

Mission System Engineer
D. Kusnierkiewicz
Mission Software Engineer
M. Chu

Mission Autonomy Engineer
R. Harvey

Mission Ops. Mgr.
W. Knopf
- Mission Ops. Team
- R. Nordeen
- M. Packard (SS)
- R. Dragonette (SS)
- P. Boie (SS)
- C. Kowal
- D. Tady
- G. Chiu
- PJ Clark
- D. Wichard
- S. Lundfelt

Int. & Test Director
S. Kozuch
- I&T Engineers
- M. Colby
- M. Hill
- H. Nguyen
- R. Bachtell
- V. Bailey
- S. Dion (Safety)
- J. Coopersmith (Contam.)

Ground Sys. Eng.
P. Grunberger
E. Rodberg
H. Winters (SW)
- Mission Ops. Center
  - E. Rodberg
  - W. Mitnick (LSE)
- Ground Station
  - S. Gemeny
- Mission Data Center
  - P. Lafferty
- Payload Ops. Centers
  - SABER - R. Grube
  - TIDI - D. Gell
  - GUVI - B. Orgazalek
  - SEE - G. Tate

S/C Sys. Eng.
D. Kusnierkiewicz
Flight Software
M. Chu
- Mechanical - S. Vernon
- Structure - E. Schaefer
- Power - G. Dakermanji
- G&C - W. Radford
  - D. Wilson (LSE)
- RF Comm. - R. Bokulic
- Navigation - W. Devereux
  - A. Chacos (LSE)
- C&DH - J. Perschy
  - S. Williams (LSE)
- Thermal - B. Williams
- EMC - G. Seylar
- Mfg. - R. Stanford
  - J. Hogan
  - J. Weiner

Payload Manager
E. Prozeller
Payload Sys. Eng.
K. Heffernan
Payload Software
R. Gary
- SABER - D. Fort (TDA)
- GUVI - B. Ogorzalek (SE)
- SEE - A. El Dinary (TCM)
- TIDI - D. Mehoke (TCM)

Q6

Software System Engineering (2 of 3)

- **Communication is key to success**
  - Meetings where information has been exchanged
    - Weekly management meetings
    - Weekly spacecraft meetings
    - Weekly ground system meetings to discuss and resolve issues
    - Weekly Forum meetings (with Mission Operations team) to discuss Mission Operations team's requirements and issues
    - Weekly segment software lead engineer meetings to discuss issues
    - Bi-weekly subsystem lead software engineer meetings to discuss issues and facilitate software reuse and software process
    - Monthly schedule meetings to identify schedule and cost issues
    - Daily spacecraft I&T meetings, during spacecraft environment tests

Q4,Q5

Software System Engineering (3 of 3)

- **Communication is key to success (Con't)**
  - Bring Mission Operations specialist in the program early to learn the subsystems and to voice issues with Mission Operations
  - Subsystem software lead engineer works for subsystem lead engineer to facilitate the communication between hardware and software
    - Same model used for APL Instrument team
- Mission software engineer facilitates the resolution of issues spanning subsystems (GNC, C&DH, etc.) and segments (spacecraft, ground system, and instruments)

Q4,Q5

Software Quality Assurance Plan (1 of 4)

- Documented in TIMED Software Quality Assurance Plan, 7363-9101, September, 1996
  - Defines the application of Space Department Software Quality Assurance Guidelines (SDO-9989) to the TIMED mission
  - Signed by SOR Group Supervisor, SD Chief Engineer, TIMED Project Manager, Software Quality Assurance Officer, Mission System Engineer, Mission Software Engineer, etc.
  - Defines following subjects:
    - TIMED Organization
    - Responsibilities
    - Software Categories - Deliverability, Technical risk, Development risk, and Criticality
    - Satellite Safing Modes
    - Configuration Management

Q4,Q5

Software Quality Assurance Plan (2 of 4)

- Defines following subjects:
  - Security and Privacy
  - Certification
  - Required Documentation
  - Verification and Validation - Reviews, Audits, Code Walkthroughs, and Unit testing
  - Independent Verification and Validation
- Identify the following major software subsystems :
  - Spacecraft System Segment
    - Command and Data Handling (C&DH); Mission Critical*
    - Guidance and Control (G&C); Mission Critical*
    - GPS Navigation System (GNS); Mission Critical*

Q4,Q5

* Using Software Categories

Software Quality Assurance Plan (3 of 4)

- Identify the following major software subsystems: (Con't)
  - Ground System Segment
    - Mission Operations Center (MOC); Mission Impact*
    - Mission Data Center (MDC); Mission Impact*
    - Science Data System (SDS); Mission Impact*
  - Instrument Segment
    - SABER; Mission Impact*
    - SEE; Mission Impact*
    - GUVI; Mission Impact*
    - TIDI; Mission Impact*

* Using Software Categories

Q4,Q5

Software Quality Assurance Plan (4 of 4)

Appropriate documentation for different software categories

Q4,Q5

Instrument QA Interface

SOR

PA Plan

Required PAIP written by each Inst.Team

SWQA

Required SDP written by each Inst.Team

Inst. PAIPs

- Called out all HW processes, documentation & configuration requirements, inspection & audit points, parts handling (ESD), etc.
- Approved by APL PA Engineer & Instr. Manager & monitored through weekly Telecons, TIM, & formal design reviews

Inst. SDP

- Called out all SW development processes, QA & Test tracking in detail
- Approved by APL SW Instr. Manager monitored through weekly Telecons, TIM & formal SW design reviews

Q4,Q5

Software Development Plan

- Required by the TIMED Software Quality Assurance Plan for all major software subsystems including instruments
- Developed by each subsystem software lead
- Defined by the software development process:
  - Specifies components
  - Categorizes software (criticality, usage, technical risk, and development risk)
  - Specifies documentation, testing, reviews, and configuration management
  - Signed by software leads, subsystem lead engineer, segment software engineers, segment software engineer, mission software engineer, mission system engineer, and the Software Quality Assurance Officer

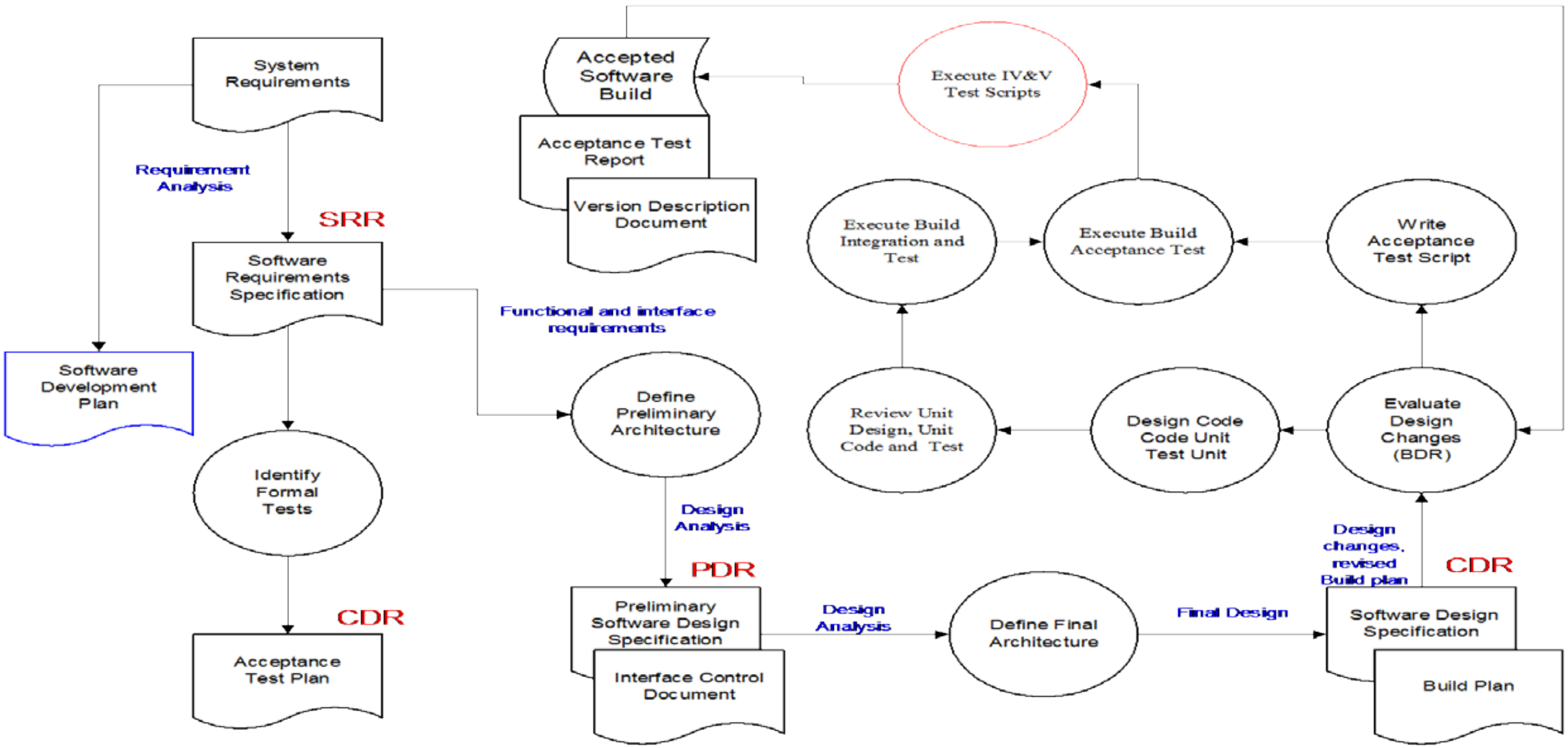
Q4,Q5

Software Development Plan

Subsystem	Sign-off date
Mission Data Center Rev. B	5/5/98
Mission Operations Center	1/17/97
Command and Data Handling	1/3/97
Guidance and Control	12/10/96
GPS Navigation System	3/13/97

Q4,Q5

TIMED General Software Development Process



Software Verification and Validation

- Reviews (SRR, PDR, CDR)
- Code walkthroughs
- Unit testing
- Module integration testing
- Independent testing at subsystem level
- Independent Validation & Verification
  - Established for C&DH, GNS and G&C
- Spacecraft Integration & Test
- Mission Simulations

Purchased Software

- Commercial Off-the-Shelf (COTS) Software
  - EPOCH 2000 - ISI product
    - Acceptance tested
  - Front End - ISI product

Q4,Q5

TIMED Subsystem Software that Performed IV&V

- AIU Boot Code
- Mongoose Boot Code
- Command and Data Handling
- Guidance and Control System including simulation models
- GPS Navigation System
- Load, Dump, and Compare Software (planned)

Q1,Q3

Configuration Management

- Documented in TIMED Mission Software Configuration Management Plan, 7360-9670, September 21, 1998
  - Document configured
    - Software Development Plans
    - Requirement Specifications
    - Interface Control Documents
    - Acceptance Test Plans
    - IV&V Test Plans
    - Controlled by Sign off

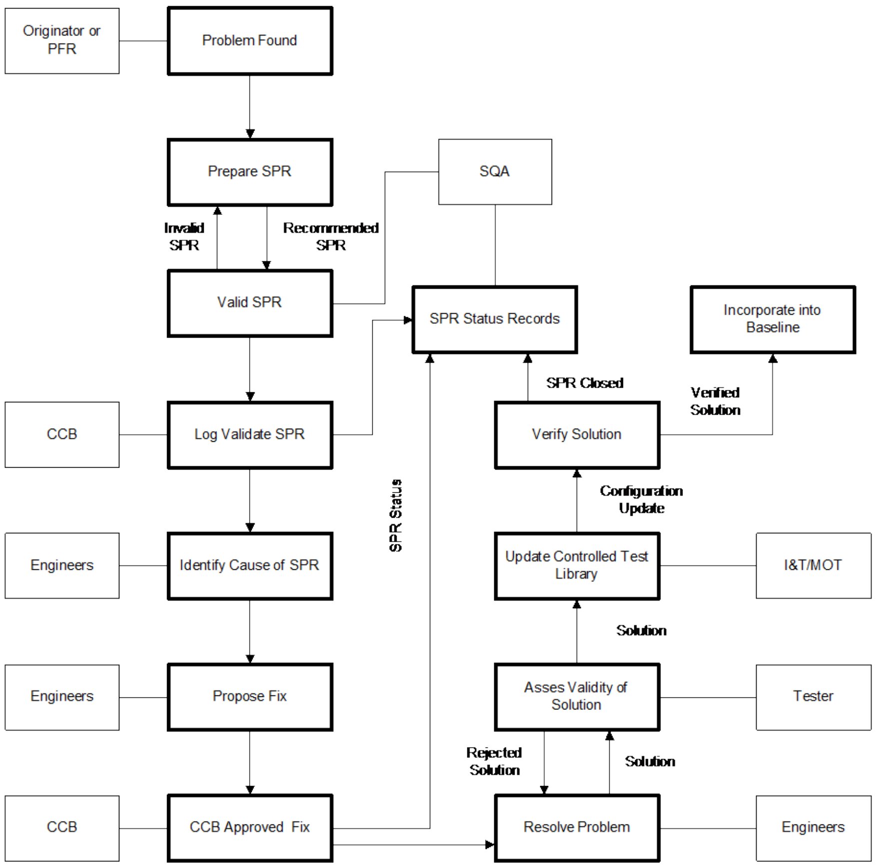
Configuration Management

– Delivered versions are archived and controlled
  - Source Code
  - Build Files
  - Input Test Data Sets
  - Output Test Data Sets (if applicable)
  - File Descriptions
  - Test Plans
  - Test Scripts (regression test scripts)
  - Test Reports

Configuration Management

- Development environments are archived and controlled
  - Compiler, Linker
  - Operating Systems
  - COTS Software
- Other items related to spacecraft are archived and controlled
  - Command and Telemetry Definition
  - Parameter and Data Structure
  - Autonomy Rules
  - Display Pages
  - Test Results
- Software Problem Report (SPR) or Problem Failure Report (PFR) are used to track changes

Software Problem Report Process



Configuration Management

- Configuration Control Board Organization
  - Software Quality Assurance Officer (Chair)
  - Mission System Engineer
  - Mission Software Engineer
  - Segment System Engineer
  - Software Subsystem Lead
  - I&T and/or Mission Operations Lead

Other Risk Reduction Action

- Software Rework

  Two Mission Operations Center Software elements planned to be rewritten due to the criticality and large number of problems
  - Command Interface Software (completed)
  - Load, Dump, and Compare (in progress)

TIMED Mission Software Status (1 of 4)

- Software last delivery date
  - Flight Software

• AIU Boot Code	11/98
• Mongoose Boot Code	9/99
• Command and Data Handling	9/00
• GPS Navigation System	8/00
• Guidance and Control	2/00
• Autonomy Rules	9/00

TIMED Mission Software Delivery Status (1 of 4)

Flight Software	First Delivery Date	Late Delivery Date
AIU Boot Code (in PROM)	11/98	11/98
Mongoose Boot Code	10/98	9/99
Command and Data Handling	10/98	10/00
GPS Navigation System	9/98	10/00
Guidance and Control	4/99	2/00
Autonomy Rules	1/00	10/00

Q4,Q5

TIMED Mission Software Delivery Status (2 of 4)

Ground Software	First Delivery Date	Late Delivery Date
Mission Operations Center	10/98	10/00
Mission Data Center	10/98	10/00
Front End	10/98	9/00
Ground Station	3/00	3/00

Q4,Q5

TIMED Mission Software Delivery Status (3 of 4)

Instrument Software	First Delivery Date	Late Delivery Date
GUVI FSW	5/99	5/99
SEE FSW	6/99	11/99
TIDI FSW	10/99	2/00
GUVI POC	5/99	3/00
SABER POC	9/99	10/99
SEE POC	6/99	9/99
TIDI POC	10/99	10/99

Q4,Q5

TIMED Mission Software Delivery Status (4 of 4)

Ground Support Equipment	First Delivery Date	Late Delivery Date
Blockhouse Control Unit	10/98	12/99
GPS Simulator	5/99	9/99
IEM Test bed	6/99	6/00
TIMED Attitude System Test and Integration Equipment (TASTIE)	6/99	9/00
RF GSE	3/99	3/99

Q4,Q5

TIMED Mission Software Status

- Executable Lines of Code
  - Flight Software

AIU Boot Code	**2,000**
Mongoose Boot Code	**11,000**
Command and Data Handling	
(not including Autonomy Rules)	**17,800**
GPS Navigation System	**32,200**
Navigation	25,200
Tracking	7,000
Guidance and Control	**43,500**
AIU	19,000
AFC	24,500

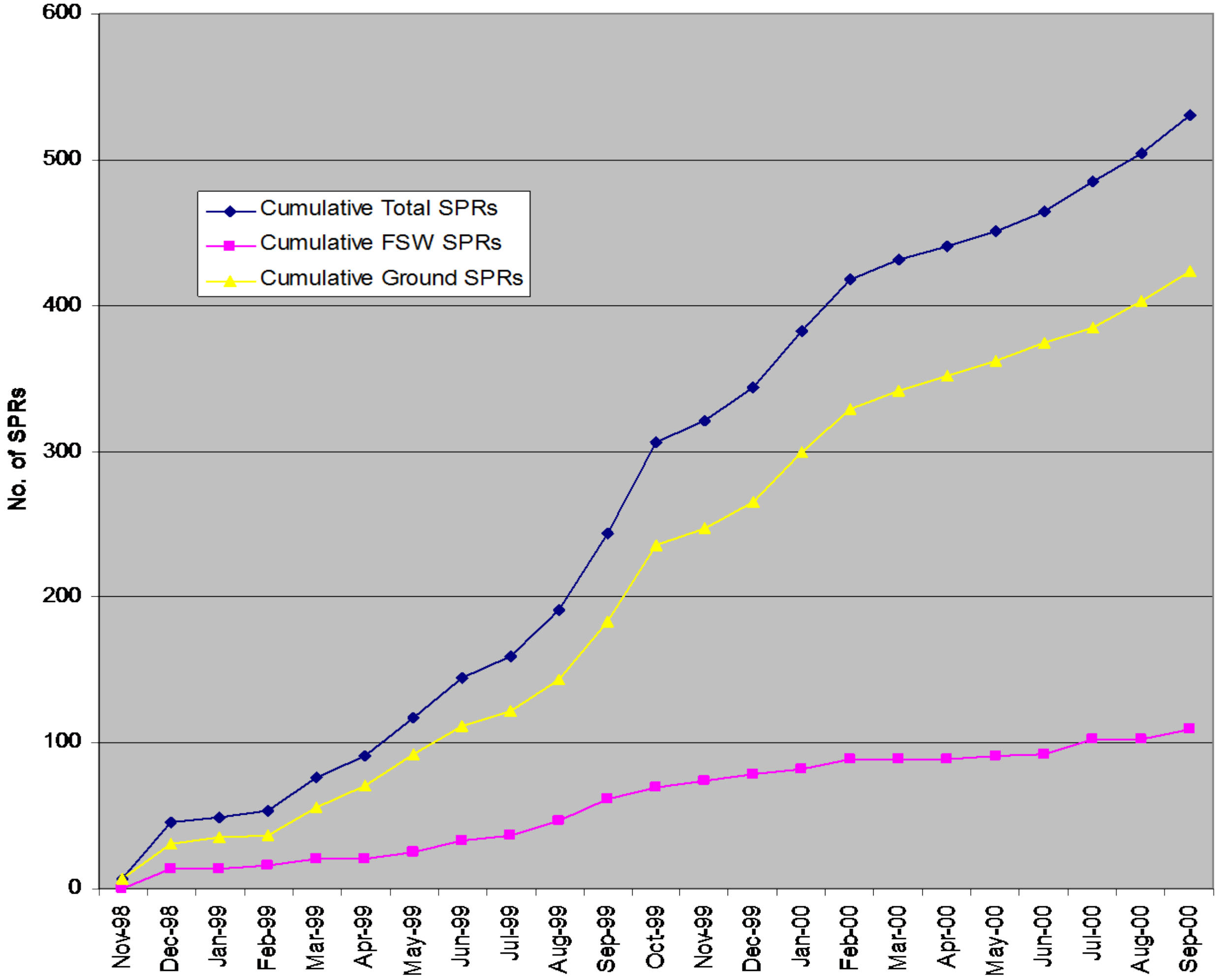
Q5

TIMED Mission Software Status

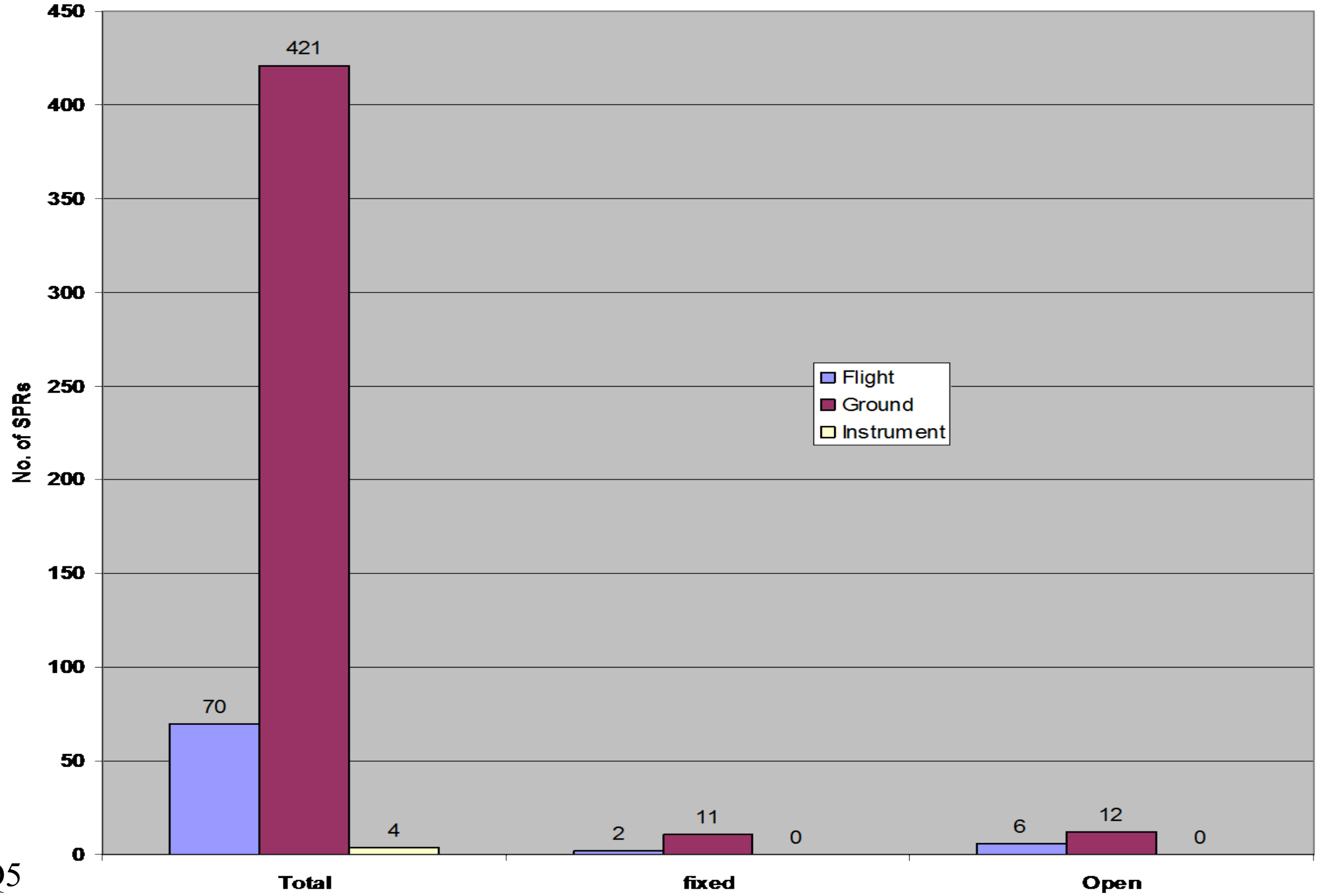
- Executable Lines of Code
  - Ground Software

Mission Operation Center	
(not including EPOCH 2000)	**67,000**
Mission Data Center	**20,700**

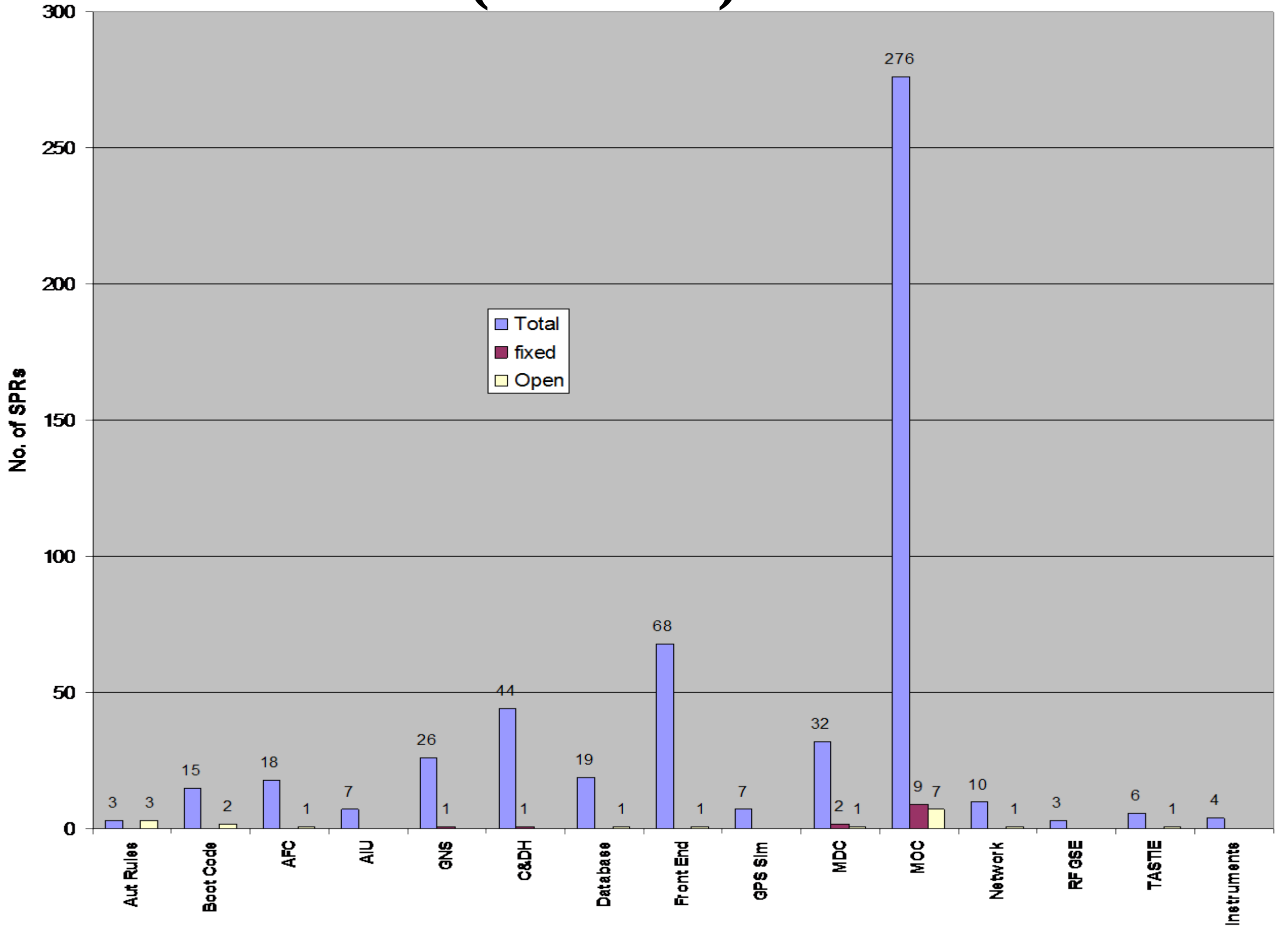
Cumulative SPRs vs Time



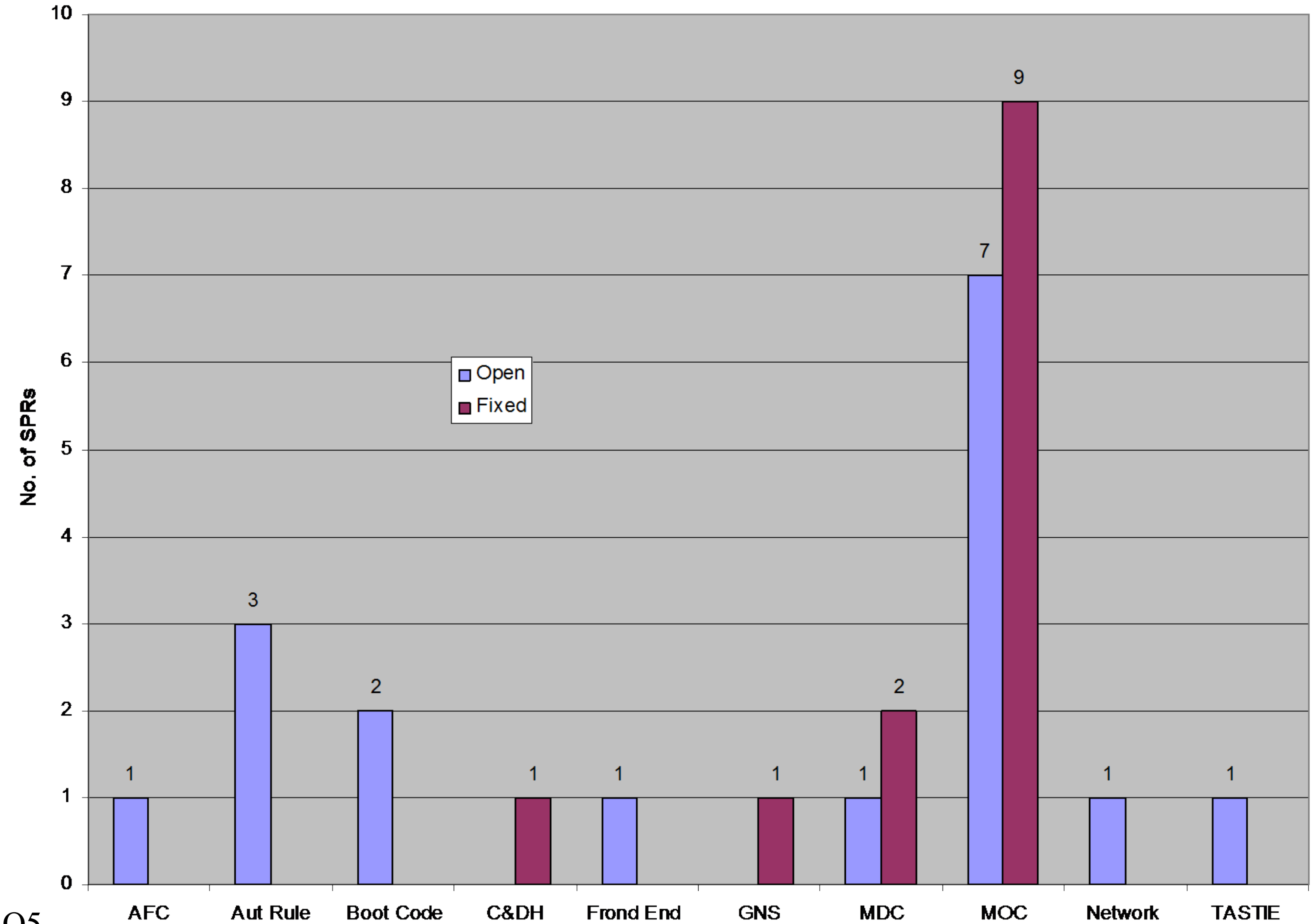
TIMED Flight, Ground and Instruments SPRs Status (10/20/00)



TIMED Flight, Ground and Instruments SPRs Status (10/20/00)



Opened SPR vs Subsystem



Residual Risks

- Delivery of Load, Dump, and Compare Software is late
  - Risk Mitigation
    - Identify problems and initiate a rewrite
    - Will perform IV&V on the software
    - Will check the FSW loading on TOPS before loaded on spacecraft
    - If the problem happens on orbit, previous FSW will still exist on the redundant processor

Residual Risks

- No formal regression tests for Ground Critical Software
  - Can easily revert to the previous version
  - Will use on the TOPS first before use on orbit

- Configuration Management Procedures for Command Scripts/Procedures, EPOCH Displays, Command Definition Data, Parameter and Data Structure, Autonomy Rules, and TOPS is in the process of developing

Q4,Q5

PERFORMANCE ASSURANCE

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SOR
SPACE RELIABILITY and QUALITY ASSURANCE

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R.H. Maurer*

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S.W. Ali *	Asst. Group Supvr.
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M.E. Goss
R.E. Lee*
R.H. Maurer
A.F. Moor *

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C.M. Castillo
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K.A. Fretz
E.J. Kane
A.F. Moor *
K.M. Warren
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EEE PARTS MANAGEMENT

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K.J. Larsen
A. Uy

SOR-5
ADVANCED TECHNOLOGY and PART QUALIFICATION

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J.R. Lander, Assist. Sect. Supvr.
G.S. Bognaski
D.J. Leopold *
E. Nhan
D.R. Roth
K.E. Waddell

* - Concurrent Assignment

SOR Management for the program

Stan Purwin

- BSEE, MSME, MBA
- 34 yrs professional experience in Engineering And Quality
- ASQ Certified Quality Manager

Syed Ali

- M.S. QA Engineering
- 27 yrs of Q.A.P.A. experience
- 20 yrs in Aerospace Fabrication process

Kim Cooper

- M.S. in Technical Management
- 19 yrs EEE reliability physics, & quality engineering
- 8 yrs NASA related projects

Heara Lee

- B.S. in Business Management
- 24 yrs experience in Materials Management
- 12 yrs experience on BMDO & NASA programs

Jim Kinnison

- B.S., M.S., Physics
- 13 yrs experience in Radiation Effects
- 13 yrs expereience for NASA & BMDO

SOR Key Staff for the program

Carlos Castillo
- B.S. in Engineering Technology
- 20+ yrs Quality Assurance experience
- 10 yrs NASA related

Jonathan Coopersmith
- BA Physics, University of Virginia, 1986.
- 13 yrs experience in clean room operations
- 13 yrs experience in scientific contamination control

John Farnan
- B.S. Business Management
- 17 yrs experience in Materials Management
- 17 yrs experience in DoD, BMDO and NASA programs

Juan Lander
- M.S. in Computer Science
- 17 yrs experience in component testing
- 14 yrs NASA related projects

Andy Moor
- M.S. Engineering Management
- 13 yrs experience space reliability parts engineering
- 10 yrs NASA based program

INTRODUCTION

(1 of 2)

- Performance Assurance for the TIMED Program consists of:
  - Reliability Engineering
    - Failures Mode and Effects Analysis (FEMA)
    - Fault Tree Analysis (FTA)
    - Probabilistic Risk Assessment (PRA)
  - Quality Assurance
  - Contamination Control
  - Radiation Effects

INTRODUCTION

(2 of 2)

•Drawing / Documentation for Flight Hardware is fully configured with documented change control system meeting Mission Requirements

•Drawing Sign-Off

- Level 2 Configuration Control

•Part grades 1 and 2 per GSFC PPL 21 or MIL-STD 975

–Identification, traceability, and controlled storage provided

P.A. REQUIREMENTS

(1of 3)

- Product Assurance Implementation per JHU/APL PA Plan 7363-9028a Sept 4 1996
- EEE parts procured to established reliability specifications (* see attached slide)
  - Parts Obtain Process Chart
  - Fabrication Flow Chart
- All the deliverable hardware including the outside vendors and TIMED instruments were reviewed by SOR (see attached slide)

P.A. REQUIREMENTS

(2 of 3)

- SOR monitored supplier PA activities and provided source inspections
- SOR performed qualification on EEE parts that had no demonstrated reliability (** see attached slide)
- EEE part traceability maintained
- GIDEP Alert System used to check all parts lists
  - each new lot
  - periodically entire inventory uploaded into GIDEP database

Parts Obtain Process

PEPL: Design Engineer

ESTABLISH PARTS LIST

APPROVE AND RECOMMEND PARTS, PERFORM RADIATION ANALYSIS

UPDATE/REVIEW PARTS LIST

PEPL FEEDBACK TO DESIGN ENGINEERS

GENERATE PURCHASE REQUISITIONS OR TRANSFER PARTS FROM EXISTING INVENTORY

KEY PURCHASE REQUISITIONS AND PURCHASE ORDERS INTO Database

REVIEW "PARTS INSPECTION / TEST WORK ORDER ROUTING"

START TO BUILD TEST FIXTURES AND PROGRAM FOR PARTS TEST SOFTWARE

EXPEDITE/CONFIRM PURCHASE ORDER

AT VENDOR, CUSTOMER SOURCE AND, OR PRE-CAP INSPECTION

Question 4

KIT VERIFICATION INSPECTION

PREPARE AND PULL PARTS FOR FABRICATION,

EPL REVIEW FOR SIGNOFF

FILE TEST WORK ORDER, PURCHASE REQUISITION/ORDER, PARTS RECEIVER, TEST DATA

STORE QUALIFIED PARTS IN STKROOM

PARTS TEST DATA REVIEW

PARTS TESTING, RADIATION EFFECTS TESTING

DISCRETE PARTS TESTING.

SEND DISCRETE PARTS TO

EXTERNAL TEST, MONITOR STATUS.

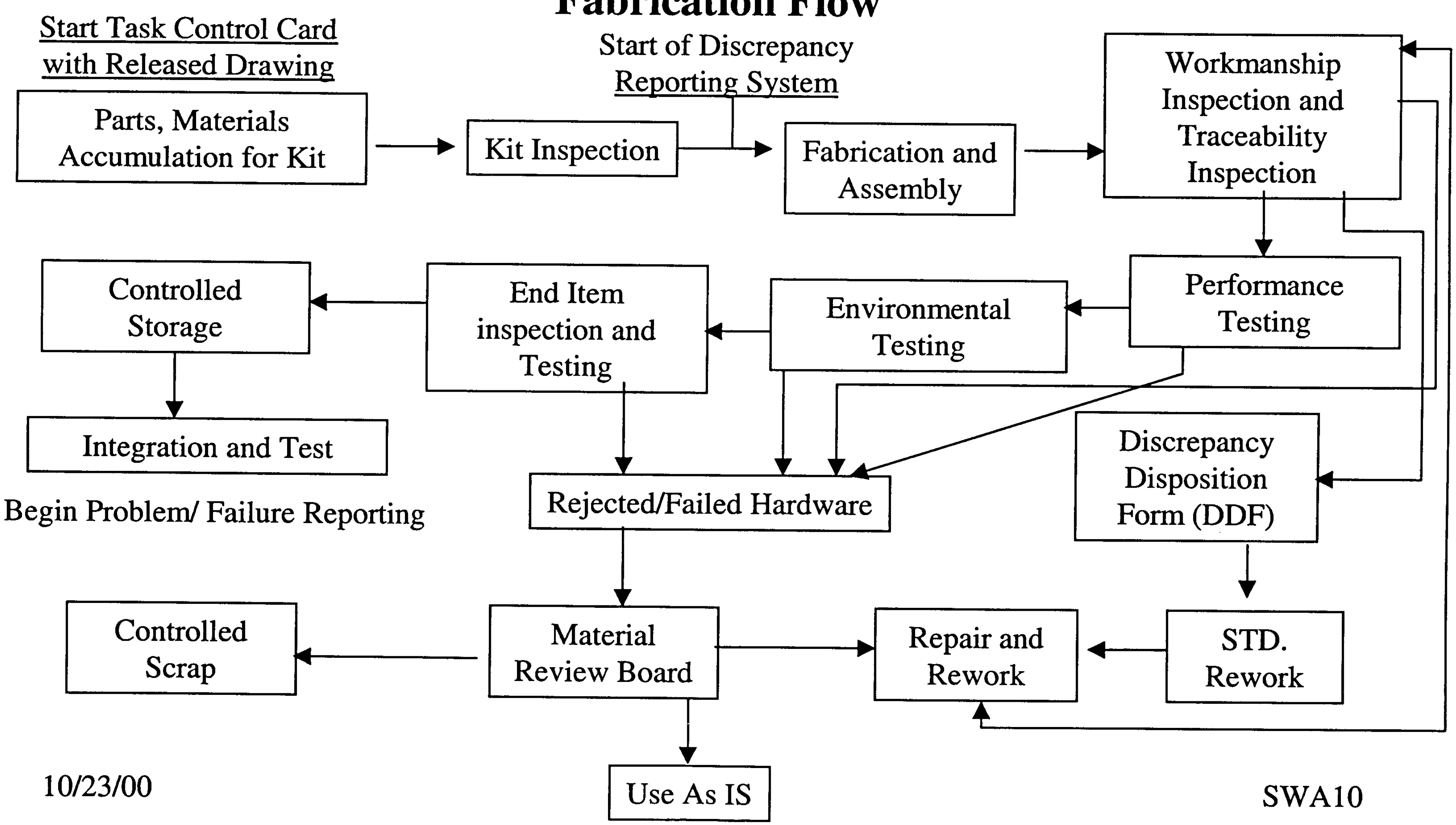
GIDEP SEARCH

BARCODE, DIM., VISUAL, INSPECTION

PRIORITIZE PARTS IN PROCESS

RECEIVE PARTS FROM VENDOR

Fabrication Flow



* Typical Established Reliability Specifications

Capacitors	-	MIL-PRF-123, Failure Rate S or R MIL-PRF-39014, Failure Rate S or R MIL-PRF-55681, Failure Rate S or R
Connectors	-	MIL-DTL-24308 MIL-DTL-38999 MIL-C-55302 S-311 specifications
Diodes/Transistors	-	MIL-PRF-19500 JTXV plus PIND & X-Ray
Filters	-	MIL-PRF-28861
Hybrids	-	MIL-PRF-38534, Class H plus PIND & X-ray (Element evaluation, as applicable)

Question - 4

* Typical Established Reliability Specifications

Microcircuits	-	MIL-PRF-883 plus PIND &X- ray MIL-PRF-38510, Class B plus PIND & X-ray MIL-PRF-38535, Class Q plus PIND & X-ray
Magnetics	-	MIL-STD-981
Relays	-	MIL-PRF-39016, Failure Rate R or P MIL-PRF-6106 (PIND& X-ray, as applicable)
Resistors	-	MIL-PRF-55182, Failure Rate S or R MIL-PRF-55342, Failure Rate S or R MIL-PRF-39007, Failure Rate S or R
Wire	-	MIL-W-22759/43 and 44(TEFZEL) Only

Instrument QA Interface

SOR

PA Plan

Required PAIP written by each Inst.Team

SWQA

Required SDP written by each Inst.Team

Inst. PAIPs

•Called out all HW processes, documentation & configuration requirements, inspection & audit points, parts handling (ESD), etc.

•Approved by APL PA Engineer & Instr. Manager & monitored through weekly Telecons, TIM, & formal design reviews

Inst. SDP

•Called out all SW development processes, QA & Test tracking in detail

•Approved by APL SW Instr. Manager monitored through weekly Telecons, TIM & formal SW design reviews

** Qualification Tests

- Radiation Hardness Assurance Tests
- Temperature Cycling
- HAST or Steady-State Temperature Humidity Bias Life Test (85/85) - (Plastic Parts Only)
- Destructive Physical Analysis
- High Temperature Operating Life

P.A. REQUIREMENTS

(3 of 3)

- Formal TIMED Drawing Tree Maintained
- As-built documentation and configuration for flight hardware maintained under Level 2 Configuration control
- Non-conforming parts/materials disposition per MRB procedures
  - Discrepancy reports generated at subassembly level then reviewed and signed off by Lead Engineer, SOR P.A.E and Fab. Rep. (Others as needed)
- Radiation hardness requirement 5 Krads (Si) maintained. Tantalum shielding used where necessary

Formal Configuration Control Boards

Different boards for different phases of program

- Fabrication Phase
  Spacecraft System Engineer, Lead Engineer, R& QA, Technical Services representatives, others as required
- Test and Integration Phase
  Spacecraft System Engineer, Lead Engineer, R& QA, others as required (for example, the software system engineer may be brought in if it is decided to fix a hardware problem in software)

PEFORMANCE ASSURANCE ACTIVITIES

- All design specifications were reviewed
- Supported subsystem, system, and Instrument design reviews
- Reviewed test plans and procedures
- Provided R&QA inputs for acceptance data package
- Monitored subcontractor activity, as necessary
- Reviewed as-build documentation and configuration control

Inspection Criteria
of APL Fabricated Hardware

- Use of NASA and/or TSD - STD 800.1 workmanship standards
  - Soldering of electrical connections NASA - STD 8739.3
  - Crimping, Cable, harness & wiring NASA - STD 8739.4
  - Conformal coating & staking NAS 5300.4 (3J)
  - Printed wiring board design MIL - PTF - 55110
  - ESD Control NASA - STD 8739.7

Instruments/Sub Contract Buyoffs

(1 of 2)

Subsystem	Vendor	Buyoff Date
Solar Array	TECSTAR	October 5, 1999
Battery Cells	Eagle Pitcher	January 7, 1999
IRU (2 ea)	Honeywell	March 24, 1999
Star Tracker (2 ea)	Lockheed Martin	August 31, 1999
TIDI	Space Physics Research Lab. University of Michigan	October 5, 1999
SEE	University of Colorado	June 23, 1999

Instruments/Sub Contract Buyoffs

(2 of 2)

Subsystem	Vendor	Buyoff Date
SABER	Space Dynamics Lab. Utah State University	September 15, 1999
Reaction Wheels (4ea)	Ithaco Space System	October 23, 1998
Torque Rods (3ea)	Ithaco Space System	February 10, 1998
Magnetometers (2ea)	SAIC	March 10, 1998
Solar Array Drive	Schaeffer Magnetic	September 5, 1998

PFRs and Waivers

•Problem Failure Reporting (PFR) begins at start of box acceptance testing at spacecraft integration (see chart)

-Written against failures and anomalies

•Waivers are issued for areas where performance does not comply with specifcations

-Example: EMC out-of-spec conditions or excessive turn-on inrush current (not classified as a failure)

•All waivers issued for instruments are at box level acceptance testing.

-Some Instrument waivers were granted within the instrument teams for non-compliances that did not affect science performance. (e.g., GUVI detector dark count, SABER filter performance)

PFR PROCESS

Test Conductor Initiate PFR by entering the failures or problems into Database from Test and Integration area

→

Test Review Board verifies the anomaly of the PFR within 24 hours and fill in verification of the problem and supporting analysis

→

Lead Engineer fill in Corrective Action

↓

The PA Engineer review the PFR for compliances

→

Program office review and approve for completeness

PFR Tally By Subsystem

Project Code	Subsystem	Open	Closed	Total PFRs
TIMED/GUVI	GUVI Instrument	0	7	7
TIMED/IEM	IEM	0	23	23
TIMED/PWR	Power	0	2	2
*TIMED/SC	Spacecraft Integration and Testing	4	104	108
TIMED/TIDI	TIDI Telescope	1	12	13
	GRAND TOTALS:	**5**	**148**	**153**

* These includes the instruments after deliver and at integration and testing process with the spacecraft

P/FR No.	Date	Originator	Cognizant Engineer	Subsystem/Drawing	Status	Closing Date	Description (Summary)	Corrective Action
TDI-012	03/12/1999	Ted Sholar	TG Sholar	7372-0000	O		Post Ship Contamination	No definitive reason for the sudden increase in surface cleanliness was ever determined. The particles were determined to be black chemglaze paint. Several tape lifts since then have resulted in little or no increase in the surface cleanliness levels in any of the 4 telescopes. Several of these tape lifts were "post-ship". The telescopes were cleaned in Sept, 1999, following redelivery to APL from SPRL. Tape lifts at the primary mirror baffle showed the worst case surface cleanliness level of < 200. Tape lifts will be performed up through field testing at VAFB.
TSC-032	07/16/1999	Paul Grunberger	Paul Grunberger	Offsite Grnd Station	O		TLM Receiver not optimized	
TSC-034	07/16/1999	Paul Grunberger	Paul Grunberger	Offsite Grnd Station	O		TLM Rcvr - Poor BER Performance	
TSC-071	11/23/1999	Michael Colby	Bernie Ogorzalek	A600	O		GUVI pinpuller wear	None for now, but when flight pyros are installed at APL before shipment to VAFB, the existing pinpuller shaft will be replaced with a new shaft.
TSC-108	09/26/2000	Mike Butler	Mike Butler	7363-0500	O		Cracked Cell	
TOTAL OPEN PFRs:		5						

Waiver Summary

Instrument/Sub Assemblies	No. of Waiver
SEE	4
GUVI	3
TIDI	4
Star Tracker	9
SABER	5
Total	25

Waiver Description

Instrument/ Sub Assemblies	Waiver Number	Date	Reference	Status C/O	Description
SEE Instrument	1	10/25/99	PFR TSC025	C	Impedance requirement of 1553 Bus Interface
SEE Instrument	2	10/14/99	Email Oct 14, 99 George Seylar	C	EMC/EMI Out of Spec.
SEE Instrument	3	10/14/99	SOR-3-99016	C	Capacitor out of spec for voltage rating
SEE Instrument	4	7/24/00	SEM-00-4-372	C	On-orbit interface temperature prediction waiver
GUVI Instrument	5	3/24/99	SOR-0006 7/3/00 GEC-99-02	C	Electromagnetic Compatibility testing
GUVI Instrument	6	7/3/00	SOR-00007	C	Waiver for out of spec Turn –on current transient

Waiver Description cont.

Instrument/ Sub Assemblies	Waiver Number	Date	Reference	Status C/O	Description
GUVI Instrument	7	7/24/00	SEM-00-4-372	C	On-orbit interface temperature prediction waiver
TIDI Instrument	8	7/8/99	055-3808 Report by John Eder	C	EMI test
TIDI Instrument	9	12/10/99	SOR-1-99019	C	Removal of profiler for space craft level vibration & acoustic and pyro test
TIDI Instrument	10	12/10/99	SOR-1-99019	C	Workmanship vibration
TIDI Instrument	11	7/24/00	SEM-00-4-372	C	On-orbit interface temperature prediction waiver
STAR Tracker	12	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for powered vibration test

Waiver Description cont.

Instrument/ Sub Assemblies	Waiver Number	Date	Reference	Status C/O	Description
STAR Tracker	13	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for power turn on transient requirements
STAR Tracker	14	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for STAR Tracker weight limit
STAR Tracker	15	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for STAR Tracker magnitude determination
STAR Tracker	16	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for a sinusoidal vibration levels. A sine burst test to be specified
STAR Tracker	17	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for gravity field sensitivity
STAR Tracker	18	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for EMI performance

Waiver Description cont.

Instrument/ Sub Assemblies	Waiver Number	Date	Reference	Status C/O	Description
STAR Tracker	19	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for one degree/sec tracking rate
STAR Tracker	20	6/10/99	Lockheed Martin Document # 2A09131	C	Waiver for power bus voltage turn on rate
SABER	21	8/31/99	SDL Waiver request # 3	C	EMC exceeded limits at various points
SABER	22	8/31/99	SDL Waiver request # 4	C	Ambient levels exceeded limits from 20 to 5 KHZ
SABER	23	8/31/99	SDL Waiver requets # 5	C	Differential mode-emission peaks every 10 HZ from 100 to 1.4 KHZ. Exceeded the limit
SABER	24	8/31/99	SDL Waiver request # 6	C	Ambient emissions were above the limit
SABER	25	9/3/99	SEM 00-4-372	C	On-orbit temperature prediction waiver

INTEGRATED ELECTRONICS MODULE (IEM)

PRESENTATION OUTLINE:

1. Overview	Paul Marth
2. Processors[1]	James Perschy
3. Solid State Recorder (SSR)	Joseph Bodanski
4. RF Communications	Christopher Deboy
5. Critical Command Decoder/ Command & Telemetry Interface	Stephen Oden
6. DC/DC Converters[2]	Deanna Temkin
7. Remote Interface Unit (RIU)	Al Reiter
8. GPS Navigation Subsystem (GNS)	Robert Heins
9. GNS Software	Al Chacos
10. C&DH Software	Stephen Williams
11. Boot Code	Susan Schneider

Note: 1. Includes C&DH, GNS and Flight Computer processors
2. Includes converters for IEM and Flight Computer

Integrated Electronics Module (IEM) Overview

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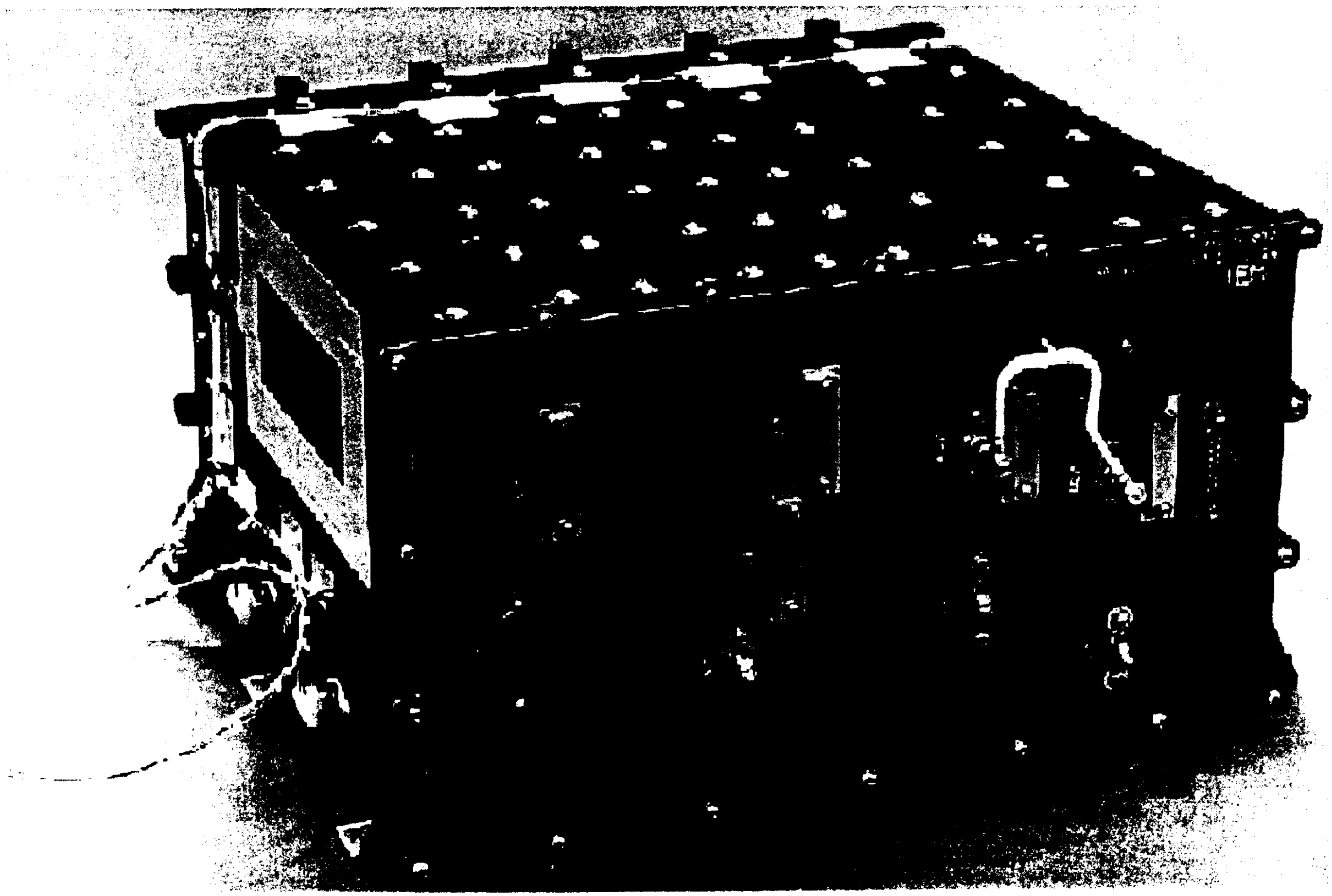
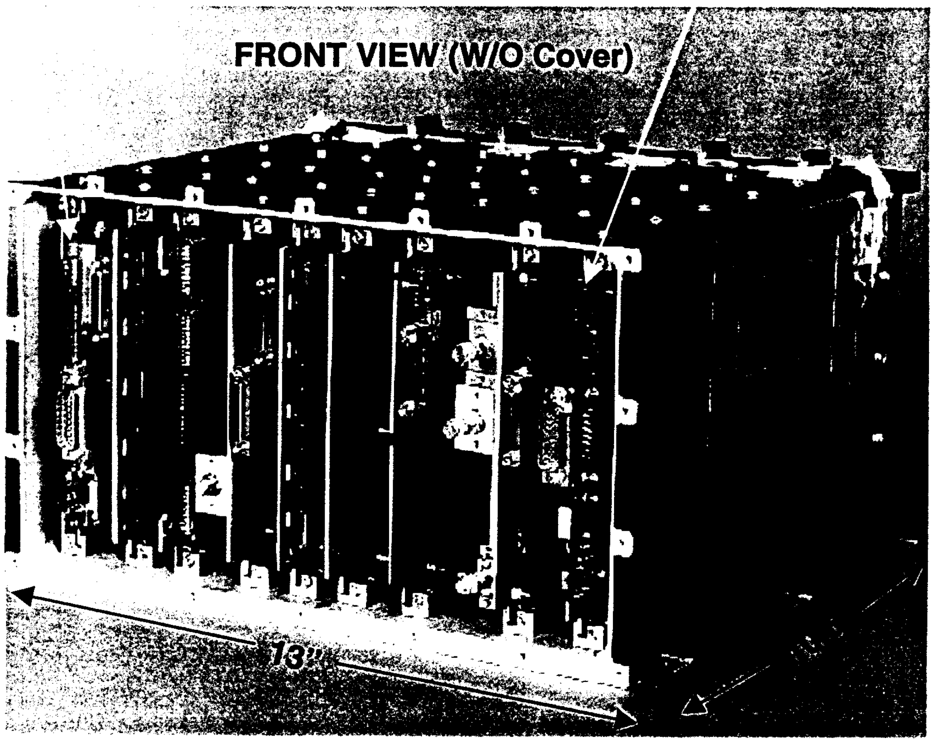
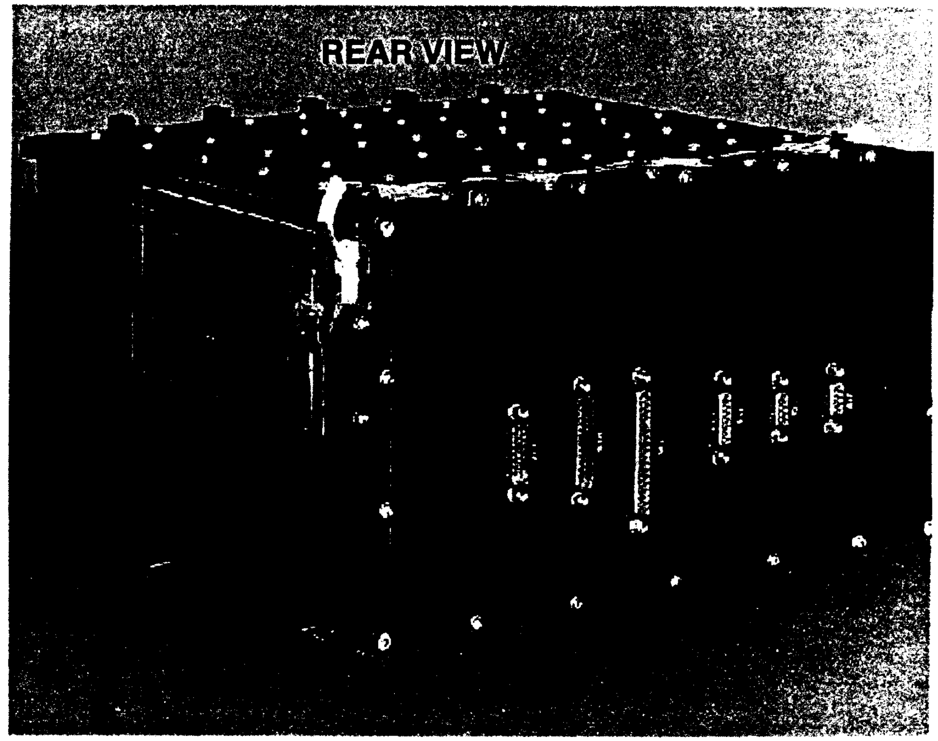
e-mail: paul.marth@jhuapl.edu

IEM



IEM





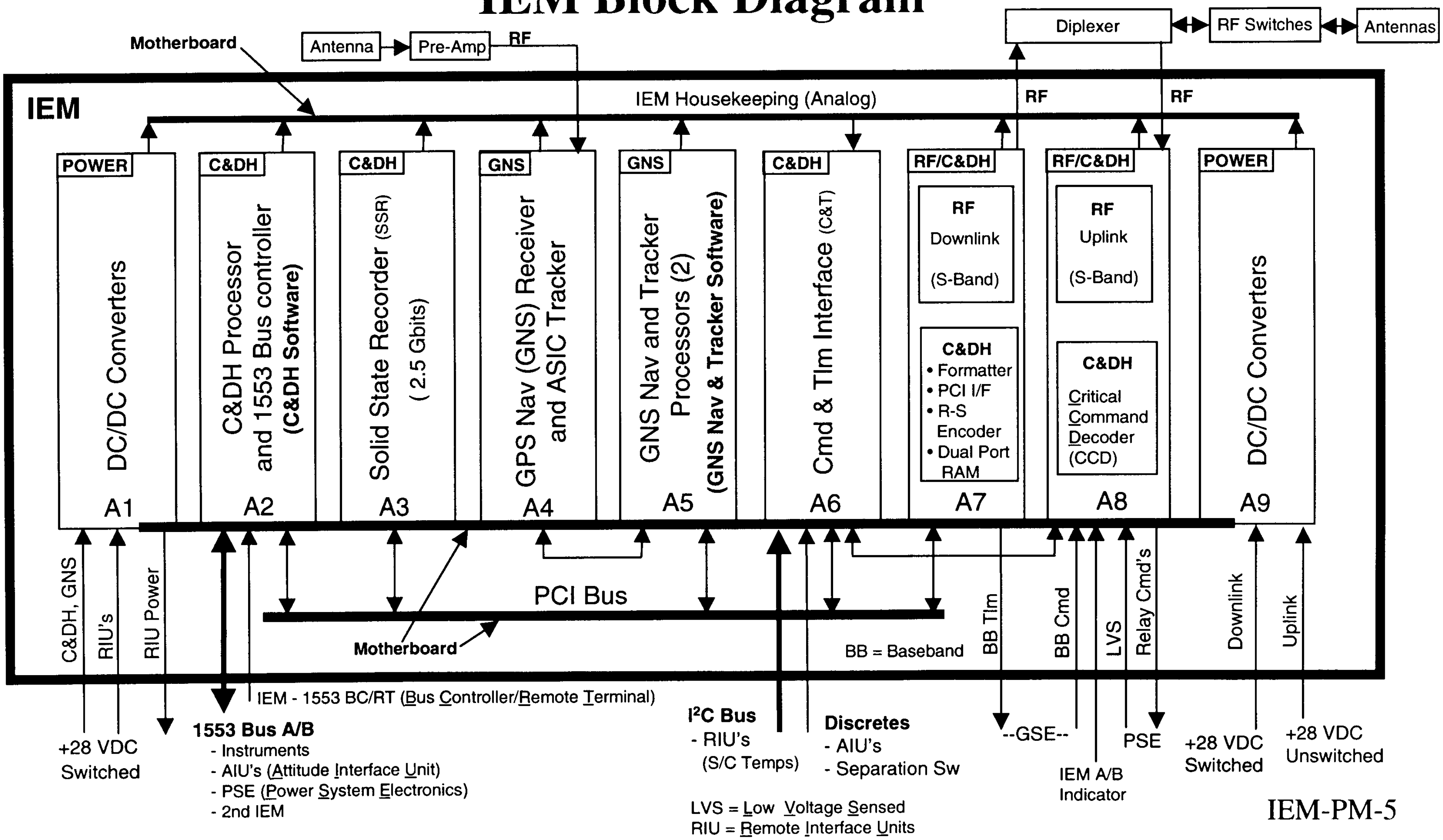
SIZE: 7.1x13x10.5 inches
WEIGHT: 25.2 lbs.
POWER: 53.3 Watts (Fully Powered)

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

IEM Block Diagram



IEM DESIGN OVERVIEW

Four Subsystems on Nine Plug-in Cards in a Common Housing

1. Command & Data Handling (C&DH) Subsystem

a. C&DH Processor (1 card, A2)
- Mongoose V Processor (12 MHz Clock)
- 2 Mbytes EDAC SRAM, 4 Mbytes EDAC FLASH EEPROM
- Summit 1553 Bus Controller
- PCI Bus Controller (Master/Target when idle)

b. Solid State Recorder (SSR) (1 Card, A3)
- 2.5 Gbits Storage with Refresh
- Read Block, Write Block, Memory Scrub Logic with EDAC
- Byte Read/Write
- PCI Bus Controller (Target)

c. Command & Telemetry Interface (C&T) (1 Card, A6)
- I^2C Bus Controller (S/C Temps)
- IEM Analog Hskp Telemetry (Mux & A/D Conv.)
- Discrete Interfaces (AIU's, Separation Sw)
- PCI Bus Controller (Target) and CCD Interface

d. Downlink Formatter, Reed-Solomon (R-S) Encoder, and PCI Controller (Master/Target) (On Downlink Card, A7)

e. Critical Command Decoder (CCD) (On Uplink Card, A8)
- Interfaces with Command Detector Unit (CDU), Power System Electronics (Relay cmds, Low Voltage Sense), and C&T Card

IEM DESIGN OVERVIEW (Con't)

2. GPS Navigation Subsystem (GNS)

a. GNS Receiver/Tracker (1 Card, A4)
- RF Downconverter
- Sampled IF(2 Bit A/D Converter Interfaces with ASIC Tracker)
- 12 Channel ASIC Tracker(Interfaces with Tracking Processor on A5 Card)

b. GNS Dual Processor (1 Card, A5)
- Mongoose V Tracking Processor (Interfaces with Nav Processor & ASIC Tracker)
- Mongoose V Navigation Processor (Configured same as C&DH Processor)
- PCI Controller (Target) (Interfaces Nav Processor to PCI Bus)

3. RF Communications Subsystem (S-Band)

a. Downlink (1 Card, A7)
- SSPA, Frequency Synth., and Vector Modulator
- Vector Modulator Interfaces with C&DH Downlink Formatter on card

b. Uplink (1 Card, A8)
- RF Downconverter, IF Section, Frequency Synth., PLL/AGC, and Command Detector Unit (CDU)
- CDU Interfaces with C&DH Critical Command Decoder (CCD) on card

4. Power Conditioning Subsystem

a. DC/DC Converters for C&DH, GNS & RIU's (1 Card, A1)

b. DC/DC Converters for RF Communications (1 Card, A9)

IEM REVIEWS

1. A formal engineering review (EDR) was not held at the IEM level. There was an informal mechanical review (FFR)[1] of the IEM housing.
2. Presentations on the IEM were given at the S/C PDR and CDR. No IEM RFA's were issued at these reviews.
3. Engineering Design Reviews, EDR's, for each IEM subsystem were held. These are covered under the subsystem presentations.
4. The motherboard and subsystem interfaces were implemented and tested on wire-wrapped and brassboard versions of the IEM and were under constant scrutiny during IEM engineering model development

1. FFR = Fabrication Feasibility Review

Question: 1

IEM DOCUMENTATION

1. REQUIREMENTS:

a. GNS

- 7363-9336, 15 Nov. 1997 - "GPS Navigation System (GNS) Requirements
- 7363-9333, 24 Sep. 1997 - "Software Requirements Specification for the GPS Navigation Subsystem"
- 7363-3348, 29 Sep. 1997 - "Software-Hardware Interfaces for the GPS Navigation Subsystem"
- 7363-9332B, 21 Apr. 1998 - "GPS Navigation System (GNS) Software External ICD"

b. C&DH

- 7363-9110, 26 Nov. 1997 - "TIMED Command & Data Handling System Software Requirements Spec."
- 7363-9115, Undated - "TIMED Command and Data Handling Software Command Spec."

c. RF Communications

- Uplink Requirements, 15 Oct. 1997 - Contained in EDR Data Package
- Downlink Requirements, 6 Apr. 1998 - Contained in EDR Data Package

d. Power Conditioning

- Requirements, 8 Apr. 1997 - Contained in EDR Data Package

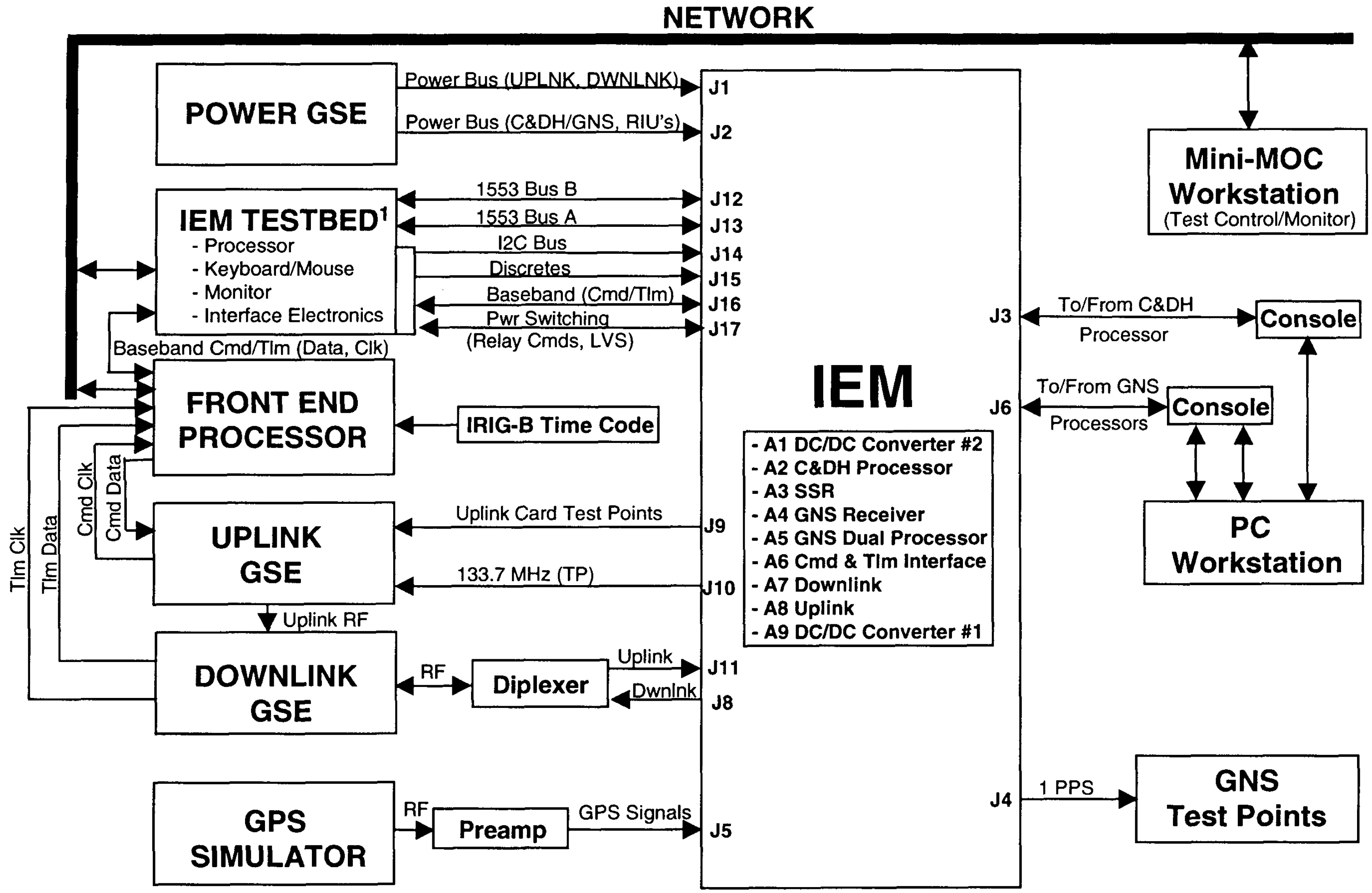
2. IEM TEST PLAN:

- Informal APL memorandum - 1 Jun 1998, "IEM EM TEST PLAN/REVISED"

3. IEM TEST PROCEDURES/REPORTS:

- Automated Test Procedure Files
- Log Books: Engineering Model, Flight Unit #1 and Flight Unit #2

IEM TEST SETUP (Box Level)



1. IEM TESTBED Simulates: RIU's, Instruments, PSE, AIU's, Separation Switch, IEM A/B Indicator and IEM RT/BC Indicator

IEM Test Verification Matrix

SUBYSTEM	INTERFACE(s)	BASELINE	PRE VIBRATION	VIBRATION	POST VIBRATION	PRE-THERMAL VACUUM	THERMAL VACUUM	POST THERMAL VAC
A. C&DH								
1. COMMANDS (Per CCSDS requirements)								
a. Critical Commands	Uplink/PSE	X	X	X	X	X	X	X
b. Processor Commands	Uplink/C&T/PCI/PSE	X	X	X	X	X	X	X
2. DATA HANDLING (Per CCSDS requirements)								
a. Instrument Data Realtime	1553/PCI/Downlink	X	X	X	X	X	X	X
b. Alternate IEM Data	1553/PCI/Downlink	X	X	X	X	X	X	X
c. Record/Playback Data	PCI/Downlink	X	X	X	X	X	X	X
d. Temperature Data (RIU's)	I^2C/PCI/Downlink	X	X	X	X	X	X	X
e. IEM Housekeeping Data	C&T/PCI/Downlink	X	X	X	X	X	X	X
f. Discrete Interface Test	C&T/PCI/Downlink	X	X	X	X	X	X	X
B. GNS								
1. GNS/C&DH INTERFACE								
a. Commands to Nav Processor	Uplink/C&T/PCI	X	X	X	X	X	X	X
b. Data from Nav Processor	PCI/Downlink	X	X	X	X	X	X	X
c. 1PPS	C&DH Interrupt	X	X	X	X	X	X	X
d. Housekeeping Monitors	C&T/PCI/Downlink	X	X	X	X	X	X	X
2. RECEIVER/TRACKER								
a. Receiver Downconverter	RF Pre-Amp/ASIC	X	X	X	X	X	X	X
b. ASIC and Tracking Processor	ASIC/Tracing Proc.	X	X	X	X	X	X	X
c. Nav/Tracking Processor Software Loading	Test Port/Nav-Track Processor Data Bus	X	X		X	X	X	X
C. RF UPLINK								
a. Uplink Acquisition Test	RF	X	X		X	X	X	X
b. Uplink Threshold Test	RF	X	X	Nom Signal	X	X	X	X
c. Housekeeping Monitors	C&T/PCI/Downlink	X	X	X	X	X	X	X
D. RF DOWNLINK								
a. Downlink Option Selection (e.g. Data Rate, Encoding)	RF/Uplink/C&T/PCI	X	X	High Rate	X	X	X	X
b. Bit Error Rate	PCI/RF Downlink	X	X		X	X	X	X
c. Power Output	RF	X	X	X	X	X	X	X
d. RF Spectrum	RF	X	X	X	X	X	X	X
c. Housekeeping Monitors	C&T/PCI/Downlink	X	X	X	X	X	X	X
E. POWER								
a. Monitor Input Currents (at 22, 28 and 35 V Input)	GSE	X	X	X	X	X	X	X
b. Monitor Internal IEM Voltages	IEM Housekeeping	X	X	X	X	X	X	X

NOTE: IEM requalification after rework included 1 axis random vibration (3 dB below acceptance levels) and 2 thermal cycles (-29^{0}C to +55^{0}C)

IEM P/FR's - IEM Level

Question:7

P/FR No.	Unit	Date	Originator	Status	Closed	Description (Summary)
TIEM-001	SSR-1	12/15/1998	Mastracci	C	03/02/1999	Solid State Recorder (Solder Re-Flow Problem) Card rejected. Hand soldered S/N-2,3.
TIEM-002	ANT-2	02/12/1999	Mastracci	C	03/02/1999	Antenna Mast Assy (Reworked)
TIEM-003	IEM-1	04/26/1999	Marth	C	06/10/1999	Stale Tlm, Cmd fails (tlm lags due to GSE delay causes proc to indicate failed cmds)
TIEM-004	IEM-1	04/26/1999	Marth	C	02/22/2000	GNS Cmd CLTU timeout (thought to be an incomplete cmd transmission by GSE)
TIEM-005	IEM-1	04/26/1999	Marth	C	06/10/1999	SSR frames lost. FTP to MDC impacts Frt End tlm process (MDC FTP priority adjusted)
TIEM-006	IEM-1	04/27/1999	Marth	C	06/10/1999	Cmd Failure, Proc. cmd-to-cmd delay too short for COP-1 (Proc. timing changed)
TIEM-007	IEM-1	04/28/1999	Marth	C	06/10/1999	Testbed not confirming relay cmds (Faulty connection to Testbed discovered, corrected)
TIEM-008	IEM-1	04/30/1999	Marth	C	06/10/1999	GNS 1 PPS Intermittent (loose TV chamber test connector, corrected)
TIEM-009	IEM-1	05/01/1999	Marth	C	06/10/1999	Random SSR Dump Data (Test procedure problem prevented start of SSR recording)
TIEM-010	IEM-1	05/04/1999	Marth	C	06/22/1999	IEM Turn ON Anomaly (same as TIEM-023)
TIEM-011	IEM-1	03/31/1999	Marth	C	06/10/1999	Erratic Downlink Card Temp. (Interface problem between C&T and Dwnlnk cards)
TIEM-012	IEM-2	03/26/1999	Marth	C	06/10/1999	Failed GNS command (conflict between manual and procedure generated cmds)
TIEM-013	IEM-2	03/31/1999	Marth	C	02/22/2000	C&DH relay cmd CLTU timeout (similar to TIEM-004)
TIEM-014	IEM-2	03/30/1999	Marth	C	02/22/2000	No response to C&DH Cmds, suspect "glitch" during IEM turn-on (Reset IEM to clear)
TIEM-015	IEM-2	03/30/1999	Marth	C	06/10/1999	Loss of GNS 1PPS Test Signal (see TIEM-008)
TIEM-016	IEM-2	03/31/1999	Marth	C	06/10/1999	Erratic Downlink card temperature (See TIEM-011)
TIEM-017	IEM-2	03/31/1999	Marth	C	06/10/1999	Apparent C&DH Cmd problem (Proc. Error caused cmds setup for wrong IEM ID)
TIEM-018	IEM-2	03/31/1999	Marth	C	10/05/1999	1st of 2 SSR dumps "Out of Sync" (PCI bus arbitration problem corrected by ACTEL change)
TIEM-019	IEM-2	03/31/1999	Marth	C	02/22/2000	C&DH relay cmd CLTU timeout (similar to TIEM-004 and TIEM-013)
TIEM-020	IEM-2	04/07/1999	Marth	C	06/10/1999	Miss 2 "Sticky Clear" Cmds (Cmd stacking due to GSE delays causes apparent failed cmds)
TIEM-021	IEM-2	04/08/1999	Marth	C	06/10/1999	Miss 2 "Critical" Relay Cmds (delay between cmds not sufficient, NOOP inserted)
TIEM-022	IEM-2	10/13/1999	Rodberg	C	10/18/1999	SSR Synch errors (SSR FIFO controller address pointer error with low probability & impact)
TIEM-023	IEM-1	10/13/1999	Rodberg	C	10/18/1999	C&DH processer hangs-up when tuned-on at cold temp. (Found/replaced fouled connector)

Question: 8

Pre-S/C Operating Hours: Flight Unit #1 - 425 Hrs, Flight Unit #2 - 193 Hrs

IEM P/FR's - Spacecraft Level

Question: 7

	P/FR No.	Unit	Date	Originator	Status	Closed	Description (Summary)
1	TSC-005	IEM-EM	11/05/1998	Colby	C	08/02/1999	CLTU error flag not functional on EM-IEM (ACTEL replaced)
2	TSC-006	IEM-EM	10/28/1998	Colby	C	06/15/1999	RF Test Conn Turning (Staked conn)
3	TSC-011	IEM-EM	12/03/1998	Kozuch	C	01/11/1999	SSR Sync Error (PCI ACTEL replaced) Also see TIEM-018 and TSC-019
4	TSC-014	IEM-2	04/19/1999	Nguyen	C	10/05/1999	SSR Missing Frm - Sync 1 Bit Lat (GSE prob.)
5	TSC-019	IEM-2	05/10/1999	Nguyen	C	10/05/1999	SSR Sync Error (PCI ACTEL replaced), Also see TSC-011 and TIEM-018)
6	TSC-023	IEM-1	06/15/1999	Nguyen	C	07/22/1999	Expected more data for CDH1 dump (Insert delay after status write and before read)
7	TSC-024	IEM-1	06/22/1999	Nguyen	C	07/22/1999	RF Cmd failures (GSE connection to wrong cmd clock causes cmd failures)
8	TSC-027	IEM-1	06/24/1999	Colby	C	03/14/2000	IEM/SEE missing/duplicate packets (not repeatable), possible PCI transaction failure
9	TSC-028	IEM-1,2	06/29/1999	Colby	C	09/20/1999	Using rf link, Xfer layer failure & cmd lockout (CCD ACTEL replaced to fix bit flip)
10	TSC-035	IEM-2	07/27/1999	Nguyen	C	09/20/1999	C&DH C2_PPT_STAT_B not correct (C&DH software modified to add this telltale)
11	TSC-042	IEM-1	08/13/1999	Nguyen	C	09/28/1999	If a processor resets while in FLASH state, have to power cycle to run application
12	TSC-043	IEM-EM	08/19/1999	Colby	C	10/18/1999	GNS 1 - No AGC (Intermittent in EM GNS connector)
13	TSC-044	IEM-1	08/30/1999	Colby	C	09/20/1999	IEM not running application (caused by software bug, ops procedure, EDAC handling)
14	TSC-045	IEM-EM	08/31/1999	Nguyen	C	10/20/1999	C&DH reset while testing GNS (Console induced reset)
15	TSC-047	IEM-1,2	09/01/1999	Nguyen	C	10/05/1999	Active AIU Select Command (cmd for each AIU needed)
16	TSC-049	IEM-2	09/14/1999	Nguyen	C	02/22/2000	GNS BB Load caused xfer failures (Noise induced error)
17	TSC-054	IEM-2	09/20/1999	Nguyen	C	02/22/2000	CDH xfer lyr fails in baseband (Noise induced error)
18	TSC-061	IEM-1,2	10/18/1999	Nguyen	C	12/08/1999	Both IEMs give SEE status when both ON, IEM(RT) status should be ignored (now is)
19	TSC-070	IEM-2	11/23/1999	Nguyen	C	12/20/1999	CLCW data mixed when both IEMs ON (MOC S/W changed to detect problem)

IEM -Residual Risk

ESTIMATED LEVEL OF RESIDUAL RISK[a] = 1

- **Failure free operation at the spacecraft level, including environmental testing and extensive use during mission simulations.**
- **Two IEM's provide full redundancy and eliminate loss of mission due to a single point IEM failure**

a. On a scale of 1 - 5, where 1 = Low Risk, 5 = High Risk

Spacecraft Processors

James A. Perschy

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- Mongoose V Processor used for C&DH, GNS, and AFC computers
- C&DH, GNS computers reside in IEM
  - GNS is a dual Mongoose configuration
- AFC is an identical hardware design to the C&DH computer, but is packaged separately with a DC/DC converter card

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Outline

Topic	Slide	Questions
Requirements	3,4,	
Specification	5,6,7	
Engineering Design Review	8 through 15	1,3,9
Actel FPGA Design Verification	16	3,7,8
Card Test Sequence	17	3,7,8
Card Block Diagrams and Layouts	18 through 23	
AFC Block Diagram and Layout	24, 25	
Card Level Testbed, Performance Ver.	26, 27, 28	3
AFC Test Sequence	29	3,7,8,9
AFC Thermal Vacuum Test	30	3,8
Test Matrix (SW vs Hardware Tested)	31	3
Test Procedure (Sample)	32	3
Processor Card Test History	33	3,7,8,9

Processor Requirements (1 of 2)

- CPU
  - 32-bit architecture for ease of SW development
  - IEEE-754 floating point for navigation and attitude
- Space environment
  - Latchup free
  - No heavy ion or proton induced non-recoverable upsets
- Throughput
  - 3-VAX MIPS minimum with separate C&DH, GNS, & Attitude Flight Computer (AFC) processors
- Memory capacity
  - 2-megabyte EDAC SRAM, 4-megabyte EDAC Flash EEPROM, scrubbing to eliminate soft errors

Processor Requirements (2 of 2)

- Input/Output
  - MIL-STD-1553 for C&DH and AFC processors
  - PCI bus for C&DH and GNS processors
  - Local bus for GNS processor (16 address and 16 data lines)
  - Interrupts and discretes to meet C&DH, GNS, and AFC requirements. The driver is GNS.
  - All non-transformer coupled interfaces have series protection resistors

Processor Specification (1 of 3)

- CPU
  - Mongoose-V MIPS based processor
- Throughput
  - 3-VAX MIPS, 10 RISC MIPS at 12 MHz using no-wait-state SRAM
- Memory
  - 2- megabyte SRAM using 4-Meg Iridium/Motorola/Auston epi-MCM6246, 5 total for 32-bit word with 8-EDAC parity bits
  - 4 -megabyte Flash EEPROM using Intel M28F008, 5 total for 32-bit word with 8-EDAC parity bits
  - 1 -megabyte console boot ROM using Intel M28F008, one for 8-bit wide bus

Processor Specification (2 of 3)

- Input/Output
  - UTMC Summit 1553 protocol ASIC for NEAR SW heritage
    - External wired BC/RT control
    - External wired RT address
  - PCI bus with 8-Kbytes UTC138 dual port SRAM
  - Local bus for GNS dual processor card to GTA card
- Interrupts
  - 12 total external interrupts used
- Power
  - +5V, 3.5-W peak at 12 MHz per processor w/o 1553, add 4-W peak for 1553 at 100% transmit

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Processor Specification (3 of 3)

Card SEU Est. Based On JDK Component Est. at CDR 12/4/97

Memory	Peak errors/dev/day (in SAA)	errors/bit/sec	Prob 1 err/ 40bit-30 sec (scrub rate)	Prob 2 error/ 40bit-30sec (Poisson dist)	Prob 3 error/ 40bit-30sec (Poisson dist)	Prob > 1err/ 512K-Word-year	Prob > 2err/ 512K-Word-year
Motorola SRAM in SAA	1895.00	5.23E-09	6.28E-06	1.9688E-11	4.1181E-17	0.883029012	1.84702E-06

Motorola powered SRAM detected and corrected error/year = 2.9E5 (Assume SAA peak = 15 min 8 times/day)

Motorola powered SRAM prob of detected uncorrecatble error/year = .883

Summit 1553 SEU = 7E-6 errors/device-day = 2.6E-3 errors/device-year

Motorola powered SRAM prob of undetected error/year = 1.847E-6

Flash EEPROM errors are not held. They are only valid for the word being accessed.

Actel	error/module-day	error/FF-day	err/FF-year	PCI Actel err/year	1553 Actel err/year
A1280 C-module	6.90E-09	1.38E-08	5.04E-06	1.06E-03	3.32E-04

2x8x32K RH SRAM for MIL-STD 1553 errors/bit-day	2x8x32K RH SRAM for MIL-STD 1553 errors/year	2x8x4K RH DPM for PCI errors/bit-day	2x8x4K RH DPM for PCI errors/year
1.00E-11	1.87E-03	1.00E-11	2.34E-04

Triple Modular redundant (TMR) Actel FFs	err/bit-day	err/bit-sec	Prob 1 err/ 3bit-sec	Prob 2 err/ 3bit-sec Poisson dist	Prob 3 err/ 3bit-sec Poisson dist	Prob > 1 err/ 3bit-year 1-sec refresh
Two 1280 C-Modules	1.38E-08	1.60E-13	4.79E-13	1.148E-25	1.83362E-38	3.62034E-18

Proc/1553 Card err/year
0.006097847

Engineering Design Review (1 of 8)

- C&DH Hardware EDR held November 20, 1997. R. F. Conde and P. D. Schwartz reviewers. Minutes SEE-97-0204
- Covered Processor, Recorder, Command & Telemetry
- All 22 action items closed
- Processor related action items:
  - 1, 2, 3, 5, 7, & 8 answered by J. A. Perschy
  - 4, 7, & 8 answered by J. D. Kinnison
  - 6, & 13 answered by D. E. Rodriguez
  - 19 & 22 answered by S. P. Williams
- Design engineers and reviewers each have greater than 15-years experience in spacecraft analysis and engineering. Resumes available from the HR Department

EDR (2 of 8)

1. Ensure that the practice of not using pullup resistors on some buses that are in a high impedance state for short lengths of time is consistent with worst case leakage currents (so that the bus can not transition to mid-logic levels while in the high impedance state).
   Assigned to Jim Perschy and Dan Rodriguez

The PCI bus control signals do have 10K ohm pullup resistors actively negating these functions when they are not driven by a terminal. The synchronous clock distributed on the motherboard is always actively driven. The data lines do not have pullup resisters. They input to synchronizing flip flops that can only change state on the positive going edge of the synchronous clock. The PCI backplane capacitance for 6 PCI nodes is 150 pF. The worst case leakage current for an Actel1280A IO interface over –55 degree C to +125 degree C temperature range is 10ua. The voltage change per microsecond is 50 ua/150PF x 1usec = 0.33 V. This allows sufficient time for the turn around cycles on the PCI bus.

2. Is it required to independently enable/disable EDAC for SRAM and Flash memory on the processor board.
   Assigned to Jim Perschy

SEE-00-0055

The software designers require this feature. It requires one extra control flip flop to independently enable/disable these two functions.

3. Ensure that the +12V power used to reprogram the flash memory is put in a known state when the +12V is turned off.
   Assigned to Jim Perschy

SEE-00-0055

The +12volts is bled through a 3.48 K ohm resister added to its output on the DC/DC converter card. It is also bled through the resistor divider network which inputs to the 12 volt telemetry channel. When the voltage drops below 11.5 volts, the flash memories internally disable erase and write functions.

4. Is there any permanent or temporary damage caused by an upset during flash memory reprogramming; what is the probability of this happening.
   Assigned to Jim Kinnison

SOR-5-96068, December 5, 1997, J. D. Kinnison "C&DH hardware EDR Action Item 4 Response"

5. Consider additional protection (on-board or off-board) on processor board console interfaces, especially since may need to interface flight hardware to a Sun workstation.
   Assigned to Jim Perschy

SEE-00-0055

The processor console interfaces to the processor card through 1 K ohm series resistors located in both the console and the on the processor card. The console is battery powered. To complete the decoupling a Telebyte ™ model 268 RS-232 opto isolation modules give 1500 VAC isolation across the UART.

6. Ensure that the PCI interface is adequately terminated during all possible test configurations, especially single board test configurations.
   Assigned to Dan Rodriguez

Board Level Testing: The HP PCI tester (E2925) is interfaced to the board under test through an adapter card which provides appropriate pull-up or pull-down termination for all of the PCI control signals consistent with the PCI specification. The multiplexed address/data lines use a current limiting 330-Ohm series resistor resident on the board under test. These lines are always driven either by the HP card or the board under test.

IEM Chassis: The PCI control signals are all terminated with either pull-up or pull-down resistors on the motherboard. The multiplexed address/data bus is always driven either by the addressed target controller or by the master, including when there are no active transactions. The C&DH processor contains a PCI master controller and the system arbitration logic. The arbitration logic is designed so that the C&DH processor is the default controller on startup, reset, and when no transactions are occurring. It is the first card to be populated in the chassis thus always ensuring that the PCI signals are appropriately driven.

1. Consider triple voting and refreshing critical portions of Actel FPGAs. Critical portions include those, that if upset, would either have a detrimental effect at the system level, or would result in potential hardware overstress, such as bus contention.
   Assigned to all Actel designers: Jim Perschy, Dan Rodriguez, Al Reiter, Steve Oden, Joe Bogdanski, George Theodorakos, John Penn

After review of the Critical Command Decoder (CCD) and C&T Interface ACTEL's, triple voting was added in a number of places, particularly in the CCD. Refreshing of these circuits was included wherever possible.

No triple voting was provided in the Downlink "Framer" ACTEL. It essentially refreshes itself at every frame time and should "reset" itself in the case of SEUs.

2. Calculate the upset rate of each C&DH subsystem.
   Assigned to Jim Perschy and Jim Kinnison

SEE-00-0055

The upset rate of the processor card is: 0.83 uncorrectable but detected upsets per year in EDACed SRAM, assuming 30 second scrub and two hours in the South Atlantic Anomaly per day, and 0.006 upsets per year, mostly due to non-TMR voted, flip flops in the Summit 1553 controller and the Actel FPGAs. See Excel spreadsheet - Single Event Upsets.xls.

What happens if there is a PCI bus time-out when the other master is not present (a test only condition).
Assigned to Dan Rodriguez

The arbitration logic, which resides on the C&DH processor card, is designed to always default to the C&DH processor as the PCI master controller. In the event that a bus time-out occurs due to a problem on the bus, while there is no other master present, the arbitration logic will indeed attempt to transfer bus control to the non-existent (downlink card) master. However, since the Downlink card is not present, it's request line (PCI_REQ#) will not be active. This signal is resistively pulled to its inactive state on the motherboard. The arbitration logic will in turn simply cycle control back to the C&DH processor card. The state transition from C&DH control through Downlink Card control and back requires four PCI clock cycles. One additional clock cycle is required before the C&DH processor begins to drive the PCI Address/Data bus. The total time during which the bus is un-driven is 2μsec. This is a benign condition as identified in the response to action item #1.

10. Determine the upset rate of the SSR control logic (not the DRAM).
    Assigned to Joe Bogdanski

SEE-00-0047

11. Consider simplifying the CCD GSE interfaces.
    Assigned to Steve Oden

SEE-00-0048

Some changes were made to the CCD GSE interfaces, and were accepted as reasonable by all affected parties.

12. Consider changing the 54AC14 to an HCS14 on the CCD-Converter I/F.
    Assigned to Steve Oden

SEE-00-0048

The power-on-reset interface from the converter to the CCD was changed to use a CD40106 Schmitt trigger circuit (no restrictions on rise/fall times) for buffering the signal to both the CCD and the receiver CDU ACTEL's.

13. Ensure adequate demonstration of margin for synchronous circuits in Actel FPGAs which do not use global clock networks - the concern is clock skew between flip flops. The primary issue is that for those cases where it is not possible to use a global clock OR ensure proper operation by design (e.g. use master/slave flip flops for shift registers that don't use a global clock), that adequate margin can be shown for each flip flop. Is margin demonstrated by successful simulation, or by examining margin at the terminals of each flip flop, or some other method ?
    Assigned to Dan Rodriguez

For the designs which employ internal buffering and distribution of clock signals (instead of the low-skew clock driver macros) margin is ultimately demonstrated by careful simulation over the full mil-temp and voltage ranges, -55°C to 125°C and ±10%, respectively. Margin is determined by successful simulation since the in-spec operating range of the devices on the spacecraft is -30°C to 65°C for temperature and no worse than ±5% for voltage.

If further analysis is desired to determine the extent of margin available, this can be accomplished by running the Actel "Timer" application software. This is a static timing analysis tool with which the clock chain timing delays can be observed element by element from the clock source to each of the destination flip-flops. By comparing the relative time delays through each of the paths, clock skew can be determined.

The logic structures that typically fall under greatest question are long shift registers. If the global clocks cannot be used, an alternative master/slave flip-flop structure has been devised that provides greater assurance of correct operation by using the clock state instead of edges to propagate the data through the chain. This eliminates the sensitivity to clock edge skew but is dependent on clock period. Hence, a slower clock will provide greater margin

14. Substitute a CD40106 as the I2C bus data receiver due to HCTS risetime limitations.
    Assigned to Steve Oden

SEE-00-0048

A CD40106 Schmitt trigger circuit will be used to buffer the I2C input data to the C&T Interface card. The output of this circuit is buffered by an HCTS14 Schmitt trigger circuit into the C&T ACTEL, but rise/fall times are not a problem there.

15. How can I2C bus data line interfaces be adequately protected.
    Assigned to Al Reiter and Steve Oden

SEE-00-0048, SRI-00-028

The bi-directional data line at the C&T card interface is connected to a transistor collector with a 1.5K pull-up resistor (data out) and to a CD40106 Schmitt trigger circuit (data in). A decision was made to add no additional protection circuitry. The RIU did add 10K resistors in series with its CD40106 inputs.

16. Determine if the Command and Telemetry board will add PCI bus pullup resistors.
    Assigned to Steve Oden

SEE-00-0048

50K pull-up resistors were added on the internal C&T data bus lines to the "B" side of the dual-port RAM's.

17. Add risetime and falltime control on the I2C data and clock interfaces.
    Assigned to Steve Oden and Al Reiter

SEE-00-0048, SRI-00-0028

Rise and fall times were measured on the breadboard C&T card and RIU setup, and were found to be acceptable without additional circuitry.

18. Determine if collisions are possible between the Downlink Framer and Processor if both try to read Status Word 1 on the Downlink Framer board at the same time.
    Assigned to John Penn

Yes, collisions are possible and are handled by the processor polling the status word and rewriting the status if necessary. Software "fix" has been tested.

19. Ensure that there are spacecraft commands to support all the modes in the Downlink Framer board.
    Assigned to Steve Williams

SEE-98-0034

20. Ensure that the processor software periodically refreshes control information it loads in the dual port RAM on the Downlink Framer board.
    Assigned to Steve Williams

SEE-98-0034

21. How are SSR codeblocks synchronized to CCSDS packets.
    Assigned to John Penn

After a "reset", the PCI Downlink ACTEL looks for the first word count from an SSR codeblock transaction. Each additional SSR codeblock transaction should follow the known pattern of repeating counts due to the mismatch in size between data packets and SSR codeblocks. If "sync" error occurs, meaning the expected first word of an SSR codeblock transaction does not match the expected count then a flag is set and transmitted in the frame indicating that an unexpected codeblock count occurred. No action is taken to correct the error by the hardware. Only error "detection" occurs which needs to be recognized by the processor/software. The "sync" error is cleared by a hardware or a "soft reset" for restarting an SSR dump.

22. Determine the maximum harness length possible for the power and ground lines daisychained to the RIUs, while keeping the voltage to the RIUs in specification due to IR drops in the harness and connector pins.
    Assigned to Al Reiter

SRI-00-028

Processor Actel FPGA Design Verification

- Most detailed logic designs incorporated in Actel FPGAs
- For SEU mitigation: only C-modules used in processor card Actel FPGAs, triple Modula redundancy use for critical circuits, watchdog timer
- Actel FPGA functional design modified, as required, for 100% testability
  - resets, test mode pins added
- Test vectors generated
- 100% parametric and functional testing of programmed flight Actel FPGAs performed at -55, 0, and +125 degrees centigrade

IEM Processor Card Test Sequence

- Verify discrete component values, power consumption
- Pre-Mongoose V Installation - verify correct impedance on all Mongoose-V attachment points, power consumption
- Mongoose-V pins ground isolation check
- Ambient & Thermal Card Test 10% V, -29° to +65° C
- Environmental Stress Screening 20 cycles -34° to + 90° C
- Three powered thermal test cycles -29° to +65° C
- Conformal Coat
- Ambient & Thermal Card Test 10% V, -29° to +65° C
- Delivery

Note: Visual inspection before and after each electrical test

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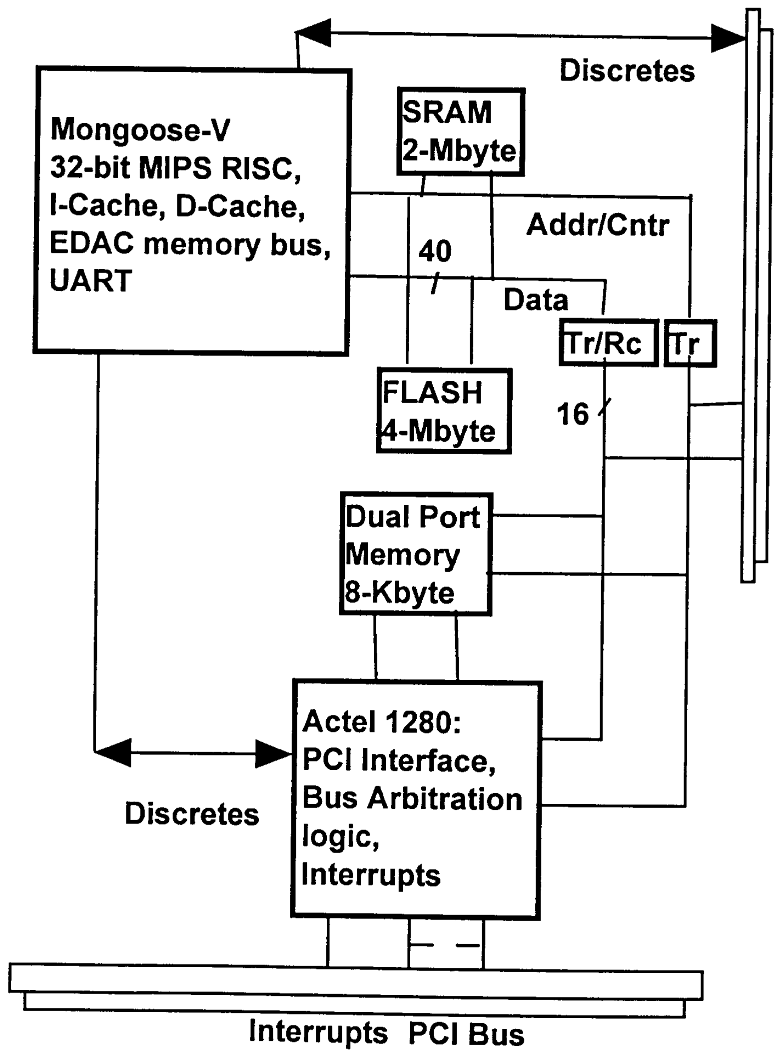
Common Processor Board - Card Side A



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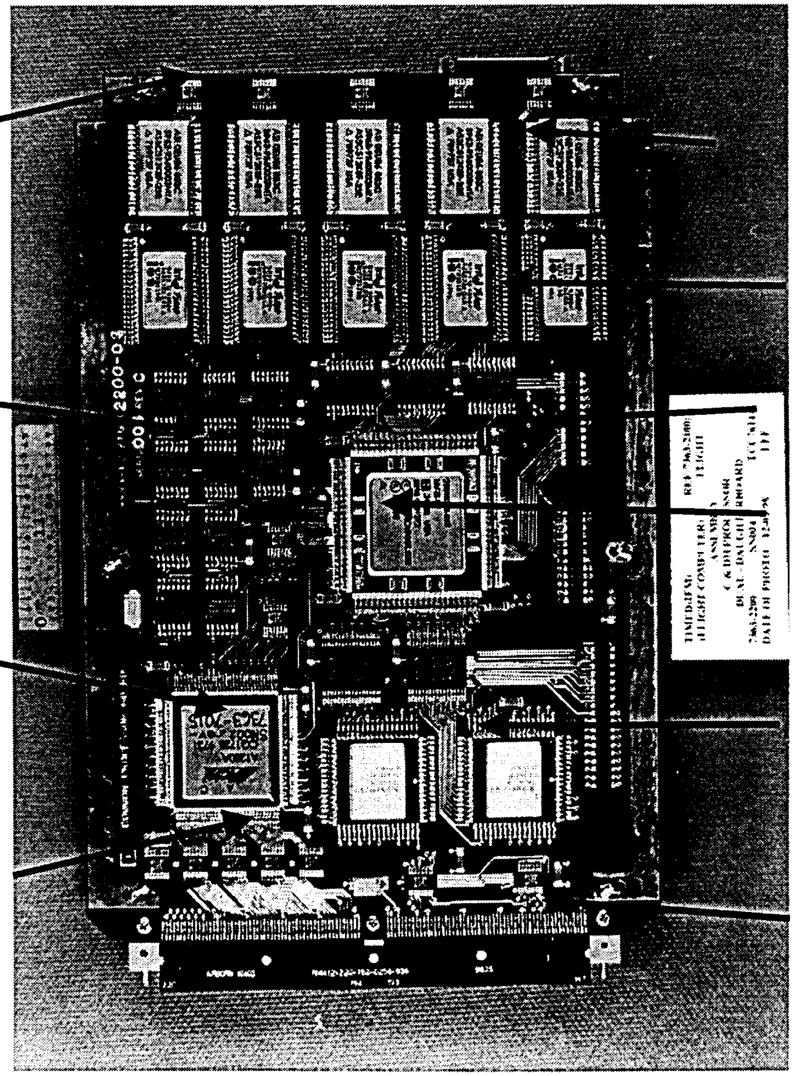
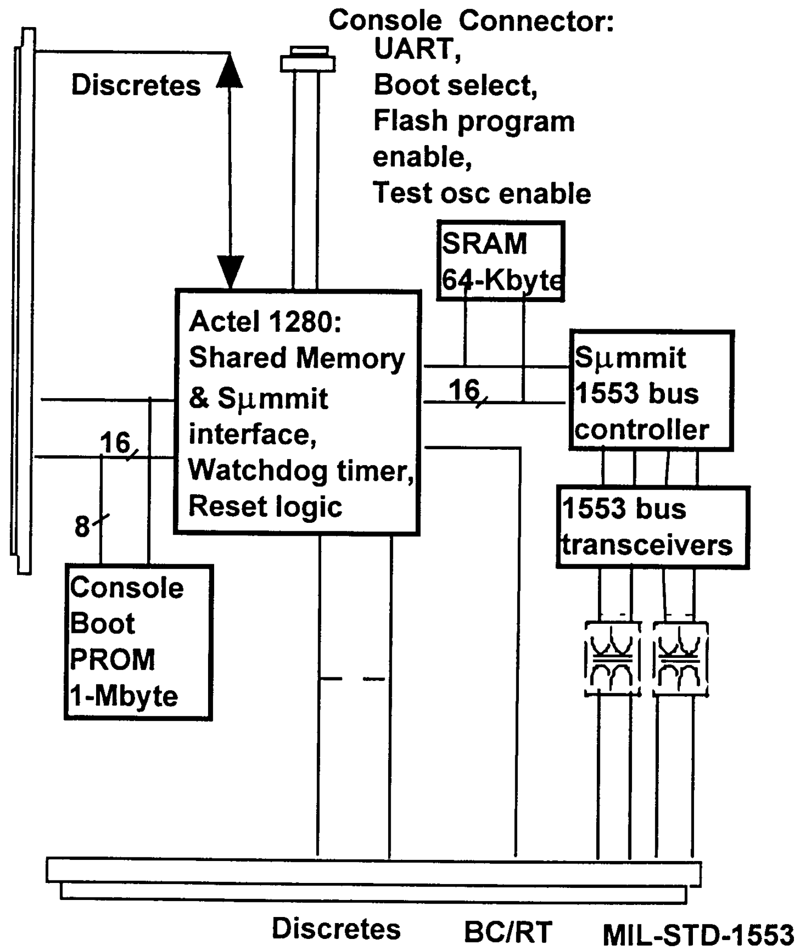
Common Processor Board - Card Side A



MIL-STD-1553 Board - Card Side B



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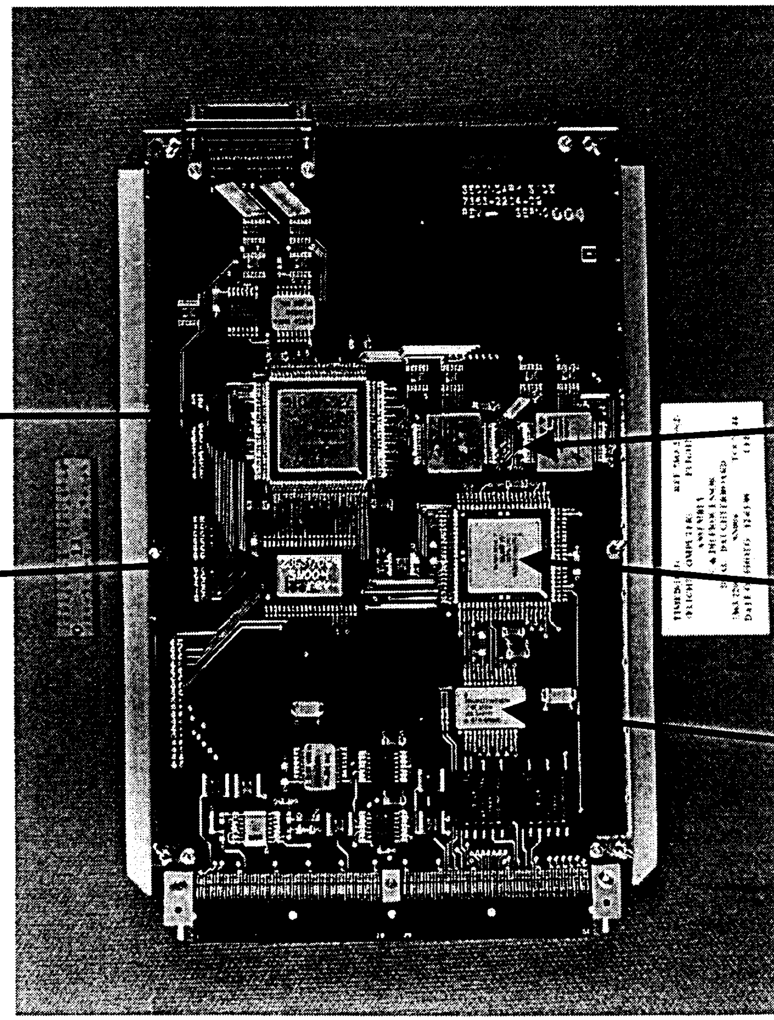
MIL-STD-1553 Board - Card Side B

Actel 1280
C-Modules only

Intel Flash for
console boot

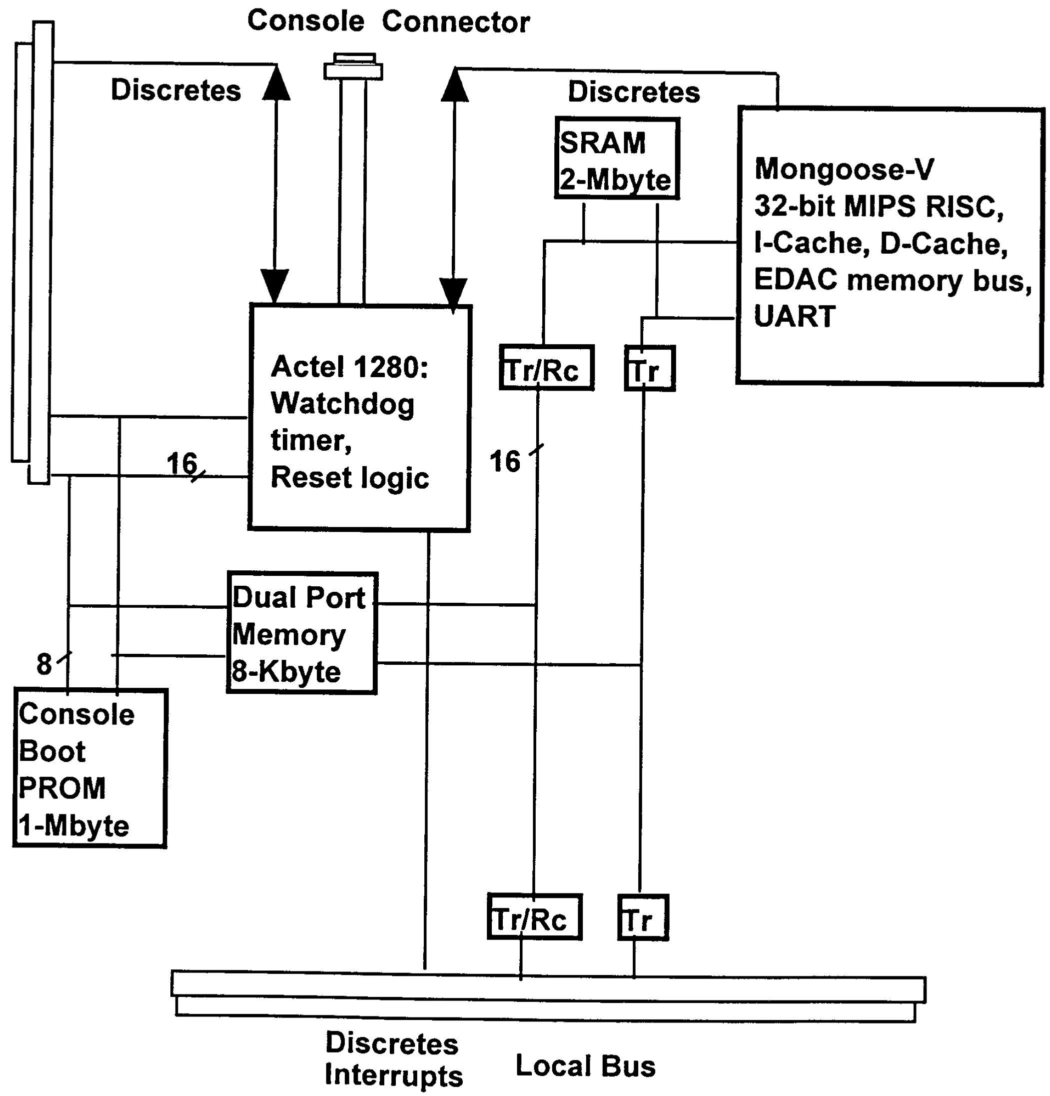


Lockheed Martin
SRAM

UTMC
Summit

Transceiver

GPS Track Processor Board - Card Side B



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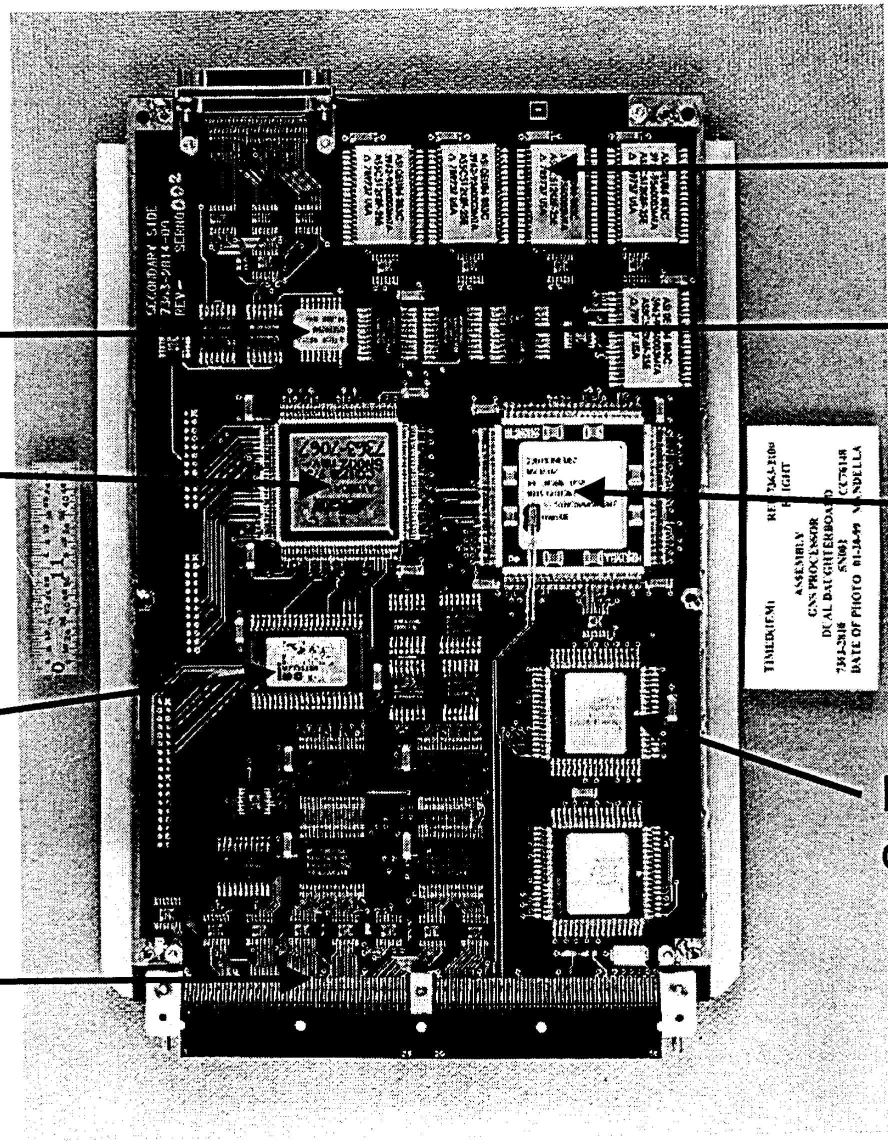
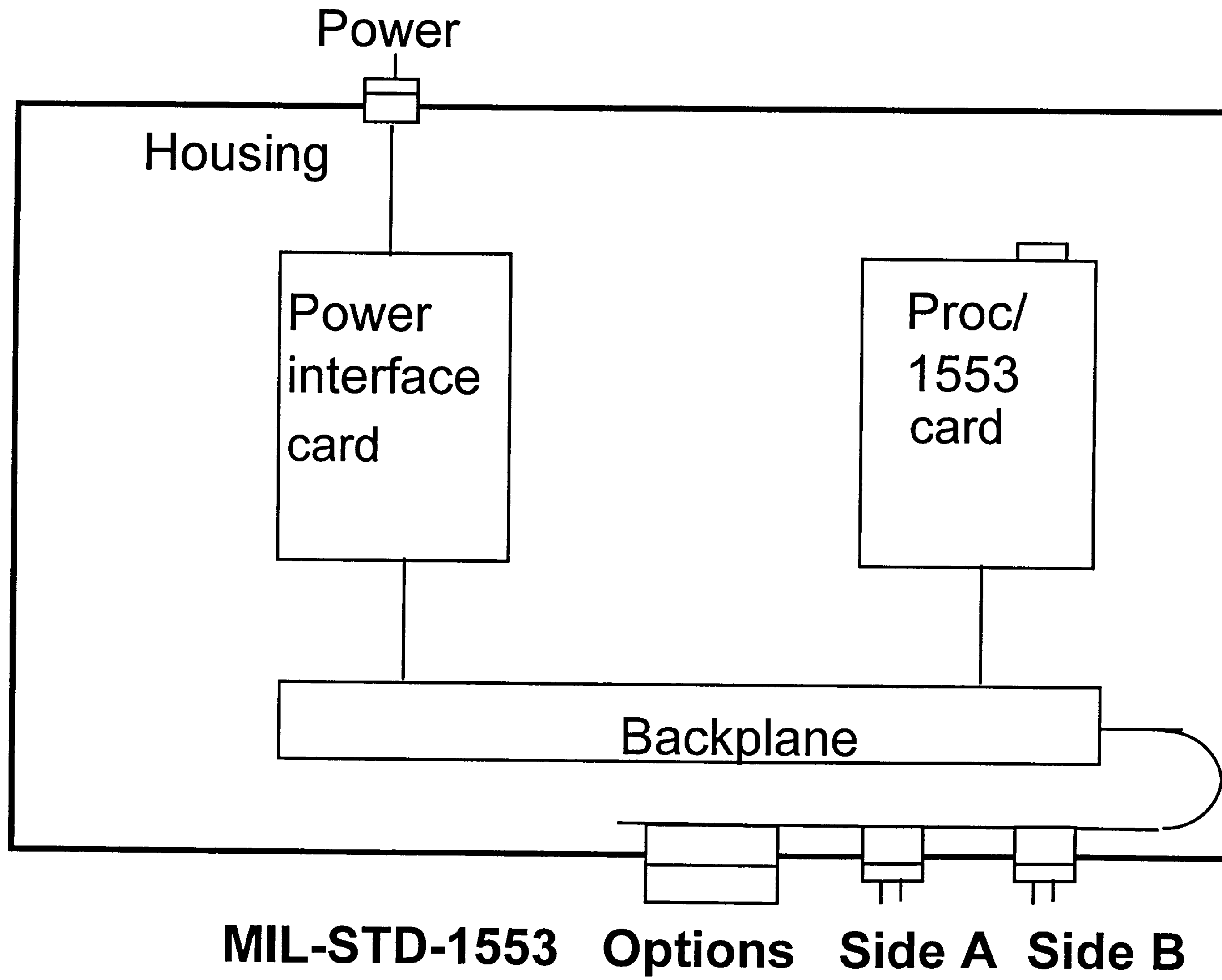
GPS Track Processor Board - Card Side B



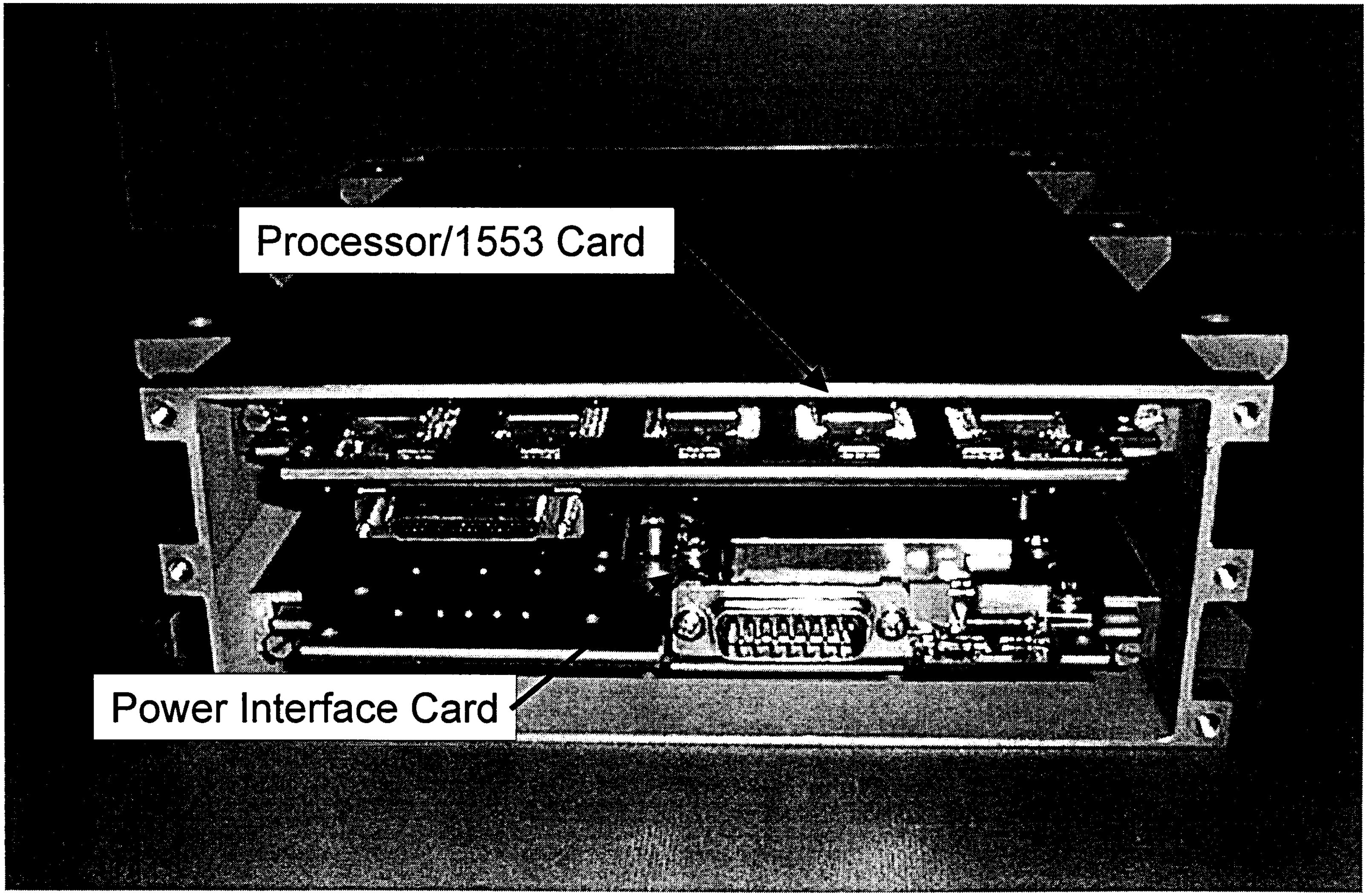
Attitude Flight Computer



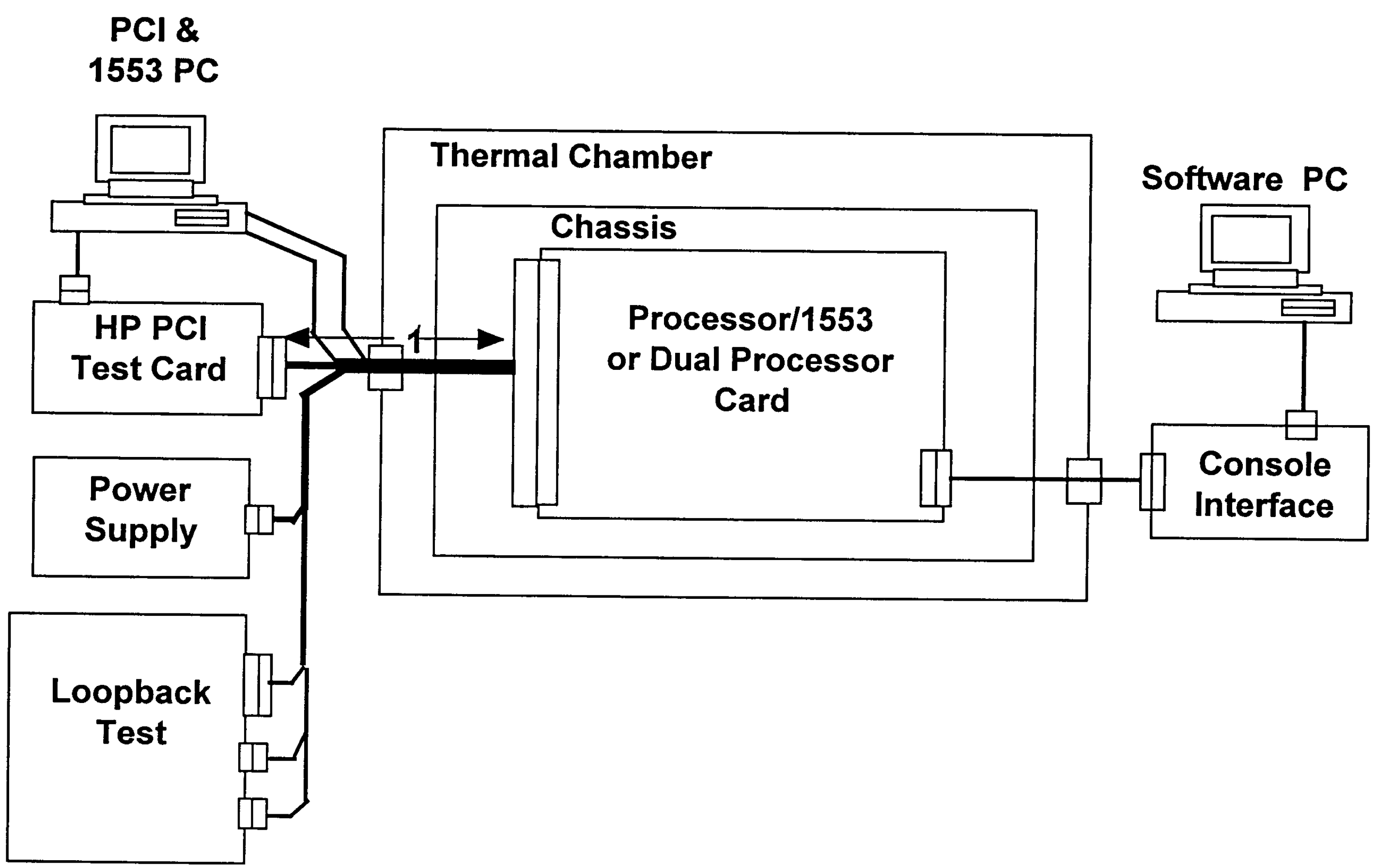
TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

EM Attitude Flight Computer



Card Level Testbed



TIMED

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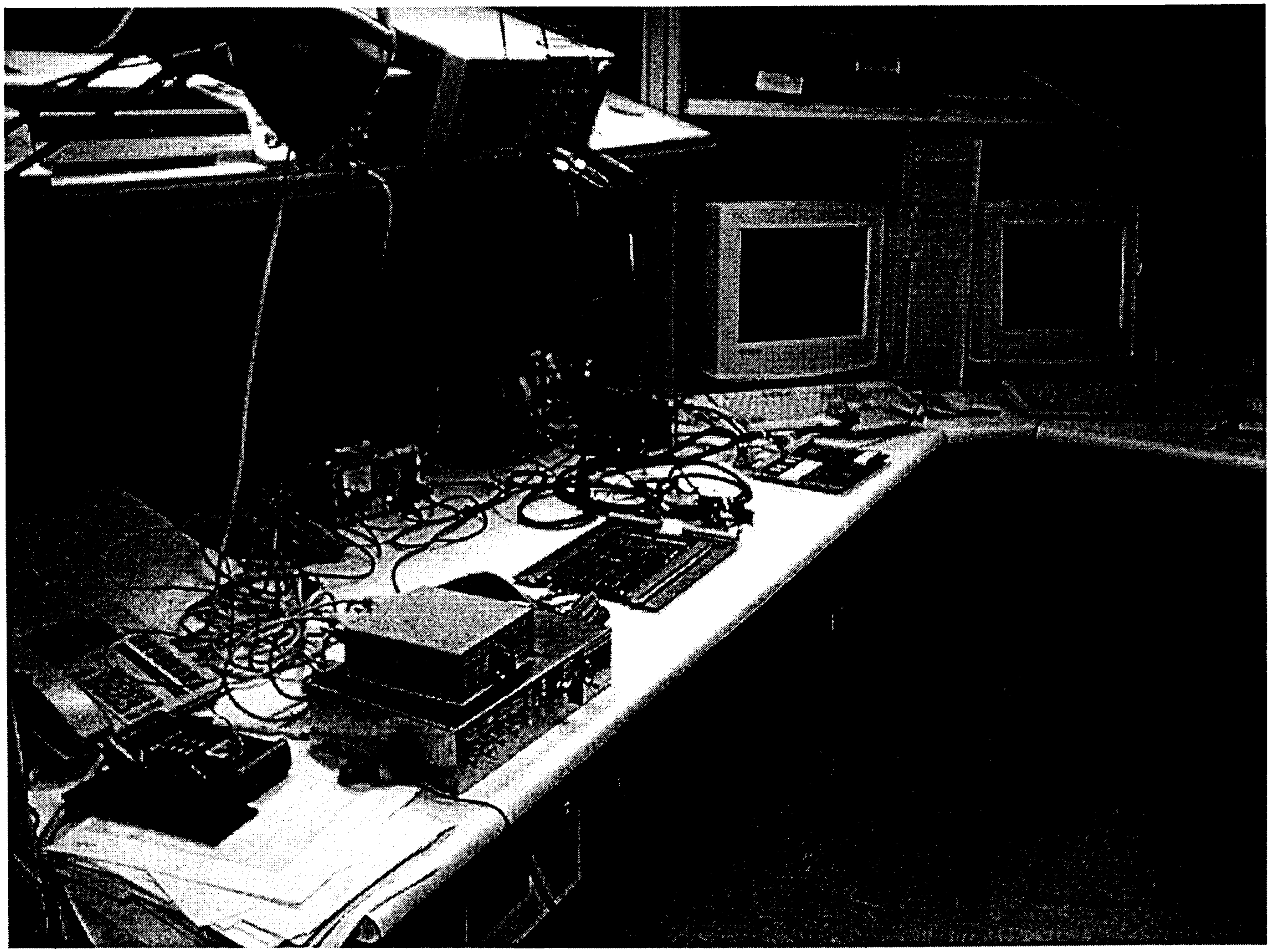
Processor Card Test Bench



TIMED

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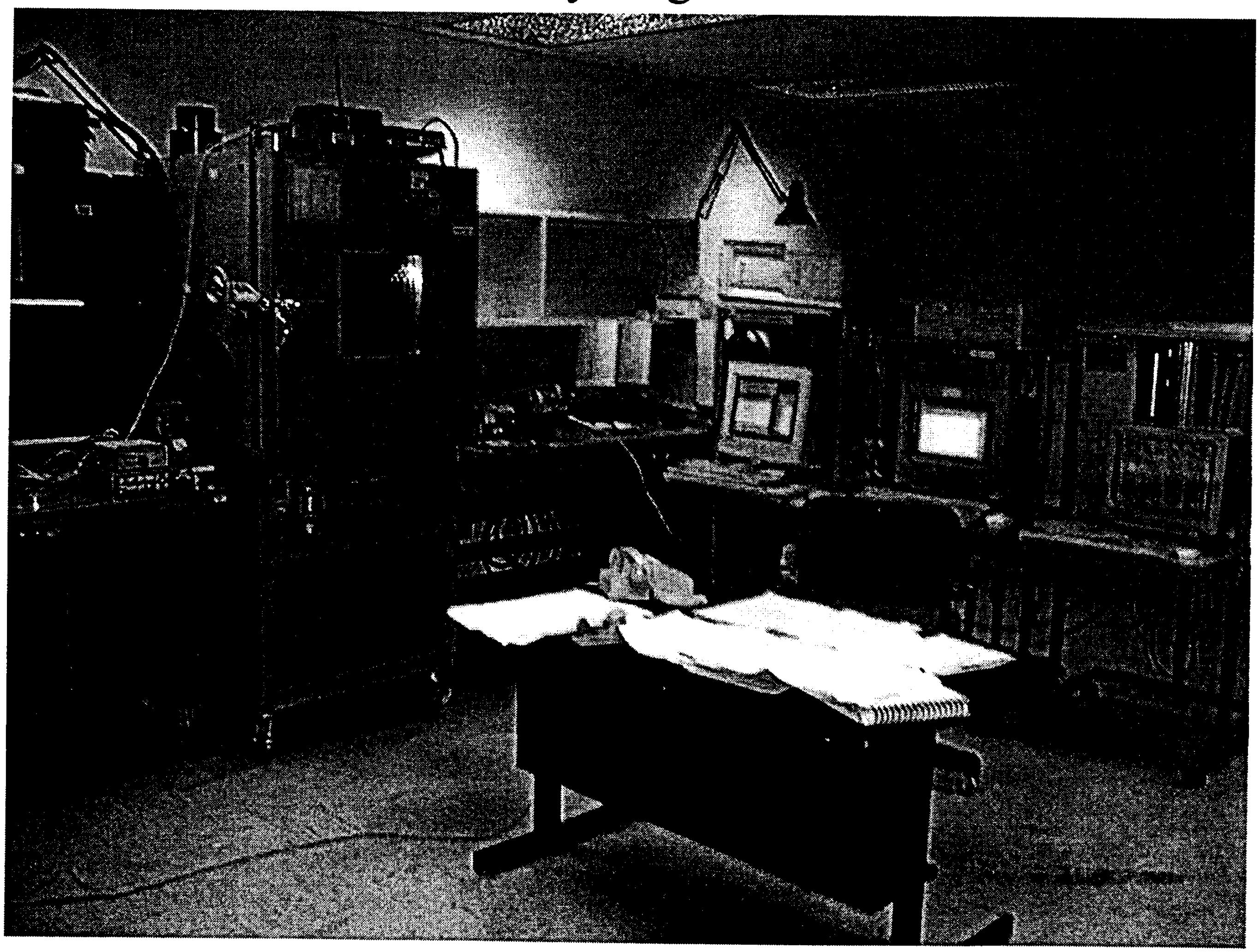
Processor Card Powered Cycling and Performance Verification



Attitude Flight Computer Test Sequence

- Ambient & Thermal Unit Test -29° to +55° C
- Powered Vibration
  - Sine Survey, 3 axis
  - Sine, 3 axis
  - Random, 3 axis
- Thermal Vacuum
  - One unpowered survival cycle
  - Six operational cycles -29 C to +55 C
    - Cold and hot turn-on, min and max temp
    - Complete test procedure at plateaus, 1st and 6th cycle
- Baseline Test

Note: No discrepancies encountered during test of flight units 1 and 2

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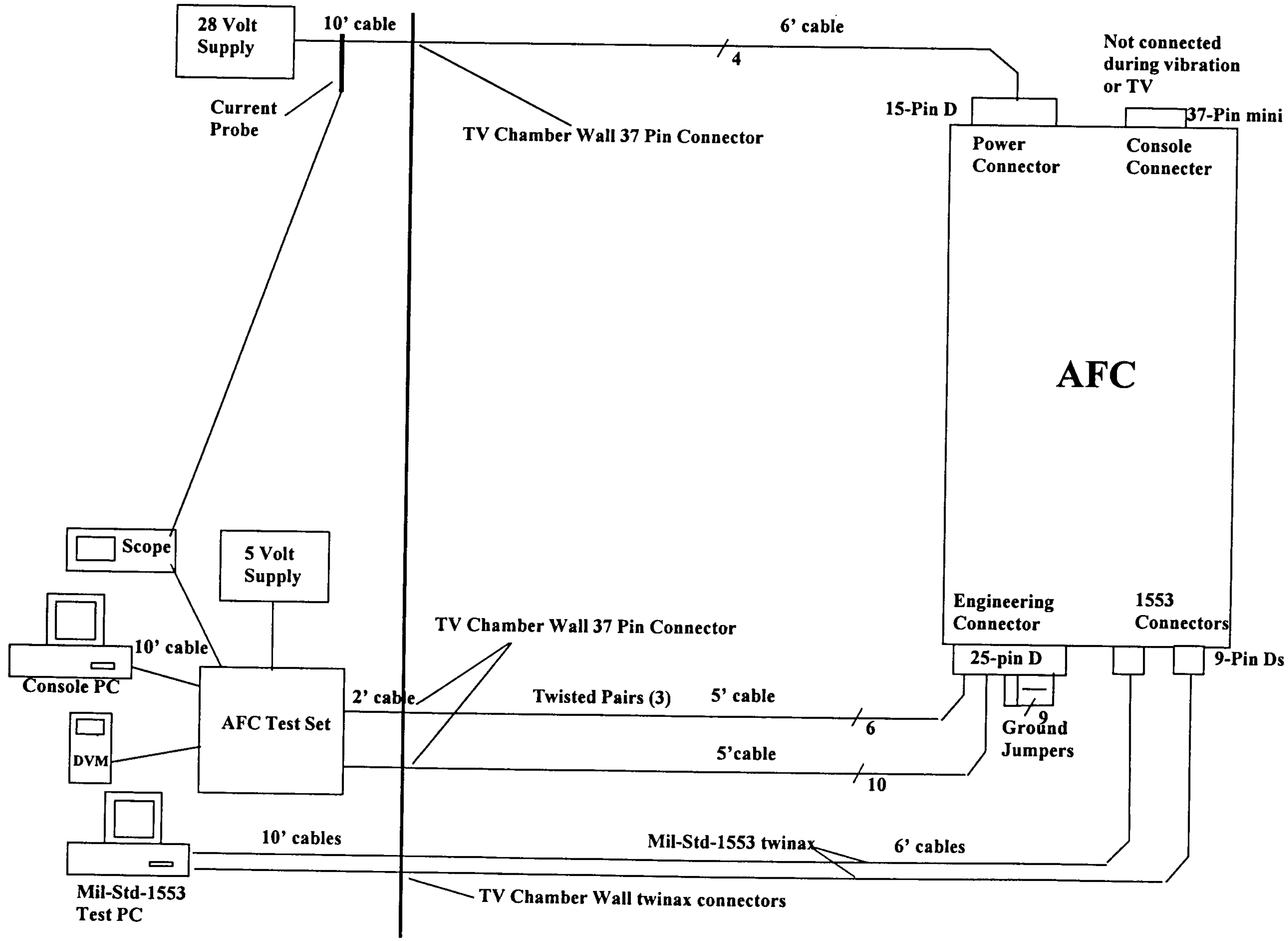
Attitude Flight Computer Thermal Vacuum Test



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Processor Test Matrix

Test Software Used

Hardware Tested

Common Processor "A" Side	Console Boot	Memory Test	EDAC Flash Load	EDAC Flash Boot	PCI Test	1553 Test	TRK Boot	Local Bus Test
Microprocessor	√	√	√	√	√	√	√	√
Bus Control Logic	√	√	√	√	√	√	√	√
Mamory Address Sync Latch	√	√	√	√	√	√	√	√
EDAC SRAM	√	√*Option A	√	√	√	√	√	√
EDAC Flash			√*	√*			√	
IO Address and Data Buffers	√		√		√	√	√	√
PCI & Dual Port Memory Interface		√*Option B	√		√			
1553 Processor "B" Side								
Actel Discretes						√*		
Shared Memory		√*Option C				√*		
Summit Setup						√*		
1553 IO						√*		
Console Interfaces	√	√	√	√	√	√	√	√
Console Boot Flash	√*							
GNS Processor "B" Side								
Microprocessor-2							√*	√
Bus Control Logic-2							√*	√
Mamory Address Sync Latch-2							√*	√
EDAC SRAM-2		√*Option D					√*	√
Dual Processor DPM-2		√*Option E					√*	√
Local Bus-2							√	√*
Reset Actel							√*	√
Console Interfaces	√*						√	√
Console Boot Flash	√*							

Notes:
1. * is comprehensive test
2. Option: Comprehensive memory test: start address & block length

Processor/1553 Card Test Procedure - One Page

No.	Test	Do	Notes	1	2	3	4	5	6
1	Console boot	Processor reset switch							
2	SRAM in DRAM space	mt	DRAM space option set.						
		gmw fffe,0184	fffe,0184 = 0XXX,XXXX						
3	SRAM in SRAM space	mt B002,0000 20,0000	fffe,0184 = 0XXX,XXXX						
3a	Current Check	IDD=	1(600-ma)						
			2 (640 ma lv w mt & 1553)						
			3 (710 ma nv w mt & 1553)						
			4						
			5						
			6						
4	UART-1	set hostport tty1							
		set dlecho on							
		load							
		sw mon to uart-1							
		type char & verify echo							
		sw mon to uart-0							
		^c							
		set hostport tty0							
		reset							
5	PCI DPM	mt BE20,0000 2000							
6	1553 memory	mt BC00,0000 1,0000							
7	1553 Activity &	load							
	Interrupt 4	download Init7-28-98.s3r							
		g							
		activate merlin*							
		mt BC00,0000 8000	Pass test w/o errors						
	smh BC00,F50A&C:	AAA0	return BC005544						
		x5550	return BC00AAA4						
		r c0_cause	int-4 pending						
		load Nop.s3r, g	run op code						
		r c0_cause	int-4 pending						
		stop merlin							
		smh BC10,CB40 0	clear int 4						
		load Nop.s3r, g	run op code						
		r c0_cause	no int-4 pending						
7a	Current Check	IDD=	1 (640-ma)						
			2 (500 ma wo mt)						
			3 (530 ma w 1553)						
			4						
			5						
			6						

Test History of Processor Cards

				10 hrs		16 hrs	10 hrs
Flight Processor Card / Tests	To	Before M-V Attach	M-V Isolation Check	Elec/Thermal #1	Post ESS Elec/Thermal	Post Conform Elec/Thermal	Post PCI Actel Replace
Processor/1553 #1	AFC #1	11/5/98	11/16/98	11/17/98		1/7/99	
Processor/1553 #2	IEM #1	10/30/98	11/16/98	11/18/98	12/8/98	1/21/99	8/30/99
Processor/1553 #3	IEM #2	10/28/98	11/19/98	11/20/98	12/14/98	1/13/99	7/29/99
Processor/1553 #4	AFC #2	10/28/98	11/20/98	11/23/98		12/15/98	
Daul Processor #1	GNS #1	11/7/98	12/3/98	1/5/99	2/15/99 with RF	3/2/99	
Dual Processor #2	GNS #2	10/21/98	12/3/98	12/4/98	1/12/99	2/18/99	

3,7,8,9

Processor Hardware Residual Risk

- None
  - Processor card failure and upset rate have been evaluated and accepted

Solid State Recorder

J. F. Bogdanski

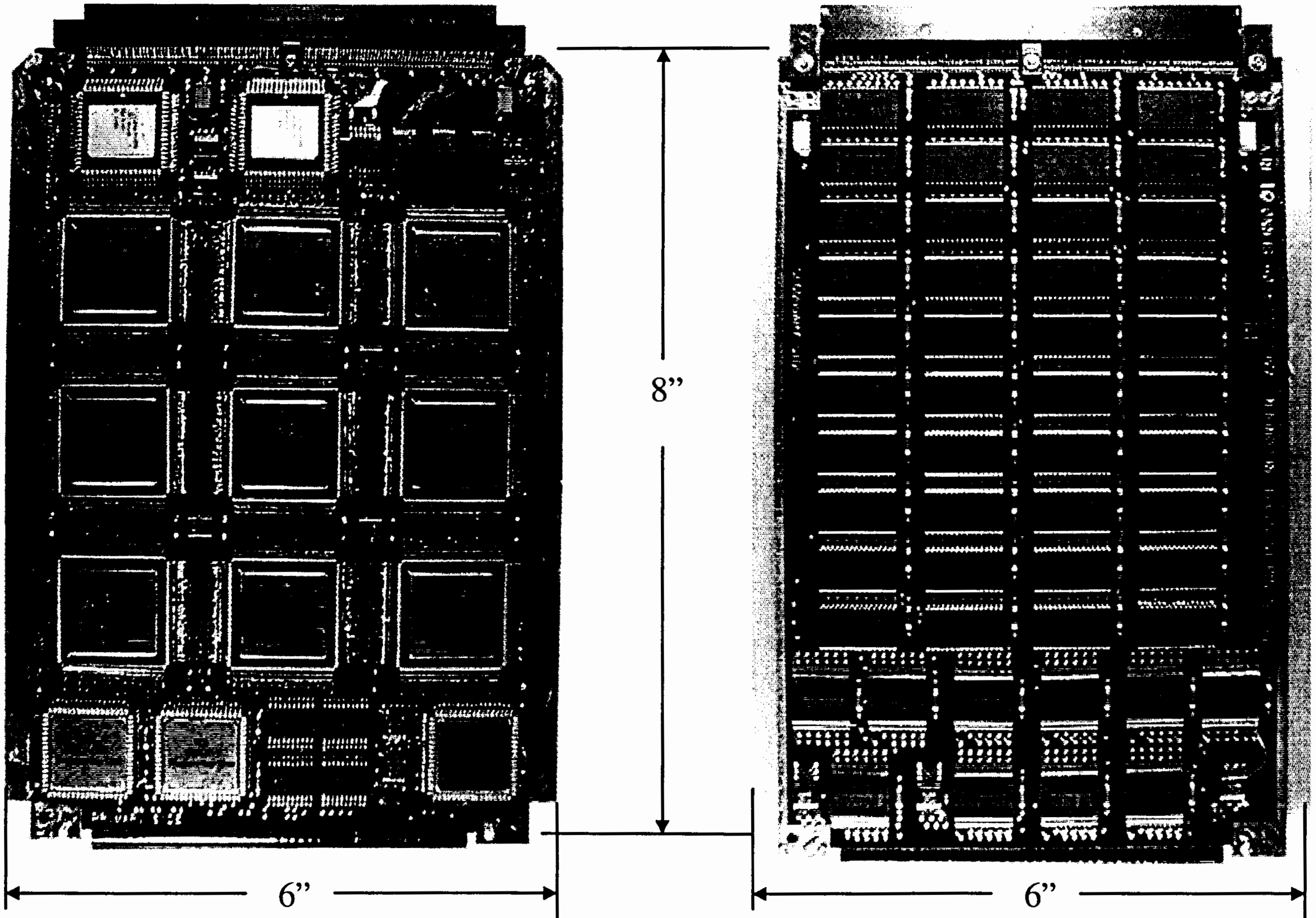
The Johns Hopkins University

Applied Physics Laboratory

11100 Johns Hopkins Road

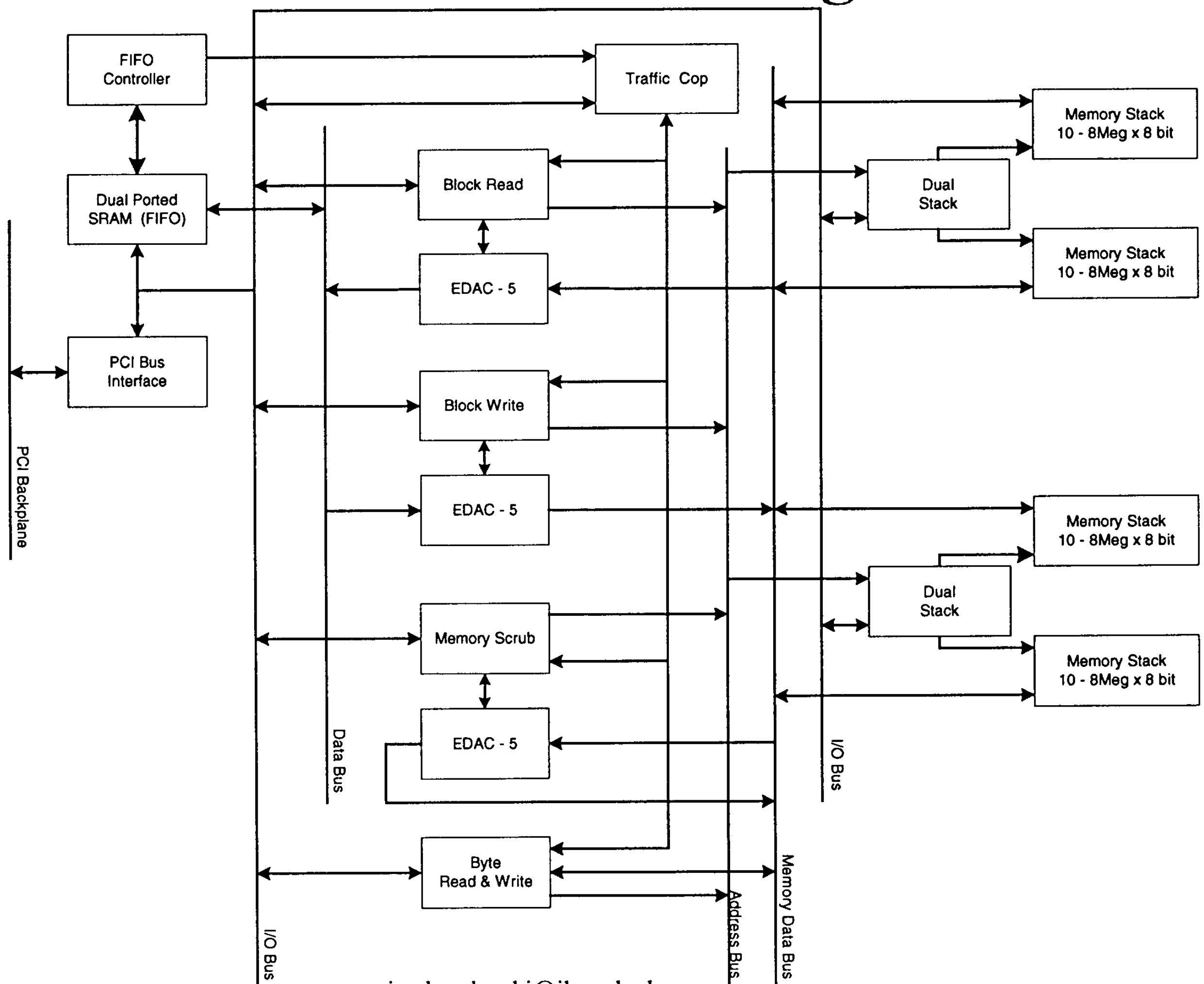
Laurel, MD 20723-6099

TIMED SSR Board



2.5 Gigabits

TIMED SSR Block Diagram



SSR Specifications

- **Requirements**
  - 1.9 Gbits User Data Space
  - Read 4Mbits/sec
  - Write 30Kbits/sec
  - Simultaneous Read/Write
  - Random Read/Write
  - Low Power Mode
  - Map Around Bad Memory
  - PCI Bus
  - Size 6"x8" effectively double sided board
  - Radiation
    - » No latchup
    - » 15krads
    - » Low probability of SSR induced data error.

- **Performance**
  - 2.5 Gbits User Data Space
  - Read 5Mbits/sec
  - Write 5Mbits/sec
  - Simultaneous Read/Write
  - Random to the block level (244 bytes/block)
  - 5.35Watts Operate, 1.1 Watts Standby
  - Read/Write Pointers can be set by Processor
  - PCI Bus
  - Size 6"x8" effectively double sided board
  - Radiation
    - » No latchup
    - » 15krads
    - » $< 10^{-8}$ errors/year in control section
    - » $< 10^{-20}$ errors/day in memory

Design Review

- **C&DH EDR held November 20, 1997.**
  - **R. F. Conde and P. D. Schwartz reviewers.**
  - **Minutes SEE-97-0204**
- **Reviewers**
  - **R. F. Conde 17 years designing flight hardware**
  - **P. D. Schwartz 25 years designing flight hardware**
- **Action item closed**
  - **EDR item #7 (memo SEE-00-0046)**
  - **EDR item #10 (memo SEE-00-0047)**
- **Other documents**
  - **TIMED SSR User Guide (memo SEE-99-0011)**
  - **Clarification of Actel A1280 Error Rates (memo SOR-5-97064)**
  - **TIMED C&DH Hardware EDR (memo SEE-97-0204)**

Q1

SSR Test Verification Matrix

Requirements	Test Type
1.9 Gbits User Data Space	S
Read > 4Mbits/sec	S
Write > 30Kbits/sec	S
Simultaneous Read/Write	S
Random Read/Write	S
Low Power Mode	S
Map Around Bad Memory	S
PCI Bus	S, D
Size 6"x8"	D, F
Radiation	D, P
Temp ESS -34°C to +90°C	E
Temp Working -15°C to +68°C	S

Tests Key

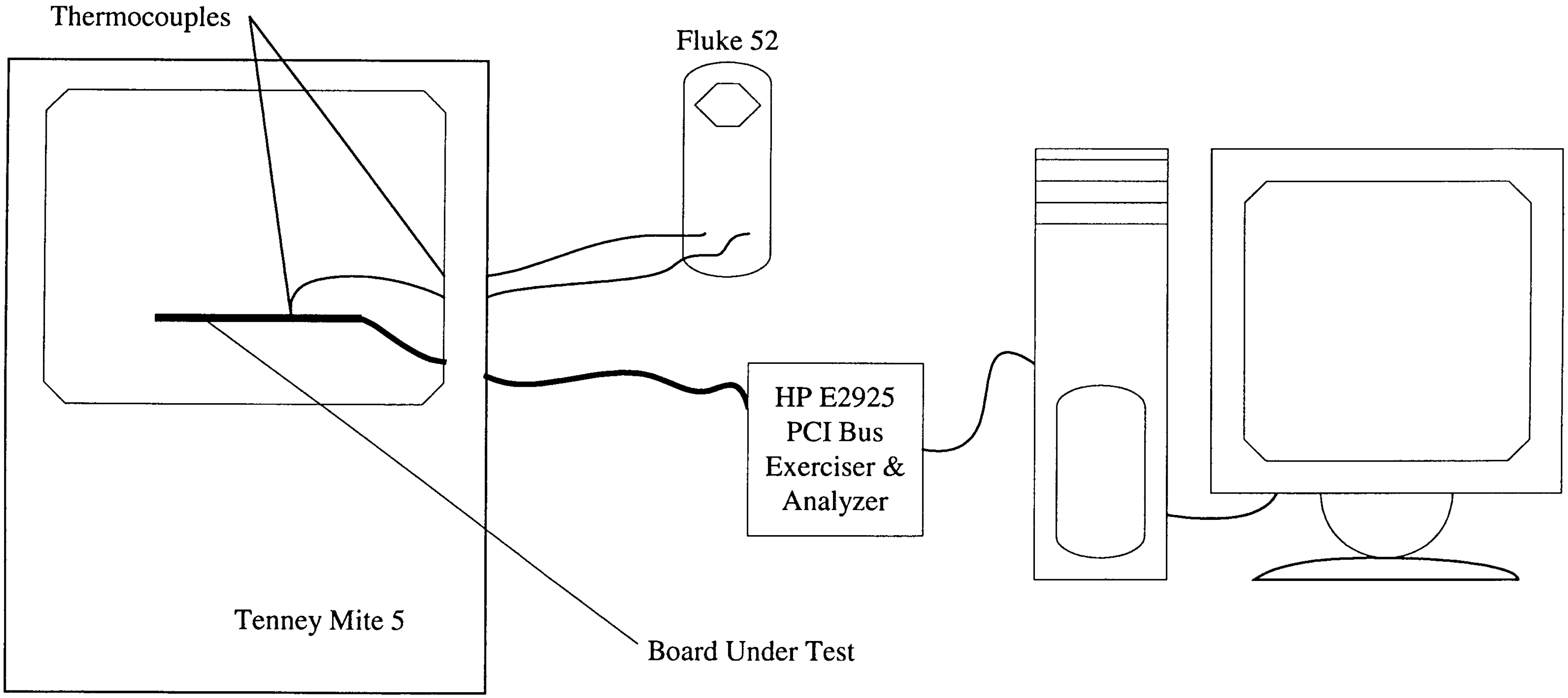
D	by Design
E	Environmental Stress Screening
F	Fit Check
P	Part Test & Screening (SOR)
S	Software Test (Bench, Base Line, Short, Full)

Q3

Margin Test

- **Engineering Model**
  - 24MHz crystal (Design Frequency)
    - » Board Test Passed
    - » Data Rate 5.35Meg-bits/sec
  - 32MHz crystal (+33% Design Frequency)
    - » Board Test Passed
    - » Data Rate 6.62Meg-bits/sec
  - 40MHz crystal (+66% Design Frequency)
    - » Board Test Failed

Thermal Test Setup



SSR Cards - Test Chronology

Test/Operation	S/N-001		S/N-002		S/N-003	
	Date	Result	Date	Result	Date	Result
1. Visual Inspection (by engineer)	12/21/98	Passed	1/12/99	Passed	1/18/99	Passed
2. Turn ON	12/23/98	In Limits	1/13/99	Passed	1/18/99	Passed
3. Bench Test (Preliminary)	12/23/98	Failed	1/13/99	Passed	1/19/99	Passed
4. Baseline Test (Room Temp.)	--------	--------	1/13/99	Passed	1/19/99	Passed
5. Rework	12/29/98	Non-Flight	--------	No Rework	--------	No Rework
6. ESS	--------	--------	1/15/99	Passed	1/20/99	Passed
7. Post ESS Baseline Test (Room Temp.)	--------	--------	1/18/99	Passed	1/22/99	Passed
8. Pre-Coat Thermal Test (1 cycle)	--------	--------	1/21/99	Passed	1/23/99	Passed
9. Conformal Coat	--------	--------	1/22/99	---------	1/24/99	---------
10. Post Coat Visual	--------	--------	2/2/99	Passed	2/4/99	Passed
11. Post Coat Turn ON	--------	--------	2/2/99	Passed	2/9/99	Passed
12. Post Coat Baseline Test (Room Temp)	--------	--------	2/2/99	Passed	2/9/99	Passed
13. Thermal Test (5 cycles) - Short SSR Test	--------	--------	2/2/99	Passed	2/10/99	Passed
14. Thermal Test (1 cycle) - Full SSR Test	--------	--------	2/3-4/99	Passed	2/11-12/99	Passed
15. Final Inspection and closeout	--------	--------	2/4/99	Passed	2/12/99	Passed
16. Delivery (IEM I&T)	--------	--------	2/8/99	Passed	2/15/99	Passed

Notes:
1. Thermal Test Range (on card): -15°C to +68°C (card powered)
2. ESS = Environmental Stress Screening: 20 cycles, -34°C to +90°C (card unpowered)
3. Short Test: Checks all controllers and spot checks memory
4. Full Test: Checks all controllers and test all memory
5. Baseline: Checks all controllers and memory boundaries
6. After extensive rework S/N-001 was declared Non-Flight. Cause of failures was reflow solder technique. This was corrected before S/N-002 and S/N-003 builds.

SSR Cards - Powered Test Hours

Test/Operation	S/N-001		S/N-002		S/N-003	
	Date	Time (Hrs)	Date	Time (Hrs)	Date	Time (Hrs)
Turn ON	12/23/98	0.5	1/13/99	0.5	1/18/99	0.25
Bench Test (Preliminary)	12/23/98	Failed	1/13/99	1	1/19/99	1
Baseline Test (Room Temp.)	---------	----------	1/13/99	7.5	1/19/99	7.5
Post ESS Baseline Test (Room Temp.)	---------	----------	1/18/99	8	1/22/99	8
Pre-Coat Thermal Test (1 cycle)	---------	----------	1/21/99	15	1/23/99	15
Post Coat Turn ON	---------	----------	2/2/99	1	2/9/99	1
Post Coat Baseline Test (Room Temp)	---------	----------	2/2/99	7.5	2/9/99	7.5
Thermal Test (5 cycles) - Short SSR Test	---------	----------	2/2/99	7.5	2/10/99	7.5
Thermal Test (1 cycle) - Full SSR Test	---------	----------	2/3-4/99	15	2/11-12/99	15
Totals (As Delivered to Space Craft)	---------	----------	2/8/99	63	2/15/99	62.75

Notes:
1. Thermal Test Range (on card): -15°C to +68°C (card powered)
2. ESS = Environmental Stress Screening: 20 cycles, -34°C to +90°C (card unpowered)
3. Short Test: Checks all controllers and spot checks memory
4. Full Test: Checks all controllers and test all memory
5. Baseline: Checks all controllers and memory boundaries
6. After extensive rework S/N-001 was declared Non-Flight. Cause of failures was reflow solder technique. This was corrected before S/N-002 and S/N-003 builds.

Q8

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SSR Residual Risk

- **To Date**
  - **None**

Integrated Electronics Module (IEM)

- **Uplink Card Critical Command Decoder (CCD)**
- **Command and Telemetry (C&T) Interface Card**

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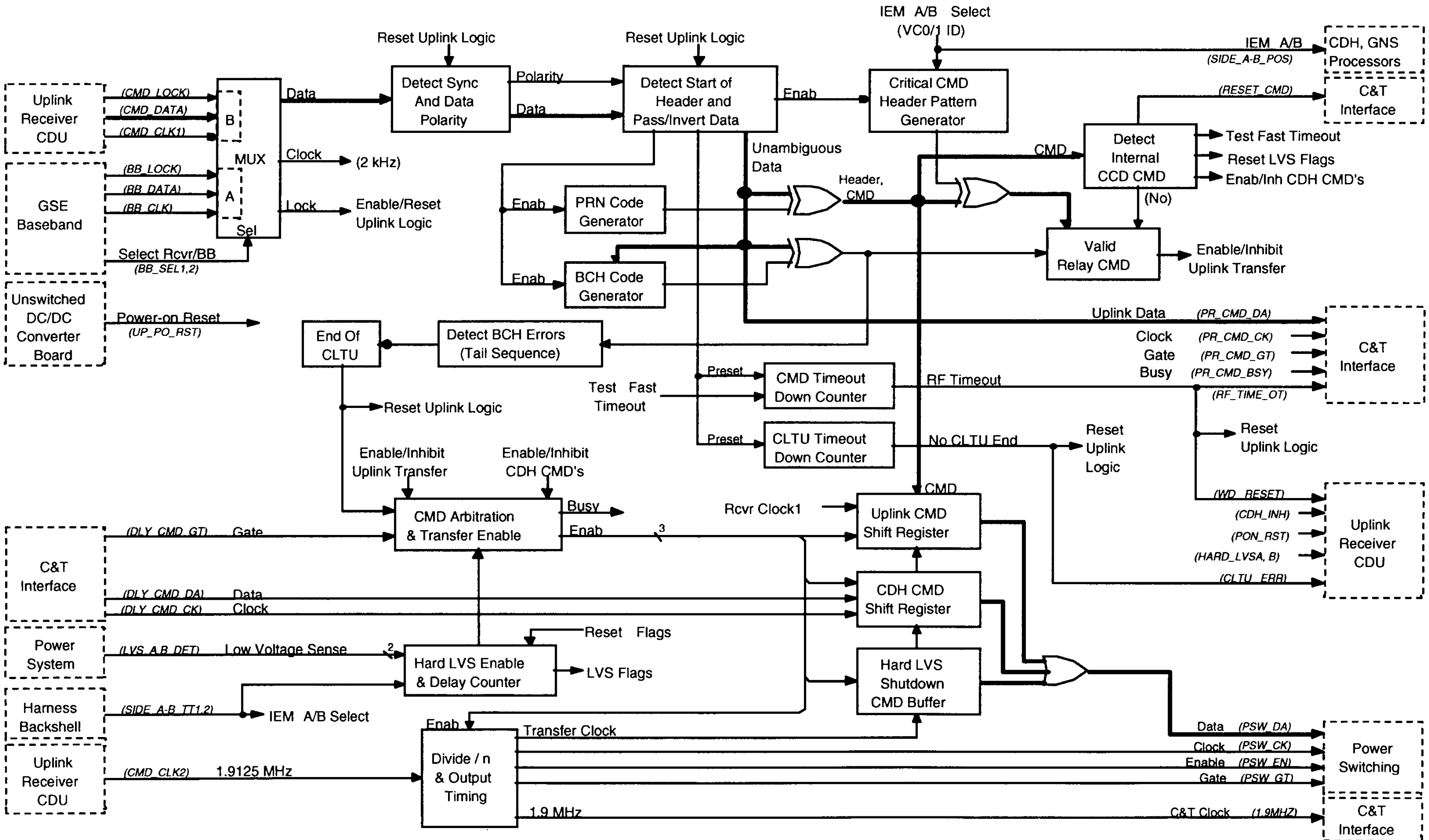
TIMED IEM UPLINK CARD

CRITICAL COMMAND DECODER (CCD) REQUIREMENTS

- **Receive CCSDS compatible commands from Uplink Receiver Command Detector Unit (CDU) or from GSE (baseband)**
- **Forward all commands to C&DH Processor via Command & Telemetry Interface card**
- **Send all uplinked, locally addressed relay commands to Power Switching Unit**
- **Decode and implement several internal CCD (non-relay) commands**
- **Send C&DH Processor-generated relay commands to Power Switching Unit; notify Processor when relay command has been sent**
- **Upon receipt of a "Hard" low bus voltage indication from the Power Subsystem, issue a stored set of relay commands for orderly load reduction; send flag(s) to C&DH Processor**
- **Perform "No commands received" timeout (RF Watchdog Timer); reset CCD and CDU digital circuits and send flag to C&DH Processor**
- **Provide stable clock to Command & Telemetry Interface card**

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics
Red Team Review 31 Oct. - 3 Nov. 2000



TIMED IEM Uplink Card Critical Command Decoder (CCD) ACTEL

IEM Uplink Card Critical Command Decoder (CCD) Design Review History & Action Item Status

1. System PDR: 18 February 1997
   - No Action Items

2. CCD PDR: 17 March 1997
   - 9 Action Items: all closed (ref. memo SEE-00-0043, 16 September 2000

3. CCD EDR (part of Uplink EDR): 15 October 1997
   - 5 Action Items: all closed (ref. E-mail, "Uplink EDR Action Items", S.F. Oden to C.C. DeBoy, 31 October 1997

4. CCD EDR (part of C&DH EDR): 20 November 1997
   - 3 Action Items: all closed (ref. memo SEE-00-0048, 20 September 2000

5. System CDR: 2-3 December 1997
   - 1 Action Item (#13), assigned to G. Dakermanji and S.F. Oden: closed (ref. E-mail, "CDR Action 13 Response", from G. Dakermanji and S.F. Oden to E.J. Hoffman, 24 February 1998

(Questions 1, 9)

IEM Uplink Card Critical Command Decoder (CCD)

Action Item Number	Brief Description of Action Item	Status	Document
1	Provide shortened version of Uplink RF watchdog timer for ground test	Closed	SEE-00-0043
2	Consider implication that CCD has no "security" or authentication capability		
3	Determine if PRN-encoded Uplink to CCD is a problem for LEO-T ground station		
4	Determine use of antenna co-ax relay tell-tale on Uplink or C&T card		
5	Determine shielding requirements for CCD relay command interface to Power Switching		
6	Provide power-on resets to Uplink and C&T wirewrap boards in breadboard IEM		
7	Review all inter-IEM signal interface lines to verify sufficient ESD protection		
9	Develop a test philosophy for integrating the CCD with the rest of the Uplink circuitry		
11	Consider changing the GSS baseband power interface to the Uplink card CCD		

Card Level PDR Action Item Summary

(Questions 1, 9)

Disposition of Problem Report Issued on the TIMED IEM Uplink Card

P/FR NO: TSC-028

P/F Date: 07/29/99

Description of problem: Occasional loss of commanding capability via RF link while locked.

Cause of problem: A design flaw in the Uplink card Critical Command Decoder (CCD) ACTEL would reverse the necessary inversion of command data if the RF/analog circuitry had locked to *inverted* data (ambiguous) *and* a non-inverted CCSDS sync pattern was detected later in the data.

Diagnosis and Correction: The error was verified in an ACTEL simulation when the above conditions were used. A simple design change insures that the polarity of the CCSDS sync pattern detected following RF lock is stored and held as long as lock is maintained. Simulation verified the effect of the correction.

Verification: The above design change was implemented by replacing the CCD ACTEL in one IEM. Spacecraft testing verified that the problem did not occur in the modified unit, but still occurred in the other IEM; the modification was then made to the second IEM. Both IEM's were re-qualified following the ACTEL replacements (workmanship vibration and thermal cycles).

(Question 7)

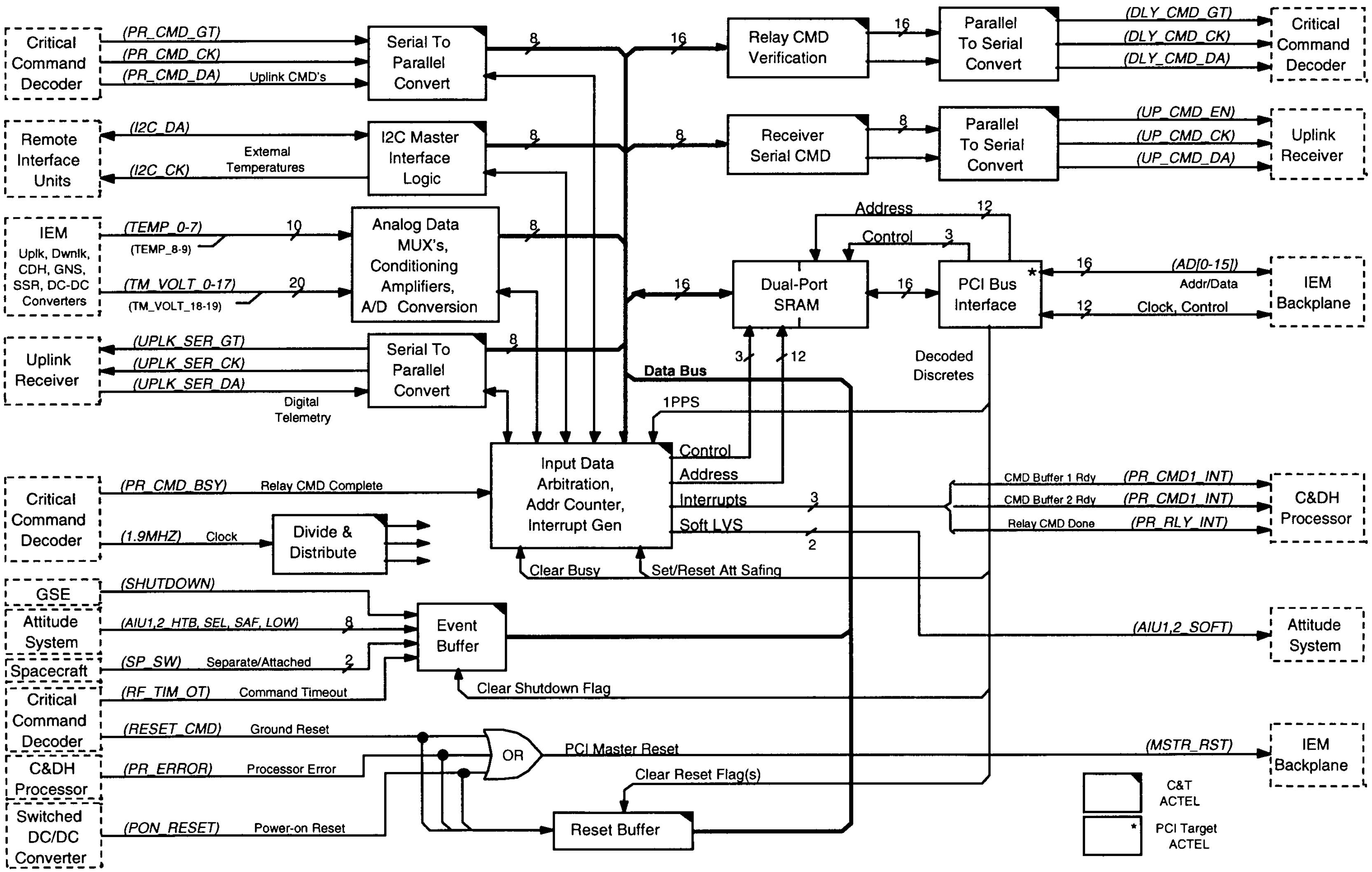
IEM Uplink Card Critical Command Decoder (CCD) Residual Risk Assessment

After a review of the CCD design, ACTEL simulations, card level testing, IEM level testing, and spacecraft system level testing, there appears to be no residual risk to its use in the TIMED mission.

TIMED IEM

COMMAND & TELEMETRY INTERFACE CARD REQUIREMENTS

- Route all uplink commands from Critical Command Decoder (CCD) to C&DH Processor
- Route all C&DH Processor-generated relay commands to Critical Command Decoder
- Collect remote temperature and voltage telemetry data via I2C serial bus
- Collect and digitize IEM temperature and voltage telemetry data
- Collect serial digital telemetry data from IEM Uplink card
- Collect and report "Events" to C&DH Processor
- Detect error conditions and generate Master Reset for IEM PCI functions



TIMED IEM Command & Telemetry (C&T) Interface Card

IEM Command and Telemetry (C&T) Interface Card Design Review History & Action Item Status

1. System PDR: 18 February 1997
   - No Action Items

2. C&T Card PDR: 17 March 1997
   - 4 Action Items: all closed (ref. memo SEE-00-00-0043, 16 September 2000)

3. C&T Card Hardware EDR (part of C&DH EDR): 20 November 1997
   - 5 Action Items: all closed (ref. memo SEE-00-0048, 20 September 2000)

4. System CDR: 2-3 December 1997
   - No Action Items

* No PFR's issued against C&T Interface Card *

(Questions 1, 7, 9)

IEM Command & Telemetry (C&T) Interface Card

Action Item Number	Brief Description of Action Item	Status	Document
6	Provide power-on resets to Uplink and C&T wirewrap boards in breadboard IEM	Closed	SEE-00-0043
7	Review all inter-IEM signal interface lines to verify sufficient ESD protection		
8	Provide means of testing the "Separation" sequence in thermal vacuum tests		
10	Make the C&T card power-on reset receiving circuit a Schmitt trigger type		

Card Level PDR Action Item Summary

(Questions 1, 9)

Flight Card	Test Description	Test Date(s)	Requirements Verified	Record of Test Results	Total Operating Time Prior to Spacecraft Integration
S/N 001	Initial Functional * (Ambient)	Nov.9-12,1998	√	Logbook, Test Data Sheets	Approx. 450 Hours (Includes IEM testing)
	ESS Screening ** (-34C to +90C)	Nov.13-16,1998		(20 unpowered cycles)	
	Pre-pot Thermal * (6 cycles -35C to +65C)	Nov.17-18,1998	√	Logbook, Test Data Sheets	
	Post-pot Thermal * (-35C to +65C)	Dec.3-4,1998	√	Logbook, Test Data Sheets	
S/N 002	Initial Functional * (Ambient)	Nov.13-16,1998	√	Logbook, Test Data Sheets	Approx. 217 Hours (Includes IEM testing)
	ESS Screening ** (-34C to +90C)	Nov.17-19,1998		(20 unpowered cycles)	
	Pre-pot Thermal * (6 cycles -35C to +65C)	Nov.20-23,1998	√	Logbook, Test Data Sheets	
	Post-pot Thermal * (-35C to +65C)	Dec.4-7,1998	√	Logbook, Test Data Sheets	

* Reference: SEE-98-0121 (C&T Card test set-up and test procedure)
SEE-98-0122 (C&T Card test results)

** Reference: SOR-98014 (Thermal cycling of TIMED boards)

IEM Command & Telemetry (C&T) Interface Card Test Summary

(Questions 3, 7, 8)

IEM Command and Telemetry (C&T) Interface Card Residual Risk Assessment

After a review of the C&T Interface card design, the C&T ACTEL design and simulations, card level testing, IEM level testing, and spacecraft system level testing, there appears to be no residual risk to its use in the TIMED mission.

Command and Data Handling Software
Red Team Review

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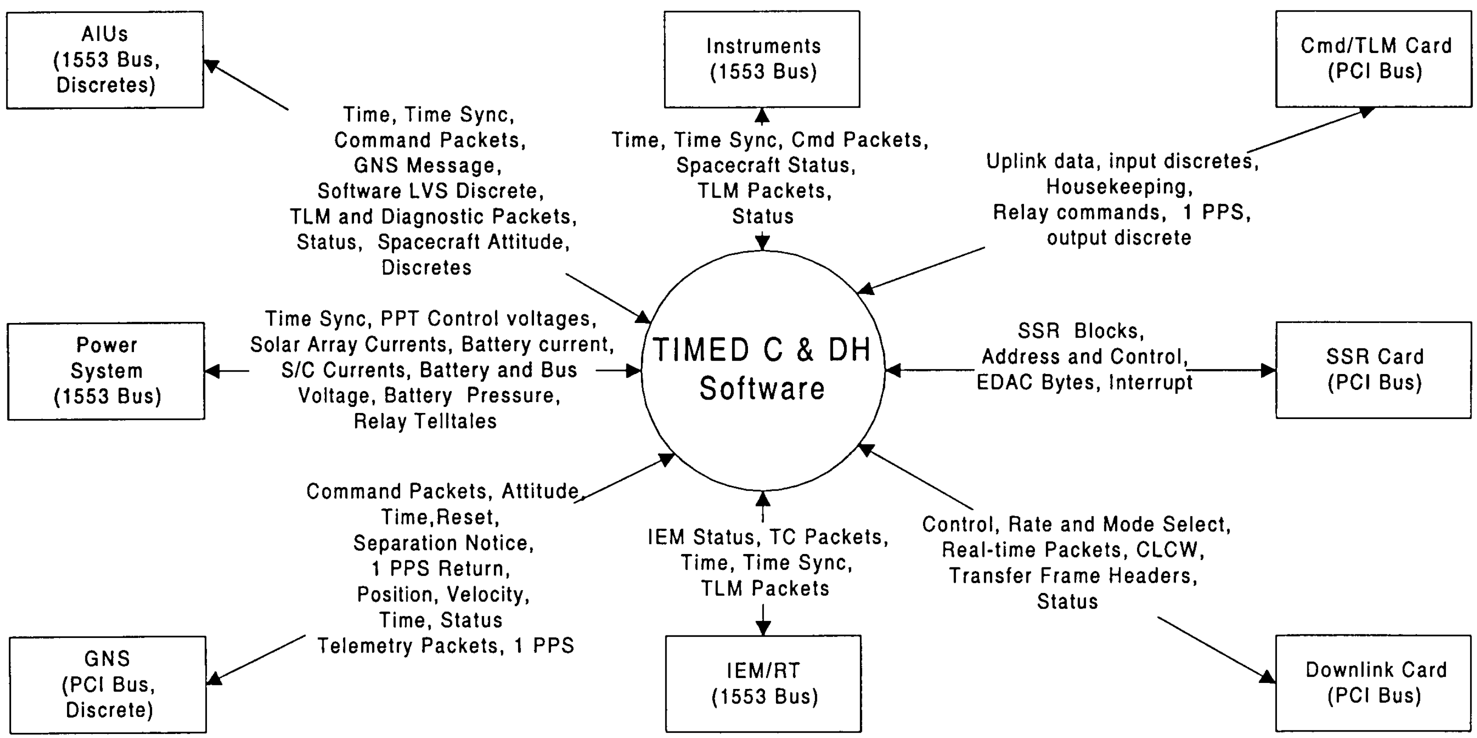
Agenda

- Software Overview
- Software Development
- High-level Reviews
- Code Walkthroughs
- Testing
- Software Problem Reports
- Residual Risk

Software Overview



Software Development - 1

(addresses review item 4)

- Software Development Plan, 7363-9000
  - version 2.0 was final version, 01/30/98
- Three deviations from this plan
- 1. No formal PCI Bus Specification was produced
  The hardware designer of the PCI bus produced ample documentation of how the bus worked. A detailed Excel spreadsheet listing all the individual transactions and all relevant information about each one was kept by the lead C & DH software engineer. The lead C & DH software engineer was the person who wrote the PCI software driver and the software to implement all of the PCI bus transactions. He is the only person who needed the information that would be contained in a formal PCI bus specification, and the spreadsheet was an excellent way to maintain this information.

Software Development - 2

(addresses review item 4)

- 2. No Detailed Design Reviews were held for Builds 2 and 3 of the software
  The software PDR and Build 1 detailed design review both contained design information for the complete design. Build 1 contained at least 50% of the software, provided the overall software structure, and supported all external interfaces. A great deal of time and effort went into the preparation for the Build 1 review. No major changes to the design occurred as a result of this review. The designs of Builds 2 and 3 were well understood by the software development team. Formal detailed design reviews for these builds would have consumed limited time that was more productively devoted to testing, and likely would not have resulted in any changes to the design.

Software Development - 3

(addresses review item 4)

- 3. No code walk-throughs were held for Builds 2 and 3
  The software might have benefited from code walk-throughs for these builds. However, due to the schedule and budget constraints, the lead C & DH software engineer decided that the time was better spent doing testing than doing code walk-throughs.

Deviation from the Mission Software Configuration Management Plan

(addresses review item 4)

- We delivered a document to the Mission Software Engineer that summarized the changes and testing of the new build. We delivered the new .s3r file to Mission Operations. We did not deliver source code, data sets, a test plan and test scripts to the Mission Software Engineer.
- We did not perform regression testing on software deliveries after Build 3.7. We relied on the C & DH baseline performance test developed by the I & T team and run on the spacecraft

High-Level Reviews - 1

(addresses review items 1, 2 and 4)

- Software Interface Design Review
  - held on 04/25/97
  - chaired by Harry Utterback, SOR Software Quality Assurance
  - no designated reviewers, but 32 attendees acted as the review board and generated 4 RFAs (SOR-97015)
  - RFAs responded to in SEE-97-094
- Software Requirements Review
  - held on 06/09/97, chaired by Harry Utterback
  - no designated reviewers, but 25 attendees acted as the review board and generated 14 RFAs (SOR-97027)
  - Software Requirements Specification JHU/APL 7363-9110
  - RFAs responded to in SEE-97-0131 and SEI-97-070

RFA Summary for Software Interface Review

(addresses review items 1, 2 and 4)

RFA Summary of C & DH Software Interfaces Review - 04/25/97		
Item #	**Brief Description**	**Closure**
1	Decouple the scanning for bad SSR blocks from the updating of the bad block maps.	SEE-97-0094.
2	Consider distinguishing between transmission errors and data content errors in 1553 data wraparound test.	SEE-97-0094.
3	Provide better accounting of telecommand packet delivery failures.	SEE-97-0094.
4	Review telemetry data volumes to see if adequate margin exists on the SSR.	SEE-97-0094.

RFA Summary of C & DH Software Requirements Review

(addresses review items 1, 2 and 4)

RFA Summary of C & DH Software Requirements Review - 06/09/97		
Item #	**Brief Description**	**Closure**
1	Minor changes to the Requirements Specification document itself	SEE-97-0131
2	Consider changes to the format of the Command Check Failure buffer.	SEE-97-0131.
3	Should future time-tagged commands be stopped if there is a failure in one of them?	SEE-97-0131.
4	Possible compatibility problems between "sticky" uplink problem reports and lights out out operation.	SEE-97-0131.
5	Does the ground need to keep memory maps of internal C & DH memory, particularly with respect to autonomy and time-tagged rules?	SEE-97-0131.
6	Application ID's listed in the requirements specification were incorrect.	SEE-97-0131.
7	Recommendation to report the most recent N entries of the packet success and packet failure buffers each second in telemetry.	SEE-97-0131.
8a	Justify elimination of the CCSDS-designated "Wait" state.	SEE-97-0131.
8b	Concerned actions taken when a time-tagged rule had a bad checksum.	SEE-97-0131.
8c	Specify actions taken to disable autonomy rules when the switch is made from bus controller to remote terminal.	SEE-97-0131
9	Have a checksum on the code.	SEE-97-0131
10	Provide a way to identify the desired initial state of an autonomy rule after a processor reset.	SEE-97-0131
11	Provide more details about actions taken when a switch from bus controller to remote terminal is made.	SEE-97-0131
12	Add information about pseudo-random telemetry output modes to the specification.	SEE-97-0131
13	Expand the data handling configuration information that is preserved through a soft reset to contain enough information to allow the automatic resumption of SSR recording.	SEE-97-0131
14	Does the specified telecommand packet timeout period satisfy the needs of Mission Operations?	SEI-97-070
15	Can a randomized code block be detected as a tail sequence?	SEE-97-0131

High-Level Reviews - 2

(addresses review items 1, 2 and 4)

- Software Preliminary Design Review
  - held on 07/25/97, chaired by Harry Utterback
  - reviewers were Brian Heggestad (FUSE flight S/W), Doug Reid (TIMED G & C S/W) and Michael White (FUSE flight S/W)
  - Software Functional Design Document - JHU/APL 7363-9113
  - 11 action items (SOR-97-033, responses in SEE-97-0197)

RFA Summary of C & DH Software PDR

(addresses review items 1, 2 and 4)

RFA Summary of C & DH Software Preliminary Design Review - 06/25/97		
Item #	**Brief Description**	**Closure**
1a	Fix miscellaneous errors in the design document.	SEE-97-0197
1b	Provide a rationale for the 4 millisecond offset between the start of a 1553 major frame in the bus controller and the sending of the time synchronization message to the C & DH/remote terminal.	SEE-97-0197
1c	Determine the threshold of bad blocks before the software declares an entire SSR memory chip to be bad.	SEE-97-0197
2	Fix miscellaneous errors in the presentation material.	SEE-97-0197
3	Is there a possibility of losing command data on the 1553 bus when there is a missing 1 PPS?	SEE-97-0197
4	Can the software evaluate time-tagged rules and arithmetic checks when the 16 Hz counter has a value of 0?	SEE-97-0197
5	Is there an advantage to having a time-out of the watchdog timer interrupt the processor instead of resetting it?	SEE-97-0197
6	Consider adding a higher level data flow diagram showing task dependencies.	SEE-97-0197
7	Consider adding to data flow diagrams control flow showing the effects of interrupts.	SEE-97-0197
8	Consider showing all external interfaces on lower level data flow diagrams.	SEE-97-0197
9	Consider adding information about downlink hardware to two of the control flow diagrams.	SEE-97-0197
10	Are there data flow diagrams for the SSR Playback, 1 Hz and 16 Hz functions?	SEE-97-0197
11	Is there any way to provide information to the instruments about loss of 1553 functions?	SEE-97-0197

High Level Reviews - 3

(addresses review items 1, 2 and 4)

- Software Detailed Design Review - Build 1
  - held on 05/20/98, chaired by Harry Utterback
  - reviewers were Walter Mitnick (TIMED Ground System S/W), David Artis (FUSE Flight S/W), Martha Chu (TIMED S/W)
  - Software Functional Design Document, 1553 Bus Specification (JHU/APL 7363-9111), C & DH Command Specification Document (JHU/APL 7363-9115)
  - no formal action items, 4 concerns (SOR-98027)
  - concerns addressed in the design, and formally in SEE-00-0049

RFA Summary of C & DH Software Detailed Design Review Build 1

(addresses review items 1, 2 and 4)

RFA Summary of C & DH Software Detailed Design Review Build 1 - 05/20/98		
Item #	**Brief Description**	**Closure**
1	What problems are presented by dynamically re-assigning task priorities, and how will this be tested?	SEE-00-0049
2	Is there enough information being collected when an autonomy rule triggers?	SEE-00-0049
3	Will the use of command macros lead to the fragmentation of the memory area where they are stored?	SEE-00-0049
4	What is the drift in the internal C & DH clock that is used when the GNS-generated 1 PPS is not present? How long can time generated by the internal clock be declared valid?	SEE-00-0049

Code Walkthroughs - 1

(addresses review items 1, 2 and 4)

- A total of nine code walkthroughs were held from 9/98 through 11/98, covering all Build 1 code and SSR code from Build 2.
- Three walk-throughs of 1553 bus controller software
  - reviewers not on the C & DH software team were Russ Redman (TIMED IEM Testbed S/W) and Paul Haring (NEAR AIU and TIMED AIU Flight S/W)
  - RFAs and their responses are in SER-98-048, SEE-98-0096 (review 1); SER-98-050 (review 2); SER-98-052 (review 3); SEE-00-0050 (all)
- One walk-through of low-level hardware functions, interrupt handlers, PCI bus driver, and the GNS interface software
  - reviewers not on the C & DH software team were Horace Malcom (TIMED GNS Flight S/W) and Rich Conde (ACE C & DH System)
  - RFAs and their responses are in SEE-98-0095

Code Walkthroughs - 2

(addresses review items 1, 2 and 4)

- One walk-through of CCSDS Uplink Processing software
  - reviewers not on the C & DH software team were PJ Clark (TIMED Ground System - Uplink software) and Mike Mitchell (TIMED Boot code)
  - RFAs and their responses are in SER-98-056, SEE-98-0099, SEE-00-0050
- Two walk-throughs of C & DH Command Processing software
  - reviewers not on the C & DH flight software team were Rich Conde and Michael White (FUSE Flight S/W)
  - RFAs and their responses are in SER-98-058, SER-98-061 and SEE-98-0104 (review 1); SER-98-059 and SEE-98-0112

Code Walkthroughs - 3

(addresses review items 1, 2 and 4)

- Two walk-throughs of Downlink, Memory Dump and Solid-state Recorder software
  - reviewers not of the C & DH software team for the first review were Rich Conde and Michael White, with no external reviewers for the second review.
  -RFAs and responses to both reviews are in SEE-98-0115 and SEE-00-0050.

Testing - 1

(addresses review item 3)

- Testing Environment

  - Hardware platform for most testing was the IEM breadboard, and occasionally the IEM Engineering Model

  - Crossview debugger hooked to Mongoose serial port for low-level testing.

  - logic analyzer support for processor, PCI bus

  - 1553 bus analyzer

  - High-level testing used the IEM testbed, mini-MOC, and front end.

  - IEM testbed simulated all external interfaces, allowed sending of bad commands, could be configured as bus controller or remote terminal, could simulate non-responsive 1553 remote terminals, could generate specific data under user control, generated and reported its own telemetry.

Testing - 2

(addresses review item 3)

- Primary testing was performed by individual not on the C & DH flight software team (John Hueber)
  - generated Software IV & V Test Plan, JHU/APL 7363-9114
  - produced three documents describing the tests for each software build and the requirements tested by each test, and a matrix relating requirements and tests
  - produced many tests attempting to "break" the software
- Additional tests developed by a developer of the IEM testbed software (Russ Redman)
  - provided better testing of SSR, some aspects of 1553 operation, and C & DH as a remote terminal. Tests summarized in SEE-00-0041.

Testing - 3

(addresses review item 3)

- Complete suite of tests was run by the C & DH software lead before the delivery of Build 3.7, which was the "final" delivery and implemented all software features. Results summarized in SRS-99-113.
- For subsequent deliveries, this suite of tests was not run. Reasons included schedule pressures, the small scale of the changes that were made, the presence of "false positive" errors in a number of the tests, and the existence of a good baseline test developed by the I & T team. Testing by the software team verified the changes had the desired effect, and basic functionality (commands, telemetry, 1553 activity).
- Software "stress" tests developed and run by Russ Redman on Build 3.10. Results summarized in SEE-00-0041.

Testing - 4

(addresses review item 3)

- We were dependent on spacecraft testing and other individuals to verify certain aspects of the software.
  - Peak power tracking software operation was verified by power system engineers
  - Operation of C & DH as a remote terminal and interaction between the two C & DH processors is best tested at a spacecraft level.
  - The interface between the GNS and C & DH processors is best tested at a spacecraft level.
  - Although John Hueber and the autonomy software developer tested autonomy software, the best testing has been done by the Autonomy System Engineer.

Software Problem Reports

(addresses review items 7 and 9)

- All Software Problem Reports relating to the C & DH software have been answered.
- Where SPRs indicated a software bug, either a new software load has been made that fixes the bug or a conscious choice has been made not to fix the bug.

C & DH SPRs - 1

(addresses review items 7 and 9)

SPR No.	System	Version	Summary	Action	Status	Date
17	C&DH		Transfer frames drop out	not a software bug	Closed	12/02/98
18	C&DH	C&DH 1.4	Drop out of Transfer frames	not a software bug	Closed	12/02/98
19	C&DH		Command rejection: bad BCH code	not a software bug	Closed	12/02/98
27	C&DH		Soft reset telltale not set	fixed in later release	Closed	12/03/98
29	C&DH	C&DH 1.5	Charge/discharge command rejected	fixed in later release	Closed	12/03/98
30	C&DH		GNS reset command causes Coulometer reset	fixed in later release	Closed	12/03/98
31	C&DH	C&DH 1.5	Transfer frames that are too long causes exception	fixed in later release	Closed	12/03/98
32	C&DH	C&DH 1.5	GNS message to AIU too long	fixed in later release	Closed	12/03/98
33	C&DH	C&DH 1.5	Aggregation reporting of packets in error		Closed	12/03/98
37	C&DH	C&DH 1.5	C & DH lost track of packet histories	fixed in later release	Closed	12/07/98
34	C&DH	C&DH 1.5	Ping-pong transfers out of sync	fixed in later release	Closed	12/03/98
44	C&DH		Missing telemetry point	fixed in later release	Closed	12/10/98
49	C&DH	C&DH 1.5	Retransmit flag not set	fixed in later release	Closed	12/14/98
67	C&DH	Unknown	Add figures of merit to C&DH-to-AIU GNS message	fixed in later release	Closed	02/24/99
68	C&DH	C&DH 2.5	Not wrapping around SSR	fixed in later release	Closed	03/03/99
75	C&DH	C&DH 2.5	GNS position and velocity data same in TLM	fixed in later release	Closed	03/12/99
62	C&DH	C&DH 2.5	No status msg on 1553 B	fixed in later release	Closed	02/05/99
63	C&DH		C2_1553_RET_FLR incrementing in error	fixed in later release	Closed	02/05/99
64	C&DH	C&DH 2.3	Invalid Telemetry Packets during GUVI fit check	fixed in later release	Closed	02/17/99

C & DH SPRs - 2

(addresses review items 7 and 9)

122	C&DH	C&DH 3.2	Total Command Count increments by 2 instead of 1	fixed in later release	Closed	05/24/99
127	C&DH	C&DH 3.2	C&DH needs to invert NO_BIT_LOCK value in CLCW	fixed in later release	Closed	05/28/99
186	C&DH	C&DH 3.7	Telemetry off; BC C&DH was processing	not a software bug	Closed	08/10/99
172	C&DH	C&DH 3.5	Word 532 not sent correctly to BC from RT	fixed in later release	Closed	07/25/99
188	C&DH	C&DH 3.5	Loading C&DH application version 3.5	never observed again	Closed	08/10/99
206	C&DH	C&DH 3.7	S/C C&DH and GNS interface on time output	fixed in Build 3.9	Closed	08/24/99
212	C&DH	C&DH 3.8	G&C RAM direction bit failed to toggle	fixed in Build 3.9	Closed	09/03/99
237	C&DH	C&DH 3.8	Watchdog reset was observed	not a software bug	Closed	09/13/99
251	C&DH	C&DH 3.7	Peak Power Tracking needs to be tested	additional testing	Closed	09/24/99
252	C&DH	C&DH 3.7	Telecommand Packet load command needs to be tested	additional testing	Closed	09/24/99
253	C&DH	C&DH 3.7	Test the C&DH as a remote terminal on the 1553 bus	additional testing	Closed	09/24/99
254	C&DH	C&DH 3.7	Test GNS and C&DH interface	additional testing	Closed	09/24/99
255	C&DH	C&DH 3.7	Test SSR continue writing after soft reset	additional testing	Closed	09/24/99
256	C&DH	C&DH 3.7	Stress test on C&DH	additional testing	Closed	09/24/99
268	C&DH	C&DH 3.8	Delay after power-down warning	not a software bug	Closed	10/05/99
272	C&DH	C&DH 3.9	Autonomy rule clear fire count command	fixed in Build 3.10	Closed	10/12/99
337	C&DH	C&DH 3.10	CDH1 got packet delivery failure from CDH2	fixed in Build 3.11	Closed	11/24/99

C & DH SPRs - 3

(addresses review items 7 and 9)

340	C&DH	C&DH 3.10	Software swaps two TLM points	fixed in Build 3.11	Closed	12/02/99
352	C&DH	C&DH 3.11	Autonomy current fire cnt exceeded max. fire cnt for Rule 303	not fixed	Closed	12/13/99
356	C&DH	C&DH 3.11	Out of sequence packets being received	not a software bug	Closed	12/20/99
383	C&DH	C&DH 3.11	Noticed 1553 errors during a commanding problem	not a software bug	Closed	01/19/00
331	C&DH	C&DH 3.8	1553 retry failures occurred on both IEM Sides 1&2	not a software bug	Closed	11/07/99
332	C&DH	C&DH 3.8	Abort cmd is to get executed before any no-ops	fixed in Build 3.10	Closed	11/07/99
530	C&DH	C&DH 3_11b	Watchdog timer reset	fixed in Build 3.11c	released	09/18/00
540	C&DH	C&DH 3.11	AIU #2 Stopped outputting packets to C&DH 1553 bus	fixed in Build 3.11b	Closed	09/20/00

Recent Software Deliveries

(addresses review items 7 and 9)

- Build 3.8, on 09/07/99. Documented in SRS-99-147. Fixed PFR TSC-039, 044 and SPR 237.
- Build 3.9, on 10/05/99. SRS-99-176. Fixed SPRs 206 and 212. Changed the implementation of the Autonomy Rule Fire Count Clear as requested by the Autonomy Engineer.
- Build 3.10, on 11/04/99. SRS-99-195. Fixed PFR TSC-070, SPRs 272 and 332.
- Build 3.11, on 12/03/99. SRS-99-209. Fixed SPRs 337, 340.
- Build 3.11b, on 08/17/00. SRS-00-132. Fixed SPR 540.
- Build 3.11c, on 10/03/00. SRS-00-173. Fixed SPR 530.

Residual Risk

(addresses review item 13)

- Risk is that there are software bugs that have not been found during testing to this point.
- The amount of testing that the software has received on the spacecraft and in the lab provide confidence that any such bugs will be minor.
- New software can be loaded to the spacecraft to correct any bugs deemed major enough to require correction.
- Evidence from testing shows that the robust nature of the software watchdog timer means that the software is very good at detecting its own faults.

Common Boot Software

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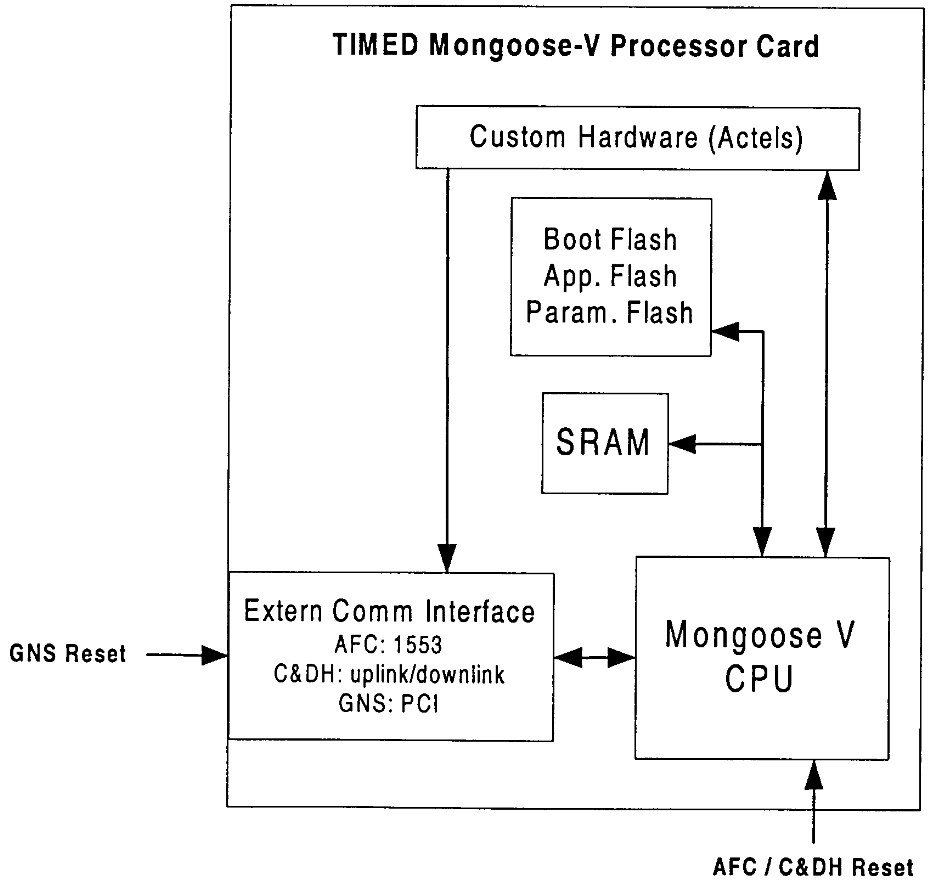
Agenda

- Acronym List
- Common Boot Simplified Hardware Block Diagram
- Common Boot Requirements Overview
- Common Boot Design Overview
- Common Boot Statistics
- Common Boot Development Overview (review criterion 4)
- Summary of Documentation (review criterion 4)
- Summary of Reviews and Action Items (review criteria 1, 4, 9)
- Summary of Test, Verification, and Validation (review criteria 3, 4, 7)
- Summary of Software Deliveries (review criterion 8)
- Summary of Configuration Management (review criterion 4)
- Summary of Boot Archive
- Residual Risk (review criterion 8)
- Review Action Items and Attendees (review criteria 1, 4, 9)
- Software Problem Reports (review criteria 4, 7)

Acronym List

AFC	Attitude Flight Computer
AIU	Attitude Interface Unit
ACTEL	ACTEL-FPGA
BBC	Boot Block Cell
BIT	Built In Test
CCB	Change Control Board
CCSDS	Consultative Committee for Space Data Systems
CD	Compact Disk
CDR	Critical Design Review
C&DH	Command & Data Handling
CI	Command Interpreter
CPU	Central Processing Unit
CUC	CCSDS Unsegmented Time Code
EDAC	Error Detection and Correction
FPGA	Field Programmable Gate Array
GNS	GPS Navigation System
GPS	Global Positioning System
HW	Hardware
Hz	Hertz
I&T	Integration & Test
ICD	Interface Control Document
IEM	Integrated Electronics Module
ISR	Interrupt Service Routine
JHU/APL	Johns Hopkins University Applied Physics Laboratory
Kbyte	Kilobyte
Mbyte	Megabyte
MKS	Morton Kern Systems, Inc.
MOPS	Mission Operations
PCI	Peripheral Component Interconnect
OFP	Operational Flight Program (Application Image)
PDR	Preliminary Design Review
PMON	PROM Monitor
PROM	Programmable Read Only Memory
RAM	Random Access Memory
S/C	Spacecraft
SPD	Software Preliminary Design Document
SPR	Software Problem Report
SQA	Software Quality Assurance
SRAM	Static RAM
SRR	Software Requirements Review
SRS	Software Requirements Specification
SW	Software

Common Boot Simplified Hardware Block Diagram



Common Boot Software Functional Requirements Overview

- Support AFC, C&DH, and GNS subsystems / Mongoose-V processor
- Activated on processor reset
- Initialize EDAC, perform Built In Tests on SRAM, scrub SRAM
- Load Application Program from Flash to SRAM and jump to Application Program (based on Boot configuration parameters in Flash); supports enabling HW watchdog prior to jump to Application
- Detect, report, and act on Boot failures
- Determine reason for reset
- Support loading Application Programs and data to Flash
- Accept commands to control Boot configuration, loading, dumping, and soft resets
- Provide telemetry including Boot status and memory dump

Common Boot Software Design Overview (1 of 2)

- Resides in Flash segment 0 which is read-only post-launch
- Initially executes from Flash then copies portion of code to SRAM and jumps there to allow Flash programming and faster execution
- Identical code for all three subsystems senses subsystem identity via Actel
- Uses redundant Boot configuration parameters stored in Flash segments 1 and 2
- Supports external communications interface specific to each subsystem to receive commands and provide telemetry:
  - 1553 bus for AFC
  - uplink / downlink hardware for C&DH
  - PCI bus for GNS

Common Boot Software Design Overview (2 of 2)

- Initializes Mongoose and external communications interface to support Boot operations, performs BIT, loads Application
- Waits 10-20 seconds for "Stay In Boot" command
- Provides Boot status telemetry while waiting
- Normally jumps to Application if "Stay In Boot" not received
- Provides reset reason to Application, may enable HW watchdog prior to jumping to Application
- Accepts other commands if "Stay In Boot" received, does memory scrub

Common Boot Statistics

- Lines of Code:
  - 11,000 C / Assembly Statements
  - 22,000 comment lines
- Size of Executable:
  - 243.4 Kbytes
- SRAM Usage:
  - 632 Kbytes (Boot code, data and buffers, exception vectors)
  - up to 1.416 Mbytes for Application
- Interrupt Rate:
  - 32 Hz for C&DH, 10 Hz for AFC, 1 Hz for GNS
- SRAM Scrub Rate:
  - 2 Mbytes / 32 sec
- Boot Time:
  - ~ 40 seconds includes 20 second delay waiting for "stay in boot" command

Common Boot Development Overview

- Per TIMED Software Quality Assurance (SQA) Plan, JHU/APL 7363-9101
- AFC Boot development evolved into Common Boot development
- Common Boot Software is considered Mission Critical
- SQA Plan covers software requirements, design, coding, testing, delivery, and maintenance
- SQA Plan identifies required documentation, software reviews, test and verification, and configuration management

Common Boot Software Documentation (1 of 2)

- Development Plan:
  - TIMED Software Quality Assurance (SQA) Plan, JHU/APL 7363-9101
- Operational Concept:
  - information provided in design documentation
- Requirements:
  - TIMED Boot Program Software Requirements Specification Document, JHU/APL 7363-9354, Rev-0-1
- Top Level Design:
  - TIMED Boot Program Software Preliminary Design Document, JHU/APL 7363-9358, initial release
- Detailed Design and Interface Control:
  - TIMED Boot Program Software Detailed Design / Interface Control Document, JHU/APL 7363-9358, Rev-0-4

Common Boot Software Documentation (2 of 2)

- Requirements Matrix:
  - for flowdown to design / code in JHU/APL 7363-9358
  - TIMED Common Boot Program Requirements Verification Matrix, SRS-00-159
- Test:
  - TIMED Boot Program Unit Test Completion Report, SRS-00-160
  - TIMED Boot Program Command and Telemetry Processing Unit / Integration Test Document, JHU/APL 7363-9351, Rev-0-A
  - TIMED Boot Software Version 0.7 Regression Testing, SRS-99-204
- Operations Guide:
  - information in design document, e-mails to MOPS, no formal document
- Version Description and Maintenance Manual:
  - TIMED Common Boot Program Version Description Document, JHU/APL 7363-9394, Boot Version 0.7
- Configuration Management
  - TIMED Boot Software Archive Description, SRS-99-207

Common Boot Review Summary (1 of 2)

Review	Date	Action Items	Responses	Status
SRR*	10/30/97	SOR-97-053	SRS-97-136 SEI-97-117	13 items / all closed; 11 adopted / 2 not adopted
S/C CDR*	12/4/97	None	N/A	N/A
SRR / SW PDR*	4/6/98	SOR-98-018	SRS-98-034	20 items / all closed; 18 adopted / 2 not adopted
SW CDR*	6/12/98	SOR-98-030	SRS-00-151	8 items / all closed; 7 adopted / 1 not adopted

* Independent Reviewers

Review Criterion: 1, 4, 9

Common Boot Review Summary (2 of 2)

Review	Date	Action Items	Responses	Status
Code Walkthroughs* reviewers from AFC, C&DH, GNS subsystems	7/30/98 8/4/98 8/6/98 8/11/98 9/4/98 9/8/98 9/11/98 10/30/98	SRS-00-161	SRS-00-161	all bugs found were fixed (a small number); numerous items related to style or clarity closed
Post Software Delivery Review*	9/27/99	None	N/A	N/A
Post Environmental Review*	2/22/00	None	N/A	N/A

* Independent Reviewers

Review Criteria: 1, 4, 9

Common Boot Test and Verification

- Unit / Integration Testing
  - complete unit / integration testing performed
  - record of unit testing documented in APL memo SRS-00-160
  - documented tests, procedures, expected results, date of tests, and results for unit / integration testing of all Common Boot commands and telemetry
- Acceptance / Regression Testing
  - archived acceptance / regression test scripts
  - documented procedures, date of tests, and results in SRS-99-204
  - used on Boot Versions 0.6 and 0.7

Common Boot Verification and Validation

- Verification
  - all requirements verified by combination of unit, build, and acceptance / regression tests, documented in APL memo SRS-00-159
- Independent Verification
  - requirements and design verified by independent reviewers
- Independent Validation
  - Independent regression testing
  - MOPS demonstrated ability to load new application program and exercise Boot on all subsystems supported by Common Boot on each delivery of Common Boot or Application

Common Boot Software Deliveries

Common Boot Version	Delivery Date	SPRs Addressed
Flat Boot	10/98, 1/99	Initial Boot development version; SPR 28: change Boot to use caching
BOOT 0.1	4/19/99	Initial Boot flight version
BOOT 0.2	5/17/99	SPR 118: add support for parameter loading
BOOT 0.3	5/27/99	No SPRs addressed; modifications to Boot initialization
BOOT 0.4	6/22/99	SPRs 128, 141, 145: adjustments to C&DH downlink and AFC 1553 interfaces, initial
BOOT 0.5	6/23/99	SPRs 128, 141, 145: same as above, final
BOOT 0.6	7/21/99	SPRs 168, 169, 171: checksum recording, scrub disabling, soft reset counting
BOOT 0.7	9/7/99	SPR 217: race condition in GNS 1553 initialization plus several issues documented in TIMED Boot Software Version 0.6 Problems Investigation, SRS-099-169

Common Boot Configuration Management

- Per TIMED Mission Software Configuration Management Plan, JHU/APL 7363-9670
- Applied to Common Boot software and key documents
- E-mail and written change proposals, evaluation, and approval pre-I&T
- SPRs, written change proposals, evaluation, and CCB approval during I&T and beyond
- MKS Source Integrity for version control
- Software deliveries via online Common Boot archive and CD; include Version Description Document
- Regression testing for software changes
- Backup / restore capability for all software
- All SPRs closed or have work-around plan
- Documents supplied to TIMED Library

Common Boot Archive Summary

- Archive Resides on APL Space Department UNIX System:
  - MOPS Delivery Archive
    - executables and tools needed to load Boot on S/C
  - Boot Document Archive
    - archive document, flash procedures, design, requirements,
    - unit test, verification matrix
  - Flat Boot Archive
    - form of Boot used in early application development
  - Flight Boot Archive
    - complete source for flight Boot
  - PMON Archive
    - console Boot used in development only
  - Boot Test Archive
    - regression and other test scripts
  - Boot Tools Archive
    - tools supporting Boot build, disassembly, load, etc.

Common Boot Software Residual Risk

- Residual Risk is LOW
  - Common Boot has been thoroughly tested and verified
  - Boot 0.7 has been in use over one full year running on three subsystems on S/C with no problems (failure free run time, ~600 nominal reboots for C&DH / GNS, ~200 nominal reboots for AFC, 8-12 application loads per subsystem)
  - All known software problems or bugs have been identified in SPRs (13 total) , evaluated, and fixed (9) or work-arounds provided (4)
  - Significant portions of Boot code taken from application code development - the shared design / implementation has been verified in application as well as Boot
  - TIMED SQA and Configuration Management Plans followed for Common Boot development

Common Boot Software Requirements Review
Action Item Summary (1 of 3)

AI #	Description	Status	Response
1	Should EDAC on SRAM be disabled during RAM tests and then enabled?	Closed / Adopted	Yes. Also, EDAC always enabled when executing out of RAM. See also SW CDR action item #8.
2	Consider using walking 1's test and walking 0's test for writing to memory in SRAM tests instead of specified tests.	Closed / Not Adopted	Decided not to use walking 1's and 0's tests. Changed data pattern 0xAAAA.5555 to 0xA5C3.E169.
3	An ICD is needed to define actions needed for MOPS to prepare uploads, initiate program execution, System Boot Block Cell Management, etc.	Closed / Adopted	MOPS agrees to generate a "TIMED Processor Load and Dump Detailed Design Document" to address this item.
4	Clarify when 10 second Boot delay period occurs so that "Stay In Boot" command can be properly timed.	Closed / Adopted	Clarification added to requirements document.

Common Boot Software Requirements Review
Action Item Summary (2 of 3)

AI #	Description	Status	Response
5	Relocate a sentence in requirements document.	Closed / Adopted	Done.
6	State command checksum size.	Closed / Adopted	Command checksum size is 16-bits.
7	Clarify action taken for unused cells when copying a Flash segment to the SRAM buffer.	Closed / Not Adopted	This is considered a design issue.
8	Assess impact of the Boot rejecting dump commands when a dump is already in progress.	Closed / Adopted	MOPS indicates this is the desired and expected approach.
9	Access the adequacy of the Parameter Block Dump commands.	Closed / Adopted	The Mongoose V processor boards will support separate enabling/disabling of EDAC for Flash and SRAM. Therefore, the Boot can dump parameter block flash segments using the physical memory dump command.

Common Boot Software Requirements Review Action Item Summary (3 of 3)

AI #	Description	Status	Response
10	Determine method to initiate soft reset.	Closed / Adopted	This command shall support resetting the processor by accessing the soft reset discrete or via the watchdog. Note: the requirement was later changed to eliminate the watchdog option.
11	Suggest moving Boot Block Cell design information to an appendix.	Closed / Adopted	Moved to design document.
12	Clarify details of requirements for telemetry.	Closed / Adopted	Done.
13	Fix minor typos and other errata.	Closed / Adopted	Done.

Common Boot Software Preliminary Design Review Summary (1 of 4)

AI #	Description	Status	Response
SRS 1	Add definition of ACTELS to requirements document.	Closed / Adopted	ACTEL is the name of the company that manufactures Field Programmable Gate Arrays (FPGA). Added both to acronmy list.
SRS 2	Increase Boot delay to 20 seconds to be sure "Stay In Boot" command delivery.	Closed / Adopted	Interval made a Boot Block Cell parameter which can range between 10 and 20 seconds.
SRS 3	State what will happen if the ground attempts to erase Flash segment 0.	Closed / Adopted	The Boot will reject the command.
SRS 4	Restate motivation for Dump Abort command.	Closed / Adopted	It is a convenient way to correct an operator error.
SRS 5	Duplicate requirements.	Closed / Adopted	Removed duplicate requirements.
SRS 6	Duplicate requirements	Closed / Adopted	Removed duplicate requirements.

Common Boot Software Preliminary Design Review Summary (2 of 4)

AI #	Description	Status	Response
SPD 1	Add definition of ACTELS to preliminary design document.	Closed / Adopted	ACTEL is the name of the company that manufactures Field Programmable Gate Arrays (FPGA). Added both to acronym list.
SPD 2	Typo	Closed / Adopted	Fixed.
SPD 3	Consider simplifying action to take on failure of RAM tests.	Closed / Not Adopted	Considered suggestion. Decided to keep flexibility in design.
SPD 4	Update encoding of reset information.	Closed / Adopted	Done.
SPD 5	Clarify location of command interpreter portion of Boot code at run time.	Closed / Adopted	Command Interpreter will be located and run from Flash with the rest of the Boot. The code to implement the Flash erase and write must be copied to and executed from SRAM by the Boot before programming Flash. Note: A later change was to copy the entire command interpreter function of the Boot to SRAM and execute from there.

Common Boot Software Preliminary Design Review Summary (3 of 4)

AI #	Description	Status	Response
SPD 6	Suggest MOPS fill incomplete program cells with pad value.	Closed / Adopted	MOPS agrees to use 0-fill for incomplete program cells.
SPD 7	Delete reference to "active FC"	Closed / Adopted	Table containing reference is AFC specific. Removed from Common Boot description.
SPD 8	Do not reference C&DH command documentation for descriptions of Boot commands.	Closed / Adopted	Boot commands will be described in Boot design documentation.
SPD 9	Memory dump packet is missing a word count.	Closed / Adopted	Add word count to memory dump packet.

Common Boot Software Preliminary Design Review Summary (4 of 4)

AI #	Description	Status	Response
SPD 10	How can the following be avoided in the Boot: an endless cycle of resets if the Boot reads an unitialized location in Flash which can cause a double-bit EDAC error / processor reset.	Closed / Adopted	Response indicates that the hardware automatic reset on double-bit error will be disabled to handle this (done by Reset Actel). Note: Furthermore, the Boot initializes EDAC for all of SRAM prior to enabling EDAC interrupts. These steps prevent the problem.
SPD 11	Consider a "lost contact" time-out after the boot program 'stay' has been issued. Go to application if all else OK.	Closed / Not Adopted	Determined that if Boot commanded to wait in command interpreter it should do so. Suggestion not implemented.
SPD 12	Specify word-boundaries for Flash access.	Closed / Adopted	Specified 32-bit word boundaries for dumping memory including Flash.
SPD 13	Identify subsystem specific Boot requirements for C&DH and GNS.	Closed / Adopted	It was determined that there were no subsystem specific Boot requirements for the C&DH or GNS.

Common Boot Software Critical Design Review Summary (1 of 2)

AI #	Description	Status	Response
1	Fix errata. Determine differences in hard and soft SRAM tests.	Closed / Adopted	There is no difference in the tests performed except for the following: different memory ranges can be specified in the Boot Block Cell for hard and soft SRAM tests.
2	Provide a means to trigger all software interrupt service routines. Recommend adding Boot command to do so.	Closed / Not Adopted	Boot interrupt service routines were tested during software development. Post-development their functioning can be inferred from indicators in the telemetry and the correct functioning of higher level commandable functions. Suggestion not implemented.
3	Determine length of time interrupts disabled in Flash programming and impact on Boot operation.	Closed / Adopted	Interrupts are off no longer than 20 micro-seconds at a time. This will not lengthen with aging of the Flash and does not interfere with Boot operations.
4	Confirm whether CUC time is available to use in tagging rejected commands.	Closed / Adopted	Boot telemetry and rejected command time tags are: CUC for the AFC subsystem, and an internal count of seconds since the last reset for the C&DH and GNS subsystems.

Common Boot Software Critical Design Review Summary (2 of 2)

AI #	Description	Status	Response
5	Determine if all commands except the "Stay In Boot" are to be rejected during the Boot idle period.	Closed / Adopted	Yes, they are.
6	Determine the need for the Boot to support the Buffer Dump command.	Closed / Adopted	Not absolutely necessary, but requires little additional code and provides a convenience for MOPS.
7	Do not reset the hardware registers that capture the reset cause so that the Boot does not clear the Actel reset cause register is available to the application programs.	Closed / Adopted	The Boot will preserve the contents of the Actel reset cause register as requested.
8	Delete the requirements to disable EDAC during memory test. This is no longer needed since double bit errors will no longer cause a processor reset.	Closed / Adopted	Requirement deleted.

AFC Boot Software Requirements Review Participants

Harry Utterback*	Chair
Shane Hutton	Presenter
Mike Packard*	TIMED Mission Ops
Walter Mitnick*	TIMED Ground System
Steve Williams*	TIMED C&DH Software
Sean McGhee*	TIMED Ground System Software
Ray Harvey*	TIMED Autonomy Rules
Horace Malcom*	TIMED GNS Software
Mike Mitchell	TIMED Flight Software
Warren Frank*	TIMED G&C Software
Al Chacos*	TIMED GNS Software
Martha Chu*	TIMED Mission Software
Steve Offenbacher*	TIMED G&C Software

*independent reviewers

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Mike Mitchell	Presenter
John Hayes*	Boot Expert
Dan Ossing*	TIMED Mission Ops
Horace Malcom*	TIMED GNS Software, Boot Expert
Steve Williams*	TIMED C&DH Software

* independent reviewers

Common Boot Software Detailed Design Review Participants

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Mike Mitchell	Presenter
John Hayes*	Boot Expert
Dan Ossing*	TIMED Mission Ops
Horace Malcom*	TIMED GNS Software, Boot Expert
Steve Williams*	TIMED C&DH Software
Steve Offenbacher*	TIMED G&C Software

* independent reviewers

Common Boot SPR Summary (1 of 3)

SPR #	Description	Status	Response
28	Flat Boot fails to successfully load application.	Closed / Fixed	Enabling caching in Boot corrects problem.
118	Boot 0.1 does not support parameter loads.	Closed / Fixed	Added requirements to support parameter loads. Implemented and verified parameter load and compare commands. Delivered in Boot 0.2.
128	Boot 0.2 does not operate properly on the C&DH in the low rate downlink mode (also a problem for C&DH application code).	Closed / Fixed	Determined that a 1.6 msec delay in the low rate downlink mode corrects the problem. Delivered in Boot 0.5.
141	Boot 0.3 does not successfully load the AFC application.	Closed / Fixed	Modified Boot implementation of Mil-Std 1553 validation algorithm to handle command messages which span two major frames. Delivered in Boot 0.5.
145	Same as SPR 141	Closed / Fixed	Same as SPR 141

Common Boot SPR Summary (2 of 3)

SPR #	Description	Status	Response
168	Boot 0.5 does not record the calculated checksum of the Boot Command Interpreter (CI) program.	Closed / Fixed	Record the CI checksum calculated by the Boot in the Boot Transfer Region of SRAM and downlink the value in Boot telemetry. Delivered in Boot 0.6.
169	Boot 0.5 does not use the Boot Block Cell enable/disable memory scrub parameter correctly.	Closed / Fixed	Correct problem. Delivered in Boot 0.6.
171	Boot 0.5 does not count soft reset commands properly.	Closed / Fixed	Correct problem. Delivered in Boot 0.6.
217	Boot 0.6 occasionally gets in a degraded mode and is unable to jump to AFC application. Power cycle required to recover.	Closed / Fixed	Corrected race condition by initializing a Boot state variable before enabling interrupts instead of after. Delivered in Boot 0.7.

Common Boot SPR Summary (3 of 3)

SPR #	Description	Status	Response
263	Boot 0.7 has the wrong CCSDS packet length specified in its telemetry packets.	Closed / Correct Operation Verified	Testing Boot telemetry flowing through USN and APL systems detected no problems as a result of this software bug. Code not changed.
341	Boot 0.7 Reset Counter Bug: reset counter in Boot software does not work properly.	Closed / Workaround	Using two types of workarounds for reset counting. AFC using change to Boot Block Cell which causes Boot reset counter to work. C&DH and GNS using combination of autonomy rule reset counting and application reset counting. Code not changed.
531	Incorrect Reset Type reported in Boot normal telemetry for soft resets from application.	Closed / Workaround	Workaround: correct reset type available elsewhere in normal telemetry. Code not changed.
532	Erased Flash segment incorrectly marked invalid in Boot telemetry.	Closed / Workaround	Since actual segment status is unaffected and correct status is reported when segment is reprogrammed or following reset, no code change is needed.

New SPR Summary

SPR #	Description	Status	Response
557	Boot 0.7 does not accept desired application starting addresses; jumps to application using slower than desired DRAM address space.	Open / Workaround	Opened 10/18/00. Workaround identified: application code change. C&DH and GNS subsystems already use workaround / meet application timing requirements. AFC evaluating impact and need for code changes if any. Boot documentation will be updated to reflect valid jump addresses.
558	Boot 0.7 normal telemetry does not indicate RAM test address range specified in Boot Block Cell (BBC).	Open / Fix Documentation	Opened 10/20/00. Update documentation to reflect valid ranges for RAM tests.

GPS Navigation System (GNS) Software

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Presentation Overview (1 of 3)

Presentation Overview (2 of 3)

Presentation Overview (3 of 3)

- Appendix (p38)
  - GNS Software Test Verification Matrix (7 pages)
  - GNS Software Build Timeline (3 pages)
  - Compilation of GNS Software-Related Action Items and Responses (10 pages)

GNS Purpose

- **The GNS is the TIMED spacecraft's autonomous navigation and timekeeping system and will provide position, velocity, time, Sun vector, and notification of defined orbital events in realtime, as well as, generate tables of event predictions up to 60 hours in advance.**

GNS Functional Requirements Overview (1 of 4)

- **Determine and Output Realtime Navigation Products (once per second):**
  - **Position (Inertial and Lat/Long/Height)**
  - **Velocity (Inertial and East/North/Up Earth Relative)**
  - **Time (GPS Time)**
  - **Earth-Sun Vector (Inertial Normalized)**

GNS Functional Requirements Overview (2 of 4)

- **Determine and Output Realtime Event Notifications (once per second):**
  - Primary Ground Station Contacts
  - Backup Ground Station Contacts
  - South Atlantic Anomaly Encounters
  - Terminator Crossings
  - Polar Region (defined Latitude) Crossings

GNS Functional Requirements Overview (3 of 4)

- **Determine and Output Prediction Tables (once every 12 hours):**
  - Primary Ground Station Contacts in next 60 hours (AOS/LOS)
  - Backup Ground Station Contacts in next 60 hours (AOS/LOS)
  - South Atlantic Anomaly Encounters in next 60 hours (Entry/Exit)
  - State Vector for each Primary and Backup Contact
  - NORAD-type Elset for each Primary and Backup Contact

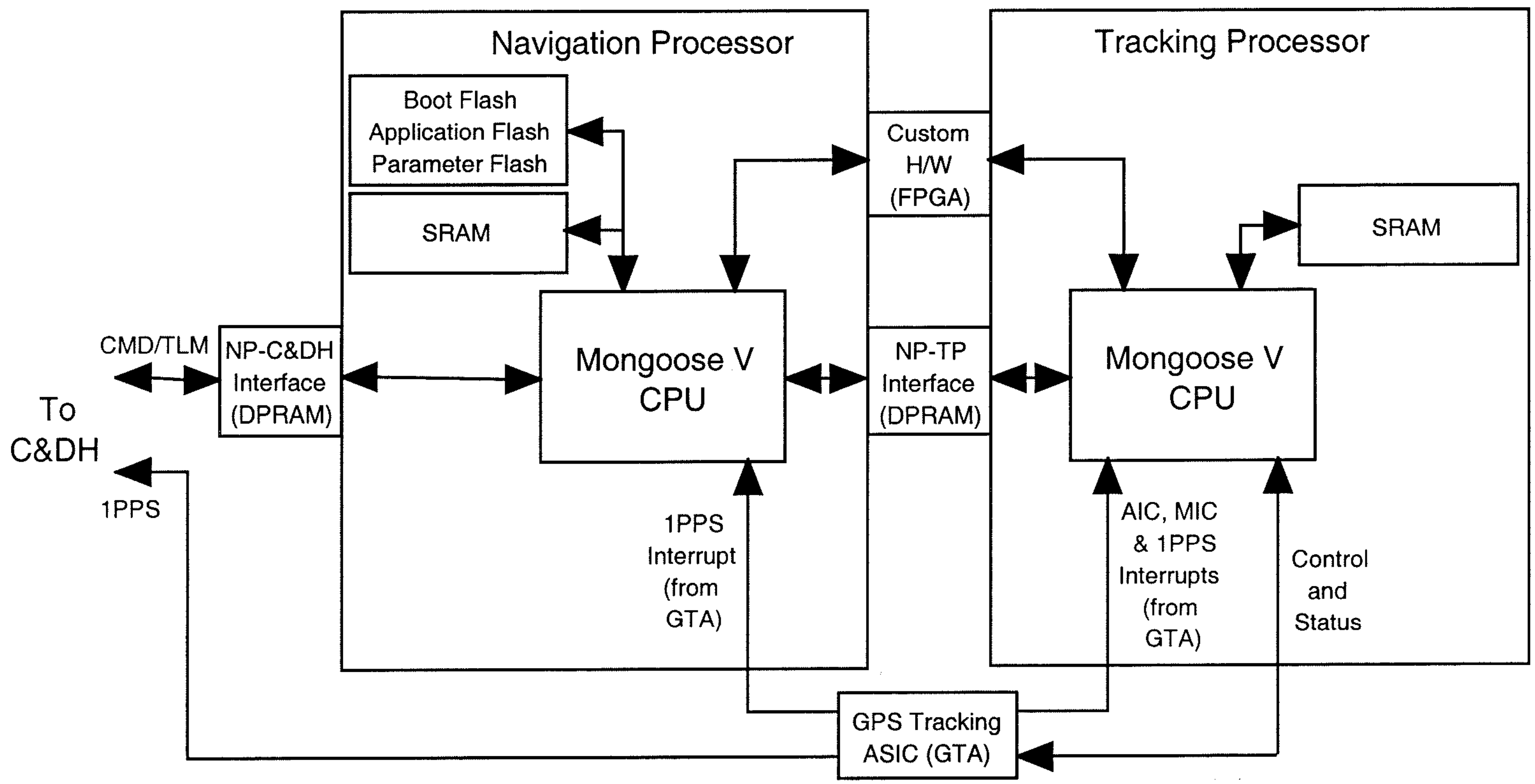
GNS Functional Requirements Overview (4 of 4)

- **Continuously steer a hardware generated 1 PPS signal to within 100us of UTC 1-second epochs**
- **Operate autonomously on-orbit (i.e. acquire, track and navigate without requiring any initialization information)**
- **Provide sufficient command and telemetry capability to enhance the tracking and navigation functions, if desired, as well as, diagnostic insight**

GNS Dual Processor Architecture

- **The GNS contains two processors; namely, the Tracking Processor which is responsible for controlling and interacting with the GPS hardware in order to obtain raw tracking data, and the Navigation Processor which is responsible for command and telemetry handling, determination of navigation solutions, generation of tracking acquisition aids and generation of all of the GNS output data products.**

GNS Simplified Hardware Block Diagram



GNS Tracking Processor Statistics

- **Lines of Code:**
  - 7,208 Non-comment LOC
  - 12,185 Comment LOC
  - 19,393 Total Source LOC
- **Size of Binary Executable:**
  - 128 KBytes
- **SRAM Usage:**
  - 13% (of 2MBytes available)
- **Interrupt Rate:**
  - 667 microsecond
- **CPU Utilization:**
  - 81% (1 second peak)
  - 60% (128 second average)

GNS Navigation Processor Statistics

- **Lines of Code:**
  - 25,239 Non-comment LOC
  - 21,045 Comment LOC
  - 46,284 Total Source LOC
- **Size of Binary Executable:**
  - 456 KBytes
- **SRAM Usage:**
  - 66% (of 2MBytes available)
- **Interrupt Rate:**
  - 1 second
- **CPU Utilization:**
  - 34% (average w/ 30 second KF crank interval)
  - Maximum of 28 milliseconds per second required for realtime processing

GNS Software Development/Testing Team

Mark Asher - Kalman Filter Design and Testing, and GNS System-Level Software Regression Testing

Stan Cooper - Command/Telemetry Testing

Rich DeBolt - GNS System-Level Software Regression Testing

Rich Dragonette (MOC GNS S/C Specialist) - Cmd/Telemetry Regression Testing

Dennis Duven (GNS Lead Analyst) - Navigation and Tracking Design Analysis

Bob Heins (GNS System Engineer) - GNS System-Level Testing

Tom Kusterer - Navigation Software Design, Implementation and Testing

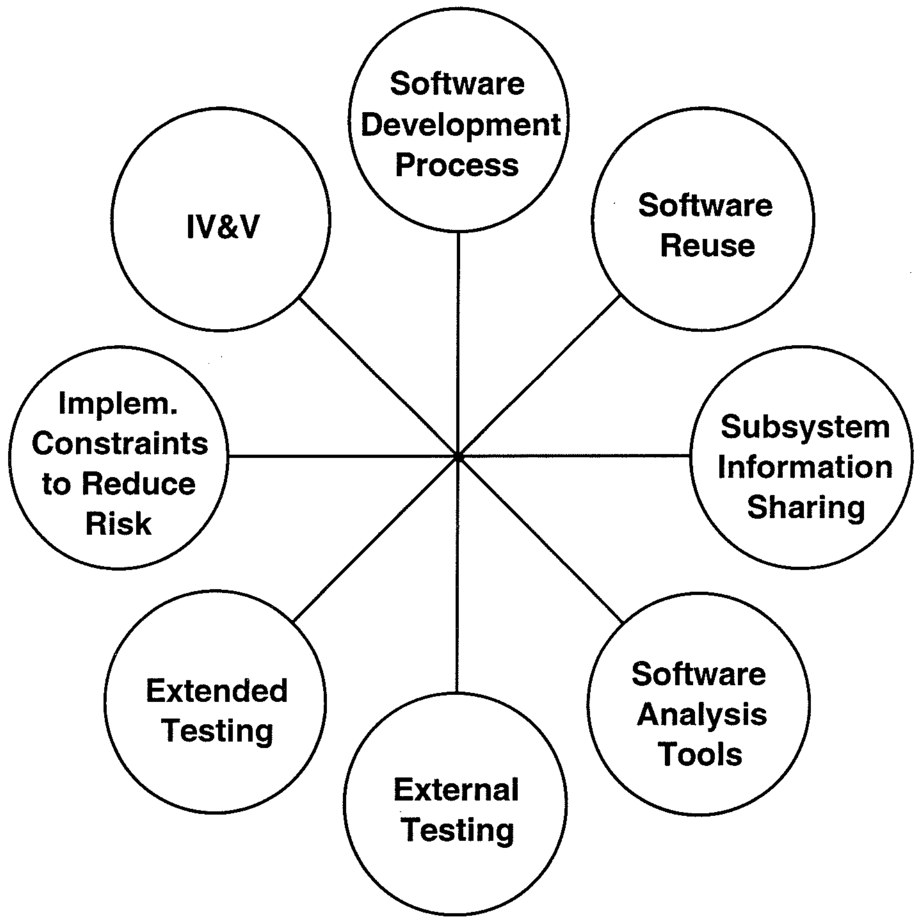
Bryan Leavens - C&DH Emulator Software and GSE Software Utilities

Lloyd Linstrom - Tracking Software Design, Implementation and Testing

Horace Malcom - Navigation Command/Telemetry Design, Implementation and Testing and Embedded Operating System Configuration and Testing

Susan Schneider - Tracking Command/Telemetry and Housekeeping Design, Implementation and Testing

GNS Software Reliability Components



The following are discrepancies with respect to implementation of the Software Development Plan:

1) Software build definitions were changed to accommodate spacecraft needs and software task completion dates.

2) Not all changes to delivered software were handled through the SPR (Software Problem Report) mechanism; however, ALL changes were noted in the build release notes which were distributed widely by the Mission Software Engineer. A verbal waiver was given by the Spacecraft System Engineer and the Mission Software Engineer due to the fact that most software builds were delivered to the spacecraft prior to the completion of build testing in order to expedite the spacecraft testing schedule.

3) There was no IV&V performed on the software implementation due to resource limitations.

4) The black-box IV&V was not performed by an external organization. It was performed by APL in a non-Space Department lab (NAVSIL - Navigation and Guidance System Integration Laboratory) which specializes in GPS testing and is used for programs such as the Tomahawk Land-Attack Missile (TLAM), theater ballistic missile defense (TBMD), Terrier Lightweight Exoatmospheric Projectile (LEAP) program, and Standard Missile (SM-3) program.

Software Development Process (1 of 12)

- **Software Development Plan**
  - Plan was generated but not updated to reflect changes
  - Plan was followed in general, but deviations were made to reflect changes in personnel and resources available.
- **Software Development Schedule**
  - Schedule was generated and maintained
  - Schedule was periodically reviewed by program office
- **Software Configuration Management**
  - Tracking software maintained within MKS
  - Navigation software maintained in archived directories
  - Build 4.00 software and documentation provided to the program for archiving

GNS Software Test Verification Matrix

(p1 of 7)

Note: SRD = System Requirements Document

Section	GNS Software Requirements Specification Document Description	Requirements Flowdown Source	Requirement #	Requirement Implemented?	Requirement Tested?
2.0	SOFTWARE REQUIREMENTS	---	---	---	---
2.1	Navigation Processor	---	---	---	---
2.1.1	Major Functions for Output Product Generation	---	---	---	---
2.1.1.1	Realtime Navigation	---	---	---	---
	#1: Position	GNS SRD: 5.4.2	1	Yes	Yes, (see Section 2.1.8.1.3.x)
	#2: Velocity	GNS SRD: 5.4.2	2	Yes	Yes, (see Section 2.1.8.1.4.x)
	#3: Time	GNS SRD: 5.4.2	3	Yes	Yes, (see Section 2.1.8.1.5.x)
	#4: Earth-Sun Vector	GNS SRD: 5.4.5	4	Yes	Yes, (see Section 2.1.8.1.6.x)
	#5: Notification of Terminator Crossings	GNS SRD: 5.2.1	5	Yes	Yes, (see Section 2.1.8.1.7.1)
	#6: Notification of SAA Encounters	GNS SRD: 5.5.3.1	6	Yes	Yes, (see Section 2.1.8.1.7.2)
	#7: Notification of Proximity to Polar Regions	Verbal	7	Yes	Yes, (see Section 2.1.8.1.7.3)
	#8: Notification of Valid Contacts	GNS SRD: 5.5.1.1	8	Yes	Yes, (see Section 2.1.8.1.7.4.x)
2.1.1.2	Event Prediction	GNS SRD: 5.5.4	9	Yes	Yes, (see Section 2.1.8.2)
2.1.1.3	Orbital Element Set Generation	GNS SRD: 5.6	10	Yes	Yes, (see Section 2.1.8.2.3)
2.1.1.4	1PPS Signal Steering	GNS SRD: 5.3.2	11	Yes	Yes, (see Section 2.1.9.2)
2.1.2	Major Functions for Generation of Data for Internal Use	---	---	---	---
2.1.2.1	SV Acquisition Aids Generation	GNS SRD: 5.9.4.1	12	Yes	Yes, (see Section 2.1.10.3.1)
2.1.2.2	Tracking Data Processing	Derived	13	Yes	Yes, (see Section 2.1.10.2.2)
2.1.2.3	GPS Message Processing	Derived	14	Yes	Yes, (see Section 2.1.11)
2.1.3	Modes of Operation	---	---	---	---
2.1.3.1	Non-GPS Navigation Mode	---	---	---	---
	#1: Non-GPS Navigation Mode	GNS SRD: 5.9.8.2	15	Yes	Yes, Functional Test
	#2: Mode Entry and Exit	Derived	16	Yes	Yes, Launch Timeline Test
	#3: Mode Operation	Derived	17	Yes	Yes, Launch Timeline Test
	#4: State Vector Age	Derived	18	Yes	Yes, Module-Level Test
	#5: Error Action	Derived	19	Yes	Yes, Module-Level Test
2.1.3.2	GPS Navigation Mode	---	---	---	---
	#1: GPS Navigation Mode	GNS SRD: 5.9.2	20	Yes	Yes, Functional Test
	#2: Bootup Default	Derived	21	Yes	Yes, Functional Test
	#3: Mode Entry and Exit	Derived	22	Yes	Yes, Functional Test
	#4: Mode Operation	Derived	23	Yes	Yes, Functional Test
	#5: Mode Flywheel	GNS SRD: 5.9.6	24	Yes	Yes, Functional Test
2.1.3.3	Separation Sequence Mode	---	---	---	---
	#1: Separation Sequence Mode	GNS SRD: 5.9.8	25	Yes	Yes, Functional Test
	#2: Mode Entry and Exit	Derived	26	Yes	Yes, Launch Timeline Test
	#3: Command Checks	GNS SRD: 5.9.8.1	27	Yes	Yes, Launch Timeline Test
	#4: Monitor for Separation	GNS SRD: 5.9.8.2	28	Yes	Yes, Launch Timeline Test
	#5: Mode Operation	GNS SRD: 5.9.8.2	29	Yes	Yes, Launch Timeline Test
	#6: Error Action	Derived	30	Yes	Yes, Module-Level Test
2.1.3.4	Test Modes	GNS SRD: 5.9.7	31	Yes	Yes, Functional Test
2.1.3.4.1	GPS Static Receiver Test Mode	GNS SRD: 5.4.9	32	Yes	Yes, Functional Test
2.1.3.4.2	Built-In Test Mode	---	---	---	---

Software Development Process (2 of 12)

- **Software Requirements Generation**
  - **Listing shows requirements flowdown from the GNS System Requirements Document (see appendix for complete listing - GNS Software Test Verification Matrix)**
  - **(221) Requirements listed**
  - **All requirements were implemented**
  - **All requirements were tested**

GNS Software Design Documentation

Document Tracking Number	Initial Release Date	Current Release Date	Current Release Version	Author	Pages	Document Title
7363-9331	3/13/97			A. A. Chacos	18	Software Development Plan for the GPS Navigation Subsystem
7363-9360	4/18/97	2/1/00	Release G	A. A. Chacos	539	GPS Navigation System (GNS) Navigation Processor Data Dictionary
7363-9333	9/24/97	9/21/00	Release B	A. A. Chacos	21	Software Requirements Specification for the GPS Navigation Subsystem
7363-9348	9/29/97	2/1/00	Release D	A. A. Chacos	28	GPS Navigation System (GNS) Software Internal ICD
7363-9332	11/13/97	2/1/00	Release F	A. A. Chacos	59	GPS Navigation System (GNS) Software External ICD
7363-9361	9/15/98			M. S. Asher	89	Mathematical Specification for the TIMED GNS Kalman Filter
NONE	9/15/98			S. E. Schneider	- -	Record of IV&V for the Mathematical Specification for the TIMED GNS Kalman Filter
7363-9335	9/18/98			T. L. Kusterer	8	Mathematical Specification for the TIMED GNS Kalman Filter Short-Term Propagator
NONE	9/18/98			S. E. Schneider	- -	Record of IV&V for the Mathematical Specification for the TIMED GNS Kalman Filter Short-Term Propagator
SEA-97-0047(A)	11/17/98	10/4/00	2000-0056	L. A. Linstrom	40	GPS Navigation System (GNS) Algorithms for Tracking GPS Signals & Recovering the GPS Message
SEA-99-0006	1/14/99			M. S. Asher	20	Submission of Changes to the TIMED GNS Kalman Filter Math Spec for IV&V
7363-9337	11/17/98	10/4/00		Linstrom/Schneider	108	TIMED GPS Navigation System (GNS) Tracking Processor Software Detailed Design Document
VRF-5-99U-004	9/30/99			R. F. Holsopple	55	Results of TIMED [GNS] Independent Validation & Verification (IV&V) Testing in NAVSIL
SEA-99-0070	12/3/99			M. S. Asher	1	Comments on TIMED GNS IV&V Report (NAVSIL Blackbox Testing)
SEI-99-056	12/15/99			R. A. Dragonette	35	TIMED GPS Navigation System (GNS) Spacecraft Subsystem Information Manual
7363-9334	Draft			Chacos/Kusterer		TIMED GPS Navigation System (GNS) Navigation Processor Software Detailed Design Document
Design Memos:						
SEA-98-0037	6/24/98			Asher/Kusterer	13	Documentation for TIMED GNS Orbit Propagator
SEA-98-0086	11/30/98			Asher/Linstrom/Boehme	5	Effect of GNS Oscillator Frequency Wobble on the Kalman Filter
SEA-99-0056	9/10/99			M. S. Asher	4	Relaxation of Requirement for Uploads to GNS
SRS-099-171	10/5/99			S. E. Schneider	9	GPS Navigation System (GNS) Tracking Processor Software Timing Measurement Data & CPU Load Estim.
SEA-2000-0006	3/8/00			T. L. Kusterer	9	Documentation of TIMED PVT and Orbital Element Set Data Flow
Testing Memos:						
SEA-98-0023	4/30/98			Asher/Kusterer	26	Description of TIMED GNS Orbit Propagator Testing
SEA-98-0041	6/29/98			Asher/Kusterer	9	TIMED GNS Orbit Propagator Test Results to Date
SEA-99-0004	1/12/99			M. S. Asher	4	Recent Testing of TIMED GNS Navigation System Using the GPS Simulator System
SEA-99-0005	1/13/99			Kusterer/Asher	4	Recent Testing of TIMED GNS Navigation System Using TOPEX Data Downloaded from the Internet
SEA-99-0010	1/29/99			M. S. Asher	6	Methodology and Interfaces for PC Platform Testing of the TIMED GNS Kalman Filter Code
SEA-99-0054	8/25/99			S. B. Cooper	5	Results of TIMED GNS IV&V Static Command Testing
SEA-2000-0004	3/3/00			M. S. Asher	26	Analysis of TIMED GNS Real-time Data Products from January 96 Hour Thermal-Vacuum Test
SEA-2000-0005	3/3/00			M. S. Asher	4	Validation of TIMED GNS Performance in Orbital Insertion Mode
SEA-2000-0008	3/13/00			M. S. Asher	8	Analysis of TIMED GNS Real-time Data Products from March 76 Hour Test
SEA-2000-0011	3/23/00			M. S. Asher	6	Consistency Verification Test of TIMED GNS Element Sets

Software Development Process (3 of 12)

- **Software Design Documentation**
  - **Listing details extensive design documentation**
  - **Critical documentation periodically updated to maintain an up-to-date design description**

GNS Software Design Reviews

Date	Design Reviews	Software Presenters	Reviewers (N/G = NASA/GSFC)	Software Related Action Items
6/25/96	Task Start			
6/29/96	Mini-CoDR	Chacos	Audience	0
10/15/96	Program Status Review	Chacos	Audience	0
2/18/97	Mission PDR	Chacos	Hoffman, Chiu, Frank, Gaddy (N/G), Gold, Huebschman, Stengle (N/G), Wolff (N/G), Woods (N/G)	2
11/17/97	Software Requirements Review	Chacos	Knopf, Goldsten, Horstcamp, Williams	13
11/17/97	Software PDR	Linstrom, Asher, Kusterer, Malcom	Knopf, Goldsten, Horstcamp, Williams, Levy, Lim	16
12/3/97	Mission CDR	Chacos	Hoffman, Wonsever (N/G), Conde, Day (N/G), Ebert, Frank, Jenkens (N/G), Ross (N/G), Santo, Woods (N/G)	1
4/14/98	Propagator Code Walkthrough	Kusterer	Winters, Gary, Asher	- - -
7/2/98	NP Build #1 (Cmd/Tlm) Detailed Design Review	Malcom	Chu, Mitnick	1
8/3/98	NP Build #1 (Cmd/Tlm) Code Walkthrough	Malcom	Chacos	- - -
9/25/98	NP Build #2 (KF) Detailed Design Review	Kusterer	Utterback, DeMajistre, Heyler, Lyons	4
11/22/98	NP Build #2 (Cmd/Tlm) Detailed Design Review	Malcom	Utterback, Chu, Hayes, Schneider	2
11/22/98	TP Builds #1&2 Detailed Design Review	Linstrom, Schneider	Utterback, Chu, Hayes, Goldsten	2
1/15/99	NP Build#2 (KF) Code Walkthrough	Kusterer	Chacos	- - -
2/17/99	NP Build #2 (Cmd/Tlm) Code Walkthrough	Malcom	Hayes, Kusterer, Schneider	- - -
			Total	41

Software Development Process (4 of 12)

- **Software Design Reviews and Resulting Action Items**
  - **- Listing details (14) software design reviews**
  - **- (41) Action Items (RFAs) were generated and all have written responses (see appendix - Compilation of GNS Software-Related Action Items and Responses)**

GNS Software Build Timeline

(p1 of 3)

Date	Software Build #	NP Ver. #	TP Ver. #	CP Ver. #	NCP Ver. #	Release Interval (Days)	Changes/ SPR #	SPR Status	Type	Comments
10/19/98							27	Closed	H/W Workaround	To preserve reset cause for non-master reset
3/10/99	**Build 2.02**	**2.02**	**N/A**	**N/A**	**N/A**					**[INITIAL SPACECRAFT RELEASE] Provided Non-GPS Navigation (i.e. SV propagation)**
3/10/99							72	Closed	O.S. Fix	For Nucleus+ to save FPU context when switching tasks
3/11/99							74	Closed	Bug Fix	For Command Handler Task to recognize TCmd packets for IEM #2 (Unable to test with/EM)
							Rel. Notes		Enhancement	To improve the mechanism for setting the spacecraft time (i.e. 3 minute delay eliminated)
							Rel. Notes		Bug Fix	To correct the execution of the TP Antenna Select command
							Rel. Notes		Enhancement	To eliminate potential problem due to commanding a new GNS time
							Rel. Notes		Bug Fix	To correct the time precision change threshold
							Rel. Notes		Gnd S/W Workaround	To modify the GNS logical memory dump structure to replicate the structure ID
3/15/99	Build 2.03	2.03	N/A	N/A	N/A	5				
3/15/99							79	Closed	Bug Fix	For Tlm Output Task to mark Tlm packets correctly for IEM #2 (Unable to test w/EM)
3/16/99	Build 2.04	2.04	N/A	N/A	N/A	1				
6/2/99	**Build 3.00**	**3.00**	**3.00**	**N/A**	**N/A**	**78**				**Provided full GPS navigation & prediction products. Added the following:**
										Flash task, Delayed MIC task, Prediction task, and Message Handler task. In addition,
										reorganized software structure.
							Rel. Notes		Bug Fix	To correct clearing of tracking data when tracking is lost
							Rel. Notes		Bug Fix	To correct the execution of Load Acquisition Aids command
							Rel. Notes		Added Functionality	To add (9) commands intended to be included with Build 3.00
							Rel. Notes		Added Functionality	To add the capability to navigate in static mode (navigating antenna on roof)
							Rel. Notes		Added Functionality	To complete flash memory functionality
							Rel. Notes		Added Functionality	To add the capability to load default data from flash in order to easily deal with a bad upload
							Rel. Notes		Added Functionality	To modify the interpretation of the 16-bit channel dataword to initially provide tracking info
							Rel. Notes		Added Functionality	To change the memory dump address range to include the entire SPEC0 address range
							Rel. Notes		Added Functionality	To update the error code list
							Rel. Notes		Added Functionality	To widen the defined valid time range
6/14/99	Build 3.01	3.01	3.01	N/A	N/A	12				
6/15/99							150	Closed	Bug Fix	To look at correct bit for +12v status from C&DH (Unable to test w/EM)
6/27/99	**Build 4.00**	**4.00**	**4.00**	**0.00**	**0.00**	**13**				**Provided complete GNS functionality. Added the following:**
										EDAC capability, memory scrub task, capability to stop/restart individual tasks,
										capability to load TP with initial parameter values, clear parameter value command,
										enhanced memory dump capability, TP heartbeat processing in Delayed MIC task,
										improved KF task error codes, capability to handle TP errors and memory scrub data.
										Restructured the task handling to move Telemetry Builder, Telemetry Output,
										Command Handler and Delayed MIC tasks into Timer2 HISR.
8/5/99							179	Closed	Bug Fix	To correct handling of GN_TURN_ATT_SV command
							Rel. Notes		Bug Fix/Enhancement	*Build 4.00 was delivered to the spacecraft prior to completion of subsystem build testing*
										and optimization so that spacecraft testing could occur in parallel, resulting in a
										large number of software changes. This was anticipated as noted in the Build 4.00
										release notes. The need for approximately (70) NP and (11) TP optimizations or
										bug fixes were all determined by ongoing subsystem testing and not by spacecraft
										testing. For descriptions of the changes, see Build 4.01 release notes
8/5/99	Build 4.01	4.01	4.01	0.00	0.00	39				
							Rel. Notes		Bug Fix	To correct handling of (6) commands

Software Development Process (5 of 12)

- **Software Implementation (Incremental Builds)**
  - **Listing details (14) software builds (see appendix for complete listing - GNS Software Build Timeline)**
  - **A software build consists of a change to one or more of the following components:**
    - **Tracking Processor software**
    - **Navigation Processor software**
    - **Non-Critical Parameters**
    - **Critical Parameters**

GNS Software Problem Reports

Date	Changes/ SPR #	SPR Status	Type	Comments
10/19/98	27	Closed	H/W Workaround	To preserve reset cause for non-master reset
3/10/99	72	Closed	O.S. Fix	For Nucleus+ to save FPU context when switching tasks
3/11/99	74	Closed	Bug Fix	For Command Handler Task to recognize TCmd packets for IEM #2 (Unable to test with/EM)
3/15/99	79	Closed	Bug Fix	For Tlm Output Task to mark Tlm packets correctly for IEM #2 (Unable to test w/EM)
6/15/99	150	Closed	Bug Fix	To look at correct bit for +12v status from C&DH (Unable to test w/EM)
8/5/99	179	Closed	Bug Fix	To correct handling of GN_TURN_ATT_SV command
10/25/99	315	Closed	Bug Fix	To prevent a floating point exception due to low eccentricity orbits
10/28/99	324	Closed	Bug Fix	To have Flash write operations use non-cacheable address space
1/13/00	378	Closed	Operations Constraint	Reset of NP during a Flash memory write operation is to be avoided
2/11/00	404	Closed	Bug Fix	To correct two time related conversions in the orbital elements generation
2/12/00	417	Closed	Bug Fix	To correct Prediction Task index to point to primary ground station, not backup
2/12/00	418	Closed	Bug Fix	To eliminate a 6-second error in the Prediction Task products
2/21/00	429	Closed	Bug Fix	To correct the ground station contact rise/set lead time flag
2/23/00	430	Closed	Enhancement	To eliminate an application opcodes conflict with boot code opcodes
6/22/00	481	Closed	Enhancement	To improve acquisition time (set time to within 1 second with 1 SV in track)
6/29/00	486	Closed	Enhancement	Duplicate of SPR #430
6/29/00	487	Closed	Bug Fix	To correct handling of almanac health information
6/29/00	488	Closed	Bug Fix	To correct phase bias portion of H matrix when SA states are turned off
7/27/00	497	Closed	Enhancement	To filter zeta parameter values which would cause a divide by 0 exception
7/27/00	498	Closed	Bug Fix	To correct a problem if a measurement is taken at the week boundary (seconds = 0)
7/27/00	499	Closed	Enhancement	To add process noise capability to the phase bias states
7/27/00	500	Closed	Enhancement	To improve acquisition time (save frequency bias)
7/27/00	501	Closed	Bug Fix	To increase delay time to 5 seconds before KF enters its initialization loop
8/22/00	508	Closed	Bug Not Corrected	FOM's rollover from 255 to 0, instead of holding at 255
9/20/00	541	Closed	Bug Not Corrected	A 1-second (late) delay exists in the Time Jump Notification Flag

Software Development Process (6 of 12)
Testing

- Extensive testing was performed at the implementation level, subsystem level and spacecraft level (see appendix for GNS Test Verification Matrix)
- (25) GNS-related Software Problem Reports (SPRs) were generated and all have been closed

BG-14 Software: Originally developed by McDonnell Douglas under a NASA contract, the software has a long heritage and is noted for its high reliability and high fidelity. It has been used for many years for both Earth orbiting missions, as well as, interplanetary missions.

Motion File: A file of position, velocity and time in a format required to drive the GPS simulator.

Novatel GPS Receiver: A purchased GPS receiver capable of handling orbital velocities.

Rinex PR & IC File: A file of Pseudorange and Integrated Carrier data in a standard GPS data format (Rinex).

Trajectory File: A file of position, velocity and time which can be compared against the 'truth' motion file to verify the correct operation of the software in test.

Testing:

The tracking software and navigation Kalman filter software were developed in stages in an effort to help isolate problems that surfaced during testing. This approach was advantageous and efficient due to the complexity and interaction of the software. The following sequence of test configurations was executed:

A => 1 => B, then B was compared against A (Scripted tracking software and Matlab Kalman filter software)

A => 2 => B, then B was compared against A (Procured tracking software and Matlab Kalman filter software)

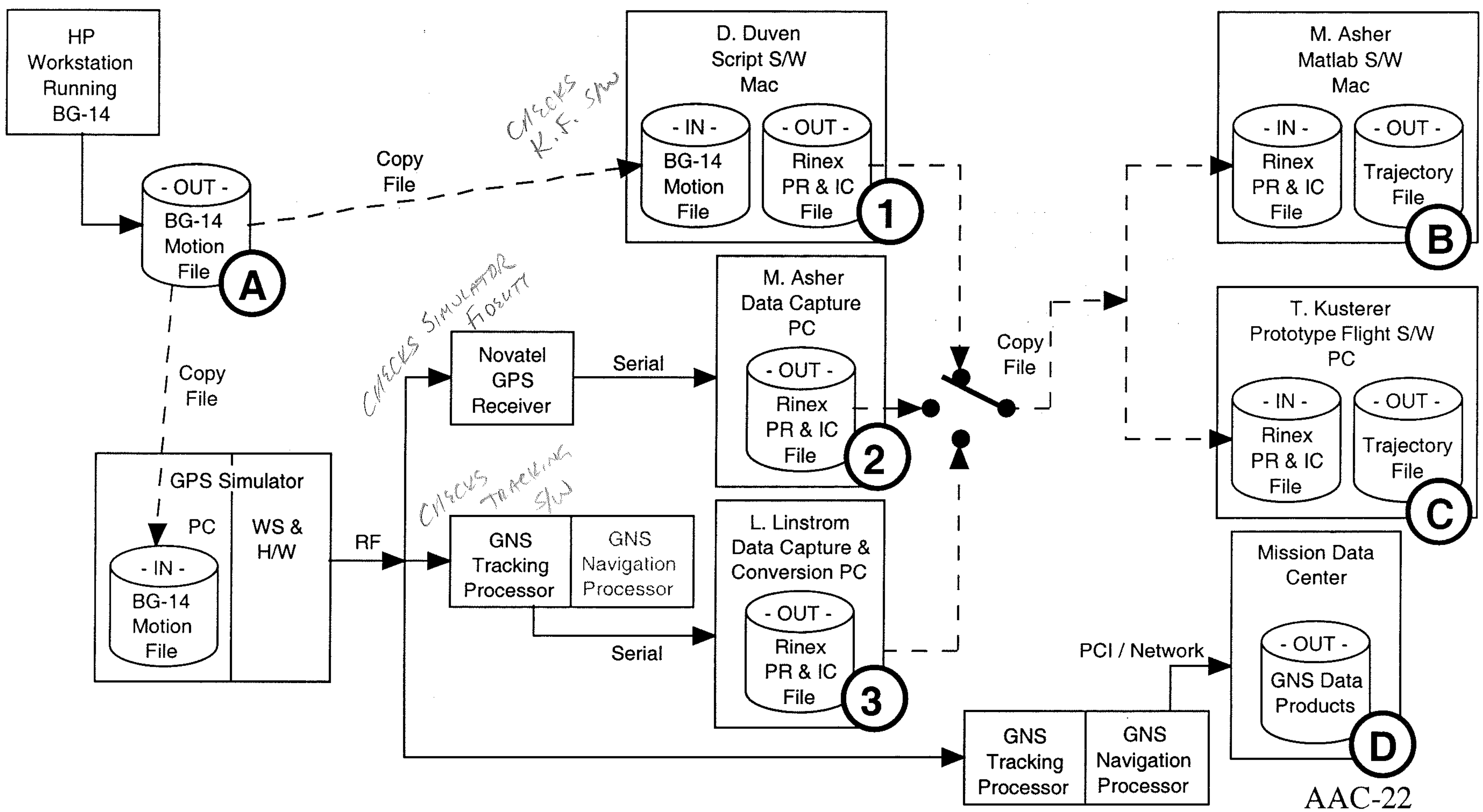
A => 3 => B, then B was compared against A (Flight tracking software and Matlab Kalman filter software)

A => 3 => C, then C was compared against A (Flight tracking software and Prototype flight Kalman filter software)

A => D, then D was compared against A (Flight tracking software and Flight Kalman filter software)

Note that the Kalman filter has partial origins from BG-14 and was originally implemented by Mark Asher in Matlab in order to develop and test the algorithms. The Matlab software was then ported to 'C' by Tom Kusterer and tested on a PC. When the PC version was operating correctly, it was ported to the flight hardware computer under the embedded operating system.

Software Development Process (7 of 12)
Testing



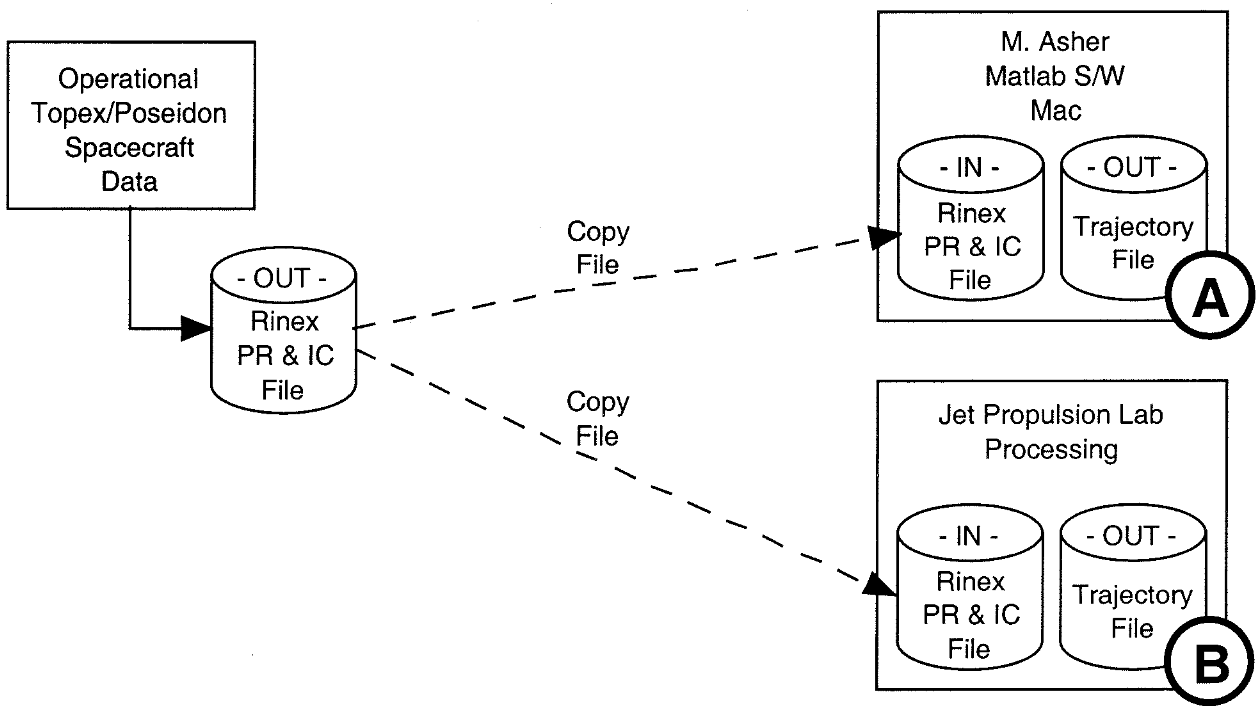
Rinex PR & IC File: A file of Pseudorange and Integrated Carrier data in a standard GPS data format (Rinex).

Trajectory File: A file of position, velocity and time which can be compared against the 'truth' trajectory file to verify the correct operation of the software in test.

Testing:

Pseudorange and Integrated Carrier data from the on-orbit operational Topex/Poseidon spacecraft was received and used to generate a trajectory file (A). This file was compared against the trajectory file generated by JPL (B).

Software Development Process (8 of 12)
Testing



BG-14 Software: Originally developed by McDonnell Douglas under a NASA contract, the software has a long heritage and is noted for its high reliability and high fidelity. It has been used for many years for both Earth orbiting missions, as well as, interplanetary missions.

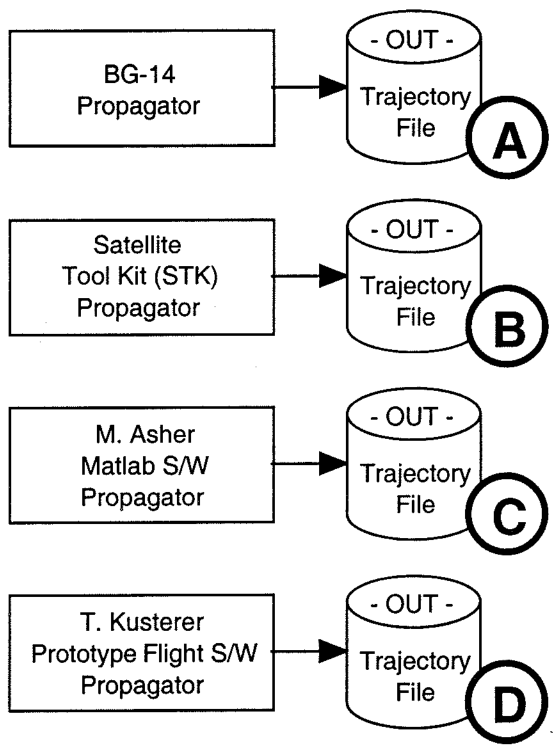
Satellite Tool Kit (STK): Well known and high-quality purchased software used for planning and analyzing satellite orbits.

Trajectory File: A file of position, velocity and time which can be compared against the 'truth' trajectory file to verify the correct operation of the software in test.

Testing:

Four versions of the propagation software were executed and the results compared (A, B, C, and D)

Software Development Process (9 of 12)
Testing



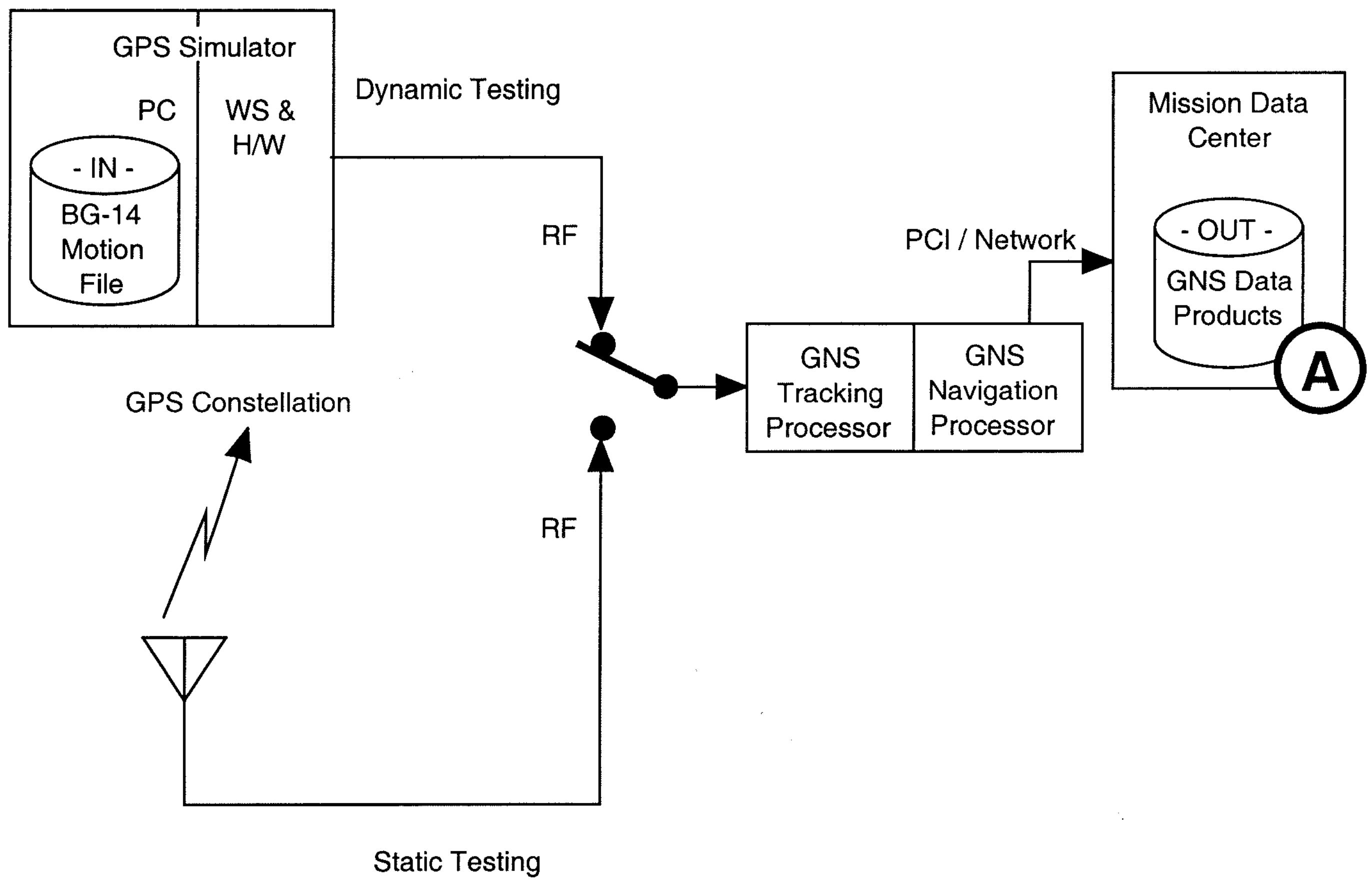
All outputs agreed

BG-14 Software: Originally developed by McDonnell Douglas under a NASA contract, the software has a long heritage and is noted for its high reliability and high fidelity. It has been used for many years for both Earth orbiting missions, as well as, interplanetary missions.

Testing:

The GNS can be operated in either dynamic (for on-orbit) or static (for Earth-based testing) modes. The static testing provides the capability to test parts of the software which are common with the dynamic software. This static testing 'navigates' the GPS roof antenna using the real GPS constellation and extracts the GPS ephemeris and almanac from the transmitted message.

Software Development Process (10 of 12)
Testing



Software Development Process (11 of 12)
Testing

FUNCTIONAL TESTS

- Short-Term Propagation Test
  - Compares events with truth file
- Long-Term Propagation Test
  - Verifies prediction data by comparing with realtime data
- Message Handler Test
  - Compares GNS data with independent message capture software
- Memory Scrub Test
  - Verifies correct operation by inserting single & double bit errors
- Delayed MIC Test
  - Verifies data is correctly transferred between processors
- Flash Programming Test
  - Verifies flash against data buffer

GNS Software Regression Tests

Procedure Name	Creator	Description	Items Tested/Analyzed/Monitored	Test Execution	Test Report
Regression Analysis	M.S. Asher	Performs an error analysis between the true trajectory data and the estimated data of the GNS and calculates statistics on this error.	Position	Jan 2000 96-Hour Test	SEA-2000-004
			Velocity	Mar 2000 76-Hour Test	SEA-2000-008
		Compares the time of event flags generated by the GNS to the true time of the events.		Aug 2000 96-Hour Test	Pending
			Primary Ground Station Event (PGS)		
			Backup Ground Station Event (BGS)		
			South Atlantic Anomaly Event (SAA)		
			Polar Region Event (POL)		
			Day/Night Terminator Event (ECL)		
Trend Line Analysis	R.J. DeBolt	Produces trend line graphs of specific GNS performance telemetry points.	Position Figure of Merit	Jan 2000 96-Hour Test	Data Packet
			Velocity Figure of Merit	Aug 2000 96-Hour Test	Pending
			Time Figure of Merit	Sep 2000 Launch Seq. Test	Data Packet
			Receiver Frequency Bias		
			Receiver Clock Bias		
			MIC Register Count		
Status Analysis	R.J. DeBolt	Graphs the various event notification states of the GNS.	Commands Accepted	Jan 2000 96-Hour Test	Data Packet
			Tracking Processor Errors	Aug 2000 96-Hour Test	Pending
			Navigation Processor Errors	Sep 2000 Launch Seq. Test	Data Packet
			Event Notification (PGS, BGS, SAA, POL, ECL)		
			Validity Flags (PVT, Sun Vector, Events)		
			Telemetry Mode		
			Number of GPS Satellites in Track		
			Navigation Mode		
			Time Precision Mode		
Almanac Analysis	R.J. DeBolt	Tests the ability to upload/download and compare the GPS Almanac stored in the GNS.	GPS Message Almanac Data Store 7.0	Aug 2000 96-Hour Test	Pending
Time Correlation Test	R.J. Heins	Tests the performance of the 1 PPS signal generated by the GNS.	1 PPS	Jan 2000 Stand Alone Test	Data Packet
				Sep 2000 Stand Alone Test	Data Packet
Time Jump Verification Test	R.J. DeBolt	Tests the operation of a GNS time jump.	Tracking Processor	Aug 2000 Stand Alone Test	Bench-Level Only
			Navigation Processor		
			Time Jump Algorithm		
Functional Test	R.A. Dragonette	Executes every command in the GNS command set to test the functional status of the GNS.	Complete GNS Command Set	Routinely executed on S/C	
12-Hour Prediction Data Products Test	R.J. Heins	Compares the GNS event prediction data to the true events.	PGS Prediction Table	Jan 2000 96-Hour Test	Data Packet
			BGS Prediction Table	Aug 2000 96-Hour Test	Pending

Software Development Process (12 of 12)
Testing

- **Software Regression Testing**
  - **(8) tests have been created which thoroughly analyze the GNS operation**
  - **Some of these tests are run routinely**
  - **Some of the tests are only run on significant spacecraft tests**

Software Reuse

- (20) Matrix Utility Routines (written by Tom Kusterer)
- (4) Matrix Utility Routines (from Numerical Recipes)
- (1) QR Matrix Routine (written by John Harris)
- 8th-order Runge-Kutta Fehlberg Orbit Integrator (ported from BG-14 software which was originally developed by McDonnell Douglas under NASA contract)
- Gravity and Drag Force Models (ported from BG-14)
- Various Routines (ported from BG-14):
  - Sun Vector Calculation
  - Coordinate Transformations (CIS to CTS, CTS to CIS, Lat/Long from CIS)
  - Time and Date Conversions (GPS Time to Calendar Date)

Subsystem Information Sharing (C&DH, G&C, GNS, Boot)

- Accelerated Technologies Nucleus Plus Embedded Operating System
  - Initialization file configuration
  - Anomalous behavior information
- BSO Tasking Compiler/Linker
  - Software configuration
  - Compiler bug information
- Mongoose Processor Hardware
  - Register configuration information
  - Anomalous behavior information

Software Analysis Tools

- McCabe & Associates (Battlemap)
  - Software module complexity analysis using flowgraphs
  - Count of a modules decisions & unstructured constructs
  - Numerous metrics
- Abraxas Software Inc. (Code Check)
  - Insight into portability, maintainability and aesthetics

MAGIC NUMBERS
CHARACTERS PER LINE
1 IDENTIFIER PER LINE
VARIABLE NAMES MAY NOT BE PORTABLE

- Gimple Software (C-Lint)

TYPE MISMATCH, IGNORING RETURN VALUES

  - Extensive and thorough vetting of source code
- Multiple Compilers (Visual C++, Watcom, BSO)
  - Review of compiler warnings from each (non-uniform)

External Software Testing

- GNS Orbit Propagator provided to and tested by the TIMED Mission Data Center for use in mission planning
- Orbital Elements data products tested by the TIMED Mission Operations Center with the MSX satellite.

Extended Software Testing

- The TIMED GNS lab is setup for extended testing using the GPS Simulator and a Engineering Model GNS
- Due to simulator limitations, the maximum duration of a single continuous test is approximately 10 days
- There have been numerous extended tests performed on the GNS over the past year.
- There have been (2) 8 1/4 day tests performed on the GNS software build 4.07 (approximately 400 hours). The data on both tests indicated proper operation of the GNS.
- There have been (2) 8 1/4 day tests performed on the GNS software build 4.07.1 (approximately 400 hours). The data on both tests indicated proper operation of the GNS.

Implementation Constraints to Reduce Risk

- **ANSI C**
- **No Assembly (except for a C startup file an operating system file, and one small (~150 lines) application file for Navigation Processor booting the Tracking Processor)**
- **No Dynamic Memory Allocation (except for initial memory allocation to reduce binary image size)**

GNS Kalman Filter Math Specification IV&V Summary

Document ID and Author:
7363-9361 by Mark Asher

Reviewers/Analysts:
Dr. Richard C. Morgan
John Garner (Outside Consultant)

Document Versions:
Revisions 0.3 thru 0.7

Timeline:
5/22/98 - Specification (Rev 0.3 - Baseline) distributed to the two reviewers.
8/25/98 - Specification (Rev 0.4) distributed to the two reviewers.
9/10/98 - Specification (Rev 0.6) distributed to the two reviewers.
9/15/98 - Specification (Rev 0.7) signed-off by the two reviewers.

Final Sign-off:
Dated 9/15/98, by Dr. Richard C. Morgan, and John P. Garner (of Garner and Associates).

IV&V Results:
Both reviewers signed-off on the specification signifying that they had participated in the IV&V effort in the role of Kalman filter experts and independent reviewers, that they reviewed the baseline and revisions of the document and to the best of their judgement, find that Revision 0.7 is mathematically correct and complete.

Changes Following the IV&V Review:
Memo SEA-99-0006, dated 1/14/99, by Mark Asher. During implementation of the specification, several minor errors were noticed in the specification and the changes are noted in the memo

IV&V (1 of 3)

- The "Mathematical Specification for the TIMED GNS Kalman Filter" documents in great detail (~90 pages) the algorithms used in the implementation of the Kalman filter.
- The Kalman filter is the kernel of the Navigation Processor software, and represents the most complex and critical component of the software. Thus, the document was a strong candidate for limited IV&V resources.

GNS Math Specification Short-Term Propagator IV&V Summary

Document ID and Author:
7363-9335 by Tom Kusterer

Reviewers/Analysts:
Dr. Richard C. Morgan
Robert DeMajistre
Mark Asher (GNS Analyst)

Document Versions:
Revisions 0.0 thru 0.3

Timeline:
9/9/98 - Specification (Rev 0.0 - Baseline) distributed to the three reviewers.
9/15/98 - Specification (Rev 0.1) distributed to the three reviewers.
9/18/98 - Specification (Rev 0.2) distributed to the three reviewers.
9/18/98 - Specification (Rev 0.3) signed-off by the three reviewers (Date is correct, it was expedited).

Final Sign-off:
Dated 9/18/98, by Dr. Richard C. Morgan, Robert DeMajistre, and Mark Asher.

IV&V Results:
All three reviewers signed-off on the specification signifying that they had participated in the IV&V effort as mathematicians/independent reviewers, that they reviewed the baseline and revisions of the document and to the best of their judgement, find that Revision 0.3 is mathematically correct and complete.

IV&V (2 of 3)

- **The "Mathematical Specification for the TIMED GNS Kalman Filter Short-Term Propagator" documents the algorithms used to generate the GNS data products.**
- **The reliability of the GNS data products is critical to the operation of the spacecraft and of the overall science mission. Thus, the document was a strong candidate for limited IV&V resources.**

GNS Blackbox IV&V Summary

Tester/Analyst:
Robert Holsopple

Software Version Tested:
S/W Build 4.00

Timeline:
6/27/99 - GNS Software Build 4.00 released
7/02/99 - The move to NAVSIL of the GNS EM & associated command/telemetry system was completed.
8/04/99 - The execution of the (5) IV&V tasks were completed (analysis & report generation remain).
9/30/99 - The analysis and accompanying report were completed.

Final report:
Memo VRF-5-99U-004, dated 9/30/99, by Robert Holsopple

IV&V Approach:
The IV&V testing was broken down into 5 tasks:
Task 1) Initial Acquisition – To determine how long it takes the GNS to navigate from a cold power up in an orbit with a nominal altitude of 625 km above the earth's surface.
Task 2) Continuous 48 hour Navigation – To determine how well the GNS navigates over a 48-hour period at an orbital altitude of 550 km. In addition, determine how well the GNS tracks time with respect to the GPS epoch.
Task 3) Continuous 5-hour Navigation – To determine how well the GNS navigates over a 5-hour period at an orbital altitude of 625 km.
Task 4) Reacquisition – To determine how well the GNS reacquires GPS satellites and begins navigating after multiple 'RF outages' of varying lengths of time.
Task 5) Acquisition Aids – To determine how well the GNS uses its aiding algorithms to facilitate acquiring and tracking GPS satellites.

IV&V Results:
Test results indicate that the GNS, in the five tasks identified, meets the requirements as stated in the TIMED GPS Navigation System Requirements document (7363-9336). There were no performance issues with respect to initial acquisition, navigating after 10 minutes after TTFF and 10 hours after TTFF, 1PPS jitter, and reacquisition during a less than 60 minute GPS RF outage.

There was an error growth issue identified (even though the errors were within spec) during the IV&V testing which was reviewed by the GNS analyst and which resulted in a velocity process noise modification (implemented in GNS Software Build 4.02).

Response to Final Report Conclusions:
Memo SEA-99-0070, dated 12/3/99, by Mark Asher

IV&V (3 of 3)

- In order to have a high degree of confidence that the GNS will be successful on orbit, it was decided that 'Black-Box' IV&V testing of the system was critical.
- The IV&V testing was performed in a separate GPS lab (NAVSIL at APL) using a GPS simulator from a different manufacturer than used by the GNS development team. In addition, a different propagator (other than BG-14) was used to generate the truth file.

  IV&V Simulator:

  Interstate Electronics Corp. GPS Satellite Constellation Simulator (SCS) Model 2400

  GNS Development Simulator:

  Global Simulation Systems, Inc. (GSSI) (formerly Northern Telecom) Model STR2760

Residual Risk

The GNS has low residual risk for the following reasons:

- **The system lends itself to extensive testing using procured GPS simulators.**
- **The system was successfully tested with two different GPS simulators.**
- **The system has been tested for thousands of hours in the lab and thousands of hours on the spacecraft.**
- **Parts of the software were successfully tested using a roof antenna and the real GPS constellation.**

Appendix

- **GNS Software Test Verification Matrix**
- **Design Review Action Item (RFAs) Responses**
- **Full Software Build Timeline**

GNS Software Test Verification Matrix

Note: SRD = System Requirements Document

GNS Software Requirements Specification Document Section	Description	Requirements Flowdown Source	Requirement #	Requirement Implemented?	Requirement Tested?
2.0	SOFTWARE REQUIREMENTS	- - -	- - -	- - -	- - -
2.1	Navigation Processor	- - -	- - -	- - -	- - -
2.1.1	Major Functions for Output Product Generation	- - -	- - -	- - -	- - -
2.1.1.1	Realtime Navigation	- - -	- - -	- - -	- - -
	#1: Position	GNS SRD: 5.4.2	1	Yes	Yes, (see Section 2.1.8.1.3.x)
	#2: Velocity	GNS SRD: 5.4.2	2	Yes	Yes, (see Section 2.1.8.1.4.x)
	#3: Time	GNS SRD: 5.4.2	3	Yes	Yes, (see Section 2.1.8.1.5.x)
	#4: Earth-Sun Vector	GNS SRD: 5.4.5	4	Yes	Yes, (see Section 2.1.8.1.6.x)
	#5: Notification of Terminator Crossings	GNS SRD: 5.2.1	5	Yes	Yes, (see Section 2.1.8.1.7.1)
	#6: Notification of SAA Encounters	GNS SRD: 5.5.3.1	6	Yes	Yes, (see Section 2.1.8.1.7.2)
	#7: Notification of Proximity to Polar Regions	Verbal	7	Yes	Yes, (see Section 2.1.8.1.7.3)
	#8: Notification of Valid Contacts	GNS SRD: 5.5.1.1	8	Yes	Yes, (see Section 2.1.8.1.7.4.x)
2.1.1.2	Event Prediction	GNS SRD: 5.5.4	9	Yes	Yes, (see Section 2.1.8.2)
2.1.1.3	Orbital Element Set Generation	GNS SRD: 5.6	10	Yes	Yes, (see Section 2.1.8.2.3)
2.1.1.4	1PPS Signal Steering	GNS SRD: 5.3.2	11	Yes	Yes, (see Section 2.1.9.2)
2.1.2	Major Functions for Generation of Data for Internal Use	- - -	- - -	- - -	- - -
2.1.2.1	SV Acquisition Aids Generation	GNS SRD: 5.9.4.1	12	Yes	Yes, (see Section 2.1.10.3.1)
2.1.2.2	Tracking Data Processing	Derived	13	Yes	Yes, (see Section 2.1.10.2.2)
2.1.2.3	GPS Message Processing	Derived	14	Yes	Yes, (see Section 2.1.11)
2.1.3	Modes of Operation	- - -	- - -	- - -	- - -
2.1.3.1	Non-GPS Navigation Mode	- - -	- - -	- - -	- - -
	#1: Non-GPS Navigation Mode	GNS SRD: 5.9.8.2	15	Yes	Yes, Functional Test
	#2: Mode Entry and Exit	Derived	16	Yes	Yes, Launch Timeline Test
	#3: Mode Operation	Derived	17	Yes	Yes, Launch Timeline Test
	#4: State Vector Age	Derived	18	Yes	Yes, Module-Level Test
	#5: Error Action	Derived	19	Yes	Yes, Module-Level Test
2.1.3.2	GPS Navigation Mode	- - -	- - -	- - -	- - -
	#1: GPS Navigation Mode	GNS SRD: 5.9.2	20	Yes	Yes, Functional Test
	#2: Bootup Default	Derived	21	Yes	Yes, Functional Test
	#3: Mode Entry and Exit	Derived	22	Yes	Yes, Functional Test
	#4: Mode Operation	Derived	23	Yes	Yes, Functional Test
	#5: Mode Flywheel	GNS SRD: 5.9.6	24	Yes	Yes, Functional Test
2.1.3.3	Separation Sequence Mode	- - -	- - -	- - -	- - -
	#1: Separation Sequence Mode	GNS SRD: 5.9.8	25	Yes	Yes, Functional Test
	#2: Mode Entry and Exit	Derived	26	Yes	Yes, Launch Timeline Test
	#3: Command Checks	GNS SRD: 5.9.8.1	27	Yes	Yes, Launch Timeline Test
	#4: Monitor for Separation	GNS SRD: 5.9.8.2	28	Yes	Yes, Launch Timeline Test
	#5: Mode Operation	GNS SRD: 5.9.8.2	29	Yes	Yes, Launch Timeline Test
	#6: Error Action	Derived	30	Yes	Yes, Module-Level Test
2.1.3.4	Test Modes	GNS SRD: 5.9.7	31	Yes	Yes, Functional Test
2.1.3.4.1	GPS Static Receiver Test Mode	GNS SRD: 5.4.9	32	Yes	Yes, Functional Test
2.1.3.4.2	Built-In Test Mode	- - -	- - -	- - -	- - -

GNS Software Test Verification Matrix

2.1.4	Management of the GNS to Spacecraft Comm. (PCI) Interface	- - -	- - -	- - -	- - -
2.1.4.1	Telecommand Packet Ingestion/Decoding	- - -	- - -	- - -	- - -
	#1: CCSDS Telecommand Packet	TIMED SRD: p8 of 17	33	Yes	Yes, All Tests
	#2: Packet Testing	Derived	34	Yes	Yes, Module-Level Test
	#3: Packet Size	Derived	35	Yes	Yes, Module-Level Test
	#4: Notification of the Number of Packets	Derived	36	Yes	Yes, All Tests
	#5: Maximum Number of Commands	Derived	37	Yes	Yes, Module-Level Test
2.1.4.2	Telemetry Packet Building/Transmission	- - -	- - -	- - -	- - -
	#1: CCSDS Telemetry Packet	TIMED SRD: p8 of 17	38	Yes	Yes, All Tests
	#2: Checksum	Derived	39	Yes	Yes, All Tests
	#3: Packet Size	Derived	40	Yes	Yes, All Tests
	#4: Notification of the Number of Packets	Derived	41	Yes	Yes, All Tests
2.1.4.3	Unpacketized Data Building/Transmission	Verbal	42	Yes	Yes, All Tests
2.1.4.4	Attitude Data	GNS SRD: 5.7	43	Yes	Yes, Module-Level Test
2.1.5	Management of the Navigation Processor Serial Interface	- - -	- - -	- - -	- - -
2.1.6	Executive Functions	- - -	- - -	- - -	- - -
2.1.6.1	Telecommand Packet Verification	GNS SRD: 5.10.3.1	44	Yes	Yes, Routine Operation
2.1.6.2	Command Verification	GNS SRD: 5.10.3.1	45	Yes	Yes, Routine Operation
2.1.6.3	Software Version Number	Derived	46	Yes	Yes, Routine Operation
2.1.6.4	Parameter Table Write Count	Derived	47	Yes	Yes, Routine Operation
2.1.6.5	Memory Scrubbing	Derived	48	Yes	Yes, Routine Operation
2.1.6.6	Watchdog Timer Management	Derived	49	Yes	Yes, Routine Operation
2.1.6.7	Input & Output Data Format	Derived	50	Yes	Yes, Routine Operation
2.1.7	Commands	GNS SRD: 5.9.2	51	Yes	Yes, Routine Operation
2.1.7.1	Normal Commands	- - -	- - -	- - -	- - -
2.1.7.1.1	Set GNS Time	GNS SRD: 5.3.9	52	Yes	Yes, Functional Test
2.1.7.1.2	Load GPS Almanac	GNS SRD: 5.9.8	53	Yes	Yes, Functional Test
2.1.7.1.3	Load TIMED State Vector	GNS SRD: 5.8.2	54	Yes	Yes, Functional Test
2.1.7.1.4	Load Solar Flux Data Table	GNS SRD: 5.6.2	55	Yes	Yes, Functional Test
2.1.7.1.5	Load Geomagnetic Index Data Table	GNS SRD: 5.6.2	56	Yes	Yes, Functional Test
2.1.7.1.6	Load Polar Wander Data Table	GNS SRD: 5.11.3	57	Yes	Yes, Functional Test
2.1.7.1.7	Load GPS-UT1 Data Table	GNS SRD: 5.11.3	58	Yes	Yes, Functional Test
2.1.7.1.8	Load Launch Vehicle Separation PV	- - -	- - -	- - -	- - -
	#1: State Vector	GNS SRD: 5.9.8	59	Yes	Yes, Launch Timeline Test
	#2: Coordinate System	GNS SRD: 5.9.8.1	60	Yes	Yes, Launch Timeline Test
2.1.7.1.9	Select Primary and Backup Ground Stations	GNS SRD: 5.5.8	61	Yes	Yes, Functional Test
2.1.7.1.10	Modify Ground Station Database	GNS SRD: 5.5.8	62	Yes	Yes, Functional Test
2.1.7.1.11	Modify SAA Coordinates	GNS SRD: 5.5.8	63	Yes	Yes, Functional Test
2.1.7.1.12	Modify Valid Contact Duration	GNS SRD: 5.5.8	64	Yes	Yes, Functional Test
2.1.7.1.13	Modify Contact Notification Lead/Lead Interval	- - -	- - -	- - -	- - -
	#1: Command	GNS SRD: 5.5.8	65	Yes	Yes, Functional Test
	#2: Maximum Value	Derived	66	Yes	Yes, Module-Level Test
	#3: Default Value	GNS SRD: 5.5.8	67	Yes	Yes, Module-Level Test
2.1.7.1.14	Enable Navigation Processor Memory Scrubbing	Derived	68	Yes	Yes, Functional Test
2.1.7.1.15	Enable Tracking Processor Memory Scrubbing	Derived	69	Yes	Yes, Functional Test
2.1.7.2	Contingency, Diagnostic, and Test Commands	- - -	- - -	- - -	- - -
2.1.7.2.1	Increment/Decrement GNS Time	GNS SRD: 5.3.9	70	Yes	Yes, Functional Test

GNS Software Test Verification Matrix

2.1.7.2.2	Select Navigation Mode	GNS SRD: 5.11.6	71	Yes	Yes, Functional Test
2.1.7.2.3	Load Navigation Parameter Table	GNS SRD: 5.11.3	72	Yes	Yes, Functional Test
2.1.7.2.4	Reset/Boot Tracking Processor	GNS SRD: 4.2.3.4	73	Yes	Yes, Functional Test
2.1.7.2.5	Initialize State Table	GNS SRD: 5.11.3	74	Yes	Yes, Functional Test
2.1.7.2.6	Set Process Noise Value	GNS SRD: 5.11.3	75	Yes	Yes, Functional Test
2.1.7.2.7	Enable/Disable Use of Phase Measurements	Derived	76	Yes	Yes, Functional Test
2.1.7.2.8	Enable/Disable Use of SA States	Derived	77	Yes	Yes, Functional Test
2.1.7.2.9	Change Status of Specific GPS SV's	Derived	78	Yes	Yes, Functional Test
2.1.7.2.10	Enable/Disable Use of Specific Tracking Channels	Derived	79	Yes	Yes, Functional Test
2.1.7.2.11	Enable/Disable Measurement Processing	Derived	80		Yes, Functional Test
2.1.7.2.12	Enable/Disable Navigation Processing	Derived	81	Yes	Yes, Functional Test
2.1.7.2.13	Enable/Disable Acquisition Aiding	GNS SRD: 5.9.4.1	82	Yes	Yes, Functional Test
2.1.7.2.14	Load Acquisition Aids Table	GNS SRD: 5.9.4.1	83	Yes	Yes, Functional Test
2.1.7.2.15	Enable/Disable Event Notifications	GNS SRD: 5.5.8	84	Yes	Yes, Functional Test
2.1.7.2.16	Enable/Disable Event Predictions	Derived	85	Yes	Yes, Functional Test
2.1.7.2.17	Enable/Disable Orbital Element Generation	Derived	86	Yes	Yes, Functional Test
2.1.7.2.18	Enable/Disable GPS Mode Flywheel Operation	- - -	- - -	- - -	- - -
2.1.7.2.19	Enable/Disable Diagnostic Data Output	GNS SRD: 5.10.6	87	Yes	Yes, Functional Test
2.1.7.2.20	Modify State Table Values	GNS SRD: 5.11.3	88	Yes	Yes, Functional Test
2.1.7.2.21	Modify Parameters	GNS SRD: 5.11.3	89	Yes	Yes, Functional Test
2.1.7.2.22	Memory Dump	GNS SRD: 5.11.4	90	Yes	Yes, Functional Test
2.1.7.2.23	Suspend/Resume TP Execution	- - -	- - -	- - -	- - -
2.1.8	Data Products	- - -	- - -	- - -	- - -
	#1: Stabilization Constraint	GNS SRD: 5.9.1	91	Yes	Yes, Regression Test (M.Asher)
	#2: 1 Hz Rate	GNS SRD: 5.10.3	92	Yes	Yes, Routine Operation
2.1.8.1	Realtime (1Hz) Data Products	- - -	- - -	- - -	- - -
2.1.8.1.1	Synchronization	GNS SRD: 5.3.2	93	Yes	Yes, Time Correlation Test
2.1.8.1.2	Valid Data Latency	- - -	- - -	- - -	- - -
	#1: 10 min after TTFF	GNS SRD: 5.4.7	94	Yes	Yes, Functional Test
	#2: 10 hrs after TTFF	GNS SRD: 5.4.7	95	Yes	Yes, Functional Test
2.1.8.1.3	Position	- - -	- - -	- - -	- - -
2.1.8.1.3.1	Coordinate System	- - -	- - -	- - -	- - -
	#1: CTS Coordinate System	GNS SRD: 5.4.3	96	Yes	Yes, Routine Operation
	#2: CIS Coordinate System	GNS SRD: 5.4.4	97	Yes	Yes, Routine Operation
2.1.8.1.3.2	Uncertainty	GNS SRD: 5.4.7	98	Yes	Yes, Regression Test (M.Asher)
2.1.8.1.3.3	Data Types	- - -	- - -	- - -	- - -
	#1: Signed/Unsigned Integers	Verbal	99	Yes	Yes, Routine Operation
	#2: Double-Precision Floats	Verbal	100	Yes	Yes, Routine Operation
2.1.8.1.4	Velocity	- - -	- - -	- - -	- - -
2.1.8.1.4.1	Coordinate System	- - -	- - -	- - -	- - -
	#1: CTS Coordinate System	GNS SRD: 5.4.3	101	Yes	Yes, Routine Operation
	#2: CIS Coordinate System	GNS SRD: 5.4.4	102	Yes	Yes, Routine Operation
2.1.8.1.4.2	Uncertainty	- - -	- - -	- - -	- - -
	#1: 10 min after TTFF	GNS SRD: 5.4.7	103	Yes	Yes, Regression Test (M.Asher)
	#2: 10 hrs after TTFF	GNS SRD: 5.4.7	104	Yes	Yes, Regression Test (M.Asher)
2.1.8.1.4.3	Data Types	- - -	- - -	- - -	- - -
	#1: Signed Integers	Verbal	105	Yes	Yes, Routine Operation

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	#2: Double-Precision Floats	Verbal	106	Yes	Yes, Routine Operation
2.1.8.1.5	Time	- - -	- - -	- - -	- - -
2.1.8.1.5.1	Format	GNS SRD: 5.3.6	107	Yes	Yes, Routine Operation
2.1.8.1.5.2	Uncertainty	GNS SRD: 5.4.7	108	Yes	Yes, Time Correlation Test
2.1.8.1.6	Sun Vector	- - -	- - -	- - -	- - -
2.1.8.1.6.1	Coordinate System	- - -	- - -	- - -	- - -
	#1: Signed Integers	GNS SRD: 5.4.5	109	Yes	Yes, Routine Operation
	#2: Double-Precision Floats	GNS SRD: 5.4.5	110	Yes	Yes, Routine Operation
	#3: Signed Integers	GNS SRD: 5.4.5	111	Yes	Yes, Regression Test (M.Asher)
2.1.8.1.6.2	Uncertainty	GNS SRD: 5.4.7	112	Yes	Yes, Regression Test (M.Asher)
2.1.8.1.6.3	Data Types	Derived	113	Yes	Yes, Routine Operation
2.1.8.1.7	Event Occurrence Notification	- - -	- - -	- - -	- - -
2.1.8.1.7.1	Terminator Crossing Notification	- - -	- - -	- - -	- - -
	#1: Uncertainty	GNS SRD: 5.5.2.2	114	Yes	Yes, Regression Test (M.Asher)
	#2: Flag Notification	GNS SRD: 5.5.2.1	115	Yes	Yes, Routine Operation
	#3: Defined Flag Values	GNS SRD: 5.5.2.1	116	Yes	Yes, Routine Operation
	#4: Flag Transition	GNS SRD: 5.5.2.3	117	Yes	Yes, Routine Operation
2.1.8.1.7.2	South Atlantic Anomaly Notification	- - -	- - -	- - -	- - -
	#1: Uncertainty	GNS SRD: 5.5.3.3	118	Yes	Yes, Regression Test (M.Asher)
	#2: Flag Notification	GNS SRD: 5.5.3.1	119	Yes	Yes, Routine Operation
	#3: Defined Flag Values	GNS SRD: 5.5.3.1	120	Yes	Yes, Routine Operation
2.1.8.1.7.3	Polar Region Notification	- - -	- - -	- - -	- - -
	#1: Uncertainty	Verbal	121	Yes	Yes, Regression Test (M.Asher)
	#2: Flag Notification	Verbal	122	Yes	Yes, Routine Operation
	#3: Defined Flag Values	Verbal	123	Yes	Yes, Routine Operation
2.1.8.1.7.4	Ground Station Contacts	- - -	- - -	- - -	- - -
2.1.8.1.7.4.1	Ground Station Coordinates	- - -	- - -	- - -	- - -
	#1: Number of Ground Stations	GNS SRD: 5.5.1.3	124	Yes	Yes, Functional Test
	#2: Primary and Backup Stations	GNS SRD: 5.5.1.2	125	Yes	Yes, Functional Test
	#3: Changes	GNS SRD: 5.5.1.2	126	Yes	Yes, Functional Test
2.1.8.1.7.4.2	Contact Notification	- - -	- - -	- - -	- - -
	#1: Notification	GNS SRD: 5.5.1.1	127	Yes	Yes, Regression Test (M.Asher)
	#2: Uncertainty	GNS SRD: 5.5.1.5	128	Yes	Yes, Regression Test (M.Asher)
	#3: Timing	GNS SRD: 5.5.1.6	129	Yes	Yes, Regression Test (M.Asher)
	#4: Flag Notification	GNS SRD: 5.5.1.1	130	Yes	Yes, Routine Operation
	#5: Defined Flag Values	GNS SRD: 5.5.1.1	131	Yes	Yes, Routine Operation
2.1.8.1.8	Leap Seconds	- - -	- - -	- - -	- - -
2.1.8.1.9	Data Quality Indicators	- - -	- - -	- - -	- - -
2.1.8.1.9.1	Data Validity Flags	GNS SRD: 5.4.10	132	Yes	Yes, Routine Operation
2.1.8.1.9.2	Data Figure of Merit Values	GNS SRD: 5.4.10	133	Yes	Yes, Routine Operation
2.1.8.1.10	Realtime Data Mode Indicators	- - -	- - -	- - -	- - -
2.1.8.1.10.1	Mode Flag	GNS SRD: 5.4.10	134	Yes	Yes, Routine Operation
2.1.8.1.10.2	Flywheel Flag	GNS SRD: 5.4.10	135	Yes	Yes, Routine Operation
2.1.8.1.11	Time Precision Indicators	- - -	- - -	- - -	- - -
2.1.8.1.11.1	Raw Time Flag	GNS SRD: 5.3.11	136	Yes	Yes, Routine Operation
2.1.8.1.11.2	Coarse Time Flag	GNS SRD: 5.3.11	137	Yes	Yes, Routine Operation
2.1.8.1.11.3	Semi-Coarse Time Flag	- - -	- - -	- - -	- - -

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2.1.8.1.11.4	Precision Time Flag	GNS SRD: 5.3.11	138	Yes	Yes, Routine Operation
2.1.8.1.11.5	Time Jump Flag	GNS SRD: 5.3.4	139	Yes	Yes, Routine Operation
2.1.8.1.12	Receiver Channel Tracking Status	GNS SRD: 5.10.6	140	Yes	Yes, Routine Operation
2.1.8.1.13	Receiver AGC Functionality Status	GNS SRD: 5.10.3	141	Yes	Yes, Routine Operation
2.1.8.2	Prediction Data Products	---	---	---	---
2.1.8.2.1	Ground Station Contact Prediction Table	---	---	---	---
	#1: Every 12 Hours	GNS SRD: 5.5.4	142	Yes	Yes, Prediction Products Test (R.DeBolt)
	#2: Uncertainty	GNS SRD: 5.5.4	143	Yes	Yes, Prediction Products Test (R.DeBolt)
	#3: 60 Hour Propagation	GNS SRD: 5.5.4	144	Yes	Yes, Prediction Products Test (R.DeBolt)
	#4: 15 Valid Contacts	GNS SRD: 5.5.4	145	Yes	Yes, Prediction Products Test (R.DeBolt)
2.1.8.2.2	South Atlantic Anomaly Encounter Prediction Table	---	---	---	---
	#1: Every 12 Hours	GNS SRD: 5.5.4	146	Yes	Yes, Prediction Products Test (R.DeBolt)
	#2: Uncertainty	GNS SRD: 5.5.4	147	Yes	Yes, Prediction Products Test (R.DeBolt)
	#3: 60 Hour Propagation	GNS SRD: 5.5.4	148	Yes	Yes, Prediction Products Test (R.DeBolt)
	#4: 15 Valid Contacts	GNS SRD: 5.5.4	149	Yes	Yes, Prediction Products Test (R.DeBolt)
2.1.8.2.3	Ground Station Contact Orbital Element Sets	---	---	---	---
	#1: Every 12 Hours	GNS SRD: 5.6.1	150	Yes	Yes, Regression Test (M.Asher)
	#2: NORAD Format	GNS SRD: 5.6.1	151	Yes	Yes, Regression Test (M.Asher)
	#3: For SGP4	Verbal	152	Yes	Yes, Regression Test (M.Asher)
	#4: Maximum 4 km Error	GNS SRD: 5.6.2	153	Yes	Yes, Regression Test (M.Asher)
	#5: 36 Hours in Advance	GNS SRD: 5.6.2	154	Yes	Yes, Regression Test (M.Asher)
2.1.8.2.4	Predicted Data Mode Indicators	---	---	---	---
2.1.8.2.4.1	Mode Flag	---	---	---	---
2.1.8.2.4.2	Flywheel Flag	---	---	---	---
2.1.8.3	Diagnostic Data Products	Derived	155	Yes	Yes, Routine Operation
2.1.9	Management of the 1PPS Interface	---	---	---	---
2.1.9.1	Oscillator Drift Rate Correction	---	---	---	---
	#1: Resolution	GNS SRD: 5.8.4	156	Yes	Yes, Routine Operation
	#2: From NP to TP to GTA	Derived	157	Yes	Yes, Routine Operation
2.1.9.2	1PPS Steering	---	---	---	---
	#1: Align with UTC	GNS SRD: 5.3.2	158	Yes	Yes, Time Correlation Test
	#2: Maximum Error	GNS SRD: 5.3.2	159	Yes	Yes, Time Correlation Test
	#3: Unperturbed in Non-GPS Navigation Mode	GNS SRD: 5.8.3	160	Yes	Yes, Time Correlation Test
2.1.9.3	1PPS Jumps	---	---	---	---
	#1: Extend 1PPS up to 1 second	GNS SRD: 5.3.4	161	Yes	Yes, Time Jump Notification Test
	#2: Time Jump Flag	GNS SRD: 5.3.4	162	Yes	Yes, Time Jump Notification Test
	#3: One-Time Event Upon Power-up	GNS SRD: 5.3.4	163	Yes	Yes, Time Jump Notification Test
2.1.10	Management of Navigation Proc. to Tracking Proc. Interface	---	---	---	---
2.1.10.1	Reset/Boot of the Tracking Processor	---	---	---	---
	#1: Reboot Tracking Processor	GNS SRD: 4.2.3.4	164	Yes	Yes, Functional Test
	#2: Transfer Application Software from NP to TP	Derived	165	Yes	Yes, Routine Operation
2.1.10.2	Data Inputs	---	---	---	---
2.1.10.2.1	MIC Counter	Derived	166	Yes	Yes, Routine Operation
2.1.10.2.2	Raw Tracking Data	---	---	---	---
	#1: Input Data	Derived	167	Yes	Yes, Routine Operation
	#2: Process Data	Derived	168	Yes	Yes, Routine Operation
2.1.10.2.3	GPS Message Subframes	---	---	---	---

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	#1: Validated Subframes	Derived	169	Yes	Yes, Routine Operation
	#2: Input Frames	Derived	170	Yes	Yes, Routine Operation
2.1.10.2.4	Tracking Channel Status	Verbal	171	Yes	Yes, Routine Operation
2.1.10.2.5	CPU Heartbeat	Derived	172	Yes	Yes, Routine Operation
2.1.10.3	Data Outputs	---	---	---	---
2.1.10.3.1	Acquisition Aids	---	---	---	---
	#1: Acquisition Aids	GNS SRD: 5.9.4.1	173	Yes	Yes, Routine Operation
	#2: Sky-Search SV List	Derived	174	Yes	Yes, Routine Operation
2.1.10.3.2	Disabled SV List	---	---	---	---
	#1: Disabled SV List	Derived	175	Yes	Yes, Routine Operation
	#2: Not Use Disabled SVs	Derived	176	Yes	Yes, Routine Operation
2.1.10.3.3	Disabled GTA Channel List	---	---	---	---
	#1: Disabled Channel List	Derived	177	Yes	Yes, Routine Operation
	#2: Not Use Disabled Channels	Derived	178	Yes	Yes, Routine Operation
2.1.10.3.4	MIC Register Value	Derived	179	Yes	Yes, Routine Operation
2.1.10.3.5	Software Execution Suspend/Resume Flag	---	---	---	---
2.1.10.3.6	Memory Scrub Flag	Derived	180	Yes	Yes, Module-Level Test
2.1.11	GPS Ephemeris and Almanac Builder	---	---	---	---
	#1: Ephemeris	Derived	181	Yes	Yes, Routine Operation
	#2: Almanac	Derived	182	Yes	Yes, Routine Operation
2.1.12	Clock Management	---	---	---	---
2.1.12.1	GPS Clock	---	---	---	---
	#1: CUC Format	Derived	183	Yes	Yes, Routine Operation
	#2: Set/Incr/Decr Clock	GNS SRD: 5.3.9	184	Yes	Yes, Functional Test
	#3: Unperturbed in Non-GPS Navigation Mode	GNS SRD: 5.8.3	185	Yes	Yes, Functional Test
2.1.12.2	GNS Uptime Clock	Derived	186	Yes	Yes, Routine Operation
2.1.13	GNS Memory for Data Storage	---	---	---	---
2.1.13.1	Non-Volatile Memory	GNS SRD: 5.9.13	187	Yes	Yes, Routine Operation
2.1.13.2	Protected Memory	---	---	---	---
2.1.14	System Integrity Monitor	---	---	---	---
2.1.15	GPS Data Integrity Monitor	GNS SRD: 5.9.9	188	Yes	Yes, Routine Operation
2.2	Tracking Processor	---	---	---	---
2.2.1	Autonomy	Derived	189	Yes	Yes, Routine Operation
2.2.2	Major Functions	---	---	---	---
2.2.2.1	SV Code and Carrier Tracking	GNS SRD: 5.2.3.2	190	Yes	Yes, Routine Operation
2.2.2.2	Tracking Channel Allocation	Derived	191	Yes	Yes, Routine Operation
2.2.2.3	SV Acquisition and Tracking	GNS SRD: 5.9.3.1	192	Yes	Yes, Routine Operation
2.2.2.4	GPS Message Subframe Builder	---	---	---	---
	#1: Bit and Frame Synchronization	Derived	193	Yes	Yes, Routine Operation
	#2: Parity Checks	Derived	194	Yes	Yes, Routine Operation
2.2.3	Modes of Operation	---	---	---	---
2.2.3.1	Sky Search Mode	GNS SRD: 5.9.3.1	195	Yes	Yes, Routine Operation
2.2.3.2	Aided Search Mode	GNS SRD: 5.9.4.1	196	Yes	Yes, Routine Operation
2.2.3.3	Built-In Test Mode	---	---	---	---
2.2.4	Management of Tracking Proc. to Navigation Proc. Interface	---	---	---	---
2.2.4.1	Data Inputs	---	---	---	---
2.2.4.1.1	Acquisition Aids	---	---	---	---

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	#1: Acquisition Aids	GNS SRD: 5.9.4.1	197	Yes	Yes, Routine Operation
	#2: Channel Assignments	Derived	198	Yes	Yes, Module-Level Test
2.2.4.1.2	Disabled SV List	---	---	---	---
	#1: Disabled SV List	Derived	199	Yes	Yes, Routine Operation
	#2: Not Use Disabled SVs	Derived	200	Yes	Yes, Routine Operation
2.2.4.1.3	Disabled GTA Channel List	---	---	---	---
	#1: Disabled Channel List	Derived	201	Yes	Yes, Routine Operation
	#2: Not Use Disabled Channels	Derived	202	Yes	Yes, Routine Operation
2.2.4.1.4	MIC Register Value	Derived	203	Yes	Yes, Routine Operation
2.2.4.1.5	Software Execution Suspend/Resume Flag	---	---	---	---
2.2.4.1.6	Memory Scrub Flag	Derived	204	Yes	Yes, Module-Level Test
2.2.4.2	Data Outputs	---	---	---	---
2.2.4.2.1	MIC Counter	---	---	---	---
	#1: MIC Counter	Derived	205	Yes	Yes, Routine Operation
	#2: No Rollover	Derived	206	Yes	Computed
2.2.4.2.2	Raw Tracking Data	Derived	207	Yes	Yes, Routine Operation
2.2.4.2.3	GPS Message Subframes	---	---	---	---
	#1: Validated Subframes	Derived	208	Yes	Yes, Routine Operation
	#2: Output Frames	Derived	209	Yes	Yes, Routine Operation
2.2.4.2.4	Tracking Channel Status	Verbal	210	Yes	Yes, Routine Operation
2.2.4.2.5	CPU Heartbeat	Derived	211	Yes	Yes, Routine Operation
2.2.5	Management of Tracking Processor Serial Interface	---	---	---	---
2.2.6	Management of Tracking Hardware (GTA)	---	---	---	---
	#1: 12 Tracking Channels	Derived	212	Yes	Yes, Routine Operation
	#2: Read Data at 1 Hz	Derived	213	Yes	Yes, Routine Operation
2.2.7	Memory Scrubbing	Derived	214	Yes	Yes, Module-Level Test
2.3	Miscellaneous Requirements	---	---	---	---
2.3.1	Software Reprogrammability	GNS SRD: 5.9.10	215	Yes	Yes, MOC Tests
2.3.2	Simultaneous Receiver Channels	GNS SRD: 5.2.3.2	216	Yes	Yes, Routine Operation
2.3.3	Low Earth Orbit Signal Dynamics	GNS SRD: 5.2.3.4	217	Yes	Yes, Routine Operation
2.3.4	Loss of Signal	GNS SRD: 5.3.10	218	Yes	Yes, Routine Operation
2.3.5	GNS Time Set and Transfer at Power-Up	---	---	---	---
	#1: Initial Value	GNS SRD: 5.3.8	219	Yes	Yes, Routine Operation
	#2: Number of Integer Seconds	GNS SRD: 5.3.8	220	Yes	Yes, Routine Operation
2.3.6	Pulse-to-Pulse GPS 1PPS Epoch Stability	GNS SRD: 5.3.5	221	Yes	Yes, Time Correlation Test

GNS Software Build Timeline

Date	Software Build #	NP Ver. #	TP Ver. #	CP Ver. #	NCP Ver. #	Release Interval (Days)	Changes/ SPR #	SPR Status	Type	Comments
10/19/98							27	Closed	H/W Workaround	To preserve reset cause for non-master reset
3/10/99	**Build 2.02**	**2.02**	**N/A**	**N/A**	**N/A**					**[INITIAL SPACECRAFT RELEASE] Provided Non-GPS Navigation (i.e. SV propagation)**
3/10/99							72	Closed	O.S. Fix	For Nucleus+ to save FPU context when switching tasks
3/11/99							74	Closed	Bug Fix	For Command Handler Task to recognize TCmd packets for IEM #2 (Unable to test with/EM)
							Rel. Notes		Enhancement	To improve the mechanism for setting the spacecraft time (i.e. 3 minute delay eliminated)
							Rel. Notes		Bug Fix	To correct the execution of the TP Antenna Select command
							Rel. Notes		Enhancement	To eliminate potential problem due to commanding a new GNS time
							Rel. Notes		Bug Fix	To correct the time precision change threshold
							Rel. Notes		Gnd S/W Workaround	To modify the GNS logical memory dump structure to replicate the structure ID
3/15/99	Build 2.03	2.03	N/A	N/A	N/A	5				
3/15/99							79	Closed	Bug Fix	For Tlm Output Task to mark Tlm packets correctly for IEM #2 (Unable to test w/EM)
3/16/99	Build 2.04	2.04	N/A	N/A	N/A	1				
6/2/99	**Build 3.00**	**3.00**	**3.00**	**N/A**	**N/A**	**78**				**Provided full GPS navigation & prediction products. Added the following:**
										Flash task, Delayed MIC task, Prediction task, and Message Handler task. In addition,
										reorganized software structure.
							Rel. Notes		Bug Fix	To correct clearing of tracking data when tracking is lost
							Rel. Notes		Bug Fix	To correct the execution of Load Acquisition Aids command
							Rel. Notes		Added Functionality	To add (9) commands intended to be included with Build 3.00
							Rel. Notes		Added Functionality	To add the capability to navigate in static mode (navigating antenna on roof)
							Rel. Notes		Added Functionality	To complete flash memory functionality
							Rel. Notes		Added Functionality	To add the capability to load default data from flash in order to easily deal with a bad upload
							Rel. Notes		Added Functionality	To modify the interpretation of the 16-bit channel dataword to initially provide tracking info
							Rel. Notes		Added Functionality	To change the memory dump address range to include the entire SPEC0 address range
							Rel. Notes		Added Functionality	To update the error code list
							Rel. Notes		Added Functionality	To widen the defined valid time range
6/14/99	Build 3.01	3.01	3.01	N/A	N/A	12				
6/15/99							150	Closed	Bug Fix	To look at correct bit for +12v status from C&DH (Unable to test w/EM)
6/27/99	**Build 4.00**	**4.00**	**4.00**	**0.00**	**0.00**	**13**				**Provided complete GNS functionality. Added the following:**
										EDAC capability, memory scrub task, capability to stop/restart individual tasks,
										capability to load TP with initial parameter values, clear parameter value command,
										enhanced memory dump capability, TP heartbeat processing in Delayed MIC task,
										improved KF task error codes, capability to handle TP errors and memory scrub data.
										Restructured the task handling to move Telemetry Builder, Telemetry Output,
										Command Handler and Delayed MIC tasks into Timer2 HISR.
8/5/99							179	Closed	Bug Fix	To correct handling of GN_TURN_ATT_SV command
							Rel. Notes		Bug Fix/Enhancement	*Build 4.00 was delivered to the spacecraft prior to completion of subsystem build testing*
										and optimization so that spacecraft testing could occur in parallel, resulting in a
										large number of software changes. This was anticipated as noted in the Build 4.00
										release notes. The need for approximately (70) NP and (11) TP optimizations or
										bug fixes were all determined by ongoing subsystem testing and not by spacecraft
										testing. For descriptions of the changes, see Build 4.01 release notes
8/5/99	Build 4.01	4.01	4.01	0.00	0.00	39				
							Rel. Notes		Bug Fix	To correct handling of (6) commands

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							Rel. Notes		Enhancement	To improve handling of the abort/restart command
							Rel. Notes		Enhancement	To improve memory scrub mechanism
							Rel. Notes		Enhancement	To disable the 'write to protected flash segment' flag after every flash operation
							Rel. Notes		KF Tuning	To modify the velocity process noise value (e-12 to e-9) to correct an error growth problem
9/9/99	Build 4.02	4.02	4.01	0.01	0.01	35				
							Rel. Notes			Modified GPS Ephemeris and Almanac week dependence
9/13/99	Build 4.03	4.03	4.01	0.01	0.01	4				
							Rel. Notes		Bug Fix	To correct handling of MIC counts
							Rel. Notes		Bug Fix	To correct setting of EDAC enable bit during Flash programming
							Rel. Notes		Bug Fix	To fix the command which loads the polar region latitude value
							Rel. Notes		Bug Fix	To correct DStore12 reference values upon startup & change function name
							Rel. Notes		Enhancement	Improved reinitialization handling flags
							Rel. Notes		Enhancement	To reduce the delay for generating prediction products after a reset
							Rel. Notes		Bug Fix	To modify DRAM and SPEC0 Mongoose configuration registers
							Rel. Notes		Bug Fix	To correct end-of-GPS-week tracking problem related to rejection of bad subframes
							Rel. Notes		Bug Fix	To correct the coordinates of Pretoria, South Africa ground stations
							Rel. Notes		Enhancement	To optimize the frequency process noise value
							Rel. Notes		Enhancement	To add Flash Write Enable command for Flash erase or write operations.
10/7/99	Build 4.04	4.04	4.01	0.02	0.02	24				
10/25/99							315	Closed	Bug Fix	To prevent a floating point exception due to low eccentricity orbits
10/28/99							324	Closed	Bug Fix	To have Flash write operations use non-cacheable address space
							Rel. Notes		Enhancement	To ensure EDAC parity is disabled during Flash write operations
							Rel. Notes		Bug Fix	To sleep for 1 second after Separation Sequence initialization
11/16/99	Build 4.05	4.05	4.01	0.02	0.02	40				
1/13/00							378	Closed	Operations Constraint	Reset of NP during a Flash memory write operation is to be avoided
2/11/00							404	Closed	Bug Fix	To correct two time related conversions in the orbital elements generation
2/12/00							417	Closed	Bug Fix	To correct Prediction Task index to point to primary ground station, not backup
2/12/00							418	Closed	Bug Fix	To eliminate a 6-second error in the Prediction Task products
							Rel. Notes		Bug Fix	Corrected Acquisition Aids time tag
							Rel. Notes		Enhancement	Orbital element set generation to use data store info and not hard-coded values
							Rel. Notes		Bug Fix	Corrected orbital element set generation to use the correct reference frame
							Rel. Notes		Requirements Change	To remove the Telecommand packet sequence error notification
							Rel. Notes		Requirements Change	To relocate an unpacketized data parameter into cross-strapped data
							Rel. Notes		Enhancement	To add Flash Task Active bit to unpacketized telemetry
							Rel. Notes		Enhancement	To delay LTP for 5 (was 3) KF cranks to improve LTP products
2/16/00	Build 4.06	4.06	4.01	0.02	0.02	92				
2/21/00							429	Closed	Bug Fix	To correct the ground station contact rise/set lead time flag
2/23/00							430	Closed	Enhancement	To eliminate an application opcodes conflict with boot code opcodes
6/22/00							481	Closed	Enhancement	To improve acquisition time (set time to within 1 second with 1 SV in track)
6/29/00							486	Closed	Enhancement	Duplicate of SPR #430
6/29/00							487	Closed	Bug Fix	To correct handling of almanac health information
6/29/00							488	Closed	Bug Fix	To correct phase bias portion of H matrix when SA states are turned off
7/27/00							497	Closed	Enhancement	To filter zeta parameter values which would cause a divide by 0 exception
7/27/00							498	Closed	Bug Fix	To correct a problem if a measurement is taken at the week boundary (seconds = 0)
7/27/00							499	Closed	Enhancement	To add process noise capability to the phase bias states
7/27/00							500	Closed	Enhancement	To improve acquisition time (save frequency bias)
7/27/00							501	Closed	Bug Fix	To increase delay time to 5 seconds before KF enters its initialization loop

GNS Software Build Timeline

8/2/00	Build 4.07	4.07	4.01	0.02	0.02	168				
8/22/00							508	Closed	Bug Not Corrected	FOM's rollover from 255 to 0, instead of holding at 255
9/20/00							541	Closed	Bug Not Corrected	A 1-second (late) delay exists in the Time Jump Notification Flag
10/2/00	Build 4.07.1	4.07	4.01	0.02	0.02	61				Miscellaneous Parameter Tuning (by command) - 11 parameters changed

AAChacos 9/1/00

Compilation of GPS Navigation System (GNS) Software-Related Action Items and Responses

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Mini-CoDR (6/29/96)

No Software-Related Action Items

Program Status Review (10/15/96)

No Software-Related Action Items

Mission PDR (2/18/97)

(2) Software-Related Action Items

MPDR Action Item #4 (for D. Duven)

The spacecraft center-of-mass is physically separated from the phase centers of the GPS antennas by the order of 1 meter. The GPS measurements are referenced to the phase centers, but it is the C-M that follows the orbit. Does the GPS Kalman filter need to account for this separation, to avoid unnecessary error growth when propagating the orbit?

Action Item #4 Response (by D. Duven)

See memo SRM-97-016 dated 5/1/97

MPDR Action Item #19 (G. Cameron)

Two orbit prediction accuracy requirements were stated: 1) predict future passes to < 5 seconds (chart WSD-6), 2) < 1km uncertainty for future (next 12 passes) planning cycle (chart WSD-7). Are these requirements tighter than necessary for planning purposes? Are these requirements consistent with the knowledge requirement of 0.25m/sec? Won't an orbit state propagated with this velocity error exceed 1km in one orbit? Can the GPS requirements be better defined so that they are self-consistent and the minimum required?

Action Item #19 Response (by G. Cameron)

See memo GEC-97-09 dated 10/31/97

Software Requirements Review (11/17/97)

(13) Software-Related Action Items

SRR Action Item #1 (for A. Chacos)

Memory mapping of SRAM. In H/W-S/W Interface Document, update sections 2.1.1.2.3 and 2.1.3.2.3 to reflect new mapping of SRAM into DRAM memory space. Also, update sections 2.2.4.1.3 and 2.2.7.2.5.

SRR Action Item #1 Response (by A. Chacos)

The document was renamed to GNS Software Internal ICD (7363-9348) after the initial release indicated above. In subsequent releases, the specified corrections were made.

SRR Action Item #2 (for A. Chacos)

Resets. Reference 2.1.1.2.1 of H/W-S/W Interface Document. The data written to the watchdog timer register is important – it must be a specific value.

SRR Action Item #2 Response (by A. Chacos)

The GNS Software Internal ICD (7363-9348) section 2.1.2.1 indicates that the value of 0x965A is to be used. It was confirmed that this value is being used in the Navigation Processor software. (\cmd_tlm\c\gnsmain.c(154): MG5_WATCHDOG = 0x965A)

SRR Action Item #3 (for A. Chacos)

Protected memory. Consider keeping three copies of all parameters stored in protected memory, and doing a majority vote on these copies after a soft reset.

SRR Action Item #3 Response (by A. Chacos)

The software design was changed which made this issue no longer applicable (i.e. no protected memory and no soft resets). Nevertheless, the GNS parameters are separated into two distinct groups (non-critical and critical), and each has their own dedicated Flash segment. In addition, there is a second copy of these two Flash segments and either pair can be designated for use by the application software. After reset, the parameter data is copied from Flash into SRAM, and a number of checksums are run on the data and the results are placed in DS 5 which can be downlinked using a logical memory dump and the expected values can be alarmed if desired.

SRR Action Item #4 (for A. Chacos)

Consider modifying the command structures such that the commands require no prior knowledge of the configuration.

SRR Action Item #4 Response (by A. Chacos)

This action item was prompted by the implementation of a telemetry packet selection command which was eliminated from the software design. None of the other ~60 commands have this potential problem in their syntax.

SRR Action Item #5 (for M. Packard, A. Chacos, and M. Asher)

Verify the ELSET telemetry packet has all needed variables for a ground ELSET.

SRR Action Item #5 Response (by M. Packard)

The ELSETS for ground tracking require an epoch, mean motion or semi-major axis, eccentricity, inclination, argument of perigee, right ascension of ascending node, and mean or true anomaly. The GNS puts all this information out in packetized telemetry for each contact.

SRR Action Item #6 (for A. Chacos)

Tagging individual bits representing telemetry packet enable/disable. Suggestion: define "modes" for the GNS telemetry states. If you have nominal configurations for the GNS telemetry outputs, define which APIDs are involved in that mode and have a command to enter that mode. This way, a single command would turn on the correct APIDs without ground management. For instance: Set nominal mode; Set diagnostic mode, etc. You would probably want these modes to be mutually exclusive.

SRR Action Item #6 Response (by A. Chacos)

This action item was prompted by the implementation of a telemetry packet selection command which was eliminated from the software design. Three telemetry packet output modes are defined in the GNS External ICD (7363-9332), Figures 8-10:

Hi-Rate (5.5 Pkts/sec): For Navigation Processor and Tracking Processor diagnostic purposes
Med-Rate (2.5 Pkts/sec): For Navigation Processor diagnostic purposes
Lo-Rate (0.5 Pkts/sec): For normal mission operations

SRR Action Item #7 (for A. Chacos)

Telemetry packet checksum. Please consider adding a 16-bit XOR checksum to Telemetry packets to be consistent with G&C and C&DH.

SRR Action Item #7 Response (by A. Chacos)

The checksum was added. See GNS External ICD (7363-9332), Figure 5.

SRR Action Item #8 (for A. Chacos)

Status telemetry. Each IEM will produce a status to send to the other IEM. GNS status will be included in this. Please identify roughly twelve bytes of your status that you wish to be included in this.

SRR Action Item #8 Response (by A. Chacos)

(7) bytes of cross-strap data was defined. See GNS External ICD (7363-9332), Figure 4.

SRR Action Item #9 (for A. Chacos)

For GNS testing is it possible to command GNS to terminate heartbeat toggling? This would then indicate to the C&DH that the GNS is malfunctioning.

SRR Action Item #9 Response (by A. Chacos)

At the time of the design review, it was not possible to terminate the heartbeat for testing. A command was subsequently added to provide this capability. See GNS External ICD (7363-9332), Section 3.4.2 Enable/Disable NP Actions.

SRR Action Item #10 (for A. Chacos)

Since the 12 hour processing is not able to be kicked off by command, how can these processes be tested? How can these products be generated and compared?

SRR Action Item #10 Response (by A. Chacos)

At the time of the design review, it was not possible to initiate this processing by command for testing. A command was subsequently added to provide this capability. See GNS External ICD (7363-9332), Section 3.4.16 Abort/Restart of Prediction Processing. However, there are constraints on when the processing will start since the software is designed such that the processing is synchronous with contact clusters so that the generated data will be written to the SSR just prior to the first pass of a cluster.

SRR Action Item #11 (for A. Chacos)

In 2.1.7.1.13 in the Software Requirements Specification, consider not making the contact notification lead/lag interval symmetric. It is typical to watch the contact shut down properly while still in view, but come over the hill fully transmitting.

SRR Action Item #11 Response (by A. Chacos)

The SRS does not imply that they are symmetric -- they are, in fact, commanded separately. See GNS External ICD (7363-9332), Section 3.3.9 Set Contact Event Notification Lead Intervals.

SRR Action Item #12 (for A. Chacos, R. Nordeen, and R. Harvey)

Consider allowing the State Vector Time of Validity to be up to 24 hours old and perform the propagation on-board the S/C instead of the ground. This implies a trade-off between the accuracy of the ground vs. on-board propagators. If they are the same, it seems like it should be done on-board to remain in line with the reduction in ground operations complexity.

SRR Action Item #12 Response (by A. Chacos)

The propagator used in the GNS is a high-fidelity propagator and was provided by the GNS developers to the Mission Data Center for use in their mission planning. The GNS has a Long-Term Propagation (LTP) task which propagates out every 12 hours for 60 hours looking for ground contacts and SAA encounters. For every ground contact, a set of orbital elements is generated. These element sets, along with the ground contact and SAA info, is sent to the SSR for subsequent downlinking.

SRR Action Item #13 (for A. Chacos)

Software/Hardware Interface Document: Correct paragraph 2.1.2.1.3 with proper addresses. Correct paragraphs 2.1.3.1.3, 2.1.5.1.2, 2.1.7.3, and 2.2.5.3.

SRR Action Item #13 Response (by A. Chacos)

The document was renamed to GNS Software Internal ICD (7363-9348) after the initial release indicated above. In subsequent releases, the specified corrections were made.

Software PDR (11/17/97)

(16) Software-Related Action Items

SPDR Action Item #14 (for L. Linstrom)

Can the FLL lock onto message sidebands during strong S/N conditions? What action is taken?

SPDR Action Item #14 Response (by L. Linstrom)

The tracking software actually has a mode that tests for likely sideband lock-up and chooses the strongest signal before running the FLL.

SPDR Action Item #15 (for L. Linstrom)

Consider setting selected filter coefficients to unity to enhance speed. Also, investigate if simpler forward (reverse) integrator will suffice (as opposed to trapezoidal).

SPDR Action Item #15 Response (by L. Linstrom)

The current gains are all powers of two that are implemented with shift instructions. The trapezoidal integrator is not much more significant computation then the forward (or reverse) integrator. Reducing control overhead would provide a much bigger pay-off in enhancing the software performance.

SPDR Action Item #16 (for L. Linstrom)

Consider alternate algorithms for code and carrier lock monitors to enhance computation speed, e.g. replace divide by 1/x look-up and fast multiply.

SPDR Action Item #16 Response (by L. Linstrom)

Lock-monitors run so infrequently that there is only a limited pay-off in optimizing them for speed. Unlike many older flight processors, the Mongoose V has a hardware divide instruction so the 1/x table look-up was not used.

SPDR Action Item #17 (for L. Linstrom)

The carrier NCO delta word includes the Doppler due to SV-to-tracker dynamics, the nominal zero Doppler frequency (1.405 MHz) and the oscillator offset multiplied up to 1575 MHz. If the oscillator is off by 1 Hz (from 10 MHz) the measured Doppler will be off by ~1540 Hz and the local code rate by ~1 chip/sec. I believe that because of the Doppler inversion, the polarity with which the two Doppler components (real dyanmics and the oscillator) affect the delta range is the same (i.e., by applying 1/1540 of the measured Doppler, the oscillator effect on the pseudorange is also removed). You may want to double check to ensure that the code loop is not aided –2x the oscillator error if the SIGN happens to be opposite.

SPDR Action Item #17 Response (by L. Linstrom)

The sign is the same as used by other receivers with the same frequency plan.

SPDR Action Item #18 (for L. Linstrom)

The sample clock (5.7… MHz), which is effectively the time standard of the tracker, is not an even number and although small, will result in pseudorange bias that accumulates over time. Since it will be common to all satellites that are initialized simultaneously, it will become part of the clock error solution. When a satellite is newly acquired, its pseudorange will not have the same accumulated bias. Will this be compensated for, and if not, how much difference would it make?

SPDR Action Item #18 Response (by L. Linstrom)

The clock has a nominal 175ns period, so even though the frequency is not an even number, the tracker keeps track using multiples of the period.

SPDR Action Item #19 (for L. Linstrom)

If there is message bit sync false-lock, most likely due to low signal level, the carrier loop will still achieve phase lock and able to decode correct message. Would it be worth running the bit-sync monitor even after the initial bit sync (at a penalty of having to maintain 1-ms outputs)?

SPDR Action Item #19 Response (by L. Linstrom)

We have not seen this with the tracking software. We have a very conservative threshold for initially determining bit synchronization.

SPDR Action Item #20 (for L. Linstrom)

The Tracking Processor software description needs a data flow diagram.

SPDR Action Item #20 Response (by L. Linstrom)

See the Software Design Description document for the most up-to-date flow diagram.

SPDR Action Item #21 (for L. Linstrom)

The description of the Tracking Processor software was inadequate. There were no lists of processes, diagrams of process control, data stores, architectural description, etc. We believe the algorithm description captured that aspect very well but we are at a loss as to the functioning of the Tracking processor software. This must be captured before detailed design proceeds.

SPDR Action Item #21 Response (by L. Linstrom)

See the Software Design Description document for details on the implementation. Since the processes, algorithms, and processing rates are the core of the software and the time for the review is limited, we focused on them for the PDR and the implementation details during the CDR.

SPDR Action Item #22 (for A. Chacos and S. Williams)

Reconsider the wisdom of requiring the separation time provided by the C&DH to be within 10 seconds of the current GNS time.

SPDR Action Item #22 Response (by A. Chacos)

The 10-second delay constraint on the separation time has been removed. As long as the Separation Time is considered valid, it will be used.

SPDR Action Item #23 (for A. Chacos)

A dataflow diagram of the entire GNS system is needed.

SPDR Action Item #23 Response (by A. Chacos)

See the Software Design Description document for the most up-to-date flow diagram.

SPDR Action Item #24 (for M. Asher)

How are the GNS navigation algorithms, specifically the Kalman filter, going to handle GPS measurements from the Tracking Processor which are invalid or erroneous? Is some automatic editing being done? Along this line, have the algorithms been tested with data that has statistical outliers (large and small, few or many)?

SPDR Action Item #24 Response (by M. Asher)

As a first line of defense, the tracking processor does not present measurements from satellites whose health is bad, as indicated by the GPS navigation message. There is also a RAIM (Receiver Autonomous Integrity Monitoring) algorithm that edits single measurements which are inconsistent with the orbital solution. This algorithm has not been tested using synthetic data with statistical outliers, but has been exercised on an anecdotal basis.

SPDR Action Item #25 (for M. Asher)

Examine Sparse QR routines developed by John Harris of PSA for more efficient processing.

SPDR Action Item #25 Response (by M. Asher)

John Harris was contacted regarding the sparse QR routines. Porting them to the TIMED software would have been difficult, as they were coded in C++. Since the QR algorithm from numerical recipes did not seem to represent a large portion of the CPU load, it was decided not to port them.

SPDR Action Item #26 (for M. Asher)

Evaluate if any efficiency can be gained by using sequential processing of measurements in Square Root KF. This will also facilitate residual analysis of the measurements for editing or fault detection purposes.

SPDR Action Item #26 Response (by M. Asher)

Since this part of the measurement update was not a large part of the computational burden, we did not investigate the potential improvements of scalar processing. The form of the measurement editing we implemented does not require scalar processing. The RAIM works by comparing the vector of measurements at an epoch with the prediction of the measurements from the measurement update at the previous epoch (as opposed to measurements from different PRN's at the current epoch). If this residual is much larger than its predicted standard deviation (20 sigma is the default threshold), it is eliminated from consideration.

SPDR Action Item #27 (for M. Asher)

Investigate use of 3-state Markov process model for more accurate residual gravity effects modeling in the KF and in predicting forward in time. (See NSWC-DL document by Swift).

SPDR Action Item #27 Response (by M. Asher)

The gravity is currently accounted for by white process noise driving velocity, which is simple and robust in that it is defined by a single parameter. Adding states, which are dynamically coupled with the velocity, increases the time update computational load dramatically. We therefore decided to stick with the white process noise model.

SPDR Action Item #28 (for M. Asher)

Can the upper triangle square root of Q be directly calculated from solving a "square root" differential equation, rather than calculating Q from its Qdot equation and then getting its Cholesky square root? Also, why use the Qdot equation when simpler relations exist for getting Q?

SPDR Action Item #28 Response (by M. Asher)

Since great numerical precision is not required for the propagation of the discrete time process noise Q, we decided to retain the covariance form of the Q. The covariance form enables us to easily incorporate legacy code.

SPDR Action Item #29 (for M. Asher)

It may be possible to use the stabilized form of the KF for more efficient processing.

SPDR Action Item #29 Response (by M. Asher)

In general, time did not allow for investigations into more efficient implementations of the filter, unless the computational burden was too great for the Mongoose V processor.

Mission CDR (12/3/97)

(1) Software-Related Action Item

MCDR Action Item #20 (for G. Cameron)

Consider adding some type of summary telemetry that enables Mission Operations to evaluate the last 24 hours of performance of the major subsystems (C&DH, G&C, GNS, etc.) by looking at a small number of parameters. (For example, the number of consecutive frames that GNS data has been in spec, with sticky telltale. This would allow Mission Operations personnel unskilled in GNS operations to quickly evaluate GNS performance).

Action Item #20 Response (by A. Chacos)

A telemetry parameter was added to provide this capability. See GNS External ICD (7363-9332), Figure 4, NP Realtime Output Products Validity Flag Count. A command was added to clear this parameter as needed. See GNS External ICD (7363-9332), Section 3.4.26 Clear Parameter Value. A description of the use of this parameter can be found in the GNS Navigation Processor Data Dictionary (7363-9360), Appendix A, Section 3.3.4.1.

Navigation Processor "Build #1" (Command/Telemetry S/W) Detailed Design Review (7/7/98)

(1) Software-Related Action Item

NPB1DDR Action Item #1 (for H. Malcom)

In the GNS Software External ICD, sections 4.3.1 and 4.3.2 imply that the checksum for physical memory dumps is a 32-bit XORing of the entire 248-byte data section. Per the action item response for TIMED Mongoose V Boot Program, reference p20, paragraph 4.5.3, the checksum for memory dump telemetry includes everything in the packet. The GNS telemetry dump checksum should therefore be based on 260 bytes, not 248 bytes.

Action Item #1 Response (by H. Malcom)

See memo SRS-98-122 dated 7/15/98

Navigation Processor "Build #2" (Kalman Filter S/W) Detailed Design Review (9/25/98)

(4) Software-Related Action Items

NPB2DDR Action Item #1 (for A. Chacos)

Verify the coordinate frame of nominal launch trajectory data. Is it EF, meaning velocities are relative to a rotating earth, or is it snapshop inertial with x-axis frozen at launch pad inertial longitude?

Action Item #1 Response (by M. Packard)

The coordinate system provided by the launch vehicle provider is an inertial coordinate system fixed at time of launch. The insertion vector is then transformed into an EF coordinate system and provided to the GNS team to load to the spacecraft. This final vector then is independent of launch time unless the launch vehicle provider needs to change the trajectory.

NPB2DDR Action Item #2 (for A. Chacos)

Verify that 'early ops' requirements are consistent with the services provided by the launch vehicle and the other activities on the spacecraft. There should probably be an Early Ops Plan for the GNS (is there isn't one already).

Action Item #2 Response (by B. Heins)

Since the GNS subsystems are not intended to navigate until the separation of the spacecraft from the launch vehicle, the only requirement is the ability to send a few commands prior to launch (set time, load separation state vector, and load an almanac, etc.), a capability which will be available. GNS Early Ops information was provided by the GNS team to Mission Operations who are responsible for generating the overall Early Ops plan.

NPB2DDR Action Item #3 (for M. Asher and T. Kusterer)

Consider using elevation cutoff unequal to zero when computing GSENF's (Ground Station Event Notification Flags). The rise and set lead times can still be in conjunction with this elevation angle (e.g. 5 degrees).

Action Item #3 Response (by A. Chacos)

To minimize the software effort, it was desired to have a fixed elevation angle. After discussions with Mission Operations, it was mutually agreed that 0 degrees would be satisfactory.

NPB2DDR Action Item #4 (for T. Kusterer and A. Chacos)

1) The software design document needs to have the error handling elaborated. See paragraphs 3.1.2, 3.1.3, and 3.2.2 line4.
2) Tie the timeline diagram, Appendix B, to the flow diagram Appendix A, page 1.
3) Include the timeline diagram in document 7363-9335, 18 September 1998, Mathematical Specification for the TIMED GNS Kalman Filter Short-Term Propagator.
4) Update the flow diagram, Appendix A, page 1, to indicate that it is the GPS Satellite state that is being propagated.
5) Differentiate subroutines from 'direct action' in the flow diagram, Appendix A.

Action Item #4 Response (by A. Chacos)

The corrections have been noted, but it is not intended to release an updated version of this document. The set of software design documentation will capture all of the relevant information.

Navigation Processor "Build #2" (Command/Telemetry S/W) Detailed Design Review (11/22/98)

(2) Software-Related Action Items

NPB2DDR Action Item #1 (for H. Malcom)

Error Handling: Error handling is needed when Timer 2 times out. For the Telecommand, please use the sequence number to detect missing data. How are errors handled during the handshake between the Tracking Processor (TP) and the Navigation Processor (NP)?

Action Item #1 Response (by A. Chacos)

TIMER2 is used to signal event interrupts. When TIMER2 'times out' the interrupt handler is signaled which in turn calls the appropriate event handling function.

For Telecommand packets, a check of the (CCSDS) packet sequence number in the header was implemented in the GNS software and an error was generated if a packet was received out of sequence (i.e. missing). However, the ground software does not differentiate between subsystems when it increments the sequence number so that a 'packet missing' error was generated whenever a packet was received by the GNS after a packet was sent to another subsystem. This caused numerous 'errors' to be generated within the GNS which could potentially mask other errors. We requested that the ground system software be modified so that each subsystem would have their own sequence count, but the request was rejected and it was suggested that we remove the sequence checking software to eliminate the generation of the errors. The checking was subsequently removed.

There is no handshaking between the TP and the NP. The data is a realtime stream synchronized by interrupts.

NPB2DDR Action Item #2 (for H. Malcom)

Errata in the TIMED GPS Build2 Software Design Document:

1) Page 8, line 9: change 10ms to 1 second

2) Page 10, section 4.3.1.2: change se to set.
3) Page 27, section 6.3.2.3, Input: place semicolon after logical structure ID, missing 'and' between physical dump start and physical dump size.

Action Item #2 Response (by A. Chacos)

The corrections have been noted, but it is not intended to release an updated version of this document.

Tracking Processor "Builds #1 & #2" Detailed Design Review (11/22/98)

(2) Software-Related Action Items

TPB12DDR Action Item #1 (for L. Linstrom)

Should investigate any potential tracking problems (tracking artifacts, side-lobe locking, etc.) at high S/N ratios.

Action Item #1 Response (by L. Linstrom)

As with most GPS receivers, potential tracking problems can occur at high signal to noise ratios. We routinely test +10 to +15 dB over our expected highest signal-to-noise ratio levels using a GPS simulator to insure that the software has adequate margins.

TPB12DDR Action Item #2 (for L. Linstrom and Susan Schneider)

The Tracking Processor may run out of resources (computing power). There is a need to document the performance when all of the software is in place. If too much resource is used, action needs to be taken before launch.

Action Item #2 Response (by Susan Schneider)

The performance analysis of the Tracking Processor has been completed and documented in memo SRS-099-171 dated 10/5/99. The 128-second average processor utilization is 59.6% and the 1-second peak processor utilization is 81.3%. These are satisfactory values and no changes to the software are required.

TIMED GPS Navigation System (GNS)

Hardware Test

Spacecraft System Level Test

Prepared by : Robert J Heins

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GNS Presentation Topics

GNS Block Diagram

Documentation

- Design Review RFAs, System Requirements, Test Plans, Procedures

GNS Flight Hardware Component Test Summary

- GPS flight antennas test
- Preamplifier module level test
- Downconverter module level test
- GTA ASIC

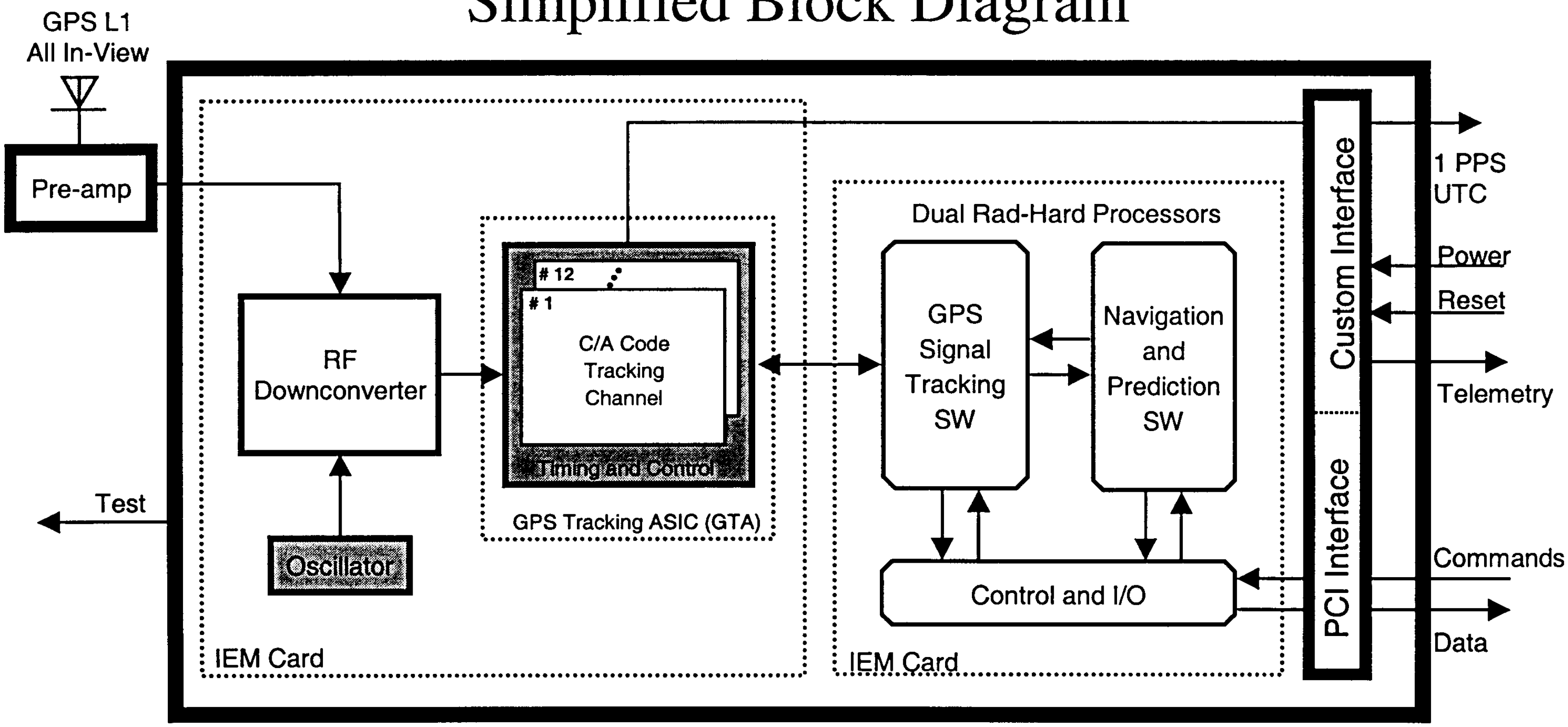
GNS Card Level Test Summary

- GNS processor card level test
- GNS receiver card level test
- Integrated GNS receiver and processor card test (Powered Thermal)
- Extended Engineering Model Test (Susceptibility, 1PPS long term jitter)

Spacecraft Level Test GNS Data Evaluation

- EMI Susceptibility
- Thermal-Vacuum (T-V)
- Post T-V

Simplified Block Diagram

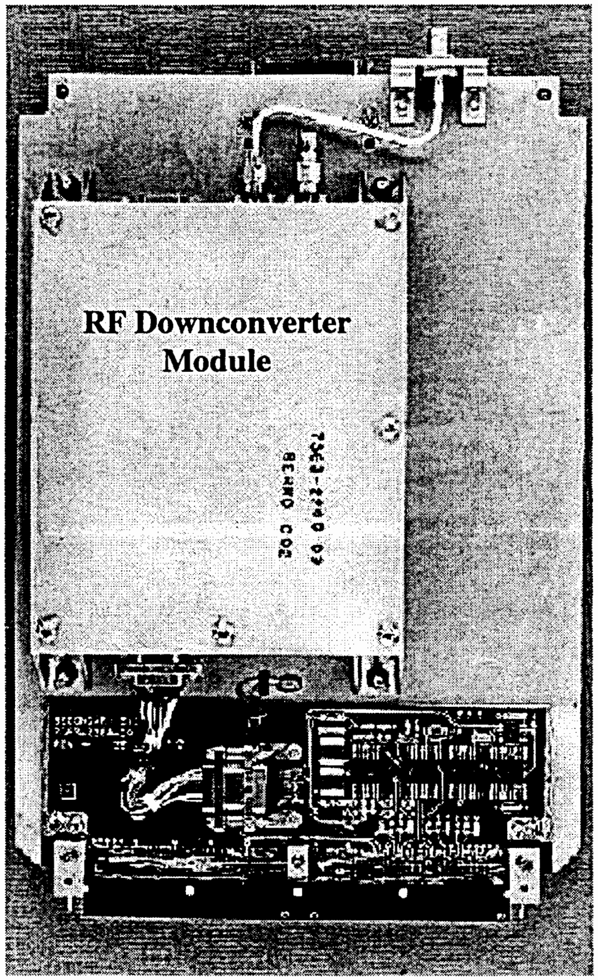


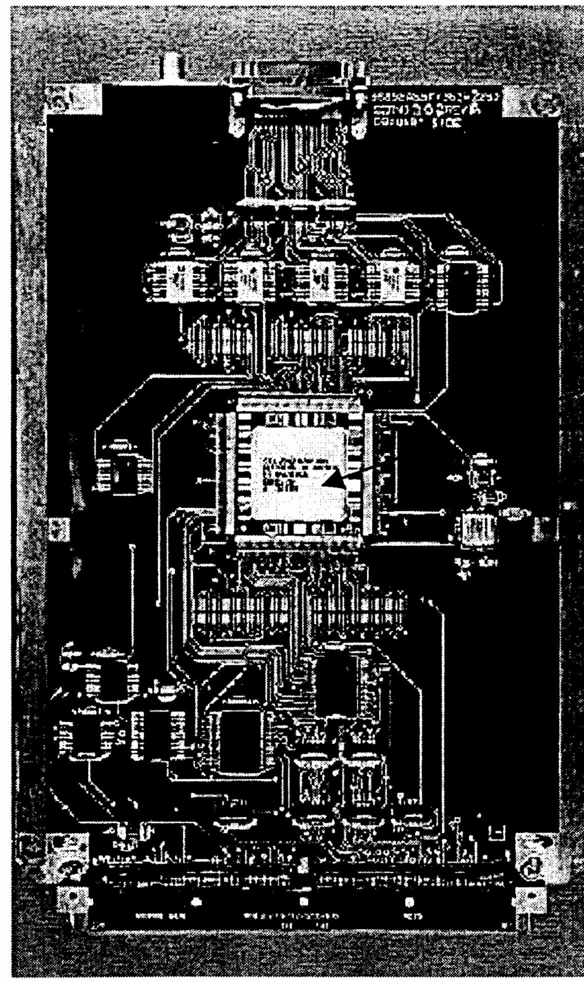
TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

GNS Receiver Card

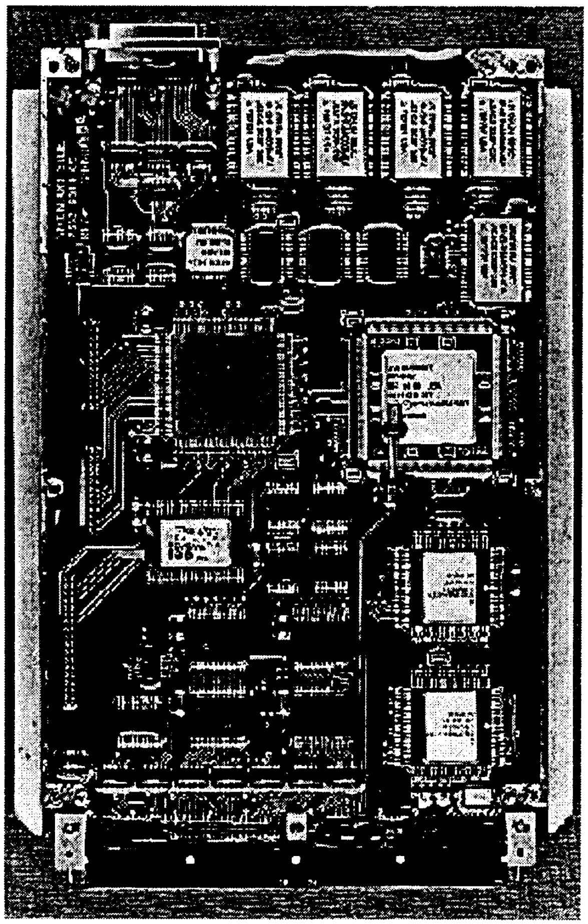




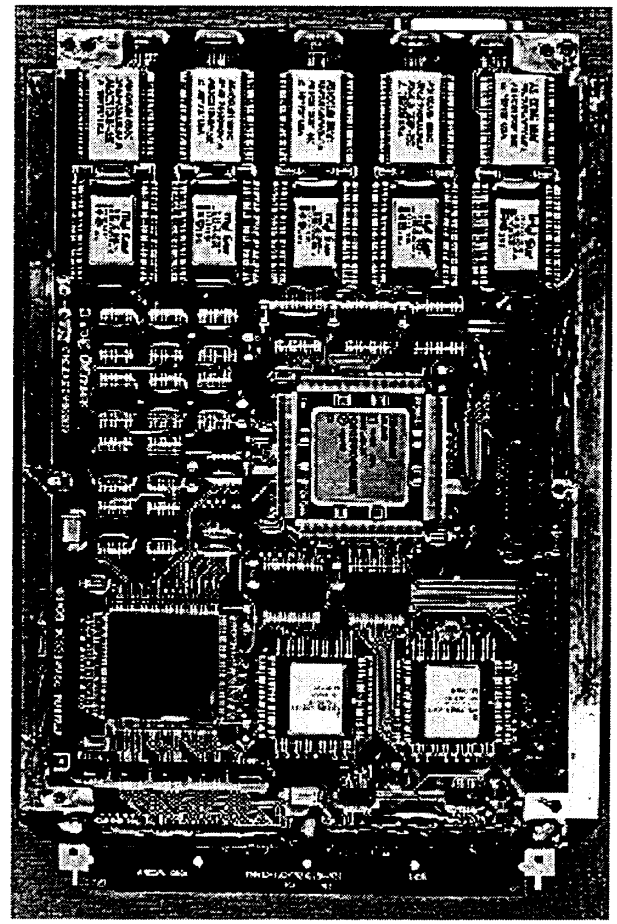
GTA
ASIC

GNS Dual Processor Card

Tracking Processor



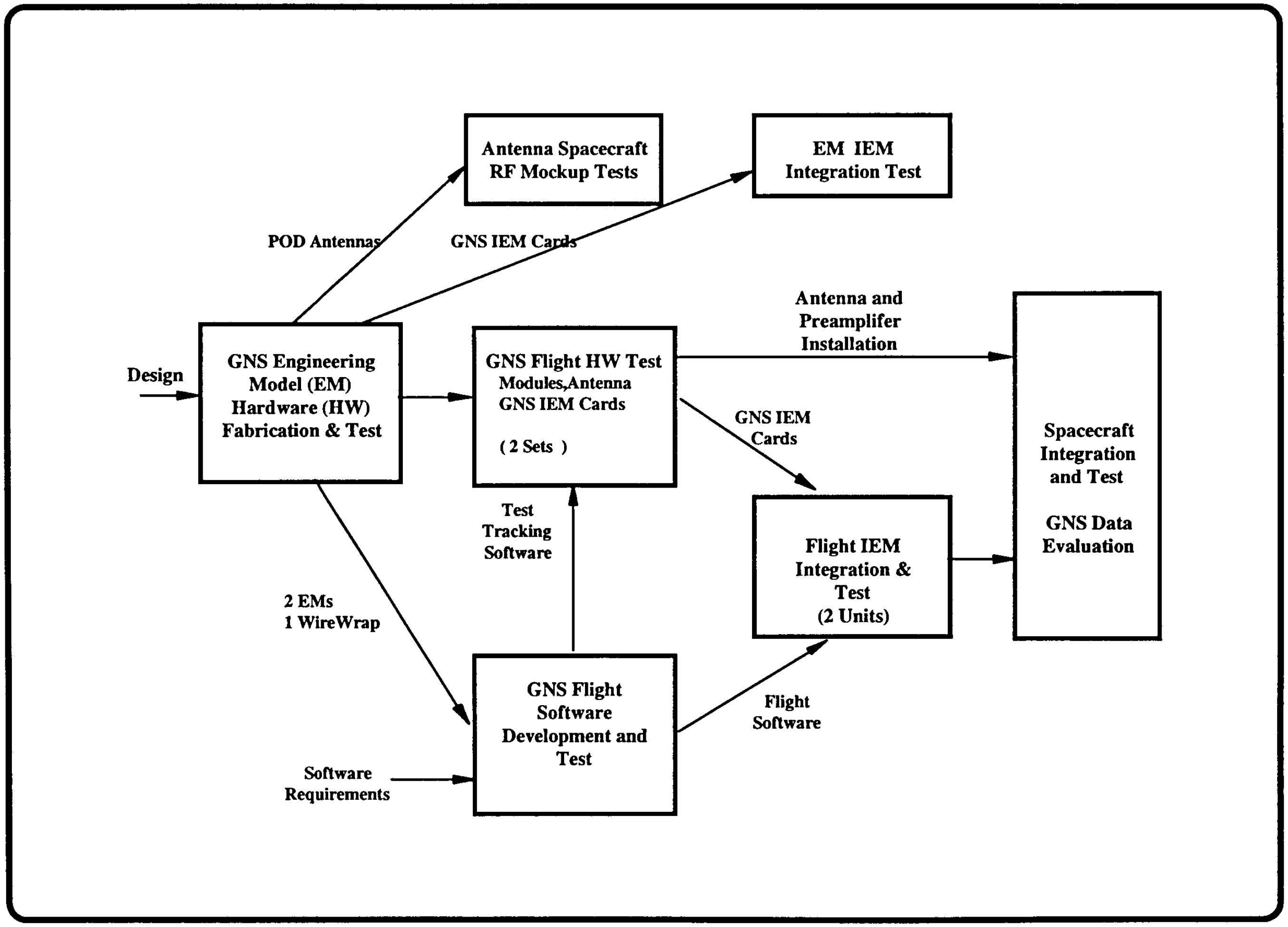
Navigation Processor



GNS Preliminary Design Review -- April 10, 1997

	RFA	Response
GNS PDR Reviewers: **David Kushnierkiewicz (TIMED Spacecraft System Engineer)** **Paul Marth (IEM System Engineer)** **George Seylar (TIMED EMI/EMC Engineer)** **James Perschy (IEM Hardware Engineer)** **Ed Reynolds**		
	Determine if a 1PPS warning flag is needed	A 1PPS flag is included in the GNS design and specified in the GNS System Requirements Document 7363-9336
	Add 12 volt monitor	A GNS 12 volt telemetry monitor was added to the IEM design
	Determine if the IEM cards have a common end panel	End panels have been deleted from the IEM design
	Identify GNS test connector signals	Test signals are documented in JHU/APL memorandum SEA-97-0051
	Determine how electrical isolation is maintained between the GNS GSE and spacecraft	Isolation techniques are described in JHU/APL memorandum SEA-97-0051
	Clarify the inband wideband isolation requirement	Isolation requirements of -120 dBm per MHz are specified in the GNS System Requirements Document 7363-9336
	Assess worse case E-fields at launch site	Documented in TIMED EMC Control Plan and EMI Performance Requirements Specification document number 7363-9038
	Determine if 1PPS 100 μs spec is adequate for non-coherent navigation experiment	The 100 μs specification has been determined more than adequate for the non-coherent navigation experiment
	Provide estimates of power consumption for an ACTEL GTA design	An estimate of 0.5 watts per channel was provided to the TIMED system engineer

TIMED GNS Test Flow (Simplified)



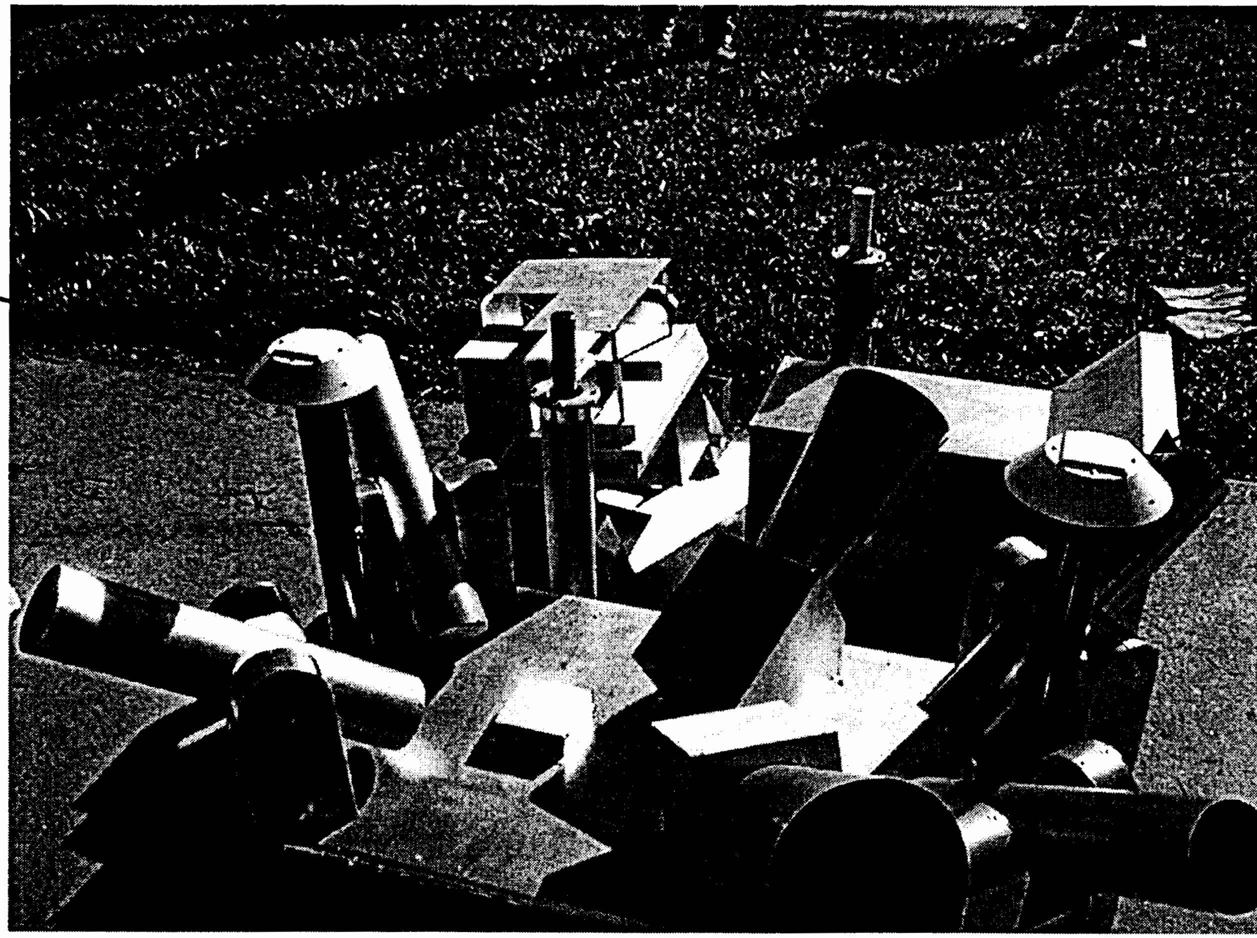
GNS Documentation

Document No.	Date	*Document Title*
GNS System Requirements (Exclusive of Software)		
7363-9336	Nov-97	GPS Navigation System (GNS) Requirements
SEA-99-0040 Attachment 3	Aug-99	GPS Tracker ASIC(GTA) for TIMED -- Requirements and Description
SEA-97-0067	Jul-97	GPS Navigation System Antenna Procurement
GNS Test Plans & Procedures -- Hardware Components		
SEA-98-0077	Oct-98	Documentation of TIMED GNS Preamplifier Module Test Plan
SEA-98-0032	May-98	TIMED GPS Navigation System Preamplifier Test Procedure
SEA-98-0078	Oct-98	TIMED GNS RF Downconverter Module Test Plan
SEA-98-0045	Jul-98	TIMED GPS Navigation System Downconverter Test Procedure
SEA-98-0080	Oct-98	Documentation of TIMED GNS Antenna Test Plan
QT702630	Oct-96	Qualification Test Procedure, Globalstar GPS Antenna
SEA-98-0079	Oct-98	Documentation of TIMED GNS Receiver Card Test Plan
SEA-98-0070	Sep-98	GPS Navigation System Receiver Card Functional Test Procedure
SER-98-064	Oct-98	Flight Qualification Test Procedure for RF Coaxial Cable Assemblies

GNS Documentation -- Continued

Document No.	Date	*Document Title*
GNS Test Plans & Procedures -- System Level		
SEA-98-0088	Nov-98	TIMED Integrated GNS Test Plan
SEA-2000-0025	Jun-00	Documentation of GNS Acqusition and Track Thresholds Test Procedure
SEA-2000-0018	Jun-00	TIMED Spacecraft GNS Time Correlation Test Procedure Used at the Goddard Space Flight Center (GSFC) Facility
Analysis		
SEA-99-0040 Attachment 2	Sep-99	Functional Description of VHDL Source Files for the GPS Tacking ASIC
SEA-98-0095	Dec-98	TIMED GPS Navigation System Flight Model Preamplifier Test Results
SEA-99-0022	Mar-99	AGC TLM Oscillation in TIMED IEM GNS Receiver
SRM-008-97	Apr-97	Effect of RF/IF Filter Bandwidth on Delay-Locked Loop Tracking Noise
SRM-025-97	Jul-97	Analysis of Preliminary GNS SAW Filter performance Predictions
SEA-97-032	Mar-97	Algorithm for Construction of Psuedorange for TIMED
SEA-97-0047	Apr-97	Investigation of Algorithms for Tracking GPS Satellites
Action Item Response		
SEA-98-0016	Feb-98	TIMED Mission CDR Action Item #12
SEA-97-0051	May-97	Response to GNS PDR Action items #4 and #5
SEA-2000-0047	Sep-00	Responses to TIMED GNS Preliminary Design Review Action Items

TIMED GNS Antennas Installed On Spacecraft RF Mockup



GNS Antenna Verification Test Matrix

	Vendor Acceptance Tests				JHU/APL Test					
Item	Pre/Post SiO2 VSWR	Vib-ration	T-V, Thermal Life	VSWR, Range Test	VSWR, Range Test	RF Mockup	T-V	Hat-Couple	Optical Bench Vib	S/C Install
POD SN001	X			X	X	X		X		
POD SN002	X-No SiO2			X	X	X		X		
Flight SN003	X	X	X	X	X-VSWR				X	X
Flight SN004	X	X	X	X	X-VSWR				X	X
Flight SN005	X	X	X	X	X-VSWR		X			

Ref Question #: 3

Summary of Vendor (Ball Aerospace) Antenna Test Results

Item	Requirement	Measured Following Vib & T-V		
		SN003	SN004	SN005
RHCP Gain				
Peak	• 4 dBic	5.03 dBic	5.02 dBic	5.07 dBic
Elev 10 to 90° Elev	• -3 dBic	> -2.5 dBic	> -2.5 dBic	> -2.5 dBic
@ 2215 MHz	n/a	< -4 dBic	< -4 dBic	< -4 dBic
VSWR	Š 1.5:1	< 1.2	< 1.2	< 1.2
RHCP Sidelobe				
Elev 0 to -90° Elev	< -7 dBic 70% coverage	> 72 %	> 72 %	> 72 %
LHCP Suppression				
Elev 10° to +90°	< -7 dBic 90% coverage	> 99 %	> 99 %	> 96 %
Elev 10° to -90°	< -9 dBic 80% coverage	> 85 %	> 85 %	> 86 %

Note: Values shown are worse case values measured over ±2.5 MHz bandwidth centered about 1575.42 MHz

Vendor Flight Antenna Test Detail

- Vendor -- Ball Aerospace
- GlobalStar test heritage, modified per PI 305894 test requirements
- Tests performed following SiO2 Coating
- Thermal-Vacuum
  - -105°C to 80°C for 10 cycles
  - 17 minute soak time
- Mechanical Vibration
  - APL vibration specifications in PI 305894 (include effects of mounting pedestal)
- Thermal Life Cycle
  - -100°C to 75°, 350 cycles
- Range test (RHC & LHC gain pattern, phase)
  - 2° increments, 360° coverage

RF Mockup Test

RHCP Gain

	Requirement	POD #1	POD #2
Gain: Elev 10° to 90° Elev	• -4 dBic 90% coverage	> 90%	> 90%

RF Coupling Measurements

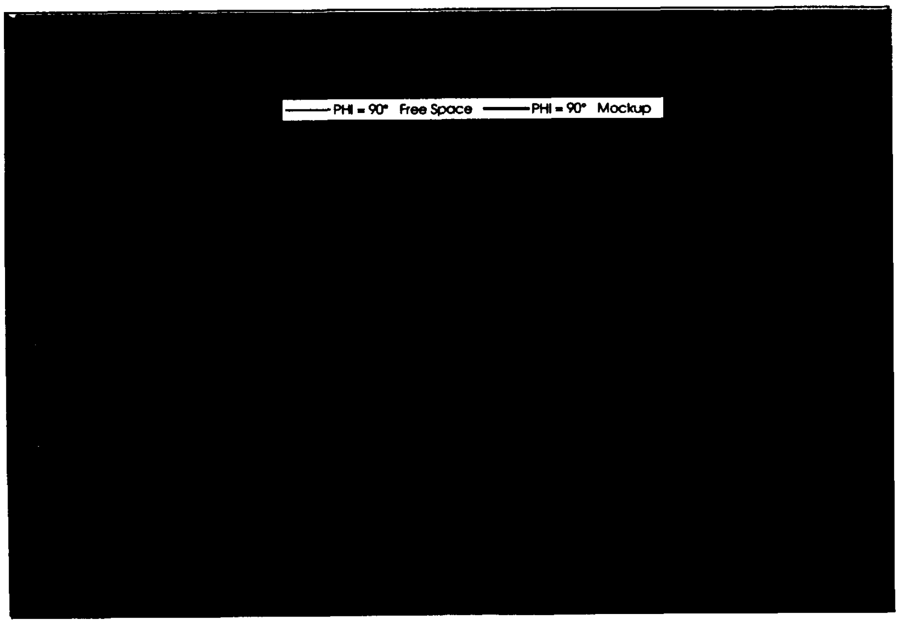
Between GNS Antennas and Zenith Side S-Band Downlink (Contingency) Antennas

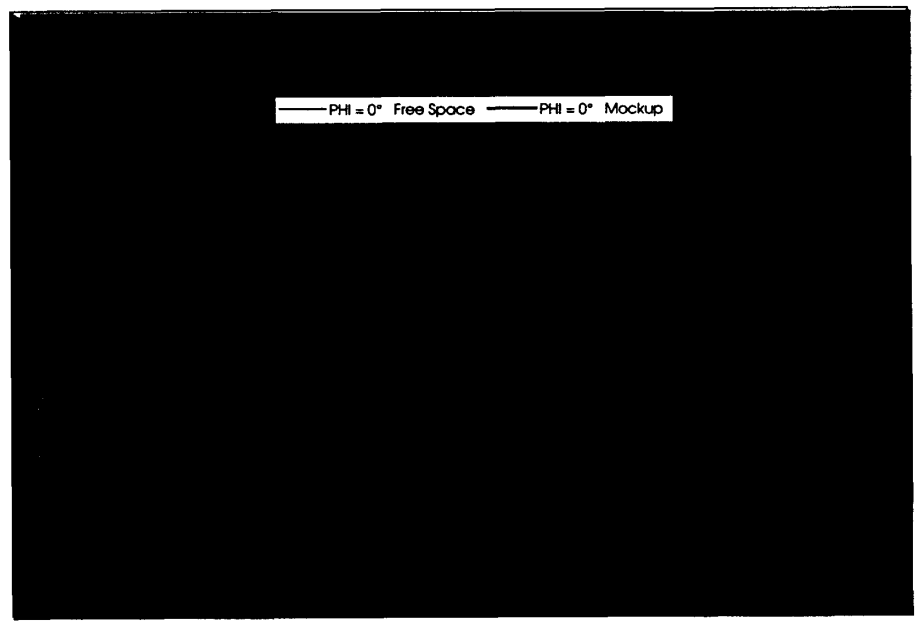
	Requirement	1575.42 MHz	2000 MHz	2215 MHz
POD 1 to S-Band #1	< -25 dB	-63.6 dB	-65.8 dB	-68.7 dB
POD 1 to S-Band #2	< -25 dB	-56.8 dB	-56.5 dB	-71.1 dB
POD 2 to S-Band #1	< -25 dB	-63.6 dB	-59.4 dB	-53.4 dB
POD 2 to S-Band #2	< -25 dB	-57.2 dB	-48.2 dB	-45.2 dB
POD 1 to POD 2		-49.8 dB	-59.4 dB	-62.5 dB

RF Mockup Tests

POD 2 Elevation Cut Gain Patterns

RF Mockup Measurements Compared to 'Free Radiation' Antenna Measurements

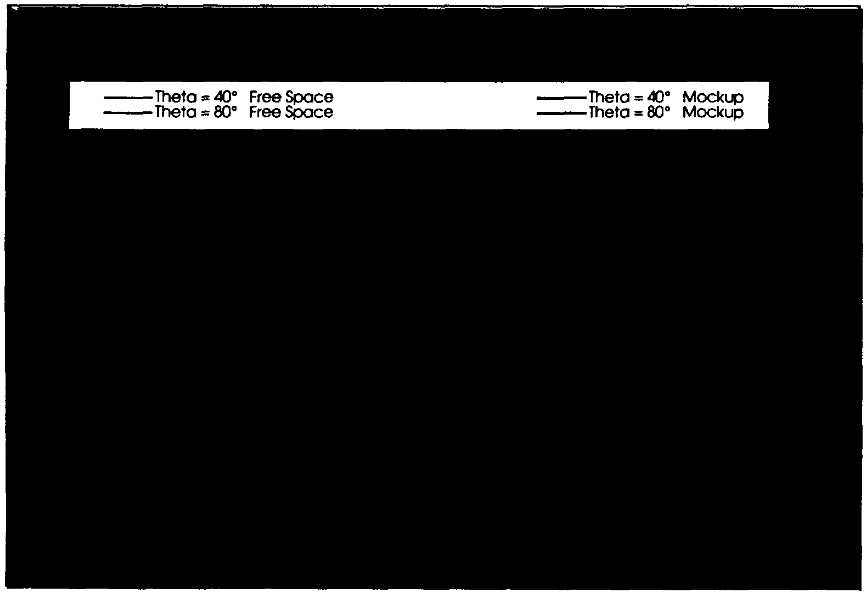


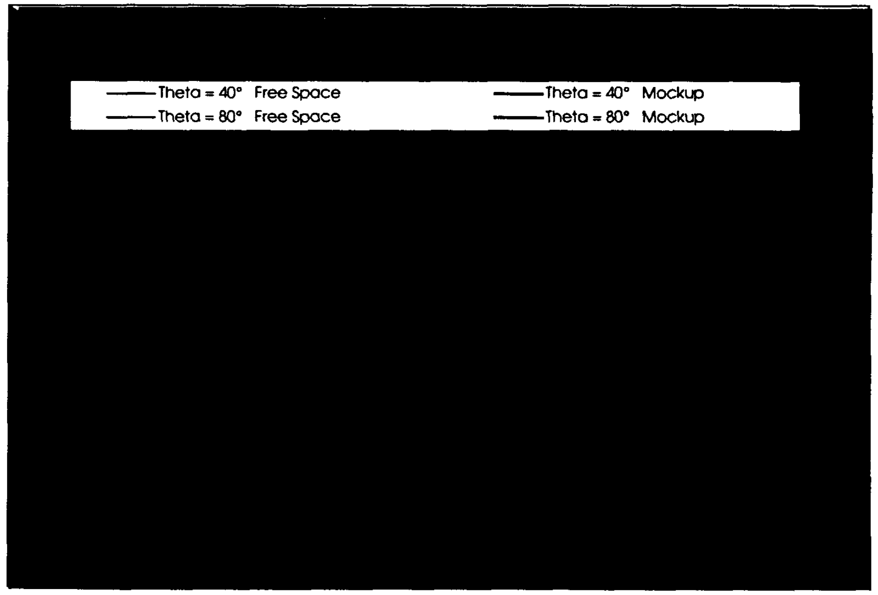


RF Mockup Tests

POD 1 and 2 Conic Cut Patterns

RF Mockup Measurements Compared to 'Free Radiation' Antenna Measurements

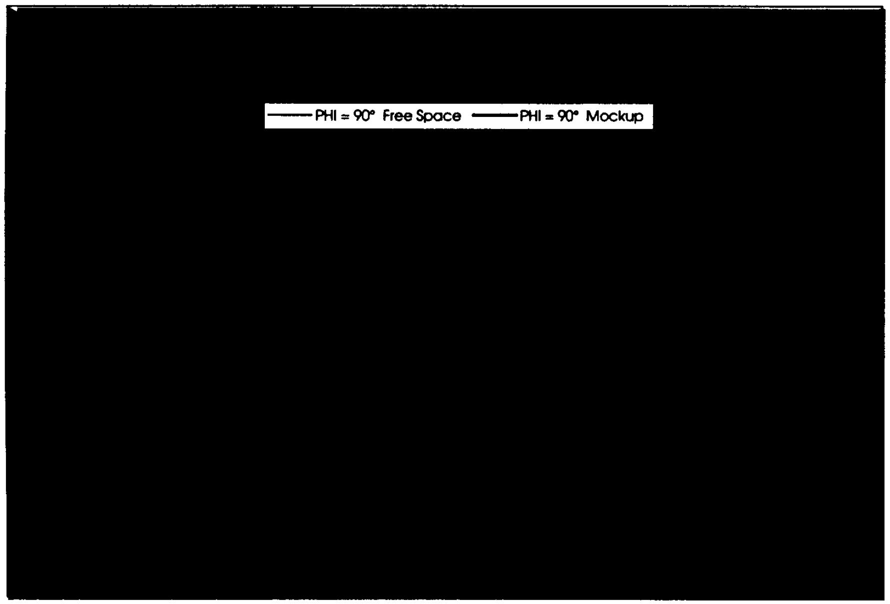


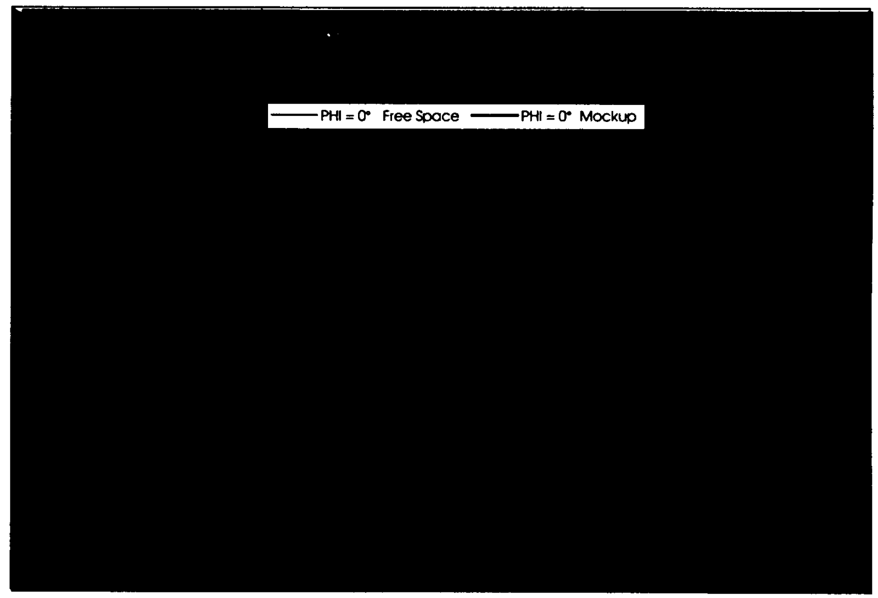


RF Mockup Tests

POD 1 Elevation Cut Patterns

RF Mockup Measurements Compared to 'Free Radiation' Antenna Measurements





JHU/APL GPS Antenna Test Summary

- Optical bench vibration test
  - Flight antennas SN003 and SN004 assembled on pedestals and installed on optical bench
  - Antenna return loss measured before, during, after vibration
- Spare flight antenna SN005 thermal-vacuum test
  - -100°C to +75°C, six cycles
  - Return loss monitored for any relative change
- Spacecraft RF Mockup
  - Performed with two POD antenna units, SN001 and SN002
  - $\leq \pm 2$ dB variation in gain wrt prior antenna 'free radiation' baseline test
  - No nulls found in antenna FOV
  - Coupling from S-Band to GPS antennas < -45 dB@S-band, , < -57 dB @ 1575 MHz
- Antenna hat-coupler test
  - VSWR and coupling loss through antenna measured
  - Coupling losses measured on order of 19.5 dB
  - Hat couplers used for spacecraft level GNS test
- No anomalies

Preamplifier Module Test Summary

- Purchased from vendor (Delta MicroWave)
- Powered thermal from -30°C to 80°C, nominal and ±10% voltage
- Preamplifier test results given in SEA-98-0077
- Requirements satisfied

Preamplifier RF Cables Test

- Ultra low loss cables purchased from vendor (Gore)
- Tests documented in SER-98-064
- S parameters measured at -70°C to 75°C, 1 to 3 GHz

Preamplifier Module Test Summary

Parmeter	Requirement	Measured* SN114	Measured* SN113
Noise Figure	Š 3.1 dB	< 2.25 dB	< 1.94 dB
Current	Š 65 ma	< 59.9 ma	< 52 ma
Input VSWR	Š 1.5 over 2.5 MHz BW	< 1.28	< 1.18
Output VSWR	Š 1.5 over 2.5 MHz BW	< 1.18	< 1.27
DC Impedance	Š 1 ohm	< 0.39 ohms	< 0.28 ohms
Passband Gain	• 25 dB	> 33.81 dB	> 33 dB
Gain Ripple	Š 1 dB p/p over 5 MHz	< 0.47 dB	< .36 dB
3 dB Bandwidth	36 MHz ± 3 MHz	33.81 to 38.4 MHz	36.02 to 36.87 MHz
250 MHz StopBand	• 90 dB	> 87.5 dB	> 90.7 dB
Phase Linearity	Š 6° p/p over 3.5 MHz	< 4.99°	< 5.05° p/p
Gain Compression	• 5 dBm over 39 Mhz BW	> 7.6 dBm	> 6.4 dBm

Note : Measured* values listed are worse case values measured over -30°C to +80°C, Nominal and Nominal ±10% Voltage

RF Downconverter Module Pre-Encapsulation Test Verification Matrix

Parameter	Temperature --> Pwr Voltage --> Requirement	-30°C Nominal, +10%, -10%	+25°C Nominal, +10%, -10%	+80°C Nominal, +10%, -10%
Total DC Power	< 850 mw	X	X	X
Analog BB Cen Freq	4.309 MHz ±1 kHz	X	X	X
Min Gain	> 85 dB	X	X	X
AGC Dynamic Range	> 40 dB	X	X	X
Passband				
1 dB Bandwidth	> 1.8 MHz	X	X	X
6 dB Bandwidth	< 2.8 MHz	X	X	X
25 dB Bandwidth	< 3.5 MHz	X	X	X
Analog BB Spurs	< -20 dBc over 20 MHz	X	X	X
A/D Digital BB Freq	1.401 MHz ±1.5 kHz	X	X	X
Osc Freq Offset	10 MHz ±10 Hz	X	X	X
Osc Phase Noise				
@ 1 Hz	Š -65 dBc	X	X	X
@ 100 Hz	Š -125 dBc	X	X	X
@ 10 kHz	Š -145 dBc	X	X	X

Ref Question #: 3

Special Parts Screening and Test -- RF Downconverter Chip

- GEC Plessey GP2010

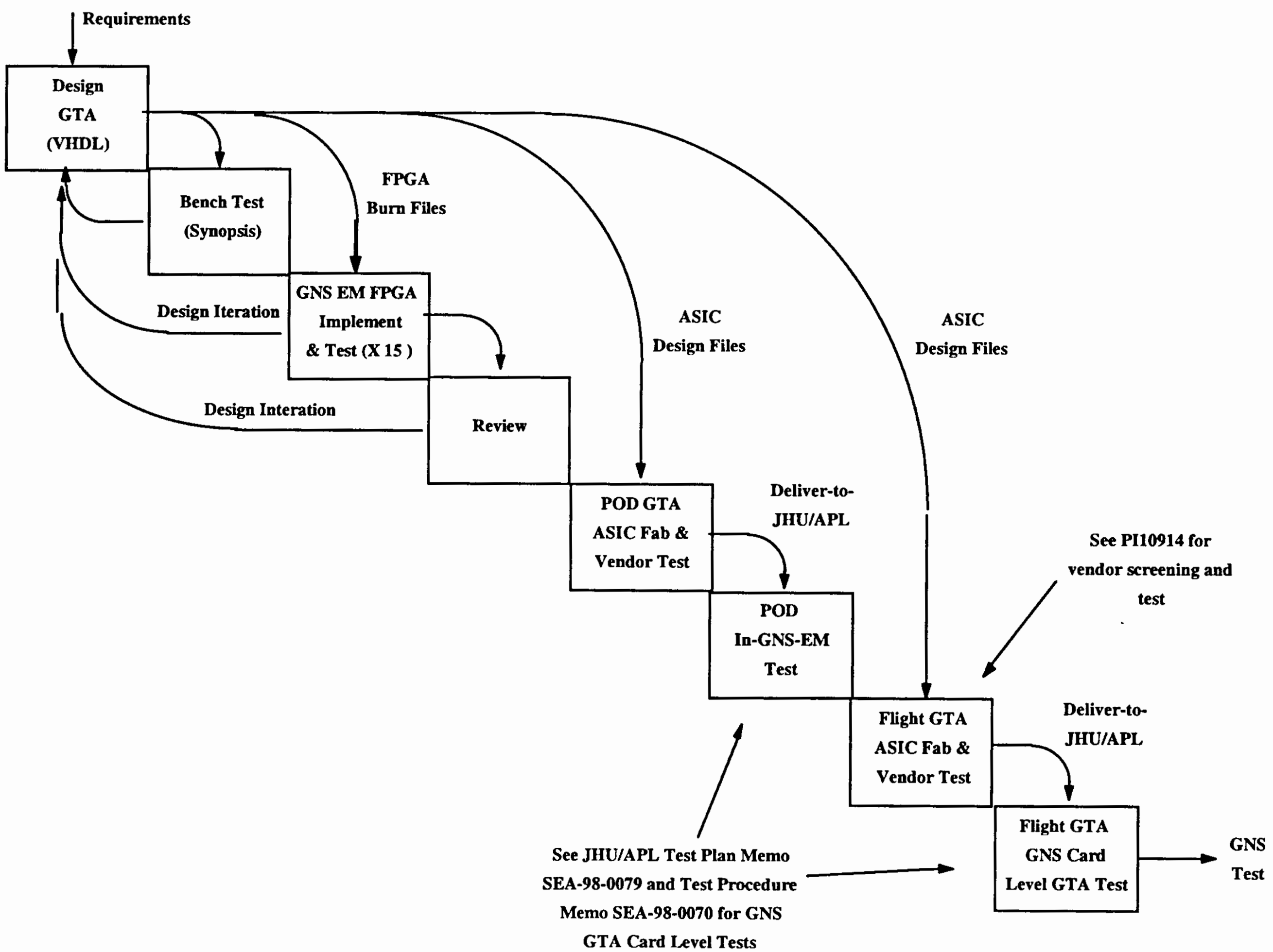
- On all units
  - GIDEP Review
  - Visual
  - Dimensions check
  - Initial electrical test, -40°C, 25°C, +100°C
  - X-Ray
  - 24 hour +125°C bakeout (flight parts)
  - Visual
  - Flight parts bagged

- On selected parts from lot
  - 1000 hour, +125°C lifetest (22 samples)
  - 20 temperature cycles, -50°C to +150°C (15 samples)
  - 200 hour 85/85 THB test (15 samples)
  - Destructive parts analysis (5 samples)

GPS Tracking ASIC

- Key GNS component that implements digital functions for 12 channels of GPS tracking, data recovery, and timing
- Designed by Dr. D.M. Gruenbacher of KSU
- Designed using VHDL language and environment
- Design synthesized and tested using Synopsis design and test compilers
- Implemented in Honeywell 2300 series CMOS gate array
  - Radiation hard to 1 Mrad(Si)
  - Latchup immune
  - Low SEU rates
  - Temperature -55°C to +125°C
  - 150 mw power
- Functional description of VHDL source files and GTA requirements are documented in JHU/APL memorandum SEA-99-0040
- Vendor requirements, including Vendor screening and test , given in JHU/APL PI 10914

GNS GTA Development and Test Flow



Honeywell GTA ASIC Test

- Wafer lot acceptance
- Mil Spec PRF-38535 Class Q
  - 10 cycles, -65°C to 150°C (unpowered)
  - Constant acceleration
  - Particle Impact Noise Detect
  - X-ray
  - Hermetic test
  - 3 temperature (25°C, -55°C, 125°C) powered electrical
  - Pre-Condition Burn-in (powered), 21 hours @ 150°C
  - 25°C powered electrical test
  - Dynamic burn-in(powered), 125 hours @ 150°C
  - Repeat 3 temperature (25°C, -55°C, 125°C) powered electrical
  - Final visual
- Group B test
- Group C life test (500 hours @150°C)
- Group D (package evaluation)

GNS Receiver Card Function Test
GTA Function Verification Matrix

Temp --> / Voltage --> / GTA Function Test	EM -30°C Nominal +10% -10%	EM 25°C Nominal +10% -10%	EM +80°C Nominal +10% -10%	Flight 25°C Nominal +10% -10%
GTA Test Points	X	X	X	X
1PPS Function	X	X	X	X
1PPS Distribution	X	X	X	X
1PPS Freq Stability	X	X	X	X
Code Rate	X	X	X	X
Carrier Phase Measure Function	X	X	X	X
Code Phase Measure Function	X	X	X	X
I & Q Accum Funct -- Noise Input	X	X	X	X
I & Q Accum Funct -- Static SIGN and MAG Input	X	X	X	X
I & Q Accum Funct -- Autocorrelation	X	X	X	X
PRN Code Generation	X	X	X	X
GTA Master Reset	X	X	X	X

Note: Follow-on integrated flight GNS card tests are performed over multiple temperature cycles

GNS Receiver Card Level Test
GTA Function Test Description

GTA Function Test	Test Description	Flight Unit Pass/Fail
GTA Test Points	Active PRN code and code epoch signals are detected at test points	Pass
1PPS Function	1PPS Frequency is measured as a function of programmed 1PPS rates	Pass
1PPS Freq Stability	The standard deviation of 1PPS frequency measurements is measured	Pass
1PPS Distribution	Distribution of multiple 1PPS signals over the backplane is verified	Pass
Code Rate	Code epoch rate is measured as function of programmed code NCO rate	Pass
Carrier Phase Measure Function	Integrated phase is measured as a function of programmed 1PPS and carrier NCO rates	Pass
Code Phase Measure Function	Code phase is measured as a function of programmed 1PPS and code NCO rates	Pass
I & Q Accum Funct - Noise Input	I & Q Correlation values are read and compared with expected result 'noise' only input	Pass
I & Q Accum Funct -- Static SIGN and MAG Input	I & Q Correlation values are read and compared with expected result for static MAG and SIGN input values	Pass
I & Q Accum Funct -- Autocorrelation	Early, Prompt, Late accumulator autocorrelation profiles verified using locally generated test signal	Pass
PRN Code Generation	Each GTA channel is tested to verify the capability to track any of the 32 PRN codes in the GPS constellation.	Pass
GTA Master Reset	Reset of the GTA --to default 1PPS and NCO rates -- via the IEM backplane signal is verified	Pass

Flight GNS Receiver Card SN001 Test Chronology

Test	Date	Remarks
Receiver Pre Stress Card Function	Dec 98	Ambient
Receiver Unpowered Thermal Stress	Dec 98	20 cycles, -34°C to +90°C
Receiver Post Stress Card Function	Jan 99	Ambient
Integrated GNS Test	Jan 99	6 Cycles, +25°C,-29°C, 80°C,+25°C; Nominal, +10%,-10% volt Tested with GNS processor SN002
Receiver Post Conformal Coat	Jan 99	AGC test point oscillation detected
Receiver Card Rework	Feb 99	Per DCN E21489/90
Receiver Requalificatiom	March 99	1 cycle, 25°C,-29°C, +80°C ; Flight processor SN001
Receiver Card Integrated in IEM	March 99	--
GNS Receiver SN001 Operating Test Time		96 Hours

Flight GNS Processor Card SN002 Test Chronology

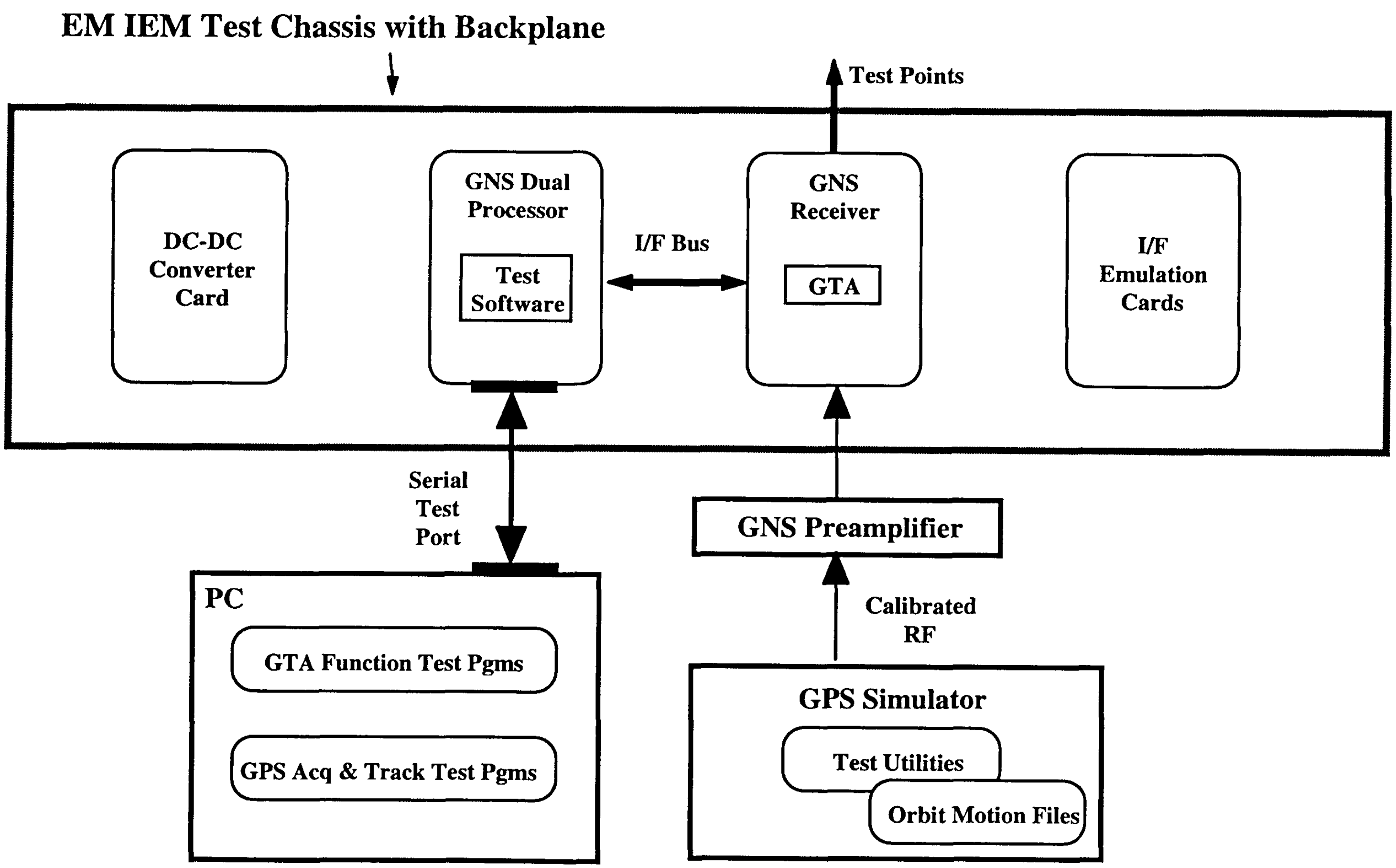
Test	Date	Remarks
Processor Pre Stress Card Function	Dec 98	1 cycle powered thermal, +25°C, -30°C, +65°C
Processor Unpowered Thermal Stress	Dec 98	20 cycles, -34°C to +90°C
Processor Post Stress Card Function	Dec 98	1 cycle powered thermal, +25°C, -30°C, +65°C
Integrated GNS Test	Jan	6 Cycles, +25°C,-29°C, 80°C,+25°C; Nominal, +10%,-10% volt Tested with GNS receiver card SN001
Processor Post Conformal Coat	Jan 99	1 cycle powered thermal, +25°C, -30°C, +65°C
Processor Card Integrated in IEM	Feb 99	Integrated in IEM with temporary EM receiver
GNS Processor SN002 Operating Test Time		96 Hours

Integrated GNS (Powered Thermal) Test Verification Matrix

GNS Receiver SN001 and Processor SN002

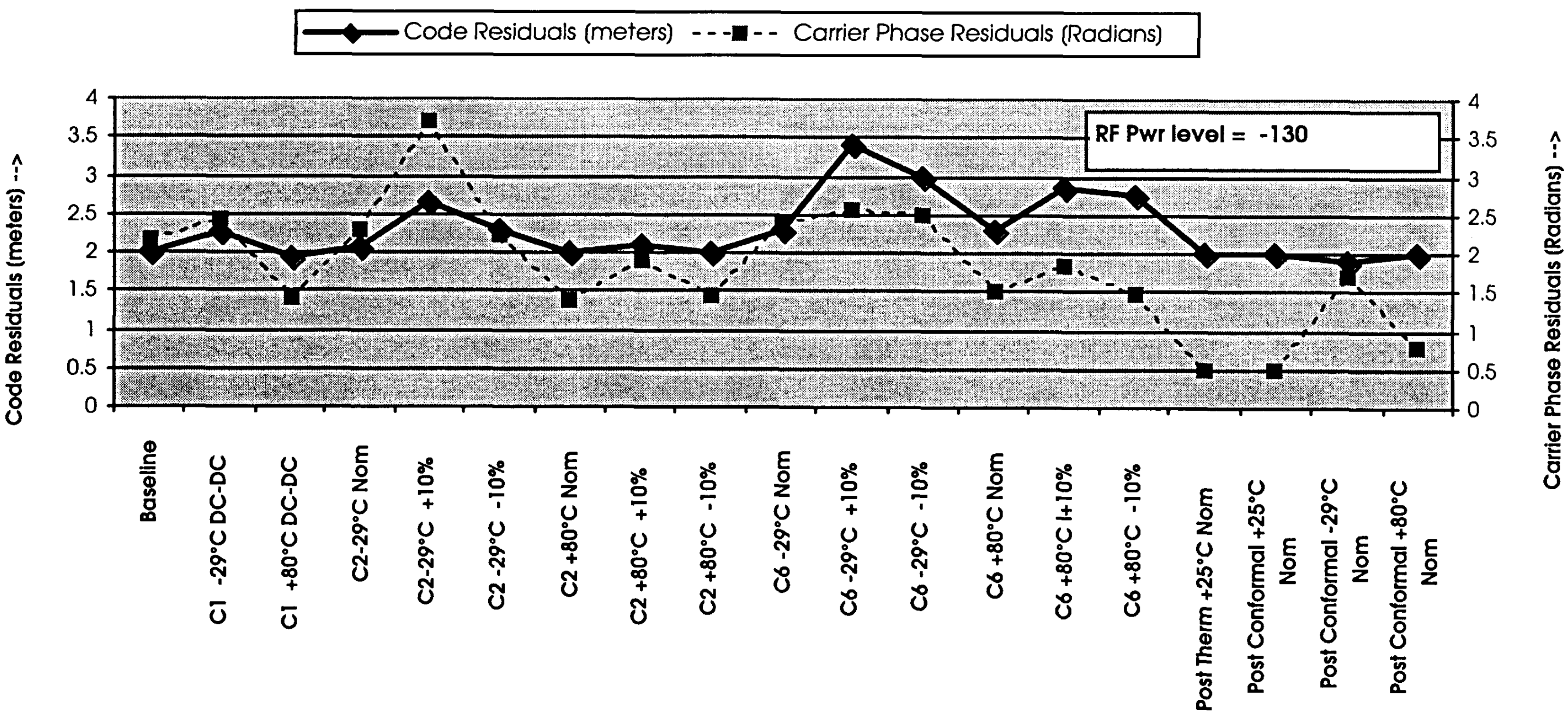
GNS Test	Test Cycle -->	Post Stress Baseline	Cycle 1	Cycles 2 to 6	Post Thermal	Post Conformal Coat
	Temp -->	+25°C	-29°C +80°C	-29°C +80°C	+25°C	-29°C +80°C
	Voltage ->	Nominal	DC-DC Card	Nominal +10% -10%	DC-DC Card	Nominal
Health Discretes I/F		X	X	X	X	X
1PPS I/F		X	X	X	X	X
Osc Freq offset		X	X	X	X	X
Master Reset		X	X	X	X	X
Code/Carr Track Verif (PRN 1 -> PRN 32)		X	X	X	X	X
Code/Carr Track Jitter (-115 to -140 dBm)		X	X	X	X	X
Power Draw		X		X	X	X

Basic Test Configuration for GTA Function and Integrated GNS Card Tests



Integrated GNS Card Test -- Powered Thermal
Code & Carrier Phase Track Residuals (Jitter)

Flight Rcvr Card SN001/Dual Processor SN002 -- Jan-Mar 1999



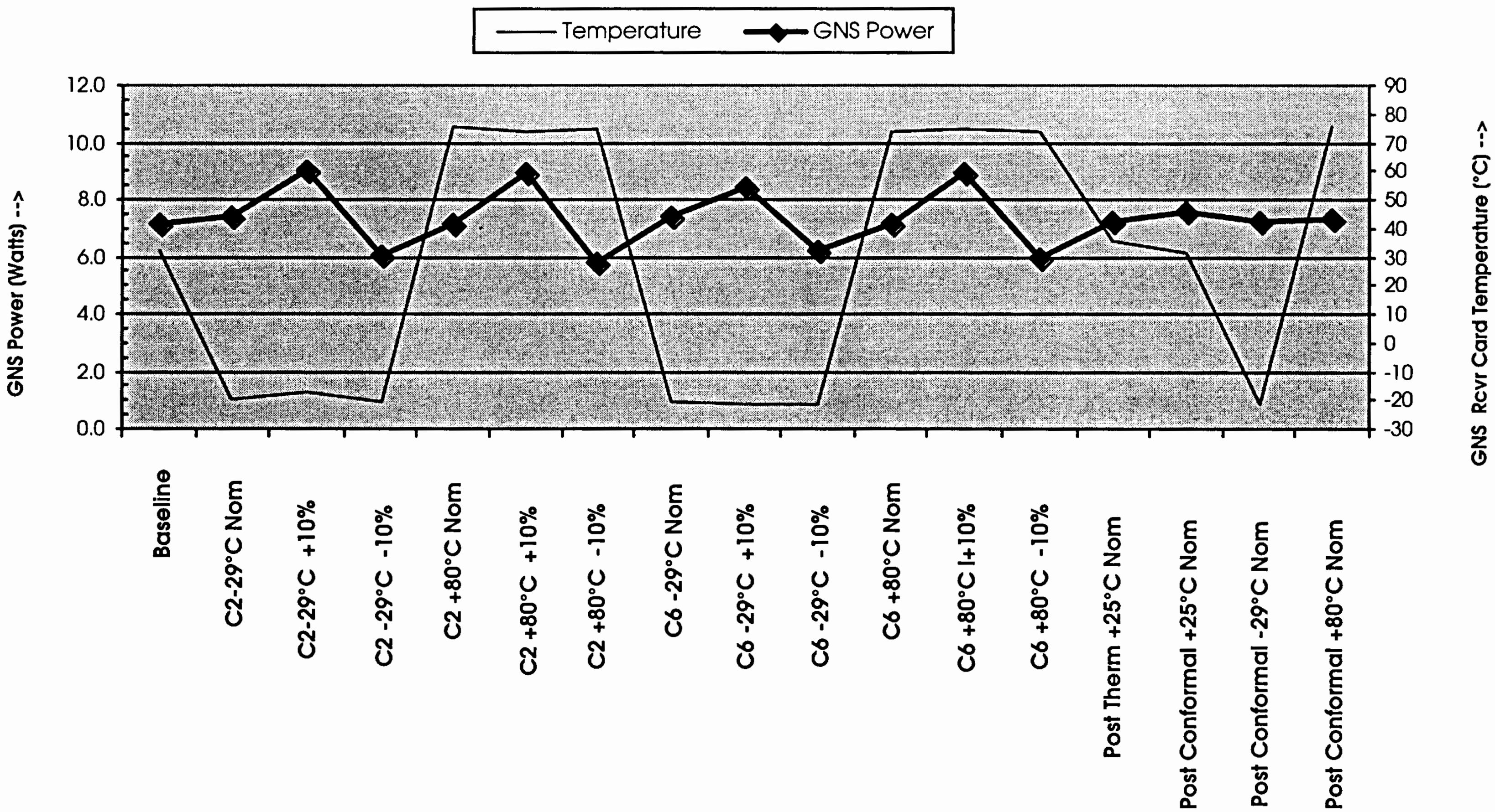
TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

Integrated GNS Card Test -- Powered Thermal Power Consumption

Flight Rcvr Card SN001/Dual Processor SN002 -- Jan-Mar 99



Flight GNS Receiver Card SN002 Test Chronology

Test	Date	Remarks
Receiver Pre Stress Card Function	Jan 99	Ambient
Receiver Unpowered Thermal Stress	Jan 99	20 cycles, -34°C to +90°C
Receiver Post Stress Card Function	Feb 99	Ambient
Integrated GNS Test --Thermal Cycle 1	Feb 99	+25°C,-29°C, 80°C, +25°C ; Nominal, +10%,-10% voltage tested with Flight GNS processor SN001
Receiver Card Rework	Feb-Mar 99	Per DCN E21489/90
Receiver Post Conformal Coat	March 99	Ambient temp, nominal voltage ; tested with EM processor
Integrated GNS Test -- Cycles 2-3-4	March 99	25°C,-29°C, 80°C, 25°C ; Nominal, +10%,-10% voltage, tested with EM processor
Receiver Card Integrated in IEM #2	March 99	
GNS Receiver SN002 Operating Time		64 Hours

Flight GNS Processor Card SN001 Test Chronology

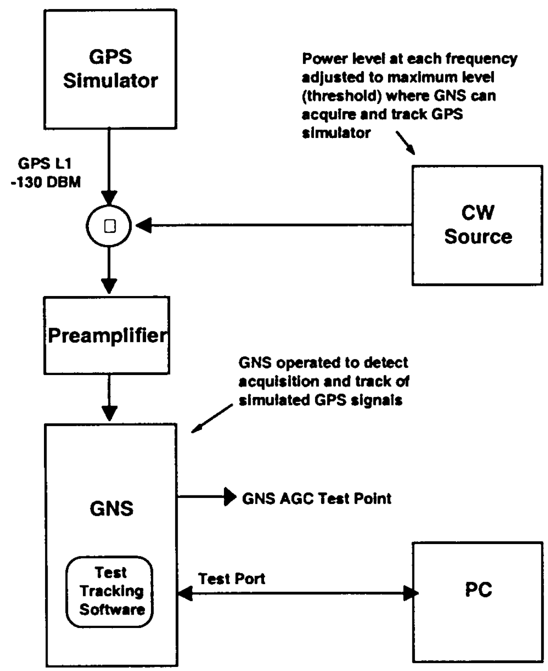
Test	Date	Remarks
Processor Pre Stress Card Function	Jan 99	1 cycle powered thermal, +25°C, -30°C, +65°C
Processor Unpowered Thermal Stress	Jan 99	20 cycles, -34°C to +90°C
Processor Post Stress Card Function	Jan 99	1 cycle powered thermal, +25°C, -30°C, +65°C
Integrated GNS Test -- Cycle 1	Feb 99	+25°C,-29°C, 80°C, +25°C ; Nominal, +10%,-10% voltage tested with GNS receiver card SN002
Processor Post Conformal Coat	Feb 99	1 cycle powered thermal, +25°C, -30°C, +65°C
Used to Requal Receiver SN001	March 99	1 cycle, 25°C,-29°C, +80°C
Processor Integrated in IEM	March 99	
GNS Processor SN001 Operating Time		48 Hours

IEM GNS Integration

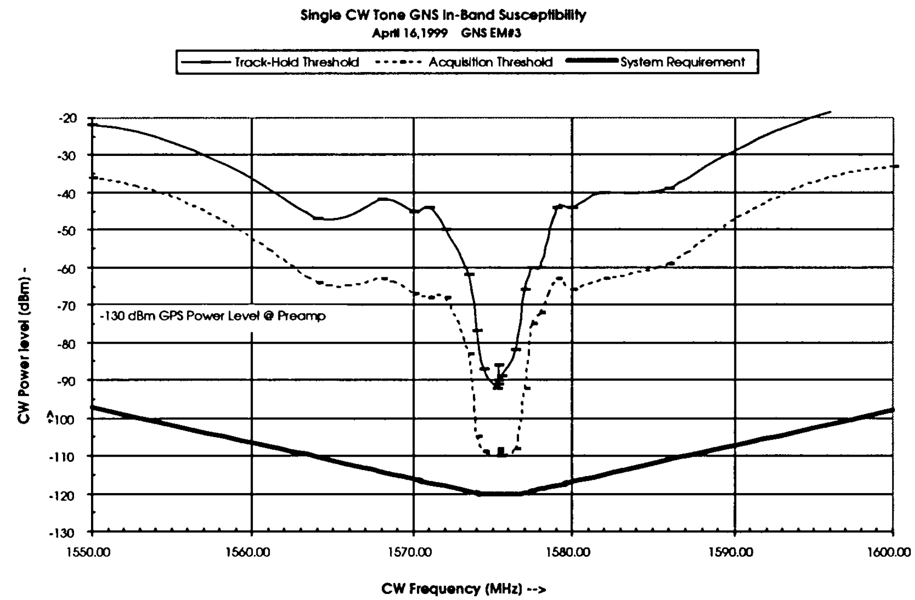
- **Test tracking software loaded to evaluate tracking performance**
- **Version 3.01 navigation processor software installed to evaluate functionality of GNS command and telemetry interface**
- **GNS function tests performed before and after each axis of IEM mechanical vibration**
- **GNS function tests performed at temperature plateaus in IEM thermal vacuum test (six cold-hot cycles)**

GNS EMI Susceptibility -- GNS Engineering Model Measurements

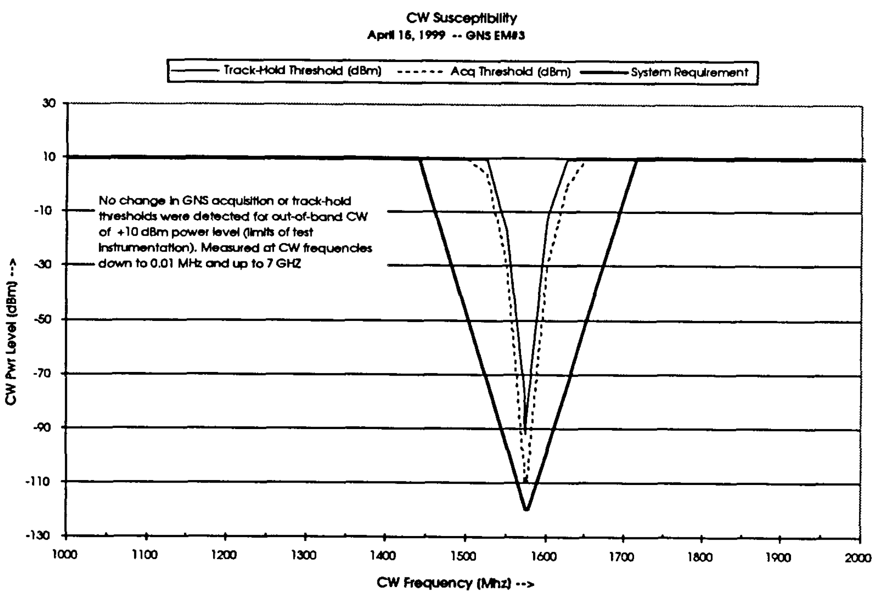
Test Configuration to Measure GNS Susceptibility to CW EMI



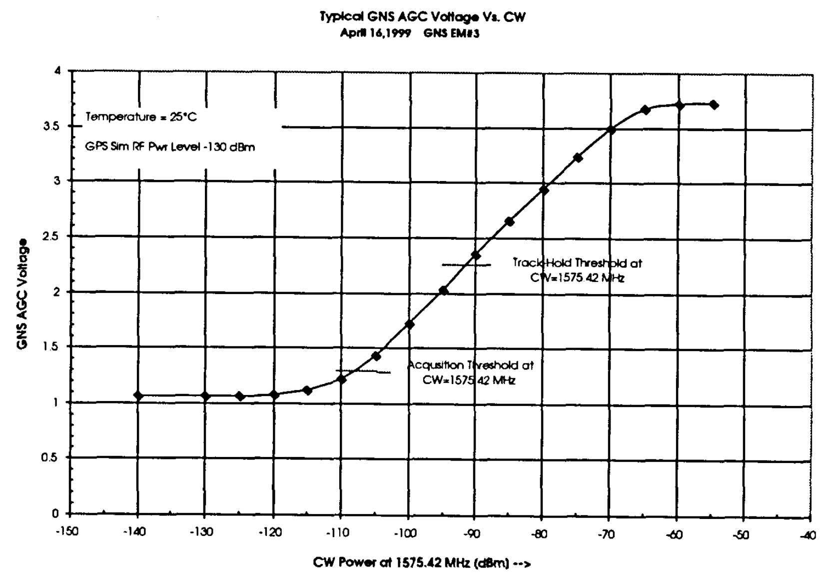
Measured GNS Susceptibility to In-Band CW EMI



Measured GNS Susceptibility to CW EMI



GNS AGC Test Point Voltage As Function of CW Power Level



Spacecraft Level 'Free Radiation' Test (GNS EMI Susceptibility)

Purpose

Determine if GNS performance is susceptible to EMI from spacecraft subsystems

GNS Susceptibility Detection -- Method 1

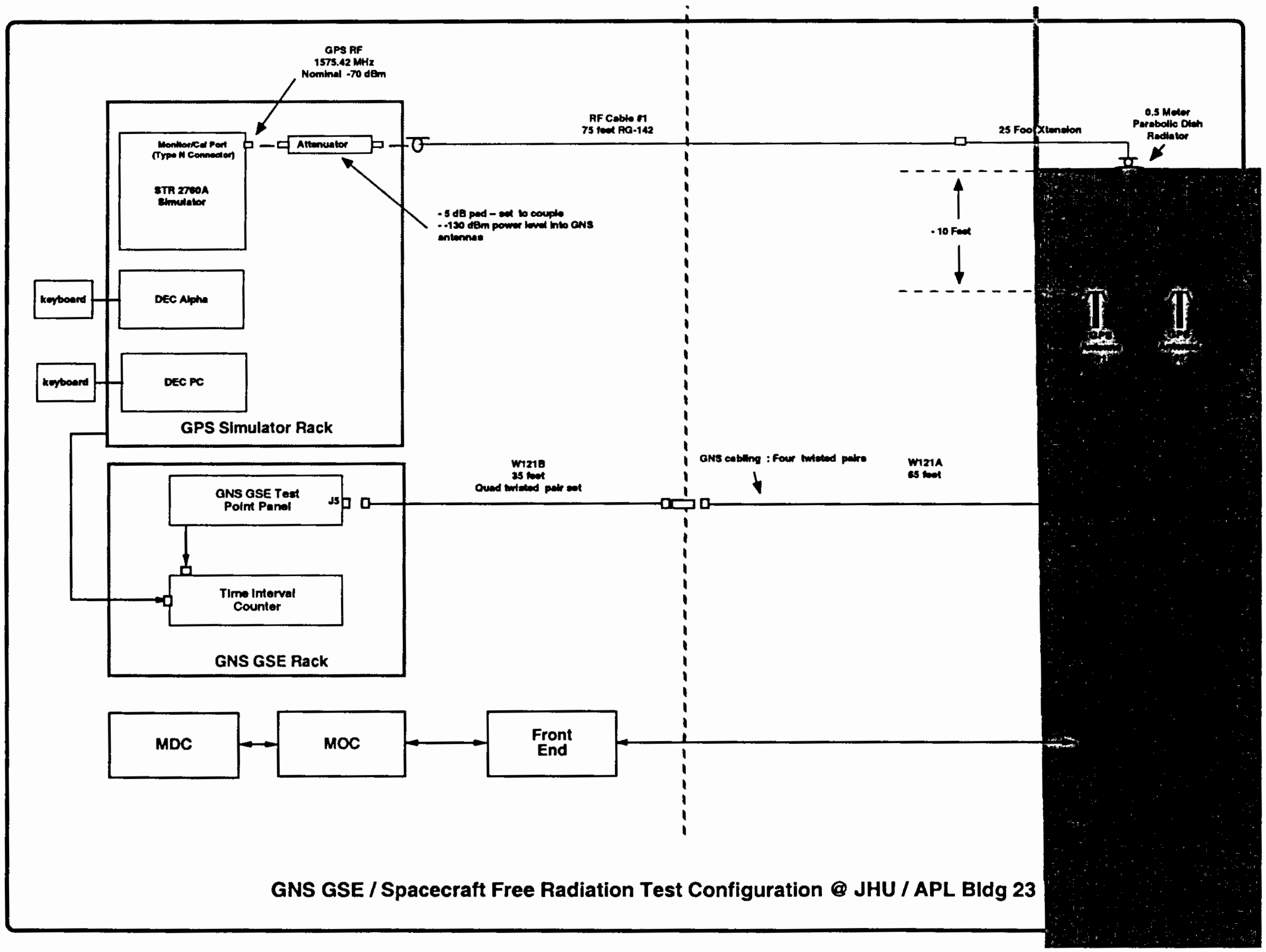
Detect changes in telemetered GNS receiver AGC voltage relative to measurements taken when the spacecraft is in the baseline configuration (instruments off)

GNS Susceptibility Detection --Method 2

Detect changes in GPS signal acquisition and track-hold RF threshold levels relative to measurements taken when the spacecraft is in the baseline configuration (instruments off)

- **Acquisition threshold - lowest GPS simulator RF power level at at which GNS channels can acquire GPS SV signals**
- **Track-hold threshold - lowest GPS simulator RF power level at at which GNS channels maintain normal tracking of GPS SV signals and navigate**

Spacecraft Level 'Free Radiation' Test (GNS EMI Susceptibility) Test Configuration



Spacecraft Level Free Radiation GNS Test Summary

Test Date	Systems Installed	AGC Measurements	RF Acq & Track Threshold Measurements
5/13/1999	GUVI, G&C, S-Band	AGC measurements within ±0.1 volt wrt baseline	Measurements within ±1 dB of baseline
6/30/1999	SEE, GUVI, G&C, S-Band	AGC measurements within ±0.1 volt wrt baseline	Measurements within ±1 dB of baseline
9/22/1999	SABER, SEE, GUVI, G&C, S-Band	AGC measurements within ±0.1 volt wrt baseline	Measurements within ±1 dB of baseline
10/7/1999	TIDI, SABER, SEE, GUVI, G&C, S-Band	AGC measurements within ±0.1 volt wrt baseline	Measurements within ±1 dB of baseline

All AGC and RF Threshold measurements were within the normal range of measurement variability. It is concluded any EMI is below the level where GNS operation is affected.

Spacecraft Level GNS Performance Verification

Spacecraft Test --> / GNS Test Item	Separation Simulation	GNS Performance (Side 1 and 2)	Event Driven (Side 1 and 2)	96 Hour	Spacecraft Time Correlation
GNS Cmd & TLM Function		X			
Parameter Limits	X	X	X	X	X
PVST Accuracy					
Motion File-GNS PV Residuals	X	X	X	X	
Sun Vector Residuals	X	X	X	X	
Telemetered Range/Phase Residuals	X	X	X	X	X
Time Accuracy					
KF Clk/Freq Bias	X	X	X	X	X
1PPS Test Point Offset					X
Spacecraft Time Correl					X
Event Flag Accuracy	X	X	X	X	
Event Prediction Accuracy				X	
Orbit Elements Accuracy				X	

GSFC Spacecraft Thermal Cycle Tests Jan 2000

GNS Test Evaluation

Spacecraft T-V Test Cycle --> Spacecraft Test	PreTV	Cold #1 Hot #2	Cold #3 to Hot #6	Cold #7 Hot #8	Post TV	Test Length
Separation Simulation		X		X	X	- 9 hours
GNS 1 Performance	X	X		X	X	- 45 min nav
GNS 2 Performance	X	X		X	X	- 45 min nav
Event Driven 1 Mission Sim		X		X	X	- 6 hours
Event Driven 2 Mission Sim		X		X	X	- 6 hours
96 Hour Mission Sim			X			96 hours
Spacecraft Time Corr	X			X		- 1 hour

Summary of GNS Performance During Spacecraft Level Tests

GNS Product	GNS Requirement	S/C T-V Jan 00 96 Hour Test S/W Version 4.05 *SA On*	S/C Mar 00 72 Hour Test S/W 4.06 *SA On*	S/C Aug 00 96 Hour Test & Time Corr S/W 4.07 *SA OFF*
Position Accuracy (ECEF,ECI)	100 meters (1 sigma / axis)	< 25.5 meters RMS	< 23 meters RMS	< 18 meters RMS
Velocity Accuracy (ECEF, ECI)	8.33 cm/sec (1 sigma / axis)	< 2.4 cm/sec RMS	< 2.2 cm/sec RMS	< 1.9 cm/sec RMS
Sun Vector Accuracy	0.02° (1 sigma)	< 0.001° RMS	< 0.001° RMS	< 0.001° RMS
Time Accuracy				
GNS Level	100 μs	< 1 μs (1PPS T.P. offset)	n/a	< 1 μs (1PPS T.P. offset)
Spacecraft Level	±10 ms	< 6 ms (Ground-S/C Corr)	n/a	< 6 ms (Ground-S/C Corr)
Event Flag Accuracy				
Contact Rise Event	±5 seconds	±1 second	±1 second	0 seconds
Contact Set Event	±5 seconds	10 sec lag/SPR 429	10 sec lag	0 seconds
Terminator Crossing Event	±5 seconds	0 seconds	0 seconds	0 seconds
SAA Event	±5 seconds	0 seconds	0 seconds	0 seconds
Polar Event	±5 seconds	0 seconds	0 seconds	0 seconds
Prediction Products Accuracy		SPR 418		
Contact Predictions	±5 seconds	6 second offset	±1 seconds	0 seconds
SAA Event Predictions	±5 seconds	6 second offset	0 seconds	0 seconds
Orbit Elements Accuracy	4 km (3 sigma) 36 hour span	SPR 404	< 500 m @ 36 hour	in progress

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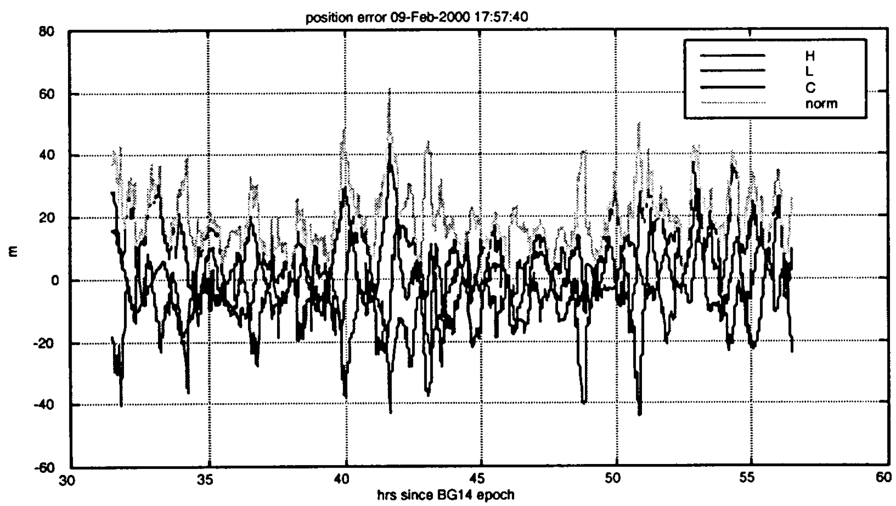
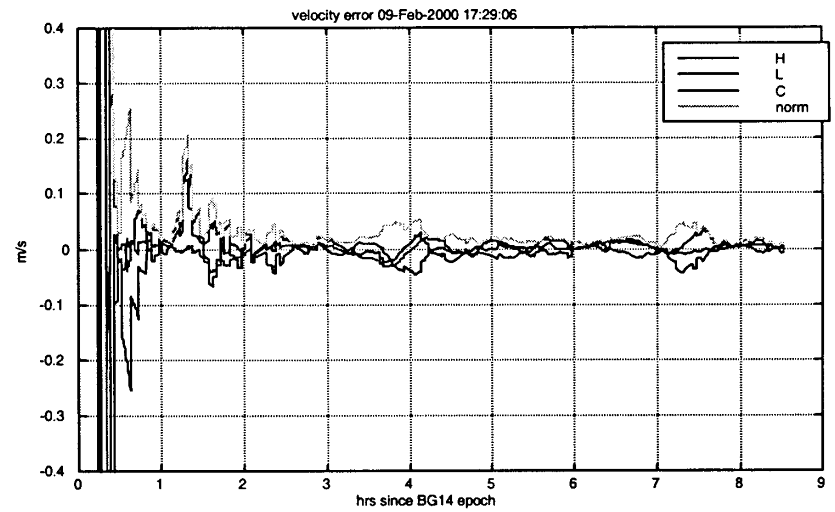
Red Team Review 31 Oct. - 3 Nov. 2000

Example of Position and Velocity Residuals -- SA Enabled
Difference Between GPS Simulator Motion file PV and GNS 1 PV
96 Hour Test Jan 2000



ECEF Position Error in HLC (GRT Jan 19, 2000)

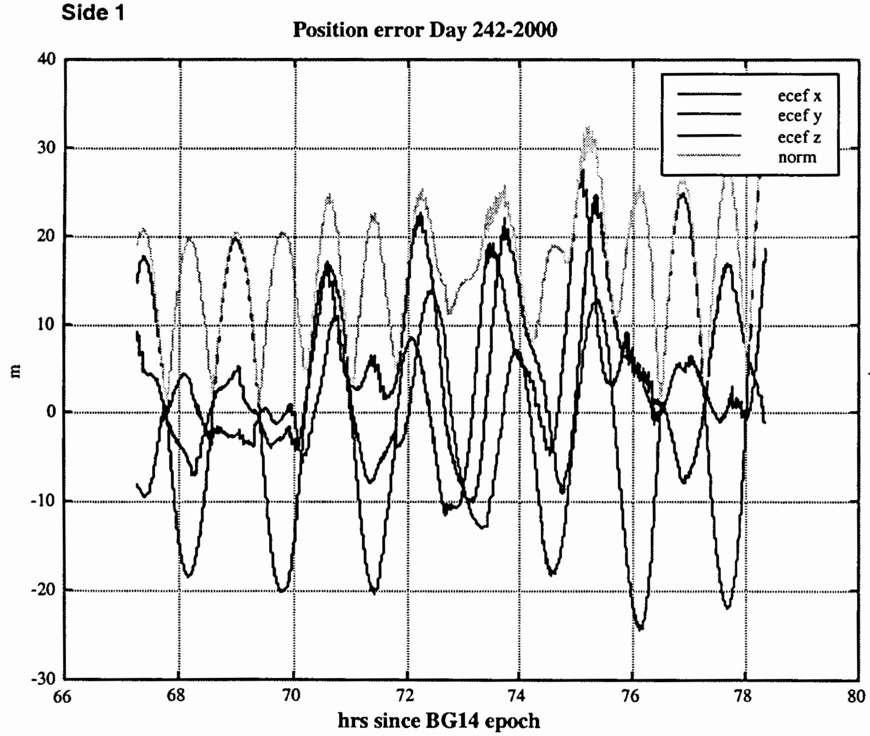


ECEF Velocity Error in HLC (Jan 17, 2000 GRT)

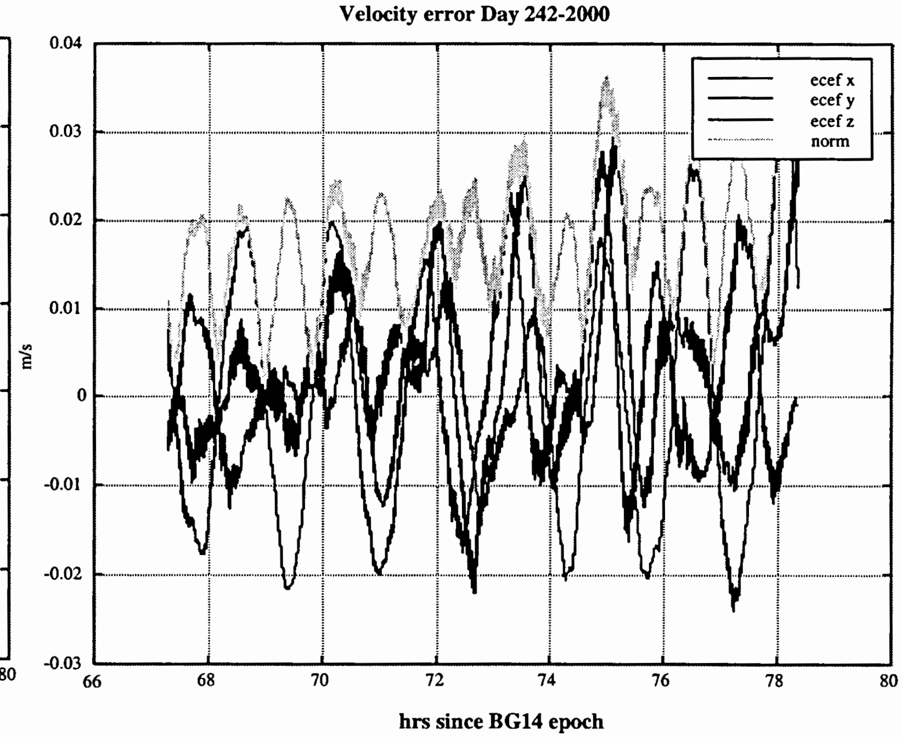
Ref Question #: 7

Example of Position and Velocity Residuals -- SA Disabled
Difference Between GPS Simulator Motion file and GNS PV
96 Hour Test Aug 2000

Side 1



Side 2



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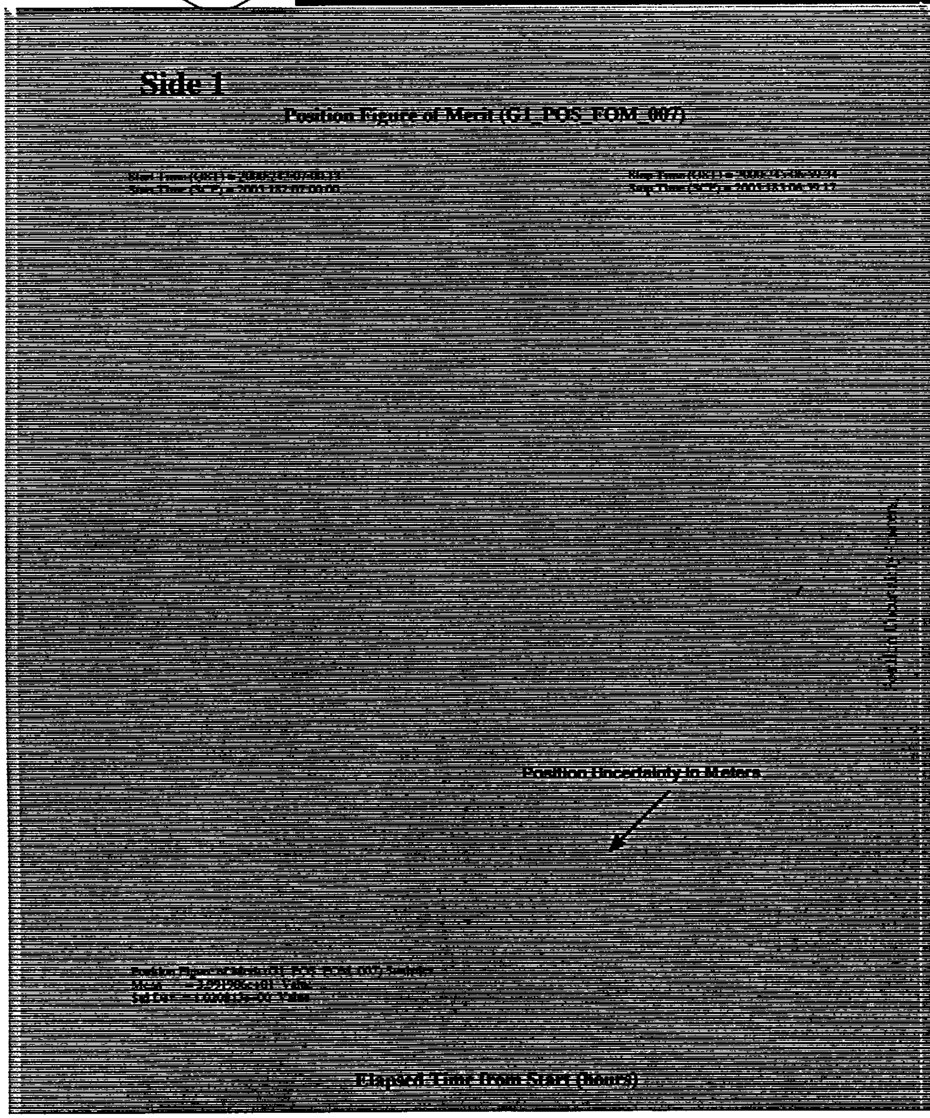
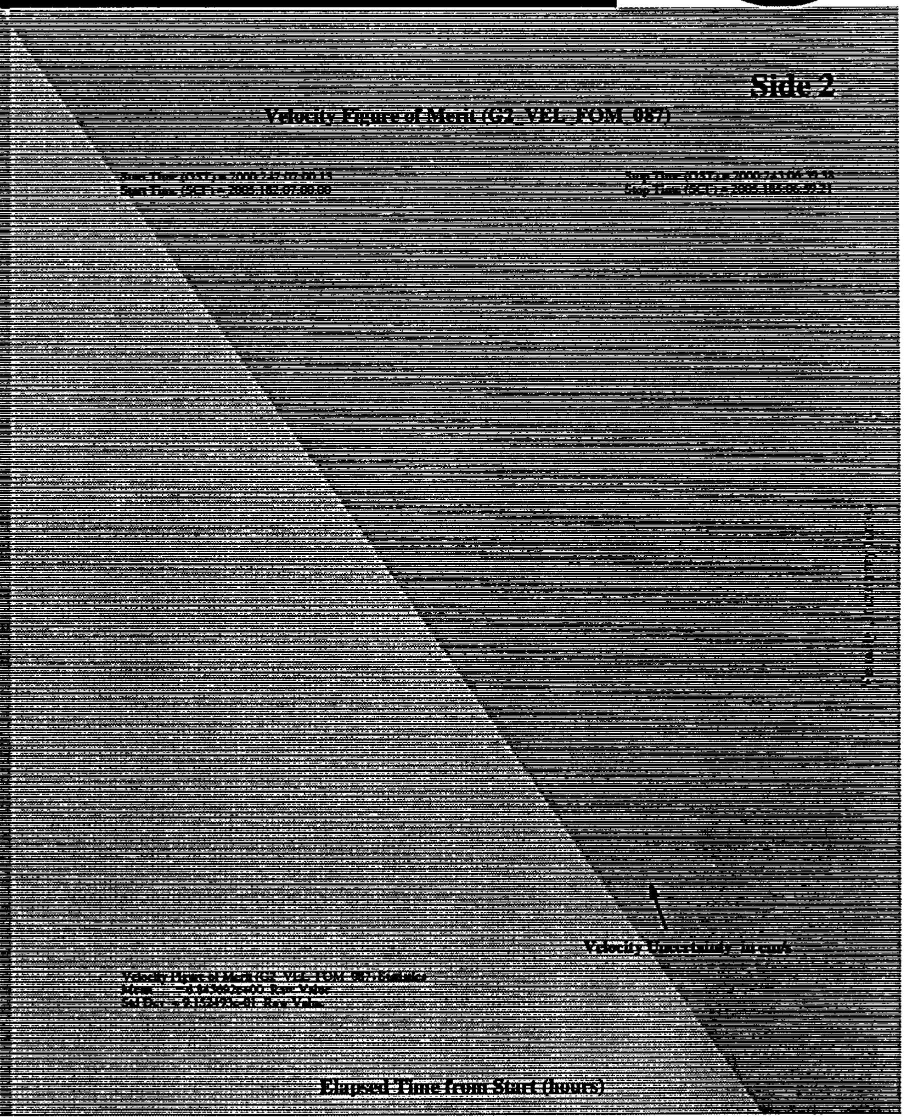
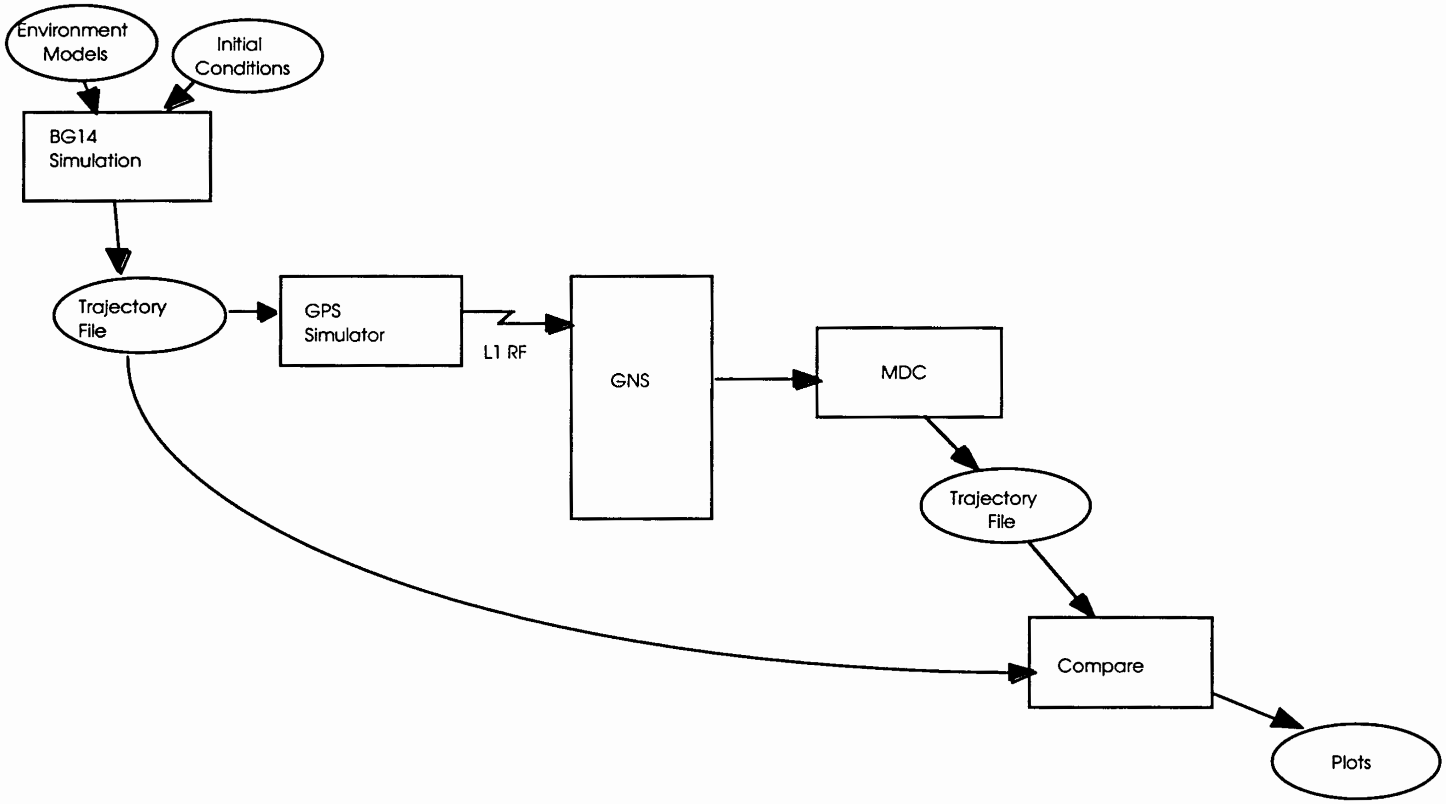




Ref Question #: 7

GNS PVT Residuals Test Flow



Motion File Configuration

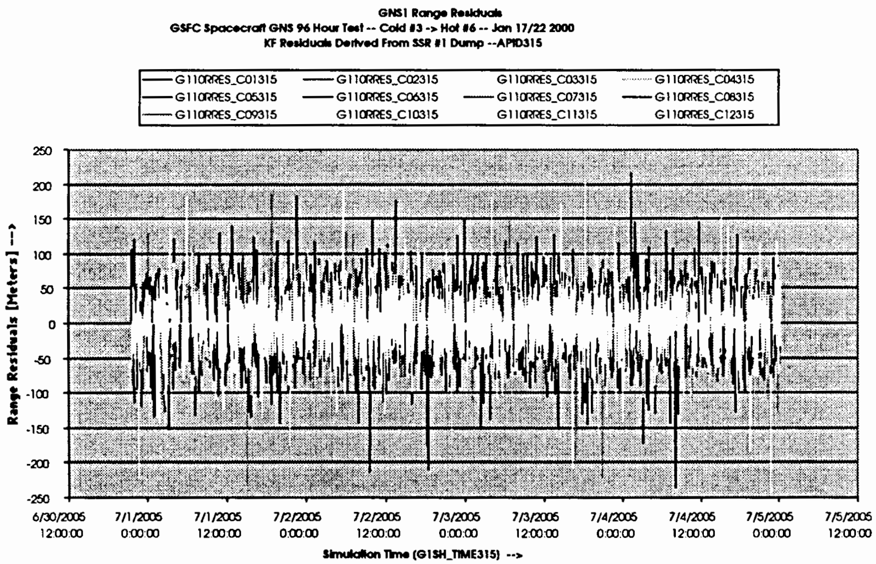
- Generated using BG-14 Propagator
- Orbit : 625 km height, 74.1° inclination
- Solar flux and geomagnetic index models : peak of last solar cycle
- Third body effects enabled
- Gravity model GEM10 30X30
- Nadir pointing spacecraft (Except Separation Simulation Test)

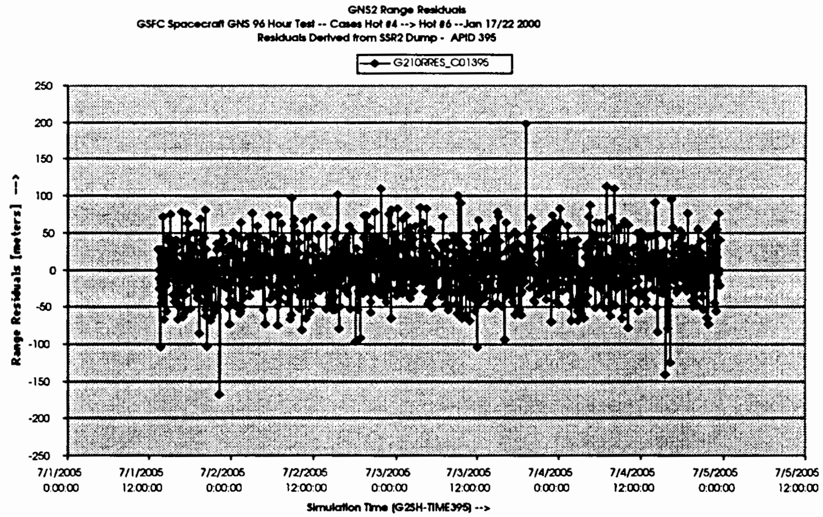
GPS Simulator Configuration

- Calibrated signal levels to GNS preamp module inputs (RF cable and antenna hat-coupling losses compensated for)
- GPS satellite antenna simulation enabled
  - -130 dBm @ 90° and 5° elevation
- GNS antenna simulation enabled
  - Antenna gain pattern based on measured flight antenna data
- Selective Availability enabled through June 2000 tests -- Disabled for August 2000 Tests
- Lever arm : -1 meter along zenith
- GPS Ephemeris and almanac message simulation data derived from actual GPS message data
- GPS Ephemeris : Includes perturbation parameters in augmented Kepler parameter set

Telemetered Range Residuals

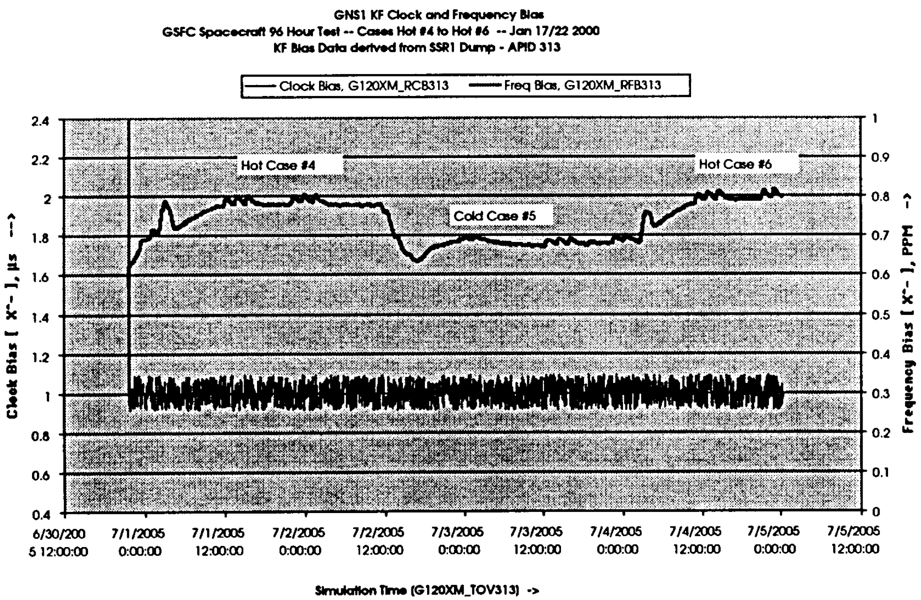
Jan 2000 96 Hour Test

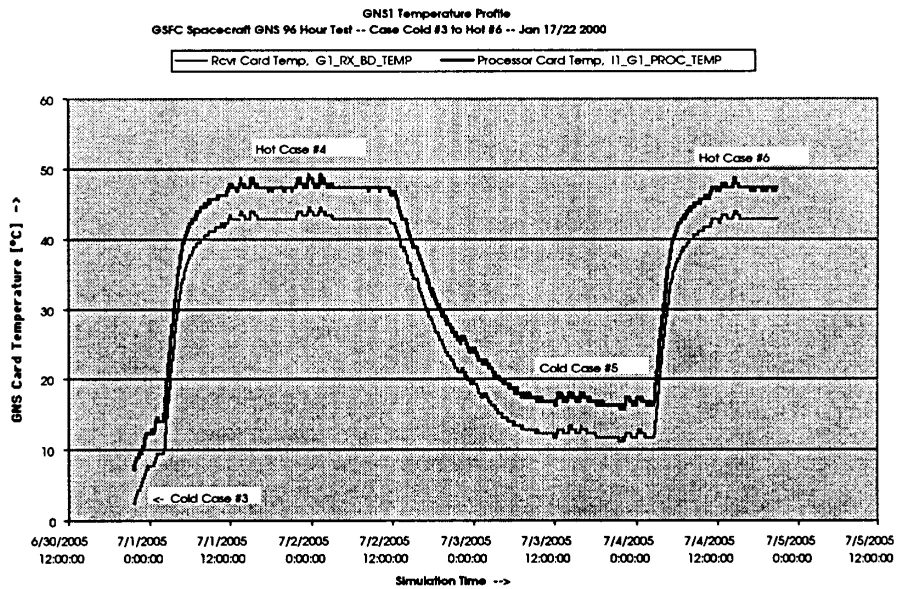




Trended Parameters From 96 Hour Spacecraft T-V Test Jan 2000

GNS 1 Clock and Frequency Bias Variation With Temperature





Ref Question #: 7

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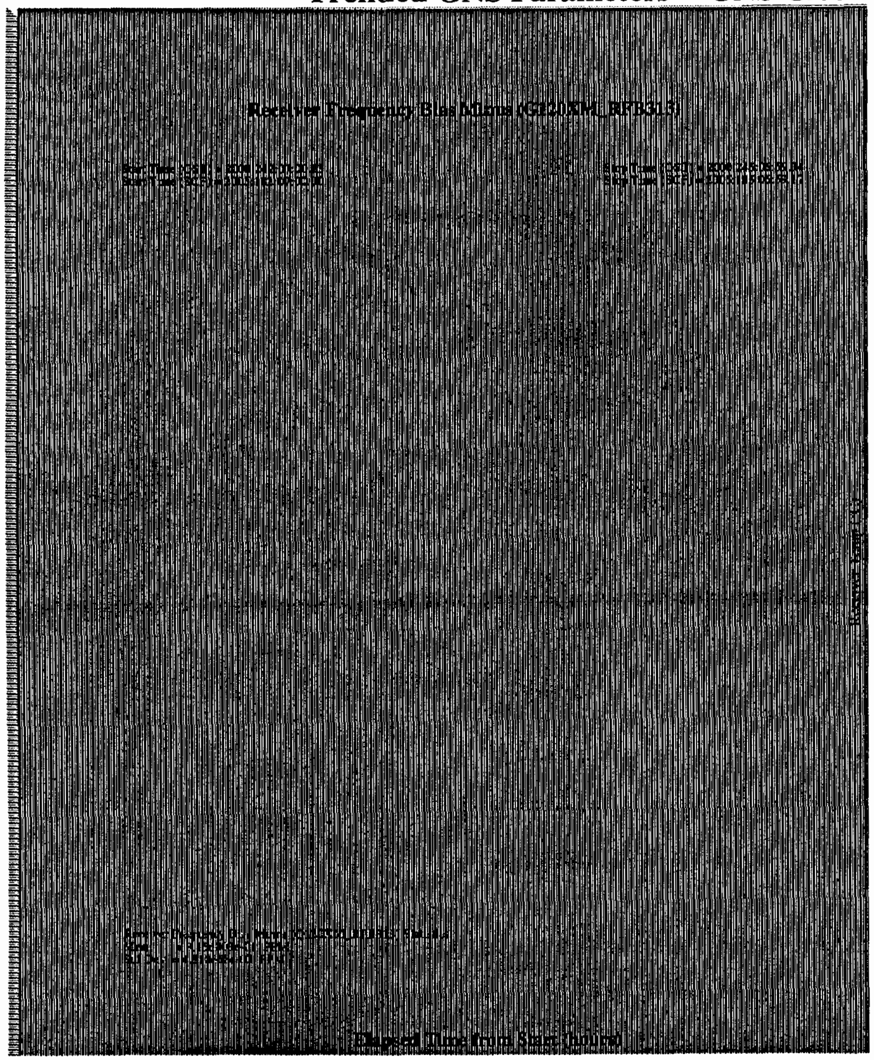
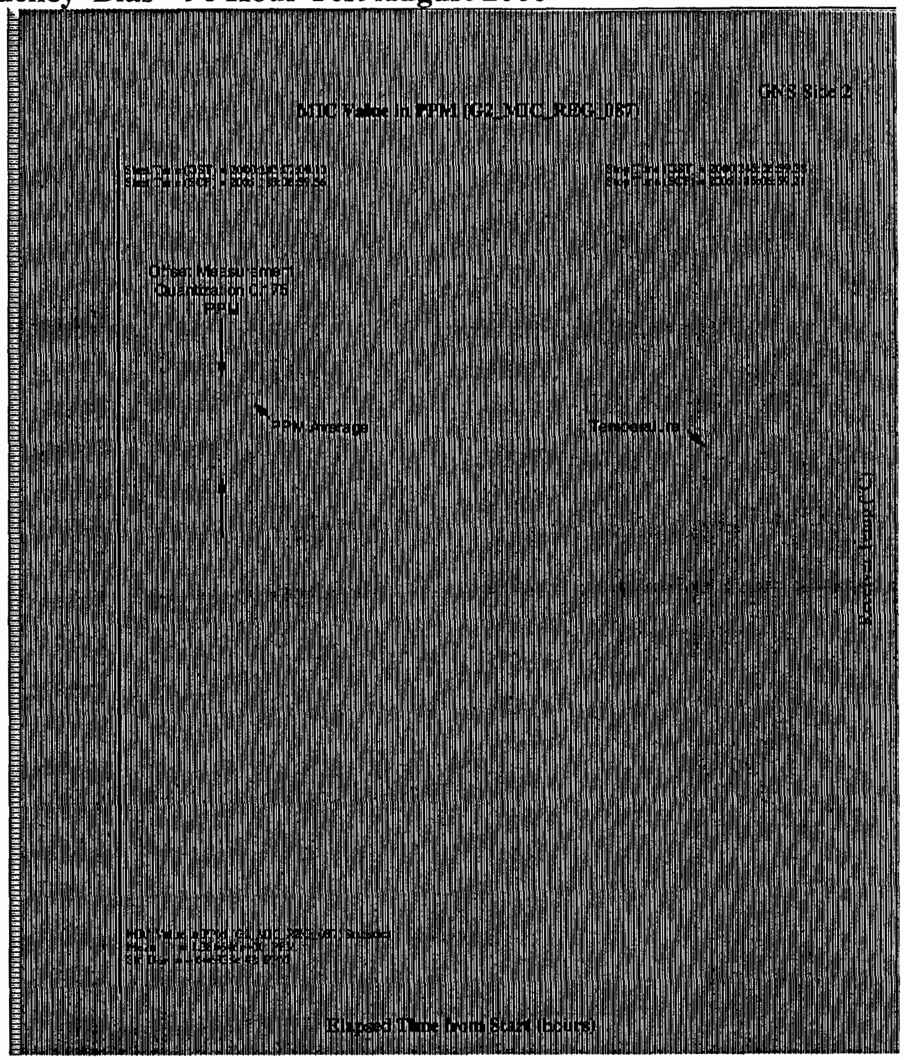
Trended GNS Parameters -- GNS Clock Frequency Bias-- 96 Hour Test August 2000





Ref Question #: 7

rjh-50

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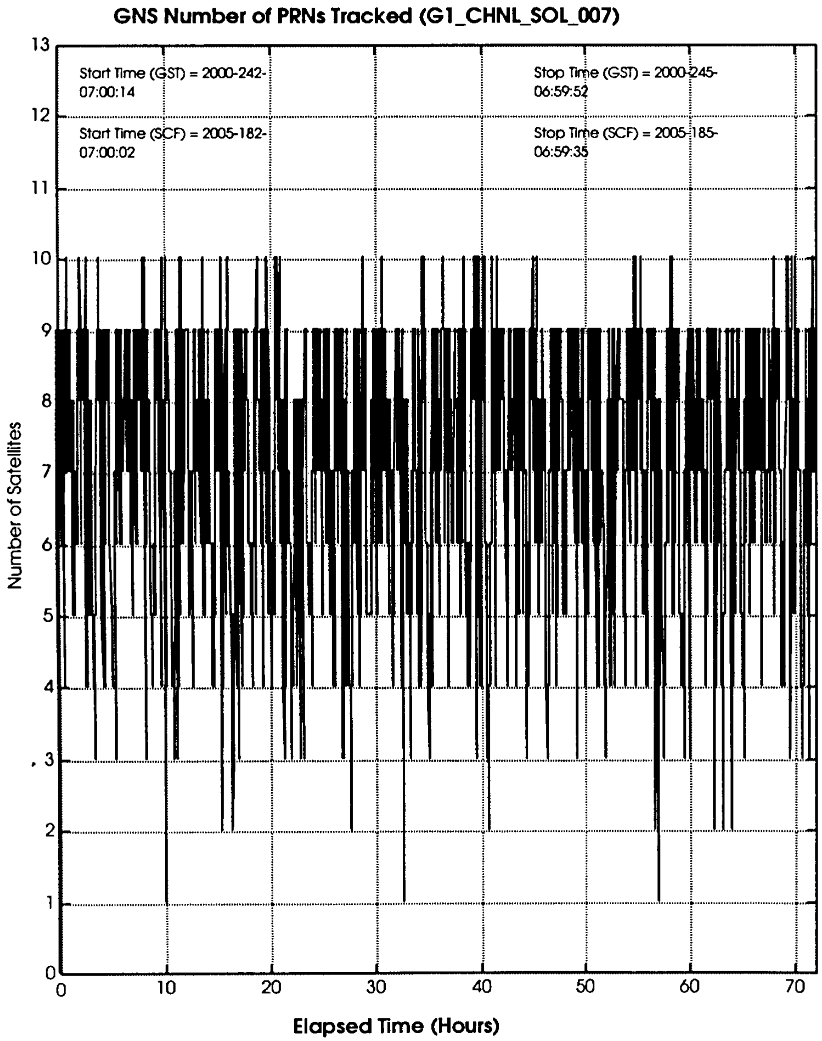
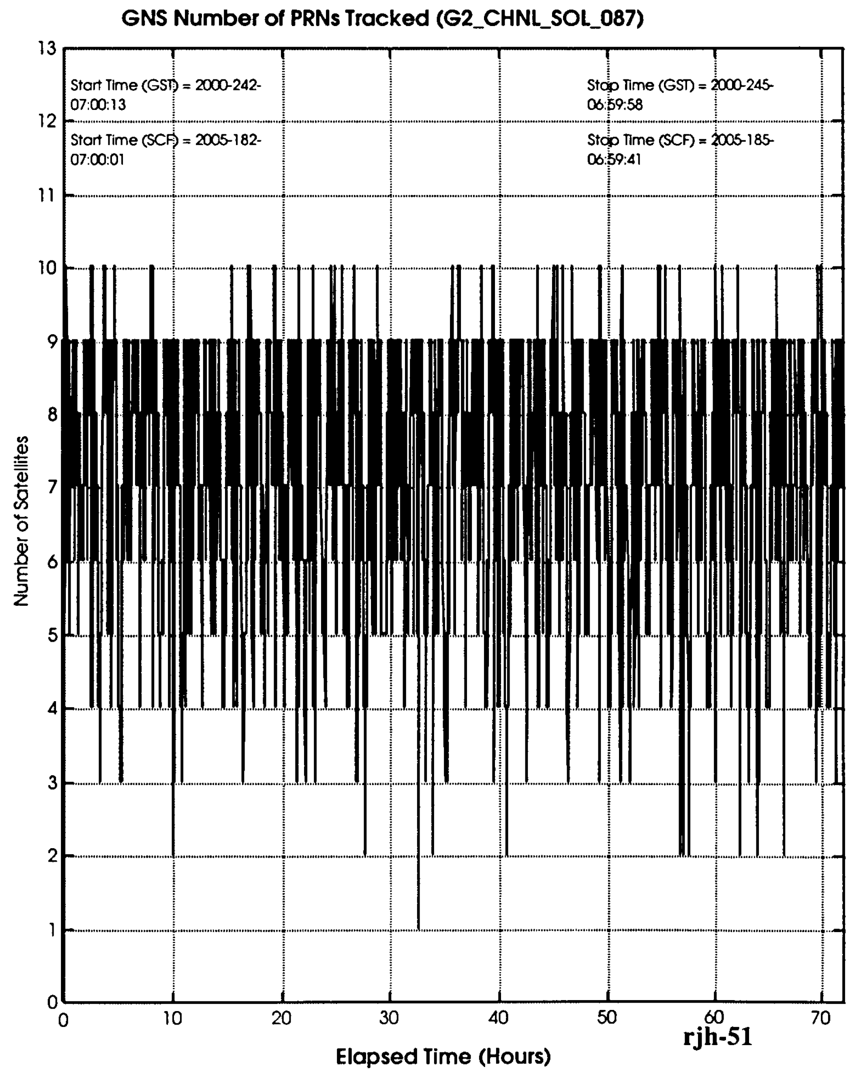
Example of GNS Status Data -- Number of GPS SVs Tracked -- Aug 2000 96 Hour Test

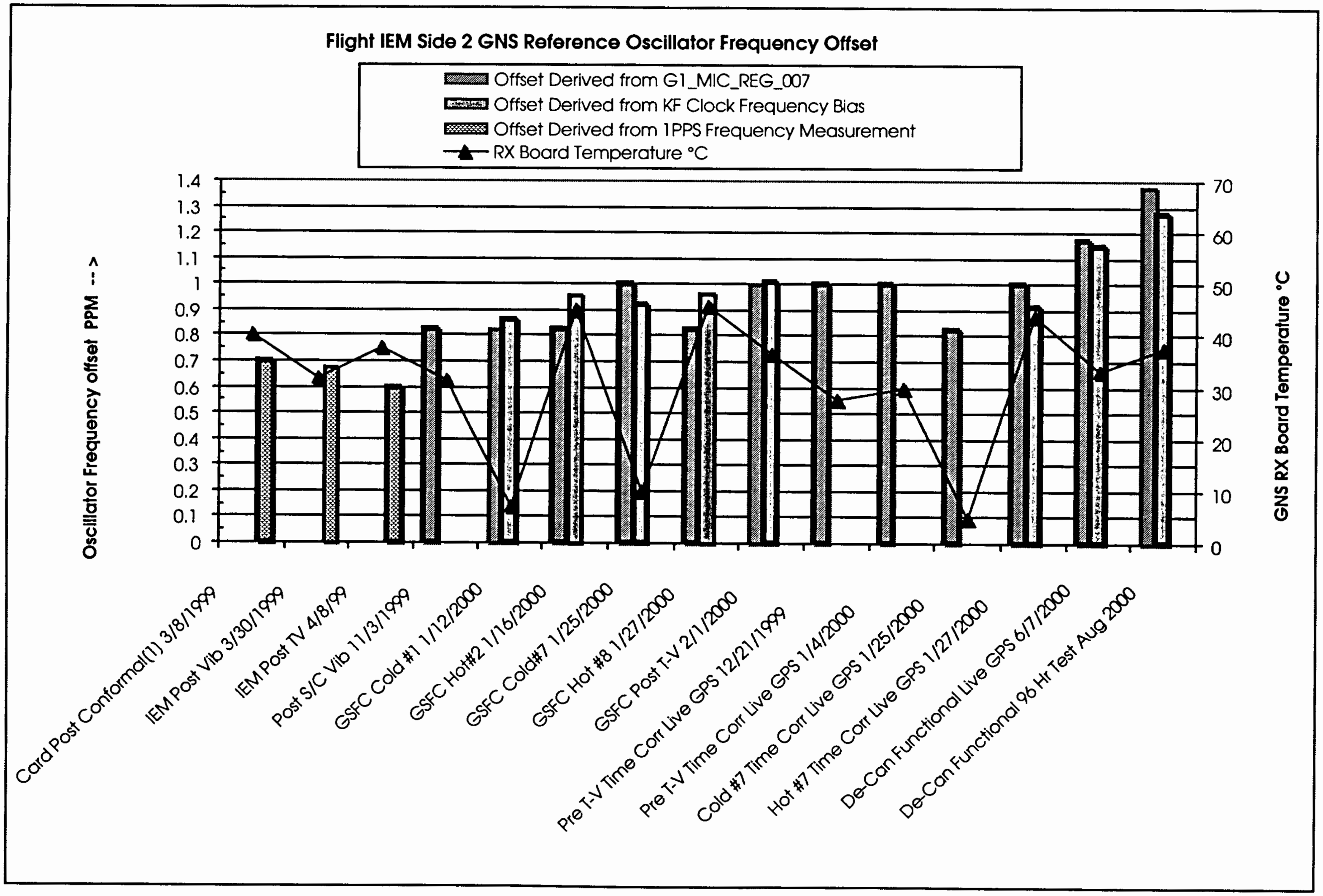




Ref Question #: 7

rjh-51

IEM GNS Side 2 Oscillator Aging



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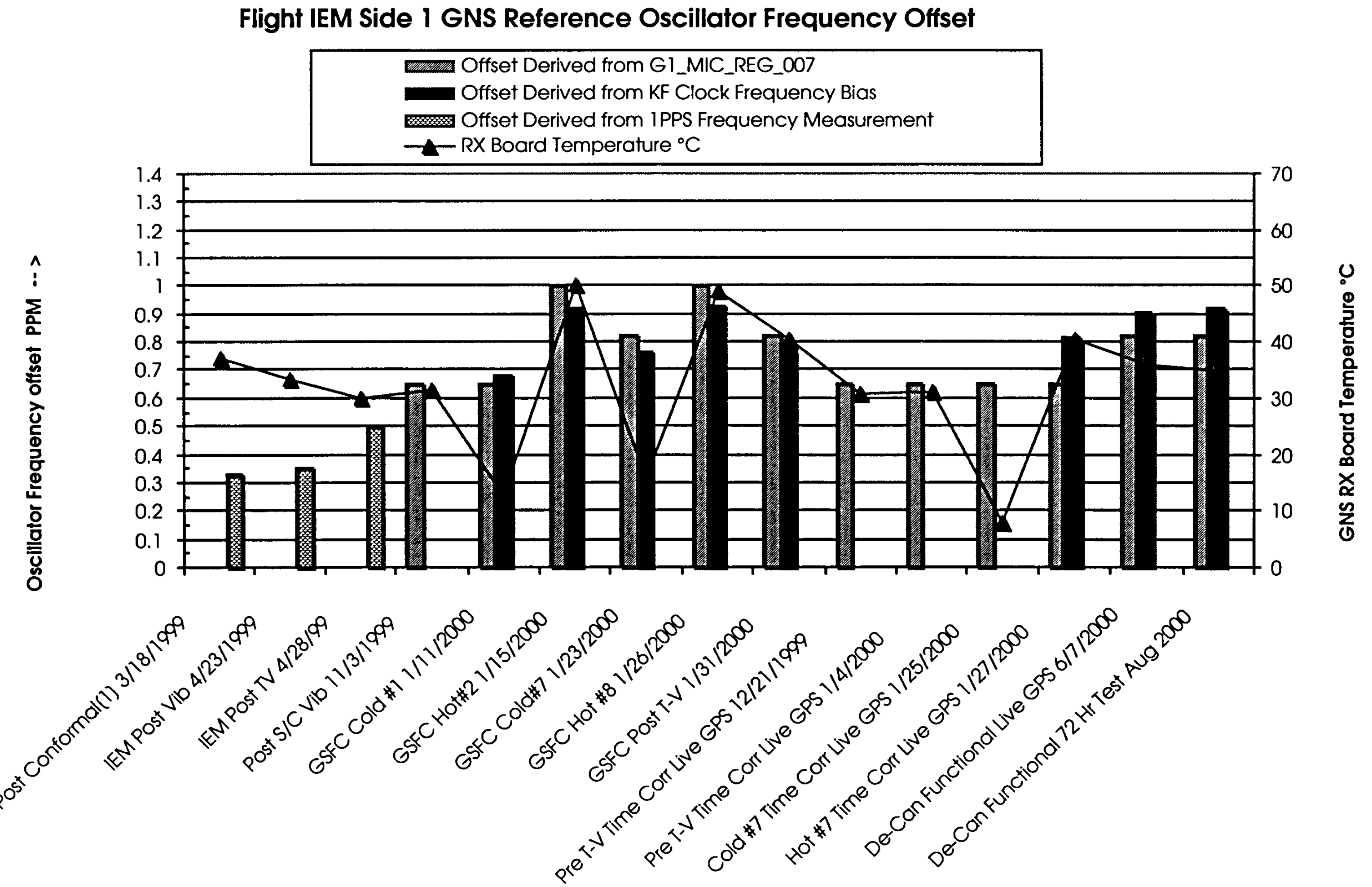
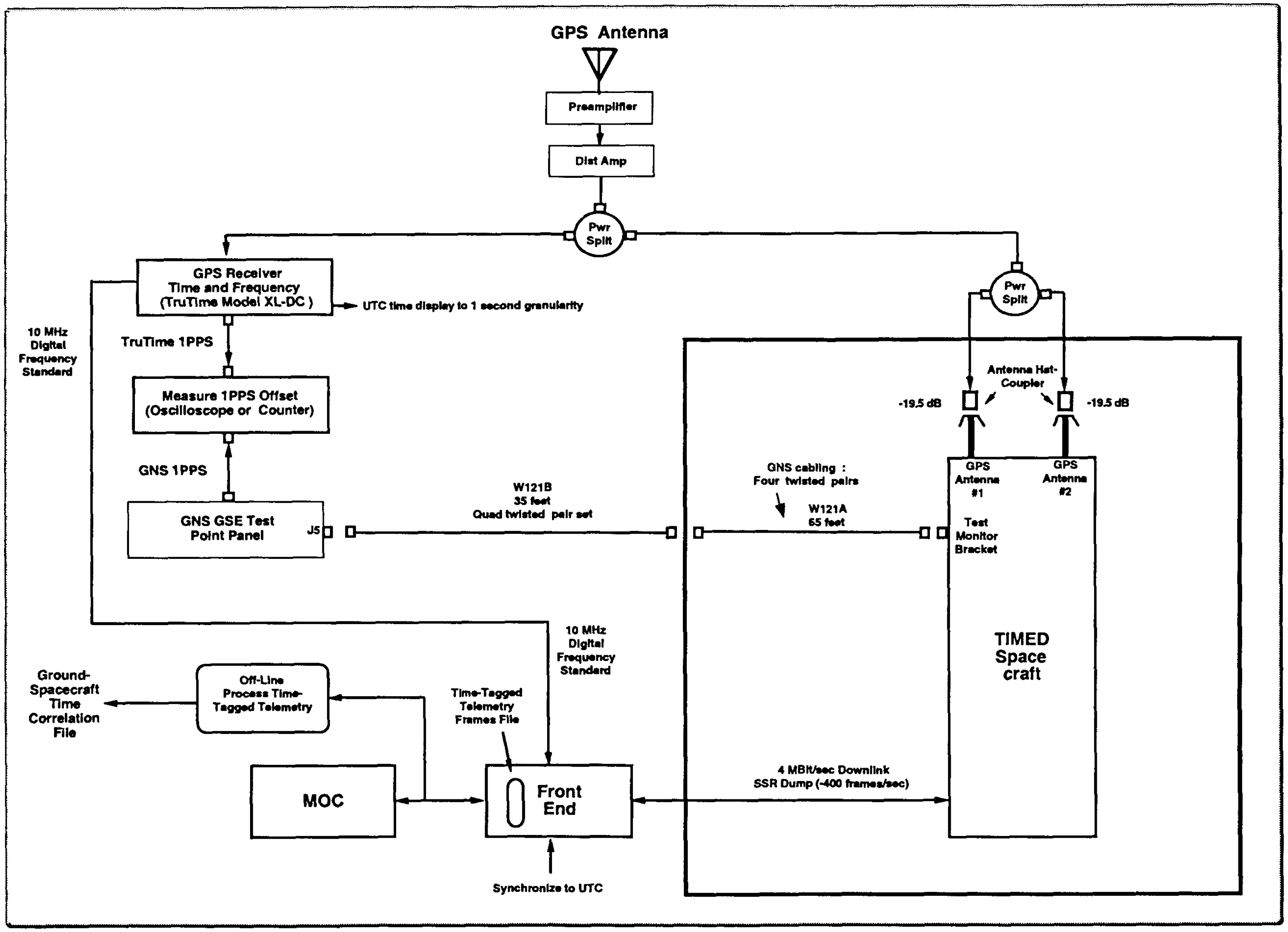
IEM GNS Side 1 Oscillator Aging



Ref Question #: 7

Spacecraft-Ground Time Correlation Test Configuration



Ref Question #: 7

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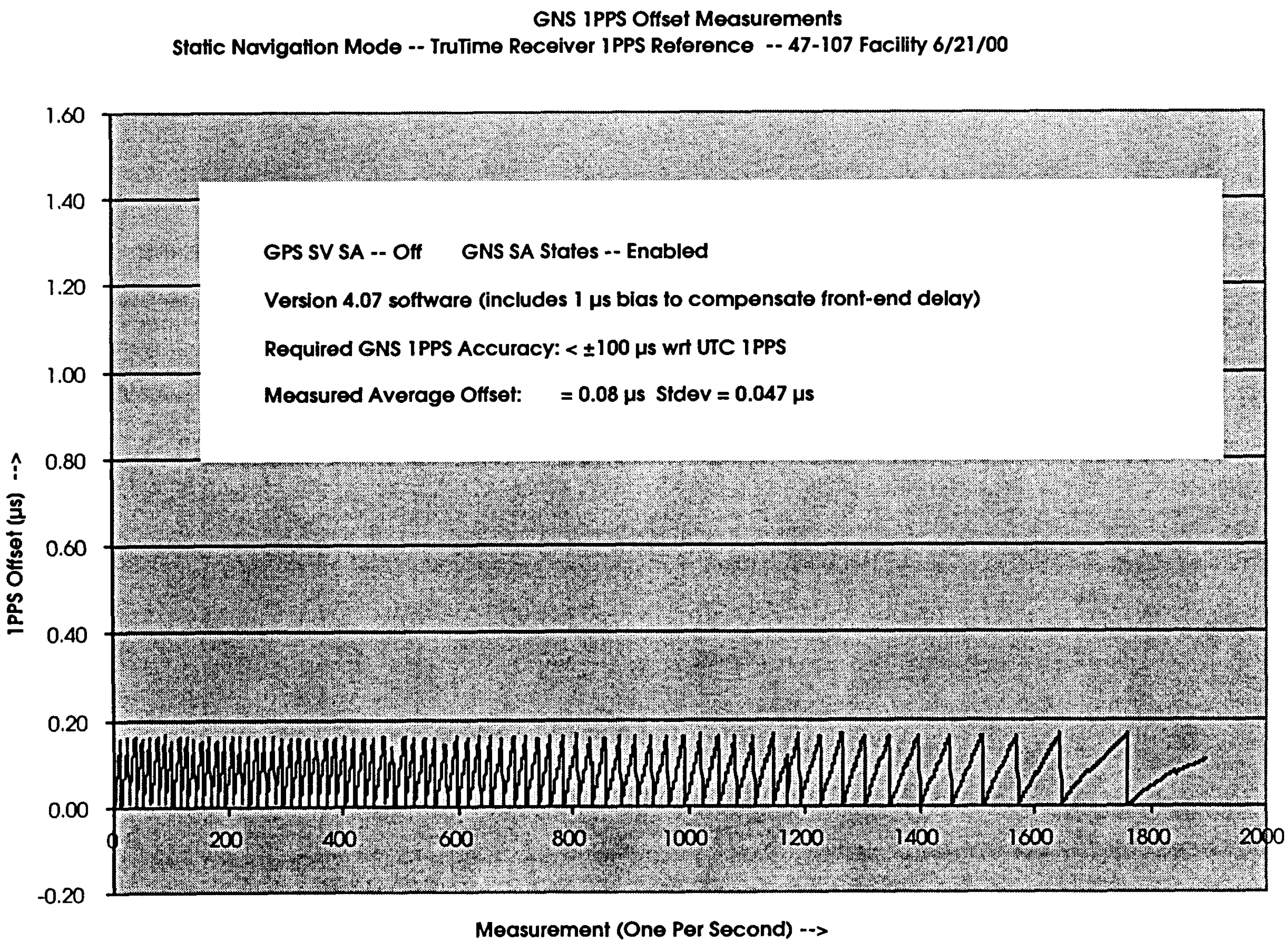
Example of UTC Reference 1PPS and GNS 1PPS Time Difference



Ref Question #: 7

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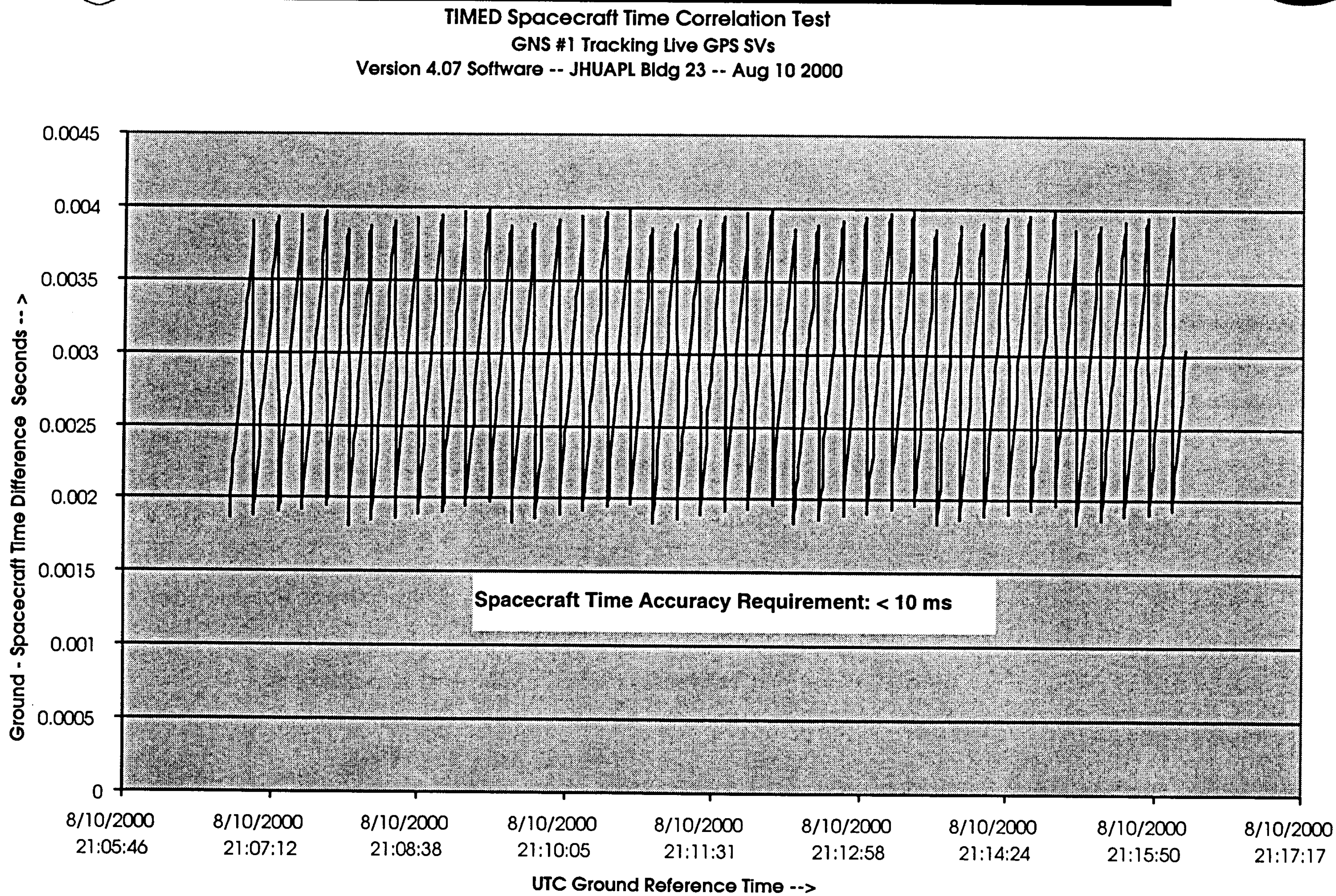

Ref Question #: 7

rjh-56

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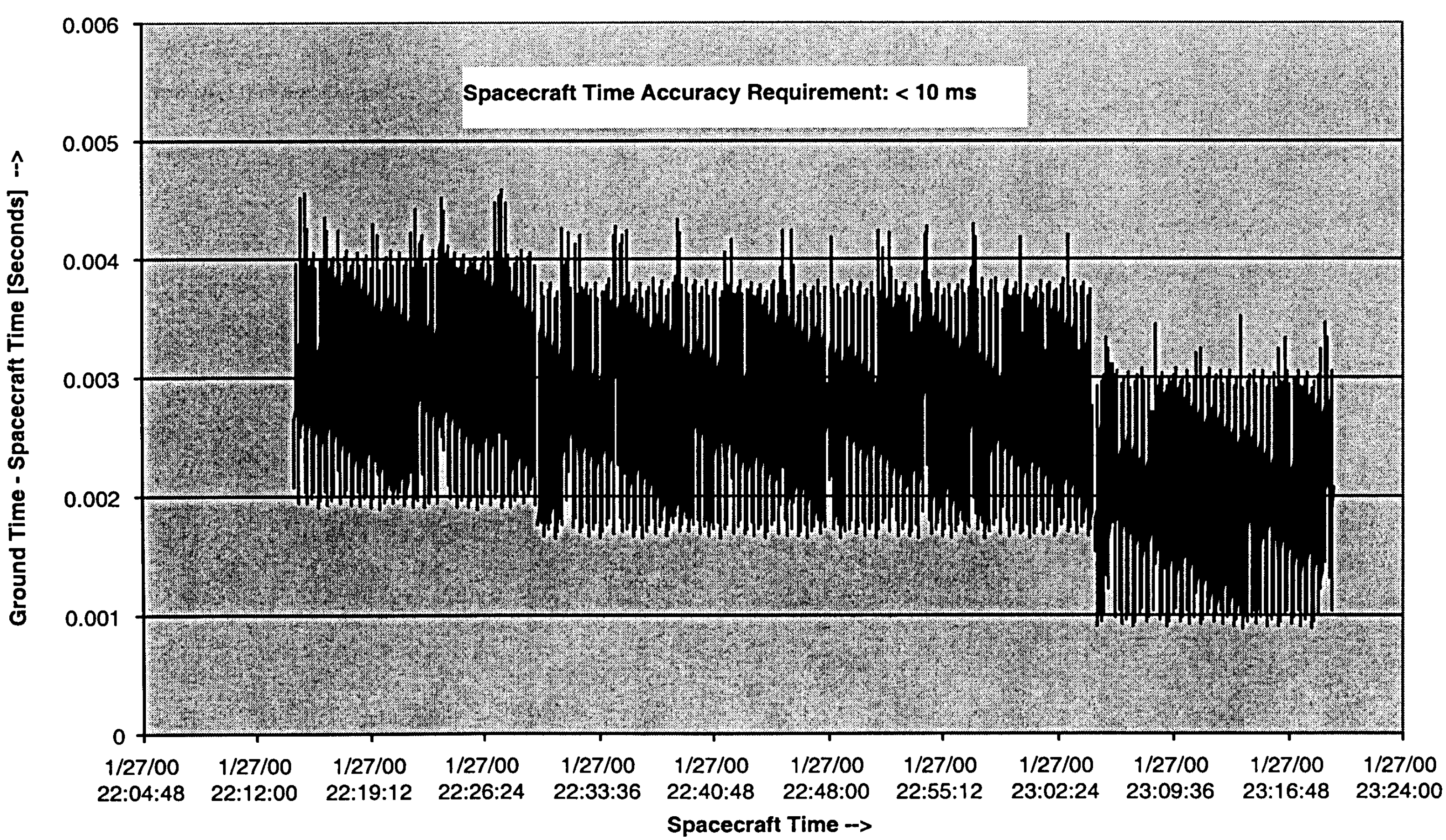
Ground Time Vs. Spacecraft Time

GSFC Spacecraft Time Correlation Test -- Hot #8 Jan 27 -- GNS2 Tracking Live Signals

Bus Controller #2



Ref Question #: 7

rjh-57

GNS SPR Summary

SPR 315	Navigation Processor Exception occurred in Element Set Generation task	Closed: Correction to prevent exceptions included in version 4.05 software loaded prior to January 2000 spacecraft test
SPR 378	GNS locked up trying to load boot code	Closed: GNS performance test procedure modified to delay navigation processor reset command following boot code load commands
SPR 404	GNS Orbit Element sets need to be given in UT time (not TDT) for use by SGP4 propagator	Closed: Time conversion correction included in navigation processor software version 4.06
SPR 418	Six second error in prediction products	Closed: Correction tested and included in navigation processor software version 4.06
SPR 417	Prediction task sets wake-up time incorrectly	Closed: Correction to index pointer tested and included in navigation processor software version 4.06
SPR 429	Contact Flag Lead Time	Corrected in navigation processor software version 4.07

Residual Risk

(All of the following items are considered very low risk)

- External In-band EMI (None found in test)
- EMI due to change in a spacecraft subsystem
- RF Mockup tests only approximate actual antenna gain patterns
- First time space application for GTA ASIC and RF Downconverter chip
- Simulated on-orbit environment during tests Vs actual on-orbit environment

Reference RTR Item vs GNS VG number

Reference Item	Description	<-- GNS VG # -->																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
3	Level & thoroughness of test & verification program											x	x	x						x		x	x	x		x	x	x	x	x	x
5	Systems management imposed and implemented..		x	x	x	x		x	x	x															x						
7	Results of test & integration process										x				x	x	x	x	x		x										
8	Operating Time																												x		
9	Results of technical review process						x																								
13	Risk																														

Reference Item	Description			-->																									
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
3	Level & thoroughness of test & verification program			x	x	x		x	x		x	x					x	x												
5	Systems management imposed and implemented..																													
7	Results of test & integration process	x	x				x			x			x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	
8	Operating Time			x																										
9	Results of technical review process																													
13	Risk																													x

TIMED RF Communications System

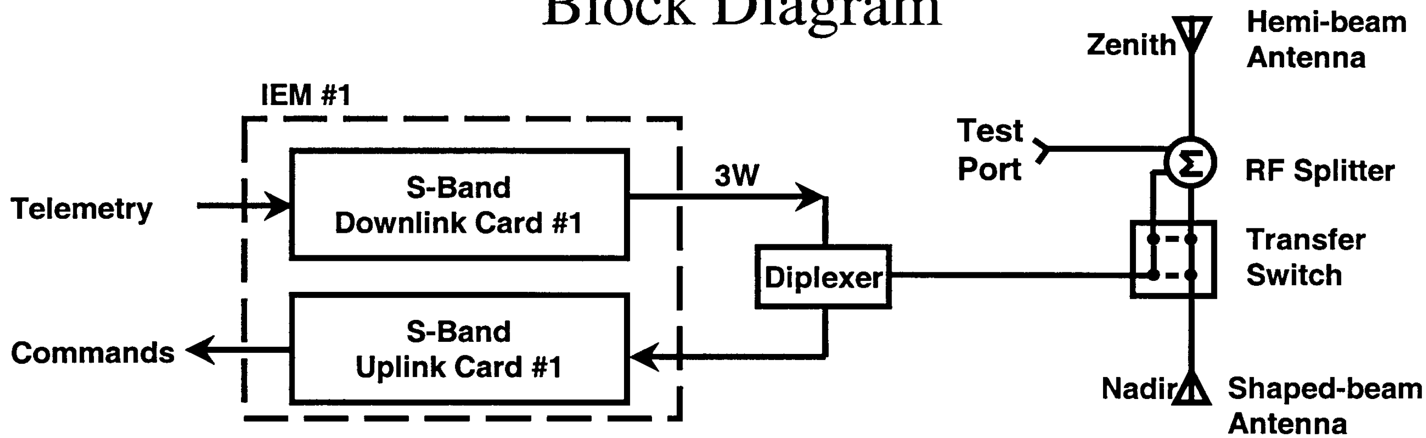
Chris DeBoy

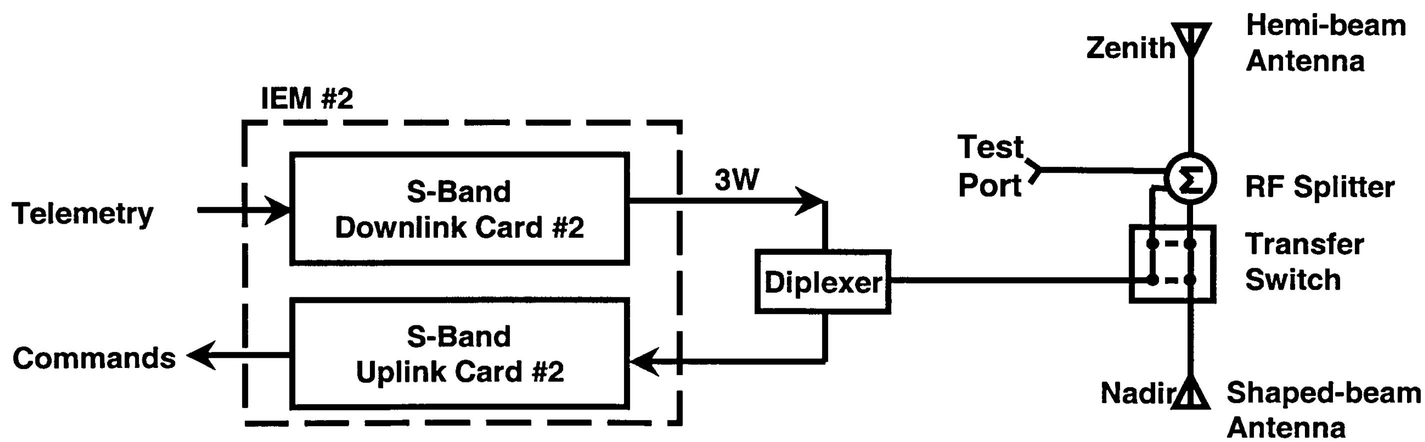
RF Engineering Group
Space Department
JHU/APL

Red Team Question/Slide Index

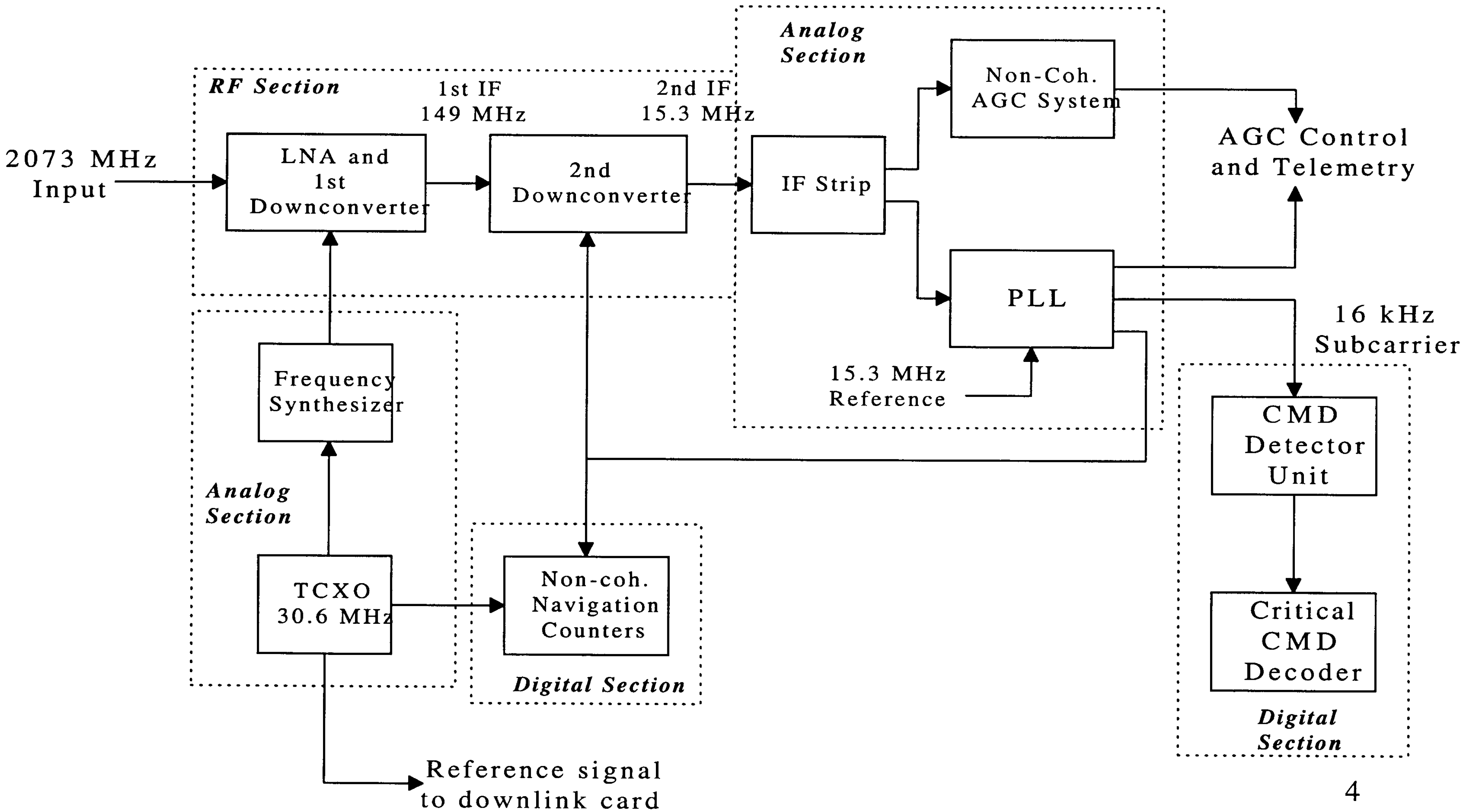
Technical Reviews	Question 1	Slides 7-11
Verification Matrix	Question 3	Slide 14
Review Doc. & RFA Status	Question 9	Slides 7-11, 17, 18
Test Results & PFR Status	Question 7	Slides 12, 13, 16

RF Communication System Block Diagram

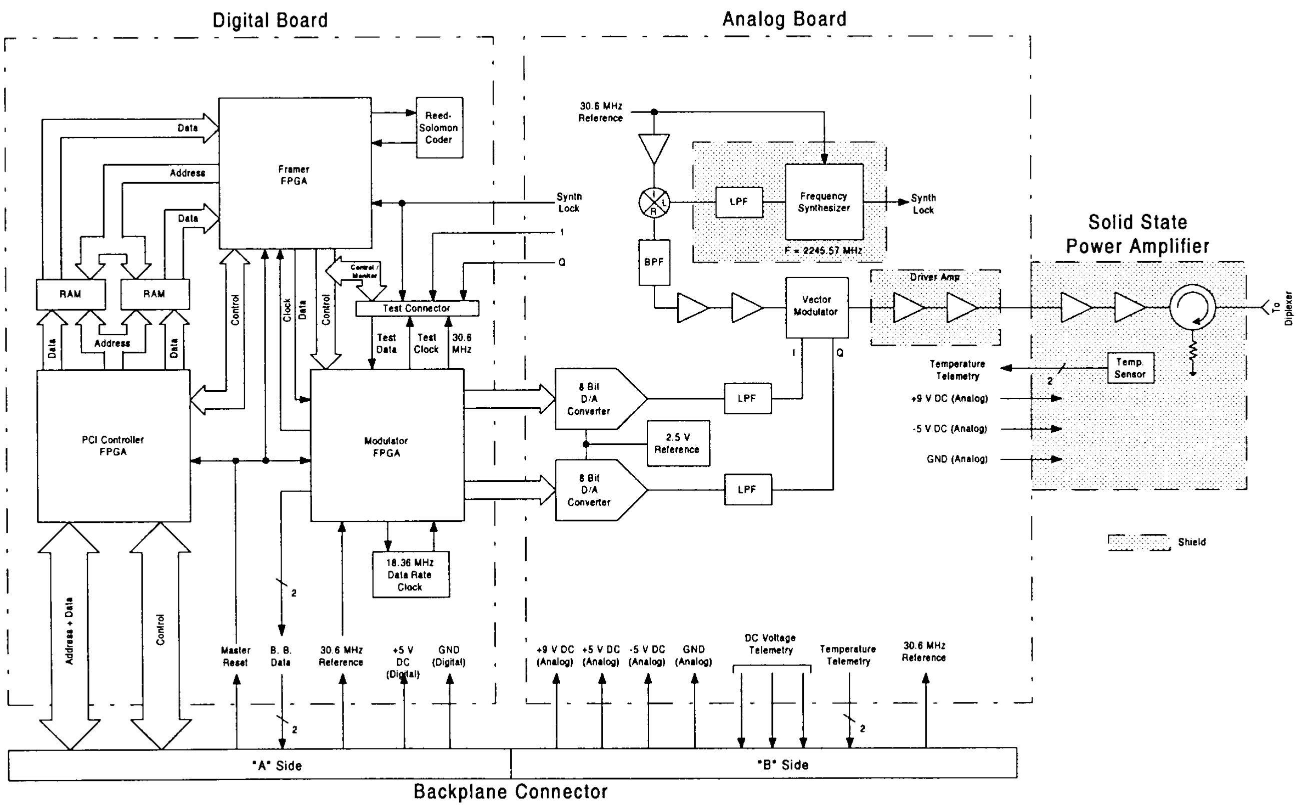




Uplink Card Block Diagram



Downlink Card Block Diagram



System Requirements

- Fully redundant
- Compatible with APL, backup, and contingency ground stations
- Compatible with NTIA emission requirements, CCSDS recommendations
- Bit Rates
  - High rate downlink 4.59 Mbps Reed-Solomon encoded
  - Low rate downlink 10.36 kbps Reed-Solomon encoded
  - Uplink at 2 kbps
- Link Margin Requirements
  - Downlink High Rate: > 3 dB (P_e = 1E-7)
  - Downlink Low Rate: > 3 dB (P_e = 1E-6)
  - Uplink: > 6 dB (P_e = 1E-6)
- Antenna Requirements
  - Downlink High Rate: cover a 66° cone about nadir
  - Uplink and Downlink Low Rate: cover 95% of the sphere about the S/C

RF System Technical Reviews

Subassembly Reviews

Uplink Card (Receiver)

Engineering Design Review held 15 October 1997

Technical Reviewers (all APL):

- M. Reinhart, SER (Lead RF Engineer, CONTOUR)
- M. Boehme, SEA (RF Design Eng'r, GPS Applications)
- J. Bogdanski, SEE (Senior Digital Design Engineer)

List of RFA's:	D. Tracy, SOM-2-97-028, 22 Oct 97
EDR RFA Responses:	C. DeBoy, SER-98-044, 9 Sep 98
RFA Status:	All Closed

Question 1, 9

RF System Technical Reviews, cont'd

Subassembly Reviews

Downlink Card (Transmitter, Framer and PCI ACTELs)

Engineering Design Review held 12 April 1998

Technical Reviewers (all APL):

- M. Reinhart, SER (Lead RF Engineer, CONTOUR)
- M. Boehme, SEA (RF Design Engineer, GPS Applications)
- G. Theodorakis, SER (Senior Digital Design Engineer)
- J. Bogdanski, SEA (Senior Digital Design Engineer)

List of RFA's:	D. Tracy, SOM-2-98-007, 13 Apr 98
EDR RFA Responses:	S. Cheng, SER-98-046, 8 Sep 98
	S. Cheng, SER-00-068, 20 Oct 00
RFA Status:	All Closed

Question 1, 9

RF System Technical Reviews, cont'd
Subassembly Reviews

Downlink Card (Modulator ACTEL)

Engineering Design Review held 17 Oct 1997

Technical Reviewers (all APL):

G. Theodorakis, SER (Senior Digital Design Engineer)
J. Bogdanski, SEA (Senior Digital Design Engineer)

List of RFA's:	R. Bokulic, SER-97-088, 22 Oct 97
EDR RFA Responses:	K. Fielhauer, Downlink EDR pkg, 6 Apr 98
	S. Cheng, SER-98-046, 8 Sep 98
RFA Status:	All Closed

RF System Technical Reviews, cont'd

Subassembly Reviews

<u>Antennas</u>

Antenna Engineering Design Review held 13 Jul 98

Technical Reviewers (all APL):

B. Mallalieu (Fleet Systems) (Senior Antenna Design Engineer)

J. von Mehlem (SER) (Senior RF System Engineer)

RFA's: (one) Examine Reliability of Soldered Interconnects for the Nadir Antenna

EDR RFA Responses: G. Clatterbaugh, TSE-98-060, 5 Aug 98

RFA Status: Closed

Question 1, 9

RF System Technical Reviews, cont'd

Subassembly Reviews

Cable and Switch Assemblies

Engineering Design Review held 12 Mar 98

Technical Reviewer:

P. Schwartz, SEE (Senior Electrical Design Engineer)

List of RFA's:	D. Tracy, SOM-2-98-006, 13 Mar 98
EDR RFA Responses:	J. Goldman, SER-98-022, 29 Apr 98
RFA Status:	All Closed

Question 1, 9

RF System Test Program

Cards:
- Initial Performance Test (-34°C to +85°C)
- Environmental Stress Screening (refer to SOR-98014, -34°C to +90°C, unpowered)
- Post-Conformal Coat (-34°C to +85°C)
- Post-IEM Integration

Antennas:
- Initial Performance Test
- Radiation Patterns
- Thermal Vacuum(-100°C to +75°C) and Vibration Testing

Cables:
- Electrical Testing (at WLGore and APL, -70°C to +75°C)
- Dielectric Withstanding Voltage Test (at WLGore)
- TDR Testing (-70°C to +75°C)
- Pre-integration Bakeout (+70°C)
- Post-integration Testing

Switch Assembly:
- Electrical Testing (vendor and APL, -34°C to +85°C)
- Thermal Vacuum and Vibration Testing (-34°C to +60°C)
- Post-Integration Testing

RF System Test Results

Uplink Card	Test Procedure	C. DeBoy	SER-99-002
	Flight Test Report	C. DeBoy	SER-99-012
	Flight Test Report, CCD Circuitry	S. Oden	SEE-99-016
Downlink Card	Test Procedure	S. Cheng	SER-99-010
	Flight Test Report	S. Cheng	SER-99-014
Antennas	Test Procedure	R. Stilwell	SER-98-074, 075
	Flight Test Results	R. Stilwell	SER-99-036
System	Final Link Analysis	R. Bokulic	SER-99-017

Question 7

RF System Verification Matrix

	Subassy Performance	Post ESS	Post Conformal Coat	Post IEM Integration	IEM Vibration	IEM TV
Uplink Card						
Best Lock Frequency	√	√	√	√	√	√
Swept Acquisition Threshold	√	√	√	√	√	√
Drop-Lock Threshold	√	√	√	√	√	√
Non-Swept Acquisition Threshold	√	√	√	√	√	√
Tracking Range	√	√	√	√	√	√
Dynamic Range	√	√	√	√	√	√
AGC Telemetry	√	√	√	√	√	√
SPE Telemetry	√	√	√	√	√	√
Subcarrier Lock	√	√	√	√	√	√
Command Threshold	√	√	√	√	√	√
DC Power Consumption	√	√	√	√	√	√
Downlink Card						
Output Power, all modes	√	√	√	√	√	√
Output Frequency	√	√	√	√	√	√
Frame Error Rate, all modes	√	√	√	√	√	√
Harmonics and Spurious	√	√	√	√	√	√
Telemetry and Status Indicators	√	√	√	√	√	√
DC Power Consumption	√	√	√	√	√	√
Other					*(non-IEM)*	*(non-IEM)*
Switch Configurations (all)	√	–	–	–	√	√
Cables (all)	√	–	–	–	√	√
Antennas	√	–	–	–	√	√

Pre-S/C Delivery Operating Hours

Unit	Operating Hours Prior to S/C Integration
Uplink Card SN001 (IEM#1)	~ 520 hours
Uplink Card SN002 (IEM#2)	~ 285 hours
Downlink Card SN001 (IEM#2)	~ 200 hours
Downlink Card SN002 (IEM#1)	~150 hours

P/FR's (1)

TIEM-002

FAILURE: Delamination of a bonded joint between antenna and mast cylinder, identified through thermal cycling and vibration tests.

CAUSE: Joint insufficiently cleaned prior to bonding

RESOLUTION: Joint on both units was cleaned and rebonded. 8 rivets were added through the circumference of the antenna masts and upper flange supports to mechanically join them. Units were vibrated and VSWR tested for verification.

STATUS: CLOSED

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Red Team Review 31 Oct. - 3 Nov. 2000

Summary of RFA's for RF Subsystems

Subsystem	*Origin, #*	*Nature of RFA*	*Status*	*Closing Documentation*
Antennas	EDR, 1 of 1	Reliability of solder interconnections for nadir antenna	CLOSED	TSE-98-060
Downlink Card	EDR, 1 of 19	Output power spectral density at GPS receive frequency	CLOSED	SER-98-046
	EDR, 2 of 19	Add staking and strain relief notes to drawings	CLOSED	SER-98-046
	EDR, 3 of 19	Specify match criteria for pre-modulation filters	CLOSED	SER-98-046
	EDR, 4 of 19	Consider adding attenuation to improve filter match	CLOSED	SER-98-046
	EDR, 5 of 19	Consider adding RF output power monitor	CLOSED	SER-98-046
	EDR, 6 of 19	Verify amplifier is stable over temperature and voltage	CLOSED	SER-98-046
	EDR, 7 of 19	Reverify total board capacitance	CLOSED	SER-98-046
	EDR, 8 of 19	Conduct system-level conducted emissions examination?	CLOSED	SER-98-046
	EDR, 9 of 19	Check total capacitance on +5V digital supply line	CLOSED	SER-98-046
	EDR, 10 of 19	Explain 0.5 dB difference in output mode powers	CLOSED	SER-98-046
	EDR, 11 of 19	Characterize performance over voltage	CLOSED	SER-98-046
	EDR, 12 of 19	Characterize performance with varying 30.6 MHz reference	CLOSED	SER-98-046
	EDR, 13 of 19	Explain increase in phase noise with temperature	CLOSED	SER-98-046
	EDR, 14 of 19	Update power estimate and thermal predictions	CLOSED	SER-98-046
	EDR, 15 of 19	Revisit the divide-by-5 circuit	CLOSED	SER-98-046
	EDR, 16 of 19	Coordinate testing of ACTELs	CLOSED	SER-98-046
	EDR, 17 of 19	Pseudo-random pattern in SSR for easier BER measurements?	CLOSED	SER-98-046
	EDR, 18 of 19	Complete parts stress analysis	CLOSED	SER-98-046
	EDR, 19 of 19	Consider using leading-edge pulse generator in framer	CLOSED	SER-98-046
	Modulator, 1 of 9	Need pull-down resistors on downlink card	CLOSED	D/L EDR Package
	Modulator, 2 of 9	Differential QPSK type should be jumper-set	CLOSED	D/L EDR Package
	Modulator, 3 of 9	Verify 330ohm resistors are large enough to limit current	CLOSED	D/L EDR Package
	Modulator, 4 of 9	Add a reset requirement in the specification	CLOSED	D/L EDR Package
	Modulator, 5 of 9	Will D/A converters power the output circuits with ACTEL off?	CLOSED	SER-98-046
	Modulator, 6 of 9	Baseband umbilical and landlines to use NRZ-L	CLOSED	D/L EDR Package
	Modulator, 7 of 9	Revisit the divide-by-5 circuit implementation	CLOSED	SER-98-046
	Modulator, 8 of 9	Consider incorporating master/slave flip-flops	CLOSED	D/L EDR Package
	Modulator, 9 of 9	Should we add resistors to op-amps' power supply lines?	CLOSED	D/L EDR Package

Question 9

Summary of RFA's for RF Subsystems

Subsystem	*Origin, #*	*Nature of RFA*	*Status*	*Closing Documentation*
Uplink Card	EDR, 1 of 21	Plans for integrating breadboard into wire-wrap IEM	CLOSED	SER-98-044
	EDR, 2 of 21	Perform a sensitivity analysis for the PLL	CLOSED	SER-98-044
	EDR, 3 of 21	Devise a plan to examine conducted susceptibility	CLOSED	SER-98-044
	EDR, 4 of 21	Tolerance for 30.6 and 133.7 MHz signal interfaces	CLOSED	SER-98-044
	EDR, 5 of 21	Do we need a commandable CDU/CCD reset?	CLOSED	SER-98-044
	EDR, 6 of 21	Examine increasing the AGC telemetry slope for better resolution	CLOSED	SER-98-044
	EDR, 7 of 21	Compensate SPE, AGC telemetry over temperature?	CLOSED	SER-98-044
	EDR, 8 of 21	Re-evaluate power consumption of the digital board	CLOSED	SER-98-044
	EDR, 9 of 21	Determine how to derate the +6V maximum Plessey part	CLOSED	SER-98-044
	EDR, 10 of 21	Determine whether a turn-on transient will exceed this maximum	CLOSED	SER-98-044
	EDR, 11 of 21	Ensure proper derating of resistors for voltage, temperature, res.	CLOSED	SER-98-044
	EDR, 12 of 21	Examine CTE mismatch issues between boards	CLOSED	SER-98-044
	EDR, 13 of 21	Consider using S-modules instead of C-modules in ACTEL	CLOSED	SER-98-044
	EDR, 14 of 21	Check phasing of all flip-flops not on global clocks	CLOSED	SER-98-044
	EDR, 15 of 21	Check flip-flops in CDU for SEU susceptibility	CLOSED	SER-98-044
	EDR, 16 of 21	Ensure CDU design is testable by SOR	CLOSED	SER-98-044
	EDR, 17 of 21	Consider using S-Modules instead of C-modules in counter	CLOSED	SER-98-044
	EDR, 18 of 21	Check flip-flops in CCD for SEU susceptibility	CLOSED	SER-98-044
	EDR, 19 of 21	Define what is reset in the CCD by the CDU lock signal	CLOSED	SER-98-044
	EDR, 20 of 21	Document CCD particulars for Mission Ops team	CLOSED	SER-98-044
	EDR, 21 of 21	Examine input signal filtering for false triggering likelihood	CLOSED	SER-98-044
Switch	EDR, 1 of 3	Environmental Test prior to installation on bracket?	CLOSED	SER-98-022
Assembly	EDR, 2 of 3	Multipaction in diplexer	CLOSED	SER-98-022
	EDR, 3 of 3	Do all components have vent holes?	CLOSED	SER-98-022

Question 9

Residual Risk

After reviewing the hardware design, RFA's, P/FR, and test results pre- and post- integration, no residual risk is noted.

Mission Data Center (MDC)

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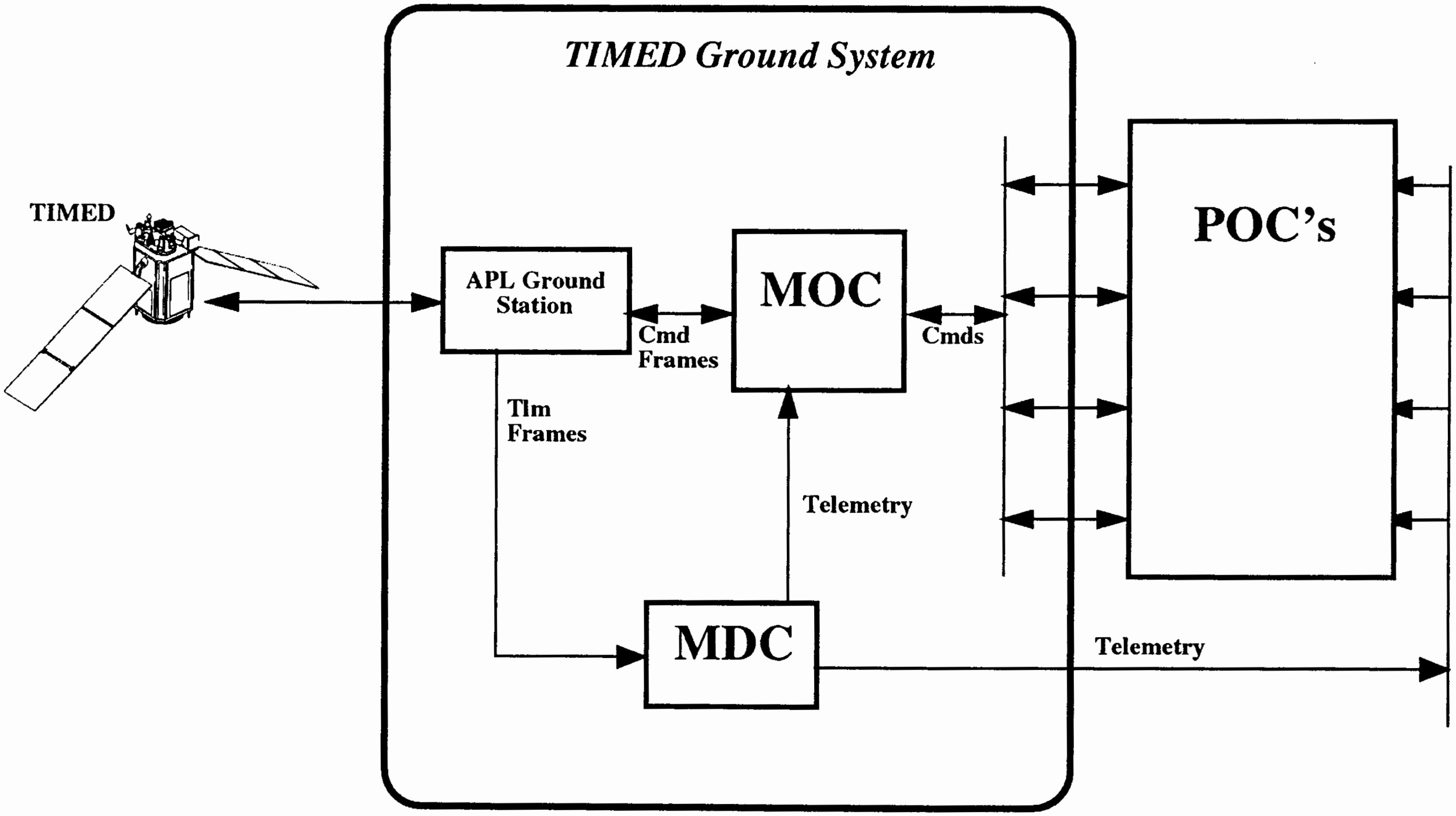
Simplified TIMED Ground System Diagram



MDC Services Supporting MOC & POCs

- **Telemetry Service**
  - Sole responsibility for telemetry archives
  - Level-0 telemetry is on line for entire mission
  - Two types of stream service
    - » Real-time stream - guaranteed current data
    - » Playback archived stream - reliable data service (no skips)
- **Orbit Files Production**
  - Position, Velocity, Attitude, and Orbital Elements
  - For mission planning and contact scheduling
  - Distributed via web (http and FTP)

MDC Software Requirements (1 of 2)

(Addresses review item 5)

- **TIMED Mission Data Center Software Requirements Specification, JHU/APL 7363-9327**
  - **Covers Real-time and Playback Telemetry Service**
  - **Real-time and dump telemetry archiving**
  - **Command archiving**
  - **USN Telemetry Retrieval and Archiving**
  - **Archive Map utility**

MDC Software Requirements (2 of 2)

(Addresses review item 5)

- **Section 8.0 of the TIMED General Instrument Interface Specification, JHU/APL 7363-9050**
  - **Covers Interface Requirements between MDC and POCs**
  - **Covers Orbit File requirements used by the POCs and the MOC**

- **Requirements Verification Matrix is at the end of this package.**

MDC Software Release Overview (1 of 4)

(Addresses review item 5)

- **Build 1 Release**
  - Included Telemetry Server Software
  - Provided MDC in support of Mini-MOCs
  - Real-time and playback stream services
  - Ground receipt time indexing.
  - Released in March, 1998 (labeled MINIMOC)

MDC Software Release Overview (2 of 4)

(Addresses review item 5)

- **Build 2 Release**
  - Provided support for Integration and Test Phase.
  - Added additional capabilities
    - » Archiving based on archive flag
    - » Allowed hexadecimal APID directives, etc.
    - » Added console port to allow real-time re-configuration without shutting down telemetry server
  - Added additional support utilities
    - » Archive Map
    - » MDC status telemetry to MOC
    - » Command Spooler
    - » Raw telemetry archival to tape
  - Released in October, 1998 (labeled IT_1_1). No interim releases required.

MDC Software Release Overview (3 of 4)

(Addresses review item 5)

- **Build 3 Release**
  - Provided necessary support for Flight Operations.
  - Added capability to playback telemetry by spacecraft time.
  - Added support for USN contacts and telemetry retrieval.
  - Added notification of updates to telemetry archive to MOC.
  - Five Build 3 releases labeled as OPS_1_0 through OPS_1_4
    - » Release OPS_1_0, 04/30/99 - Initial Release.
    - » Release OPS_1_1, 09/05/99 - Added S/C time index caching to speed ingest performance.
    - » Release OPS_1_2, 10/15/99 - Limited S/C time indexing to only those packets identified as from the spacecraft (also to speed ingest performance.)

MDC Software Release Overview (4 of 4)

(Addresses review item 5)

- **Build 3 Release (continued)**
  - » **Release OPS_1_3, 09/18/00 - Added support (S/C indexing, Orbit Products, etc.) for S/C simulator.**
  - » **Release OPS_1_4, 10/11/00**
    - **Removed restriction from archiving future data beyond day 001 of 2006 in support of launch day simulation which used day 66 of 2006.**
    - **Fixed a bug in playback service where playback stopped prematurely when reaching a day without any data.**
  - – **Less than 50 lines of code changed since Release OPS_1_2, release 10/15/99.**

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

MDC Reviews Summary

(Addresses review items 1, 2, and 4)

Review	Date	Chairperson	Review Team	Action Items	Responses	Status
Build 1 Rqmts Rev. & Design Rev.	04/01/97	Harry Utterback (TIMED Software Quality Assurance)	13+ attendees; TIMED senior and principal staff	SOR-97013	SRS-97-128 thru 139 and SRS-98-001 thru 004	14 items / all closed
S/C CDR	12/4/97	Dave Grant (TIMED Program Mgr.)	(Refer to CDR materials)	None for MDC	N/A	N/A
Build 1 Code Walkthrough	12/15/97	Kevin Lyons (MDC Lead Engineer)	6+ attendees; TIMED software developers	Informal - Notes in MDC files	Informal - Notes in MDC files	66 items / all closed
Additional Build 1 Code Walkthrough	02/06/98	Kevin Lyons	6+ attendees; TIMED software developers	Informal - Notes in MDC files	Informal - Notes in MDC files	4 items / all closed
Build 2 Rqmts. Rev.	04/09/98	Kevin Lyons	13+ attendees; TIMED senior and principal staff	SRS-98-109	SRS-98-109	14 items / all closed
Command Spooler Code Walkthrough	04/30/98	Kevin Lyons	6+ attendees; TIMED software developers	Informal - Notes in MDC files	Informal - Notes in MDC files	7 items / all closed
Build 2 Design Rev.	06/03/98	Martha Chu (TIMED Mission Software Systems Engineer)	11+ attendees; TIMED senior and principal staff	SRS-98-112	SRS-00-176	6 items / all closed
Archive Map and FTP Monitor Code Walkthroughs	08/25/98	Kevin Lyons	6+ attendees; TIMED software developers	Informal - Notes in MDC files	Informal - Notes in MDC files	10 items / all closed
Build 3 Rqmts. Rev.	12/21/98	Harry Utterback	10+ attendees; TIMED senior and principal staff	SOR-98050	SRS-00-177	3 items / all closed
Build 3 Design (Lead engineer & developer collaboration; not a formal review)	N/A	Kevin Lyons	Lead engineer and module developer	None; design issues handled informally	N/A	N/A

MDC Testing (1 of 6)

(Addresses review item 3)

- **Build 1 Testing**
  - Test plan generated 03/04/98, Software Test Plan and Procedures (Build 1), JHU/APL 7363-9357
  - Testing performed and report submitted on 03/25/98 per memo SRS-98-055.
  - Testing performed by MDC lead engineer.
  - Total of 5 tests focussing on the primary performance requirements.
  - All tests passed except test #5 - Playback stream configuration capabilities. Playback streams were not supplied with terminating message when complete.
  - The problem was fixed in Build 2 and re-tested successfully.

MDC Testing (2 of 6)

(Addresses review item 3)

- **Build 2 Testing**
  - **Test plan generated 09/24/98, Software Test Plan and Procedures (Build 2), memo SRS-98-175**
  - **Testing performed and report submitted on 10/19/98 per memo SRS-98-182.**
  - **Testing performed by lead engineer.**
  - **Total of 7 tests focussing on the primary performance requirements.**
  - **All tests passed.**

MDC Testing (3 of 6)

(Addresses review item 3)

- **Build 3 Testing**
  - **S/C Mission Operations testing served as primary test mechanism for Build 3.**
  - **Formal Build 3 testing at the sub-system level with a formal report was forgone in light of the following:**
    - » **Lessening manpower funding during Build 3 development and testing phases.**
    - » **New capabilities were tested informally by MDC lead engineer.**
    - » **Reliance on S/C Mission Operations testing was considered sufficient.**

MDC Testing (4 of 6)

(Addresses review item 3)

- **Archive Map Utility Testing**
  - Test plan generated 09/3/98, memo SRS-98-159
  - Testing performed and report submitted on 09/22/98 per memo SRS-98-170.
  - Total of 20 tests focussing on the primary performance requirements.
  - All tests passed.

MDC Testing (5 of 6)

(Addresses review item 3)

- **Command Spooler Testing**
  - Test plan generated 07/08/98, memo SRS-98-136
  - Testing performed and report submitted on 08/07/98 per memo SRS-98-136.
  - Total of 3 tests focussing on the primary performance requirements. Tests 1and 2 (MDC internal) tests passed.
  - Test 3 (a MOC to MDC test with various command sizes and command rates) was not performed as written in the test plan.
    - » An informal operational test was completed but command sizes and data rates were not recorded.
    - » Soft requirement. There are no plans to utilize the service.
    - » Considering removing requirement. Commands are redundantly logged in ASCII form in EPOCH event log.

MDC Testing (6 of 6)

(Addresses review item 3)

- **Orbit File Generation Utility Testing**
  - MDC subsystem testing of the orbit file generation software was performed and results were generated on 10/19/99.
  - Test plan and report followed on 02/02/00, memo SRS-00-010
  - The test revealed an error in the decoding of GNS validity flags. This error was fixed prior to release for mission operations testing.
  - Additional releases (minor changes needed for bug fixes) tested as part of 96 hour mission operation tests in Mar, Aug, and Oct of 2000.
    - » Release 1.0, 02/02/00
    - » Release 1.1, 02/24/00
    - » Release 1.2, 03/13/00
    - » Release 1.3, 05/26/00
    - » Release 1.4, 09/28/00

MDC Software Problem Reports (1 of 4)

(Addresses review item 7 and 9)

- **Total of 32 SPR's written against MDC.**
- **29 have been closed, 3 remain open.**
- **Open SPRs**
  - SPRs 243 and 244 address an issue where telemetry archival and playback were too slow resulting from input telemetry containing disordered time stamps.
    - » Both SPRs fixed with release OPS_1_1 and OPS_1_2
    - » Both SPRs awaiting closure of related SPR 361 because ...
    - » SPR 361 affects MDC configuration and processing speed.
    - » We want to test the fix for the above SPRs in the final MDC configuration.

MDC Software Problem Reports (2 of 4)

(Addresses review item 7 and 9)

- **Open SPRs (continued)**
  - SPR 361 addresses the set up of a separate MDC for S/C only telemetry.
    - » Original plan called for a single MDC to serve and store S/C data as well as simulator telemetry and test bed telemetry.
    - » The science community and the Mission Operations Manager requested a separation of S/C telemetry from test bed telemetry both in the routing and archiving processes.
    - » In Aug. 2000, we set up a 2 separate MDC configuration.
    - » The 2nd computer system was a less capable computer and turned out to be too slow at archiving (real-time was OK).
    - » Now in process of upgrading to a new computer twice as fast as the original. The new computer is due 10/30/00.

MDC Software Problem Reports (3 of 4)

(Addresses review item 7 and 9)

Problem_Id	Function	Problem_Release	Summary	State	Date_Sub
11	MDC	MDC Rel_IT_1_1	TCP/IP indication during real time TM reception	Closed	12/1/1998 16:34
12	MDC	MDC Rel_IT_1_1	Playback: PTP size error	Closed	12/1/1998 16:39
47	MDC	MDC Rel_IT_1_1	SABER POC rejected by firewall	Closed	12/10/1998 16:35
58	MDC	MDC Rel_IT_1_1	TLM stops when local network disconnected	Closed	1/20/1999 9:02
114	MDC	MDC rel_ops_1_0 & MOC 3.0-1	Archive Server	Closed	5/11/1999 13:46
136	MDC	MDC rel_ops_1_0 & MOC 3.0-1	Exceeding the capacity of MDC archiving software	Closed	6/9/1999 14:17
138	MDC	MDC rel_ops_1_0 & MOC 3.0-1	No data in MDC archive	Closed	6/9/1999 16:08
209	MDC	MDC 3.0	MDC failed to archive, store, and forward	Closed	8/26/1999 13:58
243	MDC	MDC rel_ops_1_1	MDC archival ingestion is too slow	Released	9/15/1999 16:24
244	MDC	MDC rel_ops_1_1	Playback rate is also below specs.	Released	9/15/1999 16:33
259	MDC	MDC rel_ops_1_1	Only 8-minutes of data available on the MDC	Closed	9/29/1999 11:30
269	MDC	MDC rel_ops_1_1	Correct Time Checking for Packets to be Archived	Closed	10/7/1999 10:42
311	MDC	MDC rel_OPS_1_2	GRTime outside the range	Closed	10/22/1999 10:20
316	MDC	MDC rel_OPS_1_2	Change Archive Map Web Page default values	Closed	10/26/1999 9:30
317	MDC	MDC rel_OPS_1_2	Start time outside range and playback halts	Closed	10/26/1999 12:13
325	MDC	MDC rel_OPS_1_2	Archive server and MDAS_run_FLG_418 not running	Closed	11/3/1999 15:54

MDC Software Problem Reports (4 of 4)

(Addresses review item 7 and 9)

Problem_Id	Function	Problem_Release	Summary	State	Date_Sub
359	MDC	MDC rel_OPS_1_2	MDC Orbit Product Generation software	Closed	12/23/1999 13:15
361	MDC	MDC rel_OPS_1_2	Set up a MDC for mission data only	Submitted	12/28/1999 16:26
367	MDC	MDC rel_OPS_1_2	C&DH High Priority Housekeeping	Closed	1/7/2000 16:39
375	MDC	MDC rel_OPS_1_2	Automatic Ftp push from FE to MDC failed for VC6 & VC7	Closed	1/13/2000 14:00
397	MDC	MDC rel_OPS_1_2	Component Change MDC Orbit Processor Software	Closed	1/24/2000 16:26
405	MDC	MDC rel_OPS_1_2	Add to the MDC ability to manually seed the PVAT	Closed	2/11/2000 16:53
411	MDC	MDC rel_OPS_1_2	Telemetry lost and over-ran messages seen	Closed	2/17/2000 16:42
415	MDC	MDC rel_OPS_1_2	Move directory for telemetry status	Closed	2/17/2000 17:00
449	MDC	ORBIT PROCE 1.2	Time stamps for PVAT are supposed to be "centered"	Closed	3/16/2000 14:36
450	MDC	ORBIT PROCE 1.2	The delimiter is missing.	Closed	4/6/2000 9:38
474	MDC	MDC rel_OPS_1_2	Modify and provide means of distributing s/c data	Closed	6/9/2000 10:23
503	MDC	ORBIT PROC 1.3	Verify FOM's on state vectors used to create predicted PVAT's.	Closed	8/10/2000 15:03
522	MDC	MDC rel_OPS_1_2	Time Checking of Source 65 data	Closed	9/1/2000 11:49
535	MDC	MDC rel_OPS_1_2	Unable to retrieve data from the MDC	Closed	9/19/2000 17:49
547	MDC	MDC Rel_OPS_1_3	MDC Real-time ingest failed with 2 different TOPS SC time days	Closed	9/27/2000 10:45
552	MDC	MDC Rel_OPS_1_3	MDC failed to archive telemetry with GR time in 2006.	Closed	10/6/2000 8:43

MDC Requirements Verification Matrix (1 of 13)

(Addresses review item 12)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Real-Time Telemetry Service (RTS)						
MDC-TS-1	The RTS shall be capable of receiving telemetry from multiple sources. The format of the data shall be a form of augmented transfer frame described above. The protocol used shall be TCP/IP sockets with the RTS acting as a server to a source client.	Test	Build 1.0	Test #1	TLM SVC Test #1	
MDC-TS-2	The RTS shall be responsible for transforming the input data into a Supplemented Telemetry Frame.	Test	Build 1.0	Test #2		
MDC-TS-3	The RTS shall be able to handle at least 4 simultaneous input streams.	Test	Build 1.0	Test #1	TLM SVC Test #1	
MDC-TS-4	The RTS shall be capable of receiving data via a TCP/IP stream at a rate of 70 kbps, not including delays due to network traffic.	Test/ Analysis	Build 1.0	Test #1	TLM SVC Test #1	
MDC-TS-5	The RTS shall be capable of receiving telemetry on all virtual channels prior to Launch.	Test	Build 1.0	Test #1	TLM SVC Test #1	
MDC-TS-6	The RTS shall provide Supplemented Telemetry Packets (STPs), CCSDS Telemetry Packets (TPs), POC Telemetry Packets (PTPs), Supplemented Telemetry Frames (STFs) and Telemetry Frames (TFs).	Test	Build 1.0 Build 1.5	Test #1	TLM SVC Test #1	

MDC Requirements Verification Matrix (2 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Real-Time Telemetry Service (RTS)						
MDC-TS-7	The RTS shall be capable of providing telemetry to multiple clients. The protocol used shall be TCP/IP sockets with the RTS acting as a server to a destination client.	Test	Build 1.0	Test #1	TLM SVC Test #1	
MDC-TS-8	The RTS shall allow selection of data based on source, front-end, virtual channel, application ID, and quality.	Test	Build 1.0	Test #3, Test #5	TLM SVC Test #2, #4	
MDC-TS-9	The RTS shall provide a stream service for at least 30 clients for a total aggregate rate of 1320 kbps, not including delays due to network traffic.	Test	Build 1.5, Build 2.0	Test #1	TLM SVC Test #1	
MDC-TS-10	The RTS shall be capable of supporting service at least 68.8 kbps for each stream up to 30, not including delays due to network traffic.	Test	Build 2.0	Test #1	TLM SVC Test #1	
MDC-TS-31	The RTS shall restrict access to input client services based on a maintained list of valid input client IP addresses.	Test	Build 2.0		TLM SVC Test #5	
MDC-TS-32	The RTS shall provide the capability to maintain a list of valid input client IP addresses that allow RTS input client access.	Test	Build 2.0		TLM SVC Test #5	

MDC Requirements Verification Matrix (3 of 13)

Telemetry Service (TS)			Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Real-Time Telemetry Service (RTS)							
	MDC-TS-33	The RTS shall restrict access to output client services based on a maintained list of valid output client IP addresses.	Test	Build 2.0		TLM SVC Test #5	
	MDC-TS-34	The RTS shall provide the capability to maintain groups of output clients. The output client groups shall contain at a minimum a group name, list of valid IP addresses that allow RTS output client access, and a maximum number of concurrent connections for	Test	Build 2.0		TLM SVC Test #5	
	MDC-TS-35	The RTS shall restrict access to the MDC operator console services based on a maintained list of valid MDC operator console IP addresses.	Test	Build 2.0			Tested informally by MDC lead engineer. Feature no longer used. Access now restricted by firewall.
	MDC-TS-36	The RTS shall provide the capability to maintain a list of valid MDC operator console IP addresses that allow administrative access.	Test	Build 2.0			Tested informally by MDC lead engineer. Feature no longer used. Access now restricted by firewall.
	MDC-TS-52	The RTS shall disconnect any input telemetry stream where the Ground Receipt Time differs from the RTS system time by more than one hour. Notification of this event will be included in the Telemetry Server Monitor status telemetry.	Test	Build 3.0			Tested during Mission Operations Testing
	MDC-TS-57	The RTS shall allow the exclusion of APIDs from output by user specification.	Test	Build 3.0			Often used capability. Tested during Mission Operations Testing.

MDC Requirements Verification Matrix (4 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Playback Telemetry Service (PTS)						
MDC-TS-11	The PTS shall provide Supplemented Telemetry Packets (STPs), CCSDS Telemetry Packets (TPs), POC Telemetry Packets (PTPs), Supplemented Telemetry Frames (STFs) and Telemetry Frames (TFs).	Test	Build 1.0, Build 1.5	Test #4	TLM SVC Test #3	
MDC-TS-12	The PTS shall allow selection of data based on source, front-end, virtual channel, application identification (AP ID), quality, and Spacecraft or Ground Receipt time, allowing a client to give a start and stop time for data.	Test	Build 1.5	Test #5	TLM SVC Test #4	Build 1 & 2 tests tested ground receipt time order. S/C time order tested during Mission Operations Testing
MDC-TS-13	The PTS shall allow the time ordering to be selected by Ground Receipt Time.			Test #4, Test #5	TLM SVC Tests #3, Test #4	
MDC-TS-37	The PTS shall allow the time ordering to be selected by Spacecraft Time.	Test	Build 3.0			Tested during Mission Operations Testing
MDC-TS-14	The PTS shall provide a playback service for 50 clients for a total aggregate rate of 1542 kbps, not including delays due to network traffic.	Test	Build 1.5, Build 2.0	Test #4	TLM SVC Test #3	
MDC-TS-15	The PTS shall be capable of supporting a 123 kbps service for each of the clients, if the number of clients is 10 or less.	Test	Build 1.5	Test #4	TLM SVC Test #3	

MDC Requirements Verification Matrix (5 of 13)

		Test Plan		Test Reports		Comments
Telemetry Service (TS)		Qualification Method	Notes	Build 1 Tests	Build 2 Tests	
Playback Telemetry Service (PTS)						
MDC-TS-16	The PTS shall be capable of supporting a (1296 kbps)/N aggregate service for each of the clients where N is the number of clients, if the number of clients is greater than 10 and less than 49.	Test	Build 1.5, Build 2.0	Test #4	TLM SVC Test #3	
MDC-TS-17	The PTS shall maintain the rate of 123 kbps for each of at least two MOC clients.	Test	Build 2.0	Test #4	TLM SVC Test #3	
MDC-TS-38	The PTS shall restrict access to input client services based on a maintained list of valid input client IP addresses.	Test	Build 2.0		TLM SVC Test #6	
MDC-TS-39	The PTS shall provide the capability to maintain a list of valid input client IP addresses that allow PTS input client access.	Test	Build 2.0		TLM SVC Test #6	
MDC-TS-40	The PTS shall restrict access to output client services based on a maintained list of valid output client IP addresses.	Test	Build 2.0		TLM SVC Test #6	

MDC Requirements Verification Matrix (6 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Playback Telemetry Service (PTS)						
MDC-TS-41	The PTS shall provide the capability to maintain groups of output clients. The output client groups shall contain at a minimum a group name, list of valid IP addresses that allow PTS output client access, and a maximum number of concurrent connections for	Test	Build 2.0		TLM SVC Test #6	
MDC-TS-42	The PTS shall restrict access to the MDC operator console services based on a maintained list of valid MDC operator console IP addresses.	Test	Build 2.0			Tested informally by MDC lead engineer. Feature no longer used. Access now restricted by firewall.
MDC-TS-43	The PTS shall provide the capability to maintain a list of valid MDC operator console IP addresses that allow administrative access.	Test	Build 2.0			Tested informally by MDC lead engineer. Feature no longer used. Access now restricted by firewall.
MDC-TS-53	The PTS shall provide playback service based on data quality (indicated in the Ground Receipt Header). Good data only, bad data only and both good and bad services shall be provided.	Test	Build 3.0			Often used capability. Tested during Mission Operations Testing.
MDC-TS-58	The PTS shall allow the exclusion of APIDs from output by user specification.	Test	Build 3.0			Often used capability. Tested during Mission Operations Testing.

MDC Requirements Verification Matrix (7 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Telemetry Archive						
MDC-TS-18	The MDC shall archive all telemetry data online.	Demonstration	Build 1.5	Test #1	TLM SVC Test #1 RATS Test #1, #2	
MDC-TS-19	The MDC shall archive all original telemetry formats for the life of the mission for re-ingestion in case of ingest failure.	Analysis	Build 2.0		RATS Test #1, #2	
MDC-TS-44	The MDC shall provide backup and recovery services for the online telemetry archive.	Test/ Demonstration	Build 2.0			Legato tape backup system in place.
MDC-TS-20	The MDC shall make the archived data available within 20 seconds of receipt at the MDC over a network connection.	Test	Build 1.5, Build 2.0			Tested by ground system, TLM playback test.
MDC-TS-45	The MDC shall make the archived data available within 10 minutes of receipt of a telemetry data file via a File Transfer Protocol (FTP) from a Ground Station Front-end.	Test	Build 2.0			Pending arrival of newly ordered faster computer, due 10/30/00. Target test completion date is Nov. 00.
MDC-TS-46	The MDC shall provide the capability to receive telemetry frames without archiving. The MDC will determine on a message by message basis, whether or not the data should be archived.	Test/ Analysis	Build 2.0			Tested during Mission Operations Testing
MDC-TS-54	The MDC shall provide the capability to switch by operator command the archiving of duplicate telemetry.	Test	Build 3.0			Have never implemented this requirement and no one has noticed or cares about it. Intend to consider removing this requirement. Target review completion date is Dec. 00.

MDC Requirements Verification Matrix (8 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Telemetry File Service (TFS)						
MDC-TS-21	The TFS shall provide telemetry files upon requests.	Test	Build 3.0			Capability available on the TIMED/MDC web site. Used often.
MDC-TS-22	The TFS shall allow selection of data based on source, front-end, virtual channel, application ID, quality, and Spacecraft or Ground Receipt time, allowing a client to give a start and stop time for data.	Test	Build 3.0			Capability available on the TIMED/MDC web site. Used often.
MDC-TS-23	The TFS shall allow the time ordering to be selected by Ground Receipt Time.	Test	Build 3.0			Capability available on the TIMED/MDC web site. Used often.
MDC-TS-47	The TFS shall allow the time ordering to be selected by Spacecraft Time.	Test	Build 3.0			Capability available on the TIMED/MDC web site. Used often.
FTP Telemetry File Requirements						
MDC-TS-24	The MDC shall be capable of receiving and archiving telemetry data from the ground station via FTP.	Test	Build 2.0			Tested during mission operations testing.
MDC-TS-25	The MDC shall be capable of using FTP to get telemetry data from the ground station and store the data.	Test/ Demonstration	Build 2.0			Have the capability but implemented as a Push from MOC instead of Pull from MDC.
MDC-TS-55	The MDC shall monitor the real-time telemetry stream and detect a message indicating the availability of a telemetry file from Universal Space Net.	Test	Build 3.0			Tested informally by MDC lead. Additional testing forthcoming via mission operations testing.

MDC Requirements Verification Matrix (9 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Command Archive						
MDC-TS-26	The MDC shall provide the capability to maintain an offline copy of all data that is sent to the spacecraft.	Analysis	Build 2.0		Cmd Spooler Test #1 RATS Test #1, #2	
Other Telemetry Requirements						
MDC-TS-27	The MDC shall provide the capability to configure and control all TCP/IP socket connection services without affecting operations. This includes at a minimum adding and removing valid IP addresses to and from client lists, closing active connections, and m	Test	Build 2.0			Tested both informally by MDC lead engineer and also used often during mission operations testing. Now use firewall to restrict access.
MDC-TS-28	The MDC shall provide a Telemetry Server monitor service to the MOC. The protocol used shall be TCP/IP socket with the MDC acting as a client to the MOC server.	Test	Build 2.0		TLM SVC Test #7	
MDC-TS-29	THIS REQUIREMENT DELETED - The MDC shall provide the capability to determine and set the quality of the telemetry frame, by the state of the quality flags within the message.	Test	Build 2.0			Requirement deleted
MDC-TS-30	The MDC shall provide a daily report containing the processing status of the Telemetry Server processes.	Test/Analysis	Build 2.0			Not implemeted. Have real-time capability to check MDC health. Intend to consider deleting the requirement. Target review completion date is Dec. 00.

MDC Requirements Verification Matrix (10 of 13)

Telemetry Service (TS)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Other Telemetry Requirements						
MDC-TS-48	The MDC shall provide the capability to generate on demand the Archive Map sorted by Ground Receipt Time. This report shall contain at a minimum for each AP ID all contiguous ranges of CCSDS packets stored in the Telemetry Server.	Test/ Analysis	Build 2.0		Archive Map Test #1, #2, #3, #4	
MDC-TS-49	The MDC shall provide the capability to generate on demand the Archive Map sorted by Spacecraft Time. This report shall contain at a minimum for each AP ID all contiguous ranges of CCSDS packets stored in the Telemetry Archive.	Test/ Analysis	Build 3.0			Often used capability. Tested during Mission Operations Testing.
MDC-TS-50	The MDC shall provide the capability to generate the Archive Change Report. This report shall be ordered by the time of ingestion by the archive, and shall contain at a minimum for each AP ID all contiguous ranges by Ground Receipt Time of CCSDS packets p	Test/ Analysis	Build 2.0			Tested during Mission Operations Testing.
MDC-TS-51	The MDC shall provide the capability to generate the Archive Change Report. This report shall be ordered by the time of ingestion by the archive, and shall contain at a minimum for each AP ID all contiguous ranges by Spacecraft Time of CCSDS packets proce	Test/ Analysis	Build 3.0		Archive Map Test #1, #2, #3, #7	
MDC-TS-56	The MDC shall provide the MOC with two text reports for each telemetry dump received from a ground station. a) The MDC shall provide a report showing the APIDs and spacecraft time of the blocks of telemetry updated in the archive as a result of the proce	Test	Build 3.0			Tested during Mission Operations Testing.

MDC Requirements Verification Matrix (11 of 13)

Data Product Production (DPP)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Planned and As Flown Timeline Files						
MDC-DPP-1	The MDC shall provide the individual Planned and As Flown Timeline Files as received from the MOC, POCs and Project Scientist. The MDC shall make these files available to the MOC, POCs, and Project Scientist.	Test	Build 2.0		DPP Test #1, #2, #12	
MDC-DPP-2	The MDC shall produce four weekly merged Timeline Reports for the MOC, POCs and Project Scientist (Delivered in the next build).	Test	Build 3.0			
	The Long Range Planning Report shall contain all timeline data for eight weeks after the date of generation. This report shall only be available until the next one is generated.					Not yet implemented. Currently MOC only needs the timelines the MOC generates itself. Target completion Jan. 01.
	The Short Range Planning Report shall contain all timeline data for one week after the date of generation. This report shall only be available until the next one is generated.					Not yet implemented. Currently MOC only needs the timelines the MOC generates itself. Target completion Jan. 01.
	The MOC Planning Report shall contain timeline data for the following events: high priority, yaw maneuvers, software uploads, contacts and real-time commanding. The report shall include data for eighth weeks after the date of generation. This report shal					Not yet implemented. Currently MOC only needs the timelines the MOC generates itself. Target completion Jan. 01.
	The As Flown Report shall contain all timeline data for [(generation time – 246 hours) to (generation time – 78 hours)]. The MDC shall update these reports as needed.					Not yet implemented. Currently MOC only needs the timelines the MOC generates itself. Target completion Jan. 01.

MDC Requirements Verification Matrix (12 of 13)

Data Product Production (DPP)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Planned and As Flown Timeline Files						
MDC-DPP-3	The MDC shall provide the TIMED data users the capability to run an additional report for which the users will be able to specify a time range and the source(s) of the timeline data for either Planned or As Flown timelines	Test	Build 3.0			Tested informally by the software developer.
File Change Notification Message						
MDC-DPP-4	The MDC shall provide a File Change Notification Message for the MOC, POCs, and Project Scientists to indicate the availability of a new data product or an update of an existing data product. The File Change Notification Message will be provided for the	Test	Build 2.0		DPP Test #1, #2, #3, #4, #5, #6, #7, #8, #9, #10, #11, #12	

MDC Requirements Verification Matrix (13 of 13)

Data Product Production (DPP)		Test Plan: Qualification Method	Test Plan: Notes	Test Reports: Build 1 Tests	Test Reports: Build 2 Tests	Comments
Spacecraft Telemetry Definition File						
MDC-DPP-5	The MDC shall be capable of receiving and storing the Spacecraft Telemetry Definition Files as sent from the MOC. The MDC shall make these Spacecraft Telemetry Definition Files available to the POCs.	Test	Build 2.0		DPP Test #3, #4, #5, #6, #7, #8, #9, #10, #11, #12	
Other Data Product Requirements						
MDC-DPP-6	The MDC shall be responsible for protecting all of the data products that the MDC receives or produces from loss or corruption. The MDC shall maintain a copy of all data products on a stable off-line medium for the life of the mission. This data shall be	Test/ Demonstration	Build 2.0			Legato tape backup system in place

Primary Ground Station (APL)

November 3, 2000

Steve Gemeny
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Johns Hopkins University / Applied Physics Laboratory
Laurel, MD

Agenda

Overview

PDR

CDR

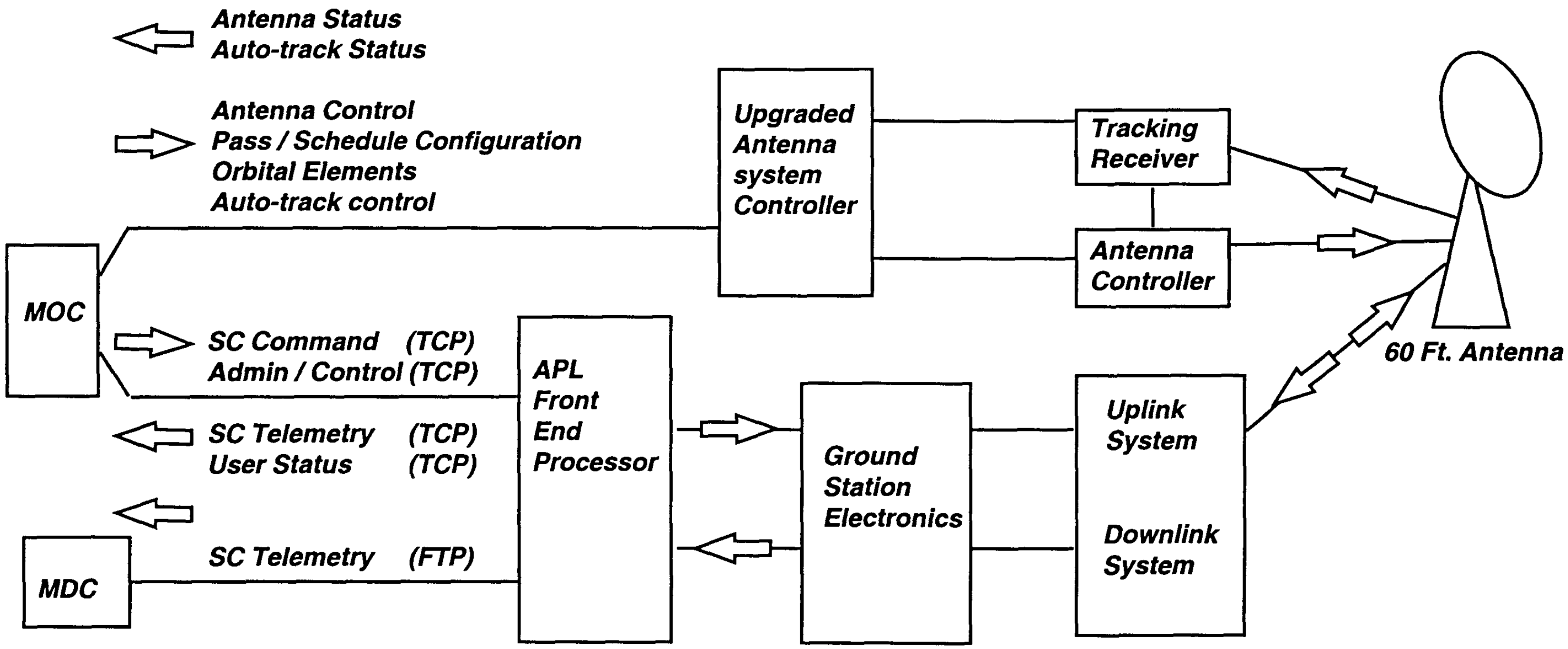
Station Antenna Subsystem

Station Electronics Subsystem

Overview

- Prime Ground Station for TIMED is the existing APL 60 Foot Antenna system
- Selection was driven by RF interference issues and the need to co-exist with other assets on a non-interfering basis
- Required modifications were determined to be within the bounds of sound engineering practice and within the limits of the available resources
- Post modification testing yielded negligible degradation in the prior performance
- The modified 60 foot antenna system, along with the station RF equipment and telemetry system, has participated in mission testing and simulations since early in I&T

Station Diagram
Overview



Ground Station
Preliminary Design Review

- **PDR - August 22, 1997**

– **Chairman**	**Rich Huebschman**	**22 Years Space RF Systems Design & Spacecraft Systems Engineering**
– **Members**	**Bob Heins**	**36 Years RF Systems Development**
–	**Alan Jablon**	**15 Years RF, Microwave Systems & Antenna Design**
–	**Glen Baer**	**26 Years Spacecraft Power Subsystem, Ground Systems, and Operations**

- **Action Items**
  - » **9 Action Items were generated along with 17 Issues (SEI-97-098)**
  - » **All action Items and many issues were closed via the Ground Station CDR**

Addresses review item 1 & 2

Ground Station
Critical Design Review

- **CDR - November 14, 1997**

– Chairman	Rich Huebschman	22 Years Space RF Systems Design & Spacecraft Systems Engineering
– Members	Glen Baer	26 Years Spacecraft Power Subsystem, Ground Systems, and Operations
–	Bob Heins	36 Years RF Systems Development
–	Ed Prozeller	34 Years RF, Ground Systems
–	Bill Gray	Bio

  - **Action Items**
    - » **14 Action Items were generated on the Ground Station Design**

Addresses review item 1 & 2

Ground Station
Critical Design Review

- **CDR Action Items**
  - » **14 Action Items were generated on the Ground Station Design**
    - **2 were eliminated from the final implementation**
    - **1 Pending Item is to be closed in December 2000**
      - **Pass Analysis with latest mask**
    - **2 Ongoing Items to be completed January 2001**
      - **Verify completed Pre-pass Tests**
      - **Finalize Antenna Control Documentation**
    - **9 were included in the final design**
- **Ground Station Requirements Document 7363-9318 released**

Addresses review item 1, 2 & 9

Major Sub Systems

- Antenna System
  - Antenna
  - Antenna Control Electronics
  - Antenna Scheduling system
- Electronic Equipment Suite
  - Receivers
  - Bit Syncs
  - Sub Carrier Generators
  - Exciters
  - Power Amps
- Front End Processor
  - CCSDS Telemetry & Command processing
  - Equipment configuration
  - Sub system Scheduling

Antenna

- **Previous Supported missions include:**
  - **Transit (Navy)**
  - **GEOSAT(Navy)**
  - **Various Missile Tracking Events**
  - **MSX (BMDO)**
    - » Tracking on a daily basis now
      - Demonstrate mission readiness for TIMED
      - Generate reliability statistics for Antenna
    - » MSX passes tracked using NORAD Element Sets downloaded daily.
    - » TIMED will be tracked using Spacecraft provided, per pass ELSETS

Addresses review item 10

Modifications to support TIMED

- **Addition of Up-link Capability to Antenna System**
  - Added Diplexers RHC & LHC (Purchased)
  - Added Auto-track Band Pass filters (Purchased)
  - Upgraded LNAs to mitigate G/T degradation
  - Installed dual, low loss up-link coaxial cables
- **Post modification testing showed:**
  - No measurable changes in auto-track performance
  - No measurable changes in bore sight alignment
  - System G/T average of 23.3 dB (0.7 dB degradation)
  - Results Documented in internal Memos SER-98-027 & SER-98-065

Addresses review item 3

Antenna Tracking Statistics

- **Statistics for the TIMED Primary Ground Station**
  - November 1999 - September 2000
- **Based on MSX passes**
  - Out of 243 attempted passes, 241 were successful.
  - Of the 241 successful passes,
    - » 115 attempted to utilized the Auto-Track capability
    - » 115 Successfully acquired Auto-Track
    - » Total Auto-Track duration of 1089 minutes.
  - This represents a **success rate of 99.2%,** and an **MTBF of 120 passes** measured over a total of 243 passes.

Addresses review item 8 & 10

Antenna Tracking Statistics

(continued)

- **Failure Items during the test period:**
  - A Limit light failure, causing a continuous limit condition was detected prior to the pass and not included as a failed contact
  - A Hydraulic control device failed after electrical storm causing failure to move antenna
  - Tachometer failure induced excessive rate causing the system to self safe

Addresses review item 7, 8 & 10

Antenna Control Electronics

- **Existing system**
- **Extensive operational history**
- **APL Design and implementation**
- **In house Technical support**
- **NO Changes were required to support TIMED**

Addresses review item 7, 8 & 10

Antenna Scheduling system

- New design
- Currently operational for other APL assets and programs
  - 5 Meter Antenna
    - MSX
    - NOAA
  - 10 Meter Antenna - MSX Operational Passes
  - 60 ft. - MSX Confidence Passes
- Participated in TIMED simulations (August & September)
  - Launch and Separation Simulation
  - 96 Hour Mission Simulation
  - Event Driven Simulation

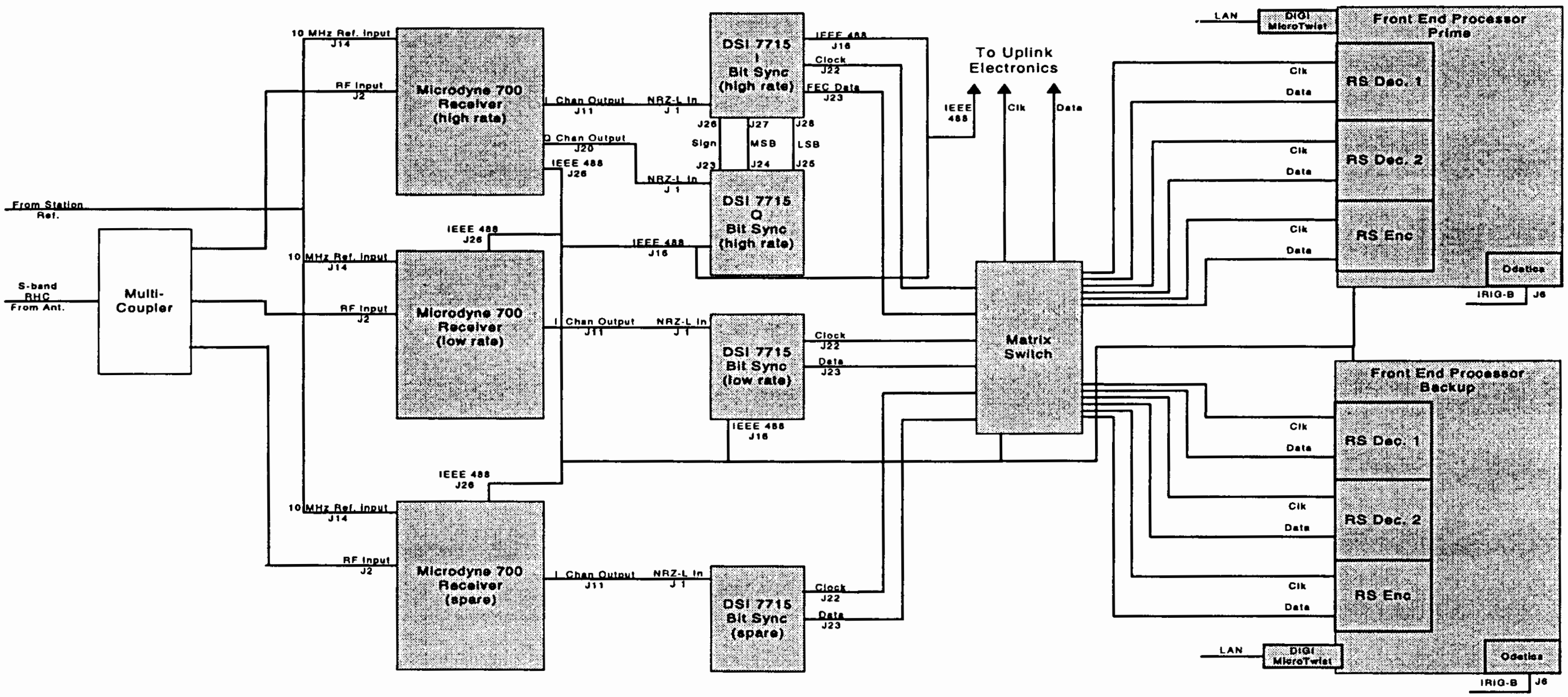
Addresses review item 7, 8 & 10

Antenna Scheduling system
(continued)

- **SCF provided software**
  - **Not under TIMED program Control**
  - **Is under Configuration Control within SCF**
  - **TIMED interfaces with this system for scheduling**
- **Simple Scheduling workaround is available**

Station Detailed Block Diagram

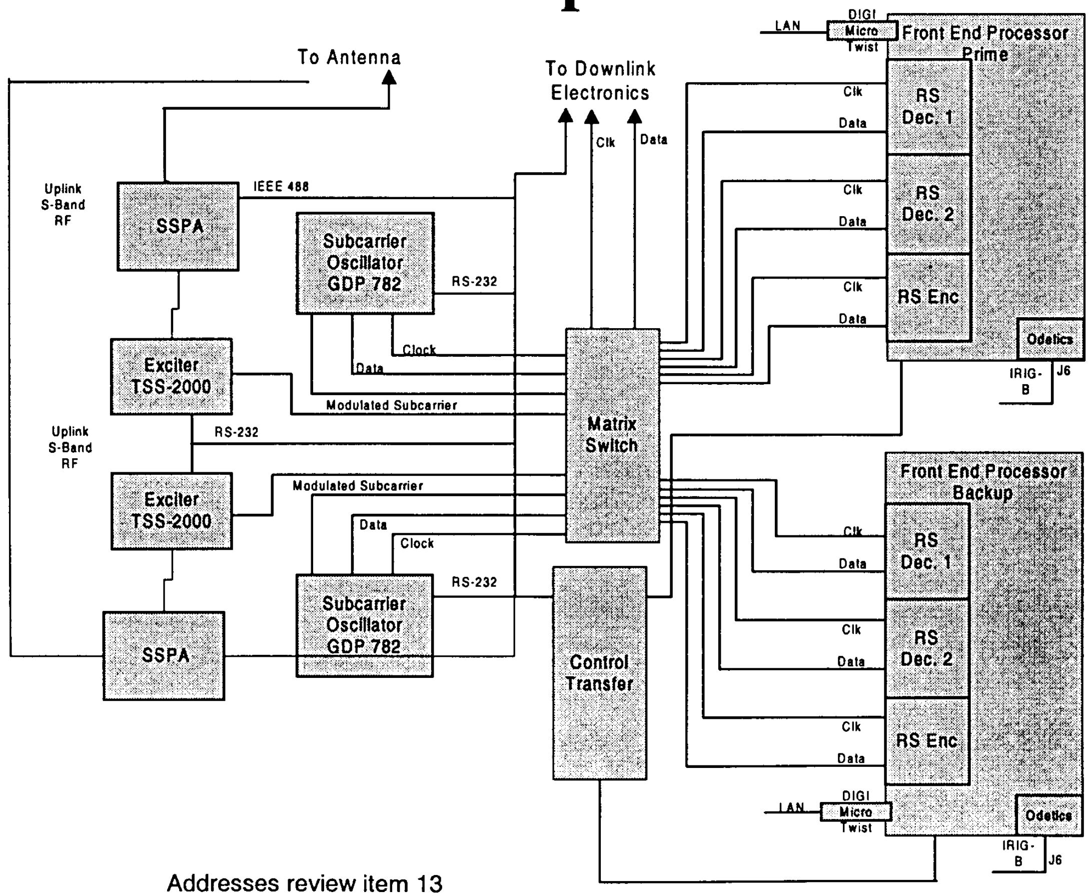
Downlink



Addresses review item 13

Station Detailed Block Diagram

Uplink



Addresses review item 13

Electronic Equipment Suite

- COTS LEO-T Ground Station
  - Purchased system
- Enhancements to standard LEO-T to meet TIMED requirements
  - Differential QPSK (DQPSK) Support
  - Remote Scheduling via Socket interface
  - Backup Uplink equipment chain
  - Spare Downlink equipment
  - Backup Front End Processor

Addresses review item 6 & 13

Electronic Equipment Suite
(continued)

- **Operated with Spacecraft RF since early 1999**
  - Monitored telemetry during I&T
  - Monitored telemetry post Environmental testing
  - Supported **All simulated contacts** during all mission simulations performed at APL

Addresses review item 10

RF & Baseband Equipment

- **RF equipment Purchased for TIMED**

Downlink

- **Receivers**
  - MR700 - 1 High Rate
  - MR700 - 2 Low Rate
  - MR700 - 3 Spare
- **Bit Synchs**
  - DSI 7715 - 1 High Rate
  - DSI 7715 - 2 High Rate
  - DSI 7715 - 3 Low Rate
  - DSI 7715 - 4 Spare
  - DSI 7715 - 5 Spare

Uplink

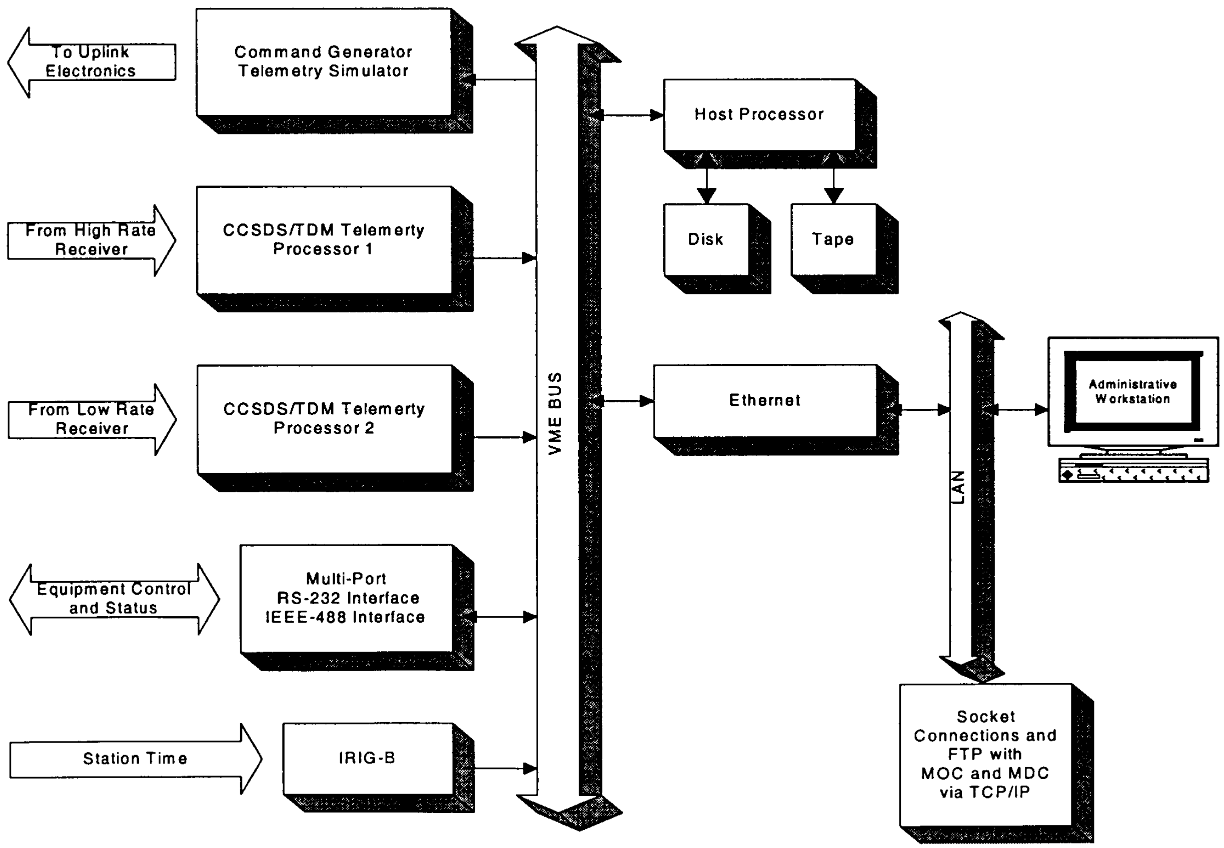
- **Subcarrier Generators**
  - GDP782 -1 Primary
  - GDP782 -2 Backup
- **Exciter**
  - TSS2000 -1 Primary
  - TSS2000 -2 Backup
- **Solid State Power Amplifier**
  - SSPA - 1 Primary
  - SSPA - 2 Backup

Miscellaneous

- RS-232 Switch
  Control Transfer
- Matrix Switch - 1
  Signal Transfer
- Matrix Switch - 2
  Spare

Addresses review item 6 & 13

Detailed Block Diagram
Front End Processor



Front End Processor

- COTS LEO-T CCSDS Telemetry and Command Processor
- Purchased from Integral Systems Inc. Lanham, MD
- Enhancements to meet TIMED requirements
  - Software TCP/IP interface to APL Antenna control software
  - Redundant up-link chains
  - TIMED Specific Ground Receipt Header
  - Auto delete after Successful FTP
  - GPIB Driver for Instrument Control
- Participated in TIMED Testing:
  - Bench Level Testing
  - I&T
  - Environmental
  - Simulations

Addresses review item 6, 10 & 13

Front End Software Deliveries

Date	Version	Change
• 10/27/98	1.7	Initial Delivery
• 12/01/98	1.7.10	CLTU Tail Sequence fix
• 03/23/99	TIMED FE 1.0	Minor Upgrade, GPIB driver
• 08/15/99	Sun OS 2.5.1	Y2K Patch
• 09/15/99	TIMED FE 1.04	GPIB Driver, Database Updates
• 12/29/99	TIMED FE 1.05	Fix CLCW processing
• 02/26/00	TIMED FE 1.06	Attempted Viewer bug fix
• 09/21/00	TIMED FE 1.07	Equipment Driver Updates, Fix Viewer Bug

Addresses review item 8

Front End SPR Summary

- 66 Total SPRs
- 65 Closed
- 1 Open
  - Avtec Telemetry Processor Card freezes when put into standby mode.
  - ISI and Avtec have both been here to analyze problem.
  - Avtec claims it is a Modcomp (COTS OS supplier) problem.
  - They have been contacted, with no results.
  - Problem has not occurred on operational system since February 2000.

Addresses review item 7 and 8

Front End Testing Status

- System tests run with the Spacecraft and with TOPS
- System used for all IEM subsystem level testing
  - Development
  - Flight hardware qualification
- System used for all Spacecraft level testing
- System used for all Mission Simulations
  - All operational features exercised
- FE Contingency Procedures
  - Switchover to backup front end, testing completed
  - Switchover to backup uplink RF equipment string, Nov 2000
  - Track autonomous spacecraft downlink rate change

Addresses review item 3

Pending Items

- To Do List
  - Free Radiate Test
  - Pass Analysis with latest mask
  - Verify finalized PRTs
  - Finalize Antenna Control Documentation
- Red Tag List
  - HPA Drive to Full
  - Exciter Drive to Full
  - RF switch from I&T to Antenna
- Residual Risk
  - Antenna is 35 years old
  - Limited End - to - End testing with Antenna
  - No Pre-Pass Testing using the Antenna
- Mitigation
  - Adequate Spares, Expertise and Backup Ground Stations
  - Part of 96 Hour Testing, Continuing with TOPS until Launch
  - To be completed in November as part of Free Radiate Testing

Requirements Matrix
1 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
General	The Primary Ground Station has responsibility for commanding the satellite and receiving telemetry and science data transmissions. The Primary Ground Station shall make use of existing JHU/APL Satellite Communications Facilities assets to the degree prac	TRUE
	The Primary Ground Station shall be capable of simultaneous uplink and downlink to the TIMED Satellite.	Testing... Mission Simulations, I&T
	The Primary Ground Station shall support rapid, during-pass, receive mode detection and switch-over in order to minimize data loss in the event of an unexpected autonomous switch by the satellite from Mode 1a, 1b, 3a or 3b to Mode 2 as defined in section	Testing... Mission Simulations, I&T
	The Primary Ground Station shall be automated. It shall allow scheduling, configuration, and conduct of passes under control of the MOC.	Testing... Mission Simulations, I&T
	The Primary Ground Station shall be located on the campus of The Johns Hopkins University, Applied Physics Laboratory in Laurel, Maryland.	TRUE
4.3.1	Pointing Requirements	
	The Primary Ground Station shall have the ability to acquire and track the TIMED satellite at any point in a pass, using 2-Line Element Sets as the sole external source of pointing data. Orbital Elements will be provided in NORAD 2-line format prior to t	Testing... MSX Tracking Tests Ongoing analysis and Testing

Requirements Matrix
2 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
4.3.2	Auto-track	
	The ability to auto-track the satellite is a derived requirement. In the event of loss of auto track lock the auto track system shall revert to program track and attempt to reacquire lock for the duration of the pass.	Testing... MSX Tracking Tests
4.4.1	Command Handling	
4.4.1.1	The Primary Ground Station shall ingest, in real time, CCSDS Telecommand Frames from the MOC	Testing... Mission Simulations, I&T
4.4.1.2	The physical interface from the MOC shall be TCP/IP via 100 Mbps Ethernet LAN dedicated to TIMED.	Testing... Mission Simulations, I&T
4.4.1.3	Telecommand Frames shall be randomized and packaged into Command Link Transmission Units (CLTUs) using 64-bit codeblocks	Testing... Mission Simulations, I&T
4.4.1.4	Physical Link Operations Procedure - 2 (PLOP-2) shall be used to initiate a command uplink sequence.	Testing... Mission Simulations, I&T
4.4.1.5	PLOP - 2, Acquisition Sequence, Carrier Modulation Mode - 2 (CMM-2) shall consist of at least 500 bits of "1010...".	Testing... Mission Simulations, I&T
4.4.1.6	There shall be one (1) Transfer Frame per CLTU.	Testing... Mission Simulations, I&T
4.4.1.7	For contiguous CLTUs, Idle Sequence, Carrier Modulation Mode - 4 (CMM-4) shall consist of a minimum of 1 octet and a maximum of 3 octets of "1010...".	Testing... Mission Simulations, I&T
4.4.1.8	The COP-1 Protocol shall not be enabled in the Ground Station.	Testing... Mission Simulations, I&T

Requirements Matrix
3 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
4.4.1.9	Command CLTUs shall be transmitted as an NRZ-L formatted serial bit stream at a 2 kbps rate, bi-phase modulated on a 16 kHz sinewave subcarrier which is in turn residual carrier phase modulated on the main uplink carrier.	Testing... Mission Simulations, I&T
4.4.1.10	The command data clock shall be coherent with the uplink subcarrier.	Testing... Mission Simulations, I&T
4.4.1.11	Doppler compensation of the RF uplink signal shall be made for the initial Space Craft acquisition and subsequent re-acquisition in accordance with Section 4.4.1.11 of TIMED Ground Station Requirements Document, 7363-9318	Testing... Mission Simulations, I&T
4.4.2	RF Requirements	
	Shall support the downlink modes and formats described in Section 4.5.4 of TIMED Ground Station Requirements Document, 7363-9318	Testing... Mission Simulations, I&T
4.5.1.1	Receive serial digital TIMED satellite telemetry and science data via RHC single downlink carrier	Testing... Mission Simulations, I&T
4.5.1.2	Polarization diversity is not a requirement	Testing... Mission Simulations, I&T
4.5.1.3	Recover data from the CCSDS compliant telemetry frames transmitted by the TIMED satellite	Testing... Mission Simulations, I&T
4.5.1.4	Provide bit synchronization for each specified modulation mode (Table 1, sec. 4.5.5). Perform, or bypass (as configured) CCSDS Convolutional decoding (rate ½, K=7).	Testing... Mission Simulations, I&T
4.5.1.5	Perform frame synchronization on the bit synchronized data and de-randomization in accordance with Ref. 7, section 6	Testing... Mission Simulations, I&T
4.5.1.6	Perform, or bypass (as configured) CCSDS Reed - Solomon Decoding on the received transfer frames	Testing... Mission Simulations, I&T

Requirements Matrix
4 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
4.5.2	Data Handling	Testing... Mission Simulations, I&T
4.5.2.1	Add a Program-defined Ground Receipt Header to each received telemetry frame time tagged with an accuracy of 1 msec with regard to UTC as defined in Ref. 6 section 5.0 Table 1	Testing... Mission Simulations, I&T
4.5.2.2	Provide for separation of dump telemetry data (VC6) from the real-time data (VC7)	Testing... Mission Simulations, I&T
4.5.2.3	Provide for short term storage of all received data for 72 hours	Testing... Mission Simulations, I&T
4.5.3	Data Delivery	Testing... Mission Simulations, I&T
4.5.3.1	Immediately forward all data to the MOC via TCP/IP socket interface	Testing... Mission Simulations, I&T
4.5.3.2	VC7 Frames shall be given priority for forwarding whenever they are available	Testing... Mission Simulations, I&T
4.5.3.3	Frames shall be buffered in the ground station for 72 hours	Testing... Mission Simulations, I&T
4.5.3.4	Post pass the Primary Ground Station shall support the forwarding of all stored data to the MDC via FTP push	Testing... Mission Simulations, I&T
4.5.3.4	VC6 and VC7 shall be available in separate files	Testing... Mission Simulations, I&T

Requirements Matrix
5 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
4.5.4	RF Requirements	
	Shall support the downlink modes and formats described in Section 4.5.4 of TIMED Ground Station Requirements Document, 7363-9318	Testing... Mission Simulations, I&T
4.6.1	Configuration and control shall be provided both locally and remotely from the TIMED MOC for all ground station functionality necessary to support a pass	Testing... Mission Simulations, I&T
4.6.2	Remote operations shall be effected using TCP/IP via 100 Mbps Ethernet LAN dedicated to TIMED	TRUE
4.6.3	The existing antenna system shall be able to be scheduled from the MOC without the need for local support for the scheduling of the pass or the conduct of the scheduled pass. Any pass shall be scheduled in accordance with predefined conflict rules.	Testing... Mission Simulations, I&T
4.6.4	The station shall permit control from the MOC to conduct pre-pass testing of command and telemetry data flow	Testing... Mission Simulations, I&T
4.6.5	Operational control over the existing antenna system(s) and equipment shall be available to the MOC to the extent currently available for recovery from anomalous operational conditions occurring during a pass	Testing... Mission Simulations, I&T
4.6.6	Shall provide for monitoring of status parameters for TIMED specific downlink electronics	Testing... Mission Simulations, I&T
4.6.7	Shall have the capability to provide monitoring of status parameters for the antenna systems.	Testing... Mission Simulations, I&T
4.7.1.1	The Primary Ground Station shall be capable of supporting up to six passes per day.	Testing... MSX Tracking Tests
4.7.1.2	All segments of a pass interrupted by antenna 'keep-out-zones' shall be supported.	Testing... MSX Tracking Tests
4.7.1.3	The antenna travel limits shall support at least 1 unsegmented pass per cluster down to an elevation of 5 degrees.	Analysis
4.7.1.4	The Primary Ground Station shall be available to support at least 80% of the pass time at elevation angles above 5 degrees.	Testing... MSX Tracking Tests
4.7.2	The MTBF shall be 100 passes, demonstrated by support over a minimum of 300 passes.	Testing... MSX Tracking Tests
4.7.3	The MTTR shall not exceed 60 hours, based on repairs over the most recent 2 years.	Testing... MSX Tracking Tests
4.8.1	Shall support automated telemetry data-flow testing	Testing... Mission Simulations, I&T

Requirements Matrix
6 of 6

Category or reference to Requirements Document	Description	Demonstrated via: (Method)
4.8.2	Shall support automated command data-flow testing	Testing... Mission Simulations, I&T
4.8.3	Shall conform to Ground Support Equipment (GSE) telemetry requirements stated in Ref. 5, SEI-97-062	Testing... Mission Simulations, I&T
4.9	Shall provide standard NTSC video signal from a camera for operators in the MOC to verify nominal operation of the antenna.	True, Existing
4.10.1	The Primary Ground Station shall not be capable of causing damage to other R. F. systems on the APL campus.	Analysis, Testing, Free Radiation
4.10.2	While operating in other than the contingency mode, the Primary Ground Station shall not interfere with MSX operations.	Analysis, Testing, Free Radiation
4.10.3	The Primary Ground Station shall not be susceptible to damage due to radiation form other nearby systems.	Analysis & Testing... MSX Tracking Tests

Mission Operations Center Software Red Team Review Presentation

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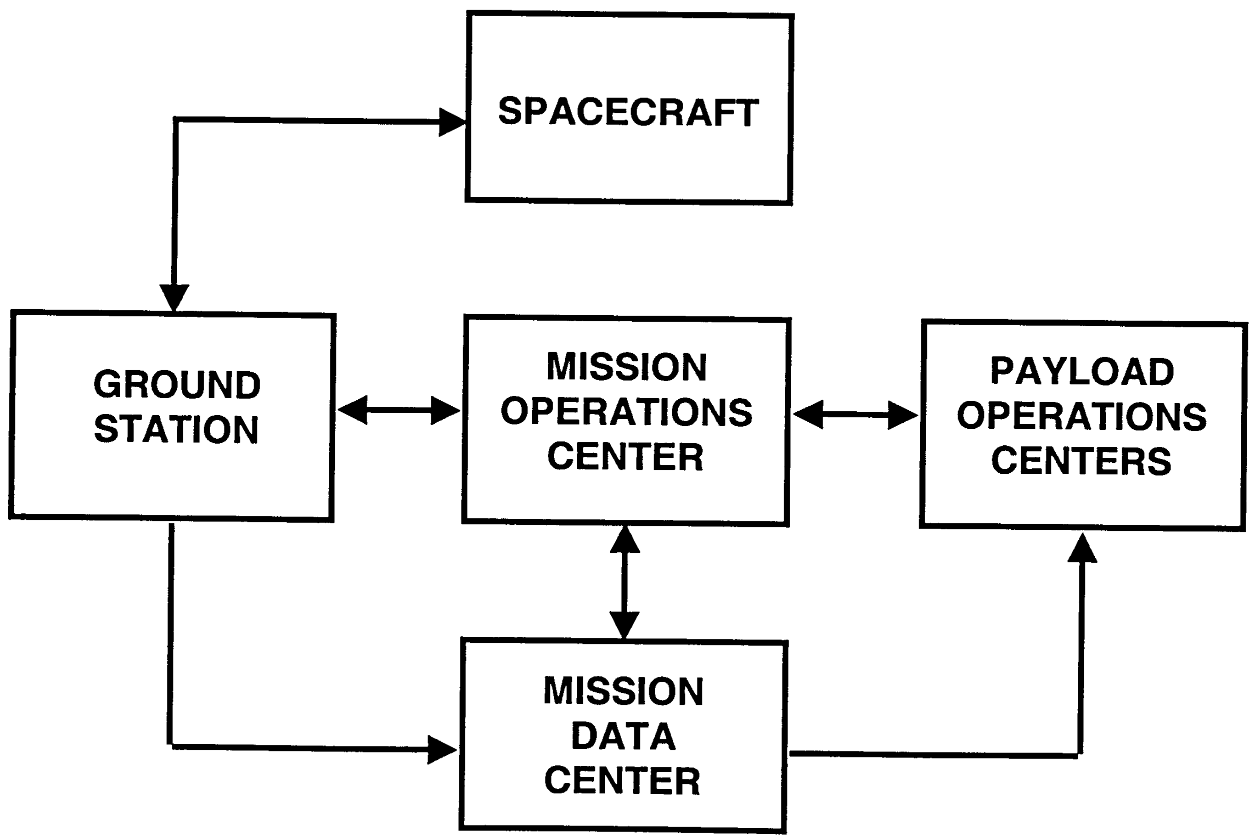
Introduction

- The MOC Software Development Plan (SDP) , document # 7363-9035, included the following sections:
  - System Overview
  - Software Components
  - Build Schedule
  - Design Review Plan
  - Configuration Management Plan
  - Test Plan
  - Documentation Plan

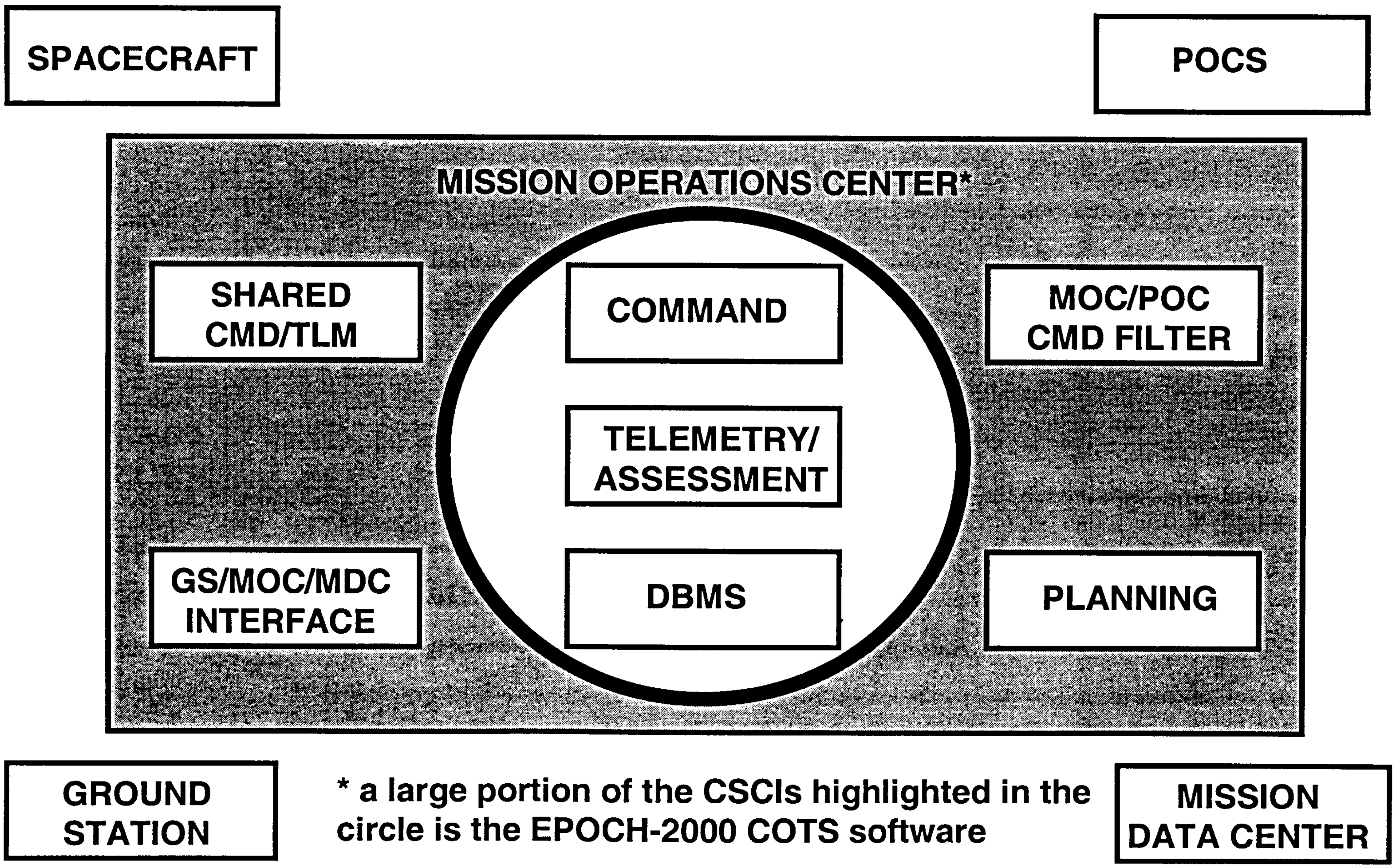
Introduction (continued)

- This talk will discuss the plan versus what actually happened.
- This talk will also discuss the following topics
  - SPR status
  - CMDIF rewrite
  - PROCL rewrite
  - Software operational time
  - Improved test environment

MOC Software System Overview:
MOC Architecture



MOC Software System Components:
Computer Software Configuration Items (CSCIs)



* a large portion of the CSCIs highlighted in the circle is the EPOCH-2000 COTS software

MOC Software Builds

Software Development Plan	Accomplished (Y/N)
Mini-MOC Build	Y
Integration and Test Build	Y
Mission Operations Build	Y

Addresses review item 4.

MOC Software Build Schedule

- Build 1: Mini-MOC Build
  - delivered 9/1997
- Build 2: Integration and Test Build
  - delivered 7/1998
- Build 3: Mission Operations Build
  - delivered 4/1999
- Build 4: More Mission Operations Software
  - not in SDP, delivered 6/1999
- Each major build included interim minor builds, as per the SDP

MOC Software Design Review Plan

Software Development Plan	Accomplished (Y/N)
Design review for each build	Y
Detailed design reviews as needed	Y
Code Walk-throughs for each CSCI	Y

Addresses review items 1, 2, 4, and 5.

MOC Software Design Reviews

- Design reviews - 3 reviews chaired by H. K. Utterback, the TIMED Software Quality Assurance engineer (over 30 years of space-related software experience).
- Peers usually from within TIMED project - approximately 25 per review

			Memo #	Items	Responses Memo #(s)	Items Resolved
MOC Software Build 1 Design Review	05/08/1997	H. K. Utterback and peer	SOR-97020	8	SEI-98-027	8
MOC Software Build 2 Design Review	04/22/1998	H. K. Utterback and peer	SOR-98023	6	SEI-98-036	5
					SEI-98-053	1
MOC SW Mongoose Processor Load, Dump, and Compare Design Review	07/22/1998	Peers	SEI-98-054	19	SEI-98-081	19
MOC SW Builds 3 & 4 Design Review	01/20/1999	H. K. Utterback and peer	SOR-99004	5	SEI-99-015	5
CMDIF Rewrite Design Review	07/15/2000	Peers				
PROCL Rewrite Design Review	07/19/2000	Peers				

Addresses review items 1, 2, 6, and 9.

MOC Software Design Reviews (continued)

- Code Walk-throughs - always included at least one reviewer that was not part of the MOC software team - usually about 6-8 people attended each walk-through

Date	Program	Presenter
07/29/1997	Telemetry Spreadsheet Load and Dump	Walter Mitnick
10/16/1997	Telemetry Chooser I	Dan Wilson
12/18/1998	Build Telemetry Utility	Dennis Whichard
12/21/1998	MOC/POC Command Filter I	P. J. Clark
01/18/1998	EPOCH/APL Command Interface	Sean McGhee
02/10/1998	Telemetry Chooser II / Event Logger	Dan Wilson
06/17/1998	MOC/POC Command Filter II	P. J. Clark
06/24/1998	AIU Load, Dump, and Compare	Sean McGhee
08/09/1998	Uptime Processing Utility	Bob Davis
08/23/1998	Engineering Dump Utility	Dennis Whichard
02/09/1999	Autonomy Rule Compiler	Bob Davis
02/10/1999	Mongoose Image Load, Dump, and Compar	Sean McGhee
02/24/1999	Derived Telemetry Utility	Dennis Whichard
06/28/2000	CMDIF Rewrite	Dennis Whichard
11/20/2000	(Planned) PROCL Rewrite	Knopf/Clark

Addresses review items 1, 4, and 6.

MOC Configuration Management

Software Development Plan	Accomplished (Y/N)
Source code management system	Y
Software problem reports	Y
Release management	Y
Release notes	Y
A method to roll back to a prior version	Y
should a new release fail	

Addresses review items 4, 5, and 7.

MOC Software Test Plan

Software Development Plan	Accomplished (Y/N)	
Formal acceptance testing for EPOCH-2000	Y	
Unit testing by developer for APL code	Y	
Integration testing by software lead	Y	
Ground system level integration by	Y and N*	
ground software segment engineer		
Unit development folder for each CSCI	Y	
User documentation	Y and N**	
*The ground software segment engineer role was filled several times		
but later cut out. Early integration tests and subsequent use of the		
software provided testing at this level.		
** Some user documentation was provided. The rest was written		
by the MOT in their operations manuals.		

MOC Software Test Plan (continued):
Acceptance testing

- EPOCH-2000 (COTS from Integral Systems, Inc., ISI) acceptance test was conducted in January 1998.
- The results were documented in memos SEI-98-006 and SEI-98-025.
- Acceptance testing was run versus the MOC Requirements Document.
- Results were documented in a spreadsheet with one line per requirement. Each requirement was either to be satisfied by ISI or APL.

MOC Software Test Plan (continued):
Acceptance testing

- After several iterations (i.e. bug fixes and enhancements), ISI eventually satisfied all requirements that APL expected to be satisfied by ISI code.
- APL did not run a formal acceptance test against the requirements to be satisfied by APL code.
- We have informally updated this requirements matrix (included in this package as reference).

Addresses review items 3, 4, and 5.

MOC Software Test Plan (continued):

Acceptance testing

- Summary of the requirements matrix update:
  - 166 total requirements
  - 106 satisfied by ISI code
  - 58 satisfied by APL code
  - 2 unsatisfied requirements
- Unsatisfied requirements:
  - Resource management tools
  - Graphical telemetry software

MOC Software Test Plan (continued):
Unsatisfied Requirements: Graphical Telemetry Software

- This software shall account for the status of the data recorder, processor memory, autonomy rules, downlink, battery, momentum, and other resources. The model shall track these resources in response to planned events.
  - APL's C&DH Memory Allocation Manager (MAX) accounts for processor memory and autonomy rules. Software to manage the other resources has not been produced.
  - Management of these resources is currently performed manually.

MOC Software Test Plan (continued):

Unsatisfied Requirements: Resource Management Tools

- The MOC shall include COTS software that provides graphical representations for commanding and telemetry via products such as Dataviews, PV-Wave, and/or IDL.
  - Telemetry is currently viewed via tabular displays and plots.
  - There is an Advanced Technology Development project underway that has integrated GSFC's GENSAA and GENIE expert systems with EPOCH-2000. TIMED plans to take advantage of these products.

MOC Software Documentation Plan

Software Development Plan	Accomplished (Y/N)
Requirements document	Y
Design specification	Y
Design specification for each build	Y
Detailed design specification for each CSCI	Y
Unit development folder for each CSCI	Y
User documentation	Y and N*
* Some user documentation provided. MOT wrote their own in their operations manuals.	

MOC Software Documentation Delivered

Document Name	Date	Document #
TIMED Autonomy Rule Compiler Design Document	06/15/2000	7363-9309
Build TP and Build STF Interface Control Document	06/21/1999	
C&DH Memory Allocation Examiner User's Guide	03/23/1999	
C&DH Memory Allocation Examiner User's Reference Guide	03/23/1999	
APL/EPOCH Command Interface Program Design Document	08/01/2000	7363-9307
Derived Telemetry User Information and Notes	09/15/2000	
APL/EPOCH Interface Directives User's Manual	03/27/2000	
Engineering Dump GUI Interface Manual	06/18/1999	
Engineering Dump Points File Usage Manual	09/15/2000	
How to build a TIMED minor release	09/15/2000	
Merge Utility Manual	06/18/1999	
Mission Operations Center Build 2 Functional Software Design Specification	08/14/1998	7363-9310
MOC Software: Build 3 Design Notes	01/21/1999	
MOC Software: Build 4 Design Notes	06/16/1999	
Mission Operations Center Build 1 Functional Software Design Specification	11/21/1997	7363-9304
Mission Operations Center Preliminary Software Design Specification	11/08/1996	7363-9036
Mission Operations Requirements Document	11/01/1996	7363-9021
Mission Operations Center Software Development Plan	01/17/1997	7363-9035
MOC/POC Command Filter and Recover CP Interface Control Document	10/06/1998	
MOC Processor Memory Load, Dump, and Compare Design Document	02/04/2000	7363-9308
Trending Processing Utility Document	01/04/1999	
Uptime Processing Utility Document	06/18/1999	
EPOCH-2000 Documentation	09/01/2000	

Open MOC Software Problem Reports
(as of 10/23/2000)

SPR #	Program	Problem summary	Status
289	Telemetry chooser	Font problem - underscores are obscured on certain terminals	Submitted
303	Dump capture	Actual image corrupted	Released
384	Dump capture	Dumping RAM corrupted AIU actual image	Released
410	Engineering dump	Save as enhancement	Submitted
451	Processor load (PROCL)	Various problems	Submitted
452	Telemetry load	Datasize wrong for various front-end status telemetry points	Submitted
485	Processor load (PROCL)	Error in generating cell files	Submitted
519	POC demon	Generated lowercase ARR files for zero length files	Released
527	Telemetry interface (TLMIF)	Obscure bug in leap second conversion	Released
538	Derived telemetry	Assign source designation for derived telemetry	Fixed
546	Dump capture	Add some G&C parameters to load, dump, and compare	Released
549	Dump capture	Bad filename generated in /tmp.	Fixed
553	Dump capture	Enhancement to add flash expected image	Submitted
554	Command Interface (CMDIF)	GSE client connection enhancement	Fixed
555	Dump capture	Expected image bad for certain GNS parameter loads	Fixed

Addresses review items 4 and 7.

CMDIF rewrite

- CMDIF is the APL Command Interface to EPOCH-2000.
- CMDIF takes commands from EPOCH-2000 and puts them into CCSDS packets.
- CMDIF had been relatively successful since its initial release in 1997 - it was utilized in the Mini-MOCs.
- Extensive use by the I&T team and the Mission Operations Team kept uncovering new bugs.
- Code inspection revealed that an extensive rewrite was the best solution.

CMDIF rewrite (continued)

- Multi-threaded program reduced to one thread.
- C program re-written in C++.
- Design review and code walk-through were conducted.
- Tested on TOPS before release to the spacecraft.
- Current version, delivered 6/1/2000, is stable.
- Only one SPR is open (submitted 10/11/2000, status is fixed)

Addresses review items 1, 4, and 7.

PROCL rewrite

- PROCL is the APL Processor Load Utility
- PROCL takes loads from processor developers and turns them into STOL procedures and updates expected images
- PROCL was used to create the processor loads during I&T
- New requirements evolved after the program was in use
- A rewrite in Visual Basic was deemed the most efficient solution
- New features include a GUI user interface, a link to the Access database for load configuration management, and an interface with the MOC Scheduler for fitting load scripts into available contacts

PROCL rewrite (continued)

- Design review was conducted
- Code walkthrough is scheduled for 11/20/2000
- Has been extensively tested on TOPS
- Planned release is 12/01/2000

MOC Software Operational Time

CSCI	Program	Initial Release	Duration (months)
Command	EPOCH-2000	09/29/1997	37
Command	CMDIF (old)	09/29/1997	NA
Command	CMDIF (new)	06/01/2000	5
Telemetry/Assessment	EPOCH-2000	09/29/1997	37
Telemetry/Assessment	Engineering Dump	06/29/1998	16
Telemetry/Assessment	Assessment DBMS	06/23/1999	8
Telemetry/Assessment	Pass Assessment	08/24/1999	13
DBMS	EPOCH-2000	09/29/1997	37
DBMS	TLM_LOAD	08/04/1998	38
MOC/POC Command Filter	MPCF/POCD	09/29/1997	37
GS/MOC/MDC Interface	TLMIF	09/29/1997	37
Shared Cmd/Tlm	PROCL (old)	03/04/1998	NA
Shared Cmd/Tlm	PROCL (new)	12/01/2000	0
Planning	CDH MAX	03/22/1999	18
Planning	MOC Scheduler	01/13/2000	9
Average Duration			22.5

MOC Software Operational Time

Build 4 Minor Releases

- Software has been operational for a average of 22.5 months, but bug fixes are ongoing
- For example, minor releases in build 4:

Date	Release #	Release summary
06/23/1999	4.0	Updates to many programs
08/24/1999	4.1	Initial release of Pass Manager, bug fixes
09/09/1999	4.2	Bug fixes
09/30/1999	4.3	Bug fixes
10/24/1999	4.4	Bug fixes
12/05/1999	4.5	Bug fixes
02/19/2000	4.6	Bug fixes
05/02/2000	4.7	CMDIF Rewrite, bug fixes
07/30/2000	4.8	Bug fixes
09/16/2000	4.9	Bug fixes

Improved Test Environment

- For early MOC releases, low-fidelity software simulators were used for testing the code
- In the last six months, TOPS (a high-fidelity simulator) has been used for testing new releases
- A better test environment results in more stable releases

MOC Requirements Matrix

Req	Requirement Description	How was it tested/satisfied?	Satisfies Req (Y/N)	ISI action required (Y/N)	Description of ISI action	APL action required (Y/N)	If not satisfied, why not?
2	**Command**						
	The MOC shall be capable of generating all commands needed to integrate, test, and operate the TIMED spacecraft.	commands vetted in Mini-MOCs; command database has been mature for over a year	Y	N		N	
	Commands shall be generated for ground support equipment as well as the spacecraft.	commands were sent to the iem test bed	Y	N		N	
2.1	**Directive Execution Environment**						
2.1.5.1	The MOC shall include a Command Language (TIMED Command Language, TCL).	STOL is the implementation of TCL.	Y	N		N	
2.1.5.1.1	TCL shall include the capability to send individual commands as well as commands grouped into scripts.	sent command "cmd a1_reboot". executed procedure atp_script1.prc.	Y	N		N	
2.1.5.1.2	Command scripts shall have the capability of calling other command scripts.	executed atp_script2.prc, which called atp_script1.prc	Y	N		N	

2.1.5.1.3	Individual command entry shall make use of editing features such as command line recall, cursor movement, overstrike mode, insert mode, etc. to facilitate data entry.	executed all of these features on series of cmd a1_reboot commands. note that cursor movement may be accomplished via mouse or arrow keys	Y	N		N	
2.1.5.2	Although most TCL statements shall be either spacecraft commands or telemetry checks (tchecks), TCL shall include wait statements and programming language-like features such as decision constructs and variables.	atp_script2 executed. this script includes a wait statement, an if then else construct, and a variable.	Y	N		N	
2.1.5.2.1	A WAIT-UNTIL or WHILE construct must be available to allow the TCL script to wait until a telemetry mnemonic is in a specified range before continuing execution.	atp_script2 executed. this script includes the required do while loop.	Y	N		N	

2.1.5.2.2	While a script is in an absolute wait (i.e. wait for n seconds), a count-down clock shall display the number of seconds left until the wait is over.	atp_script2 includes a wait 5. countdown clock is displayed in procedure window	Y	N		N	
2.1.5.3	TCL variables shall be either local (i.e. valid only in the current command script) or global (i.e. valid over all command scripts.)	atp_script3 and atp_script4 demonstrate this requirement.	Y	N		N	
2.1.5.4	TCL shall include the capability of assigning a variable to a telemetry value.	actually, the requirement should read "TCL shall include the capability of assigning a telemetry value to a variable." Demonstrated in atp_script5.	Y	N		N	
2.1.5.5	An IF-THEN-ELSE construct shall be included in TCL. It shall include a test of a condition. The test may include telemetry mnemonics, variables, or constants.	demonstrated in atp_script6.	Y	N		N	

2.1.5.5.1	Operators shall include equals, not equals, less than, greater than, less than or equal to, or greater than or equal to.	demonstrated in atp_script6.	Y	N		N	
2.1.5.5.2	An option shall be included to test a byte of data found at a given byte offset from the beginning of the packet or transfer frame. This data check (dcheck) shall include the ability to mask the data. There shall be both an AND and an OR mask.	demonstrated in atp_script11. note that telemetry points must be defined for each generic byte in order to accomplish this, e.g. we used ZMO_BYTE_000.	Y	N		N	
2.1.5.5.3	The test may be based on either the raw or the engineering value of a telemetry mnemonic.	demonstrated in atp_script6.	Y	N		N	
2.1.5.5.4	The test may include multiple conditions concatenated with an AND or an OR.	demonstrated in atp_script6.	Y	N		N	

2.1.5.5.5	TCL shall include the capability to write comments into the event log, so that the status of an IF-THEN-ELSE statement may be recorded. See Command/Telemetry Event Logger described later in this document.	demonstrated in atp_script6.	Y	N		N	
2.1.5.6	TCL scripts may call other TCL scripts with arguments.	demonstrated in atp_script6 whereby both numerical and text arguments are passedto atp_script7	Y	N		N	
2.1.5.7	TCL shall include the capability to prompt the operator.	demonstrated in atp_script8	Y	N		N	
2.1.5.7.1	The prompt capability shall include a prompt string.	demonstrated in atp_script8	Y	N		N	
2.1.5.7.2	The prompt capability shall include a variable in which the operator's response is stored.	demonstrated in atp_script8	Y	N		N	

2.1.5.8	TCL execution errors should be handled gracefully and should produce meaningful error messages.	no way to test this fully, but atp_script3 and atp_script4 generate an error for the variable A in atp_script4 with a meaningful error message. also note, epoch does not crash upon this error.	Y	N		N	
2.1.5.9	One possible TCL command argument shall be a filename. When executing a TCL statement with such an argument, the contents of the file shall be substituted for the argument.	demonstrated with atp_script8	Y	N		N	
2.1.5.10	TCL shall allow variable length commands. These commands may include a length field which shall be computed automatically.	demonstrated with atp_script8.	Y	N		N	
2.1.5.11	TCL shall include command mnemonics which map to part of a command, all of a command, or to multiple commands.	demonstrated with atp_script9.	Y	N		N	

	For example, if the command Relay 20 A means turn the star camera on, STARCAM_ON could be a mnemonic for this command, while STARCAM ON could be a mnemonic for "Relay 20" with an enumerated parameter for "A", while SENSORS_ON Relay 20 A and Relay 21 A.	demonstrated with atp_script9.	Y	N		N	
2.1.5.12	TCL shall include a WRITE command which allows values to be put into the event log. See Command/Telemetry Event Logger described later in this document.	demonstrated with atp_script8.	Y	N		N	
2.1.5.13	The information needed to build spacecraft commands from TCL statements shall be maintained in a command dictionary (rather than hard-coded).. See Database Management System described later in this document.	accomplished via a tandem of the EPOCH/ORACLE database and APL ASCII description files	Y	N		N	

2.1.5.14	TCL shall include the capability for entering a literal spacecraft command, i.e. specify the exact bits which shall comprise the CCSDS packet to be sent to the Ground Station. These bits shall be either supplied directly in the TCL command or supplied as	accomplished via the file passed through argument to a command, i.e. the filename is handed to the iem testbed, and the testbed sends the bits in the designated file. filename pass through demonstrated in atp_script_9.	Y	N		N	
2.1.5.15	TCL shall include a command to call a C program and to pass arguments to it.	demonstrated in atp_script9. note that in practice the C program needs to redirect its output to a log file.	Y	N		N	
2.1.5.16	The MOC shall be able to manage a pass autonomously. Specifically, the MOC shall be able to execute a script of commands at a given time and take actions contingent on telemetry without real-time operator action.	demonstrated with atp_script9.	Y	N		N	

2.1.5.17	The MOC shall include a redundant commanding capability so that no single hardware failure can cripple this functionality.	this requirement was dropped as documented in the signed off document MOC Functional Software Design Spec, Mini-MOC version	Y	N		N	
2.2	**Script Building Environment**						
2.2.1.1	The MOC shall include an editor for building command scripts. The process for creating new command scripts and modifying existing command scripts shall be user-friendly.	Solaris UNIX includes the /usr/dt/bin/dtpad editor which is user friendly. EPOCH accesses this editor via the environment variable EPOCH_EDITOR.	Y	N		N	
2.2.1.2	This environment shall include a test mode which shall allow for syntax checking of scripts without routing the commands to the spacecraft. This environment shall include a simulated telemetry stream.	ISI delivered the core EPOCH internal simulator w/o the loopback capability through APL's tlmif and cmdif code	Y	N		N	

2.2.1.3	The MOC shall include a utility to print a merged listing of a script. The merged listing includes script line numbers. Also, if the script calls another script, the called script is included in the listing, etc.	it works: as user gandc, cd /disks/d3/home/epoch/timed/database/procedures/timed. $EPOCH_BIN/stol_line.sh atp_script2.prc > /disks/d3/home/gandc/atp_script2.mrg.	Y	N		N	
2.3	**Remote Script Viewer**						
2.3.1.1	The script viewing utility shall provide a window of a script as it is executing, with the current line highlighted.	demonstrated with atp_script2	Y	N		N	
2.3.1.2	The lines shall have line numbers.	demonstrated with atp_script2	Y	N		N	
2.3.1.3	A TCL GOTO command shall allow the operator to branch in the script based on line number or label. Note that the operator shall not be allowed to branch into blocks such as IF-THEN-ELSE and FOR-NEXT loops.	demonstrated with atp_script1. demonstrated 2nd half of the requirement in atp_script2, by manually executing "GOTO 25".	Y	N		N	

2.3.1.4	The window shall include a script nesting stack.	demonstrated with atp_script1 and atp_script2	Y	N		N	
2.3.1.5	The window shall contain a minimum of n (TBD) lines as well as vertical and horizontal scroll bars. The script viewing utility shall also include a method to return focus to the current line if it has been scrolled off the page.	demonstrated with atp_script1 and atp_script2. note that TBD lines was configurable via resizing the window. there is a vertical scroll bar and a horizontal scroll bar.	Y	N		N	
2.3.1.6	The utility shall allow this window to be viewed by any workstation in the MOC or at a POC. Each workstation shall have control over its own vertical and horizontal scroll bars. However, when a new command is executed by the workstation controlling the	configured stream s2 to be tied to node oliver in epoch.cfg. ran s2 stream on oliver, connected to it from arnold.	Y	N		N	

2.3.1.7	A TCL STEP ON command shall put the script into step mode, i.e. when the operator sends the TCL CONTINUE command, the script shall wait after each command line.	EPOCH does not behave exactly this way. Entering "STEP" steps one line, and entering "CONTINUE" continues without stepping. However, by entering "STEP" repeatedly, the intended behavior is achieved.	Y	N		N	
2.3.1.8	A TCL STEP OFF command shall put the script into normal mode, i.e. when the operator sends the TCL CONTINUE command, the script shall execute commands until an event such as a WAIT statement or a command validation failure halts the script.	ditto the response to 2.3.1.7	Y	N		N	
2.3.1.9	The script viewing utility shall display the substituted value for TCL variables as opposed to the variables themselves.	the arguments to the script variables are expanded in the log, demonstrated in atp_script11	Y	N		N	
2.4	**Low-level Directive Processing**						

2.4.6.1	The MOC must include a command verification utility.	demonstrated in atp_script10.	Y	N		N	
2.4.6.1.1	This utility must perform syntax checking on all commands before they are sent to the spacecraft.	demonstrated in atp_script10.	Y	N		N	
2.4.6.1.2	This utility shall include the capability for the user to define command usage rules, which shall include command argument range constraints, command sequence constraints, and other TBD constraints.	demonstrated with IT_CHRG_RATE command w/ pre-tv condition IT_MODE = MOC.	Y	N		N	
2.4.6.2	The MOC shall have the capability to verify execution of commands which have telltales in telemetry. The command/telltale mapping shall exist in the command/telemetry dictionary.	temporarily modifed commands it_P_16HZ_TLM (expect non-zero) and IT_P_1HZ_TLM (expect 0) in EPOCH ORACLE command definition form to check ZMO_STP_SENT. it worked.	Y	N		N	

2.4.6.3	The MOC commanding function shall be password protected. In other words, the ability to send a command to the spacecraft shall only be granted to a user who has entered an appropriate password. This check could either be based on a password entered at t	commanding privilege was disabled in appropriate config file for user generic. generic got command rejection upon subsequent command attempt.	Y	N		N	
2.4.6.4	Normally, each command sent to the spacecraft shall wait until the previous command has been authenticated by the spacecraft. However, there shall also be a bypass mode in which commands do not wait for spacecraft authentication.	demonstrated in atp_script10.	Y	N		N	
2.4.6.5	The capability to lock critical spacecraft commands (i.e. require an "are you sure" prompt) shall be included in the MOC. There shall be a way to enable and disable the lock capability (for all commands treated as a whole) via TCL.	temporarily locked command IT_CHRG_RATE by checking "Critical" check box on EPOCH ORACLE command definition form.	Y	N		N	

2.4.6.6	MOC commanding shall include real-time commands, time-tagged commands, and processor loads.	these capabilities were tested during I&T	Y	N		N	
2.4.6.6.1	"Time-tagged commands" are commands which are the same as real-time commands with the addition of a command processor memory address in which the command is stored, and a UTC command execution time.	tested during I&T	Y	N		N	
2.4.6.6.2	There should be a general and consistent method for converting any real-time command into a time-tagged command.	tested during I&T	Y	N		N	
2.4.6.6.3	Processor loads are commands which include a processor ID, a starting address to load, a load length, and data.	tested during I&T	Y	N		N	
2.4.6.6.4	The MOC shall include the capability to break processor loads into units of delivery.	tested during I&T	Y	N		N	

2.4.6.7	The MOC shall be able to generate CCSDS telecommand packets. These packets shall be stuffed into frames. These frames shall be generated for a designated virtual channel.	demonstrated in atp_script11. tested with fe1.	Y	N		N	
2.4.6.7.1	The MOC may also include an option to send the packets without stuffing them into frames. This stuffing would then take place at the Ground Station.	EPOCH allows us to do this, however, our current design precludes it.	Y	N		N	
2.4.6.8	The MOC shall be able to generate embedded commands.	TIMED is not specifically using the NEAR style embedded commands. We expect that the MOC will handle all commands needed on TIMED.	Y	N		N	
2.4.6.8.1	The command dictionary must allow for embedded command definitions.	Ditto 2.4.6.8	Y	N		N	
2.4.6.8.2	TCL must allow for embedded command syntax.	Ditto 2.4.6.8	Y	N		N	

2.4.6.8.3	The MOC must be able to block embedded commands into the fixed-size CCSDS command packets.	Ditto 2.4.6.8, however, using CMDIF directives BEGIN_PACKET and END_PACKET we will be able to block multiple commands into a single CCSDS command packet.	Y	N		N	
2.4.6.9	The MOC must be able to include TBD CRCs and checksums for every command, including embedded commands.	Ditto 2.4.6.8, but CMDIF generates CRCs and checksums as required.	Y	N		N	
3	**Telemetry/Assessment**						
	The MOC must be capable of decommutating, displaying, and alarming all TIMED spacecraft telemetry.	tested via the Mini-MOCs; telemetry database has been mature for over 6 months	Y	N		N	
	The MOC shall be able to ingest telemetry from both the spacecraft and the ground support equipment.	tested via the Mini-MOCs	Y	N		N	
3.1	**Display Building**						

3.1.1.1	The MOC must include a utility for building telemetry displays.	tlm_if1.pag was created partially from the viewer and partially with an editor.	Y	N		N	
3.1.1.2	It should allow for cutting and pasting from a list of telemetry mnemonics.	EPOCH viewer allows this.	Y	N		N	
3.1.1.3	Invalid telemetry mnemonics on a display must be flagged when the display is invoked.	atp_display1.pag got "Error: Point not found" in event log which invoked.	Y	N		N	
3.1.1.4	The process for creating and modifying telemetry displays shall be user-friendly.	subjective, but we feel that it is user-friendly.	Y	N		N	
3.2	**Display Execution Environment**						
3.2.1.1	Telemetry shall be viewed in workstation windows.	gandc_mini_moc.scr supports this.	Y	N		N	

3.2.1.1.1	Displays may be in tabular, plot, or graphical format. The graphical format shall include the ability to display switches, red/green lights, and user-defined graphics such as representations of tape recorder reels and system schematics.	demonstrated with atp_display_8	Y	N		N	
3.2.1.1.2	Plots may include up to 5 telemetry points per plot. Plots shall include ground universal time (UT) or spacecraft UT on the dependent axis, as designated by the user.	EPOCH supports 4 points per plot. The ISI RFP response denied the ability to support 5 points per plot. APL has relaxed this requirement.	Y	N		N	
3.2.1.1.3	The telemetry may be displayed in raw or engineering units.	atp_display 1	Y	N		N	
3.2.1.1.4	Raw telemetry may be viewed in binary, decimal, or hexadecimal.	atp_display1	Y	N		N	
3.2.1.1.5	The window shall include telemetry mnemonics, values, units, and comments.	Bob's_New_Page.pag (from NEAR directory) demonstrates this.	Y	N		N	

3.2.1.1.6	Alarmed values shall be highlighted in some fashion.	telemetry point ZMO_BYTE_007 in page atp_display1 changes to red and yellow based on alarm status when running the byter telemetry simulator.	Y	N		N	
3.2.1.1.7	Stale values, i.e. telemetry mnemonics which have not received a valid value within TBD seconds, shall be highlighted in another fashion.	ISI flags a telemetry mnemonic as stale after reading n consecutive fill frames, i.e. no telemetry from any source for n seconds	Y	N		N	
3.2.1.1.8	A "Snap" utility shall allow the operator to output a copy of a display window to the printer. Snaps should be triggered by a single mouse click. Snap output should include the contents of the display window as well as the hostname of the workstation wh	snapped atp_display1 by using the SNAP button on the gandc_mini-moc viewer.	Y	N		N	

3.2.1.1.9	The color of a telemetry mnemonic on a display shall be specified in the telemetry database.	APL modified this requirement - color needs to be specified in EDL. Color needs to be removed from .scr files, then color added in .pag file. Demonstrated in atp_display1	Y	N		N	
3.2.1.1.10	Telemetry displays shall automatically include header information such as the display name, UTC, and data source (such as spacecraft VC0, simulator VC3, etc.)	the display does not automatically include any of these, however, the display builder allows the user to build displays with all of these., as demonstrated in display atp_display1	Y	N		N	

3.2.1.2.11	Telemetry displays shall be able to keep up with a full workstation screen of telemetry (approximately 128 telemetry points) which is updating once per second. (The telemetry rate is 33.33 kbps.) This performance should be maintained if an X-terminal i	We never benchmarked exactly 33.33 kbps, but the telemetry displays have routinely supported testing of all TIMED data rates. APL is relaxing this requirement.	Y	N		N	
3.2.1.3	The MOC shall be able to display telemetry from multiple input sources on one screen, and shall be able to access telemetry from multiple input sources from one TCL script.	atp_display1 with byter and tlmif supplying telemetry demonstrates this requirement. atp_script10 with same tlm sources demonstrates this requirement.	Y	N		N	
3.2.1.4	The MOC shall include a redundant telemetry decommutation capability so that no single hardware failure can cripple this functionality.	this requirement was dropped in section 11.1 of the signed off Mini-MOC Functional Design document	Y	N		N	
3.3	**Telemetry Decommutation Utility**						

3.3.2	A telemetry decommutation process shall describe the structure of telemetry.	telemetry decommutation is described in the EPOCH ORACLE database	Y	N		N	
3.3.2.1	It shall include telemetry mnemonics, engineering conversions, alarm information, formatting information, units, and other information for each item.	it does.	Y	N		N	
3.3.2.2	Telemetry decommutation shall be provided for subcommutated values.	ZMO_BYTE_007 on atp_display1 is an example of this behavior. This point is only valid when the application identifier = 0X400.	Y	N		N	
3.3.2.3	It shall be possible to generate derived values using an arbitrary function based on actual telemetry values. This derived telemetry shall be treated the same as actual telemetry values for the purposes of displaying, alarming, etc.	Satisfied by APL's Derived Telemetry Utility, that was used extensively in the G&C Mini-MOC.	Y	N		N	

3.3.2.4	Engineering units may also be based on polynomial equations, lookup tables, and state definitions.	the EPOCH ORACLE database includes these features. note that there is no EPOCH lookup table. rather, EPOCH has a lookup table of 16 pairs with linear interpolation between the values. also, note that APL has the hooks to do a lookup table.	Y	N		N	
3.3.2.5	The information needed to decommutate telemetry shall be maintained in a telemetry dictionary (rather than hard-coded). See Database Management System described later in this document.		Y	N		N	

3.3.2.6	Telemetry engineering conversions may be modified independently on a workstation by workstation basis. These changes are temporary and do not affect the telemetry dictionary. There shall be a method of restoring the conversions to the telemetry dictiona	we changed the conversion for zmo_byte_007 on atp_display5.	Y	N		N	
3.3.2.7	Telemetry decommutation and display shall include a command processor command history display and an autonomy rule status display.	EPOCH allows APL code to access telemetry. This means that at the least an APL post-EPOCH processor can accomplish this.	Y	N		N	
3.4	**Alarm Processor**						
3.4.8.1	Alarm conditions may be based on a logical combination of arithmetic expressions. For example, alarm telemetry point A if telemetry point A is greater than 10 engineering units AND telemetry point B is less than 50 raw counts.	Satisfied by context-dependent alarms.	Y	N		N	

3.4.8.2	Alarms shall include red low, yellow low, yellow high, and red high limits and messages.		Y	N		N	
3.4.8.3	Alarms shall include trigger count. A trigger count of 3 means that the alarm condition must be satisfied on 3 consecutive evaluations of the alarm's conditions.	demonstated w/ZMO_BYTE_007	Y	N		N	
3.4.8.4	Alarms shall enabled or disabled individually or as a whole via TCL.	limits * off and limits * on are global. limits ZMO_BYTE_007 off and limits ZMO_BYTE_007 on demonstrate this	Y	N		N	
3.4.8.5	Alarms shall keep displaying in an alarm status window until an acknowledge action is executed and logged.	demonstrated with ZMO_BYTE_007 and popup tlm_limit directive. alarm acknowleged by deleting or refreshing.	Y	N		N	

3.4.8.6	An alarm status window shall display all unacknowledged alarms. Each alarm shall include the time it occurred, the out-of-limit value, the limit which was exceeded, and the alarm message.	demonstrated with ZMO_BYTE_007 and popup tlm_limit directive. alarm acknowleged by deleting or refreshing.	Y	N		N	
3.4.8.7	Alarms shall be included in a time-tagged event log. See Command/Telemetry Event Logger described later in this document.	demonstrated with ZMO_BYTE_007 and popup tlm_limit directive. alarm acknowleged by deleting or refreshing.	Y	N		N	
3.4.8.8	Alarm limits may be modified through TCL.	demonstrated in atp_script11	Y	N		N	
3.4.8.9	Alarms may be modified independently on a workstation by workstation basis. This	demonstrated with ZMO_BYTE_007	Y	N		N	
3.4.8.10	The information needed to alarm telemetry shall be maintained in a telemetry dictionary (rather than hard-coded).		Y	N		N	
3.5	**Telemetry Playback Utility**						

	The telemetry playback user interface shall use a VCR paradigm, with stop, pause, forward, reverse, fast-forward, rewind, and a variable speed slider control. It shall also include a step mode, i.e. packet by packet, in the forward or reverse direction.	The requirement for reverse dropped in signed off build 1 design document. The telemetry chooser provides this function, and has been used for the last 2 years during I&T.	Y	N		N	
3.6	**Hex/Engineering Dump Utility**						
3.6.1.1	The engineering dump shall include up to 7 telemetry points on a tabular report and up to 100 telemetry points on a file designed for input to a spreadsheet. The output shall be in engineering units.	Provided by engineering dump. 100 points were never explicitly tested, but it should work. The engineering dump output has been used extensively by the GNS team.	Y	N		N	
3.6.1.2	The hex dump capability shall allow the user to view up to 10 bytes of data on a tabular report. The output shall be in hex.	Provided by engineering dump.	Y	N		N	

3.6.1.3	Telemetry access should be speedy. Specifically, it shall take less than 1 minute to produce a report of 7 or less telemetry points in engineering units for the period of one hour.	Provided by engineering dump. Requirement relaxed. Eng dump has a 6 minute overhead to read the database, so this test took 7 minutes.	Y	N		N	
3.8	**Run-Time Processing Utility**						
3.8.1.1	The software shall include the capability to produce a report which includes the daily and cumulative on-time for boxes on a spacecraft, i.e. box_a has been on for 256 hours since the start of integration. Parameters shall be based on a combination of te	Used extensively during I&T.	Y	N		N	

3.8.1.2	The software shall include the capability to produce a report which includes the daily and cumulative number of relay switches for relays on the spacecraft, i.e. relay_5 has been switched 322 times since the start of integration.	Used extensively during I&T.	Y	N		N	
3.9	**Trending Report Capability**						
	The capability shall exist to produce a report which includes the daily and cumulative minimum, maximum, and mean values for given telemetry mnemonics. Telemetry mnemonic data may be screened by a combination of telemetry conditions, i.e. only consider b	Satisfied by APL's Trending Utility.	Y	N		N	
4	**Database Management System**						
4.1	**User Input Environment**						

	The DBMS should include a forms capability.	EPOCH/ORACLE database input is accomplished via a forms interface	Y	N		N	
4.2	**Report Capability**						
	The DBMS shall be required to produce command and telemetry reports sorted by subsystem.	Provided by ISI report generator. In practice, we use APL telemetry spreadsheets and APL's Command Dictionary Report.	Y	N		N	
4.4	**Command and Telemetry Table Definition**						
	A database management system (DBMS) shall be used to maintain the command and telemetry dictionaries.	EPOCH includes ORACLE	Y	N		N	
4.5	**Database Management System Requirements**						
4.5.1	The DBMS should include a SQL interface.	ORACLE includes this functionality	Y	N		N	
4.5.2	The DBMS should include a programming language interface.	ORACLE PRO*C accomplishes this	Y	N		N	

4.5.3	The DBMS shall be password protected.	ORACLE includes this functionality	Y	N		N	
4.5.4	Dictionary reports should be generated in a timely fashion. Specifically, no report shall take longer than one hour to generate. This shall include the generation of any ascii files which serve as input to the real-time telemetry decommutation or comman	Tested extensively over the past 3 years.	Y	N		N	
5	**MOC/POC Command Filter**						
5.1	**Command Validation**						
5.1.1	The Command Filter shall check for valid source/destination pairs. Bad pairs shall be rejected, alarmed, and audited.	Provided by APL's MOC/POC Command Filter.	Y	N		N	

5.1.2	The Command Validation shall include a method to designate one user/workstation pair as the only valid source for commands origination within the MOC. This pair may be changed via a password protected utility.	this functionality is satisfied by the design.	Y	N		N	
5.2	**Command Logging**						
5.2.1	The Command Filter shall log all commands in a time-tagged command log.	Provided by MOC/POC Command Filter.	Y	N		N	
5.3	**Command Filter Control**						
5.3.1	The MOC shall be able to enable or disable each POC's ability to command the spacecraft.	Provided by the MOC/POC Command Filter's Operator Interface GUI. Used extensively during I&T.	Y	N		N	
5.4	**Command Packaging**						

5.4.1	All commands shall be packaged to satisfy TBD networking protocol requirements. At a minimum, this packaging shall include CCSDS packet information and designate the virtual channel on which the data is to be uplinked. The communication with the Ground	Tested in the IEM Mini_MOC.	Y	N		N	
5.4.2	The MOC shall also include the option of stuffing packets into transfer frames.	done in APL code	Y	N		N	
5.5	**Bad Frame Generation**						
5.5.1	The Command Filter shall include the ability to apply an arbitrary function to transfer frames. For example, a transfer frame with an invalid length could be constructed. This capability will be used to debug the spacecraft Command and Data Handling (C&	this functionality has been provided by adding a file name and a file name pass-through to EPOCH commands	Y	N		N	

5.7	**MOC/POC Command Filter Requirements**						
5.7.1	The MOC shall filter commands based on their source and destination.	Satisfied by APL's MOC/POC Command Filter.	Y	N		N	
5.7.1.1	Commands originating within the MOC shall be able to address all of the ground support equipment and all of the spacecraft.	Provided by APL's Command Interface Program and MOC/POC Command Filter Program.	Y	N		N	
5.7.1.2	Only one workstation at a time shall be able to command the spacecraft. The test conductor shall control which workstation may command at any given time.	this functionality is satisfied by the design.	Y	N		N	
5.7.1.3	Commands originating at instrument POCs shall be able to address only the appropriate instrument or its supporting ground support equipment.	Provided by APL's MOC/POC Command Filter.	Y	N		N	
5.7.1.4	Commands with unauthorized source-destination pairs shall be alarmed, audited, and rejected.	Provided by APL's MOC/POC Command Filter.	Y	N		N	

5.7.1.5	Command counters for each spacecraft source and destination as well as a counter of rejected commands shall be available as telemetry in the MOC.	MOCs display all command accept and reject counters the same as any other GSE or spacecraft telemetry.	Y	N		N	
5.7.1.6	The MOC shall control a switch (via TCL) to enable or disable spacecraft commanding from any POC. There shall also exist a TCL command to flush the command queue for any POC.	Provided by APL's MOC/POC Command Filter.	Y	N		N	
5.7.1.7	The status of the commanding enable/disable switch for each instrument POC shall be visible within the MOC as ground telemetry.	Included in MOC/POC Command Filter Telemetry and its Operator Interface GUI.	Y	N		N	
5.7.1.8	POC GSE commands shall always be enabled.	GSE commands go through CMDIF. Since MPCF provides POC filters, GSE commands bypass the filter.	Y	N		N	

5.7.1.9	A time-tagged log of all spacecraft commands sent shall be maintained in the MOC. Note that POC commands may only be stored as bits. Also note that it is a goal to include MOC GSE commands in this logging, but not POC GSE commands.	Provided by the MOC.	Y	N		N	
5.7.1.10	MOC commands shall take priority over POC commands.	Satisfied by APL's MOC/POC Command Filter.	Y	N		N	
6	**GS/MOC/MDC Server**						
6.1	**Telemetry Processor**						
6.1.1	The Telemetry Processor shall communicate with the Ground Station. The communication between the MOC and the Ground Station shall be TCP/IP.	the implementation of this functionality is being performed in APL code.	Y	N		N	
6.1.2	The Telemetry processor shall be able to receive telemetry in three different formats: Reed-Solomon encoded,Reed-Solomon decoded, Standard Telemetry Units	this requirement has been modified per signed off moc sw bld 1 des doc. now must be able to receive TF+'s. Satisfied by APL front-end and Mission Data Center.	Y	N		N	

6.1.3	The Telemetry Processor shall send real-time telemetry to Telemetry/Assessment.	demonstrated on atp_display1	Y	N		N	
6.1.4	The Telemetry Processor shall send all telemetry to the MDC. This includes both real-time and data recorder playback telemetry.	Satisfied by the APL Mission Data Center.	Y	N		N	
6.1.5.	The Telemetry Processor must be able to handle a rate of 800 kbps. This rate is derived from (the data recorder playback rate of 4.8 Mbps * a 10 minute playback) divided by one hour to subsequently play this data from the ground station to the MOC.	Satisfied by the APL Mission Data Center.	Y	N		N	
	(4800kbps*600seconds)/3600seconds = 800kbps.						
6.2	**Ground Station Replay Handler**						
6.2.1.2	The MOC shall include the capability to request the replay of stored telemetry from the Ground Station.	Provided by MDC and Front-Ends.	Y	N		N	

7	**Planning Tools**						
7.1	**Orbit Position Display**						
7.1.1	Orbit Position Display Requirements -	Satisfied by Satellite Toolkit STK.	Y	N		N	
	An Orbit position display capability (also called ground trace or orbit tracker software) shall show the satellite's position relative to a map of the earth. Predicted ground trace as well as coverage areas of the Ground Station network is required.	Satisfied by Satellite Toolkit STK.	Y	N		N	
7.2	**Orbit Analysis Tool**						
7.2.1	The MOC shall include an orbit analysis tool such as the Satellite Tool Kit.	Satisfied by Satellite Toolkit STK.	Y	N		N	
7.3	**Autonomy Rule Generation Software**						

7.3.1	Autonomy rule generation software shall provide the capability to define an autonomy rule in an English-like manner, and have it translated into TCL. (This capability becomes more or less important depending on the design of the TBD C&DH autonomy capabil	Satisfied by APL's Autonomy Rule Compiler.	Y	N		N	
7.4	**Operational Timeline Tool**						
7.4.1	A graphical representation of the spacecraft's planned operational timeline is required. Such a product must illustrate the planned/predicted operational status the spacecraft bus subsystems (an equivalent representation of the instrument operational stat	APL software produces a timeline that shows contacts and milestones such as SAA crossings and eclipses. The requirement to make this representation graphical has been relaxed.	Y	N		N	
7.5	**Resource Modeling Utility**						

7.5.1	This software shall account for the status of the data recorder, processor memory, autonomy rules, downlink, battery, momentum, and other resources. The model shall track these resources in response to planned events.	APL's C&DH Memory Allocation Manager (MAX) accounts for processor memory and autonomy rules. Software to manage the other resources has not been produced.	N	N		Y	Management of these resources is currently done manually.
8	**Shared Command/Telemetry Tools**						
8.1	**Processor Load and Dump**						
8.1.1.1	The Expected Image shall be built from a TBD source such as command loads and/or binary files.	Satisfied by CMDIF and PROCL.	Y	N		N	
8.1.1.2	The Actual Image shall be built from telemetry. A process shall check telemetry for processor dumps. If they are encountered, the actual image shall be updated.	Satisfied by PROCL.	Y	N		N	

8.1.1.3	The Actual Image shall be built from telemetry. A process shall check telemetry for processor dumps. If they are encountered, the actual image shall be updated.	Satisfied by PROCL and PROCD.	Y	N		N	
8.1.1.4	The output of the compare shall be differences.	Satisfied by PROCL and PROCD.	Y	N		N	
8.1.1.5	Other output shall be contents of either the actual or expected image.	Satisfied by PROCL and PROCD.	Y	N		N	
8.1.1.6	All operations may be specified for a range of physical or logical memory.	Satisfied by PROCL, PROCD, and PAM.	Y	N		N	
8.1.1.7	Logical memory relates to the APL data structures concept.	Satisfied by PROCL, PROCD, and PAM.	Y	N		N	
8.1.1.8	The compare utility shall be invoked by TCL as well as from a menu. A script which contains a compare statement shall halt unless the compare returns zero differences. In any case, the number of differences is included in the event log.	Satisfied by PROCL, PROCD, and PAM.	Y	N		N	

8.1.1.9	The option to output a specified range of actual or expected memory shall be invoked from a menu.	Satisfied by PROCL, PROCD, and PAM.	Y	N		N	
8.1.1.10	The capability to recognize whether differences in memory are opcodes or data is desirable.	Not a requirement.	Y	N		N	
8.2	**Command/Telemetry Graphical Extension**						
8.2.1	The MOC shall include graphical representations for commanding and telemetry via products such as Dataviews, PV-Wave, and/or IDL.	APL has not yet purchased these products, but could.	N	N		Y	Telemetry is currently viewed via tabular displays and plots.
8.3	**Command/Telemetry Event Logger**						
8.3.1	This logger shall accept input from Command and Telemetry/Assessment and possibly other processes.	epoch provides an event logger for each viewer. apl provides one for each stream.	Y	N		N	

8.3.2	This logger shall create an ascii log file which is output to disk and available to the user via a window with horizontal and vertical scroll bars. All log entries shall be tagged with ground UT.	Achieved by using nedit or dtpad when looking at the event logs.	Y	N		N	
8.3.3.	A time-tagged event log shall record commands as they are sent from the MOC.	Satisfied by APL and EPOCH's event loggers	Y	N		N	
8.3.4	This log shall include the bits associated with each command which went out in addition to the command itself.	Satisfied by APL and EPOCH's event loggers	Y	N		N	
8.3.5	Spacecraft acknowledgment (or rejection) status of the command shall also be included in this log.	Satisfied by APL and EPOCH's event loggers	Y	N		N	
8.3.6	This log shall be saved with a filename which includes a date/timestamp.	Satisfied by APL and EPOCH's event loggers	Y	N		N	
8.3.7	This log may be viewed from any MOC workstation in real-time.	Satisfied by APL and EPOCH's event loggers	Y	N		N	

8.3.8	TCL shall include the capability to write comments into the event log, so that the status of an IF-THEN-ELSE statement may be recorded.	demonstrated in atp_script7	Y	N		N	
8.3.9	Telemetry alarms shall be included in the event log.	demonstrated with EPOCH's response to byter simulated telemetry point zmo_byte_007.	Y	N		N	
8.4	**Merge Capability**						
8.4.1.1	The MOC shall have the capability to merge ascii command and telemetry event logs from the POCs and the MOC into unified command and telemetry logs.	Satisfied by APL's Merge Utility.	Y	N		N	

Summary	
Number of requirements	166
Number of requirements satisfied	164
Number of requirements which need ISI action	0
Number of requirements which need APL action	2

Ground System Engineering

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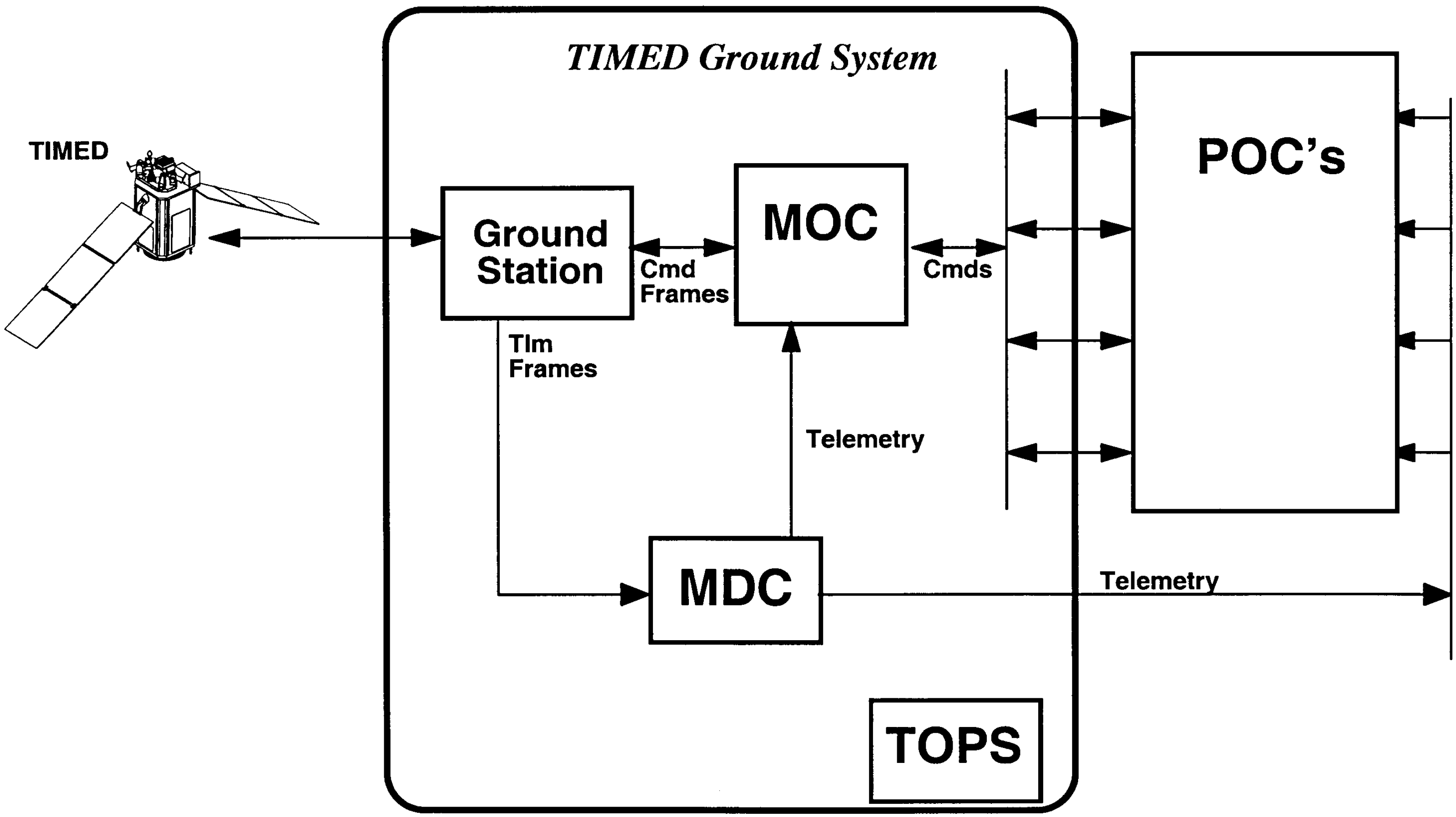
Ground System Outline

- *Architectural Overview*
- *End-to-End Data System Overview*
- *Ground System Overview*
  - *Mission Operations Center*
  - *Mission Data Center*
  - *Ground Stations*
    - » *APL*
    - » *USN*
    - » *TDRSS*
- *PFR/SPR Status*
- *System Level Testing*
- *Residual Risk*
- *Ground System Requirements Matrix*

TIMED Ground System Components



Ground System Lead Engineers

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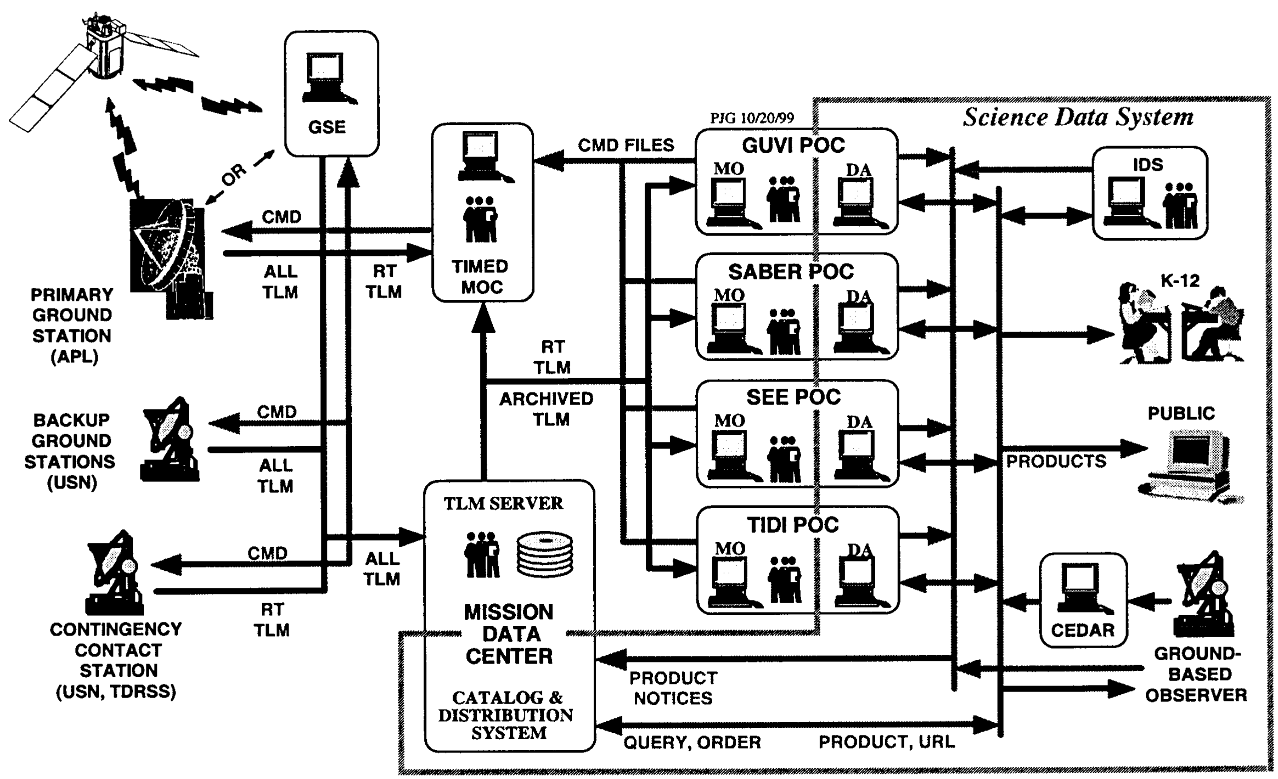
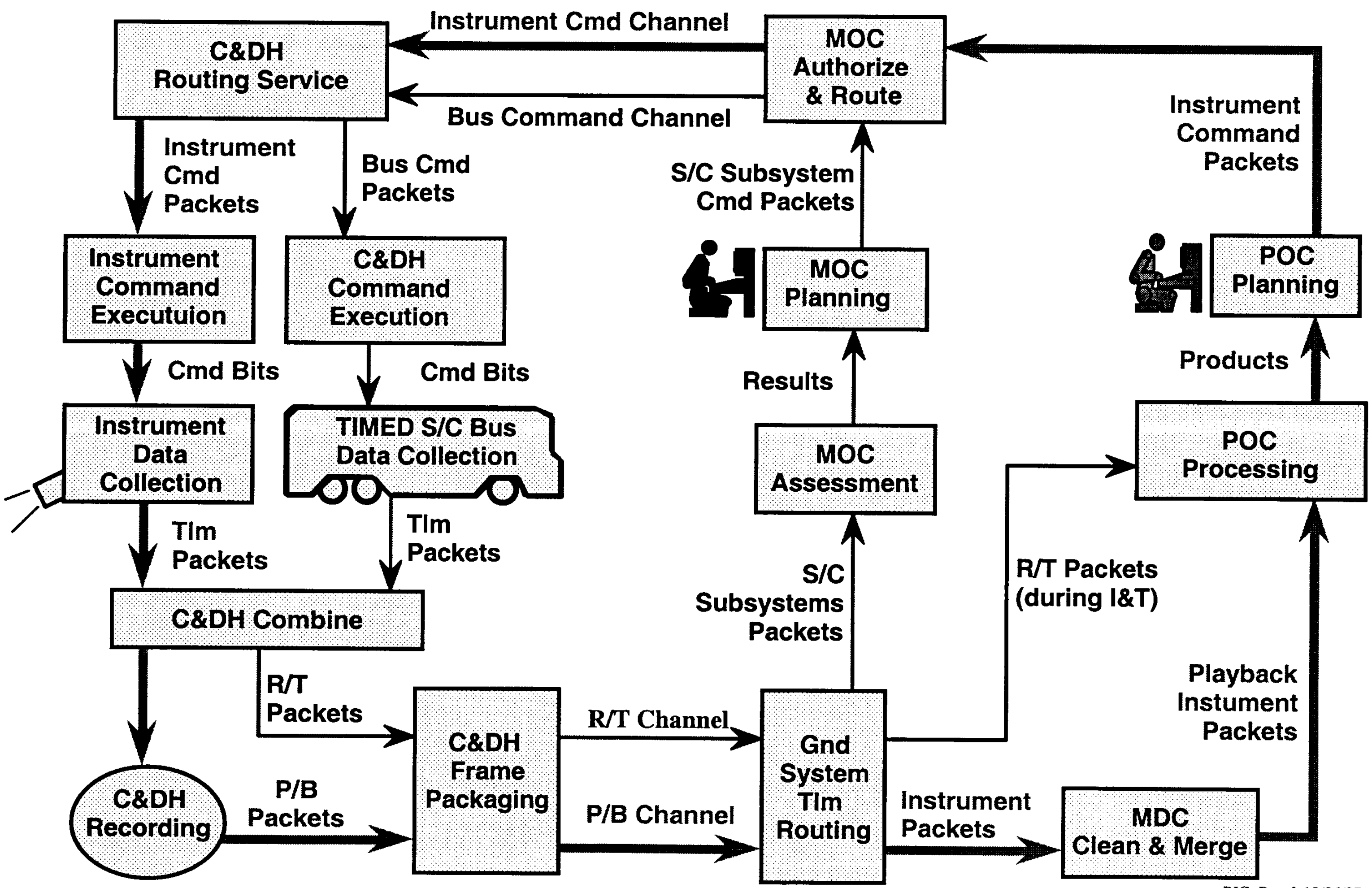
  - Walter Mitnick, Software Lead
- *Mission Data Center (MDC)*
  - Paul Lafferty, Lead
- *Science Data System (SDS)*
  - Paul Lafferty, Lead
- *APL Ground Station*
  - Steve Gemeny, Lead

Ground System Architecture

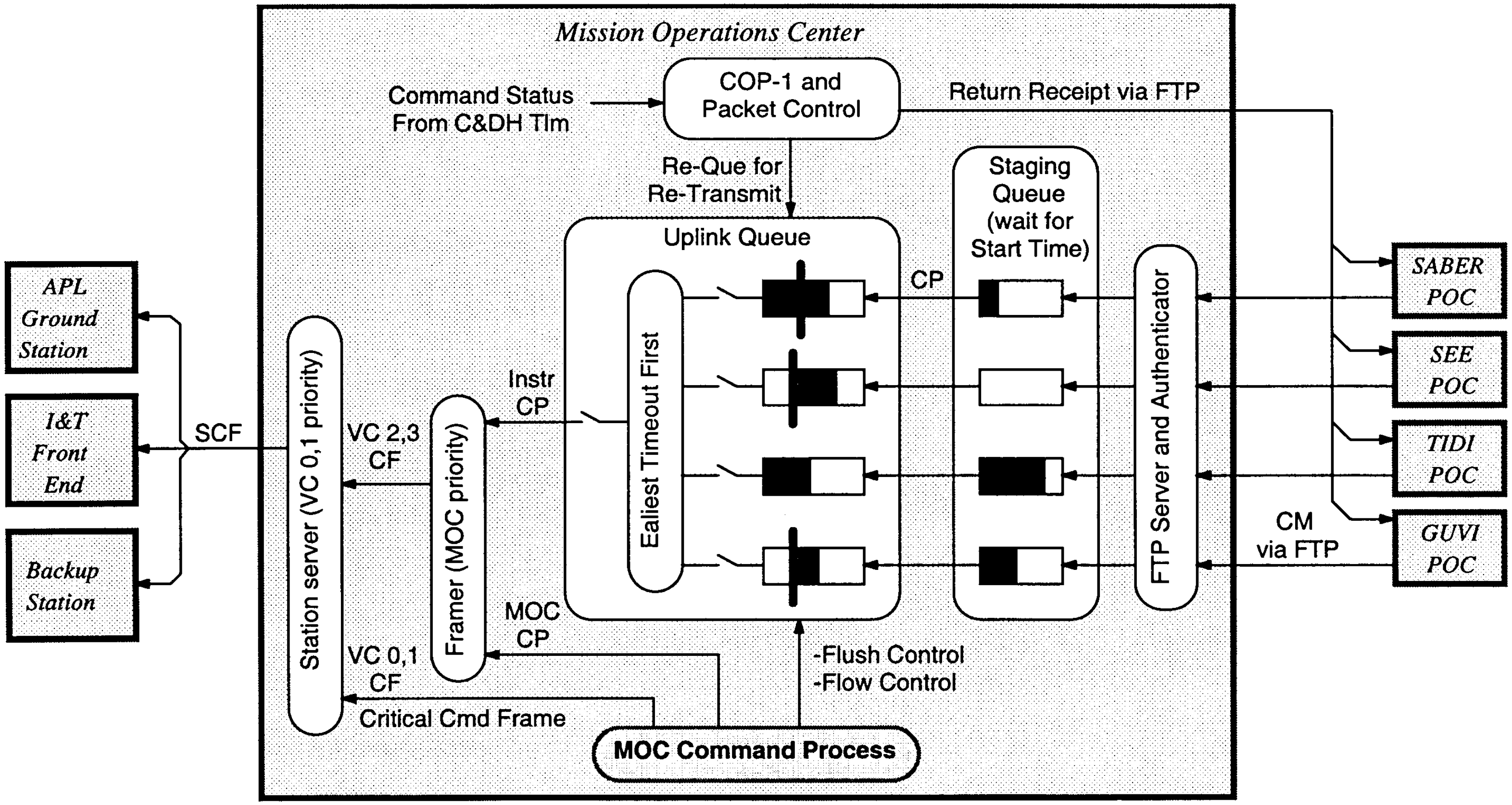


-->> TIMED Mission Data Flow -->>



PJG, Rev f, 12/26/97

Command Data Flow

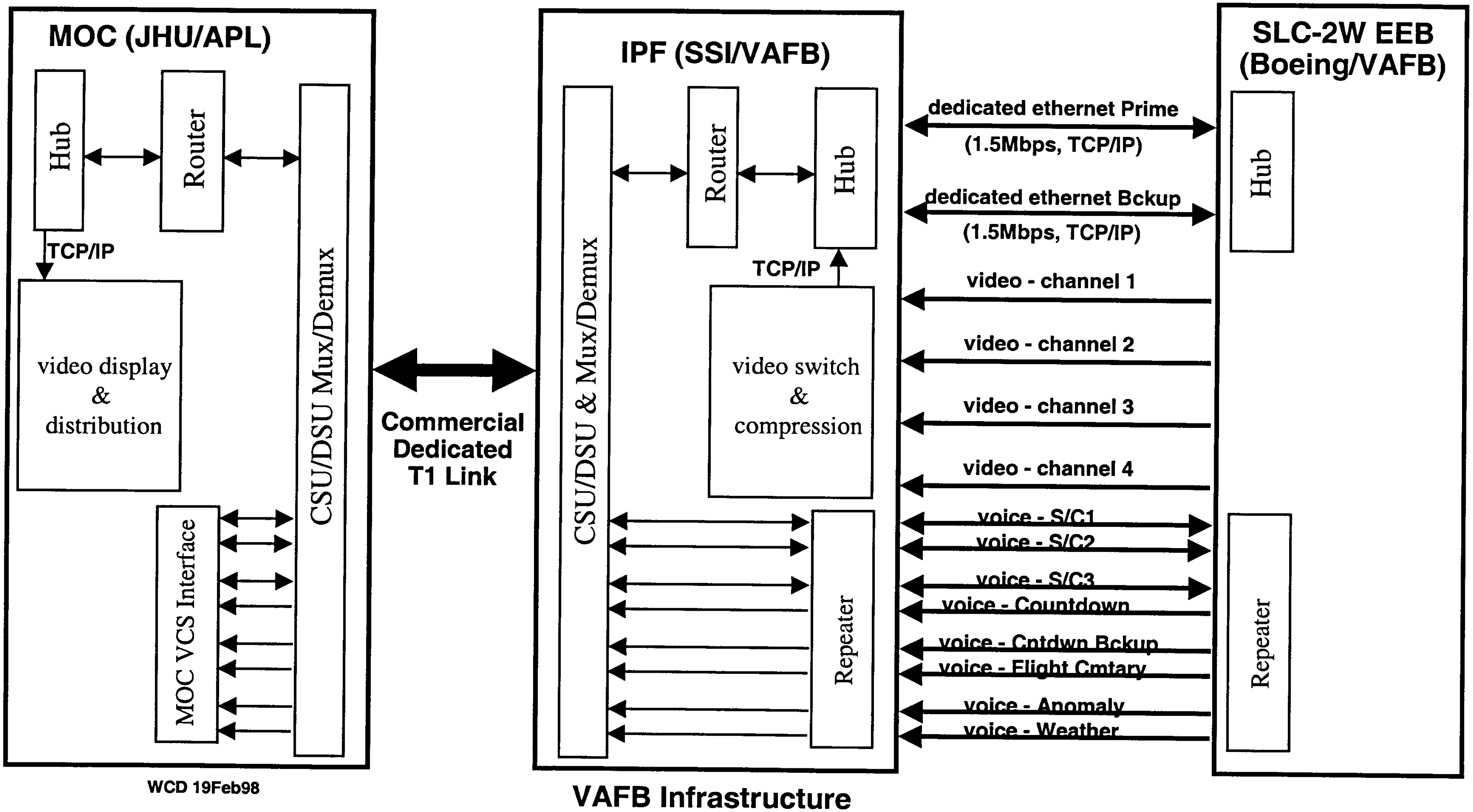


PJG, rev e, 11/12/97

Command Message Types

- CM = [POC-MOC] Command Message
- CP = Command Packet
- SCF = Supplemented Cmd Frame
- CF = Command Frame

Launch Site Ground Communications



WCD 19Feb98

Virtual Channel Assignments

Command Function	Side #1	Side #2	Comments
Hardwired Commands (Critical, Power Subsystem)	**VC0**	**VC1**	Intercepted by Uplink Interface of RF Subystem
Direct-Delivery Commands (to Instruments, C&DH, GPS Subsys, G&C susys)	**VC2**	**VC3**	Direct delivery to instruments and subsystems; sequence of delivery is allowed to differ from order of receipt by s/c

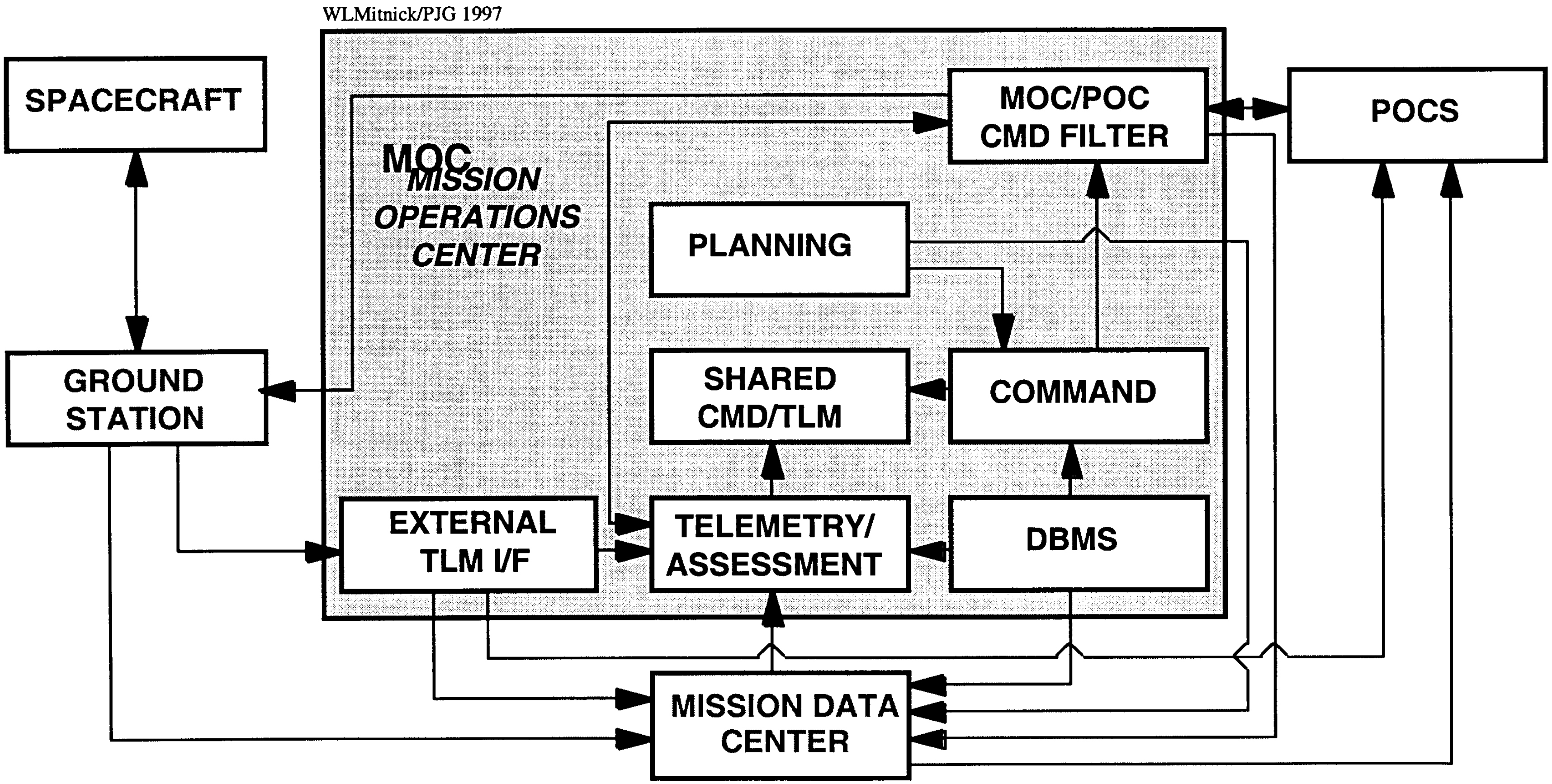
Telemetry Function	Side #1	Side #2	Comments
Downlink Board Fill	VC0	VC0	Different channels not needed; only one side has active telemetry
Dump Telemetry (Instruments, C&DH and Subsystems)	**VC6**	**VC6**	Different channels not needed; only one side has active telemetry
Real-Time Telemetry (Instruments, C&DH, and Subsystems)	**VC7**	**VC7**	Different channels not needed; only one side has active telemetry

PJG, Rev d, 11/4/97

End-to-End Data System Features

- Fully compliant with CCSDS Packet Telemetry and CCSDS Telecommand Recommendations
- Telecommand error control:
  - Frame-Delivery (COP-1) protocol operates between MOC and C&DH subsystem
- Telemetry error control
  - Reed-Solomon encoding, Frame Error Control Field (CRC)
  - Two options to re-transmit Telemetry Packets from the spacecraft SSR to the MDC
    - » Selective re-transmit under MOC control
    - » Redundant dumps with automatic gap-filling by MDC

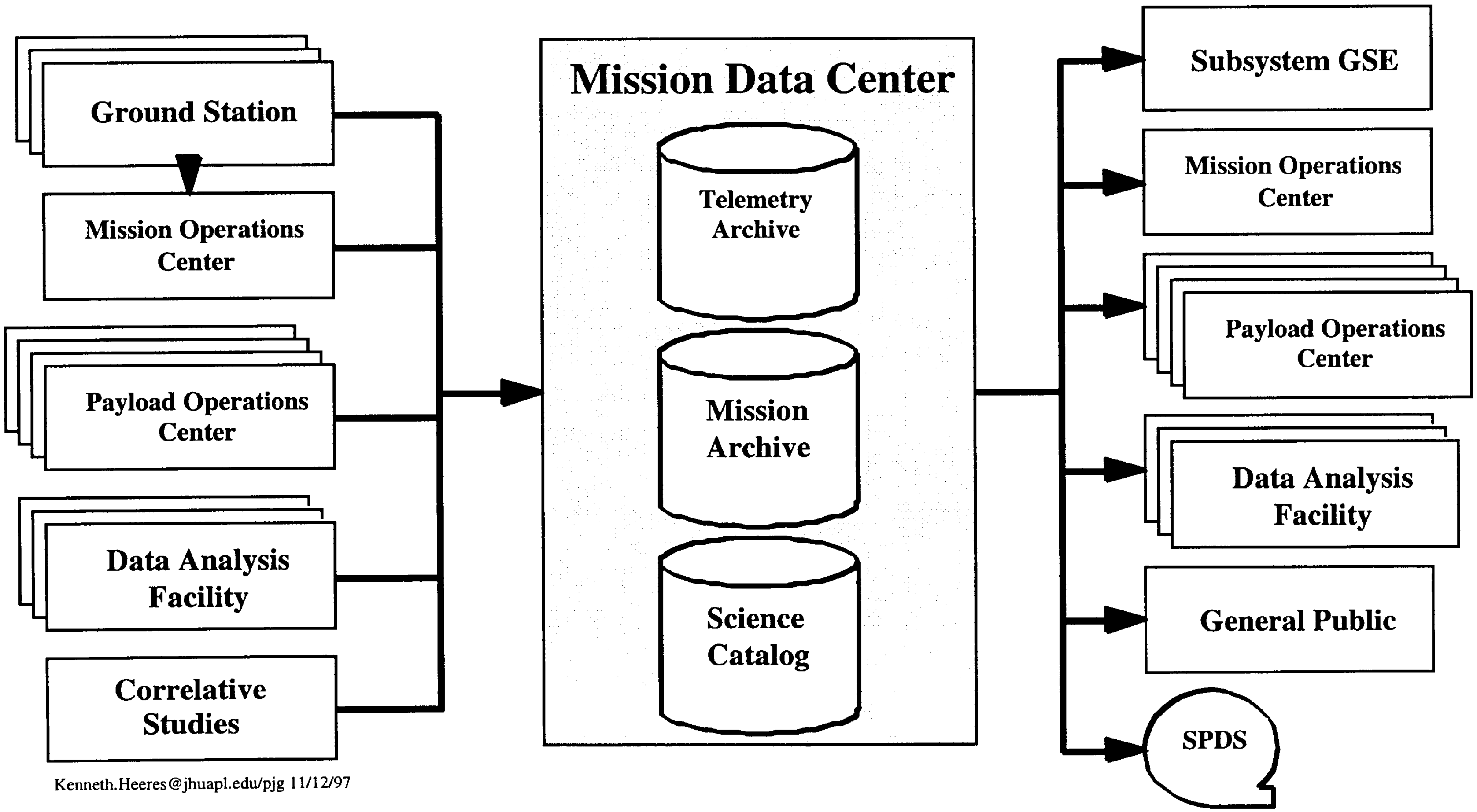
Mission Operations Center (MOC)



MOC Design Highlights

- Built around COTS software (EPOCH 2000)
- Supports independent commanding by MOC and POCs
- Supports real time or store-and-forward commands from POCs
- Uses same design for
  - Subsystem Test (Mini-MOC)
  - Integration & Test
  - Mission Operations
- GSE commanding and status telemetry interfaces
- Memory management tools for spacecraft processors
- Derived Telemetry

Mission Data Center



Kenneth.Heeres@jhuapl.edu/pjg 11/12/97

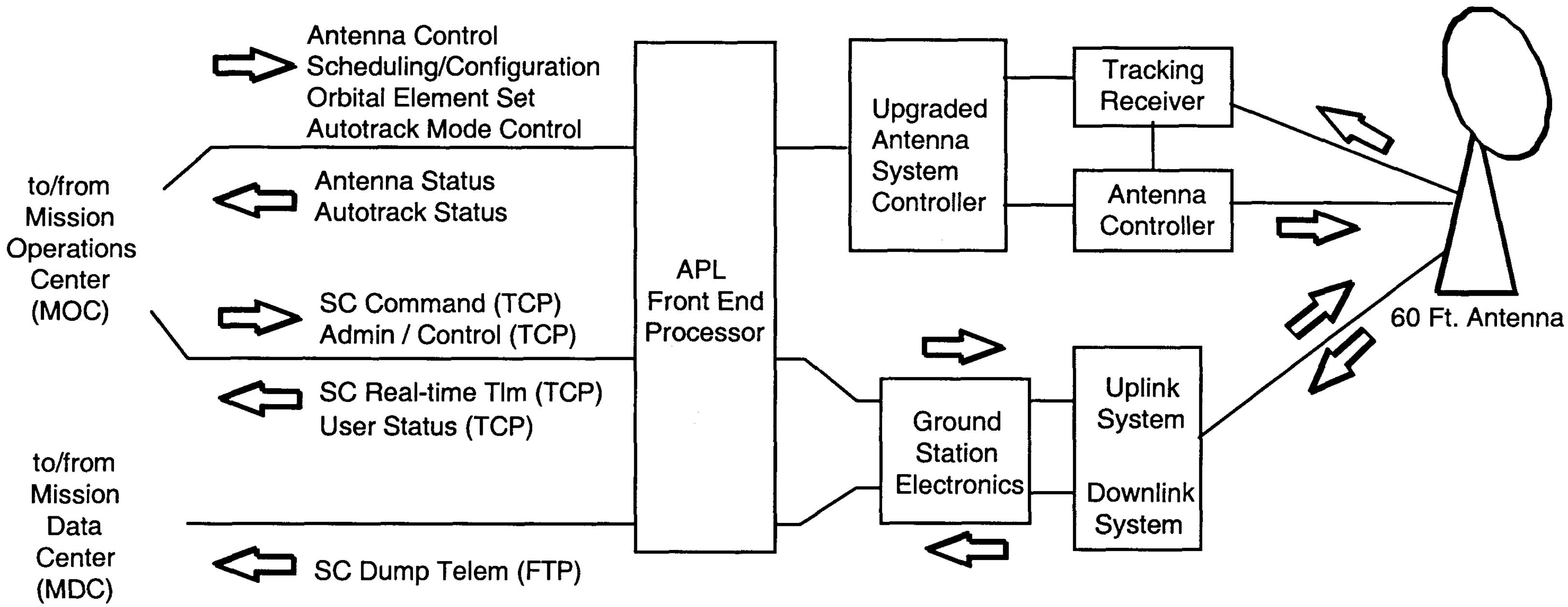
MDC Major Processes

- Telemetry Server
  - Serves all real-time clients (MOC and POCs)
  - Builds on-line archive
  - Level-0 telemetry is on line for entire mission
  - Serves all playback clients (MOC and POCs)
- Data Product Production and Distribution
  - Spacecraft attitude, ephemeris
  - Science product catalogs
  - Accepts queries and orders
  - Assembles and distributes MDC data products
  - Masters data for final archive (Space Physics Data System or other)
- Mission Publication
  - Public access through World Wide Web

Ground Station Arrangement

- Primary Ground Station is at APL
  - Use existing 60-foot antenna system
    - » Modified feed for transmit/receive
  - Logistic advantages
    - » Priority for TIMED support
    - » Local interface to MOC and MDC
    - » Accessible for integration, compatibility tests
- Backup Ground Station services provided by Universal Space Networks (Horsham, PA)
  - Expanded coverage during Early Operations
  - Available for contingency support
  - Planned contact once a week

Primary Ground Station



SEGemeny/PJGrunberger 11/12/97

Ground Station Features

- Primary Ground Station
  - Remotely scheduled from MOC
  - Automated scheduling/configuration
  - Unattended pass support capability
  - LEO-T compatible TCP/IP external interface
- Backup Ground Stations
  - remotely scheduled from MOC
  - Same look-and-feel as Primary Station to MOC/MDC
  - Two links to APL MOC/MDC:
    - » ISDN
    - » Internet socket connection

Universal Space Networks

- Test Summary
  - July 1999 at APL (2 days)
    - » RF Compatibility Testing
    - » Tested using the spacecraft
    - » Several Performance parameters out of spec, requiring retest
  - December 1999 at USN, Horsham, PA (6 days)
    - » RF Compatibility
    - » Ground System Processing and Interfaces
    - » Tested using the Engineering Model IEM
  - October 2000 at APL (2 days)
    - » RF Compatibility
    - » Tested using the spacecraft
    - » Initial results show acceptable performance improvement

Address Review Item 3

Universal Space Networks

- Tests Planned
  - November 15, 2000 at APL (3 days)
    - » End-to-End Compatibility Testing
    - » Incorporate all ground system interfaces

- Results of December 1999 Testing
  - ***Successful commanding*** of the spacecraft via RF from the APL MOC (although "long" commands were not tested)
  - ***Successful real-time spacecraft telemetry flow*** via RF to the APL MOC.
  - ***Successful status-telemetry flow*** from USN to the APL MOC (although some content issues remain).
  - ***Successful ground capture of an SSR dump*** at 4 Mb/s (although there were some problems with USN reports of non-existent gaps in the data.)
  - PFR's not closed out

Address Review Item 3, 7

Universal Space Networks

- Data system compatibility issues to be worked are:
  - APL to verify loads with "long" command frames
  - APL to verify USN's computation of the Ground Receipt Time, including adjustment for leap seconds.
  - APL to verify proper implementation of frame quality flags in the Ground Receipt Header (GRH)
  - USN to repair the telemetry gap-reporting process at high rates.
  - APL to verify USN now meets APL's requirement for minimizing idle gaps between commands.
  - USN/APL to test contact-scheduler interface.
  - USN/APL to complete and sign off USN's "USN to TIMED MOC/MDC ICD"
  - APL/USN to re-run the "TIMED USN End-to-End Compatibility Test"

Address Review Item 3, 7

TDRSS

- RF Compatibility Testing
  - December 15 and 17, 1999
  - Used IEM Engineering Unit as spacecraft
  - Will repeat with Spacecraft on November 21 and 28, 2000
  - Ground interface data flow testing on November 1 and 3, 2000
- Dec 1999 Results
  - ***Command carrier swept acquisition threshold test was successful***
    - » Performance in line with expectations.
  - ***Telemetry signal threshold tests were successful***
    - » Loss-of-lock threshold in line with expectations
    - » Acquisition threshold only 1 dB higher than the loss-of-lock
    - » The Goddard test director reported ***completely successful decoding of telemetry frames.***

Address Review Item 3, 7

TDRSS

- Dec 1999 Results (Continued)
  - ***Command acceptance threshold*** could not be determined
    - » Spacecraft rejected all commands.
    - » The good news is that the ***commands were reliably rejected***
    - » Indicates that the uplink bit stream was being successfully demodulated, and the CLTUs were being successfully detected
    - » We suspect that the cause of rejection is incorrect formatting of the commands by the WDISC.

Address Review Item 3, 7

PFR Status

- PFR 032 - USN TLM Receiver not optimized for Low Rate Tlm
  - Testing July 1999 failed to meet requirements
  - Drop threshold and acquisition threshold were higher than required
  - Tests repeated Oct 19 and 20, 2000
  - Now meeting performance, PFR Closed

- PFR 034 - USN TLM Receiver has poor Bit Error Rate performance
  - High Rate Telemetry failed testing July 1999
  - Really poor Frame Error Rate performance
  - Filter in bit synchronizer not performing properly
  - Bit Synchronizer repaired by vendor
  - Test repeated Oct 19 and 20, 2000
  - Re-test successful, performance now within required limits

Address Review Item 3, 7

PFR Status - Continued

- PFR 066 - Front End Frame Error Rate Performance
  - Frame error rate performance 3 dB off baseline measurements
  - Determined that Avtec Reed-Solomon Telemetry Processor had software bug in firmware on board
  - Also found that Receiver I & Q were out of phase
  - Avtec delivered fix - Properly reset derandomizer after flywheel frame
  - Added appropriate delay to I & Q paths
  - Re-Test in July 2000
  - Front End Frame Error Rate now within 0.8 dB of baseline measurements.

Ground System SPR Status

- SPR 401 - 1 to 3 minute telemetry dropout
  - APL Network problem
  - Problem localized to APL Firewall router
  - Workaround implemented July 2000
  - Still investigating to resolve expected problems with field operations
  - No affect on Post-Launch configuration

TIMED Operations Simulator (TOPS)

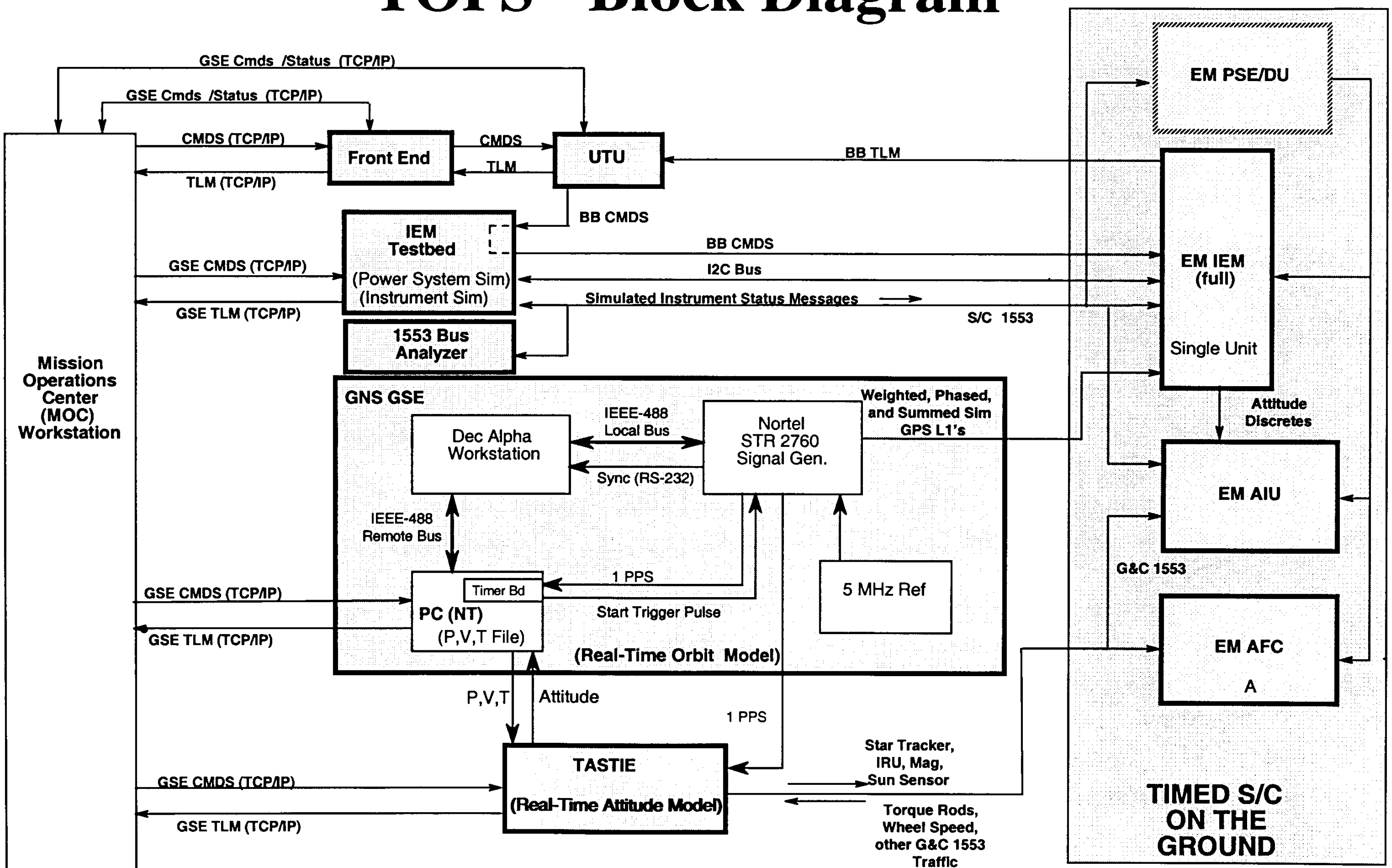
- "Satellite-on-the-ground"
  - Validate ops procedures, flight code updates, autonomy rule changes both pre- and post-launch.
- "Hardware-in-the-loop" simulator
  - Contains Engineering Models of critical TIMED subsystems.
    - » IEM, AIU, AFC, Optional PSE/DU
  - Contains all S/C subsystem flight software.
  - Includes the subsystem GSEs needed to simulate the space environment.
  - Instruments data rates and power system are simulated
  - RF to/from APL Ground Station

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

TOPS - Block Diagram



System Level Testing

- Telemetry Archiving and Playback Test Procedure
  - Exercises MOC, MDC, real-time and playback services
  - Run on October 15, 1999
  - Test not completed, several problems identified, now fixed per SPRs
  - Test will be re-run following installation of new MDC tlm server, Nov 00
- Y2K System Test Procedure
  - Intended to verify system ready for operation in 2000
  - Exercised full ground system: MOC, MDC, APL Ground Station
  - Real-time and Playback telemetry services
  - Commanding
  - Pre-Test on Aug 24, 1999
  - 1st run on Sept 25, 1999, problems identified
  - 2nd run on Oct 11, 1999, successful testing completed

Address Review Item 3, 7

Residual Risk (1 of 2)

- Ground Station Support for Early Operations
  - Lead time to prepare and test Kiruna, Sweden
    - » Pending contract between APL and USN
  - Lead time to prepare and test Hartebeesthoek, South Africa
    - » Pending DMR feedback and CSOC contract with USN
    - » First 10kbps contact after launch, Downlink only

- Remote Testing during Launch Operations
  - Unresolved 1 minute network dropouts, under investigation
  - Spacecraft and GSE control from MOC at APL
  - Local workstation at VAFB able to take control, if necessary
  - Not a problem in Post-Launch configuration

Residual Risk (2 of 2)

- GSE socket communications during simulations
  - Dynamic simulations run to test Launch, Early Ops, Nominal Orbits
  - GSE Simulators communicate using tcp sockets and GPIB
  - Repeated instances of hung GPIB bus and disconnected sockets
  - Investigating ways to make systems more robust

- Flight Software Load software rewrite
  - Software rewrite nearing completion
  - Successful testing on TOPS in progress
  - Desire to verify with spacecraft before launch

Verification Matrix (1 of 3)

End-to-End (Instrument-to-POC) Requirements		Requirement	Verification
	System Availability	95%* [was 99%] of all Source Packets produced by the payload instruments must be collected by the spacecraft bus and delivered to the Payload Operations Centers (POCs)	
	Error Probability	Fraction of Source Packets delivered with detected and flagged errors: 1 x 10-3	Verified by Analysis
		Fraction of Source Packets delivered with undetected errors: 1 x 10-10	Verified by Analysis
	Data Accumulation Capacities on Spacecraft	Daily Average Housekeeping Data Rate: 5,500 b/s	By Design
		Daily Average Instrument Data Rate: 16,954 b/s	By Design
		Spacecraft Solid State Recorder (SSR) Capacity: 2.5 Gb	By Design
Space-Ground Interface		**Requirement**	**Verification**
	High Rate downlink	Dump a 1-day accumulation in a single pass at the Primary Ground Station	96-Hour Mission Simulation
		Required information rate capacity = 3,994,862 b/s	Daily testing using High Rate Downlink
	Intermediate Rate downlink	Dump a 1-day accumulation in a single cluster of passes at the Backup Ground Station	tbd - USN testing
	Low Rate downlink	Downlink real-time engineering housekeeping telemetry to a remote station	Dec 99 USN Testing
		Required information rate capacity = 9,018 b/s	Dec 99 USN Testing
	Redundancy	The TIMED Ground Station shall have a backup	Contract with USN
	Command and telemetry protocols	per CCSDS Recommendations	C&DH software design
		COP-1 protocol performed by MOC	IV&V by independent software tester
	Uplink Data Rate	Required data rate = 2,000 b/s	Daily testing using RF Uplink

Address Review Item 3, 7

Verification Matrix (2 of 3)

Mission Operations (MO) Support		Requirement	Verification
	Commands	Instrument command uploads shall be prepared at the POCs	Instrument Tests and Mission Sims
		Spacecraft [bus] commands shall be prepared in the Mission Operations Center (MOC)	Daily Testing
		[The MOC] shall collect instrument commands from POCs, and transmit them to the instruments	Instrument Tests and Mission Sims
		[The MOC] shall generate spacecraft bus commands and transmit them to the spacecraft bus.	Daily Testing
	Telemetry	Collect all [spacecraft bus and instrument] raw telemetry [in the MDC]	Daily Testing
		Analyze spacecraft bus telemetry [in the MOC]	96 Hour Mission Simulations
		Forward all raw telemetry data [to the Science Data System] for processing and distribution to POCs	Instrument Tests and Mission Sims
		Forward all science telemetry data to the instrument POCs	Instrument Tests and Mission Sims
	The MOC shall support planning and assessment		96 Hour Mission Simulations
Integration & Test (I&T) Support		**Requirement**	**Verification**
		Support commands as indicated for MO	Daily Testing
		Support telemetry as indicated for MO	Daily Testing
		Maintain spacecraft command and telemetry dictionaries	Daily Testing

Address Review Item 3, 7

Verification Matrix (3 of 3)

Data Analysis (DA) Support		Requirement	Verification
	The TIMED Science Data System (SDS) [which includes MDC and POC components] shall:	Archive and serve all raw telemetry from the start of I&T to the end of the mission	MDC Operational
		Serve all data products necessary to support the TIMED mission	96 Hour Mission Simulations
		Support transfer of data to long-term archive at the end of the mission	B-Montly Archive process now
General Ground System Requirements		**Requirement**	**Verification**
	Cost-Related Constraints	The Primary TIMED Ground Station shall be selected to keep operations costs low	Local APL Ground Station
		The Mission Operations Center location shall be selected to keep operations costs low	Local APL Mission Operations Center
	Network Support	The Ground System shall include primary and backup voice and data networks for inter-facility communications during launch operations	By Design
POC Service Requirements		**Requirement**	**Verification**
	Commands from POC to MOC	Authentication Return Receipt	Instrument Tests and Mission Sims
	Every POC Command Message is now acknowledged with two receipts	Command Return Receipt	Instrument Tests and Mission Sims
	Telemetry from MDC to POC	Telemetry Packets	Instrument Tests and Mission Sims

Address Review Item 3, 7

Mission Operations

William P. Knopf
Mission Operations Manager

Previous Reviews

- Spacecraft PDR (February 1997)
- Spacecraft CDR (December 1997)
- MOR #1 (May 1998)
- MOR #2 (June 2000)

MOR #1 Review Team

- Madeleine Marshall (ICS) (Chairperson)
- Andy Good (APL)
  - MSX Planning Team Lead
- Mark Holdridge (APL)
  - NEAR Mission Operations Manager
- Dan Ossing (APL)
  - MSX Performance Assessment Team
- Keith Kalinowski (GSFC)
  - HST, NGST Operations
- Alex Herz (Omnitron)
  - VCL Operations
- Chris Silva (Allied Signal)
  - FUSE Operations

MOR #2 Review Team

- Eric Hoffman (APL) (Co-chairman)
- William Mack (GSFC) (Co-chairman)
- John Catena (GSFC)
- Mark Holdridge (APL)
  - NEAR Mission Operations Manager
- Eric Holmes (GSFC)
- Eric Isaac (GSFC)
- James Joyce (JHU)
  - FUSE Mission Operations Manager
- Hector Zayas (GSFC)

RFA Status – MOR #1

RFA #1 Provide capability to clear instrument staging and uplink command queues individually

-Capability has been provided

RFA #2 Provide capability to permit parameters to be transferred as part of command macro calls

-No value added in this implementation; capability not provided

RFA #3 Acquire MOT staff to perform specific functions rather than advertised concept of complete interchangeability

-Small MOT does not permit specialization

RFA Status – MOR #1 (continued)

RFA #4 Maintain all mission operations related documentation on-line

-Has been implemented

RFA #5 Insufficient margin when assuming an operations concept of only one contact per day

-Although a single contact per day is the design concept (and feasible) we intend to schedule all daytime contacts every day

RFA #6 Ground system requirements not presented

-Requirements do exist and provided at previous reviews

RFA Status – MOR #1 (continued)

RFA #7 Orbital drag calculations may need to be updated

-These are periodically updated when new information becomes available

RFA Status – MOR #2

RFA #1 Mission operations documentation requires configuration management processes

-Documentation will be formally reviewed, signed off and configuration managed

RFA #2 POCs were not included as part of this review

-Will be included at 'Delta' Mission Operations Review

RFA #3 Identify launch critical facilities

-A launch critical facilities spreadsheet has been developed and is in the review process

RFA Status – MOR #2 (continued)

RFA #4 Develop a 'disaster' plan to sustain spacecraft operations should the MOC become inoperable

-In process

RFA #5 Identify MOT organization during the on-orbit phase

-In process

RFA #6 Ground-test only commands must be purged from the on-orbit command database

-This will be implemented

RFA #7 Define pre-pass checks for USN and TDRSS contacts

-In process

RFA Status – MOR #2 (continued)

RFA #8 Prepare task list and staffing plan to complete the mission operations system

-Has been prepared

RFA #9 Consider use of background running software tool to continually search spacecraft data for trends

-Beyond the scope of the TIMED mission

RFA #10 Reconsider use of auto-promote of spacecraft operational modes

-Auto-promote is a capability that is not planned to be enabled at least during the early part of the mission

RFA Status – MOR #2 (continued)

RFA #11 Clarify safeguards in place to prevent unauthorized commanding of the spacecraft from outside the firewall

-In process

RFA #12 What is plan if GNS fails to operate to mission specifications

-In process

RFA #13 Develop software to analyze data on an orbital basis

-Current software affords this capability

RFA #14 Establish a 2-person review of all commands to be uplinked to spacecraft

-Will be implemented

Documentation

• Concept of Operations	March 1997
• Spacecraft Bus Subsystem Handbooks	
– C&DH	July 2000
– GNS	July 2000
– G&C	November 2000
– Power	July 2000
• Operations Handbook	November 2000
• Spacecraft Contingencies Procedures	October 2000
• Ground System Contingencies Procedures	November 2000
• Autonomy Rules Handbook	September 2000
• Performance Assessment Guide	September 2000
• Early Operations Plan	November 2000

MOT Experience

- William Knopf (MOT Manager)
  - Previous:
    - Delta-181 Command Evaluator, Data Retrieval Team
    - MSX Spacecraft Contingencies Procedures development
    - NEAR Mission Operations software lead
  - TIMED
    - Ground System Engineer (user perspective)
    - MOPS software tools development
    - Mission Operations Manager

MOT Experience (cont)

- Richard Dragonette
  - Previous
    - MSX Daily Planning Lead
  - TIMED
    - GNS specialist
    - Planning and contact operations lead
    - Early operations plan lead
- Michael Packard
  - Previous
    - MSX Daily Planning Team
  - TIMED
    - G&C specialist
    - Orbitologist

MOT Experience (cont)

- Paul Boie
  - Previous
    - DMSP Command and telemetry controller (3 years)
    - UARS Command controller and Flight Operations Director (3 years)
    - GGS Flight controller and spacecraft engineer (4 years)
  - TIMED
    - Spacecraft C&DH specialist
    - Performance assessment
    - Operations Handbook book-boss

MOT Experience (cont)

- George Chiu
  - Previous
    - TRIDENT range systems test and evaluation (10 years)
  - TIMED
    - None (recent acquisition)
- Charles Kowal
  - Previous
    - NEAR Mission Analyst
    - Operations Astronomer (Space Telescope Institute)
  - TIMED
    - None (recent acquisition)

Mission Simulations Summary

- Mission Simulations run as part of Baseline Performance Testing and Special Tests.
  - Baseline Performance Tests Run:
    - End of Integration (9/24/1999-10/20/1999)
    - Pre Thermal Vacuum Testing (12/1-3/1999)
    - Thermal Cycling Testing (1/10/2000-2/2/2000)
    - Post-Storage (8/18-22/2000)
  - Special Tests Run:
    - Sporadically
    - Thermal Cycling (1/17-22/2000)
    - Post Thermal Vacuum at APL (2/18/2000-3/6/2000)
    - Post Storage (8/23/2000-9/13/2000)

Mission Simulations Log

Simulation	Duration (hours)	# times run	Total Hours (hours)
Baseline Performance Tests			
Separation to Nadir Pointing	11	14	154
Event-driven	8	17	136
Safe Mode Recovery	4	12	48
Early Operations Phase Special Tests			
Day13--Day 16 Simulaitons	16	2	32
SEE 90 degree Beta	6	2	12
SEE Conrtact Timing	8	5	40
SABER Calibrations	8	2	16
Long-duration Event-driven Tests	33	1	33
	72	1	72
	96	3	288
		Total	**831**

Baseline Performance Test Simulations

- Spacecraft Separation Test
  - Consists of launch through nadir pointing.
    - Sometimes started at separation, if battery not involved.
  - Instruments were not involved with this test.
- Event Driven Test
  - Simulate orbital conditions to "flag" as many "events" in the Spacecraft Status Message as possible.
  - conduct "routine" operations (station contacts, yaw maneuver, SSR playback, etc…)

Baseline Performance Test Simulations

- Safe Mode and Recovery Test
  - With S/C and instruments in their "Normal Science Data Collection (NSDC)" state, simulate soft LVS sequences and carry through the recovery back to NSDC.
  - Ran this test following the Event Driven test.
  - Battery not used, voltage lowered through external power supply.

Spacecraft Separation Test Description

- Configure Spacecraft for launch configuration.
- Place spacecraft on battery power at launch -5 minutes.
- Trip separation switches at separation time, L+125 minutes.
- Separation switches start TASTIE and GPS Simulator. TASTIE initializes expected spacecraft tumble.
- Autonomy detects separation switches opened; C&DH begins separation sequence execution.
- AIU begins attitude capture; rates being zeroed by Magnetometer/Torque rods

Spacecraft Separation Test Description

- T_{sep}+28 min. - 1st station contact; transmitter on via separation sequence.
- Wheels get turned on when System Momentum is low enough via autonomy rule. (Timetag CMDs for last ditch turn-on.)
- S/C begins maneuver to -Z to sun safe mode.
- Continue checkout at each ground station.
- Simulate verification of proper solar array deployment.
- Perform Solar Array rotation test prior to maneuver to -Y to sun safe mode.

Spacecraft Separation Test Description

- Maneuver to -Y to sun safe mode.
- Test until Nadir Pointing achieved, and first SSR playback (first APL contact.)
- Approximate Test Time: 11 hours
- Verified
  - Separation autonomy rule and the separation sequence.
  - Autonomous de-tumble and attitude capture.

Spacecraft Separation Test

- Verified (continued)
  - Battery performance.
  - GNS propagation of the separation state vector and acquisition of GPS satellites.
  - Early operations plans for the first 8 contacts following separation.
  - Ground system performance including RF link to/from the spacecraft through the ground station.
  - Early Operations procedures for first 8 hours after separation.

Event Driven Test Description

- Configure Spacecraft into “Normal Science Data Collection” state with Spacecraft bus and instruments running as on-orbit.
- Simulate two orbits (Beta 0) which contain the conditions under which GNS “events” would occur and Spacecraft Status Message flags are set.
- Start epoch of test is June 12, 2005.
- Used operational Autonomy rules.

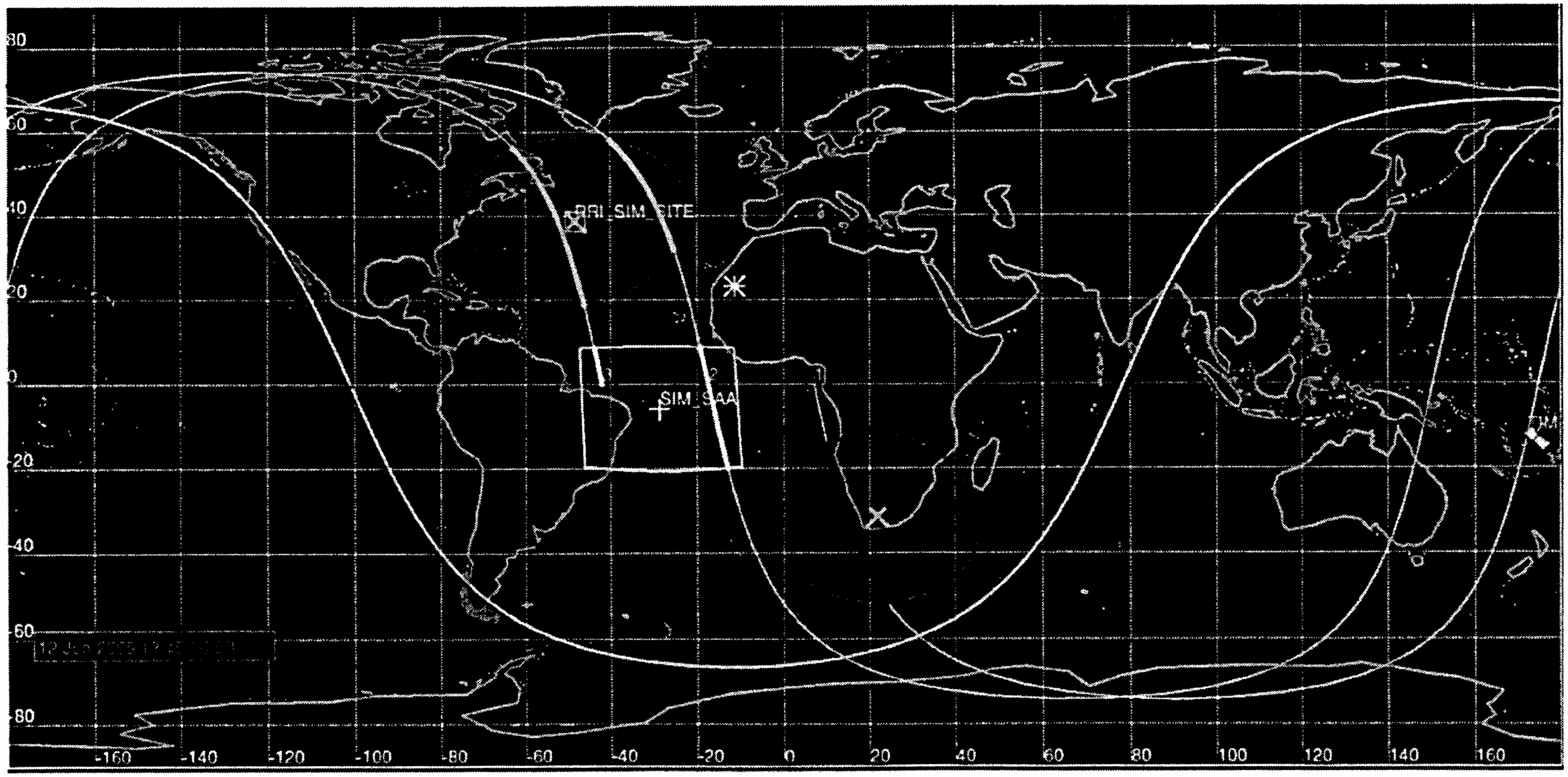
Event Driven Test Description (continued)

- Test run on Spacecraft in multiple configurations.
- Approximate test time: 8 hours each side.
- Test Included:
  - Yaw Maneuver.
  - Terminator Crossing.
  - South Atlantic Anomaly passage.
  - Polar Region passage.
  - Solar Array Rotation.

Event Driven Test Description (continued)

- Test Included (continued):
  - Primary Ground Station contacts.
  - Secondary Ground Station contacts.
  - Momentum dumping.
  - SSR readout.

Event Driven Test Description (continued)



Event Driven Test

- Verified
  - Yaw maneuver.
  - Instrument commanding
  - Normal Operations Plans.
  - Instrument response to Spacecraft Status Message events.
  - GNS event flag timing.
  - Operational autonomy rules.

Event Driven Test

- Verified (continued)
  - Ground System Performance including RF commanding and telemetry through APL ground station.
  - Spacecraft operational procedures.

Safe Mode and Recovery Test Description

- Set-up at end of Event Driven Test - Spacecraft in NSDC state.
- Induced Soft LVS #1 by lowering bus voltage below 27V.
- Instruments are warned and shutdown.
- Induced Soft LVS #2 by keeping voltage low for 2 minutes.
- Transition to Sun Safe mode - AIU switchover occurs.
- Bus voltage raised back to nominal.
- Go through LVS contingency procedures and promote to Nadir Pointing and Operational Pointing.

Safe Mode and Recovery Test Description

- Turn-on instruments as part of recovery to NSDC state.
- Test run on Spacecraft in multiple configurations.
- Approximate test time: 3.5 hours each side.

- Verified:
  - Soft LVS 1 functionality.
  - Soft LVS 2 functionality.
  - Soft LVS Recovery Procedures.

Special Test Simulations

- The following special tests have been run which exercise attitude maneuvers, complicated operations, and special requests of subsystems and instruments:
  - SEE early operations contact timing tests
    - Verified functionality and timing of SEE real-time instrument commanding during instrument checkout period.
  - SEE beta 90 test
    - Special orbit test request from SEE

Special Test Simulations

- Special tests (continued)
  - Long duration (33, 72 and 96 hour) tests
    - Allowed checkout of GNS 12 hour product generation.
    - Allowed checkout of APL ground station support.
    - Also verified:
      - Daily Planning Procedures.
      - Antenna scheduling and pointing.
      - Normal operations procedures.
      - MDC prediction products.

Special Test Simulations

- Long duration (33, 72 and 96 hour) tests (continued)
  - » G&C telemetry schedule
  - » Autonomous RF commanding
  - – Autonomy tested:
    - » Checkout bad AFC detection and switch.
    - » Checkout AIU bad wheel detection.
    - » Checkout all wheel autonomy rules.

Special Test Simulations

- Special tests (continued)
  - SABER cover release test
    - Checkout of attitude maneuver and orbit for cover release event.
    - Checkout of procedures for event setup, event monitoring, and event assessment/evaluation.
  - SABER Calibration Test
    - Checkout of SABER Calibration Event maneuvers
  - G&C Mission Sensitivity Test
    - Verify G&C Safe mode demotion at beta 4 without yaw maneuver, verify auto-promote.

Special Test Simulations

- Special early operations phase tests (continued)
  - Early Operations Day L+13 Test
    - Verification of Early Operations plans and procedures for Spacecraft and Instrument checkouts.
  - Early Operations Day L+14 Test
    - Verification of Early Operations plans and procedures for Spacecraft and Instrument checkouts.
  - Early Operations Day L+16 Test
    - Cover releases

Contingency Testing: Spacecraft

(Procedure Completion Status)

• G&C	2/20 in draft
• Power	10/10 in complete(7) or draft(3)
• C&DH	0/5 complete
• GNS	7/11 complete(3) or in draft(4)
• RF	3/5 complete(2) or in draft(1)
• Instruments	4/4 complete

Contingency Plan Testing Status

• Power	All procedures have been tested. 7/10 tested as part of baseline performance. The other 3 have been tested as part of LVSS recovery simulations
• Instruments	All 4 instrument power down procedures used routinely during mission sims to power down
• RF	3/5 tested. Negative acquisition, blind acquisition, and real-time telemetry rate switches have been tested on the spacecraft
• GNS	3/11 GNS procedures tested on the spacecraft

TOPS Testing Status

- Thoroughly tested.
  - Sims have been run more or less continuously since June
  - Weeks of autonomy testing has been done on TOPS because of its ability to allow the operator to manually set a simulated current/temperature/voltage via IEM testbed command
  - 7 Day real-time test was run using TOPS to communicate through front end 3 and the real ground station. GNS el-sets were used from this sim in real-time to drive the ground station antenna
  - Tested switching between the primary and backup AFC and AIU as part of the extensive autonomy testing.
- We are confident in TOPS functionality and performance

SAFETY

TIMED Red Team Review Committee Meeting
31 October 2000 - 02 November 2000

Shirley K. Dion

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TIMED System Safety Philosophy

The TIMED payload organization has established a comprehensive system safety plan. The system safety plan defines a systematic approach to assure that:

- Safety is Designed into the system in a timely, cost-effective manner.
- Hazards are identified, tracked, evaluated, and eliminated, or the associated risk reduced to an acceptable level.
- Safety plan encompasses historical safety data and lessons learned.
- New technology, materials or designs and new production, test and operational techniques are considered to attain minimum risk.
- Efforts to eliminate hazards or reduce risk to an acceptable level are documented
- An acceptable risk level is maintained for design, configuration, or mission requirement changes.
- Early consideration is made for disposal of hazardous materials. Wherever possible, materials are eliminated by means of substitution or deign changes.

Hazard Resolution Process

DEFINE THE SYSTEM

Define the physical and functional characteristics and understand and evaluate the people, procedures, facilities, equipment, and environment

IDENTIFY HAZARDS

Identify hazards and undesired events
Determine the causes of hazards

ASSESS HAZARDS

Determine Severity
Determine Probability
Decide to accept risk or eliminate/control

RESOLVE HAZARDS

Assume risk or
Implement corrective action
- Eliminate
- Control

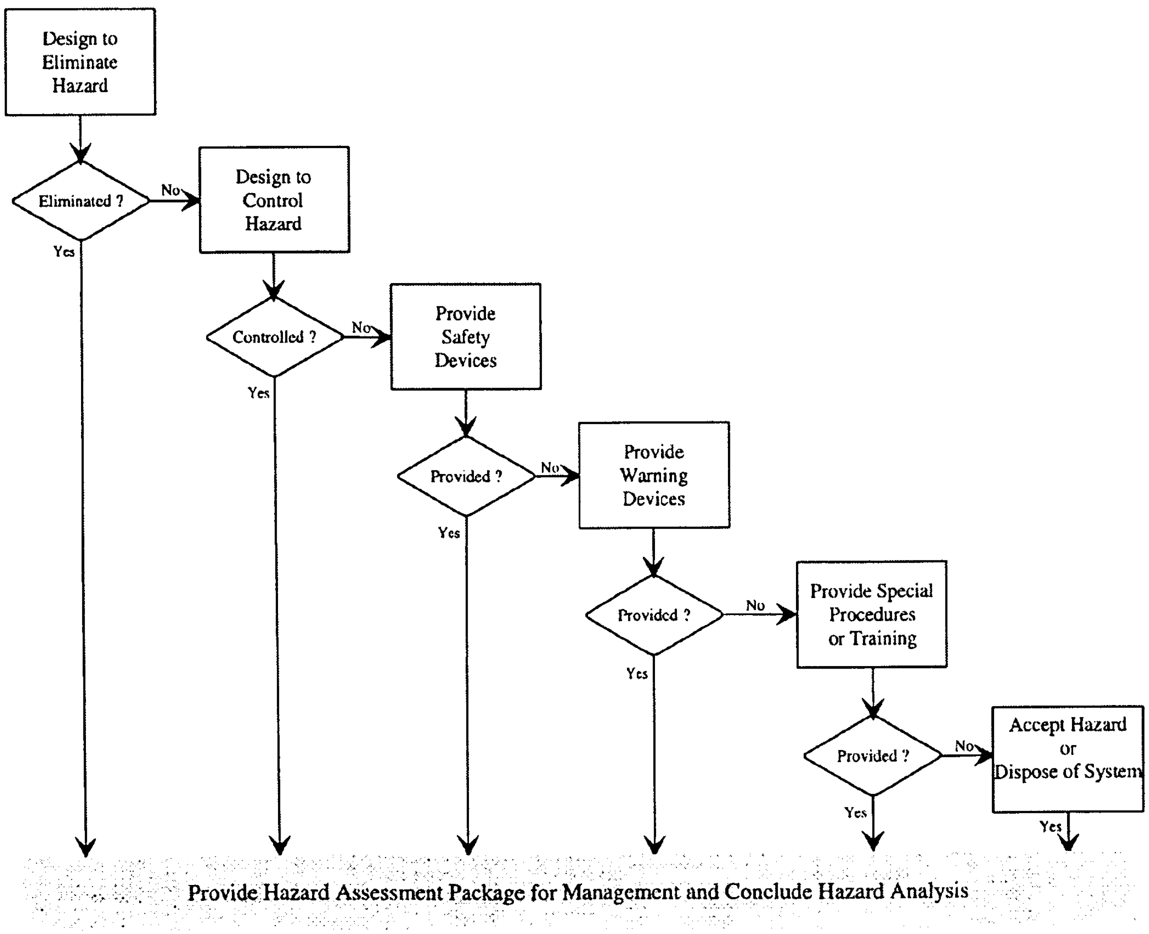
FOLLOW-UP

Track hazards to ensure elimination/control
Monitor for effectiveness
Monitor for unexpected hazards

System Safety Program Elements

- Hazard Questionnaire distributed prior to Preliminary Design Review (PDR)
- Development of Preliminary Hazard List (PHL)
- Expert Panel Meeting
- PHL serves as the basis for the Preliminary Hazard Analysis (PHA)
- Hazard Reports (HR's) are developed based on the PHA
- The Verification Tracking Log (VTL) documents the status of HR items.

Hazard Reduction Precedence



Safety Overview

The TIMED Spacecraft has limited hazards:

- TIMED does not have a Propulsion system
- There are no hydraulic systems associated with the TIMED Spacecraft
- The only cryogen system is Liquid Nitrogen used for purges
- There are no acoustic hazards associated with the integration of the Spacecraft
- No category A Pyros
- No hazardous high-power lasers

Spacecraft Safety Hazards

- Pyrotechnic Devices
- Battery
- RF/EMI
- High Voltage
- Electrical GSE
- Ionizing Radiation Sources
- Lifting Material Handling
- Purge
- Pressure System
- Hazardous Materials
- ESD

Safety Requirements

- The Spacecraft must be in compliance with the 31 March 1995 version of the Eastern Western Range (EWR) 127-1 Safety Requirements Document

- All Integration and Test activities at APL, GSFC, and at the launch site are conducted according to approved test procedures and in accordance with the TIMED Program Safety Plan

Safety Compliance Documents

APL Safety Document	S30-93-04 Space Integration and Test Facility
DOT Standards	49 CFR parts 300-399, 800-899
EWR 127-1	Eastern and Western Range Safety Requirements, 31 March 1995 version, including referenced documents
EPA Standards	40 CFR parts 1-799
GSFC Safety Document	Engineering Service Division Safety Manual

Safety Compliance Documents

(continued)

OSHA	Fed-OSHA Title 8 Administrative Code, 29 CFR 1910 Cal-OSHA Chapter 4
MDC H32240	Delta II Payload Planner Guide
MDC 92H0909	Delta II Program Safety Guide
Mil-STD-882C	System Safety Program Requirement
Mil-STD-1576	Electroexplosive Subsystem Safety Requirements for Space Systems
Mil-STD-461B	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference

Safety Compliance Documents

(continued)

AFJMAN 240204	Preparing Hazardous Materials For Military Air Shipment
NMI 1700.8	Policy to limit Orbital Debris Generation
NSS 1740.14	Guidelines and Assessment Procedures for Limiting Orbital debris
30 SWI 40-201	30 SW Radiation Protection Plan

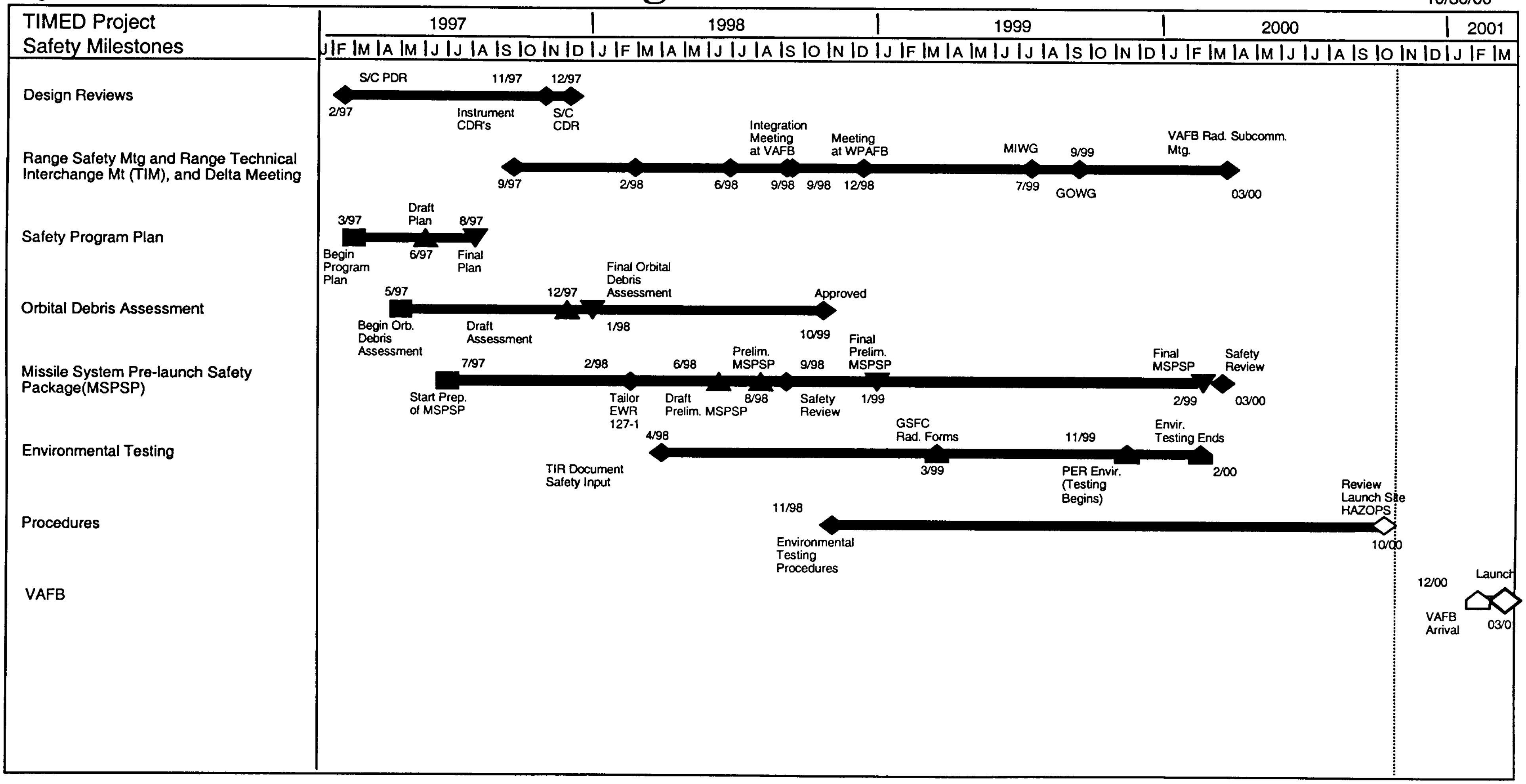
TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

TIMED Program Milestone Chart

10/30/00



TIMED Safety Documents

- Safety Program Plan 8/97
- Orbital Debris Assessment 10/98
- Preliminary Missile System Pre-Launch Safety Package (MSPSP) 04/98
- Safety Inputs to Hazardous Procedures
    - Environmental Testing Procedures 2/99
    - Range Procedures 10/00
- Final Missile System Pre-Launch Safety Package (MSPSP) 4/00
    - Seismic Analysis 4/00

TIMED Safety Program Plan

- Safety Program Plan begins at the design phase and ends at launch
- Establishes safety organization relationships, responsibilities, and management/engineering requirements to assure a comprehensive safety assessment for the entire life cycle of the TIMED spacecraft
- The safety program plan provides the following:
  - Detailed description of tasks and activities of safety required to identify, evaluate, eliminate and/or control hazards throughout the program
  - List of safety compliance documents
  - Defines System Safety Analysis to be completed on TIMED
  - Defines Mishap Reporting

TIMED Orbital Debris Assessment

- NMI 1700.8, Policy to Limit Orbital Debris Generation, requires each earth-orbiting spacecraft program to conduct a formal assessment of the potential to generate orbital debris

- NSS 1740.14, NASA Safety Standard Guidelines and Assessment Procedures For Limiting Orbital Debris, requires assessment of the following debris generation scenarios:
  - Debris generated during normal operations
  - Post-mission orbital lifetime and disposal procedure
  - Debris generated by on-orbit collisions
  - Reentry survivability of debris
  - Debris generated by explosions and intentional breakups

TIMED Orbital Debris Assessment
(continued)

TIMED is in compliance with NSS 1740.14 for the following:

- Debris generated during normal operations
- Post-mission orbital lifetime and disposal procedure
- Debris generated by on-orbit collisions
- Debris generated by explosions and intentional breakups

Reentry Survivability of Debris

- Total Debris Casualty Area = 9.1818 m2 for Object Surviving Reentry (assuming folded array spacecraft configuration at reentry interface)
- This was approved by HQ Code QS 10/99.

EWR 127-1 Requirements

- Tailoring with the WTR
- Preliminary MSPSP (with PHA and Hazard Reports developed from PHA)
- Preliminary MSPSP Review with WTR
- Incorporation of Comments
- Final MSPSP Review with WTR (completed February 2000)
- Approval of MSPSP pending closure of VTL items, -
  Sixty-seven (67) Original VTL items,
  - Sixteen (16) Current VTL items - Eight (8) items cannot be closed until after arrival at VAFB

TIMED Missile System Pre-launch Safety Package (MSPSP)

- Demonstrates compliance with Chapters 3 (Flight and GSE hardware design) and Chapter 6 (Operations) of EWR 127-1
  - Tailor EWR 127-1 with all subsystem Lead Engineers
- Only applies to operations at VAFB
- Provides detailed description of flight and GSE hardware design, as well as integration, tests, and inspections at VAFB.
  - The MSPSP consists of the following:
    - Introduction
    - Flight hardware description
    - GSE hardware description
    - Ground operations
    - Safety analysis

Other EWR 127-1 Requirements

- **RADSAFCOM**
  - TIDI Instrument ionizing sources (two 1 μCi of Europium- 152) approved by the 30SW Radiation Safety Committee 08 June 2000 for ground processing at VAFB
  - Presentation package included TIMED Mission Assessment
- **Seismic Analysis**
  - Included as Appendix G of the TIMED MSPSP
  - Hardware tie-downs will be verified at the Range

TIMED Test Procedures

Status of TIMED Test Procedures:

- Seventeen (17) procedures are planned and are in various stages of development.
- Five (5) test procedures are potentially hazardous (Range System Safety will review both hazardous and non-hazardous procedures):
  - TIMED Mechanical I & T Procedure
  - TIMED Battery Handling Procedure
  - TIMED Solar Array Mechanical Integration Procedure at VAFB Payload Processing Facility
  - TIMED Spacecraft Shipping Container Handling Procedures
  - TIMED Spacecraft Mechanical Handling Procedures at VAFB Payload Processing Facility
- All procedures are currently being reviewed at the WTR.

Spacecraft Safety Hazards

Pyrotechnic Devices

- Spacecraft Solar Arrays (2) each contains 2 sets of redundant EED's (8 Hi-Shear PC 23 total)
- GUVI payload contains 1 primary and 1 redundant EED (2 Bellows Actuator pin release total)
- TIDI payload contains 4 primary and 4 redundant EED's (8 Wire Cutters total)

Safety Considerations

- 2 separation switches
- Flight Arming Plug
- Enable relay
- Fire relay
- Pyros are category B (Non-Hazardous) / Class C

- EED's will be handled at an ESD free workstation
- Wrist grounding straps will be used
- EED's will be stored in static free containers.
- Components will be grounded

Spacecraft Safety Hazards

Battery

- Two half batteries
- 22 NiH2 cells (total)
- 50 amp/hr capacity
- Sealed cells
- Maximum Operating Pressure is 800 psig

Safety Considerations

- Battery GSE is designed to control and monitor temperature, current, voltage, and pressure
- Cells cooled during ground operations
- Manufacturer has a 3:1 safety factor for design
- Manufacturer has qualification tested design
- Battery cells will be proof tested to 1.5 X MOP
- Batteries are "leak before burst" according to the manufacturer
- Flight cells will be cycle and capacity tested

Spacecraft Safety Hazards

RF and EMI/EMC

- Transmitter for the bus operates at 2215 MHz at an RF output power level of 3 watts (S-band)
- Antennas
  - 2 shaped - beam Bifilar-Helix, Zenith pointing antennas (4dBic)
  - 2 hemispheric coverage Quadrifilar-Helix, Nadir pointing antennas (4dBic)
  - 2 Zenith pointing GPS antennas (L-band patch antennas) for receiving only

Safety Considerations

- Hat couplers will be used during ground testing
- Safe distance will be calculated, measured, and maintained during testing

Spacecraft Safety Hazards

High Voltage

- Gyro subsystem internal voltage ranges from 200-300 V (2,750 V peak)
- TIDI HV supply for calibration lamps 800 V (peak-to-peak) at 5 MHz
- SEE EGS CODACON detector operates at -2 KV max
- SEE krypton calibration lamps 800 V max at 100 MHz
- SEE GSE ion pump for EGS operator at 3.5KV
- GUVI two detector tubes operating at 4.5 KV each

Safety Considerations

- Primary control is that all circuitry is grounded and contained
- Power is fused in the bus
- All high voltage sources operate at low current

Spacecraft Safety Hazards

Electrical GSE

- Computer Work Stations
- Spacecraft Blockhouse Control Unit
- Bus Subsystem GSE
- Battery Charger
- Battery Chiller
- Power supplies
- Ion pump GSE fixture (SEE)
- Test Lamps (GUVI)

Safety Considerations

- Electrical GSE will be inspected to ensure NEC Code Compliance and/or UL listing
- EGSE used on the pad after second stage fueling will be explosion proof (within 100 ft)

Spacecraft Safety Hazards

Ionizing Radiation

- TIDI has (2) 1 μCi of Europium- 152 (Eu -152)

Safety Considerations

- TIDI sources are contained in a delrin holder inside an aluminum lamp housing cover
- TIDI sources are identical to sources that have flown previously on UARS/HRDI

Spacecraft Safety Hazards

Purge Subsystem

- Spacecraft GSE provides nitrogen purge to all instruments
- Nitrogen back-fill operation for EGS component of SEE
- K-Bottles of nitrogen are required for battery chiller GSE

Safety Considerations

- Spacecraft nitrogen purge GSE
  - Used on ACE and MSX programs
  - System is designed to meet range safety requirements
  - Nitrogen purge dewar will meet DOT Standards
- All purges will have regulators

Spacecraft Safety Hazards

Pressurized System

- SABER contains a cooler that uses He refrigerant at a nominal pressure of 400 psig
- The system contains 35.5 milliliters of He
- Internal pump is a piston pump

Safety Considerations

- Refrigerant system is completely enclosed
- Refrigerant system is designed and tested to MIL-STD-1522A

Spacecraft Safety Hazards

Hazardous Materials

- Cleaning fluids, solvent: Isopropyl alcohol
- Epoxy/staking material and lubricants
- Pyro devices
- Nitrogen purge (if used in a confined space)
- GSE lamps for GUVI contain small amounts of mercury
- Nitrogen backfill for SEE
- NiH2 Battery (KOH, H2 generation)

Safety Considerations

- Cleaning fluids, epoxies, and lubricants will be applied and discarded properly
- Mercury vapor lamps are sealed units
- Nitrogen will be used in a ventilated area (an oxygen depletion analysis will be conducted if used in a confined space)
- Pyro device circuitry design is at least 2 fault tolerant
- Battery cells are sealed

Spacecraft Safety Hazards

Electrostatic Discharge (ESD)

- Program objective is to reduce potential exposure to ESD
- Proper storage of EED's

Safety Considerations

- Use wrist grounding straps
- Payload instruments and bus components are grounded
- EED's must be stored at all times in static free containers
- EED's will be handled at an ESD free workstation

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

AGENDA

Day 4: November 3, 2000

FMEA, FTA, PRA	Farmer, STi	60 Minutes	8:00 - 9:00am
Mission Operations	Knopf	60	9:00 - 10:00
BREAK		**15**	**10:00 - 10:15**
Ground System	Rodberg	60	10:15 - 11:15
MOC	Mitnick	30	11:15 - 11:45
Ground Station	Gemeny	30	11:45- 12:15pm
MDC	Lafferty	30	12:15 - 12:45
Conclusion/Wrap-up	ALL		

TIMED Red Team Review

Spacecraft Autonomy

11/02/00

Ray Harvey
TIMED Mission Autonomy Engineer
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23-324

Outline of Discussion

- Autonomy System Description
- Autonomy System Level Requirements
- Autonomy Rule Based Design Overview
- Reviews
  - Action Item Summary/Status from the Reviews
- Autonomy Rule/Command Macro Generation Process
  - Sample format
- Autonomy Rule Releases
- Autonomy System Testing
  - Embedded Autonomy Summary
  - Rule Based Autonomy Summary
    - Test Matrices
  - Interaction Testing Summary
- Autonomy Rule Related SPRs
- Residual Risk

Autonomy System Description

- Two Types of Autonomy
  - Embedded
  - Rule Based

- Embedded Autonomy
  - Hardware and Software based processes designed within subsystems, processors, and components which perform autonomous operations

- Rule Based Autonomy
  - Functionality designed within the C&DH which allows for specification of rules used to monitor housekeeping telemetry and execute commands based on pre-defined Boolean functions.
    - Allows IF *(these conditions)* - THEN *(take these actions)* constructs. (The *conditions* are based on housekeeping telemetry).

Autonomy System Level Requirements

- Fault Tolerance and System Safing
  - Maintain a healthy Power System with a positive energy balance
    - Maintain a stable attitude with Solar Arrays facing the Sun
    - Maintain a recharged/healthy battery
  - Maintain health of the Instruments to the extent possible by the S/C bus
  - Maintain Communications Capability
  - Maintain On-board Time Reference
  - Maintain Thermal Control
- Operations Related
  - Perform functionality on-board to reduce workload on the Mission Operations Team (MOT)
  - Perform functionality on-board to assist in MOT anomaly resolution and decrease required analysis time
- Embedded Autonomy, Rule Based Autonomy, and on-board redundancy all combine to meet these requirements.

Autonomy System Design Implementation Requirement

- Because of the use of PCI bus for the IEM backplane, as opposed to 1394, IEMs are required to be powered down in a Hardware Low Voltage Shutdown (LVS) condition. This is because the PCI bus does not support switched power to the individual cards.
- Therefore, rule based autonomy will not be operational in this condition.
- An AIU is always powered and controls Safe Mode.
- This drove some of the tradeoffs between Rule Based vs. Embedded implementation.

Rule Based Autonomy Design/Capability (1 of 5)

- In the form of:

  IF *logical expression* FOR *n* times within the next *m* seconds,
  THEN execute a single command (could be a macro)
  logical expression in form:

  check1 [op1] check2 [op2] check3 [op3] check4
- Up to 4 checks per rule
- Checks are in form:

  x&M=A, x&M/=A, x&M<A, x&M>A; x = telemetry,
  M is a mask, and A is a constant or another telemetry parameter
  op1, op2, and op3 are AND or OR
  - Checks may be grouped in one of two ways:

    (((chk 1 op1 chk2) op2 chk3) op3 chk4)

    or

    (chk1 op1 chk2) op2 (chk3 op3 chk4)

Rule Based Autonomy Design/Capability (2 of 5)

- Rules are checked once per second
- Telemetry is located in the C&DH Data Collection Buffer - contains all status and housekeeping telemetry (non-packetized) from all S/C subsystems. Also internal C&DH information.
- 512 Rules per C&DH
- Normally only 1 C&DH powered
- Default state bit determines status upon reboot
- Can be loaded, enabled, disabled, suspended, resumed, and aborted via command or command macro
- Rules are loaded disabled; must be enabled for checking to commence
- Rules are prioritized (2 to 15) (Real-Time commands = 0; Real-Time macros = 1)
- Can only "suspend" rules at 3 and below (higher number).

Rule Based Autonomy Design/Capability (3 of 5)

- Overwriting safeguards - rules initially write-protected - protection must be disabled, and then cleared or overwritten (only applies to RAM)
- To clear rules from reload following a reset if stored in Flash, must clear from RAM, then copy RAM to Flash.
- 2 Groups of Rules - Fault Recovery and Routine Maintenance
- Max fire count - rule enables itself up to the max fire count. After that, it disables itself.
- Clear fire count - clears fire count and returns the rule to its Flash Copy Initial State if it has reached its max fire count
- Rule trigger based on N counts in M seconds

Rule Based Autonomy Design/Capability (4 of 5)

Arithmetic Checks

- Arithmetic checks may be defined for inclusion into rule definition (result acts as additional TM point indicating result of compare)

  ex. *IF result of (ST #1 current)(battery voltage) = ST #1 power is greater than 100 W for 10 of the next 15 seconds, then turn off ST #1.*
  Take the form:

- **A(x & M1)(y & M2) + B(x & M1) + C(y & M2) +D <, >, =, or ≠ E**

- Where x and y are telemetry points, M1 and M2 are masks that are applied to those points, and A, B, C, D and E are constants. A, B, C, and D are used to specify the Scale Factor and Offset info. for x and y conversion to Engineering units. (See next view graph for computations of A, B, C, and D).

- Result is zero or one indicating result of comparison to E. Rules compare to this by saying *"if one for 10 seconds, perform action"*.

- Result of left hand side of equation may be placed in telemetry for testing

- In this form, Arithmetic checks are limited to Multiplication, Addition, and Subtraction.

- 64 possible per C&DH; 50 are currently used.

Rule Based Autonomy Design/Capability (5 of 5)

Storage Variables

- Storage Variables allow for storage of a constant or a "snapshot" of a telemetry parameter, for use in autonomy rules. 32 Storage Variables are available.
- Allows for checking changes of previous data values.

  Ex. *Take snapshot of Total CMD Count; use in Arithmetic Check to determine if current Total CMD Count is at least 130 more than snapshot. If so, perform action and "re-snap" Total CMD Count.*
- "Snapshot" is updated by command
- A command allows for incrementing or decrementing the value of a Storage Variable.
- Can be set enabled, disabled write protected, or disabled write enabled; by a range
- Can "Clear" a range of Storage Variables by command; from RAM only
- 16 possible per C&DH; 3 are currently used.

Reviews

- 2 Red/Blue Team Reviews - Peer reviews
  - Red/Blue team format consisted of an independent team (Red) and the TIMED Engineering Team (Blue) in an exchange of information both in and out of the presentation/team interaction meetings. The reviews consisted of several meetings spaced weeks and/or months apart.
  - Red/Blue Team Review #1 - 4 meetings in 10/97
  - Red/Blue Team Review #2 - 3 meetings in 10 weeks; 11/20/98, 12/18/98, 1/25/99
- TIMED Autonomy Rule Review (TARR) - Internal review of the rule design and implementation. Review team consisted of APL only, but from NEAR, FUSE, and MSX. Also consisted of TIMED Engineering Team and Mission Operations Team (MOT) members.
  - 6 separate meetings held between 08/31/99 to 11/10/99.
- TIMED Autonomy Rule "Code Walkthrough" - May/June 2000.
  - Consisted of MOT and Systems Engr. in a grueling line by line review of each rule and associated macro.

Red/Blue Team Review #1

- Red Team Members:
  - Sue Lee - Lead Software Systems Engineer On NEAR
  - Andy Driesman - at the time a new hire to APL with Systems Engineering background - currently Systems Engineer on STEREO
  - Larry Frank - Spacecraft Systems Engineer on FUSE
  - Andy Santo - Spacecraft Systems Engineer on NEAR
  - Ralph Sullivan - Power System expert/consultant (Retired APL)
- Objectives
  - Assess overall capability of Autonomy System design to meet Requirements
- Final Report and Action Items - SEA-97-0096; 07 November 1997.
- Action Item Closure Memo - SEI-98-078; 03 November 1998.
- Action Items are summarized on next 8 charts.

#1

Red/Blue Review #1 AI Summary (1 of 9)

Number	Action Item Description Summary	Action Item Response Summary
1	Consider defining a set of integrity checks for GNS data.	CLOSED: The GNS does some checking which is conveyed through its validity flags and Figures of Merit
2	Consider having C&DH storing info. to bring GNS up quicker following a reset.	CLOSED: The GNS is specified to fully recover within 30 minutes following a reset.
3	Since they are so critical to de-tumble, consider leaving the magnetometers on at launch and finding some other way to signal separation to the AIU	CLOSED: This was reconsidered and no other viable method of notification of separation could be derived.
4	Consider orienting the S/C body for safe mode, rather than the solar panels.	CLOSED: The safest and simplest method was initially selected. Orienting the S/C body would require a more elaborate safe mode.
5	Make sure the IEM is turned OFF before the AIU's are turned ON in the LVS sequence.	CLOSED: Both IEMS are turned off just before the AIUs are turned on.
6	In Safe Mode, does the G&C use the sun sensor output or the GNS sun vector to implement Safe Mode?	CLOSED: It uses the sun sensor output (measured sun) as its only reference to the sun.
7	The following faults could cause LVS, and are not corrected in the LVS sequence.	CLOSED: see below:
7a	Soft short in a reaction wheel. Alternative - turn off the wheels in hard LVS, and control the S/C using the torque rods.	CLOSED: It has been shown through analysis that the power system can recover from a soft short in a failed wheel in Safe mode. However, if a wheel does soft short, the Hard LVS sequence will most likely be disabled because of the uncertainty of how long the S/C can maintain a stable attitude given the IEM is powered down and the rule based autonomy to turn it back off is unavailable for a period of time.
7b	An inability to control the S/C with Reaction Wheels (flaw in AIU code that does Momentum dumping, for ex.) Alternative - switching to control using torque rods.	CLOSED: Torque rod control does not provide enough torque to maneuver to Safe mode. The design of the G&C system has included what is telt to be enough safeguards to communicate to the C&DH to switch AIUs, before a Hard LVS condition caused by a sudden, inadvertent AIU problem, would occur.

#9

Red/Blue Review #1 AI Summary (2 of 9)

7c	An upset in the AIU code that does not cause a Watchdog timer or heartbeat reset - Remedy by resetting the AIU in hard LVS.	CLOSED: A soft reset cannot be implemented in the hard LVS sequence because it is implemented in the Critical Command Decoder (which only executes relay commands). An AIU switch is implemented in the Soft LVS #2 sequence which is designed to occur prior to a Hard LVS.
7d	The GNS or AFC-derived Sun vector is incorrect; Remedy by the AIU using sun sensor output alone to perform Safe Mode in hard LVS.	CLOSED: In Sun Safe mode, the AIU uses only the Sun Sensor output (measured sun) for its reference to the sun.
8	Calculate the power drain caused by a reaction wheel short just below the fuse threshold (soft short).	CLOSED: Analysis was performed based on a soft short of a wheel at Hard LVS levels as we enter eclipse. Assuming a nominal safe mode is entered when soft LVS #2 or Hard LVS is entered, the S/C should recover is approximately two orbits. For more details, please see SEI-98-078.
9	Anternate method of Solar Array panel rotation in Safe mode of rotating the panels in opposite directions.	CLOSED: Although the S/C design allows the panels to be positioned to different angles, all analysis indicates that the panels should be oriented to the same angle.
10	Consider implementing a software coulometer on the C&DH for use in Soft LVS Autonomy rules.	CLOSED: A coulometer algorithm has been incorporated; however, the parameter is output in a format incompatible with the format required to fit within the Autonomy rule structure.
11	From a power perspective, the appropriate response to a soft LVS is load shedding alone, not entering safe mode. Resolve this.	CLOSED: There are two Soft LVS sequences. The first performs instrument load shedding while staying in a nadir pointing attitude. The second Soft LVS which will execute no sooner than two minutes prior to the first (and perhaps longer depending on the result of instrument load shedding) will perform an entry to Safe mode and an AIU switch.

Red/Blue Review #1 AI Summary (3 of 9)

12	Resolve the issue of not current limit checking the Reaction Wheels at the system level and inform both subsystem leads.	CLOSED: The AIU performs wheel health checking by comparing the wheel output torque to epected torques based on an internal model. The bad health of a wheel is reported to rule based autonomy which powers it down. No more than one wheel will be identified as being bad at a time, by design, because 3 wheels are required.
13	Consider what is the best inertial orientation for the S/C during safe mode.	CLOSED: The AFC is not used in Safe mode processing. The specification to the AIU for Safe mode processing is a vector to the sun. Nominally, this will be -Y to the sun. This method does not allow a 3-axis inertial orientation.
14	Consider performing an analysis of the accuracy of NORAD orbit parameters.	CLOSED: The plan is to use the propagated GNS predictions, which are more accurate than NORAD, for several days. Analysis has shown that NORAD elements will be sufficient for station contact.
15	Recommendations for "lights-out" operations.	CLOSED: It was decided at the system level that this type of high level status checking would be done in the Ground System through "derived" red-light/green-light" conditions. The "lights-out" capabilities plan to use this information in determining the conditions to "page".
16	Reconsider the definition and use of the AIU discretes.	CLOSED: After further consideration of red-defining the AIU discretes and weighing the pros and cons of the recommended definitions and the current definitions, it was decided they should remain unchanged.
17	Consider monitoring the system momentum and switching AIU's if the momentum reaches a threshold level.	CLOSED: The G&C Health Monitor Software will monitor system momentum and report the results to Rule Based autonomy.
18	Consider switching the AIU if the solar panel movement fails	CLOSED: The AIU performs a check of solar panel movement and reports the results to the Rule Based Autonomy, which performs an AIU switch in response.

Red/Blue Review #1 AI Summary (4 of 9)

19	Consider implementing sensor consistency checks for critical G&C sensors.	CLOSED: The AIU and AFC both perform consistency checks as part of their health monitor functions. The checks are summarized in SEI-98-078.
20	Can the AIU break a solar array drive by driving it into one of the hard stops?	CLOSED: No.
21	Consider creating a way (possibly a storage variable?) to include the state of the backup units in rule definitions.	CLOSED: There is no on-board indication of failed units planned. There are checks in place of the AIUs to perform a limited health check before switching to it. In addition, if a unit fails, we would not only want the Autonomy rule not to switch to it, we would want it to reset the current one. There are methods in place on the ground to determine which rules are affected by which failed units.
22	Mission Operations must have tools to check the inter-operation timing and the exact execution time of macros to prevent interference.	CLOSED: Mission Operations has designed into their procedures constraints which allow time for particular operations to have completed. The only other sequences executing will be on-board through rule based autonomy. These sequences have been designed to operate on a non-interference basis with those operations initiated by ground command.
23	The data summary capability could be improved if a 90 minute (orbit period) rolling average was also calculated for each parameter.	CLOSED: The data summary capability was descoped late in the development effort.
24	Eliminate grouping multiple uploadable parameters in common data structures.	CLOSED: This could not be entirely avoided for various reasons; however, was reduced.
25	Allow all uploadable parameters to be dumped with a single command.	CLOSED: This is implemented within the G&C. In the C&DH the uploaded parameters may be dumped by single command based on their functionality. And in the GNS, this function can be performed through a physical memory dump.
26	Consider configuring all flight code so that it can be "patched".	CLOSED: Based upon estimates of upload time based on worst case conditions, an system-wide requirement was made to NOT make the flight code "patchable".

Red/Blue Review #1 AI Summary (5 of 9)

27	Create and document approaches, policies, and procedures for the following:	CLOSED: see below:
27a	The project's requirement, if any, to check out safe mode on-orbit.	CLOSED: Safe mode will be entered as part of the routine operation rollowing launch insertion. An early on-orbit test is also scheduled to occur to checkout the transition to safe mode from a nadir pointing attitude.
27b	The on-orbit checkout of redundant units.	CLOSED: The redundant units which will be switched to autonomously will be checked out during the Early Operations phase as stated in SEA-98-0014.
27c	Uploading new software to each on-board computer.	CLOSED: The procedure has been documented in the MOT standard operating procedures.
27d	The lgistics of obtaining and using NORAD data	CLOSED: The procedure has been documented in the MOT standard operating procedures.
27e	How to handle the case of no downlink during a planned contact.	CLOSED: This process is handled as part of the Negative Acquisition contingency plan.
27f	Any launch contingencies, for example, failure to detumbed detected at first contact.	CLOSED: These processes were developed and documented as part of the Spacecraft Contingency Plan.
28	Add a dump-and-verify of the separation rule/macro to the launch pereparation sequence, to ensure that an error does not prevent separation from occurring.	CLOSED: Dumps and compares are perfomed during the countdown sequence as well as configuration checks of the autonomy rules for determining their enable/disable states prior to launch.
29	Consider clearing out the data buffer used to store 1553 data from a subsystem between samples.	CLOSED: This is not implemented for various reasons described in SEI-98-078.
30	Limit the number of S/C subsystem telemetry formats.	CLOSED: An attempt to reduce the amount of telemetry format switching was made. Each subsystem team identified their most critical information and it was put into the "high priority" housekeeping packet which is recorded and downlinked once per second.

Red/Blue Review #1 AI Summary (6 of 9)

31	Consider putting enough bits into the command & packet history tables to save the op code of at least the first command contained in packets sent to S/C subsystems by the C&DH.	CLOSED: The telecommand packet history buffer contains the Packet Resolution (2 bytes), Packet Header (6 bytes), Time (4 bytes), and the first 8 bytes of the packet (8 bytes).
32	Consider merging the command an packet hitory tables into one.	CLOSED: These are merged through ground based processes.
33	Consider creating a fixed location in every telemetry format that has some pre-defined key information.	CLOSED: The critical information provided by each subsystem has been identified as "high priority" and is downlinked and recorded at once per second.
34	Simplify the error indications from the S/C as much as possible; even consider hanving ASCII text error messages.	CLOSED: This type of requirement would have had too much of a schedule impact across the board. The TIMED MOC will be used to display all telemetry, including error conditions, via the telemetry dictionary.
35	The G&C telemetry should include status for every subsystem under its control.	CLOSED: This is being implemented.
36	The AIU telemetry should include the torque rod status (on/off, polarity) for every time step.	CLOSED: This is being implemented.
37	Incorporate as much hardware in the loop as possible in the TOPS.	CLOSED: One IEM, one AIU and two AFCs are incorporated in the TOPS. The Power System has been purposely left out because it was felt that the benefits gained by their inclusion were minimal and did not warrant the complications presented to support their inclusion. In addition, with the IEM Testbed used in its place, the test capabilities are increased.
38	The IEM testbed and TOPS should allow tweaking of telemetry parameters for rule checkout by name, rather than by specifying the same information that are used in composing the rule.	CLOSED: The interface to specifying the parameter is the same as that within an autonomy rule; however, it is different than that specified for a telemetry display. This provides an independent verification.

#9

Red/Blue Review #1 AI Summary (7 of 9)

39	The autonomy rule "assembler" should access the MOC telemetry database when specifying the data a rule checks on.	CLOSED: This capability was descoped.
40	Recommend incorporating a feature in the C&DH to route commands to the redundant unit that is currently in use.	CLOSED: The C&DH will accept commands for 1, 2, active, or inactive, or either.
41	The following items were not explained in the discussion of the launch planning:	CLOSED: see below:
41a	How is the first contact to be accomplished when GNS orbit data is not available?	CLOSED: The first 12 hours of station contacts will occur through time tag commands relative to separation.
41b	Will the S/C turn on its transmitter autonomously?	CLOSED: Yes. The transmitter is turned on from the Separation Sequence relative to S/C separation.
41c	What happens if the launch is not nominal?	CLOSED: We are allowing for a small amount of uncertainty by adding time to the beginning and ending of station contacts. Boeing will be notifying the MOT within 20 minutes following separation whether the launch was nominal or not. They will also send an updated state vector if non-nominal, to be used in subsequenct antenna pointings.
42	Consider the rationale for placing the solar array stops at 0 and 90 deg.	CLOSED: There are no slip rings on the panels where they are connected to the drive and it was desired to keep the service loop small.
43	Recommend placing all subsystem requirements and user documentation on the WWW so that MOPS has an on-line source.	CLOSED: Much of the documentation used by the MOT is placed on a website available to them within the MOC. As additional information is identified as useful, it is placed there as well.
44	if power is available, consider leaving both IEM's powered during normal, on-orbit operations to allow both to perform some safing operations.	CLOSED: An analysis was conducted and it was determined that the long-term reliability of the backup IEM was significantly icreased if left off, because the radiation total dose does not apply to the system which is powered down. In addition, there is not much cross-strapping between the IEMs so the usefullnes of having them both monitor safing is reduced.

Red/Blue Review #1 AI Summary (8 of 9)

45	If both launch mode and operational mode rules are all stored on-board, plan for disabling the launch mode and enabling the operaitonal mode rules in the launch sequence.	CLOSED: This is planned.
46	Consider leaving the IEM on for a few (10?) seconds after hard LVS to allow time for appropriate rules (e.g. switch AIU's) to execute.	CLOSED: There is no way to input delays into the Hard LVS sequence to allow for this. Analysis was done to estimate the amount of time expected between a Soft and Hard LVS. Assuming a nominal load at Beta 0 and no solar array input, the time required to discharge from a soft LVS to a hard LVS level was 9.3 minutes; ample time for the Soft LVS to complete.
47	Consider automating the retrieval, validation, and use of the orbital elements that are downlinked from the S/C for controlling ground system configuraiton.	CLOSED: This has been implemented within the MOC software.
48	Create enough arithmetic operations to accommodate the power system needs.	CLOSED: There are 49 current limit checks and 64 total number of allowed Arithmetic Checks. At this time, 50 are used.
49	Determine the total number of Arithmetic Check requirements by counting the number of Power limit checks and add some spare for other purposes.	CLOSED: See 48 above.
50	Consider calculating the effect of an incorrect thermal design on battery lifetime.	CLOSED: Battery lifetime will be affected if there is a difference in temperature greater than that expected; however it is difficult to quantify because of all the variables involved. If the temperature difference between battery halves is permanent, the lifetime severity will be dependent on the size of the gradient. Because of this, much time and effort was put into the design, analysis, and testing of the battery thermal control system. For more details, see SEI-98-078.

Red/Blue Review #1 AI Summary (9 of 9)

51	Revisit the dynamic stability of a run-away wheel.	CLOSED: Analysis was run out for a run away wheel with all wheels remaining in the control loop and the results were not good. As a result, a model of expected wheel torques is used to determine if a wheel has failed. If so, the control algorithms will take the wheel out of the control loop and send it zero torques. Also, rule based autonomy is notified and the wheel is powered down.
52	Consider using the sun sensor data during the detumble sequence.	CLOSED: The sun sensors are being used during detumble.
53	Consider collecting all information on why the S/C demoted mode in one place.	CLOSED: A capability was added through the use of rule based autonomy to save the SSR read pointer information when critical events occur. The MOT will use this information to read-out the SSR memory around the time frame of the anomaly.
54	Consider enabling the LVS check earlier in the launch sequence.	CLOSED: The hard LVS is disabled at launch because it could be detrimental to S/C health to have the wheels turn-on too soon. The current plan is for the hard LVS to be enabled after the wheels have been powered. Prior to this, there is a separation version of Soft LVS enabled at separation.
55	Consider having autonomous detect of receiver lock on-board start the recorder dump operation autonomously.	CLOSED: This is a Ground System capability which will be utilized in a "lights-out" scenario, which will be attempted after several months on-orbit.

Red/Blue Team Review #2

- Red Review Team Members:
  - Madeleine Marshall - Interface & Control Systems (ICS)
  - Glenn Cammarata - GSFC - NGST Software Lead
  - Andy Driesman - APL - Spacecraft Systems Engineer for STEREO
  - Lou Hallock - GSFC - NGST Autonomy Software
  - Jay Offutt - ICS - Designed & Coded Rule Based Autonomy System for MSX (a TIMED predecessor)
  - Dan Ossing - APL - Mission Operations Spacecraft Specialist - MSX, STEREO
  - Ed Reynolds - APL - Spacecraft Systems Engineer for CONTOUR
  - Andy Santo - APL - Spacecraft Systems Engineer for NEAR
- Objectives
  - Assess the design and implementation of the TIMED on-board autonomy system and the system verification approach to meet requirements.
- Final Report and Action Items - ICS memo, 08 April 1999.
- Action Item Closure memo - SEI-00-062, 29 September 2000.
- All Action Items are summarized in the next 5 charts.

#1

Red/Blue Review #2 AI Summary (1 of 6)

Number	Action Item Summary	Action Item Response Summary
1-1	Fault tree - Ensure that there is sufficient error prevention on the uploadable parameter for solar array safe-mode position.	CLOSED: Commands to change these parameters will be "locked". When they are to be changed, they will be tested on the TOPS (ground based S/C simulator) prior to uplink.
1-2	Maintain a stable attitude – Insure that there is sufficient error prevention on the uploadable parameter set that affects momentum management.	CLOSED: Commands to change these parameters will be "locked". When they are to be changed, they will be tested on the TOPS (ground based S/C simulator) prior to uplink.
2-1	Note constraint on ability of system to detect a telemetry state due to 1-second sampling. If plan to use autonomy capability to recognize a fault, could miss faults which manifest themselves as a short burst. A solution is to add capability to compute telemetry statistics (pseudo-telemetry).	CLOSED: The Spacecraft health and status information being monitored by the Autonomy Rules are not expected to change significantly at rates less than once per second. Based on previous experience and knowledge that we are monitoring similar types of functions, the once per second sampling should be sufficient.
2-2a	Thought should be put into process of software uploads. Periodic uploads should be scheduled prior to launch.	CLOSED: The AIU which is the only processor required for Safe mode can be loaded in one contact. The remainder of the processors can be loaded within 24 hours. The loads will be tested thoroughly on the ground on the TOPS. To further minimize impact, the current plan is to load the redundant processor first, test it, and switch to it while the other is being loaded and tested. Because loads can be performed on the order of a day, minimal impact is seen on the mission of having to perform S/W uploads.
2-2b	Thought should be put into modularizing the event-driven code. This section of code is likely to be changed by instrument demands post-launch.	CLOSED: Good idea; however, modularized S/W was not a requirement and to make the change now does not fit under the current budget constraints. Any processor can be loaded within 24 hours if necessary.
2-2c	It appears that post-launch software quality and configuration control is not defined. If this is true, it should be worked. It would be very valuable for the project to have an estimate of the time/cost required for a software upload.	CLOSED: This was not the subject of this review; however, software QA procedures are the domain of the SRS group on the TIMED program and will apply throughout the mission.

Red/Blue Review #2 AI Summary (2 of 6)

2-3	You may want to think about the capability of defining instrument events via the C&DH rule set. This would give you the ability of modifying the event-set without a software load.	CLOSED: This can be done for those events that can be defined by telemetry that exists in the data collection buffer.
2-4	You should consider the ability to use a data-point in any packet. Limiting the rule set to the housekeeping packet will limit flexibility. An alternative method would be to set aside programmable parameters in the housekeeping packet that can be taken from any other packet source.	CLOSED: It is very late in the schedule to add this capability. Tradeoffs were done early in the program and it was envisioned that the information selected as "high priority" would be the information needed in Autonomy Rules. A change to the Data Collection Buffer would require a code change; which is possible.
2-5	You should be able to turn off autonomy on an IEM before it is powered. This would allow the "unpowered IEM" to have its rule set updated without it executing any old rule.	CLOSED: The C&DH will implement a 20 second delay between boot-up and processing of autonomy to allow a ground command to be received which would "suspend" autonomy rule checking.
2-6a	You should have a check that the correct database is uploaded to the proper flight software version. Suggest a parameter in the rule that specifies flight software version.	CLOSED: The onboard software logs the current software version number (as its checksum) and allows an Autonomy Rule dataset version number to be loaded. The current procedure calls for the "Current Configuration" script to reload the "current" autonomy set, should that be required. A history of the "Current Configuration" scripts is archived, such that a record is kept as to which Autonomy was loaded with the "current" software version.
2-6b	For every C&DH software upload you want to make sure that the rules are not compromised. This would force a rule upload with every C&DH software upload.	CLOSED: C&DH software loads may be performed without reloading of Autonomy Rules. Should it become necessary to reload the rules because of a significant C&DH change, that will be worked between the C&DH Lead S/W Engr. and the MOT.
2-7	AIU switching should be limited to a max number of times to eliminate the chance of infinite switching. This comment applies to all rules.	CLOSED via SEI-00-062 - AIU #1 switch rules have a max fire count of two and AIU #2 switch rules have a max fire count of one.

#9

Red/Blue Review #2 AI Summary (3 of 6)

2-8	Think about only switching AIU control once. This somewhat limits fault coverage, but would greatly simplify autonomy design. Given the contact frequency is once-per-day this may be acceptable.	CLOSED via SEI-00-062 - It was decided that some amount of switching was necessary for a more robust design. There are health checks prior to an actual switch. If these fail, the switch is not made. If the current AIU continues having problems following a power cycle, multiple switching opportunities allows for additional recovery attempts.
2-9a	Evaluate the impact of the C&DH buffer updating while the rule engine can be using the data and while the arithmetic calculations are being processed.	CLOSED: To avoid any potential conflicts, the C&DH software will now make a copy of the Data Collection Buffer on which it will perform its Autonomy processing.
2-9b	Is the arithmetic calculation done on the same buffer as the rule checks that will follow?	CLOSED: Yes
2-9c	Suggest copy to current value table for use by arithmetic calculations and autonomy.	CLOSED: See 9a.
2-10	Recommend an internal autonomy rule walk-through of all rules prior to launch. Step through the flow charts and logic for each rule with the applicable subsystem lead engineers, flight operations staff, and system engineers.	CLOSED via SEI-00-062 - The autonomy rules and associated macros were reviewed in a "code walkthrough" manner by the MOT and Systems Engr. during the months of May and June of 2000.
2-11	Recommend implementing a logic/usage/state checker for maintaining the autonomy rules.	CLOSED: This is beyond the scope of the current level of effort. Historical knowledge of autonomy rules will be maintained via a combination of documentation and software tools.

Red/Blue Review #2 AI Summary (4 of 6)

2-12	Rules can be disabled autonomously based on priorities. Therefore the (rule) state of a particular C&DH is not known at given times. Is autonomy telemetry downlinked on all passes? Even so, if an anomaly causes the spacecraft to go into safe-mode (shutting off the C&DH) and the other C&DH needs to be powered up, how does the ground verify that the new C&DH has the same active rules?	CLOSED: Autonomy Telemetry is recorded and downlinked continuously and therefore, the states should be known routinely. Also, the C&DH Autonomy Rule software allows a field in each rule to specify whether each rule is intended to be run on the BC, the RT, or both. Using this feature, the same rules are loaded into each C&DH. If the backup C&DH needs to be powered, it will have the same rules. It will process the BC rules, if we decide to assign it as the BC.
2-13	Verify that both sides of the C&DH have same rule base. Ground controllers must keep track of Side A&B rule bases rather than just one.	CLOSED: See response to #12.
2-14	Hold a design review of all rules as a whole. Reviewers should be given the ability to walk through the complete set of rules. Have mission Operations Team support this review.	CLOSED: Same as #10. This is planned.
2-15	How does one validate that the “Rule State” in the spacecraft dynamic simulator matches the Rule State on the spacecraft? (Particularly troublesome since C&DH sides A&B can have different rule states.) May want to consider not allowing rules/macros to enable or disable other rules. This allows one to match the state of the ground simulator and spacecraft.	CLOSED: Because the Autonomy Rule Telemetry is recorded and downlinked routinely (see #12), we should know the state of autonomy at any time. We can change the state of the simulator through scripts. We will investigate the most efficient way of configuring the simulator.
2-16	Rule organization could be less confusing if an ELSE construct was introduced.	CLOSED: Best practices in knowledge base construction advise against the use of an "Else" construct.

Red/Blue Review #2 AI Summary (5 of 6)

2-17	What is the difference in the maintenance costs between the rule implementation and a functional implementation?	CLOSED: This type of measurement is deemed too difficult to measure because of the basis for implementing the two different types of autonomy. The division was made between the two types based on the envisioned need for changing them and because the rule based autonomy is not operational in all operational states.
3-1	Develop a list of critical autonomy rules that should be tested routinely. Identify those rules that are required to prevent mission failure and those rules that are used as maintenance (i.e., transmitter on/off). Recommend defining an abbreviated regression test.	CLOSED via SEI-00-062 - There is regression testing of the C&YDH Autonomy rule functionality built into the C&DH Performance test which is run routinely following a code change.
3-2a	If auto-promote is not to be used, don't include it. If it is included then you need to test it (preferably before launch).	CLOSED: The auto-promote capabilitiy will be tested as part of the G&C IV&V effort. It was also tested during "special" mission simulation type testing.
3-2b	Plan to test auto-promote during S/C I&T if it is an assumed S/C function.	CLOSED: It will be tested as part of a "special test" at the S/C level.
3-3a	Define all rule-based autonomy tests and test requirements; give estimates of time requirements so you can do risk assessment and assign priorities.	CLOSED via SEI-00-062 - Rule-based autonomy testing requirement estimates were made and the amount of time required for testing was underestimated. From problems with the test set-ups to problems with the Ground System, the testing took longer than originally estimated.
3-3b	Generate test and test requirements matrix; include priority, where tested and by whom. Verify the software test plans fulfill your test requirements.	CLOSED via SEI-00-062 - Any Autonomy Rule test matrix exists. It was used in ensuring whether every rule and macro had gotten tested.
3-4	Generate scripts for all autonomy tests so they can be run regression test "style."	CLOSED via SEI-00-062 - As mentioned in Action Item #3-1, there is regression testing of Autonomy Rules done within the C&DH Subsystem Performance Test. Due to time and budget constraints, it was not practical to generate scripts for all autonomy testing in "regression test style".

#9

Red/Blue Review #2 AI Summary (6 of 6)

3-5	Ensure that each instrument has a method to set (force to a known state) every flag needed by Autonomy in a test scheme.	CLOSED: The capability to force all of the instrument flags is not in place. The rules will be tested on the IEM Testbed where these flags may be changed. For those rules involving a flag which cannot be forced, a different version of the rule will be used on the S/C to test that it triggers appropriately.
3-6	It is very important that the many interactions be tested. It is just such "unlikely" scenarios that caused Three Mile Island to go critical. If actual testing is not possible, then state diagrams should be employed to insure that problems do not occur.	CLOSED via SEI-00-062 - There has been considerable interaction testing done. The testing has involved things that were envisioned could happen. There have been other tests involving actions which were not envisioned, but just happened as part of the routine testing of the spacecraft and during Mission Simulations while the S/C is on the ground and not always in a post-launch configuration. The types of interaction testing done is summarized in Table 1 of SEI-00-062.
3-7	Plan to re-test autonomy rules and features when software and /or rules change. To support this, organize autonomy tests into subsets of scripts that can be run quickly, easily, and automatically.	CLOSED: See response to #3-4.

TIMED Autonomy Rule Review

- Series of 6 one-half day meetings from 8/31/99 to 11/10/99
- Internal APL Review - included TIMED Engr. & MOT as well as Non-TIMED Engineers (NEAR, FUSE, MSX).
- Objective - to assess whether rules and associated macros in their various stage of development (some coded & tested, others in-coding) were sufficient to meet the Autonomy Rule requirements.
- Workshop Sessions - no formal Action Items taken.

#1

Autonomy Rule/Macro "Code Walkthrough"

- Included Mission Operations Team and Spacecraft Systems Engineer.
- Averaged 3 - two hour sessions per week from May 1 - July 14.
- Level of detail was grueling. Could only handle two hours at a time.
- Went through each rule, parameter by parameter and each associated command macro, command by command.
- Not only good review of the rules and macros, but made MOT familiar/comfortable with the rule design and implementation.
- The things uncovered were things to make the MOT's lives easier and other cosmetic changes.
- Changes were tested on the S/C after unload from storage in June/July 2000.
- Changes documented and implemented in Autonomy Rule Release 2.0.

#1

Autonomy Rule/Command Macro Generation Process

Autonomy Rules

- Initial generation of rule set into STOL format for uplink, utilized the Autonomy Rule Compiler (ARC). This utilized an Excel spreadsheet saved as a .csv file.
- ARC had a couple of minor problems. Low priority because of ease of manual generation after initial 225 were generated.
- After the initial set was stable, changes and new rules were generated manually using a text editor.

Command Macros

- Manual process using a text editor to put into STOL format for uplink.
- Utilized a command generation GUI for generation/verification of proper STOL format of commands.

Change Process

- Rules and Macros can be loaded individually without reloading everything.
- Changes are made in the main procedure used for a complete reload, then "copied and pasted" into a smaller procedure for uplinking only that rule or smaller collection of rules.

Sample Autonomy Rule in STOL format

```
wait 2
#Rule Number: 52
#Rule Grp Name: 2 wheel off #1
# If after earlyOps 2 wheels are powered off turn all four on.
# This of course will be changed if a wheel is found to have
# failed. If wheels 1 AND 2 OR 1 AND 3 are not powered then enable rules 55 - 58
# which will power each wheel if the AIU is not reporting it as bad.
#  NOTE:  The FCIS of this rule needs to be updated to en. after wheels are initially powered.
#Cmd to Execute: CD_MACRO_EXEC_325
cmdif begin_autonomy_action
cmd CD_MACRO_EXEC 325
cmdif end_autonomy_action
cmd AUT_RUL_LOAD 52 4 0 0 \    # Rule Num, Prio, Grp Info
3 \                            # Flash mem. initial state: 1=en, 3=dis
1 1 \                          # Target: 0=both, 1=BC, 2=RT; Mode: 0=maint 1= fault
1 \                            # Max Fire count
4 \                            # Number of comparisons in this rule
0 \                            # Chain: 0=none, 1=first, 2=cont. 3=last
10 12 \                        # Rule satisfied: count/time (n of m)
0 2 275 0x0008 0 0 \           # TM/VAL; Op:1=lt, 2=eq, 3=gt, 4=ne; Offset, mask, data, TM mask
0 2 276 0x0008 0 0 \           # Comparison #2
0 2 275 0x0008 0 0 \           # Comparison #3
0 2 277 0x0008 0 0 \           # Comparison #4
0 1 0  \                       # Logical Operations: 0=AND, 1=OR
1                              # Combination Order: 0=((( ) ) ), 1=() ()
```

Sample Command Macros in STOL format

```
cmdif BEGIN_MACRO  # 2 Wheels off - enables all 4 wheels to be turned on if not "bad"
#
cmd aut_rul_st_set 3 52 54
cmd aut_rul_st_set 1 55 58
#
cmdif END_MACRO
#
WAIT 5
#
CMD CD_MACRO_LOAD 325 1
#
Wait 5
#
cmdif begin_macro   # switch from PSE/DU #1 to #2
#
cmd ps_1553_int_2 on
cmd ps_1553_sel sideb
#
cmdif begin_time_tag
cmd ps_1553_int_1 off
cmdif end_time_tag
CMD CD_TT_RULLD_REL 331 7 1 5
#
cmdif END_MACRO
#
WAIT 3
#
CMD CD_MACRO_LOAD 326 1
```

Autonomy Rule Releases

- Initial version 1.0 released on 10 January 2000.
  - Just prior to Thermal Cycling portion of Environmental Testing
- Version 2.0 released on 07 August 2000.
  - Changes following the Code Walkthrough
- Version 3.0 released on 16 October 2000.
  - Implemented prior to Launch/Separation Simulation on 18 October and the 96 hour simulation the week of 23 October 2000.

Autonomy System Testing (1 of 2)

- Embedded Autonomy was tested within that Subsystem's subsystem-level testing, S/C subsystem performance testing, and/or during S/C Level Mission Simulations.
- Rule Based Autonomy was tested on the IEM Testbed, TOPS, and the S/C.
- IEM Testbed and TOPS have the capability to set the values of the parameters being monitored in the rules in order to trigger the rules.
- Certain rules could not be tested on the S/C as is (but their macros were), but were tested on the IEM Testbed or TOPS.
- All macros associated with rules were tested on the S/C in response to rule triggers. Where the real rule could not be used to trigger, the real rule was modified to "force" it to trigger. Of course, "modified" rules were NOT written to Flash. End of testing, either S/C shutdown or C&DH reboot to ensure no Flash writes.

Autonomy System Testing (2 of 2)

- Over 150 hours of dedicated Autonomy testing on S/C since 11/99.
- All rules for normal operations were enabled for three 96 hour Mission Simulations and Event Driven Mission Simulations - all performed as expected (i.e. triggered when supposed to and DID NOT trigger when NOT supposed to).
- Rules for Early Operations were enabled for Launch Mission Simulations - all performed as expected.
- Interaction testing performed on possible interactions that were envisioned. Other interactions occurred as a result of Autonomy being enabled and the S/C not in the on-orbit configuration. As a result of the interactions, S/C was never in an undesirable state.

Embedded Autonomy Summary (1 of 2)

- G&C
  - Mode Management
    - Mode demotion - for various reasons will demote from Operational to Nadir or Safe
    - Auto Promote - capability exists if needed post-launch, in only desperate situation of daily repeated Safe mode occurrences. Disabled by high priority autonomous shutdown functions such as Soft LVS.
  - Sun Keep Out - if enter a keep out zone, transitions to Safe mode
  - System Momentum Monitoring - if System Momentum is greater than a constant, switch to the redundant set of torque rods.
  - AIU Miscellaneous Failures Response/Recovery - checks done to detect problems and actions taken to switch to redundant units or flag to C&DH to take action
    - Sun Sensor
    - Magnetometer
    - IRU
    - Solar Array Drives
    - AFCs
  - Solar Array Control - when array angle is x greater than a lookup of what it should be at the current Beta angle, then it will command a rotation to a new position
  - Wheel Health Monitor - determines if a Reaction Wheel has failed based on an internal model that computes expected torque output
  - Momentum Management - dumps momentum as required using the Torque Rods
  - IRU Switching - powers and switches to other IRU if required

Embedded Autonomy Summary (2 of 2)

- GNS
  - Event Notification
    - Primary Ground Station. Contact
    - Backup Ground Station. Contact
    - South Atlantic Anomaly (SAA)
    - Polar Regions
    - Terminator Crossing
  - On Board Time Management - based on GPS satellite constellation
  - On-Board Orbit Determination - determines position, velocity, time
- RF
  - Critical Command Decoder (CCD) Watchdog Timer - if no command is received for 40 hours, uplink circuitry in the critical command decoder gets reset.
- Power
  - Battery Charge Control
    - Peak Power Tracking (PPT) - done within C&DH software
    - Voltage-Temperature (V-T) control - hardware
  - Hard LVS - if voltage < 24V or pressure < 275 psi, turns off all non-essential loads including the IEMs.

Embedded Autonomy Test Matrix

Subsystem	Functionality	Where functionality was tested
G&C	Mode Management	
	- Mode demotion	LVS Mission Sim; (LVS-MS) Event Driven Mission Sim (ED-MS) Special Autonomy Testing (SAT)
	- Auto Promote	"Special" Mission Sim Testing
	Sun Keep Out	ED-MS
	System Momentum Monitoring	Separation Mission Sim (Sep-MS); EDMS
	AIU Miscelleneous Failures Response/Recovery	G&C Subsystem Performance Testing - IV&V
	Solar Array Control	Sep MS; EDMS; LVS MS
	Wheel Health Monitor	Special Autonomy Testing
	Momentum Management	Sep-MS and ED-MS
	IRU Switching	all levels of Mission Sims
GNS	Event Notification	
	- Primary Ground Stn. Contact	ED-MS
	- Backup Ground Stn. Contact	ED-MS
	- South Atlantic Anomaly (SAA)	ED-MS
	- Polar Regions	ED-MS
	- Terminator Crossing	ED-MS
	On Board Time Management	Subsystem, S/C level, and Mission Sims
RF	CCD Watchdog Timer	"Special" Performance Testing
Power	Battery Charge Control	
	- PPT (with C&DH)	Power Subsystem Performance and ED-MS
	- V-T control	Power Subsystem Performance
	Hard LVS	"Special" Performance Testing

Test Abbreviation Key

LVS-MS - LVS Mission Simulation

ED-MS - Event Driven Mission Simulation

Sep-MS - Separation Mission Simulation

Autonomy Rule Summary (1 of 4)

- G&C
  - AIU Health Monitoring & switching
    - AIU Program Monitor - if stuck in boot, switch to other AIU
    - AIU Heartbeat Monitor - if heartbeat fails for 10 sec. switch to other AIU
    - AIU System Momentum - if yellow too long or red, switch to other AIU
    - AIU G&C Bus Failure - if indicated by AIU based on all devices failing poll, switch to other AIU
    - Solar Array Rotation Problem - if problem commanding or positioning the arrays, switch to other AIU
    - AIU A/D Converter Failure - pre-launch- if Mags on and no IRU on, switch to other AIU; post-launch- if all wheels indicate bad (very highly unlikely to happen), then switch AIUs.
  - AFC Health Monitoring & Switching
    - AFC Not Responding to Bus Poll - if AIU indicates AFC not responding, switch AFCs
    - AFC Program Monitor - if AFC stuck in boot, switch AFCs
    - AFC High Rate Message Problem - if AIU indicates AFC High Rate message problem, switch AFCs
  - AIU Only one on; not selected - if only one AIU is powered and is not selected, select it
  - AFC Anomaly Buffer Counter - if AFC anomaly counter increases by 17, dump it
  - Magnetometers On - if after Early Ops, as magnetometer is off, turn it on
  - AFC Reset Detector/Counter - if AFC indicates in boot for 1 sec., trigger to count a reset, and dump low memory.

Autonomy Rule Summary (2 of 4)

- G&C (continued)
  - Star Tracker Monitor
    - AST Not Responding to Bus Poll - if AIU indicates it is not responding, power cycle AST
    - AFC detects frozen AST Message Counter - power cycle AST
  - Reaction Wheel Health - if AIU indicates problem with wheel based on expected output, power down that wheel and disable further power downs
  - 2 Wheels off - if 2 wheels are off, power on all four wheels, provided they are not indicated as "Bad" wheel.
  - Action Upon Safe Mode entry - warn and power down instruments, other misc. actions.
  - Action Upon Nadir Mode entry - enable Safe mode entry detection
- GNS
  - GNS Heartbeat - if GNS heartbeat fails for 10 sec, perform soft reset
  - GNS Reset Detector - monitor if in boot for 15 sec, if so, trigger to timetag the occurrence and act as a counter and dump low memory
- C&DH
  - CMD History Buffer Dump - when Total CMD count increases by 130, dump the C&DH Command Execute History Buffer.
  - C&DH Reset Detector/Counter - upon reboot, detect a reset based on bits indicating type of reset and dump low memory

Autonomy Rule Summary (3 of 4)

- RF
  - Station Contact RF Control
    - RF Turn-on/off for contact - based on Primary or backup station event flag, turns on transmitter at low or high rate depending on RF switch configuration, enables unsupported contact at 3 min. for 30 sec. for high rate contacts, and powers down transmitter in 15 min.
    - Unsupported Contact - checks for uplink carrier lock, if none, assumes transmitter is not supported by ground and turns off downlink transmitter
    - Action prior to LOS - based on event flag going to 0, no action at this time
- Power
  - Soft LVS #1 - if Main Bus voltage < 27V or Battery Pressure < 300 psi for 3 sec, warn and shutdown inst.
  - Soft LVS #2 with AIU switch - if Main Bus Voltage < 27V or Battery Pressure < 300 psi for 120 sec, switch AIUs and begin additional load shedding
  - Soft LVS #2 without AIU switch - same conditions and actions as previous one without switching AIUs
  - Battery/Power System Health
    - PSE/DU Heartbeat Monitor - if heartbeat fails, switch to other PSE/DU
    - Battery Overcharge - if battery pressure > 650 psi, command to trickle charge
    - Battery Over Temperature during discharge - if battery temp. > 20C and battery current < -3.0A and no solar array input, then shed non-essential loads
    - Battery Over Temperature during charge - if battery temp. > 20C and battery > 1.0A and solar array current > 2A, then command to trickle charge
  - Excessive Power from Bus - monitor power, if higher than max expected, either shutdown or time stamp the occurrence

Autonomy Rule Summary (4 of 4)

- Instruments
  - Instrument Survival Heater State Monitor - if instrument is powered and Survival heater is off, power on the Survival heater. If TIDI is ON and Survival heater is on, turn-off Survival heater.
  - Instrument Heartbeat Monitor - if heartbeat fails, power cycle the requested number of times before leaving it powered down.
  - SEE Survival Temp. Monitor - if < -40C for 5 minutes and in Nadir or Operational modes, power on SEE instrument
  - SEE EGS HVPS Level - if EGS State is ON AND the EGS HVPS Level > 2.2V, warn and power down SEE
  - SEE SSPP Position - if SEE SSPP Position > 185 OR < 5 deg., warn and power down SEE.
  - GUVI SIS Temp Monitor - if SIS Housing Temp > 53 degC, disable Surv. Htr and rule 196 (turns back on).
  - TIDI Request to be Powered Down - monitor shutdown bit, warn and power down
  - Instruments reached max packet count. - if packet limit reached, time stamp the occurrence
- Separation
  - Separation Detection - Sequence initiation - initiated by separation switches, deploys solar arrays, turns on RF, etc...
  - Separation Mode - wheel turn-on - AIU indicates System momentum is low enough for wheel turn-on, detect and turn-on all four Reaction Wheels
  - Separation Soft LVS - same conditions and actions as Soft LVS #2 with no AIU switch
  - Wheel On Indication to RT - if wheel is powered, disable macro 903 in the C&DH RT to avoid re-power-on
- Ground Only - Red Tag rule - removed at L-3 days.
  - Emergency Shutdown - turns off all relays except IEMs based on bit from Blockhouse Control Unit.

Autonomy Rule Test Matrix Summary (1 of 3)

Subsystem	Functionality	Number of Rules	Where/How Tested
G&C	AIU Health Monitoring & switching		
	AIU Heartbeat Monitor	12	S/C - AIU off emulates HB at zero; TOPS to emulate at one.
	AIU Stuck in Boot mode	10	S/C - AIU not allowed to boot; subsequent switching; TOPS for HB = 1
	G&C System Momentum Monitor	10	S/C - using TASTIE; forced System Momentum to "Yellow too long"; TOPS to verify "Red" indication triggers
	G&C 1553 Bus Failure	10	S/C - launch simulation with AIU not getting TASTIE info. regarding Mags and IRUs on - indicates no devices on G&C 1553 Bus
	Solar Array control problem detector	10	S/C - non-conventional configuration causes AIU HSKP to indicate SA control problem
	A/D Converter Failure Detector	12	S/C - Post-launch version - put AIU in non-conventional configuration causes AIU HSKP to indicate all 4 wheels have a problem; Launch version - Launch simulation with mags on and no IRU
	AFC Health Monitoring & Switching	6	S/C - tested with AFC off; TOPS - tested after a check for AFC on was added.
	AIU Only one on; not selected	2	S/C - select unpowered AIU
	AFC Anomaly Buffer	2	S/C - rule enabled during sim startup where AFC anomalies count up
	Magnetometers On	2	S/C - turn Mags off with rule enabled
	AFC Reset Detector/Counter	2	S/C - reset AFC
	Star Tracker Monitor	4	S/C - tested with AST off; TOPS - tested after a check for AST on was added

Autonomy Rule Test Matrix Summary (2 of 3)

G&C (Cont)	Reaction Wheel Health	15	S/C - using TASTIE; forced Wheels to fail; For 2 Wheel off rules, simply commanded 2 wheels off with rules enabled.
	Action Upon Safe Mode entry	1	S/C - during Mission Simulations
	Action Upon Nadir Mode entry	1	S/C - during Mission Simulations
GNS	GNS Heartbeat	2	S/C - commanded HB to stop
	GNS Reset Detector	1	S/C - reset GNS
C&DH	CMD History Buffer Dump	2	S/C - routinely during Mission Sims
	C&DH Reset response	1	S/C - routinely at S/C power-up if Autonomy is enabled; other times with a commanded reset
Power	Soft LVS #1	4	S/C - LVS Mission Simulation - lowered voltage using Battery simulator; also pressure
	Soft LVS #2	12	S/C - LVS Mission Simulation - lowered voltage using Battery simulator; also pressure
	Soft LVS #2 with no AIU switch	4	S/C - LVS Mission Simulation - lowered voltage using Battery simulator; also pressure
	Battery/Power System Health		
	PSE/DU Heartbeat Monitor	4	S/C - froze heartbeat using test set-up
	Battery Overcharge	3	IEM Testbed - forced values to trip levels
	Battery Over-temp during discharge	8	IEM Testbed - forced values to trip levels
	Battery Over-temp during charge	2	IEM Testbed - forced values to trip levels
	Excessive Power from Bus	58	S/C - 2 step process; 1) Verf. Arith Chk calculation by outputting result and comparing to manual calculation. 2) Bogus values to Arith Chk - verf. Rule monitoring that Arith Chk triggered.

Autonomy Rule Test Matrix Summary (3 of 3)

RF	Station Contact RF Control	8	S/C - during Event Driven Mission Sims
Instruments	Instrument Survival Htr State Monitor	5	S/C - configure Inst. And Htr. To opposite what rule states
	GUVI Heartbeat Monitor	4	S/C - with bogus rule to trigger the sequence. TOPS - verified Heartbeat failure triggers
	SABER Heartbeat Monitor	10	S/C - with bogus rule to trigger the sequence. TOPS - verified Heartbeat failure triggers
	TIDI Heartbeat Monitor	5	S/C - with bogus rule to trigger the sequence. TOPS - verified Heartbeat failure triggers
	SEE Heartbeat Monitor	4	S/C - with bogus rule to trigger the sequence. TOPS - verified Heartbeat failure triggers
	Instrument Shutdown Request	1	S/C - TIDI issued command
	GUVI SIS Temp. Monitor	1	S/C - bogus load to trigger sequence; TOPS - set values to trigger
	SEE Survival Temp. Monitor	2	S/C - bogus load to trigger sequence; TOPS - set values to trigger
	SEE EGS HVPS Level	1	S/C - lowered level to trigger sequence; TOPS - set levels to trigger sequence
	SEE SSPP Position	1	S/C - TBD; TOPS - set values to trigger sequence
	Inst. reached max packet cnt.	4	S/C - 3 of 4 on S/C during 96 hour Mission Sim. - TOPS for other one
Separation	Separation Detection - Sequence	1	S/C - Separation Mission Sim.
	Separation Mode - wheel turn-on	1	S/C - Separation Mission Sim.
	Separation Soft LVS	1	S/C - Separation Mission Sim.
	Wheel On Indication to C&DH RT	1	S/C - Separation Mission Sim.
Misc.	Emergency Shutdown	1	S/C - BCU button to trigger - Red Tag
	Totals	251	

#3

Interaction Test Summary

Subsystem	Functionality/Interaction Tested	Comments on Test
G&C	G&C Failure reporting and Rule Based actions of resets, power cycles, and switch to redundant component	Performed as expected; no negative interactions
	Mode Management: Promotion/Demotion in and out of Safe mode and associated rule actions	Performed as expected; no negative interactions
	AIU Switch Interactions	Timing of rules being disabled and re-enabled later was refined to prevent possible interference until one is completed
	Simultaneous AIU Switch	As expected, lower number rule (higher priority) completed its execution, the other aborted its attempt after trying to load the same ttag address loaded by the first.
	Wheel Failure at Separation	Wheel turned back on by commands later in sequence. Steps taken to have wheel turned back off if failed. See SPR #551.
	Soft LVS and Hard LVS interactions with other AIU Switching	Performed as expected after refining of disabled/re-enable sequences
GNS	Time Jumps	Performed as expected; no interactions
	Event Notifications	Performed as expected; no negative interactions
C&DH	Rule Based interactions where the situation of one rule counteracting previous rules	Extra checks added to verf. something is powered before action to avoid power cycle resulting in something being turned back on that wasn't supposed to be on following its shutdown
	Rules set-up to run on "both" C&DHs set-up to execute concurrently.	Executed on C&DH #1 and #2 with no unexpected interactions. It was decided to not set-up rules to operate in "both" if the rules action is to power cycle something. The 5 sec. delay in C&DH's would cause additional power cycling not required.
Power	Battery Charge Charge Control	Performed as expected; no interactions

#3

Autonomy Rule Related SPRs

SPR Number	Problem Description	Resolution/Action
341 Closed	Mongoose processor boot s/w not properly counting all reboots	Use Autonomy rules to detect reboots for C&DH, GNS, and AFCs. Add low memory dump to the action.
468 Closed	SABER Heartbeat Rules fired during a mission sim	Due to heartbeat latency during SABER telemetry rate changes, desire was to increase the trigger count from 5 to 10 seconds). Loads to fix this problem were not implemented in Flash prior to the Mission Sim. Subsequent load corrected in Flash.
469 Closed	During a Mission Sim on 2/24/00, the transmitter turned-on approximately 4 min. after GNS flag was set.	Rules had not been designed for "overlapping" ground station contacts. Correction was to modify rules slightly to treat Primary and Backup ground station contacts as mutually exclusive. Requires an Action of the MOT if there will be an actual overlapping contact, to abort the timetag that would turn it off, several minutes into the 2nd contact. SOP for MOT.
529 Closed	TIDI Survival heater rules have too short of a trigger count (10 sec).	The MOT is required to properly configure the TIDI instrument and its survival heater. There are autonomy rules (199 and 200) to back-up this operation. Increased the trigger count from 10 sec. to 30 seconds to give the MOT sufficient time to send the commands and perform proper verification.
544 Closed	Add a dump of the anomaly save buffer to the SSR in the macro which writes to it to ensure that the data is preserved. Subsequent writes, overwrite the data	Added the dump command to macro 494 which executes in response to critical events where it is desirable to maintain the SSR write pointer's position (so as to know where the critical information is on the SSR). Adding a dump command ensures the information is preserved on the SSR even though a subsequent execution of macro 494 may come along.
551 Closed	Wheel failure during Separation Test Scenario. Wheel #2 was indicated as bad and turned off properly by autonomy rules, but was subsequently turned back on.	There are commands in the Separation Sequence that were designed to turn on the wheels at the 100 min. after separation mark as a "drop-dead" time to turn-on. They have always been turned on by Autonomy rule prior to the 100 min. mark. The rules were turned on by Autonomy rule at approx. 60 min. mark. The bad wheel indication was at approx. 65 min. mark. Wheel was turned off properly. The 100 min. mark commands turned it back on. Correction, is to add a re-enabling of the bad wheel rule to the 100 min. mark such that a bad wheel would be turned back off if it were to have been indicated as bad. Also add rule 493 to detect wheels on by the C&DH RT and disable the 100 min. turn-on from occurring in the C&DH RT.

Residual Risk

- Through exhaustive testing, very confident that the rules and associated macros are constructed properly and will perform the desired actions.
- Although steps have been taken to reduce and minimize the likelihood of unexpected rule interactions possibly placing the S/C in an unexpected/undesirable state, it cannot be 100 % guaranteed.
- Risk Mitigation: Autonomy Rules are not the last ditch effort. They are turned off in a Hard LVS condition. AIU controls attitude in Safe mode and Hard LVS condition.
- Other interaction testing will be performed on TOPS as their possibilities are foreseen.

13 Red Team Question

Cross Reference

Question Number	View-graph Number
1	11, 12, 22, 29, 30
3	35, 36, 39, 44 - 47
7	48
9	13 - 21, 23 - 28

Spacecraft Thermal Design

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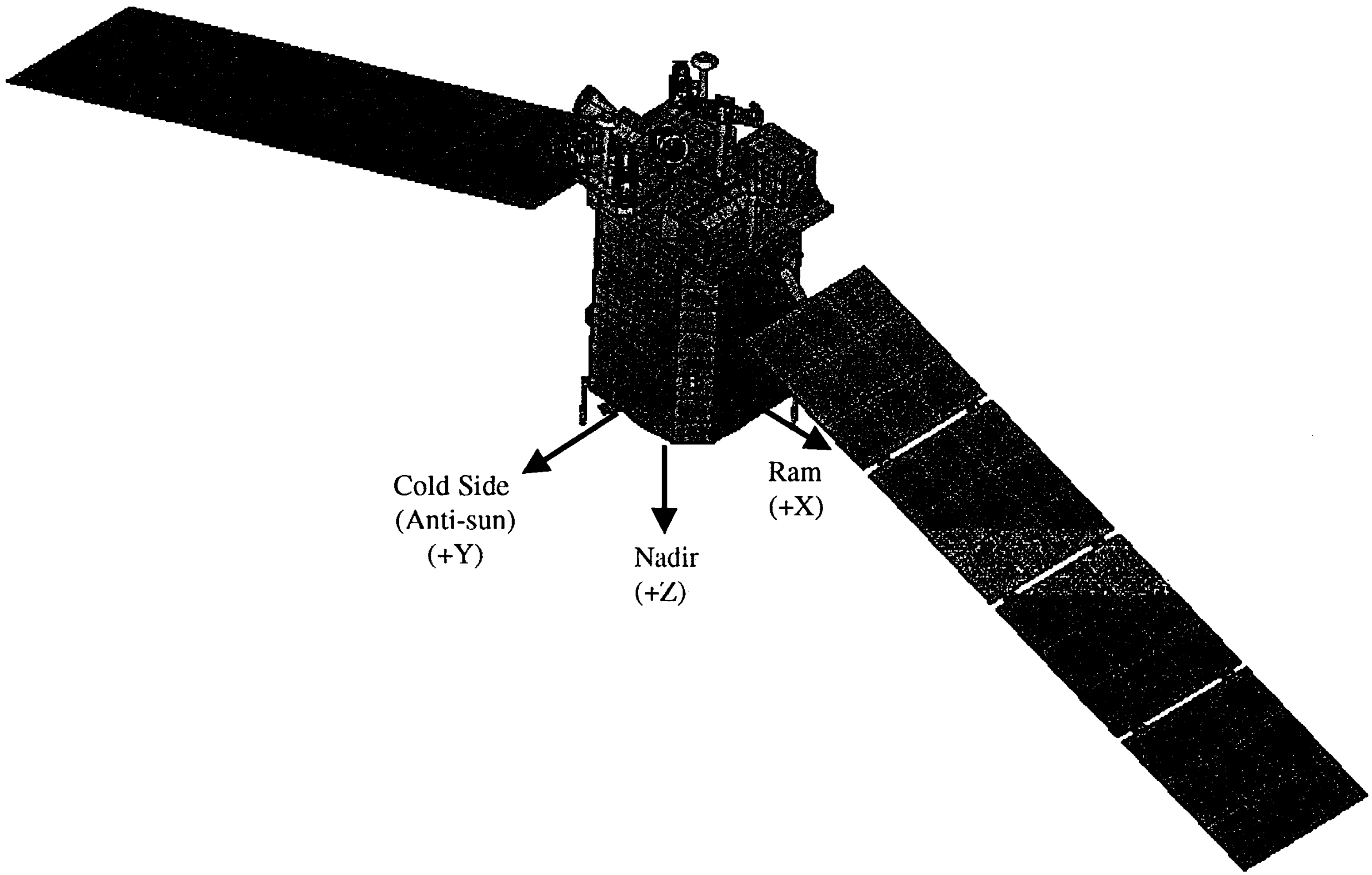
Presentation Outline

- Introduction
- Thermal Design Requirements
- Requirements flow down
- Thermal related specifications and memorandums
- Temperature limits and margins definition
- Thermal Design Approach
- Design reviews
- Testing requirements
- Component level test setups and summaries
- Instrument testing
- Spacecraft thermal balance/cycle testing setup and results
- PFR summary
- Residual thermal risks
- Conclusion and Issues

TIMED Spacecraft Beta 0 Configuration



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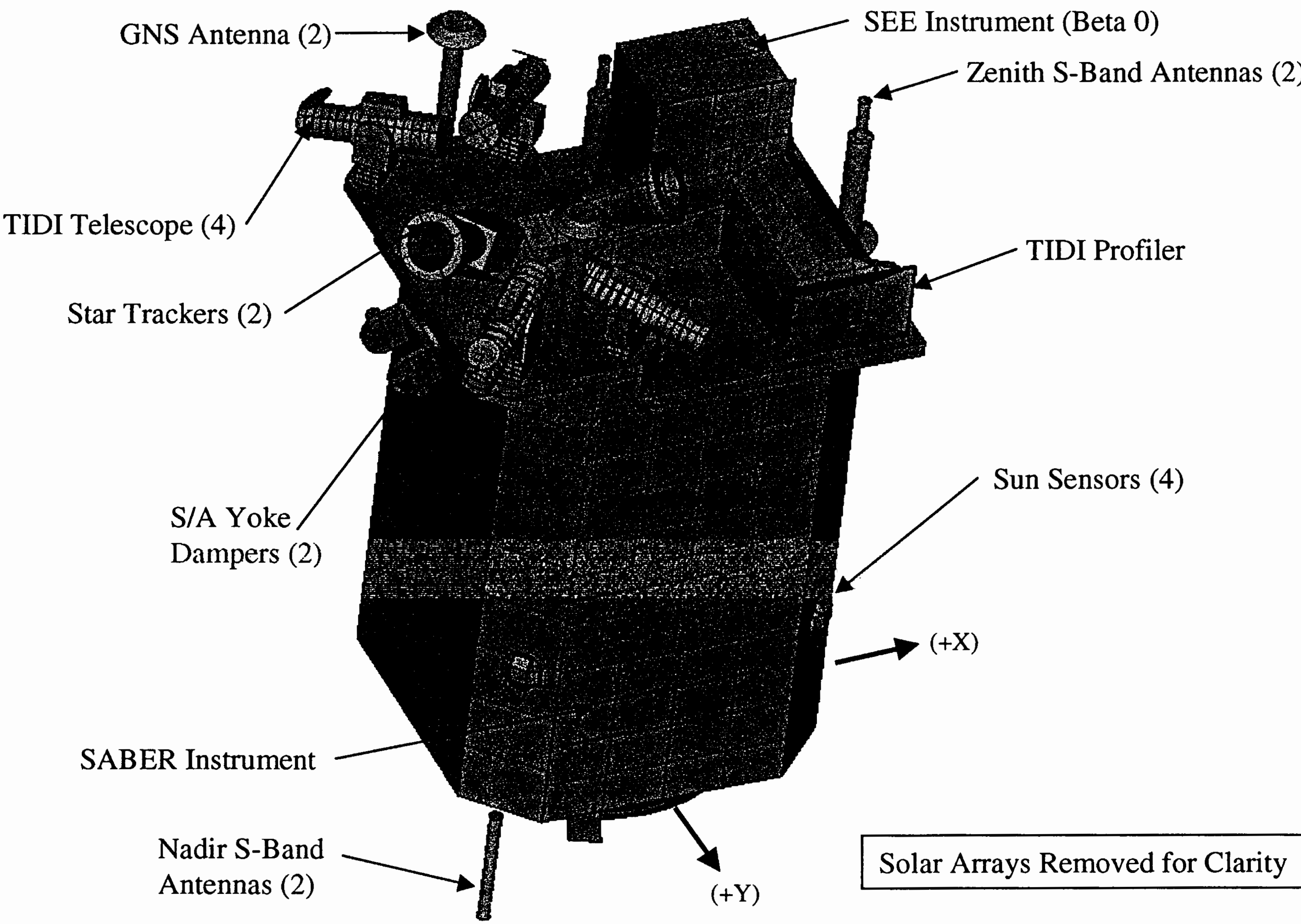
Red Team Review 31 Oct. - 3 Nov. 2000



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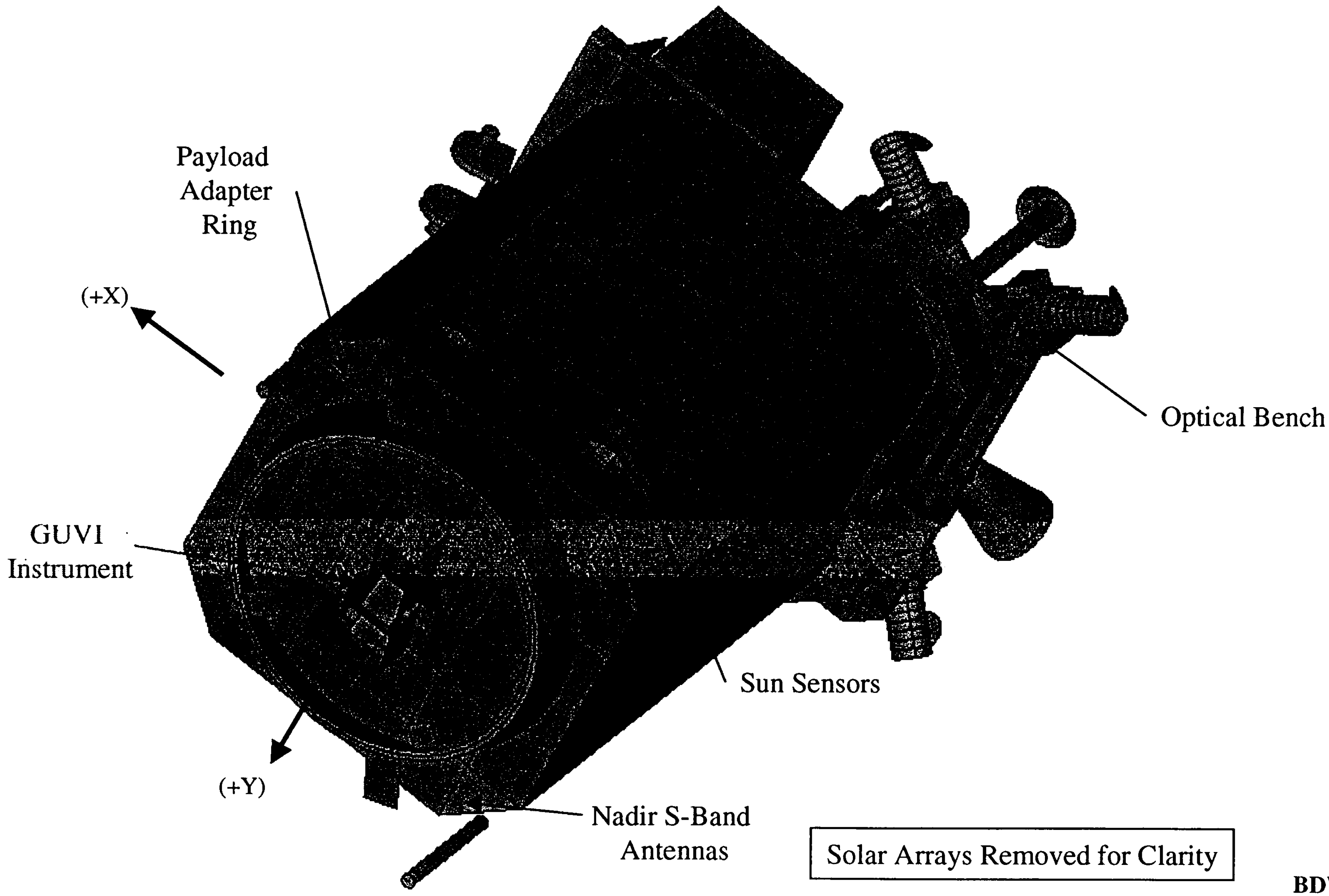


Solar Arrays Removed for Clarity

Spacecraft Thermal Design Requirements

- TIMED S/C attitude:
  - +Y side solar keep-out. Yaw Maneuver
  - +Z to Nadir
  - +/- X to ram (solar array)
  - One RPO
- 2 year design lifetime.
- Orbit: circular 625 km, 74.1° inclination (3 deg./day precession)
- Package temperature limits.
- Instrument interface temperature limits.
- Package internal heat dissipations.

Q5

Note: Presented at TIMED S/C CDR

Thermal Requirements Flow Down

1) **Electronic boxes test range (-29/+55 C) as Specified in CES.**
   (Component Environmental Specification 7363-9010)
   ===> Subtract margin (+/- 10 C)
   ===> Thermal control design range (-19/+45 C)
   = max/min on-orbit predicted temperature range

2) **Derived Temperature limits (e.g. solar arrays).**
   Max/min predicted on-orbit temperature based on worst case optical properties, power and environmental loading.
   ===> Add margin (+/- 10 C)
   ===> Test/Design range

Q5

3) **Power and temperature limits lead to spacecraft thermal design.**
   (Reviewed thermal design in numerous reviews)

Thermal Requirements Flow Down

4) Electronic box component junction temperatures below 100 C.
   Hot case thermal analyses. (55 C baseplate test condition)
   Analyses include conduction from baseplate through card lock, up board/heat sink to component location. Then across component leads/mounting configuration to case to junction.
   (Documented designs in reports)

5) Test flight electronics boxes and instruments. Documented in test reports.

6) Test spacecraft to verify s/c thermal design (box placements, instrument interfaces, heater/thermostat locations, radiator locations and sizes, MLI blanket efficiencies, etc...)
   (Documented in test report.)

Q5

Spacecraft Thermal Specification

- **Applicable Specifications:**
  - **TIMED Component Environmental Specification (7363-9010)**
  - **TIMED General Instrument Interface Specification (7363-9050)**
  - **TIMED/GUVI Specific Instrument Interface Specification (SIIS) (7363-9046)**
  - **TIMED/SABER SIIS (7363-9047)**
  - **TIMED/SEE SIIS (7363-9048)**
  - **TIMED/TIDI SIIS (7363-9049)**
  - **TIMED Interface Requirements Document (7363-9062)**
  - **TIMED Spacecraft TV Test Specification (7363-9060)**

Q3

Spacecraft Component Test Specification

- The Component Environmental Specification (7363-9010) specifies that all flight hardware will be tested to 1 survival and 6 operational thermal vacuum cycles over at least the following temperature ranges:

  Standard Electronics Box: -34/+60 °C Surv., -29/+55 °C Oper.

  Non Standard Components:

  - Solar Array Wings -100/+100 °C both Survival and Operational
  - Antennas -100/+75 °C both Survival and Operational
  - Ni-H Battery -10/+20 °C Operational
  - Star Cameras -40/+60 °C Survival, -30/+50 °C Operational
  - Optical Bench -30/+45 °C Survival, -15/+45 °C Operational
  - IRU -40/+75 °C Survival, -30/+70 °C Operational

Q3

Note: Presented at TIMED PER

Spacecraft Thermal Memorandums

•Applicable Memorandums:

MEMO NUMBER	DATE	DESCRIPTION
S3M-4-274	5/25/95	TIMED/SABER CoDR Thermal Action Item Response
S3M-4-284		TIMED/SEE CoDR Thermal Action Item Response
SEM-4-310	10/2/96	**Thermal Vacuum Testing of TIMED Spacecraft Components (Electronics boxes)**
SEM-4-314	12/5/96	TIMED Spacecraft CoDR Thermal Action Response
SEM-98-4-345	3/26/98	Timed CDR Action Item #17 and #18 Responses
SEM-98-4-358	11/18/98	Thermal Hardware Locations on the TIMED S/C
SEM-00-4-365	2/8/00	**Timed Spacecraft Preliminary TV Test Report**
SEM-00-4-371	7/7/00	Timed Solar Array Damper Thermostat Failure Analysis (S/C PER Action Item #1 Response)
SEM-00-4-372	7/24/00	TIMED On-Orbit Temperature Prediction Waiver

Q3,9

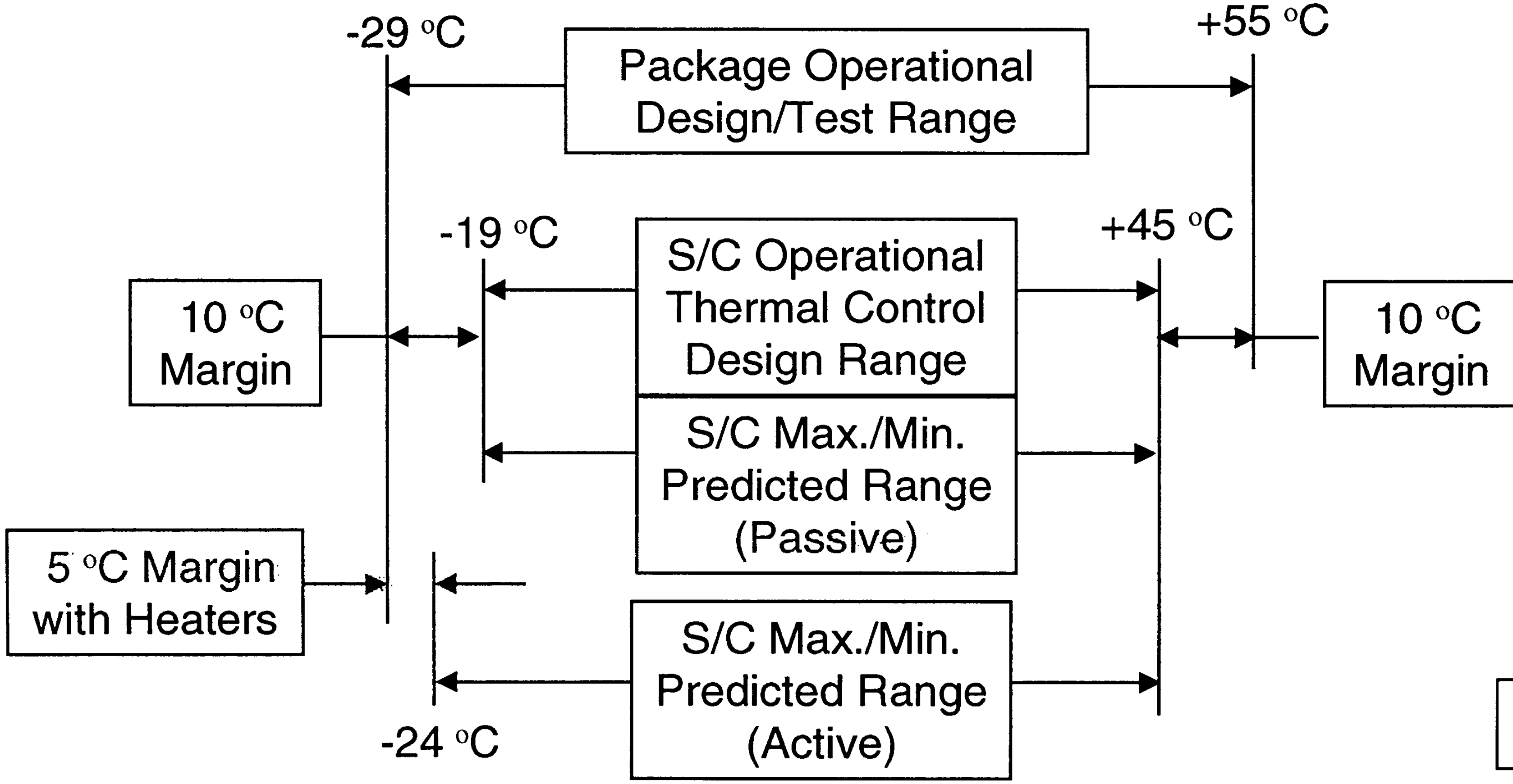
Temperature Limits and Margins

- **Test range defines the package baseplate test temperature limits (e.g. -29 to +55 °C).**
- **Reduce test range by 10 °C to obtain Thermal Control Design Range. (e.g. -19 to +45 °C). This is the margin. A 5 °C margin can be used on the cold end with heaters.**
- **Thermal Control Design Range defines the maximum and minimum on-orbit allowable temperature prediction range, which is the worst case combination of environments, dissipations, optical properties and blanket effectiveness.**
- **Thus, temperature predictions can be as wide as the Thermal Control Design Range and be acceptable.**
- **Derived temperature requirements result from worst case analyses, then adding 10 °C to each end to reach test range.**

Q5

Note: Presented at TIMED S/C CDR

Temperature Limits and Margins



Q5

Note: Presented at TIMED S/C CDR

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S/C Temperature Limits By Panel

Location	Thermal Control Design Range		Package Test Range	
	Operating Temperature (Deg. C) *	Non-Operating Temperature (Deg. C) *	Operating Temperature (Deg. C)	Non-Operating Temperature (Deg. C)
+X Panel	-14 to +45	-19 to +50	-24 to +55	-29 to +60
-Y Panel	-19 to +45	-24 to +50	-29 to +55	-34 to +60
-X Panel	-19 to +45	-24 to +50	-29 to +55	-34 to +60
+Y Panel (@ IEM)	-19 to +45	-24 to +50	-29 to +55	-34 to +60
-Z Deck (@ IRU)	-20 to +60	-30 to +65	-30 to +70	-40 to +75
+Z Deck	-13 to +45	-19 to +50	-23 to +55	-29 to +60
Optical bench [d]	-5 to +35	-20 to +30	-15 to +45	-30 to +40
Star Trackers	-25 to +40	-30 to +45	-30 to +50	-35 to +55
Batteries	-5 to +10	-15 to +20	-10 to +20	-20 to +30
Solar arrays [d]	-90 to +90	-90 to +90	-100 to +100	-100 to +100
Antenna	-90 to +65	-90 to +65	-100 to +75	-100 to +75

* 10 °C margin for passive thermal control. Except Battery and Star Cameras which use 5 °C with heaters.
d - Derived based on worst case analyses plus 10 C margin.

Q5

Note: Presented at TIMED S/C CDR

Instrument Interface Temperatures

Instrument	Thermal Control Design Range		Test I/F Range	
	Operating I/F Temperature (Deg. C) **	Non-Operating I/F Temperature (Deg. C) **	Operating I/F Temperature (Deg. C)	Non-Operating I/F Temperature (Deg. C)
SABER - Isolated	-19 to +20	-29* to +50	-29 to +30	-34 to +60
SEE - Isolated	-10 to +45	-24 to +50	-20 to +55	-34 to +60
TIDI telescopes - Isol.	-5 to +35	-20 to +30	-15 to +45	-30 to +45
TIDI profiler - Isolated	-19 to +30	-24 to +50	-29 to +40	-34 to +60
TIDI E-box - Cond.	-19 to +45	-24 to +50	-29 to +55	-34 to +60
GUVI SIS - Isolated	-14 to +45	-24 to +50	-24 to +55	-34 to +60
GUVI electronics	-14 to +45	-24 to +50	-24 to +55	-34 to +60

* 5 °C margin applied with heaters

** 10 °C margin applied to test range to obtain thermal design range.

Instrument designers use the Test I/F Range to design and test instrument thermal control.
S/C uses Thermal Control Design Range as max. allowable prediction at S/C interface to instrument.

Q5

Note: Presented at TIMED S/C CDR

Spacecraft Thermal Design Approach

- **Mostly passive thermal design of all subsystems, with heaters used to maintain minimum temperatures.**
- **Isolate components that have different temperature requirements than bulk spacecraft, like battery and instruments.**
- **Use MLI blankets to minimize heater power requirements.**
- **Use Silver Teflon as radiator surfaces to minimize solar loading impacts.**
- **Incorporated 4 heat pipes under reaction wheels and Aluminum doubler under gyros (IRU's) for enhance thermal heat transfer.**

Q5

Spacecraft Thermal Design Approach

- **Incorporated fully redundant heater circuits to insure 100% protection. Both Primary and Redundant circuits are active using thermostats with staggered setpoints.**
- **Use parallel heaters to minimize risk of single heater taking out circuit.**
- **Predict On-orbit temperatures for entire spacecraft using worst case combination of orbital environments, surface optical properties, MLI blanket efficiencies, package locations and internal heat dissipations**
- **Analyze and test components and spacecraft to insure adequate margins and provide design confirmation.**

Q5

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S/C and Inst. Internal Heat Dissipation by Panel

Component	Hot Case Internal Heat Diss. Beta=0 (Watts)	Hot Case Internal Heat Diss. Beta=90 (Watts)	Cold Case Internal Heat Diss. Beta=0 (Watts)	Cold Case Internal Heat Diss. Beta=90 (Watts)
+X Panel	75.05	58.15	48.90	35.65
-Y Panel	1.00	1.00	0.00	0.00
-X Panel	52.85	37.25	41.98	29.93
+Y Panel	87.93	87.93	62.14	62.14
+Z Deck	32.56	32.56	32.56	32.56
-Z Deck	32.21	32.21	32.21	32.21
Corner Panels	3.30	3.30	2.30	2.30
Optical bench *	1.26	1.26	1.26	1.26
Star cameras (2) *	24.62	24.62	24.62	24.62
Batteries (2) *	33.0	16.0	33.0	16.0
GUVI SIS Motor	4.0	4.0	4.0	4.0
GUVI SIS*	0.40	0.40	0.20	0.20
SABER *	58.72	58.44	58.59	59.21
SEE *	16.40	16.40	12.53	12.53
TIDI telescopes *	0.60	0.60	0.60	0.60
TIDI profiler *	0.58	0.58	0.48	0.48
Total Heat	419.9	370.1	350.8	309.1

Q5

* Thermally isolated from S/C.

Spacecraft Thermal Design Reviews

- **Spacecraft Conceptual Design Review**
- **Spacecraft Preliminary Design Review**
- **Spacecraft Critical Design Review**
- **Spacecraft Pre-Environmental Review**
- **Spacecraft Post-Environmental Review**

- **Informal Peer reviews with Thermal group throughout design development.**
- **Presented thermal design of subsystems at EDR's.**
- **Presented thermal design of cards at FFR prior to start of card fabrication.**

Q1,2,9

IC Junction Temperature Limits

- **Analyzed all electronic boards to insure integrated circuit (IC) derated junction temperatures are below 100 °C per PPL21, assuming 55 °C box baseplate temperature.**
- **Analyses take into account $\theta_{j\text{-}c}$, $\theta_{c\text{-}b}$, board and card lock resistances. Baseplate, side and top resistances are also modeled.**

MEMO NUMBER	DATE	DESCRIPTION
SEM-4-334	9/23/97	Maximum Predicted Junction Temperatures & Thermal Design input for the TIMED Peak Power Tracker (PPT) Electronics Boards (Board #7363-5210)
SEM-4-335	9/23/97	Maximum Predicted Junction Temperatures & Thermal Design Input for the TIMED Attitude Interface Unit (AIU) DC/DC Converter Boards (Board #7363-2090)
SEM-4-336	11/6/97	Maximum Predicted Junction Temperatures and Thermal Design Input for the Timed IEM Solid State Reorder (SSR) Card. Drawing Number 7363-2230.
SEM-98-4-338	1/15/98	Determination of Transistor Junction Temperature for the Timed/IEM Uplink Card's Wenzel Oscillator
SEM-98-4-340	3/18/98	Maximum Predicted Junction Temperatures and Thermal Design Input for the Timed IEM Power Converter #1 (A9) Card (Drawing #7363-2180)
SEM-98-4-341	3/18/98	Maximum Predicted Junction Temperature and Thermal Design Input for the Timed IEM Power Converter #2 (A1) Card (Drawing #7363-2190)
SEM-98-4-343	3/20/98	Maximum Predicted Junction Temperature and Thermal Design Input for the Timed Flight Computer Power Converter Cards (Drawing #7362-2440) and Processor 1553 Cards (Drawing #7363-2450) (AFC)
SEM-00-4-376	9/8/00	Maximum Predicted Junction Temperatures and Thermal Design Input for the TIMED Power Switching Electronics and Distribution Unit (PSE/DU) Electronic Boards

Q5

Spacecraft Component Test Summary

- **Flight Boxes Thermal Vacuum Tested to** *standard cycles* **as specified in Component Environmental Specification (CES)** *at APL* **prior to delivery with the test specification listed:**

IEM 1 & 2 (SSL99-034)

AFC 1 & 2 (SSL99-026)

AIU 1 & 2 (SSL99-029)

PSE, PPTCM 1 & 2, Fuse Boxes 1 & 2 (SSL99-039)

RF Switch Assemblies 1 & 2 (SSL99-018)

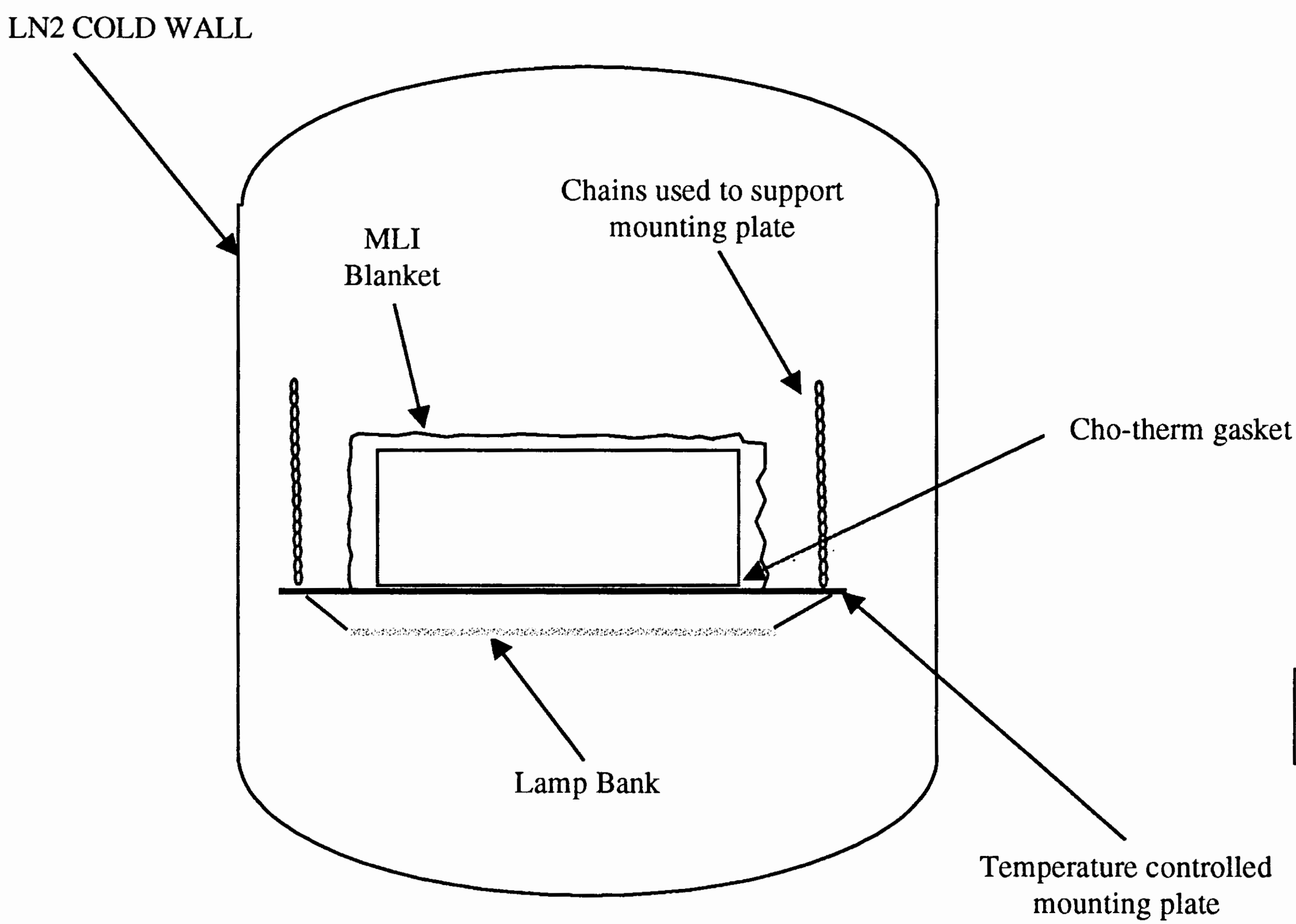
6 RIU Pairs (SSL98-054)

12 Bus Couplers (SSL98-026, SSL98-029)

Q7

Note: Presented at TIMED PER

Electronics Box Test Setup (Standard)



Q5,7

Spacecraft Component Test Summary

- **Flight Boxes Thermal Vacuum Tested to** *standard cycles* **as specified in Component Environmental Specification** *at Vendor* **prior to delivery:**
  - **2 Solar Array Drive Motors and 1 drive electronics (at Schaeffer Magnetics)**
  - **4 Reaction Wheels w/ electronics (at Ithaco Inc.)**
  - **3 Torque Rods (at Ithaco Inc.)**
  - **2 Magnetometer and electronics (at SAIC)**
  - **2 Gyros (at Honeywell)**

Q7

Note: Presented at TIMED PER

Spacecraft Component Test Summary

- **Flight Boxes Thermal Vacuum Tested to** *Non-standard cycles* **as specified in Component Environmental Specification** *at APL/Vendors* **prior to delivery:**

  2 Ni-H batteries (Flt and Spare) at APL (SSL99-040, SSL2000-05)

  2 Nadir S-Band Antennas at APL (SSL99-007)

  2 Zenith S-Band Antennas at APL (SSL99-007)

  2 GNS Antennas at APL (SSL99-007)

  6 Sun Sensor Assemblies over -100/+100 °C at APL (SSL98-061)

  2 Star Trackers (at Lockheed Martin), Requal at APL (SSL2000-16)

Q7

Note: Presented at TIMED PER

Instrument Test Summary

- **Flight Instrument Thermal Vacuum Tested to *Non-standard cycles* as specified in Specific Instrument Interface Specifications (SIIS) prior to delivery:**

TIDI Instrument:

4 Telescopes to -40/+60 °C Survival, -30/+50 °C Operational (SSL98-027)

Electronics Box to standard cycles (SSL99-046)

Profiler: 1 Survival and 4 Operational Cycles over expected flight ranges plus at least 10 °C margin. (SSL99-046)

SABER Instrument:

1 Survival and 4 Operational Cycles over expected flight ranges plus at least 10 °C margin. (at USU)

Q7

Note: Presented at TIMED PER

Instrument Test Summary

- **Flight Instrument Thermal Vacuum Tested to** *Non-standard cycles* **as specified in Specific Instrument Interface Specifications (SIIS) prior to delivery:**

SEE Instrument:

1 Survival and 6 Operational Cycles over expected flight ranges plus at least 10 °C margin. (at LASP)

GUVI Instrument:

1 Survival and 6 Operational Cycles for:

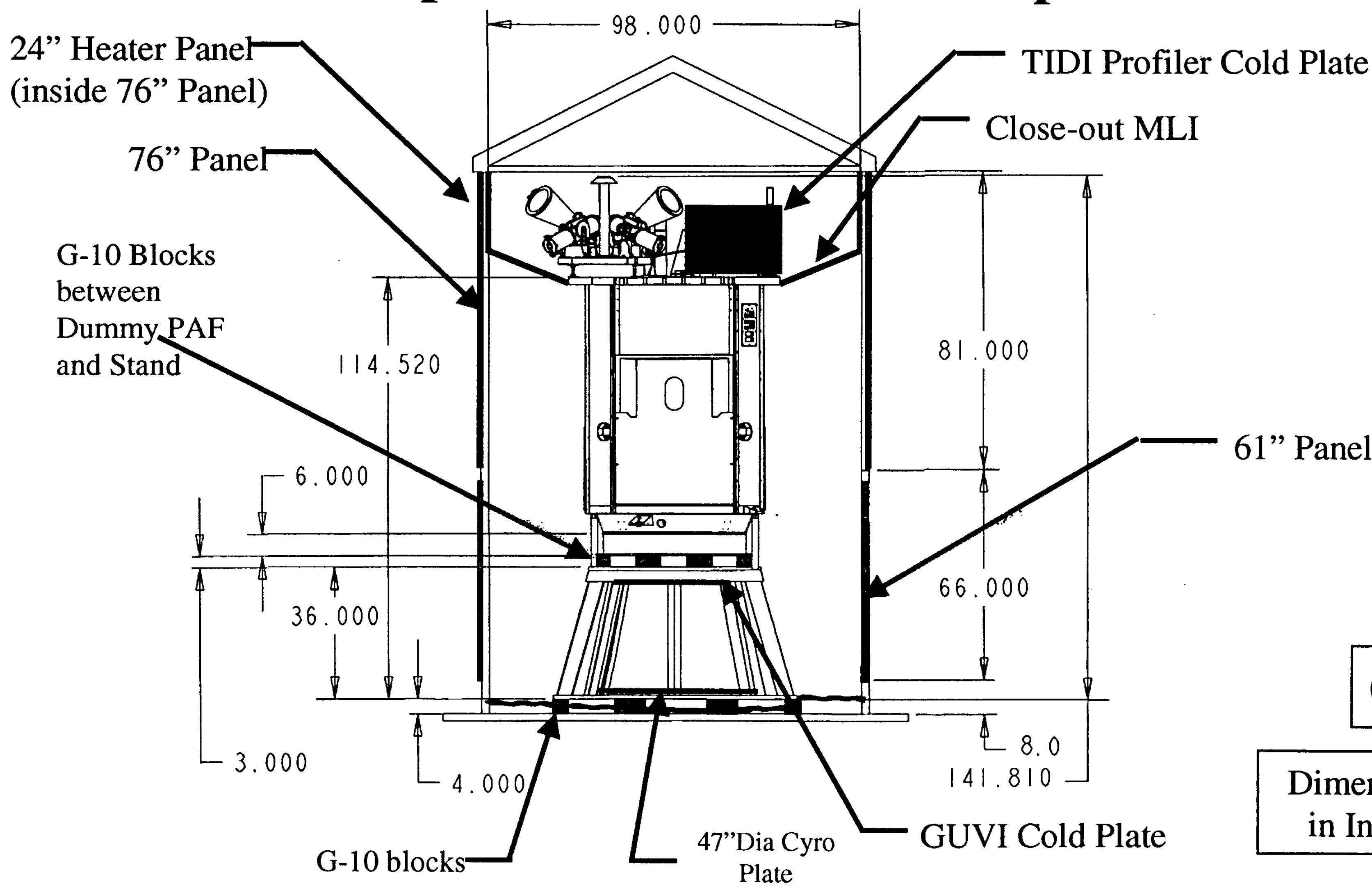
Electronics boxes from -34/+60 °C Surv., -24/+55 °C Oper.

SIS Housing over expected flight ranges plus at least 10 °C margin. (SSL99-022)

Q7

Note: Presented at TIMED PER

Spacecraft TV Test Setup

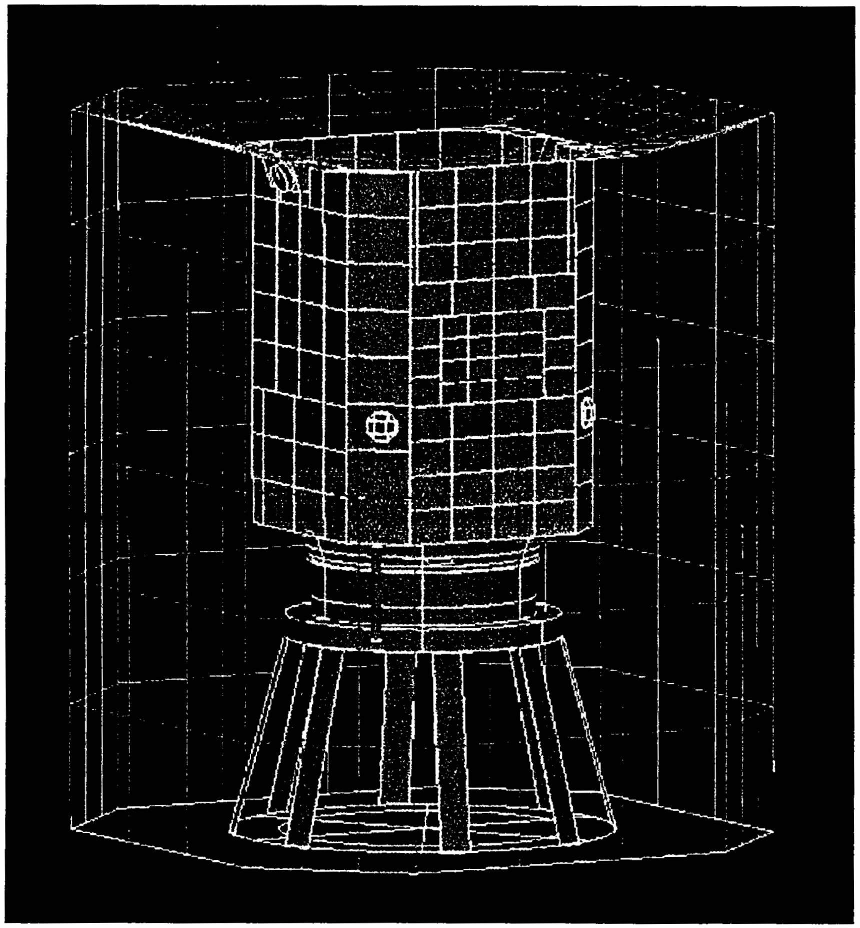


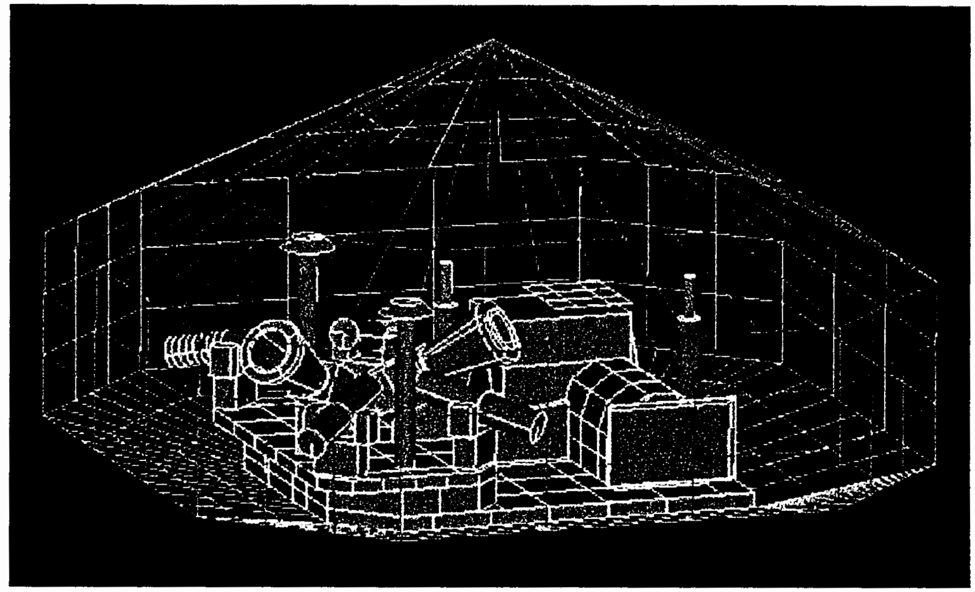
Q7

Dimensions in Inches

Spacecraft TV Test Setup (Thermal Model)

Side Panel Enclosure





Top Deck Enclosure

Q5,7

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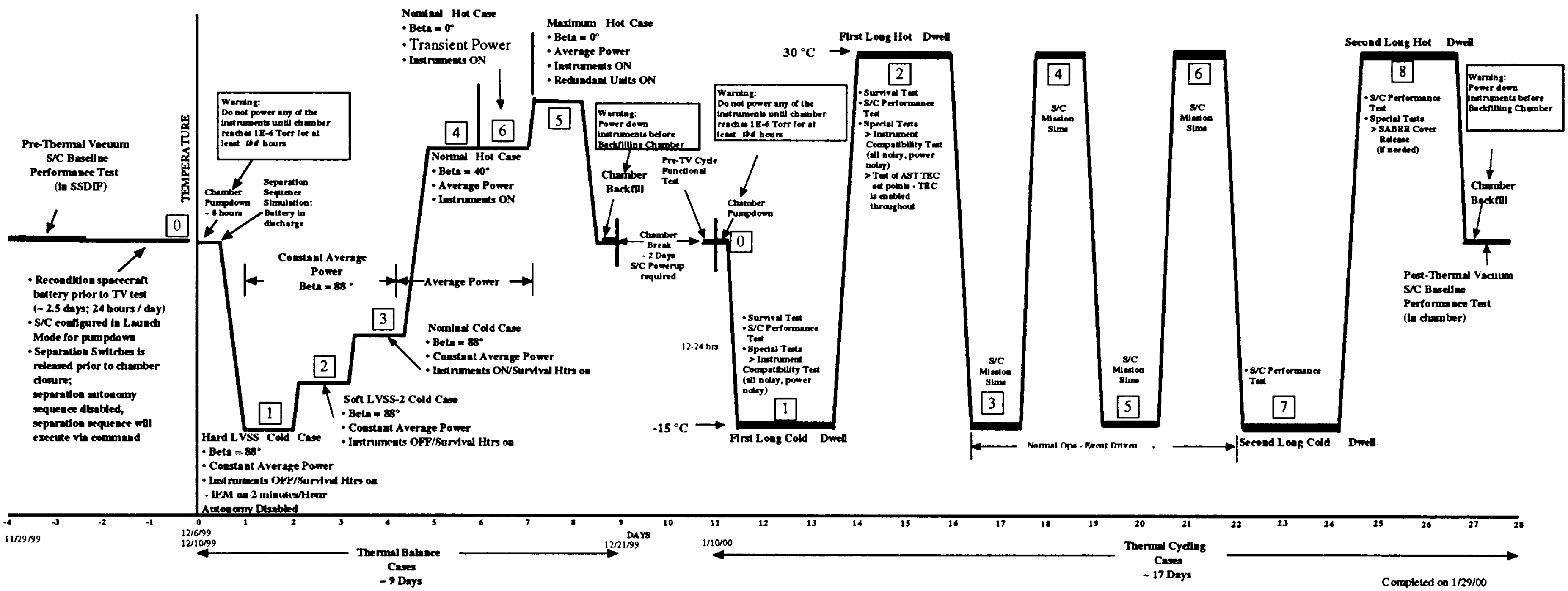
Spacecraft TV Test Profile

Figure 1

TIMED S/C THERMAL VACUUM ELECTRICAL TEST PROFILE



Q5

MLH 11/17/99

Note: Presented at TIMED Post-ER

Spacecraft Thermal Balance Test Results

- **Test successfully verified Spacecraft Thermal control design.**
- **Maintained all s/c temperatures within design ranges.**
- **Lower than expected heat dissipation from s/c boxes (~40 W).**
- **Correlated thermal model with TV data.**

- **Recommended action: Add additional heater to +/- X panels to account for lower heat dissipation.**

Q7

Thermal Related PFR's To Date

- PFR-080: Second IRU turned off during Balance Case #5. No effect on Balance case because it happened early. Accept as is. (Closed)

- PFR-082: TIDI Telescope #2 Survival Temperature Sensor showed two drop-outs during thermal cycle testing. Attempted to locate problem. Accept as is. (Closed)

- PFR-088: Reaction Wheels were left on at full speed. No concern to wheels. (Closed)

- PFR-089: AST Thermo-Electric Cooler high setpoint was different than expected. Accept as is. (Closed)

Q7,9

Note: Presented at TIMED Post-ER

S/C Thermal Residual Risk

- **Thermal design system uses fully redundant heater systems (including heaters, thermostats, fuses and relays) to maintain minimum temperatures.**

- **Component/Spacecraft level tests used to verify thermal system operations.**

- **Detailed on-orbit analyses used to simulate conditions not able to test on ground, including complex solar and earth heating.**

- **Successful spacecraft level thermal vacuum test ==>**

  Low residual risk

Q13

Conclusions and Issues

- **Thermal Vacuum testing provided a great deal of confidence in the S/C thermal design system.**
- **S/C responded as expected, with only a few minor surprises.**
- **Provided final on-orbit temperature predictions with adequate margins, except for TIDI Telescope and SABER interface temperatures (Slightly Colder than specifications).**
- **Waiver created to address interface temperature deviations. (Closed)**
- **Final temperature predictions based on TV correlated thermal model.**
- **All thermal Action Items and PFR's are closed.**
- **Prior to launch, the following major tasks must be accomplished:**
  - **Addition of flight silver Teflon to S/C radiator surfaces**
  - **Installation of MLI onto the S/C**
  - **Final close-out of MLI on launch pad**
- **In general, the S/C is thermally ready to go for launch.**

Q7,9

TIMED Spacecraft Mechanical and Structural Design, Development and Qualification Program

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Mechanical Structural Spacecraft Design

- Mechanical Review Content:
  - 2 Main Areas Covered in this Presentation Package
    - Bus Structural Design
      - Requirements and Configuration
      - Review Process
      - Testing and Qualification Program
      - Test Results
    - Optical Bench
      - Requirements and Interfaces, Configuration
      - Review Process
      - Testing and Qualification Program
      - Test Results

Mechanical Structural Spacecraft Design

- Bus Structural Design
  - General Description
    - The bus design for the TIMED mission is typical of most APL Spacecraft in that it is designed to accommodate the unique "one of a kind" requirements of this science mission. Impacts upon science due to the use of an existing bus design is discouraged however, previous technology developed and design data is incorporated as much as possible to reduce risk areas.
    - Significant Components:
      - Payload adapter (Interfaces to Delta II 3712C) mission unique fabricated by APL, Aluminum
      - Machined Aft Deck (aluminum)
      - Frameless, aluminum honeycomb panel construction
        - » Magnesium edge members
        - » Aluminum honeycomb core (perforated)
        - » Optical Bench (graphite-epoxy face sheets, alum. HC core)

Mechanical Structural Spacecraft Design

- Bus Structural Design
  - Requirements and Interfaces
    - Science Requirements:
      - Provide sufficient "Field of View" (FOV) for the instruments
      - Meet instrument interface requirements (mechanical, thermal, alignments, electrical grounding, etc.)
      - Cleanliness
    - Launch Vehicle Interfaces
      - Delta II, 3712C Payload Adapter Fitting (PAF)
      - Lateral and vertical (launch) frequency requirements
      - Envelope
    - Shipping and Handling
      - Safely satisfy all transportation and handling events without damage, or alignment changes of critical components

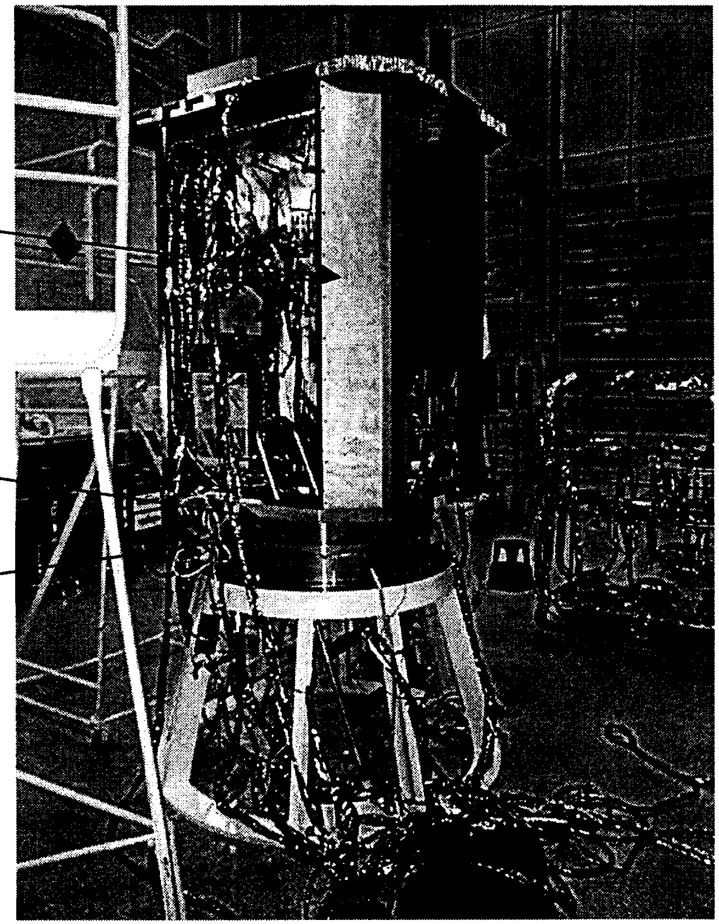
Mechanical Structural Spacecraft Design

- Basic Structure Configuration

Aluminum Honeycomb Panels

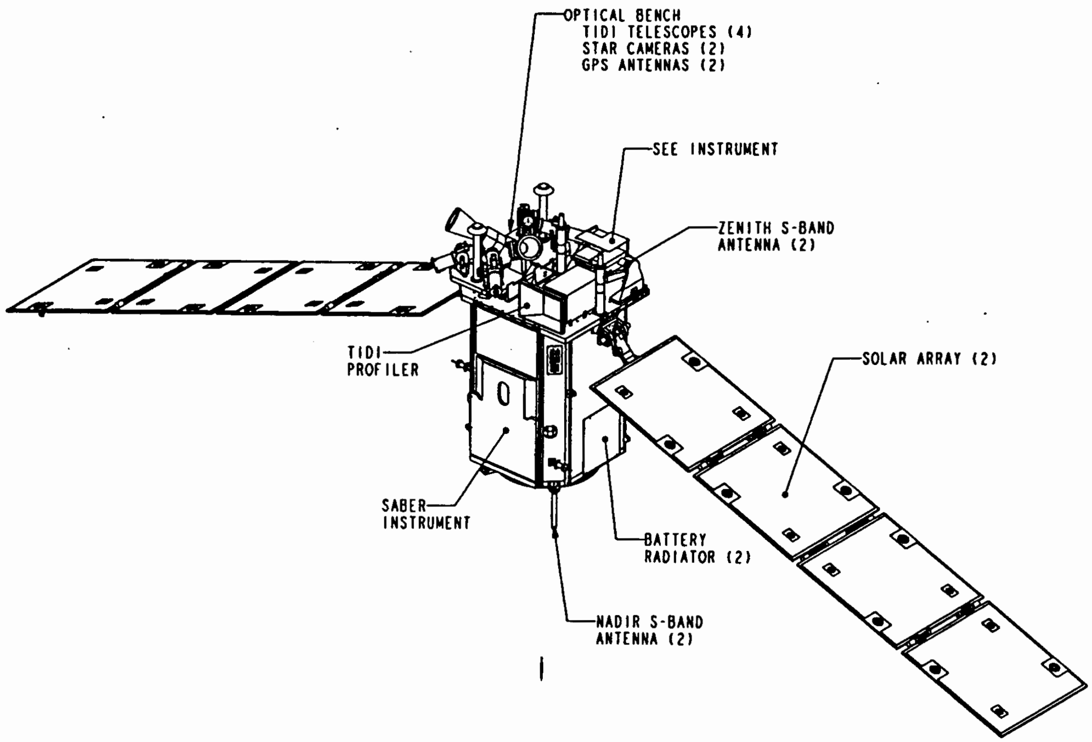
Aft Machined Deck

PAF



Mechanical Structural Spacecraft Design

- Flight Configuration



Mechanical Structural Spacecraft Design

- Review Process
  - Several types of reviews conducted
    - Weekly Status Meetings (configuration, status, etc.)
    - Spacecraft Level PDR, CDR
    - Launch Vehicle Integration Meetings (2/year average)
      - *All launch vehicle information is covered separately in the launch Vehicle presentation conducted for this Red Team Review*
  - Reviews Conducted:
    - Weekly Status Meetings
      - Ensure requirements are being met as well as passed along to the mechanical design team from the sub-systems and instruments
      - Weekly meeting minutes kept and distributed at the program level to all leads
      - Panel Members: APL Spacecraft Team Lead Personnel

Questions:1, 2

Mechanical Structural Spacecraft Design

- Review Process (continued)
  - Reviews Conducted (cont.):
    - Weekly Status Meetings Dates and Mechanical Subjects Covered
      - 10/26/96 Spacecraft Mechanical Structural Design and Solar Arrays
      - 1/14/97 Solar Arrays
      - 5/20/97 Configuration, SC layouts, etc
      - 7/1/97 Package review
      - 7/15/97 Configuration, SC layouts, etc
      - 7/29/97 Configuration, SC layouts, etc
      - 10/14/97 Structure Design, configuration, etc.
    - Meeting minutes are available for review by the Red Team Review

Questions:1, 2

Mechanical Structural Spacecraft Design

- *Spacecraft Preliminary Design Review (2/19/97)*
  - First Top Level review of the overall Spacecraft Mechanical Design
  - Review Panel Members:
    - Eric J. Hoffman (Chairman) Chair, Systems (APL)
    - Mary C. Chiu, Systems (APL)
    - Laurence J. FrankC&DH, Systems (APL)
    - Dr. Edward Gaddy, Power (NASA/GSFC)
    - Dr. Robert E. Gold, Instrumentation (APL)
    - Richard K. Huebschman, RF, Systems (APL)
    - Thomas H. Stengle, III (NASA/GSFC)
    - John J. Wolff (NASA/GSFC)
    - James W. Woods, Mechanical-Structures (NASA/GSFC)

Questions:1, 2

Mechanical Structural Spacecraft Design

- *Spacecraft Preliminary Design Review (2/19/97)*
  - Review Topics Covered at the SC PDR (summary of information)
    - Requirements
    - Changes made since CoDR (**Co**nceptual **D**esign **R**eview)
    - SC layout and configurations (launch, orbit, etc.)
    - Instrument Field of Views (FOV)
    - Structural Design
    - Optical Bench
    - Structural Analysis and Verification
      - Launch Vehicle Requirements
      - Instrument Requirements
      - Design Criteria
      - Materials
      - Margins of Safety
      - Jitter Analysis and Disturbance Torques

Questions:1, 2

Mechanical Structural Spacecraft Design

- *Spacecraft **Preliminary Design Review (PDR)** (2/19/97)*
  - RFA Status for the PDR:
    - RFA #7:Add Solar Array deployment test while attached to S/C
      - Answered by SEM-2-779 Memo dated 10/30/1997
        - » Brief Summary: *Impossible to perform due to the design of the system without unacceptable risk to flight hardware*
    - RFA#21:Perform a complete glint analysis
      - Answered by SEM-2-778 Memo dated 10/30/1997
        - » Brief Summary: *Actual glint analysis (ray tracing) is extremely expensive and complicated to perform at the SC level without finely detailed instrument inputs and models.These models are not mature enough to pass along to the SC team and meet schedule. APL models the 3D complete* Clear **FOV** *(CFOV)required by the instrument. The instrument assumes responsibility for rejection of "off axis" stray light entering outside this CFOV by the design of an adequate sunshade baffling system.*

Questions:1, 2

Mechanical Structural Spacecraft Design

- ***Spacecraft Critical Design Review (CDR) (12/24/97)***
  - Review Panel Members:

• Eric J. HoffmanCo-chair;	Systems	APL
• Josef A. Wonsever, Co-chair;	Flight Assurance	GSFC
• Richard F. Conde	C&DH	APL
• John H. Day	Power	GSFC
• Ward L. Ebert	Systems	APL
• Laurence J. Frank	Systems, C&DH	APL
• Robert W. Jenkens, Jr.		GSFC
• Robert W. Ross		GSFC
• Andrew G. Santo,	Systems	APL
• James W. Woods,	Mechanical-Structures	GSFC

Questions:1, 2

Mechanical Structural Spacecraft Design

- *Spacecraft **Critical Design Review (CDR)** (12/24/97)*
  - Review Topics Covered at the SC PDR (summary of information)
    - Requirements
    - Changes made since PDR (**P**reliminary **D**esign **R**eview)
    - SC layout and configurations (launch, orbit, etc.)
    - Instrument Field of Views (FOV)
    - Structural Design
    - Optical Bench
    - Secondary Structures (antenna masts, battery, etc.)
    - Structural Analysis and Verification
      - Launch Vehicle Requirements
      - Instrument Requirements
      - Design Criteria
      - Materials
      - Margins of Safety
      - Jitter Analysis and Disturbance Torques

Questions: 1,2

Mechanical Structural Spacecraft Design

- RFA Status
  - RFA#27 Consider a solar panel acoustic test following cell laydown and prior to flight panel acceptance
    - Brief Summary Response: APL does not typically perform this type of test. *Subsequent to the closure of this RFA, the vendor did indeed perform a panel level acoustic test after cell laydown as an additional proof of process test subsequent to cell lay-down process problems*
  - RFA#14: Regarding the use of Optical bench pyro releases and other technical information required
    - Brief Summary Response: *The RFA was overtaken by events. The Optical bench design was in flux when presented. A kinematic mounting system was designed and the pyro launch restraint system eliminated*

Question: 9

Mechanical Structural Spacecraft Design

- Hardware Test Program (chronological order)
  - Spacecraft Structure
    - Static Load Test (bare structure)
  - Components (prior to SC integration)
    - Sub-assemblies, electronic packages, instruments, etc
      - Qualified prior to Spacecraft integration per component environmental Specification APL-A-7363-9010 Rev. "A"
  - Fully populated flight ready Spacecraft in Launch Configuration
    - Sine Vibration (flight launch configuration)
      - Boeing supplied test PAF, clamp band
      - Clamp band preload specified by Boeing
    - Acoustic (flight levels, flight configuration)
    - Pyro Shock (flight levels, flight configuration)

Question:3

Mechanical Structural Spacecraft Design

- Procedures (*All available for Red Team Review)*
  - Spacecraft Package Integration Procedure(s)
    - Globally defines steps for proper package integration to ensure proper ESD, contamination, etc. processes are followed.
    - Procedure Number: APL-A-7363-9051
    - Specific procedures written for certain special cases (instruments)
    - Separate and independent mate/de-mate records kept by Mechanical Payload Engineer and Lead Integration and Test Engineer for all items integrated and removed from the Spacecraft

Questions:3,4

Mechanical Structural Spacecraft Design

- Procedures (*continued*)
  - The following list of procedures cover all mechanical events, handling and preparation for specific tests:
    - Spacecraft Static Load Test Procedure, APL-A-7363-9063
    - Spacecraft Vibration Procedure, APL-A-7363-9058
    - Spacecraft Handling Procedure for GSFC, APL-A-7363-9052
    - Spacecraft Acoustic Test Procedure, APL-A-7363-9059
    - Spacecraft Separation/Deployment Shock Test Procedure, APL-A-7363-9061
    - Solar Array Integration Procedure, APL-A-7363-9039
    - Shipping Container Handling Procedure, APL-A-7363-9040
    - Spacecraft Handling Procedure for Vandenberg AFB, APL-A-7363-9392 (Under Review by the Range)
    - Spacecraft Purge System Procedure, APL-A-7363-9319

Questions:3,4

Mechanical Structural Spacecraft Design

- Test Verification Matrix
  - In accordance with the Component Environmental Specification (APL-A-7363-9010 Rev. "A") all spacecraft sub-systems (box level) were subject to sine and random vibration tests
  - Tables 1 and 2 presented in the Pre Environmental Review Summarizes the testing that was performed on the Spacecraft Subsystems and the Instruments. *Note Table 1 is specific to the Spacecraft sub-systems while Table 2 is instrument specific.*

Question:7

Mechanical Structural Spacecraft Design

TABLE 1 SPACECRAFT SUBSYSTEMS

Spacecraft Assembly	Part No.	Serial No.	Sine Vibration	Random Vibration	Test Report
Power Subsystem					
Solar array wing (-X)	7363-0500-09	001	X	X	VTL-R-99-065
Solar array wing (+X)	7363-0500-19	001	X	X	VTL-R-99-067
Solar array drive motors	108935	001 002	X	X	MOOG ATR
Solar array electronics CU	108535	003		X[1]	MOOG ATR
Battery	7363-1500-09	001 002	X	X	VTL-R-99-037
Power system electronics	7363-5000-09	001	X	X	VTL-R-99-030 VTL-R-99-034
Peak power tracker	7363-5200-09	001 002	X	X	VTL-R-99-030
S/A fuse box	7363-5510-09	001 002	X	X	VTL-R-99-030
RF Comm. Subsystem					
RF switch assembly	7363-4140-09	001 002	X	X	VTL-R-99-012
Zenith antenna	7363-1025-09	001 002	X	X	VTL-R-99-005 VTL-R-99-013
Nadir antenna	7363-0154-09	001 002	X	X	VTL-R-99-004
Navigation Subsystem					
GPS antenna	7363-1005-09	001 002	X	X	VTL-R-99-007

Question: 7

Mechanical Structural Spacecraft Design

TABLE 1 SPACECRAFT SUBSYSTEMS

Spacecraft Assembly	Part No.	Serial No.	Sine Vibration	Random Vibration	Test Report
Attitude Subsystem					
Star tracker	AST-201	001 002	X_2	X	Lockheed Martin ATR
Reaction wheels	Type-B RWA	76831 76832 76833 76834		X_1	ITHACO ATR
Torque rods	TR100UPR	76638 76639 76640		X_1	ITHACO ATR
Inertial reference unit	YG9666EC1	51 52		X_1	Honeywell ATR
Attitude interface unit	7363-2000	001	X	X	VTL-R-99-021
Flight computer	7363-2400	001 002	X	X	VTL-R-99-010 VTL-R-99-016
Magnetometer sensor & elec.	QFM-600-000ES	TIM-002 Sor-116	X	X	VTL-R-98-004
Sun sensor	7363-1600-09	001 002 003 004	X	X	VTL-R-98-056
Integ. Elect. Subsystem					
Integrated elec. module	7363-2100-09	001 002	X	X	VTL-R-99-017 VTL-R-99-025 VTL-R-99-023
Remote interface unit	7363-2500-09	110/120 111/121 112/122 113/123 114/124	X	X	VTL-R-98-044
Instrument Subsystem					
Optical bench	7363-0900-09	001	X	X	VTL-R-99-007

Notes: 1.) ATR, denotes supplier's Acceptance Test Report
2.) X_1 Used the initial random vibration test level of 14.1 $g_{(rms)}$
3.) X_2 Performed sine burst at 25 Hz in lieu of the specified sine sweep test.

Question: 7

Mechanical Structural Spacecraft Design

TABLE 2 SPACECRAFT INSTRUMENTS

Instrument	Part No.	Serial No.	Sine Vibration	Random Vibration	Test Report
Global Ultraviolet Imager (GUVI)					
HV power supply	7366-4300	001 002	X	X	VTL-R-99-014
SIS electronics	7366-3950	001	X	X	VTL-R-99-014
SIS Instrument	7366-3000	001	X	X_1	VTL-R-99-014 VTL-R-99-024
Detector tube assembly	7366-4400	001 002	X	X	VTL-R-99-014
Focal plane electronics	7366-4200	001 002	X	X	VTL-R-99-014 VTL-R-99-064
Solar EUV Experiment (SEE)					
SEE Instrument	20550-1-0119-01	001	X	X_2	LASP 20550-0-0007
Sounding of the Atmosphere using Broadband Emission Radiometry (SABER)					
SABER Instrument	XXXX	001	X_3	X_{31}	SDL /99-35 Appendix 12
TIMED Doppler Interferometer (TIDI)					
TIDI Telescopes	7372-000-09 7372-000-19 7372-000-29 7372-000-39	001 002 003 004	X	X_4	VTL-R-99-001 VTL-R-99-003 VTL-R-99-007 VTL-R-99-009 VTL-R-99-016 VTL-R-99-036 VTL-R-98-063
TIDI Profiler**	055-0101	001	X_{41}	X_{42}	VTL-R-99-031 VTL-R-99-032 VTL-R-99-038 VTL-R-99-040 VTL-R-99-045 VTL-R-99-048 VTL-R-99-056
TIDI Electronics	055-0102	001	X	X	VTL-R-99-031

Notes;

1.) X_1 Tube failure required re-qualification of SIS instrument.

2.) X_2 A failure in XPS filter wheel motor caused the XPS to be re-qualified. After minor rework to the micro-processor and the GCI's the instrument was subjected to a workmanship test at –3 dB from proto-flight levels.

3.) X_3 The test inputs were limited the scanner response to 14.0g's

4.) X_{31} The test was limited to a response of 14.0 g_{rms} clipped responses with a (Q) greater than (2), primarily due to fixture resonance

5.) X_4 The initial testing showed significant elevation and azimuth shifts

6.) X_{41} Reduced sine sweep test levels to coupled loads times 1.25

7.) X_{42} Modified the random vibration levels above 300 Hz, based on modeling and previous spacecraft acoustic tests.

8.) ** SPRL has requested a waiver for the TIDI profiler. This waiver will exempt the TIDI profiler from the spacecraft acoustic, shock and vibration tests. These tests will be performed using a simulated mass.

Question: 7

Mechanical Structural Spacecraft Design

- Test Results
  - Summary Memo, SEM-00-1-1560, Dated Feb. 14, 2000

    Available for the Red Team Review

Question: 4

Mechanical Structural Spacecraft Design

- Open Issues and Concerns
  - None
- Residual Risk
  - None, the fully populated Spacecraft Structure, Optical Bench and the Solar Array system have successfully and smoothly passed all environmental testing which is expected to be more challenging than the environment.
- PFR's, RFA's
  - None

Question:13

Solar Array
Mechanical
Design, Development and Qualification Program

Steven R. Vernon
TIMED Payload Mechanical Engineer
TIMED Solar Array Lead Engineer

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Solar Array Development and Deployment Testing

- *Spacecraft Preliminary Design Review (2/19/97)*
  - Review #2 of the Solar Array Sub-system
  - Solar array subsystem reviewed at the Spacecraft system level review
  - Purpose:
    - To ensure top level requirement flow-down had been accurately performed and all the various teams (Spacecraft, sub-system, instrument, etc,) were aware of all the requirements and concerns across all of the disciplines
    - To ensure schedule and technical concerns were accounted for
    - Present the baseline design and the decision process that resulted in the design presented

Questions:1, 2

Solar Array Development and Deployment Testing

- *Spacecraft Preliminary Design Review (2/19/97)*
  - Review Panel Members:

• Eric J. Hoffman (Chairman)	Chair, Systems	(APL)
• Mary C. Chiu,	Systems	(APL)
• Laurence J. Frank	C&DH, Systems	(APL)
• Dr. Edward Gaddy,	Power	(NASA/GSFC)
• Dr. Robert E. Gold,	Instrumentation	(APL)
• Richard K. Huebschman,	RF, Systems	(APL)
• Thomas H. Stengle, III		(NASA/GSFC)
• John J. Wolff		(NASA/GSFC)
• James W. Woods,	Mechanical-Structures	(NASA/GSFC)

Solar Array Development and Deployment Testing

- *Spacecraft Preliminary Design Review (2/19/97)*
  - Summary Documentation
    - Viewgraphs of all information presented at the review is available for review
    - Brief summation of the content of the material *presented* is as follows:
      - Summary of requirements :As currently understood by the design engineering team
      - Trade Studies Performed: Including the criteria used for evaluation of the various design options considered during the said trade studies
      - Baseline Design: Presented as a result of the above said trade studies performed
      - Test and Qualification Plan: First top level plan presented to the team for the development and qualification

Questions:1, 2

Solar Array Development and Deployment Testing

- *Spacecraft Preliminary Design Review (2/19/97)*
  - Summary Documentation (continued)
    - Viewgraphs of all information presented at the review is available for review
    - Brief summation of the content of the material *presented* is as follows (continued):
      - Analysis Performed and Presented
        - » Array Requirements, design loads, launch and deployed
        - » Margins of Safety
        - » Primary Modes
        - » Actuator, torque margins, etc
        - » Dynamics Analysis, deployments

Questions:1, 2

Solar Array Development and Deployment Testing

- *Solar Array Engineering Design Review (7/19/97)*
  - Review #3 of the Solar Array Sub-system
  - Detailed technical review of Flight Design
  - Review Panel Members,organizations, disciplines:
    - Mike Butler, APL, Power System Lead
    - Glen Cameron, APL, Mission System Engineer
    - Thomas Coughlin, APL, Manager of Programs
    - Roger Farley (**NASA/GSFC Code 722**), Mechanical Engineer
    - Dave Grant, APL, Program Manager
    - Ken Harclerode, APL, Lead Designer
    - Mark Harold, APL, MGSE Engineer
    - Stan Kozuch, APL, Integration and Test
    - David Kusnierkiewicz, APL Spacecraft, System
    - Larry Mastracci, APL, Quality Control
    - David Persons, APL Mechanical analyst, dynamics and stress
    - Neal Primm, APL, Spacecraft Lead Designer
    - Ed Schaefer, APL, Structural Engineer
    - William Skullney, Mechanical Group Supervisor
    - Steve Vernon, APL, TIMED Mechanical Payload and Solar Array lead engineer
    - Bruce Williams, APL, Spacecraft and Solar Array Thermal Engineer
    - John Wolff (**NASA/GSFC, Code 490.0**), Program Manager
    - Jim Woods (**NASA/GSFC, Code 722.0**), NASA Mechanical Mechanism Specialist

Questions:1, 2

Solar Array Development and Deployment Testing

- *Solar Array Engineering Design Review*
  - Summary Documentation
    - Viewgraphs of all information presented at the review is available for review
    - Brief summation of the content of the material *presented* at the review is as follows:
      - Requirements and changes since PDR
      - Mechanical Design
        - » All mechanisms, materials, finishes and coatings, etc.
      - Dynamics and Stress Analysis Performed to date
      - Engineering Model
        - » Testing
        - » Correlation to the Flight Article (dynamics, inertias, materials, mechanisms, components, etc.)
      - Schedule and Status
      - Issues and Concerns

Questions:1, 2

Solar Array Development and Deployment Testing

- *Solar Array Engineering Design Review*
  - RFA Summary Status
    - 11 RFA's generated as well as 5 very good suggestions
    - All RFA's (and suggestions) closed as answered in APL memo number: SEM-2-781 dated November 10, 1997

Memo summary follows in the next few slides

Question:#9

Solar Array Development and Deployment Testing

Action Number	Subject	Assignee	Due Date	Description	Response
1	Hinge	D. Persons	09/01/1997	Determine if axial thermal growth can be accommodated by the hinge without harm to the damper. The damper shaft needs to be isolated from thermally induced axial loads and in pure torsion only. Determine the magnitude of those loads generated by thermal growth.	The hinge now incorporates a joint best described as a pin in a slot. This joint will transmit torque and allow axial movement due to temperature gradients thus eliminating loads upon the damper rotor.
2	Yoke	S. Vernon	09/01/1997	Investigate the possibility of providing a keeper on the negator spring to negate possible movement during the launch environment.	A keeper will not be incorporated for the negator spring. More than sufficient force is inherent within the spring to keep it in place during launch and integration activities.
3	Substrate	D. Persons/S. Vernon	09/01/1997	Investigate the "over-constrained" panel support "ball and sockets" to determine if a kinematic mount type of system is more advantageous.	A flexure mounting system is in design and will be incorporated in both the EngineGround straps and other APL "standard" methods will be incorporated to ensure electrical bonding.ering model and Flight hardware.
4	Substrate	S. Vernon/M. Butler	09/01/1997	Ensure that electrical bonding requirements are understood and provide a design to meet these requirements. Specifically, electrical bonding of face sheets to post cured potted inserts and panel to panel bonding.	Ground straps and other APL "standard" methods will be incorporated to ensure electrical bonding.
5	SADA	D. Persons/S. Vernon	09/01/1997	Perform the planned detailed thermal analysis required to ensure that thermal gradients across the SADA bearing (Solar Array Drive Assembly) do not adversely degrade the motor performance in orbit.	The thermal analysis has been performed by Bruce Williams (TIMED Lead Thermal Engineer) and has resulted in a 37 degree C maximum time dependent gradient. Schaeffer Magnetics representative C. John Lo has indicated the gradient presents no problem. Schaeffer will open the bearing clearances slightly to prevent binding. This action is acceptable since there are no strict pointing requirements on the arrays.

Question: #9

Solar Array Development and Deployment Testing

Action Number	Subject	Assignee	Due Date	Description	Response
6	Dampers	D. Persons/S. Vernon	09/01/1997	Determine if dual dampers at each hinge line (excluding the yoke) are required (as opposed to one) and that the presence of 2 vs. 1 dampers do not adversely affect the reliability.	The dual damper (per hinge line) design has been replaced with a single damper and torsion spring assembly. The opposing member is now baselined to be a hinge without a torsion spring. To clarify this topic further, the Engineering model will initially use a torsion spring hinge assembly without a torsion spring and damper since the hardware is already fabricated. As the new pivot hinge design comes on line, it will be incorporated into the Engineering model to maintain the high fidelity desired in the Engineering model testing. This change was made possible by the completion of the harness design. The estimated torques are now lower than originally estimated.
7	Release Assembly	D. Persons/S. Vernon	09/01/1997	Investigate moving the separation nut to the Spacecraft side as opposed to the outer panel side.	This item has been investigated thoroughly. An acceptable and reliable design (with the nut on the Spacecraft side) can not be accomplished and thus, the low shock (Hi-Shear 9400 series) separation nut will remain where it is.
8	Release Assembly	D. Persons/S. Vernon	09/01/1997	Determine the materials and surface treatments on the "cup and cone" and "ball and socket" assemblies. A Tufram coating and a 30 degree cone was suggested.	The "cup and cone" design has been replaced with a flexure mount system as outlined in AI#3 above. The materials in contact are magnesium to magnesium" and titanium(Tiodized) to magnesium. The magnesium components are irridited with a "hard" irridite per MIL-M-45202, Type 2, Class A, Grade 1.

Question: #9

Solar Array Development and Deployment Testing

Action Number	Subject	Assignee	Due Date	Description	Response
9	Testing	D. Persons/S. Vernon	09/01/1997	Explain and justify the complete testing program planned for both the Engineering Model as well as the Flight Model: 1. Specifically explain the Spacecraft System level testing plan, field operations and testing, etc. Specifically, create a test/element diagram: 2. Explain and more fully justify why complete deployment testing (not release only) of each array wing is not planned while the Array wings are physically mounted to the Spacecraft.	A. See attached test matrix chart included at the end of this document. A change from the EDR is that the Flight array wings (each) will undergo a full level vibration test as an assembly. This change was dictated by the need to limit the Spacecraft vibration levels during SC level per Ed Schaefer.B. See attached TIMED Spacecraft PDR action item #7 memo (SEM-2-779) dated October 30, 1997 for a detailed answer to this item.
10	Testing	D. Persons/S. Vernon	09/01/1997	Determine if the planned release tests and the subsequent re-assembly of the system at the Spacecraft level will adversely impact the SADA in a 1G environment.	The type 3 Schaeffer Drove motor can support the following shaft loads:Axial= 2500 pounds, Transverse = 2100 Pounds, Moments = 1800 in. Pounds. The situation has been analyzed and these allowable loads will not be exceeded by the arrays in the stowed condition during integration and testing activities nor in release tests at the Spacecraft level.
11	Release Assembly	D. Persons/S. Vernon	10/01/1997	Determine the effect, if any, of an asymmetric release of a wing.	The analysis completed to date indicates that asymmetric release will not adversely impact the wing deployment however, asymmetric testing will occur during the engineering model testing to further validate this analysis.
S1	SADA			GSFC Engineers suggested that APL closely monitor the Schaeffer Magnetics contract to ensure proper Quality Assurance plans are met due to previous GSFC experience with personnel turnover at the Schaeffer facility.	APL agrees and will closely monitor the contract. Al Sadilek has been assigned to this task.
S2	Substrates			GSFC engineers suggested alternative form of edge treatments be investigated for the substrates. The APL baseline was Kapton tape.	The APL baseline continues to be Kapton tape. APL engineers feel comfortable with this treatment due to extensive flight heritage, experience and low mass.

Question: #9

Solar Array Development and Deployment Testing

Action Number	Subject	Assignee	Due Date	Description	Response
S3	Hinge			APL and GSFC engineers noted that planned mock-ups and testing of the service loops over the hinges had not been started and emphasized that measuring the torque at hot and cold temperatures of the service loops was important..	Wiring harness assemblies are complete and service loop mockups and temperature testing will occur soon
S4	Assembly			APL engineers suggested the development of a vertical assembly fixture for single panel integration to preclude items falling on the cell cover glass when in a flat (table) position	A vertical fixture can easily be designed and will be supplied if required by the Power Systems group. A decision and request for such is needed by June, 1998.
S5	Dynamics			APL engineers suggested that a perturbed spring/damper analysis be performed to demonstrate margin on Spacecraft clearance.	APL engineers agree and will perform said parametric analysis using Working Model software with damper, friction and spring characteristics updated by engineering model testing.

Question: #9

Solar Array Development and Deployment Testing

- *Spacecraft Critical Design Review (12/3/97)*
  - Review #4 of the Solar Array Mechanical Flight Design
  - Final Review prior to flight build
  - Solar array subsystem reviewed at the Spacecraft system level review
  - Purpose:
    - Ensure final Flight Design meets all Spacecraft requirements
    - Ensure Schedules (Spacecraft and Solar Array sub-system) coincide and are compatible
    - Ensure all RFA's generated previously have been answered
    - Ensure Flight qualification and testing program is acceptable to the teams and independent reviewers prior to flight build
    - "Last Call" for design changes and/or requirement revision

Questions:1, 2

Solar Array Development and Deployment Testing

- *Spacecraft Critical Design Review*
  - Summary Documentation
    - Viewgraphs of all information presented at the review is available for review
    - Brief summation of the content of the material *presented* at the review is as follows:
      - Flight design presented with requirements
      - All mechanisms described
      - Summary of all stress and dynamics (deployment) analysis performed
      - Engineering model (full scale) deployment testing (proof of concept) results presented

Questions:1, 2

Solar Array Development and Deployment Testing

- *Spacecraft Critical Design Review*
  - RFA Status
  - RFA#22: Shaft encoders mounted to the Solar Array hinges (ground system testing data collection system) may limit and/or alter the Solar Array hinge freedom. Confirm the difference between ground testing
    - Brief Summary Response:*Deployment tests of the TIMED Flight Solar arrays were performed with and without said shaft encoders present. There were no observable differences noted. Therefore, I consider the above action item closed with the intent of the item satisfied with the satisfactory completion of several actual flight hardware tests.*
  - RFA #28:Conduct an additional Solar Array Deployment/design review
    - Brief Summary Response:*There was no formal independent re-review performed however there were numerous in-house reviews and communications regarding the changes. The program management waived another formal review for the following reasons:*
    - *1. Determination that the APL engineering staff was satisfied with the flight design.*
    - *2. Extensive full scale engineering model testing would reveal deficiencies and would be complete at Spacecraft CDR.*
    - *The Spacecraft CDR (which generated this action item) would again present the flight design* for review.

Question:#9

Solar Array Development and Deployment Testing

- Hardware Test Program
  - Brief History
    - The development of a 4 panel "free deployment" solar array system is not a completely a new one for APL. The SAS series of APL spacecraft developed in the late 1960's era incorporated a free deployment 3 panel system as well. APL engineers realized there may be many variables and unknowns involved in the development of a 4 panel system thus opting to fabricate, develop and test a very high fidelity full scale engineering model system prior to the flight fabrication to dramatically lower the risk. This engineering model system incorporated the same mechanisms, components and ground support handling and deployment equipment that would be used for flight. To assist the reviewer in identifying how all this was accomplished, ie. "just which components were tested, when, how, etc."; the following brief summary is included in the following slides in addition to the testing and verification matrix that will follow

Solar Array Development and Deployment Testing

- Hardware Test Program
  - List of Major Components
    - Substrate (honeycomb panel populated with solar cells)
    - Deployment Hinge(s)
      - Torsion spring design incorporating a viscous damper for rate control
      - Viscous damper, adjustable rate of dampening
    - Release Mechanism
      - Separation nut
      - Instrumented bolt (highly accurate tensile load verification)
      - Bolt retraction mechanism
    - Deployment Yoke
      - Angular contact bearings
      - Constant force spring

Solar Array Development and Deployment Testing

- Hardware Test Program (brief description)
  - Engineering Model Test Program
    - Flight design for the hinges and deployment yoke built to Level 1 drawings. (Level 2 is full configuration control)
    - Only minor changes required to upgrade the designs and drawings for flight level
    - Deployment testing
      - Similar inertias, mass, configuration, harness, mechanisms, etc. to flight
      - Data acquisition system and other mechanical ground support equipment (MGSE) is the same system used for flight qualification
      - Provides accurate data early for dynamics software model development and correlation

Question:#3

Solar Array Development and Deployment Testing

- Hardware Test Program (brief description)
  - Engineering Model Test Program (continued)
    - Thermal-Vacuum Testing Performed
      - Qualified worst case hot and "cold" cases for the following articles:
        - » Release mechanism bolt retraction
        - » Yoke Assembly for thermal clearances
        - » Array wing panel support flexure mounts
    - Thermal Testing Performed
      - Release mechanism (separation nut, pyrotechnic, and bolt retraction mechanism) tested hot and cold worst cases after vibration test
    - Damper Vibration Test Performed
    - Damper Measurements performed, curves generated for applied torque vs. damping rates and temperature variations

Question:#3

Solar Array Development and Deployment Testing

- Hardware Test Program (brief description)
  - Flight Qualification Test Program (sub-assembly level)
    - Deployment Hinge(s)
      - Dampers characterized for each hinge (verified damping rate vs. temperature and applied torque)
      - Dampers X-ray inspection prior to assembly
      - Friction measured for each assembly (assure adequate safety factor and provide input to dynamics software model))
      - Spring torque measured and set
    - Yoke
      - Friction and spring rates measured (assure adequate safety margin and provide input to dynamics software model)
    - Release Mechanism
      - Flight mechanism component level vibration testing and release cold

Question:#3

Solar Array Development and Deployment Testing

- Hardware Test Program (brief description)
  - Flight Qualification Test Program Performed (Assembly wing level)
    - Full wing (each) Deployment dynamics testing after initial flight assembly
      - *Baseline dynamics performance characteristics established* as captured by the data acquisition system
    - Wing level vibration testing, 3 axis
    - Release mechanism activated after vibration
    - Deployment Testing (verified no changes occurred due to vibration against the baseline)
    - Vibration and acoustic test at the SC level
    - "Pop-n-catch" pyro activated release test at the SC level (2X, each wing)
    - Deployment Testing (verified no changes occurred against the baseline)
    - Flash Testing (electrical performance)
    - Final deployment test (w/o data acquisition equipment, visual verification)
    - Pack for shipment to Vandenberg
    - Visual Inspection and Walkout

Question:#3

Solar Array Development and Deployment Testing

Test Verification Matrix

TIMED Spacecraft												
TIMED Solar Array Testing Plan Chart												
	Engineering Model						Flight Hardware					
Assembly/Component	TV Cold	TV Hot	Vib.	Torque Measure	Release Test	Deployment Dynamics	TV Cold	TV Hot	Vib.	Torque Measure	Deployment Dynamics	Release Test
Hinge Assyw/damper, spring)	Performed	Performed		Performed		Performed				05/17/1999	10/13/1999	
Damper(component)	07/27/1997	07/27/1997	03/18/1998	Performed		Performed	12/21/1998	12/21/1998		05/17/1999	10/13/1999	
Spring (component)				Performed		Performed				05/17/1999	10/13/1999	
Release Mechanism Assy						Performed	07/23/1997	07/23/1997	07/20/1999		10/13/1999	10/31/1999
Separation Nut							07/23/1997	07/23/1997			10/13/1999	10/31/1999
Ball & Socket							07/23/1997	07/23/1997			10/13/1999	10/31/1999
Support Flats							07/23/1997	07/23/1997			10/13/1999	10/31/1999
Retraction Mechanism Assy.											10/13/1999	10/31/1999
Yoke Assembly	Performed	Performed		04/15/1998	11/24/98 Hot and Cold	05/22/1998	05/03/1999	05/03/1999		04/28/1999	10/13/1999	10/31/1999
Bearings				04/25/1998			05/03/1999	05/03/1999		04/28/1999	10/13/1999	10/31/1999
Negator Spring				04/25/1998			05/03/1999	05/03/1999		04/28/1999	10/13/1999	10/31/1999
Harness				04/25/1998			05/03/1999	05/03/1999			10/13/1999	10/31/1999
Service Loop				X (hot&cold)		05/22/1998			10/13/1999	05/03/1999	10/13/1999	10/31/1999
Inter-Panel Harness				X (hot&cold)		05/22/1998			10/13/1999	05/03/1999	10/13/1999	10/31/1999
Complete Array Wing						05/22/1998			10/07/1999		10/13/1999	10/31/1999

Question: #3

Solar Array Development and Deployment Testing

- Additional Testing and Handling Events
  - Flash Testing and Cell Re-work, *Completed September/00*
    - See electrical presentation for performance data
  - QA Inspection :*Completed September 26, 00*
  - Final deployments: *Completed September 26, 00*
  - Yoke service loop testing : *Completed September, 00*
  - Package for shipment to Vandenberg , *Completed, October 17, 00*
  - Visual Inspection (Vandenberg)
  - Walkout Test (Vandenberg)
  - Spacecraft Integration

Solar Array Development and Deployment Testing

- Open Issues and Concerns
  - None
- Residual Risk
  - Damper Failure:
    - Mitigation Plans
      - Extensive flight history on other programs
      - Identical design used for other successful programs
      - Heaters used to ensure proper operating temperatures and replicate ground deployment temperatures

TIMED TESTING at APL Environmental Test Facility

CHAMBER	SEM ENGINEER	LEAD ENGINEER	DESCRIPTION	START	TEST No./Report	DAYS	TECH
TIMED Spacecraft Components							
Thermotron	Williams	Schaefer	IEM Engrg Boards Thermal Cycling	30-Jun-97	**SSL97-020**	9	DRM
VEECO-II	Williams	Powers	Card-Lock Engrg TV	26-Jan-98	**SSL98-004**	5	AJS
EAST	Williams	Williams	Work Battery EM Thermal Balance TV	09-Feb-98	**SSL98-001**	11	AJS
VEECO-II	Williams	Colby	Arming Plugs Bakeout	14-Apr-98	**SSL98-016**	2	AJS
VEECO-II	Williams	Colby	Safing Plugs Bakeout	26-Apr-98	**SSL98-017**	2	AJS
VEECO-II	Williams	Williams	Damper EM TV	01-Jun-98	**SSL98-021**	2	AJS
VEECO-II	Williams	Colby	G&C 1553 Harnesses Bakeout & TV	10-Jun-98	**SSL98-026**	3	AJS
VEECO-II	Williams	Colby	C&DH 1553 Harnesses Bakeout & TV	24-Jun-98	**SSL98-029**	2	WFH
WEST	Williams	Williams	SOLAR PANELS EM TV	05-Aug-98	**SSL98-034**	3	WFH
EAST	Williams	Colby	FLT Spacecraft Harness Bakeout	25-Aug-98	**SSL98-039**	2	AJS
EAST	Williams	Vernon	FLT Spacecraft Structure Bakeout	08-Sep-98	**SSL98-042**	3	DRM
3D3	Williams	Reiter	FLT RIU's (two sets of 8) TV	19-Oct-98	**SSL98-054**	5	AJS
Thermotron	Williams	Vernon	FLT Star Camera Brackets Temp Cycling	04-Nov-98	**SSL98-060**	2	DRM
EAST	Williams	Butler	FLT Battery Sleeves (52) Bakeout	17-Nov-98	**SSL98-065**	1	AJS
VEECO-I	Williams	Coopersmith	FLT RF CABLES BAKEOUT	23-Nov-98	**SSL98-068**	2	AJS
WEST	Williams	Vernon	Yoke EM TV	23-Nov-98	**SSL98-052**	3	DRM
WEST	Williams	Butler	FLT Sun Sensors TV	30-Nov-98	**SSL98-061**	5	DRM
Env Testing	Williams	Schaefer	FLT Optical Bench Thermal Mapping	01-Dec-98	**VTL98-055**	3	RLT
EAST	Williams	Coopersmith	GS ITEMS - BAKEOUT	04-Jan-99	**SSL99-001**	3	WFH
EAST	Williams	Stilwell	ALL FLT Antennas TV	01-Feb-99	**SSL99-007**	4	AJS
Thermotron	Williams	Timken	PSE/DIST & PPT Converters Thermal-1	08-Feb-99	**N/A**	5.5	
3D3	Williams	Perschy	FLT Computer A TV	22-Feb-99	**SSL99-012**	3	WFH
VEECO-II	Williams	Bokulic	FLT RF Switch Assys (2) TV Tests	01-Mar-99	**SSL99-018**	5	DRM
Env Testing	Williams	Schaefer	FLT Optical Bench Thermal Mapping	08-Mar-99	**SSL99-016**	4	AJS
VEECO-I	Williams	Coopersmith	FLT RF SWITCHES BAKEOUT	11-Mar-99	**SSL99-019**	1	AJS
EAST	Williams	Coopersmith	FLT ANTENNAS/COUPLERS BAKEOUT	12-Mar-99	**SSL99-020**	2	DRM
EAST	Williams	Coopersmith	FLT OPTICAL BENCH BAKEOUT	15-Mar-99	**SSL99-028**	6	DRM
Thermotron	Williams	Timken	PSE/DIST BOARDS THERMAL CYCLING	16-Mar-99	**SSL99-023**	2	WFH
EAST	Williams	Marth	IEM FLT-2 Unit TV	29-Mar-99	**SSL99-026**	11.5	WFH
Thermotron	Williams	Timken	PSE/DIST & PPT Converters Thermal-2	30-Mar-99	**N/A**	5.5	
3D3	Williams	Perschy	FLT Computer B TV	30-Mar-99	**SSL99-027**	3	AJS
EAST	Williams	Kennedy	FLT AIU Unit TV	06-Apr-99	**SSL99-029**	4	DRM
EAST	Williams	Coopersmith	FLT RF Couplers Bakeout	19-Apr-99	**SSL99-032**	4	WFH
WEST	Williams	Marth	IEM FLT-1 Unit TV	28-Apr-99	**SSL99-034**	5	WFH
Thermotron	Williams	Timken	PSE/DIST BOARDS THERMAL CYCLING	10-May-99	**SSL99-035**	2	WFH
3D3	Williams	Coopersmith	FLT RF Couplers Bakeout	10-May-99	**SSL99-037**	4	AJS
WEST	Williams	Temkin	FLT PSE/DIST & PPT Converters TV	07-Jun-99	**SSL99-039**	20	AJS
WEST	Williams	Butler	FLT Battery TV	23-Aug-99	**SSL99-040**	5	DRM
Thermotron	Williams	Radford	FLT Star Camera Thermal Cycling	09-Sep-99	**SSL99-051**	2	WFH
VEECO-I	Williams	Williams	FLT Battery MLI Blankets Bakeout	14-Sep-99	**SSL99-052**	2	WFH
3D3	Williams	Coopersmith	New Hat Coupler Bakeout/Cert	27-Sep-99	**SSL99-053**	2	DRM
VEECO-I	Williams	Coopersmith	Cables Bakeout	11-Oct-99	**SSL99-054**	2	DRM
EAST	Williams	Coopersmith	S/C Signature Panel Bakeout	20-Oct-99	**SSL99-055**	2	AJS
EAST	Williams	Coopersmith	Elephant Stand Bakeout	26-Oct-99	**SSL99-056**	2	DRM
EAST	Williams	Williams	FLT MLI Bakeouts	22-Nov-99	**SSL99-058**	2	AJS
WEST	Williams	Vernon	SOLAR ARRAYS VAC TEST	28-Feb-00	**SSL2000-04**		DRM
EAST	Williams	Butler	FLT Spare Battery TV	06-Mar-00	**SSL2000-05**		AJS
VEECO-II	Williams	Timken	PSE/DU TV TEST	12-Jun-00	**SSL2000-12**		DRM
Thermotron	Williams	Timken	PSE Thermal	26-Jun-00	**SSL2000-15**		DRM
WEST	Willaims	Radford	FLT STAR TRACKER TV (Requal)	01-Aug-00	**SSL2000-16**		AJS

TIMED/GUVI							
Thermotron	Ercol	Bernie O	Tube-1 Thermal Cycling	18-Aug-98	**SSL98-038**	1	DRM
Thermotron	Ercol	Bernie O	Tube-2 Thermal Cycling	29-Sep-98	**SSL98-047**	2	DRM
Thermotron	Ercol	Bernie O	Tube-3 Thermal Cycling	10-Dec-98	**SSL98-072**	2	AJS
Thermotron	Ercol	Bernie O	FPEs & ECU Thermal Cycling	15-Dec-98	**SSL98-063**	2	WFH
EAST	Ercol	Bernie O	Electronics Bakeout	17-Dec-98	**SSL98-073**	2	DRM
EAST	Ercol	Bernie O	Tubes Bakeout	17-Dec-98	**SSL98-074**	2	DRM
VEECO-I	Ercol	Bernie O	Tube-4 Bakeout	18-Feb-99	**SSL99-013**	2	AJS
VEECO-I	Ercol	Coopersmith	TEST MLI BLANKETS BAKEOUT	11-Mar-99	**SSL99-021**	2	AJS
WEST	Ercol	Bernie O	GUVI System TV	15-Mar-99	**SSL99-022**	5	DRM
VEECO-II	Ercol	Bernie O	NEW TUBE BAKEOUT SN-	16-Apr-99	**SSL99-031**	1	DRM
VEECO-II	Ercol	Bernie O	TUBE BAKEOUT SN-002	21-Apr-99	**SSL99-033**	2	AJS
VEECO-I	Ercol	Bernie O	TUBE SN002 Re-Bakeout	28-Apr-99	**SSL99-033**	1	AJS
3D3	Ercol	Coopersmith	GUVI Cert/Bakeout	06-May-99	**SSL99-036**	1	DRM
VEECO-II	Ercol	Bernie O	Detector Tube Bakeout	01-Sep-99	**SSL99-049**	1	DRM
Thermotron	Ercol	Bernie O	Detector Tube Thermal Cycling	07-Sep-99	**SSL99-050**	2	AJS
TIMED/TIDI							
Thermotron	Ercol	Ercol	TIDI EM Telescope Thermal	09-Mar-98	**SSL98-010**	5	AJS
Thermotron	Ercol	Ercol	TIDI EM Telescope REV Thermal	14-Apr-98	**SSL98-014**	16	AJS
Thermotron	Ercol	Sholar	TIDI EM Telescope REV Temp Cycling	01-Jun-98	**SSL98-024**	9	WFH
WEST	Ercol	Ercol	TIDI EM Telescope Thermal Balance TV	22-Jun-98	**SSL98-027**	4	WFH
VEECO-I	Ercol	Sholar	COMPONENST BAKEOUT	06-Aug-98	**SSL98-035**	1	AJS
EAST	Ercol	Sholar	TIDI PAINTED PARTS BAKEOUT	16-Sep-98	**SSL98-044**	2	AJS
WEST	Ercol	Sholar	Sunshade/Cover Assemblies TV	19-Oct-98	**SSL98-053**	2	WFH
Thermotron	Ercol	Sholar	Flt Telescope Assy Align/Distort Testing	11-Nov-98	**SSL98-059**	1.5	DRM
VEECO-I	Mehoke	Coopersmith	Cables, MLI - BAKEOUT	20-Jan-99	**SSL99-002**	2	AJS
Thermotron	Mehoke	Mehoke	Telescopes LVDT (4) Temp Test	02-Feb-99	**SSL99-006**	6.5	AJS
VEECO-I	Mehoke	Mehoke	PROFILER MLI BAKEOUT	23-Feb-99	**SSL99-014**	2	WFH
3D3	Mehoke	Mehoke	Telescope TV Test	01-Mar-99	**SSL99-015**	1.5	WFH
Thermotron	Mehoke	Mehoke	TELESCOPE CAL	06-Jul-99	**n/a**	2	
VEECO-I	Mehoke	Mehoke	PROFILER MLI BAKEOUT	14-Jul-99	**SSL99-042**	2	AJS
VEECO-I	Mehoke	Mehoke	MLI BAKEOUT	06-Aug-99	**SSL99-047**	2	WFH
WEST	Williams	Mehoke	TIDI INSTRUMENT TV	09-Aug-99	**SSL99-046**	11	DRM

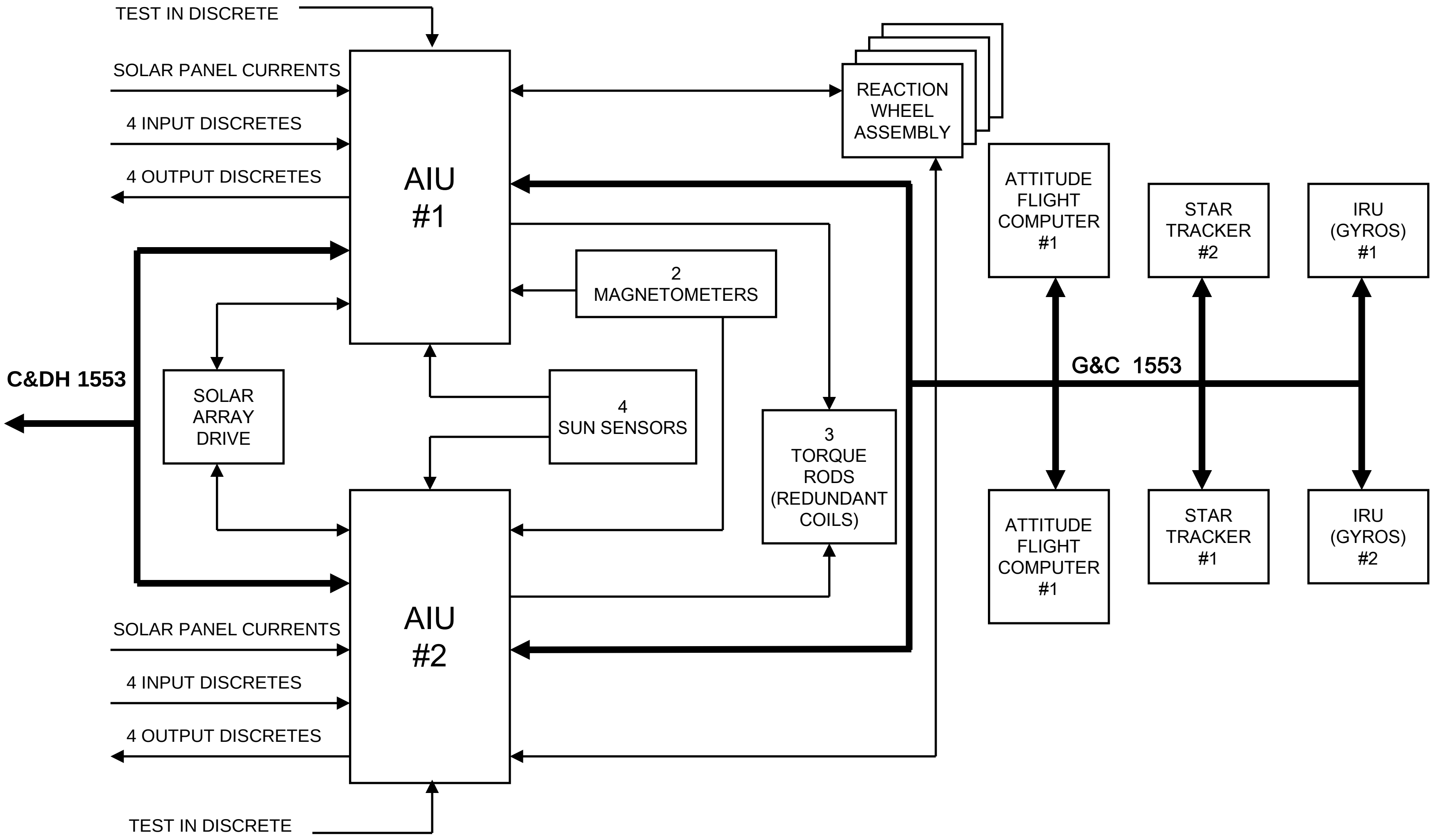
Guidance & Control Subsystem Software

Daniel S. Wilson

Agenda

- **Design Overview (7 slides)**
- **Software Development Approach (7 slides)**
- **Summary of System Level Reviews (5 slides)**
- **Summary of Subsystem Reviews**
  - **AIU Boot (1 slide)**
  - **AIU Application Program (7 slides)**
  - **AFC Application Program (6 slides)**
  - **TASTIE (1 slide)**
- **IV&V(3 slides)**
- **P/FR and SPR Summaries (4 slides)**
- **Residual Risk (1 slide)**

G&C Block Diagram



G&C Processors (1 of 2)

- Attitude Interface Unit (AIU)
  - RTX2010 6 MHz 16-bit processor (no floating point hardware)
  - 128 Kbyte RAM, 128 Kbyte EEPROM, 16 Kbyte PROM
  - 5 one-bit digital input signals (discretes)
    - 2 hard LVSS signals (one from each power system)
    - 2 soft LVSS signals (one from each C&DH)
    - 1 test-in signal enabling certain test mode commands
  - 4 one-bit digital output signals (discretes) to each IEM
    - Heartbeat (toggle)
    - Boot or application program running
    - Active/inactive (in control of wheels and rods)
    - Attitude OK/not OK (i.e., safe mode indicator)
  - Programmed in C and assembly language (FORTH-like)

G&C Processors (2 of 2)

- **Attitude Flight Computer (AFC)**
  - **Mongoose V 12 MHz 32-bit processor**
  - **Extension of MIPS R3000 architecture**
    - **Floating point coprocessor**
    - **Error Detecting and Correcting (EDAC) memory management**
  - **2 Mbyte RAM, 4 Mbyte flash memory**
  - **Programmed in C running under Nucleus Plus real-time operating system**

G&C Computer Software Configuration Items

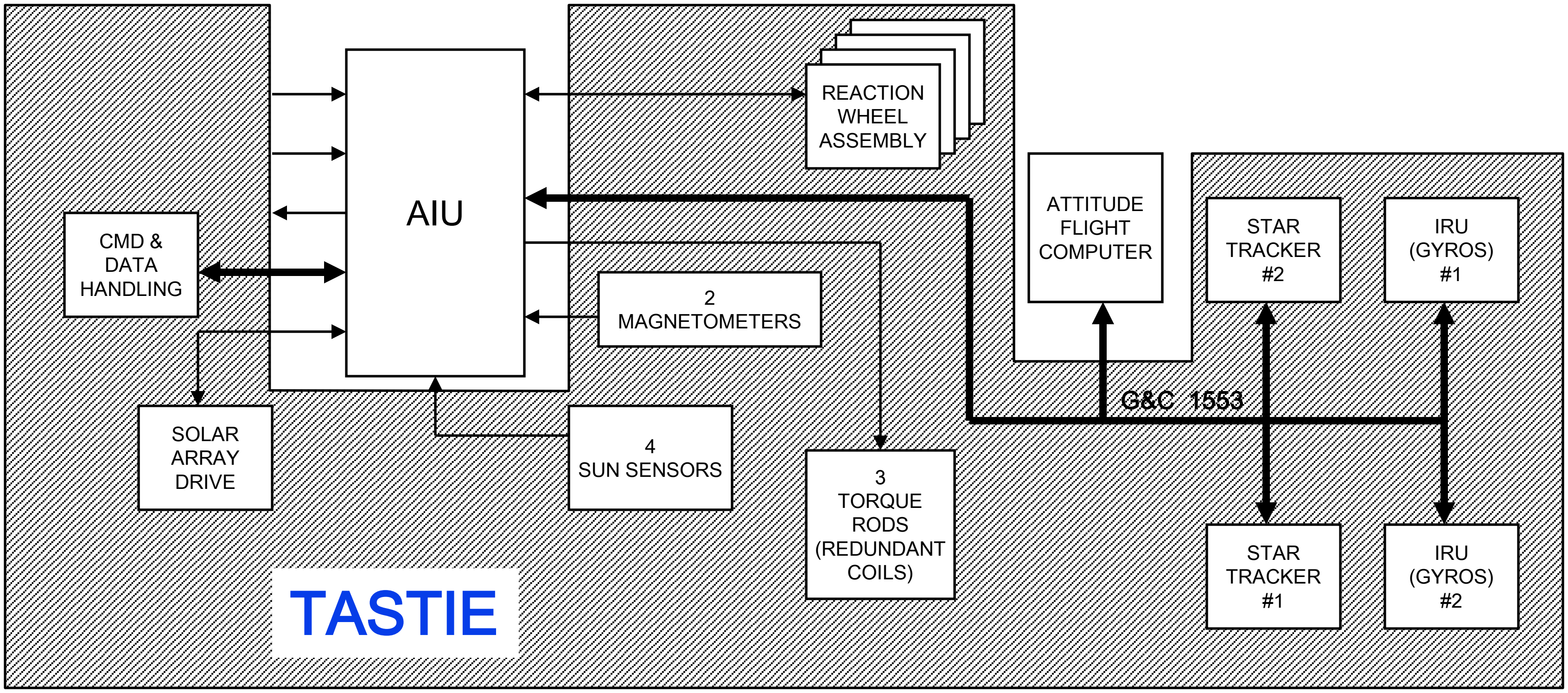
1. Attitude Interface Unit (AIU) Boot Program
   – 2,000 ELOC (56% assembly, 44% C)
2. AIU Application Program
   – 19,000 ELOC (23% assembly, 77% C)
3. Attitude Flight Computer (AFC) Application Program
   – 24,500 ELOC (100% C)
4. TIMED Attitude System Test & Integration Equipment (TASTIE) -- non-flight software for hardware-in-the-loop testbed of the same name

(Common Boot Program covered in IEM presentation)

Question 5

TIMED Attitude System Test & Integration Equipment

Hardware-in-the-Loop Simulator Concept

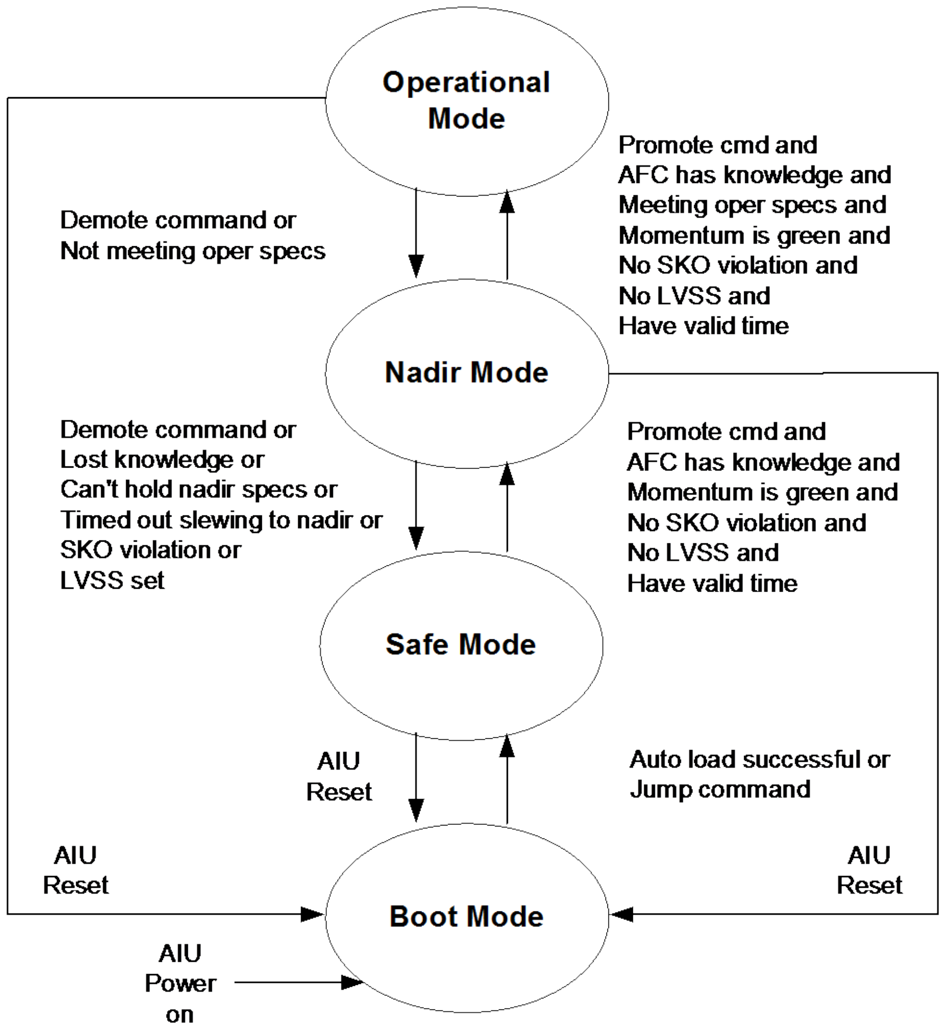


Questions 3, 4

Major G&C Software Requirements and Their Allocation

Requirement	Allocation
1. Be reprogrammable from ground	AIU Boot/Common Boot
2. Detumble s/c following LV separation	AIU
3. Dump momentum via torque rods	AIU
4. Acquire/maintain safe mode attitude	AIU
5. Acquire/maintain nadir/operational attitude	AFC
6. Acquire/maintain offset pointing	AFC
7. Enforce sun keep-out zone	AIU and AFC
8. Manage solar array rotations	AIU and AFC
9. Determine accurate 3-axis inertial attitude	AFC
10. Supply S/C Attitude Message to C&DH	AFC and AIU
11. Perform 180º yaw maneuver every 60 days	AFC
12. Monitor health of sensor/actuator hardware	AIU and AFC

GC Mode Transitions



G&C Software Development Approach (1 of 6)

Classic waterfall modified by Build method:

- Requirements definition phase
  - » Requirements review
- Design phase
  - » Design review
- Implementation phase (repeated for each Build)
  - » Coding
  - » Code/algorithm walkthru
  - » Unit testing
  - » Build integration and testing
- Independent Build testing by IV&V team using TASTIE and wire wrap and/or engineering model processor cards
- Independent release testing by Mission Ops on spacecraft

Questions 3, 4, 5

G&C Software Development Approach (2 of 6)

See G&C Software Development Plan, SRS-96-144 (7363-9103)

What We Said We Would Do for AIU Boot	What We Actually Did
Requirements document	See Doc. #7363-9104
Top-level design folder	None done (heritage from NEAR)
Detailed design document	See on-line repository (no #)
Interface documents	Doc. #7363-9372 and -9373
Requirements matrix	See on-line repository (no #)
User's manual	Combined with AIU appl doc
CM of requirements	Formal CM applied
CM of design and interface documents	Informal CM applied
CM of delivered source code	Formal CM applied
IV&V of requirements and design	Formal reviews w/outsiders held
Code walkthroughs	Walkthroughs performed
IV&V testing	See test report SEI-99-007

Questions 3, 4, 5

G&C Application Software Development Approach (3 of 6)

What We Said We Would Do for AIU Appl	What We Actually Did
Requirements document	See Doc. #7363-9107
Top-level design folder	Yes. Formally reviewed.
Detailed design document	Doc. #7363-9379
Interface documents	Doc. #7363-9372 and -9373
Requirements matrix	Not completed by IV&V team (late start). Informally verified by G&C Lead.
User's manual	Doc. #7363-9374
CM of requirements	Formal CM applied
CM of design and interface documents	Informal CM
CM of delivered source code	Formal CM applied
IV&V of requirements and design	Formal reviews w/outsiders held
Algorithm walkthroughs	Walkthroughs performed
Code walkthroughs	Walkthroughs performed
Independent testing	Both IV&V team and Msn Ops
No maintenance guide	Wrote one. See online repository

Questions 3, 4, 5

G&C Application Software Development Approach (4 of 6)

What We Said We Would Do for AFC Appl	What We Actually Did
Requirements document	See Doc. #7363-9108
Top-level design folder	Yes. Formally reviewed.
Detailed design document	Doc. #7363-9380 not complete
Interface documents	Doc. #7363-9372 and -9373
Requirements matrix	Not completed by IV&V team (late start). Informally verified by G&C Lead.
User's manual	Combined w/ design doc.
CM of requirements	Formal CM applied
CM of design and interface documents	Informal CM applied
CM of delivered source code	Formal CM applied
IV&V of requirements and design	Formal reviews w/outsiders held
Algorithm walkthroughs	Walkthroughs performed
Code walkthroughs	Walkthroughs performed
Independent testing	Both IV&V team and Msn Ops

Questions 3, 4, 5

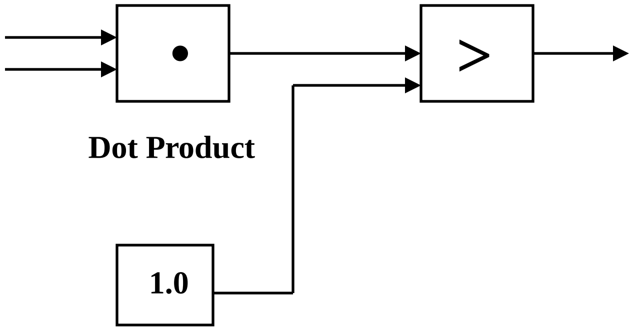
G&C Application Software Development Approach (5 of 6)

What We Said We Would Do for TASTIE	What We Actually Did
Requirements document	See Doc. #7363-9105
Top-level design folder	None done
Detailed design document	See #7363-9106 and online repository
Interface documents	Six documents in online repository
Requirements matrix	None done
User's manual	See online repository
CM of requirements	Informal CM applied
CM of design and interface documents	Informal CM applied
CM of delivered source code	Formal CM applied
IV&V of requirements and design	Formal reviews w/outsiders held
No walkthroughs	Algorithm walkthroughs performed

Questions 3, 4, 5

G&C Application Software Development Approach (6 of 6)

TASTIE, AIU, and AFC make extensive use of 'C' code automatically generated from a Matlab/Simulink model via the Real Time Workshop (RTW) code generator



Question 5

G&C Documents

- G&C Software Development Plan (7363-9103)
- G&C Boot Program Requirements (7363-9104)
- G&C Analyst Algorithm Design (7363-9381—draft)
- G&C Software ICD (7363-9372)
- G&C 1553 Bus ICD (7363-9373)
- TASTIE Requirements (7363-9105)
- TASTIE Functional Configurations (7363-9106)
- TASTIE Hardware Interfaces (7363-9382--draft)
- TASTIE ICDs with MiniMOC, GPS Sim, Solar Array Sim, and Visualizer (no numbers)
- TASTIE Software Design Description (no number)
- AIU Application Program Requirements (7363-9107)
- AIU Boot Program Design Specification (no number)
- AIU Command & Telemetry Specifications (7363-9374)
- AIU Hardware Description (7363-9376--draft)
- AIU Software Design Description (7363-9379--draft)
- AIU Software Maintenance Guide (draft)
- AFC Application Program Requirements (7363-9108)
- AFC Design Specification/Users Guide (7363-9380—draft)

Question 5

Spacecraft PDR (2/97)

RFA's relevant to G&C:

No.	Description	Closing Memo #
15	**Develop attitude knowledge vs science impact assessment**	SRI-00-030
16	**Demonstrate the separation attitude sequence works**	SEE-97-0091
17	**Will power-up of wheels react with LV?**	SEM-1-1509
20	**Does safe mode work in eclipse; does sun vector ambiguity affect thermal state of s/c?**	SEI-97-121

Question 9

Spacecraft CDR (12/97)

RFA's relevant to G&C:

No.	Description	Closing Memo #
1	**Autononmy/safing issues**	SEI-98-091
2	**Detumble/Capture/Battery DOD trades**	SRM-98-045
3	**Define autonomy rules enabled at launch**	SEI-00-035
5	**Updating Test Matrix**	SEI-00-037
6	**Define quantitatively instrument solar illum. restrictions**	SRI-00-029
9	**Checkout of redundant units**	SEA-98-0014
10	**Flight software reviews and configuration management**	SRS-98-129
11	**Common software considerations**	SRS-98-0029
16	**Uploading to processors**	GEC-99-08
18	**RWA power/heat pipe trade**	SEM-98-4-345
23	**Sun safe algorithm using minimum of sensors**	SRM-98-046
26	**"Dynamic interaction" test**	SEI-98-023
36	**Config control for TOPS and TINTS**	SEI-00-012
37	**Deployment from Delta/power generation**	SEM-98-1-1520

Question 9

Post-Delivery Software Review (9/99)

- **Chaired by Chu. No formal review committee.**
- **Reviewed what was delivered, version numbers of all development tools, location of backups, outstanding issues, etc.**
- **No RFA's assigned**

Pre-Environmental Review (10/99)

RFA's relevant to G&C:

No.	Description	Closing Memo #
2	**S/C level testing vs unit testing**	SRS-00-033
12	**AIU memory margin**	SEA-2000-0020

Question 9

Post-Environmental Review (2/00)

RFA's relevant to G&C:

No.	Description	Closing Memo #
4	**Explain and correct ACS bias error**	**SRM-00-052**
5	**Establish parameters to be trended**	**SEA-2000-0024**

G&C Subsystem Reviews -- AIU Boot Program

- **Combined Requirements and Preliminary Design review held 8/97**
  - **Chaired by Utterback. No formal review committee.**
  - **One requirements Action Item assigned**
    1. **Requesting minor editorial changes (closed by SRS-97-124)**
  - **Four design Action Items assigned (all closed)**
    2. **Document outline does not conform to Department guidelines**
    3. **Requesting clarifications and elaborations.**
    4. **Requesting an ICD with the Command & Data Handling subsystem.**
    5. **Requesting more clarifications and elaborations.**
- **Code walkthroughs performed 8/98 to 11/98**

Questions 3, 4, 5, 9

G&C Subsystem Reviews -- AIU Application Program (1 of 7)

Requirements Review held 3/98

- Chaired by Kusnierkiewicz
- Minutes and AI's (39 of them) in SEA-98-0015
- Memo SRM-98-033 closed AI 1
- Memo SRS-98-070 closed AI's 2, 4, 6, 7, 10, 13, and 15-38
- AI's 3, 5, 8, 9, 11, 12, 14, and 39 informally closed
- Requirements document baselined and signed off 4/28/98
- Revision A approved by CCB and published as SRS-99-015 (2/99)
- Revision B approved by CCB and published as SRS-99-065 (5/99)

Questions 3, 4, 5, 9

G&C Subsystem Reviews -- AIU Application Program (2 of 7)

Requirements Review Action Item Summary

1. Consider eliminating “computed” magnetic momentum dumping mode.
2. Consider eliminating “streamed” telemetry format.
3. Is low rate telemetry needed from inactive AIU? From AIU Boot program?
4. Make decision to demote to safe on star camera data dropout selectable.
5. Can we eliminate requirement to make magnetic dipole table uploadable?
6. Make momentum dumping disable flag a command instead of a parameter block.
7. Clarify requirement for one command per second to star tracker.
8. Consider making diagnostic packets distinguishable from regular packets by ApID.
9. Do we need solar array angle calibration parameters?
10. Parameter blocks constrained in length to one telemetry packet if MOC parsing desired.
11. Consider option to load parameters to RAM only.
12. How long can C&DH propagate time before it is invalid to G&C?
13. Identify portions of housekeeping telemetry that can be recorded less often than at 1 Hz.
14. Alert MOPS, power, and thermal that only one magnetometer is nominally powered.

Question 9

G&C Subsystem Reviews -- AIU Application Program (3 of 7)

Requirements Review Action Item Summary

15. Restate format specification as a requirement on AIU, not on ground software.
16. Clarify wording of star tracker requirement.
17. Remove star tracker and command message paragraphs that do not state requirements.
18. Remove or restate as a requirement the paragraph on powering down of C&DH.
19. Add specification for minimum time between rod relay commands.
20. Remove or restate as a requirement the paragraph on command format.
21. Remove or restate as a requirement the paragraph on memory load format.
22. Remove or restate as a requirement the paragraph on ignoring/using AFC control data.
23. RT addresses associated with simulated star trackers and gyros should be disabled for flight.
24. Remove or restate as a requirement the paragraph on control IRU parameters.
25. Remove or restate as a requirement the paragraph on star tracker commands.
26. Clarify spacecraft thermal issue with having both gyros on.
27. Add a command for disabling diagnostic telemetry.
28. Clarify name of buffer holding an orbit’s worth of data.

Question 9

G&C Subsystem Reviews -- AIU Application Program (4 of 7)

Requirements Review Action Item Summary

29. Rename “Resume AFC Override” command. Name is confusing.
30. Add statement that automatic state transitioning can be disabled.
31. Clarify that timeouts lead to demotion.
32. Clarify requirement for uploadable sun keep-out angle.
33. Add statement that mode shall be demoted if maximum nadir pointing error is exceeded.
34. Add statement that only the active AIU controls the solar array rotation.
35. Add requirement for keeping a command history with time tags.
36. Replace “local vertical attitude” with “roll, pitch, and yaw errors.”
37. Add comment for command history packets and streamed diagnostic telemetry packets.
38. Change terminology for sun sensors from hot/cold side to +/-Y side.
39. Consider adding a command to check the state of the test-in discrete.

Question 9

G&C Subsystem Reviews -- AIU Application Program (5 of 7)

Resolution of AIs informally closed:

- AI #3 resolved thru email dialog: Low rate telemetry from inactive AIU is supported. Also, AIU boot detects low rate mode and responds accordingly.
- AI #5 resolved thru email dialog: Table is hard-coded.
- AI #8 resolved following design review: Separate ApIDs used.
- AI #9: Solar array angle calibration parameters not implemented.
- AI #11: All parameters are loaded to RAM only. Separate commands were implemented to save all parameters from RAM to non-volatile memory (flash or EEPROM).
- AI #12: Once valid time is received by AIU, it will propagate forever.
- AI #14: MOPS was made aware that only one magnetometer is nominally on.
- AI #39: State of test-in discrete is available in housekeeping telemetry.

Question 9

G&C Subsystem Reviews -- AIU Application Program (6 of 7)

- **Design Review (combined with AFC) held 7/98**
  - **Chaired by Utterback**
  - **Review team included non-TIMED APL staff**
  - **Minutes and AI's (8 of them) in SOR-98037**

(See details in AFC discussion below)

Questions 3, 4, 5, 9

G&C Subsystem Reviews -- AIU Application Program (7 of 7)

- **Semi-formal algorithm reviews conducted for each of three Builds**
  - Primitive (records lost)
  - Basic 8/98 (Dellinger, Hutton, Strikwerda*, Shapiro, Ray*, Hunt*, Haring, Salada, Wilson)
  - Full 12/98 (Dellinger, Haring, Hutton, Hunt*, Strikwerda*, Wilson)
  - Follow-up on wheel health algorithm 3/99 (Dellinger, Hutton, Ray*, Wilson)

- **Code walkthroughs**
  - Conducted by Shane Hutton from 7/98 to 6/99

***G&C experts from outside the TIMED project**

Questions 3, 4, 5

G&C Subsystem Reviews -- AFC Application Program (1 of 6)

Requirements Review held 5/98

- **Chaired by Utterback**
- **Minutes and AI's (18 of them) in SOR-98028**
- **Memo SRS-98-172 closed all AI's**
- **Requirements document baselined and signed off 10/20/98**
- **Revision A approved by CCB and published as SRS-99-026 (2/99)**
- **Revision B approved by CCB and published as SRS-99-027 (2/99)**

Questions 3, 4, 5, 9

G&C Subsystem Reviews -- AFC Application Program (2 of 6)

Requirements Action Item Summary

1. Autonomy Engineer requested automatic mode promotion capability
2. Correct items on the errata sheet.
3. Add a health monitor telemetry packet.
4. Make sure CUC time is recorded with each anomaly. Put count in housekeeping telemetry.
5. Restate command rate constraints as requirements on AFC, not constraints on ground.
6. Add requirement to support 1553 bus schedule as dictated by bus controller.
7. Correct inconsistency between AIU and AFC requirements documents.
8. Add requirements for memory and timing margins.
9. Define spare parameter blocks, telemetry formats, etc.
10. Add accuracy specification to sensor data time tagging requirement.
11. Clarify requirement for time-tagging of sensor data.
12. Specify memory and timing constraints.
13. Add a requirement for a reason code on mode changes.
14. Add requirement for offset pointing.

Question 9

G&C Subsystem Reviews -- AFC Application Program (3 of 6)

Requirements Action Item Summary

15. Clarify requirement for low rate telemetry packets.
16. Consider adding requirement for rate determination from star tracker measurements.
17. Clarify reason for mode demotion in case of GNS orbit dropout.
18. Clarify the use of the star trackers in the estimation of gyro biases.

Question 9

G&C Subsystem Reviews -- AFC Application Program (4 of 6)

Design Review (combined with AIU) held 7/98 (chaired by Utterback)

- Minutes and AI's (8 of them) in SOR-98037. Resolution given here:
  1. RT addresses for star trackers wrong in Figure 1.1 of G&C 1553 Bus ICD. (Correction made.)
  2. Assign a document number to RTW Design/User's Guide. (Document published as SRS-99-013.)
  3. Consider automatic dump of error buffers to SSR. (AIU does it. AFC does not; it latches the first 20 and maintains the most recent 20.)
  4. How are health functions disabled during launch? (When magnetometers are powered on following separation, health monitoring begins.)
  5. Consider using true-of-date coordinate system for orbit propagation. (J2000.0 mean-of-date used instead.)
  6. Need document on conversion of Simulink diagrams to C code. (M. Salada wrote and published RTW User's Guide and Programmer's Reference. See SRS-99-013.)
  7. Need configuration plan for RTW files. (Date-stamped directories used.)
  8. Consider adding support for real-time decomposition of stream telemetry. (Support not implemented.)

Questions 3, 4, 5, 9

G&C Subsystem Reviews -- AFC Application Program (5 of 6)

- **Semi-formal algorithm reviews conducted in two parts (attitude control and attitude estimation) for each of two builds (Basic and Full). Reviewers names are given in parentheses.**
  - Basic Control algorithms 10/98 (Dellinger, Shapiro, Duven*, Ray*, Hutton, Offenbacher, Frank, Wilson)
  - Basic Attitude estimation 10/98 (Shapiro, Dellinger, Strikwerda*, Englar*, Salada, Haley*, Hutton, Wilson)
  - Full Control algorithms 6/99 (Dellinger, Strikwerda*, Hutton, Ray*, Wilson)
  - Full Attitude estimation 6/99 (Shapiro, Dellinger, Strikwerda*, Hunt*, Wilson)

***G&C experts from outside the TIMED project**

Questions 3, 4, 5

G&C Subsystem Reviews -- AFC Application Program (6 of 6)

- **Semi-formal code walkthroughs conducted**
  - Conducted by other team members, principally Frank, Offenbacher, and Wilson, from 7/98 to 7/99

Questions 3, 4, 5

G&C Subsystem Reviews -- TASTIE

- **Requirements and Functional Configurations review held 8/97**
- **Semi-formal algorithm reviews conducted in two parts. Reviewers names are given in parentheses.**
  - Environment & Dynamics algorithms 6/98 (Dellinger, Shapiro, Duven*, Ray*, Hutton, Offenbacher, Frank, Wilson)
  - Sensors & Actuators 6/98 (Shapiro, Dellinger, Strikwerda*, Englar*, Salada, Haley*, Hutton, Wilson)

***G&C experts from outside the TIMED project**

Questions 3, 4, 5

G&C Flight Software IV&V Tests
(performed on TASTIE HIL Simulator)

1. **AIU detumble and sun acquisition test**
2. **AIU rotisserie mode test**
3. **G&C mode switching test**
4. **AIU miscellaneous failures test (fail sensors and actuators)**
5. **AIU magnetometer noise test**
6. **AFC basic control test (nominal operational mode)**
7. **Yaw maneuver test**
8. **G&C/AFC miscellaneous failures test (fail sensors and actuators)**
9. **Sun keep-out zone test**
10. **Offset pointing test**
11. **Limited control (3 wheels) test**
12. **AIU command and telemetry test**
13. **AFC command and telemetry test**
14. **Star tracker command and telemetry test**

Questions 3, 4, 5

G&C Flight Software Tests Performed on S/C

- **G&C Functional Test**
  - Verify all interfaces functional and cross-strapped
- **G&C Performance Test**
  - Detumble and acquire initial safe attitude
  - Promote to nadir and operational modes, maintain momentum
  - Exercise commands
- **Special Tests**
  - Polarity verification tests
  - Launch countdown, ascent, separation, detumble, acquire safe attitude, wiggle solar arrays, slew to nadir, maintain momentum
  - Yaw maneuver (both ways)
  - Autonomy rules (LVSS, etc.)
  - Thermal Vacuum tests
  - 96-hour mission simulation

Questions 3, 4, 5

TASTIE IV&V

- **IV&V performed on selected models:**
  - **Orbit propagator**
  - **Sun & almanac functions**
  - **Disturbance torques (solar pressure, aero drag, gravity gradient)**
  - **Magnetic field**
  - **Vehicle dynamics**
  - **Star tracker**
  - **Magnetometer**
  - **Sun sensor**
  - **Gyro**
  - **Reaction wheels**
  - **Torque rod**

Questions 3, 4, 5

G&C P/FRs

TSC-020 IRUs toggling on/off. Noise spikes on magnetometer made software declare that LV separation had occurred. Hysteresis added to logic in AIU Build 4.0.

TSC-029 Lost telemetry from AIU #1. Converted to SPR 199.

TSC-037 No telemetry received from AFC. Unable to reproduce. Blamed on bug in Common Boot that was fixed. (See P/FR TSC-041 and SPR 217.)

TSC-046 AIU switching IRUs frequently. Converted to SPR 261.

G&C SPRs: AIU

SPR#	Description	Status	Response
67	Add figures-of-merit to C&DH-to-G&C GNS message	closed	S. Williams made the necessary changes to the C&DH and installed the new s/w on the s/c on 4/15/99. But never confirmed on s/c.
106	Wrong magnetometer alignment in both AIU and TASTIE	closed	W. Dellinger changed presets. Change included in AIU Build 4.00 loaded to s/c on 6/499.
132	Some AIU RTW parameters don't load correctly	closed	M. Salada fixed code generation. Fix incorporated into AIU Build 4.01, loaded on s/c on 8/5/99.
196	Delivery of AIU Build 4.01 to s/c	closed	See SPR for a list of the 15 fixes.
199	Lost AIU data when C&DH switched	closed	P/FR # 29 Fixed in AIU Build 4.01 delivered to s/c on 8/5/99
225	AIU switched IRUs rapidly when bad IRU data was sent	closed	Paul fixed it in AIU Build 4.03, which was installed on s/c on 9/8/99.
261	IRU switching on s/c when using real IRUs	closed	Translated from P/FR 46. Determined that IRU data marked unusable if both mags are off. No change required.
307	AIU didn't toggle wings moving bit	closed	Fixed in AFC Build 4.06 installed on s/c on 11/23/99
416	Momentum management performing poorly	closed	Bug found in compiler. Code changed to work around it. Fix incorporated in AIU Build 4.07.

Question 7

G&C SPRs: AFC

SPR#	Description	Status	Response
133	Some AFC RTW parameters don't load correctly	closed	M. Salada fixed code generation in AFC Build 4.01, loaded on s/c on 7/27/99.
135	AFC drove solar wings to stops when orbit had certain beta angles	closed	W. Dellinger repaired Simulink model in AFC Build 4.01, delivered to s/c on 7/27/99.
142	AFC's cmd counter incremented by 2	closed	S. Offenbacher fixed in AFC Build 4.01, delivered to s/c on 7/27/99.
197	Delivery of AFC Build 4.01 to s/c	closed	Initial release of AFC Build 4 to s/c
198	Delivery of AFC Build 4.02 to s/c	closed	Whole batch of fixes. See SPR.
203	AFC2 did not process commands	closed	Fixed in AFC Build 4.03 delivered to s/c on 8/25/99.
210	AFC jumping, them rebooting	closed	More watchdog refreshes added to AFC initialization code in Build 4.04, installed on s/c on 9/8/99.
226	AFC Build 4.04 delivery	closed	Installed on s/c on 9/9/99.
264	Wrong packet length in AFC headers	closed	Fix delivered to s/c on 10/10 with Build 4.05
282	Can't promote from nadir to oper	closed	Mismatched star tracker alignments in AFC and TASTIE
294	AFC crashed when writing to flash	closed	Fixed in AFC Build 4.06 installed on s/c on 11/23/99
335	AFC att knowledge not tested	open	Made some timing corrections to TASTIE in version 0x7CCC. Found 0.7s orbit time tag error in SC Att msg. Decided not to fix it.
345	AFC crashed when empty cmd pkt sent	closed	Nucleus O.S. bug found and fixed in AFC Build 4.07.
370	Mode bits in SC Att Msg wrong	closed	Bug found and fixed in AFC Build 4.07
400	AFC failed to declare sun keep-out zone violation when sun on +Y side of s/c	closed	3 parameters specified in wrong units (tenths of secs instead of secs). Corrected values loaded on s/c on 7/15/00. Verified in 10/2/2000 launch parameter load.
406	Mag field validity bit wrong in AFC-to-AIU message	closed	Bug found and fixed in AFC Build 4.07

Question 7

G&C SPRs: TASTIE

SPR#	Description	Status	Response
134	Some TASTIE RTW parameters don't load correctly	closed	M. Salada fixed in TASTIE TINTS version 1CCC, loaded on s/c on 6/15/99.
146	TASTIE not detecting IRU power on	closed	Fix delivered to TASTIE 3 (TINTS) on 15 June 1999, version 0x1CCC, RTW version Jun_08_99_01.
147	Torque rod simulation not bringing down momentum	closed	Fix delivered to TASTIE 3 (TINTS) on 15 June 1999, version 0x1CCC, RTW version Jun_08_99_01.
211	TASTIE memory fragmentation	closed	Workaround: reboot TASTIE/TINTS before each test.
296	TASTIE doesn't reconnect to MOC servers after a stream crash	closed	D. Reid provided a script file to restart the socket connections
335	AFC att knowledge not tested	open	Made some timing corrections to TASTIE in version 0x7CCC. Found 0.7s orbit time tag error in SC Att msg. Decided not to fix it.
524	TASTIE time not synced w/ GPS simulator	closed	Fix delivered in version 0x8CCC.

Question 7

G&C Residual Risk

- **Open SPR (#335) raises doubt about attitude knowledge**
  - **Investigation will continue until time bias fully understood**

- **Post-launch software maintenance environment not well-supported**
  - **New versions of Simulink and RTW not backward compatible and old versions not compatible with new version of UNIX**
  - **Unsupported C compiler for RTX 2010 (AIU)**
    - » **Froze versions of development tools**

Question 13

Attitude Control Authority

- **Maximum wheel torque = 0.040 N-m (rated)**
  = 0.055 N-m (measured)
- **Maximum wheel momentum = 16.6 N-m-s**
- **Maximum spacecraft acceleration = ~0.0001 rad/s^2 (per axis)**
- **Maximum spacecraft angular rate about a single axis before wheel saturation = ~1.8 deg/sec**
- **Maximum spacecraft torque = ~[0.034 0.157 0.137] N-m**
- **Maximum momentum storage capability about a single spacecraft axis**
  = [10.5 0 0] N-m-s or
  = [0 49.5 0] N-m-s or
  = [0 0 43.1] N-m-s
- **Maximum disturbance torque < 0.002 N-m**
- **Maximum theoretical torque rod momentum dump rate = 25-30 N-m-s per orbit**
- **Worst case momentum following LV separation = ~[13 6 1] N-m-s**
- **Length of eclipse at beta 0 = 35 minutes**
- **Length of yaw maneuver = 22 minutes**

Examples of Failures Tested by IV&V Team

- Fail (sequentially) each axis of each magnetometer hi/lo/stuck
- Fail (sequentially) each of six torque rods
- Fail (sequentially) each of four wheels
- Fail (sequentially) each of four cells on each of four sun sensors
- Fail (sequentially) each gyro
- Fail each star tracker and both star trackers
- Coast through an AFC reset in operational mode
- No sun observed within N minutes (AIU rotisserie test)
- Yaw maneuver with only 3 wheels
- AFC sun keepout zone violation
- AIU sun keepout zone violation
- Bad commands

G&C Spacecraft-Level Functional Test Summary

- Verify AIU select relays functional
- Toggle all input discretes to both AIUs. Verify at AIU.
- Toggle all output discretes from both AIUs. Verify at IEM.
- Toggle and verify all AIU-controlled relays (IRUs, torque rods, and Solar Array Drives)
- Stimulate each cell of each sun sensor. Verify at AIU.
- Verify proper output range of each magnetometer at AIU.
- Spin each wheel up and measure time to slow down and stop.
- Verify communication to redundant AIU and AFC.
- Verify communication to both IRUs.
- Verify command and telemetry links to both star trackers.

G&C Spacecraft-Level Performance Test Summary

- **LV separation, detumble, and sun acquisition**
- **Fail primary hot-side sun sensor**
- **Slew from safe to nadir attitude and promote to operational mode**
- **Reboot AFC and verify AIU can coast through**
- **Reboot GNS and verify AFC can coast through**

Other Spacecraft-Level G&C Tests

- **AIU command workout**
- **AFC command workout**
- **Offset pointing test**
- **Yaw maneuver test**

Regression Test Suite

- **Bench-level**
  - Safe, nadir, and operational modes
  - Exhaustive command workout test
  - Selected additional tests chosen based on nature of change
- **Spacecraft-level**
  - Functional
  - Performance
  - Command workouts
  - Offset pointing
  - Yaw maneuver

AIU Software Delivery History

Date	Build No.	Description
4/26/99	3.04	First release to s/c to support I&T
6/3/99	4.00	Last Build--full functionality
8/5/99	4.01	SPRs 196 and 199 covered 15 minor fixes detected during code walkthrus and further testing, mostly by IV&V team.
9/8/99	4.03	SPR 225: IRU switching rapidly when bad data sent. Fixed by inhibiting health check until switch is complete.
10/10/99	4.06	Fixed wheel failure detection. Added mag on counters to telemetry.
2/24/00	4.07	SPR 416: Fixed momentum management by implementing a workaround for a compiler bug.

AFC Software Delivery History

Date	Build No.	Description
6/8/99	3.02	
7/27/99	4.01	Early delivery of Build 4. Closes SPRs 133, 135, 142, 197.
8/5/99	4.02	Closed SPR 198 including 12 fixes.
8/25/99	4.03	Full functionality delivered, including yaw maneuver capability. Also fixed SPR 203.
9/9/99	4.04	Closes SPRs 200, 210, and 226.
10/10/99	4.05	Closes SPR 264 and includes launch parameter defaults.
11/23/99	4.06	Closes SPRs 294 and 307.
2/16/00	4.07	Closes SPRs 345, 370, and 406.

TIMED Spacecraft Alignments

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Spacecraft Alignments

- Alignment Process Flow
- Instrument Alignments
- Detailed Alignment Investigations
- Alignment Documentation
- Remaining Alignment Tasks

Alignment Process Flow

- Instrument boresight alignment requirements and error budgets developed in cooperation with APL Instrument managers, TIMED Project Scientist, and Mission System Engineer

Alignment Process Flow (Continued)

- Optical cubes and Alignment Fixtures
  - Specify and procure optical cubes.
  - Calibrate optical cubes at GSFC.
    - Measure orthogonality of all optical surfaces.
    - Distribute optical cubes to instruments & spacecraft.
  - Install master optical cubes on Spacecraft structure and Instrument Bench.
  - Calibrate all Spacecraft alignment fixtures.

Alignment Process Flow (Continued)

- Instrument Alignments
  - Install optical cubes on instrument.
    - Map instrument line-of-sight (boresight) and coordinate system into cube.
    - Monitor shifts in Instrument structure and boresight due to thermal, vibration, and gravity effects by pre- and post-test optical mapping of Instrument .
  - Map attitude systems into reference cubes.

Alignment Process Flow (Continued)

- Spacecraft Level Alignments
  - Input Spacecraft error sources into Instrument alignment error budgets.
  - Shim / shift instruments as required to align boresights within acceptable initial limits.
  - Map spacecraft coordinates and instrument reference cubes into spacecraft master cube.
  - Map attitude devices into S/C master cube.

Alignment Process Flow (Continued)

- Spacecraft Level Alignments (Continued)
  - Perform complete spacecraft optical mappings
    - After initial integration of instruments onto S/C, before exposure to environmental testing.
    - After vibration, before shock and T-V.
    - At the completion of environmental testing.
    - After storage and rework of some instruments.
    - After shipment to Vandenberg AFB.

Instrument Alignments

- TIDI Telescopes - all mappings performed at JHU/APL
- GUVI - Boresight mappings performed at JHU/APL
- SABER - Instrument mappings performed at USU/SDL
- SEE - Instrument mappings performed at LASP/ Boulder
- Lockheed-Martin Star Cameras
  - Boresight Mappings performed at Lock-Mart with APL oversight.
  - +/- 1G, Thermal stability bracket mappings performed at APL
- Honeywell IRU Gyros
  - IRU coordinates mapped into optical reference flats by Honeywell.
  - Mechanical/ optical axes mapped into reference cubes on housing.

Detailed Alignment Investigation

- Star Camera and mounting bracket
  - Perform star camera mapping into its reference cube.
    - Vendor boresight mapping had 350 arc sec thermally-induced error in boresight stability when measured at base of camera.
    - Temperature-based correction reduced error to 8 arc sec.
  - Perform optical mapping of star camera mounting bracket thermal distortion error.
  - Perform +/- 1G optical mapping of star camera mounting bracket distortion.

Detailed Alignment Investigation (Continued)

- Instrument Bench
  - Perform optical mapping of dummy masses into Instrument Bench master optical reference cube
    - +/- 1G mappings used to measure compliance of bench.
      - 1G/0G corrections computed for spacecraft level mappings.
    - Play in kinematic mounting required rework of bearings.
      - Clearances minimized until alignment shifts were acceptable.
    - Optical mappings performed before/ between axes/ after vibration testing of Bench to monitor suspension stability.
  - Perform optical mapping of Star Cameras, TIDI telescopes, and GPS receivers when integrated onto Bench.

Detailed Alignment Investigation (Continued)

- TIDI Telescopes
  - Perform optical mapping of engineering model telescopes.
    - Thermally-induced distortion of telescope/ mounting pedestal detected and minimized through pedestal stiffening/ kinematic mounting.
    - Play in kinematic mounting required redesign of mounting.
      - Clearances minimized until azimuth shifts were acceptable.
    - Optical mappings performed before/ after vibration testing of telescopes to verify boresight stability.
  - Perform +/- 1G mappings to measure telescope compliance.
    - 1G/0G corrections computed for spacecraft level mappings.

Detailed Alignment Investigation (Continued)

- TIDI Telescopes (Continued)
  - Perform boresight mapping of TIDI telescopes when integrated onto Bench.
  - Perform optical mapping of LVDT motion for calibration.
    - Thermally-induced distortion of telescope and shift of LVDT readout mapped over operating temperature range.
    - Corrections sent to Univ. of Michigan SPRL for corrections to telescope pointing commands.
  - Additional mapping using updated LVDT calibrations/ boresight mapping to be performed at Spacecraft level.

Alignment documentation

- Optical Bench thermal testing for estimating its on-orbit performance.
- Results of +/-1G and Pre-Post Vibration mapping of TIMED Instrument Bench.
- Results of the TIDI Telescope LVDT Calibration and Thermal Cycling Mapping.
- Results of Pre-Post Environmental mapping of TIMED GUVI Instrument.
- TIMED Spacecraft Alignment Procedure
- TIMED Spacecraft/ Instrument Bench Optical Cube Mappings
  - (Excel spreadsheet which performs trending of alignments to locate mapping errors and any shifts of instruments or spacecraft structure.)

Remaining Alignment Tasks

- Map the TIDI telescope boresights versus elevation angles at spacecraft level.
- Final Spacecraft level optical mapping at Vandenberg AFB.
- Complete the final alignment report, including corrections for gravity, thermally-induced errors, and boresight offsets of all spacecraft instruments.

TIMED Spacecraft
Launch Vehicle Interfaces

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TIMED Launch Vehicle

- Presentation Outline
  - Brief History
  - Influence on design
  - Interfaces, General, Top Level Description
  - JASON/TIMED Compatibility Issues
  - DPAF And TIMED Interface Tests Performed
  - Review Process and Requirements Flow-down
    - Reviews Held
    - Documentation
    - RFA's
    - Data Exchange
  - Current Status

TIMED Launch Vehicle

- Brief History
  - TIMED was originally slated for a Taurus rocket with a lift mass of 950 Kg. to a 625 km orbit at an inclination of 74.1 degrees. The TIMED APL engineers were then directed to design for either a Taurus or Delta II launch vehicle holding the options for both open as long as possible. Upon notification of the switch (1 week prior to PDR) to a Boeing (formerly McDonnell Douglas) Delta II launch co-manifested with the Jason Spacecraft, the APL team then tailored the design specifically for the lower mass (660 Kg.) and started development of detailed requirements and interfaces for this mission.
- Influence on Design
  - Since the Taurus vehicle and the TIMED Spacecraft were both somewhat immature, the main influence upon the design was the envelope restrictions required to fit both vehicles and mitigation of impacts to the SC design of the reduced mass available if switched from Taurus to Delta. Fortunately APL has a long history of missions on the Delta as thus was quite familiar with the interfaces as well as the vehicle

TIMED Launch Vehicle

- Interfaces, general description
  - Launch Vehicle: Delta II Medium Expendable Launch Vehicle
    - Designation is 7920-10
    - Launch from the Western Test Range Vandenberg AFB
    - 660 Kg. Maximum launch mass at 625 kilometer orbit at 74.1^0 inclination
    - Second Mission using the **D**ual **P**ayload **A**dapter **F**itting (**DPAF**)
  - **P**ayload **A**dapter **F**itting (**PAF**)
    - 3712C Standard Boeing interface
      - APL side of the adapter is mission unique and manufactured by APL
    - 2X, 37 pin umbilical connectors, pull-away at launch (standard)
    - 2X, Separation Switches (APL side of the interface)
  - T=0, Purge Fitting (new development item)
  - T=0, Class 10K Air Conditioning (fairing air and directed DPAF air)

TIMED Launch Vehicle

- Jason/TIMED Compatibility Issues
  - Contamination and Mitigation Plan
  - RF Susceptibility
  - DPAF Interface Tests, fit checks, etc. performed
  - Thermal

TIMED Launch Vehicle

- Jason/Timed Compatibility Issues (cont.)
  - Contamination and Mitigation Plan
    - Jason is Class 100K, TIMED is 10K implementation with a requirement of a 750A level surface contamination limit
    - Payload Processing Facility (PPF) maintains complete isolation between the payloads
    - DPAF encapsulation in the PPF run under class 10K rules until TIMED is contained within the DPAF
    - DPAF contamination barrier between the payloads
    - Outer DPAF surfaces covered (2 layers) scrim until removed at the pad
      - Keeps particulates from collecting immediately outside TIMED DPAF
    - JASON performs inspection, cleaning if required, certifies cleanliness prior to mating with DPAF
    - Environment ***outside*** the DPAF becomes 100K for Jason mating, DPAF ***internal*** environment maintained at 10K up to and thru launch
    - DPAF TIMED AC maintains positive internal pressure majority of the time then access holes covered when AC is terminated
    - TIMED under continuous GN_2 Purge

TIMED Launch Vehicle

- RF Susceptibility
  - Boeing RF susceptibility analysis determined a possible hazardous environment may exist to TIMED when Jason transmits S-Band inside the fairing
    - TIMED determined the SC was not susceptible to damage
      - Primary Concern: TIDI Instrument pyro circuits
        - » APL performed test on Engineering model telescope and determined no such hazard existed
        - » Communicated to Boeing and NASA/KSC
      - Secondary Concern: TIMED RF receivers
        - » APL analysis indicates no concern
        - » Pad RF compatibility test planned
      - Third Concern: JASON transmission after JASON deployment
        - » APL analysis indicates no concern

TIMED Launch Vehicle

- DPAF and TIMED Interface Tests Performed
  - Boeing supplied 3712C Test PAF and clamp-band
    - APL installed and fit properly for Spacecraft sine vibration
      - No separation switches, springs, umbilical connectors, etc.
    - Test PAF and band used for acoustic test at GSFC
    - Test PAF and clamp-band installed by APL and Boeing for Pyro Shock testing (post acoustic) at GSFC, 2X
  - Flight PAF
    - Fit check performed at GSFC 11/18/99
      - Outstanding results, no shimming, gapping and other parameters all well within tolerances
      - AC duct location, orientation and hose placement acceptable
      - T=0 purge fitting, push-off spring brackets, separation switches, umbilical connectors and bracket mates acceptable
      - DPAF harness electrically checked out
      - Boeing Issued Summary Report Memo

Question: #4

TIMED Launch Vehicle

- Thermal
  - Thermal environments supplied by Boeing to APL for evaluation and analysis:
    - Pad
      - T=0 AC for JASON, TIMED (DPAF) and TIMED Battery
    - Launch
    - Cruise (all phases)
      - SC orientation and thermal environment analyzed during the JASON events
      - SC orientation and thermal environments analyzed during the TIMED mission phase and events
  - Conclusion: Environments understood and accepted based upon APL analysis performed

TIMED Launch Vehicle

- Review Process
  - Mission Integration Reviews
    - 2X/year on average
    - Meeting minutes recorded and distributed
    - RFA's assigned, tracked from program inception
    - RFA list, *Available for Red Team Review*
  - Teleconferences
    - As needed basis, usually 2 week intervals, now occur weekly
    - Minutes kept and distributed, *Available for Red Team Review*
    - RFA list added to/updated, etc., *Available for Red Team Review*
  - Requirement Flow Down (*All Available for Red Team Review)*
    - Spacecraft questionnaire 12/97
    - APL TIMED Launch Vehicle Interface Document (APL-A-7363-9030 dated 12/15/97
    - Mission Specification

Questions:1, 2, 9

TIMED Launch Vehicle

- Data Exchange
  - Coupled Loads
    - Spacecraft Math Models
      - Model Reduction: APL submits the full math model to Swales for reduction (Craig Bampton)
      - Swales Submits to KSC-Boeing for coupled loads runs
      - First Submittal: 31 October 1997 to support the first Design Loads Cycle analysis, results were delivered to NASA on 1/2398
      - Second Submittal:01 December 1998 to support the Interim Loads Cycle analysis results were delivered to NASA on 4/6/99
      - Third Submittal:01 August 1998 (same model as second submittal) to support the Verification Loads Cycle analysis, results were delivered to NASA on 10 12/1099
  - Spacecraft Environmental Test Summary

Question: #3

TIMED Launch Vehicle

- Current Status:
  - Mission Specification-*Captures all mission unique LV requirements as well as general payload requirements*
    - Signed (KSC and Boeing), APL concurrence
    - Currently under revision
      - APL has provided feedback
  - Launch Vehicle/Payload/KSC RFA List
    - Actions and due dates assigned
    - References closure actions, communications, etc
    - Currently has 7 open items

The following several slides document the entire RFA list from inception. The first page is a list of all ***open*** *items. All subsequent pages list items closed.*

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

ACTIVE

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T. 054 08 Sep 99	Define time line when APL can not have access for trickle charging and Battery A/C (once inside the DPAF).	Boeing	Next GOWG	Open	Access not permitted during lifting, transporting and mating. Activity will be added into detailed schedule.
T. 056 08 Sep 99	Define when APL Dewar needs to be positioned at the Pad to support Purge tube cleaning & certification.	Boeing	Next GOWG	Closed 8/28/00	Required at spacecraft transport minus 3 days
T. 057 08 Sep 99	Update Purge configuration expectations for VAFB operations. – specifically change over operations and hardware requirements.	APL	Next GOWG	Open	- Provide storyboard of operations - Provide definition of purge quick disconnect
T. 063 30 Sep 99	Define the method for cleaning the FUT tubing	Boeing	08 Nov 99	Open	Boeings intent is to not re-clean the purge system prior to TIMED use. Result of current certification (for IMAGE) will be provided to APL.
T.065	Define dates for spacecraft MRR and pre-ship review	APL	10/2/00	Open	Pre-ship scheduled for 11/29/00
T.066 8/28/00	APL perform tape lift on EO-1/SAC-C DPAF	APL/Boeing	10/20/00	Open	Time to complete dependent on DPAF schedule. Required to determine is VC-3 cleanliness is acceptable for TIMED
T.067 8/28/00	Specify DPAF be double bagged while in chamber w/Jason and after integration of TIMED s/c	Boeing	01/01	Open	Bagging requirement to be added to LPD
T.068	– Provide new transmitter inhibit structure – Evaluate new transmitter inhibit structure – Evaluate need to perform new RF Hazards analysis	APL Boeing Boeing	12/15/00	Open	

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T.001 30 Jan 97	Provide updated geometry of aft end of spacecraft including antennas.	Timed	28 Feb 97	Closed 5/27/97	S/C drawing supplied 5/27/97.
T.002 30 Jan 97	Review impact of using Iridium type AC on TIMED.	MDA	28 Feb 97	Closed 3/20/97	Response provided to D. Silva by e-mail on 3/20/97.
T.003 30 Jan 97	Review providing additional performance.	MDA	28 Feb 97	Closed 3/18/97	Document by e-mail on 3/18/97 to D. Kraft.
T.004 30 Jan 97	Provide launch window requirements.	APL/JPL	28 Feb 97	Closed 7/31/97	Preliminary requirement supplied in S/C questionnaire.
T.005 22 Oct 97	Supply DPAF bounding thermal conditions (worst case hot/cold).	Boeing	5 Dec 97	Closed 2/25/98	Hot case of 113 deg F supplied during 12/5 telecon. Hot case of 104 deg F and cold case of -58 deg F supplied at 2/25/98 MIWG
T.006 22 Oct 97	Provide updated S/C questionnaire.	APL	1 Dec 97	Closed 12/22/97	Document 7363-9030 supplied by APL
T.007 22 Oct 97	Provide draft mission specification.	Boeing	13 Feb 98	Closed 1/11/99	Draft in Review
T.008 22 Oct 97	Provide quick turnaround CLA.	Boeing	26 Nov 97	Closed 11/26/97	Results transmitted to the anonymous ftp site, apogee.gsfc.nasa.gov.
T.009 22 Oct 97	Supply mass properties for separation analysis. (Maximum mass condition)	APL	21 Nov 97	Closed 12/5/97	CDR Nominal Mass (600 kg) properties per 470/TIMED-TOD-003, dated 12/15/97. Max. mass (660 kg) properties = nominal case per Goeser Email dated 11/17/97
T.010 22 Oct 97	Provide preliminary separation analysis results.	Boeing	31 Jan 98	Closed 1/21/98	Document A3-L230-M-98-001 (dated 1/12/98) supplied to NASA
T.011 22 Oct 97	Re-evaluate need/location of separation switches.	APL	21 Nov 97	Closed 11/10/97	Switches will be mounted over spring actuators (Boeing to select two positions). Ref. 470/TIMED-TOD-002

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T.012 22 Oct 97	Evaluate concept for utilizing contamination barrier in the DPAF.	Boeing	15 Dec 97	Closed 12/18/97	OLS issuing a TA for further work. Deliverables will include; configuration, NTE and schedule for implementation.
T.013 05 Dec 97	Verify DPAF tolerances used in S/A clearance analysis	Boeing	09 Jan 98	Closed 2/25/98	Clearance analysis presented in 2/25/98 MIWG
T.014A 25 Feb 98	Can the Second Stage depletion burn be covered by Malindi	Boeing	20 Mar 98	Closed 3/20/98	To view from Malindi would require the mission duration to extend to 9500 sec (from 9200 sec)-per Email from L. Fuller
T.014B 25 Feb 98	What are the facility constraints of the Hartebeesthoek station	OLS/Boeing	20 Apr 98	Closed 4/17/98	Information was provided and reviewed during the 4/17/98 telecon (Ref. Minutes from said telecon)
T.015 25 Feb 98	Supply the S/C insertion node based on updated trajectory	Boeing	20 Mar 98	Closed 3/20/98	Information supplied by email from L. Fuller
T.016 25 Feb 98	Evaluate acceptability of using the 100 lb. springs for separation	APL	20 Mar 98	Closed 3/12/98	100 lb. springs are acceptable as stated in 3/12/98 telecon
T.017 25 Feb 98	Define location (Radius and STA) of the T-O Purge interface	Boeing	6 Mar 98	Closed 3/12/98	1/2" interface location defined per FAX from J. Harvey
T.018 25 Feb 98	Provide preliminary sun angle data based on 5/18/00 launch window	Boeing	20 Mar 98	Closed 3/20/98	Information supplied by email from L. Fuller
T.019 25 Feb 98	Provide plan on supplying the DPAF SINDA model	Boeing	20 Mar 98	Closed 5/4/98	After checkout, model will be transferred to OLS who will in turn supply to APL
T.020 25 Feb 98	Define S/C configuration requirements for Flight Program Verification (Arming plugs in/out)	Boeing	3 April 98	Closed 5/21/98	APL confirmed that plugs will be in (S/C on internal) for the F-6 tests. This is the Boeing preferred config.
T.021 25 Feb 98	Assess JASON impact of working in class 10,000 environment during payload processing	JPL	3 April 98	Closed 5/12/98	Information provided from M. Davis via email to Boeing and OLS.
T.022 25 Feb 98	Define RF testing required (process facility and Pad) for the GPS and S-Band antennas	APL	3 April 98	Closed 4/17/98	Information supplied by email from L. Mosher

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T.023 24 Jun 98	Provide post separation sequence of events--first 24hrs	APL	31 July 98	Closed 7/9/98	Information supplied by Fax from L. Mosher
T.024 24 Jun 98	Asses acceptability of presented BBQ roll attitude (currently assumed to be orbit normal)	APL	28 Aug 98	Closed 9/10/98	APL requires "Broadside to the Sun" per 9/10/98 GOWG
T.025 24 Jun 98	Asses acceptability of separation attitude (-Zsc toward the sun)	APL	31 July 98	Closed 7/24/98	-Zsc toward the sun is acceptable based on contamination assessment. (Covered during 7/24/98 telecon)
T.026 24 Jun 98	Define the connector pin assignments for J10 and J11	Boeing	31 July 98	Closed 9/23/98	Pin assignments were provided 9/23/98 for APL review.
T.027 24 Jun 98	Review JASON-1 RF test plan (at SLC-2) for compatibility	APL	31 July 98	Closed 11/11/98	Test plan acceptable (Jason-1 will not radiate on Pad, receive only)
T.028 24 Jun 98	Provide A/C exit duct location and orientation	APL	10 July 98	Closed 7/24/98	Preliminary information provided by Fax from S. Vernon on 7/9/98. This information was deemed final during telecon on 7/24/98.
T.029a 24 Jun 98	Verify acceptability of S/C configured with Arm-Plugs in from T-9 till launch.	Boeing	31 July 98	Closed 7/24/98	TIMED S/C pyro arming plugs installed from T-9 until launch is acceptable (covered in 7/24/98 telecon)
T.029b 24 Jun 98	Re-consider the battery reconditioning scenario	APL	10 July 98	Closed 7/27/98	Updated flow from L. Mosher (fax on 7/27). Batteries are now discharged for DPAF encapsulation and transport.
T.030 24 Jun 98	Confirm exit velocity from T-O A/C system	Boeing	31 July 98	Closed 8/26/98	115 fps is the Boeing calculated velocity at the exit of the 2" duct. Ref email to L. Mosher from J. Harvey (8/26/98)
T.031 24 Jun 98	Provide integrated Processing Requirements matrix.	NASA-KSC	06 July 98	Closed	Matrix has been supplied to JPL, APL and Boeing. Comments were provided back to KSC.

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T.032 10 Sep 98	Confirm OLS/Swales contract and Web Site for Math Model transmission.	OLS	09 Oct 98	Closed 9/24/98	OLS Confirmed that the ftp site is available and that Swales will do the transformation (Ref. 9/24 Telecon)
T.033 10 Sep 98	Refine timeline to allow for umbilical simulator test	Boeing/APL	23 Feb 99	Closed 3/3/99	Within one week of S/C erection on Pad, Boeing will allow for test.
T.034 10 Sep 98	Address APL Purge configuration questions	Boeing	23 Feb 99	Closed 3/3/99	Boeing supplied additional information during the GOWG. APL to review and request farther clarification if required
T.035 10 Sep 98	Provide MSPSP to the Jason-1 Project	APL	23 Feb 99	Closed 3/3/99	APL stated (at GOWG) that a copy was provided to JPL
T. 036 02 Mar 99	A) Determine if/when Boeing support is required for S/C Sine Vibe testing. B) Define approach to achieving Clampband preload for sine vibe test (i.e. instrumented stud verses torque value method)	APL	02 Apr 99	Closed 3/18/99	Boeing support is not required for sine vibe testing and the Clampband will be tensioned using the torque value method (ref. 3/18 telecon)
T. 037 02 Mar 99	Define expectations on verifying MOI, POI and CG (i.e. which mass properties need to be measured)	Boeing	19 Mar 99	Closed 3/29/99	Boeing requested that the lateral CG values be measured. The remaining mass properties can be analytically determined. (Ref. email to Vernon and Mueller from Harvey)
T. 038 02 Mar 99	Confirm Test Hardware availability for 10/1 – 11/30	Boeing	19 Mar 99	Closed 4/16/99	3712C TPAF to be provided. 3724C TPAF is for contingency use at GSFC (if a conflict arises with MAP). Closed during 4/16 Telecon
T. 039 03 Mar 99	Define air cleanliness and hydrocarbon level of the T-0 Battery A/C system (based on Landsat-7 tests)	Boeing	19 Mar 99	Closed 3/18/99	Air meets Class 10,000 clean requirement and VOC constituents were detected in the parts per billion range. (Per Analysis provided by FAX from Sobczak)

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T. 040 03 Mar 99	Verify acceptability of un-controlled RH for the TIMED battery T-0 A/C system	APL	02 Apr 99	Closed 4/13/99	Acceptable, assuming the dew point is controlled to prevent condensation on the S/C. (Per email to Harvey from Vernon)
T. 041 03 Mar 99	Provide integrated facility bar-charts	NASA	19 Mar 99	Closed 4/15/99	Working Plan submitted by L. Kruse via email.
T. 042 03 Mar 99	Confirm ability to mate TIMED "earlier" so as to free up the APL GSE for Jason-1 adapter mate/fueling.	Boeing APL	2 Apr 99	Closed 8/12/99	Overcome by events. MGSE provided by Jason is now the baseline.
T. 043 13 Jul 99	Provide date for supplying S/C verified model from SWALES (Assume Nov. 1 APL delivery to SWALES)	NASA	23 July	Closed 8/26/99	Overcome by events. Existing TIMED model (correlated with static load test) will be used in the VLC.
T. 044 13 Jul 99	Provide the pressure profile at the T-O GN2 interface on the mini-skirt (during assent)	Boeing	23 July 99	Closed 7/23/99	Plots supplied to Vernon by Clark via email
T. 045 13 Jul 99	Assess pressure profile (A/I T.044) to ascertain if the differential can cause inflow and subsequent contamination.	APL	29 July 99	Closed 12/16/99	APL's position is that contamination is not an issue with the check valve spring change (per Vernon email on 11/22/99).
T. 046 13 Jul 99	Specify the GN2 Purge Tubing cleaning strategy used on MSX and FUSE	Boeing	23 July 99	Closed 9/30/99	For MSX and FUSE, the Boeing supplied flight tubing was cleaned to MIL-STD-1246C, Level 750B. APL verified acceptability for the flight tubing (ref. T.047). FUT tube cleaning is covered under T.063
T. 047 13 Jul 99	Define the GN2 Purge Tubing cleanliness expectations	APL	30 July 99	Closed 7/27/99	APL approved the cleaning defined in AI T.046 (per Vernon email)
T. 048 13 Jul 99	Incorporate the S/C to BH wiring diagram comments for review	Boeing	02 Aug 99	Closed 8/27/99	Schematic mailed on 8/27/99 to NASA and APL
T. 049 13 Jul 99	Supply comments (i.e. mark-up SSI Integration Schedule) for incorporation	APL	Prior to next GOWG	Closed 9/9/99	Comments supplied during the GOWG

Question: #9

TIMED Launch Vehicle

TIMED 10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T. 050 13 Jul 99	Supply EGSE weight and power requirements	APL	Next GOWG	Closed 12/16/99	Matrix of the EGSE (and GSE) required at the Pad supplied by Vernon on 11/22/99
T. 051 08 Sep 99	Evaluate possibility of APL utilizing the T-O A/C system (PAF portion) during F/C at GSFC for flow verification.	Boeing	21 Oct 99	Closed 10/19/99	Boeing offered options and constraints in using the T-O A/C system
T. 052 08 Sep 99	Define the "handheld dipole antenna" configuration to be used for testing S-band antennas on Pad (through DPAF vent holes). Define the method used for testing the GPS antennas on Pad.	APL	Next Telecon	Closed 8/1/00	APL provided information on the dipole antenna use on 2/23/00 (Ref. Email from Vernon). - APL dropped GPS test requirement. - Vent holes are large enough to allow access for test.
T. 053 08 Sep 99	Supply footprints of Purge Dewar and Suitcase for locating on transporter.	APL	15 Sep 99	Closed 9/15/99	Suitcase = 1' W x 3' L Dewar = 2'L x 2' W x 6'T Per email from S.Vernon
T. 055 08 Sep 99	Supply weight of purge tubing (approx. 200 ft.) that will be used during the DPAF hoisting operation.	APL	Jan 00	Closed 1/11/00	Weight (max) of the APL supplied purge tubing is 38 lbs. (per 1/3/00 Vernon email)
T. 058 08 Sep 99	Define date for Contract to fill Dewars at the Pad.	NASA	Jan 00	Closed 2/11/00	Space Mark will be responsible for filling the Dewars
T. 059 08 Sep 99	Determine worst case (T-9 to Sep) configuration of TIMED for the Stray Voltage Testing.	APL	Jan 00	Closed 10/21/99	TIMED will be in Launch configuration and trickle charging for the subject testing.
T. 060 09 Sep 99	Provide list of Boeing procedures that will be supplied to APL for integrated input.	Boeing	Oct 99	Closed 10/15/99	A summary of the integrated procedures was supplied.
T. 061 09 Sep 99	Update MSPSP with information on TIMED RF inhibits (including implementation schematics).	APL	Next Telecon	Closed 5/15/00	Information received.

Question: #9

TIMED Launch Vehicle

TIMED

10/19/00

CLOSED

Item No.	Question/Action Item	Responsibility	Date Due	Status	Response/Comments
T. 062 09 Sep 99	Define what will be done to the APL EGSE harnesses for patch panel implementation (and when are the harnesses required).	Boeing	29 Sep 99	Closed 9/29/99	Boeing will install connectors and backshells. Boeing requires harnesses by mid-March assuming 5/18/00-launch date. Per email from J. Harvey
T. 064	Confirm TIDI pyro bridgewire characteristics are correct	APL	6/27/00	Closed	Info provided.

Question: #9

Remote Interface Units (RIUs)

Alan Reiter

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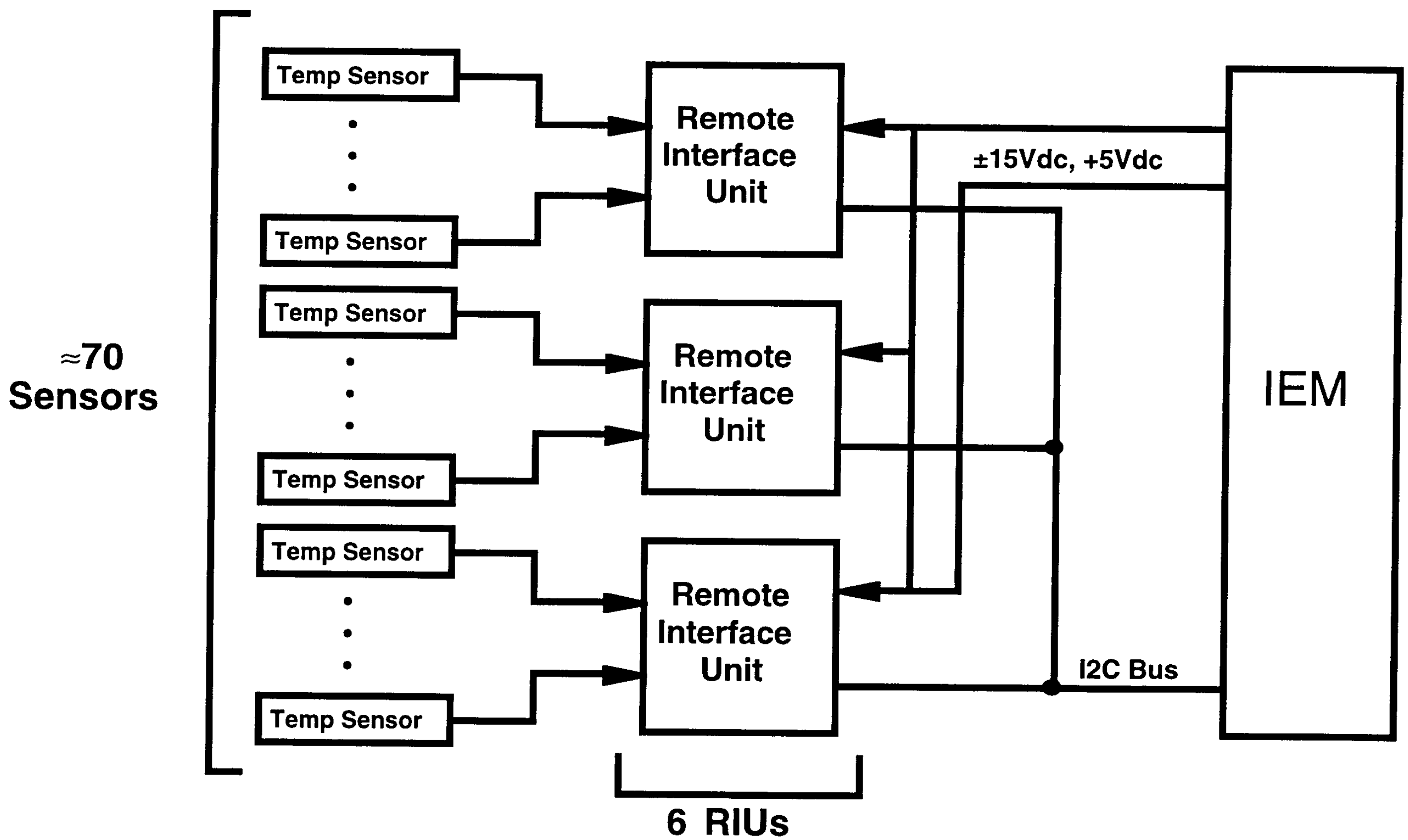
Top Level RIU Block Diagram



RIU Subsystem Description

Each Remote Interface Unit (RIU) processes up to 15 external temperature sensors. The processing consists of sequentially biasing, scaling, and A/D converting the temperature reading. Each RIU then reports all 15 temperatures via a common I2C bus to the Command and Telemetry Processing section of the IEM for telemetry downlinking.

A total of 6 RIUs exist on a single I2C bus connected to each IEM. Each string of RIUs provides ≈70 spacecraft temperatures for the housekeeping telemetry. Each RIU is paired in a stacked configuration where the bottom unit reports to IEM #1 and the top unit reports to IEM #2.

The total number of TIMED RIUs is 12 (6 per IEM) which provides redundant temperature sensing for each IEM.

Documentation Summary

Document	Contents
Requirements Memo (email 10/25/96)	Bd dimensions, I/O, voltages, power, schedule
PDR Package	Block diags, I/F dwgs, layout, tradeoffs
CDR Package	Requirements summary, block diags, I/F circuit, fusing design, packaging
Hardware EDR Package	Bd level and FPGA schematics, parts lists, layout
PreEnvironmental Ship Review	Top level diags, bd/chassis photos, test results
Test Plan	Assy/test sequence, thermal, vibration, TV
Qualification Test Procedure (SRI-98-034)	Bd checkout, test and tailor, thermal/supply perf, vibration, TV
Performance Results (SRI-98-047)	Summary of performance over all qual testing

RIU Subsystem Review

Review	Date	Level	Panel Members	AIs	AI Resolution
H/W EDR	11/20/97	Peer	RFConde, PDSchwartz	7,15,17,22	SRI-00-028

RIU Action Item Summary (1)

Action Item

PDR #13 a) Consider devoting one temperature channel on each RIU to providing a calibration point using a precision resistor. b) Consider providing RIU address strapping externally at the connector so the address can be set without re-opening a qualified RIU.

Resolution

Both considerations (a and b) were incorporated within the flight design.

Action Item

EDR #7 Consider triple voting and refreshing critical portions of Actel FPGAs. Critical portions include those, that if upset, would either have a detrimental effect at the system level, or would result in potential hardware overstress, such as bus contention.

Resolution

Triple voting was not incorporated within the RIU design because : a) The RIUs do not perform spacecraft critical functions and two sets of RIUs provide redundancy and b) The RIU FPGAs use only combinatorial logic functions which are less susceptible to radiation upsets than sequential modules.

Red Team Questions : 1,9

RIU Action Item Summary (2)

Action Item

EDR #15 How can I2C bus data line interfaces be adequately protected.

Resolution

All I2C data and clock signals are isolated by 10KΩ series resistors within each RIU. This will prevent any single RIU from taking the entire bus down due to an internal short.

Action Item

EDR #17 Add risetime and falltime control on the I2C data and clock interfaces.

Resolution

No specific risetime and falltime control was added to the I2C data and clock interfaces, however, the clock edges measured close to the desired 1μsec rise and fall intervals.

Red Team Questions : 1,9

RIU Action Item Summary (3)

Action Item

EDR #22 Determine the maximum harness length possible for the power and ground lines daisychained to the RIUs, while keeping the voltage to the RIUs in specification due to IR drops in the harness and connector pins.

Resolution

The RIU spacecraft harnessing was modeled using one 10' length between the I2C master and the first RIU and 6' lengths between each of the RIUs. Also, eight RIUs were tested instead of the flight configuration of six RIUs per IEM. Finally, the power supplies were adjusted +/- 10% (over a -35°C to +65°C temperature range) with no performance degradation. These combined measures more than adequately test beyond the IR drops in the harness and connector pins. Also, the flight harness actually places all power and ground signals for the RIUs in a ring configuration rather than the tested daisychained harness for reliability reasons and indirectly provides an additional level of margin relative to IR drops.

Test Verification Matrix

Requirement	Verification	Results
Temperature accuracy within ±2.0°C	Thermal/Supply, TV Tests	≤1.6°C Total Variation (All units, all channels)
Board Size (≈ 3.5" x 3")	EM/Flight layout design	Bd dimensions 3.5" x 3"
Max Pwr Dissipation (580 mW/bd)	EM Thermal/Supply Tests	327.50 mW (avg/bd)
Operating Survival Limits	Vibration Tests	All units passed thrust axis levels in all 3 axes
Operate through TV w/o Degradation	1 Survival, 6 operational cycles	All units passed, all cycles
12Hz/hr. (16 units combined)	TQCM Tests	10Hz/hr. (16 units combined)

Current RIU Status

* No Problem Failure Reports (PFRs)
* No Degradation Trends (analysis performed)
* No Residual Risk

IEM DC/DC Converter Cards

Deanna Temkin
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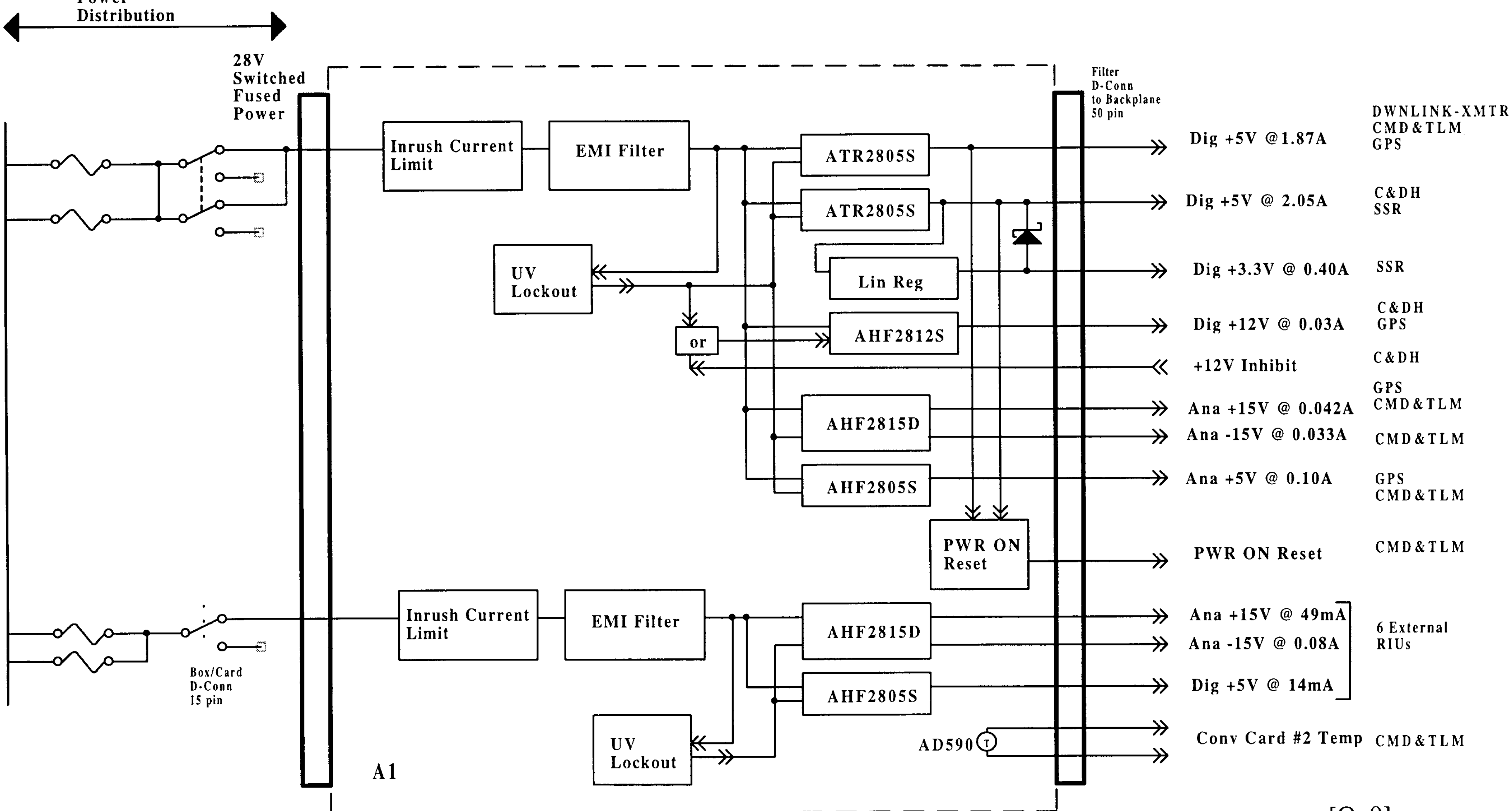
- **Requirements documented in EDR package, 11/27/97**
- **Use LAA hybrid converters with the following JHU/APL custom design:**
  - Inrush Current Limit
  - Input Under Voltage Lock Out
  - Power On Reset
  - Sequence of XMTR Analog Power
  - +9V Output for XMTR
  - +3.3V Output for SSR
  - Separate On/Off Control for +12V Flash Memory Power

TIMED IEM DC/DC CONVERTER CARD - A1

10/14/99



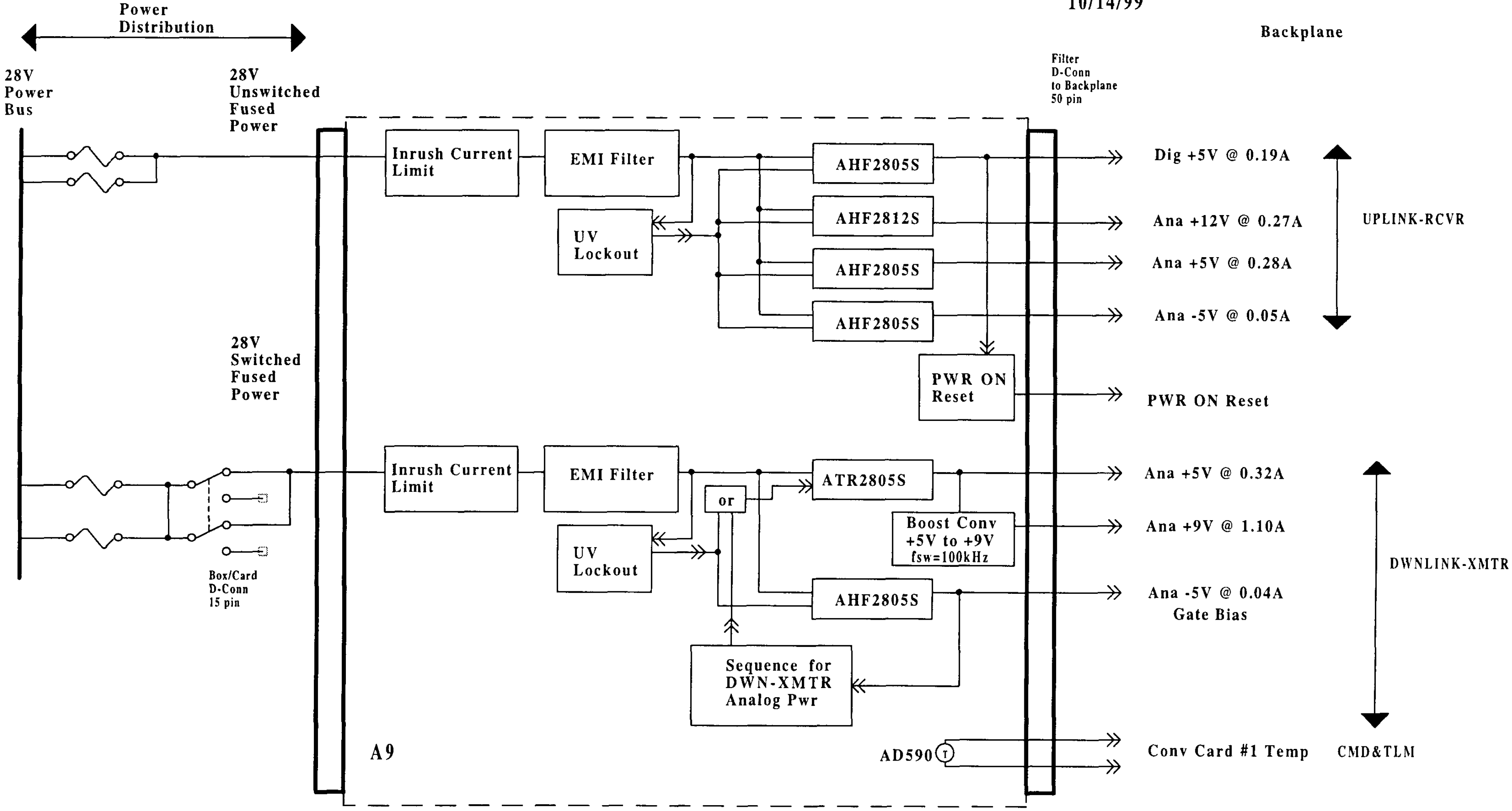
[Q: 9]

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

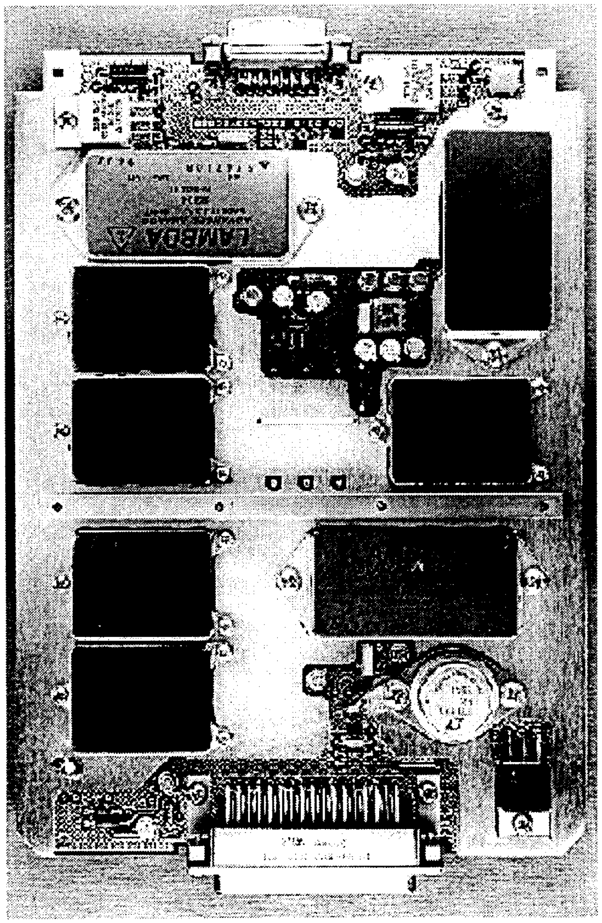
Red Team Review : 31 Oct. - 3 Nov. 2000 : IEM DC/DC Converters

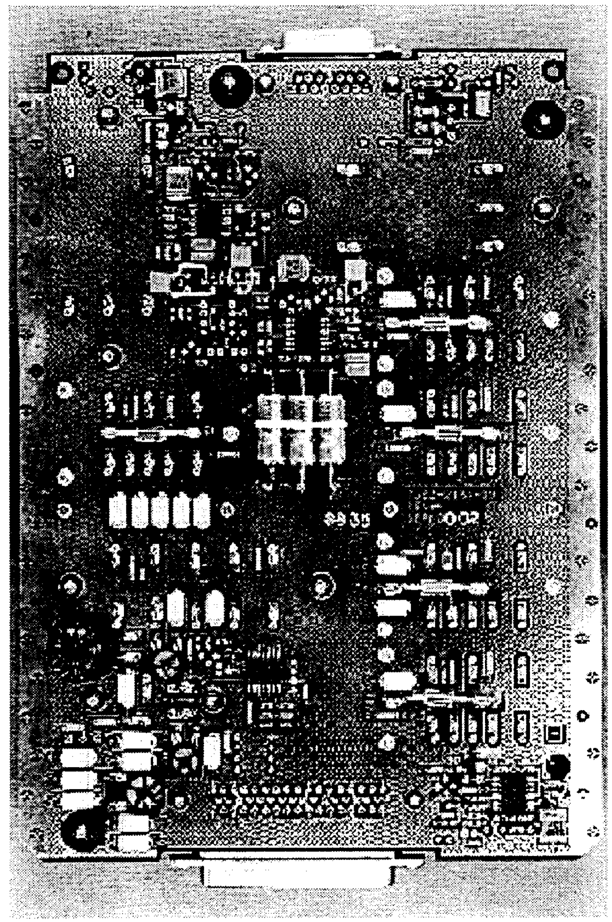
TIMED IEM DC/DC CONVERTER CARD - A9 10/14/99



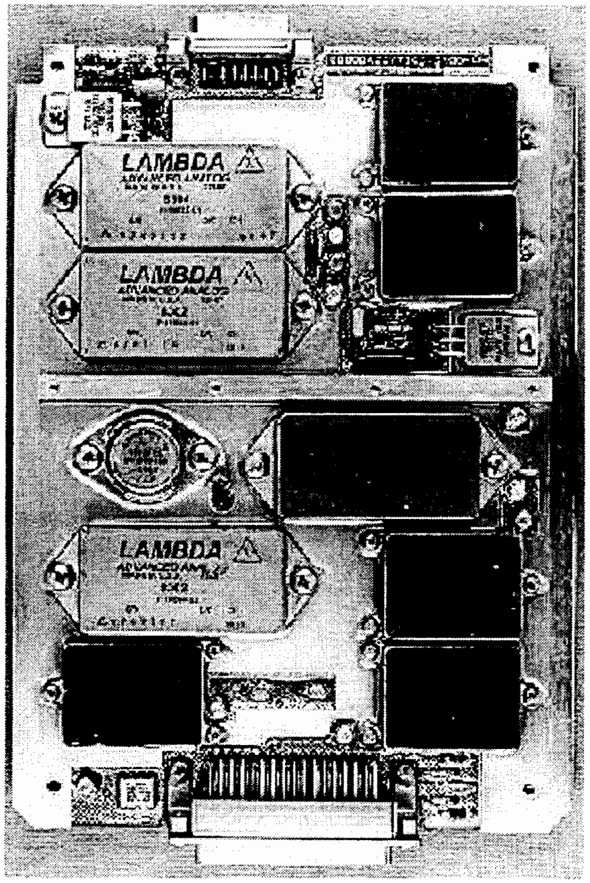
[Q: 9]

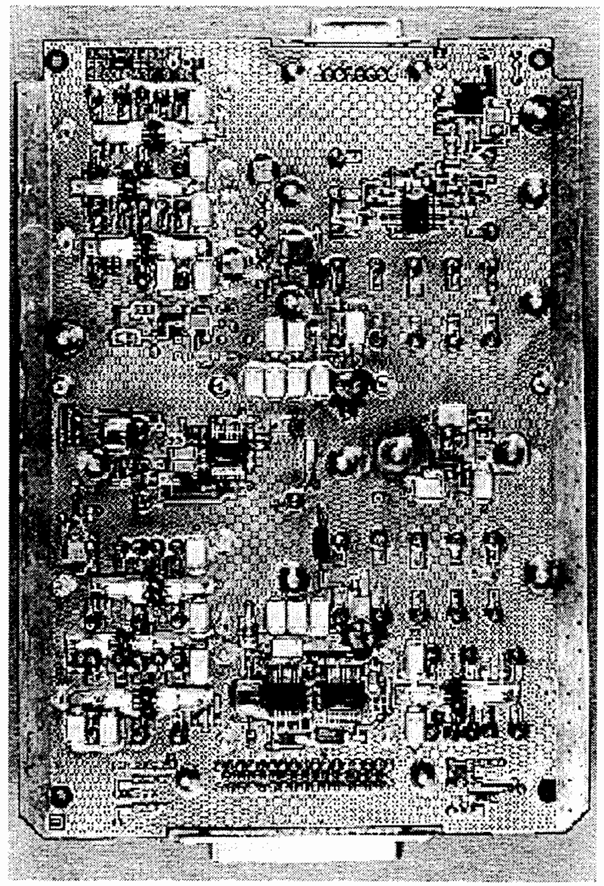
DC/DC Converter #1 (A9)





DC/DC Converter #2 (A1)





Lambda Advanced Analog Hybrid DC/DC Converter Screening and Evaluation Summary [Q: 9]

- Design Review at LAA
  - JHU/APL Reviewers: D. Kusnierkiewicz, U. Carlsson, L. Mastracci, D. Temkin
- JHU/APL imposed additional requirements above the SMD drawings: documented in Purchase Instructions PI10904-01, 02, 03, 04 and PI10835
  - Modified snubber circuits to reduce switching spikes on primary transistors and secondary diodes
  - Changed secondary diodes on dual +/-15V converters to higher voltage rating
  - Performed non-repetitive avalanche energy testing on power schottky diodes (10 samples per wafer)
  - Ceramic capacitors (>1uF)
    - » 100% Voltage Conditioning: 100hours, 125°C, at twice the rated voltage
    - » DPA 5 samples per lot (one lot rejected by JHU/APL)
  - Tantalum Capacitors
    - » 100% Voltage Aging: 40hours, 85°C, at rated voltage
    - » 100% Surge Current Testing: 5 cycles, -55°C, 25°C, 85°C, rated voltage
  - Single element lot requirements:
    - » Continuous lot of the following elements: power mosfets, secondary power diodes, PWM, ceramic capacitors > 1uf, and solid tantalum capacitors
  - Single lot/date code required per PI#
  - Use Orbit Semiconductor PWM which is latchup immune
  - PIND and X-ray on all parts
  - Performed extended burn-in: gives a total of 320 hours at 125°C
  - Life test of 3 samples from each lot (1000hours at 125°C)
  - Leakage Current on Input Filters measured at JHU/APL
- Prior to purchase performed electrical, vibration, total dose, and SEU testing on samples

IEM DC/DC Converter Cards EDR Design Review [Q: 1, 9]

Held: November 25, 1997

Reviewers (all from JHU/APL):

M. Butler
G. Dakermanji
P. Schwartz
P. Marth
D. Kusnierkiewicz
B. Heins
A. Reiter
B. Bokulic
S. Cheng
G. Cameron
J. Perschy

EDR Action Items (all closed, responses documented via memo SEE-00-0044) [Q: 9]

- **AI#1:** In the uplink power-on reset circuit, investigate inserting a diode between the LM139 and the base of Q4 2N2222A. ***D. Temkin.***

- **AI#2:** Is the Specification, for the XMTR/DWN Link analog power turn-on sequence requirement, as stated in the EDR package (p.5), sufficient to meet the system requirement. ***S. Cheng***

- **AI#3:** Investigate how much inductance can be placed in series with the converter which will cause the converter to become unstable. ***D. Temkin.***

- **AI#4:** Due to the potential risk of stressing the flight DC/DC converter cards, determine if CS-01, CS-06 conducted susceptibility testing is a requirement for the flight units. ***D. Temkin , D. Kusnierkiewicz***

- **AI#5:** Look at specifying the output electrical requirements at the output connector of the converter card. ***D. Temkin.***

- **AI#6:** Review the 9.0V output design to see if it can handle an additional 1 watt of power. ***D. Temkin***

- **AI#7:** Investigate the turn off time requirement for the +12V to see if it meets the minimum time required by the flash memory. ***D. Temkin, J. Perschy***

- **AI#8:** Review the derating requirements of tantalum capacitors in DC/DC converters over temperature with SOR. ***D. Kusnierkiewicz, L. Mastracci***

JOHNS HOPKINS
UNIVERSITY
Applied Physics Laboratory
Laurel MD 20723-6099

SEE-00-0044
September 18, 2000

To: Distribution

From: DKTemkin DKT

Subject: IEM DC/DC Converter Card EDR Action Item Responses

All the action items from the IEM DC/DC Converter Card EDR were previously addressed through various informal discussions and e-mails. This memo consolidates these responses into one record.

The IEM DC/DC converter card engineering design review was held on Tuesday November 25, 1997. Attendees were M. Butler, G. Dakermanji, P. Schwartz, P. Marth, D. Kusnierwicz, B. Heins, A. Reiter, B. Bokulic, S. Cheng, G. Cameron, and J. Perschy.

AI#1: In the uplink power-on reset circuit, investigate inserting a diode between the LM139 and the base of Q4 2N2222A. (Similar to the design utilized in the undervoltage inhibit circuit.) **D. Temkin**

This design change was incorporated in the engineering model and the flight design.

AI#2: Is the Specification, for the XMTR/DWN Link analog power turn-on sequence requirement, as stated in the EDR package (p.5), sufficient to meet the system requirement. S. Cheng (Response below is direct copy of S. Cheng's e-mail.)

The analog power turn-on and turn-off sequence specifications in the EDR package are considered adequate for the protection of the Microwave Power GaAs FETs used in the Downlink Power Amplifier. The justifications for the considerations are described below.

During the EDR a question was raised about the origin of the analog power sequencing specifications and a suggestion was made that we compare these to NEAR's to make sure that they are in line with previously established specifications.

The reason of needing to sequence the analog power is to protect the Microwave Power GaAs FET used in the Down Link Power Amplifier. As I stated during the EDR, Fujitsu Semiconductor, the vendor of the Power GaAs FETs, is reluctant to provide any timing specification other than saying that the negative gate voltage must be present and established during the turning on and off period of the positive drain voltage. To supplement this information, I should also add that Fujitsu did provide information about how the failure could occur during the time of powering on and off of the device. Their observation is that Power GaAs FET becomes very unstable at and near the zero volt gate bias region while a drain bias voltage near or above the VDS knee voltage is present. The knee voltage of a good power GaAs FET could be as low as 1 volt. If allowed to be biased in this region, the Power GaAs FET will oscillate and burn itself out. Because these are microwave devices, the onset of oscillation to failure time is very short.

<u>A comparison of NEAR's and TIMED specifications are listed below.</u>

NEAR's Output Voltage Sequencing Specifications, including revisions, are:

- At turn-on, the -5.0 volt output must appear at least 5 milli-seconds before the +9.0 volt output;

- At turn-off, the -5.0 volt output must remain on at least 5 milli-seconds after the +9.0 volt output is removed;
- Rise and fall times of each output shall not exceed 3 milli-seconds at either maximum or minimum specified load;
- On and Off shall be defined as 90% and 10%, respectively, of the nominal voltage levels. Rise times shall be determined likewise.

The specifications in page 5 of the EDR package are:

- At turn-on, -5_A must be above |-4V| for 5 milli-seconds before +9V_A and +5_A are allowed to turned on.
- At turn-off, -5_A must remain above |-4V| for 5 milli-seconds after +9V_A and +5V_A have fallen to below 0.5V.

Although the timing requirements in both sets of specs. are 5 milli-seconds, there are two subtle differences in the limiting voltages where the time is to be measured. The NEAR specs used a 10% voltage limit for turn-off. For the +9.0 volt bias, this equates to 0.9 volt, which can still be considered as "near" the knee voltage of the GaAs FET. It seems to me that it makes more sense to use a tighter 0.5 volt limit for any drain bias supply at turn-off like the specs shown in the EDR package. The other difference is the -5.0 volt turn-on and turn-off limit. The NEAR specs used the 90% limit, which equates to -4.5 volt. Although this is a tighter spec than the -4 volt the EDR package used, the 20% reduction of the gate bias voltage still ensures a good margin away from the "near" 0 volt gate bias region.

AI#3: Investigate how much inductance can be placed in series with the converter which will cause the converter to become unstable. D. Temkin.

A test was performed with the Transmitter EM power converter full design. A 50µH inductor (magnetics 55310 with 25 turns) was put in series with the HP 6032A power supply (10µF across output of power supply), and the 28V bus was brought up slowly and manually. The current limit of the power supply was set at 5A. The converters were loaded accordingly: +5V at 2.3A, -5V at 2.3A, and +9V at 1.3A. Total output power equaled 34.7W, while the expected load is 12.7W. Instabilities would be more detectable at heavy load. No instabilities were evident. Since 50µH is much more inductance than the spacecraft harness will represent, no further tests were performed. A twenty foot long twisted pair measured 5µH.

Operating the converters without the undervoltage circuit would probably affect the maximum allowed inductance between the primary power source and the converter cards.

AI#4: Due to the potential risk of stressing the flight DC/DC converter cards, determine if CS-01, CS-06 conducted susceptibility testing is a requirement for the flight units. D. Temkin & D. Kusnierkiewicz

To reduce risk to the flight units CS-01, CS-02 and CS-06 tests were only performed on the IEM engineering models.

AI#5: Look at specifying the output electrical requirements at the output connector of the converter card. D. Temkin.

Static regulation shall be within +/- 3%. This includes effects due to dc variations in the 28V input voltage, dc variations in load, initial accuracys, and temperature effects. Voltage drop due to converter card and output connector shall be less than 1% of the corresponding output voltage. For +/- 15V dual outputs, cross regulation shall be within +/-2% when the load mismatch is no more than a factor of 4.

Dynamic regulation due to input voltage transients shall be within +/-2% for CS01 and CS06 tests per 7363-9038. Dynamic regulation due to a step load shall be within +/-3% for a step load equal to 20% of full load when the minimum dc load is greater than 10% of full load.

Switching ripple shall be less than 50mVpp at 550kHz and switching spikes shall be less than 50mVpp when measured with a 10MHz bandwidth limited probe.

AI#6: Review the 9.0V output design to see if it can handle an additional 1 watt of power. D. Temkin

Since the +9V output is derived from the +5V converter, the combine power level should be reviewed when the +9V output is increased. Since EDR, the +5V output went from 2.65W to 1.7W and the +9V output went from 8.37W to 10.8W. The combined level went from 11.02W to 12.5W. The +5V converter processes this total power plus the power due to inefficiencies dissipated in the +9V boost converter. The +5V converter output power rating is 30W, which provides ample margin. The inductor in the +9V boost converter was changed to provide margin with the higher power requirement. Electrically the design can handle 1.5A on the +9V (13.5W) assuming the +5V XMTR load is 1.7W.

AI#7: Investigate the turn off time requirement for the +12V to see if it meets the minimum time required by the flash memory. D. Temkin, J. Perschy.

The flash memory has an internal threshold detector which disables writing if the 12V power is below 3V. This negates a turn off time requirement for the 12V output.

AI#8: Review the derating requirements of tantalum capacitors in DC/DC converters over temperature with SOR. D. Kusnierkiewicz, L. Mastracci

Derating is for reliability concerns, i.e., to ensure reliability failure rates apply over long term operation. The short exposure at test temperatures will not affect reliability. Derating requirements need to be met for flight, but not for ground level testing.

Background: We do not meet derating on the solid tantalum capacitors on these boards at a baseplate temperature of 55°C, which is a test condition only. *(Solid tantalums are applied with 50% derating up to 70°C. At higher temps, voltage must be derated further.)* At a baseplate temperature of 55°C, board (capacitor) temperatures will be 82°C (exceeding derating). Flight baseplate temperatures are allowed to go as high as 45°C (72°C board temperature; slightly exceeding derating); however, worst case IEM predicted baseplate flight temperatures are only 32°C (59°C board temperature). The only time that the DC/DC converter cards' board temperatures are over 70°C is during short term ground level testing and not during flight.

Distribution:
B. Bokulic
M. Butler
S. Cheng
G. Dakermanji
C. Deboy
D. Grant
B. Heins
D. Kusnierwicz
A. Lew
P. Marth
J. Perschy
A. Reiter
P. Schwartz
SEE Files
Archives

DC/DC Converter Card Level Flow [Q: 3]

- Visual Inspection
- Chip Resistor Value Verification
- Tailor Resistors Set
- Installation of Tailor Resistors
- Ambient Card Level Test
- 20 Unpowered Temperature Cycles (-34 to 90 degrees C)
- 4 Powered Temperature Cycles (-29 to 65 degrees C)
- Conformal Coat
- 2 Powered Temperature Cycles (-29 to 65 degrees C)

Flight DC/DC Converter Card Level Test

[Q: 3, 7]

Function	Ambient	Temperature Cycle
Input Undervoltage Lockout Timing & Trip Levels	X	
Inrush Current	X	X
Output Voltge Turn On	X	X
Power On Reset Timing	X	X
Power On Reset Levels	X	
Line & Load Regulation	X	X
Efficiency	X	X
Ripple Voltage	X	
Step Loads on Digital Outputs	X	
Power Up/Down Sequence for XMTR Power	X	X

Total Operating Time prior to Box Integration: 20 hours [Q: 8]

Additional Testing performed on Breadboard and/or EM DC/DC Converter Card Tests [Q: 3]

- CS01/01/06
- CE01/03/07
- Survival Input Voltage Transient

Residual Risk

- Residual risk due to converter failure is low due to the following:
  - IEM's are redundant
  - Imposed additional converter burn-in and screening requirements
  - Imposed additional screening of converter piece parts
  - Experienced no failures in breadboards, EMs, or flight converter cards [total cards built including BBs, EMs, & flight = 12, corresponds to 156 converters and 48 filters with no failures to date] [flight cards have > 2500 hours of on time]

POWER SUBSYSTEM

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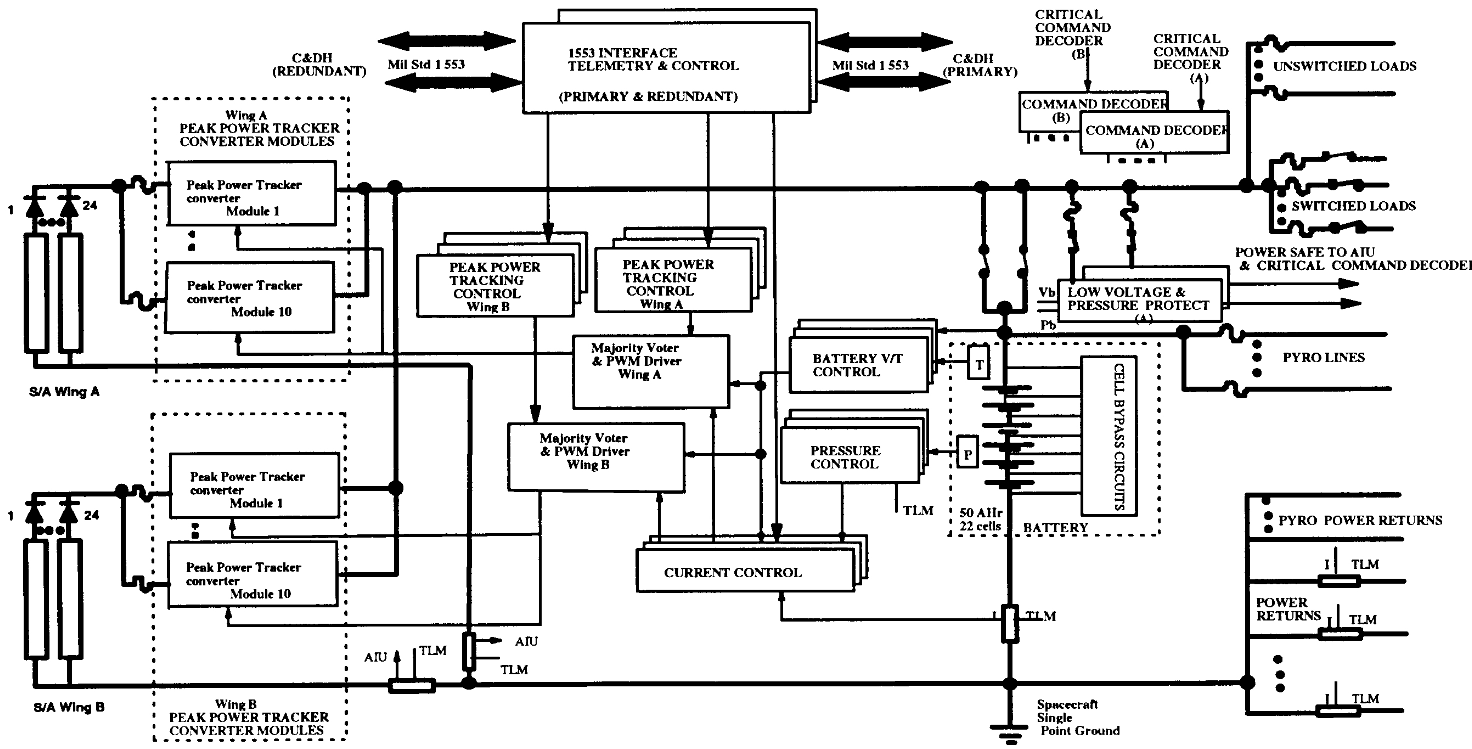
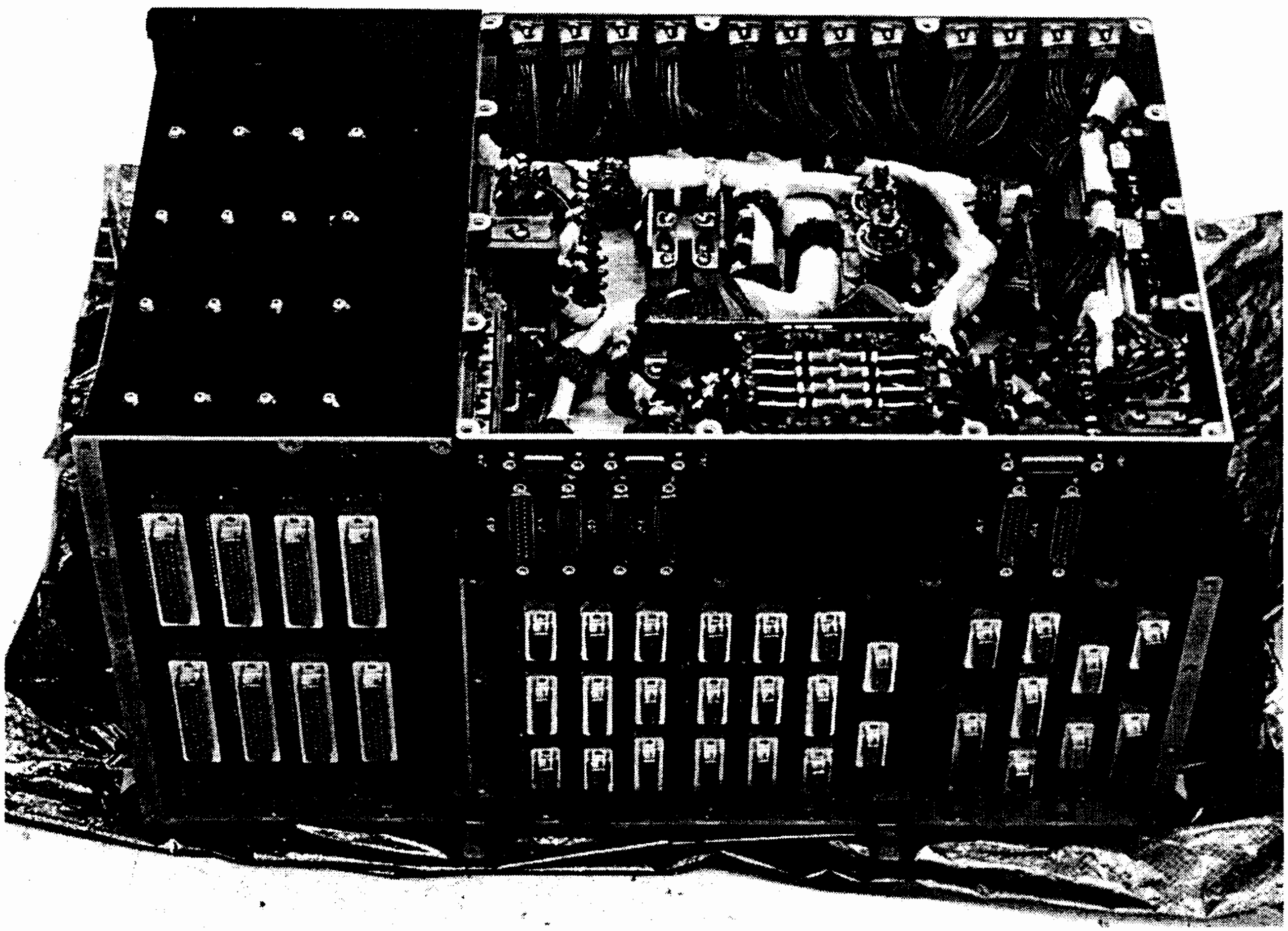
POWER SUBSYSTEM OUTLINE

- Power Subsystem Block Diagram
- Power Subsystem EDR
- Solar Array
  - Design Reviews at Vendor
  - Qualification & Bend Panel testing
  - Test Summary
  - Environmental Tests with Spacecraft
- Battery
  - Design Reviews at Vendor
  - Battery EDR
  - Test summary
- Power Subsystem Electronics
  - Test Summary
- Power Subsystem Problem/Failure Reports

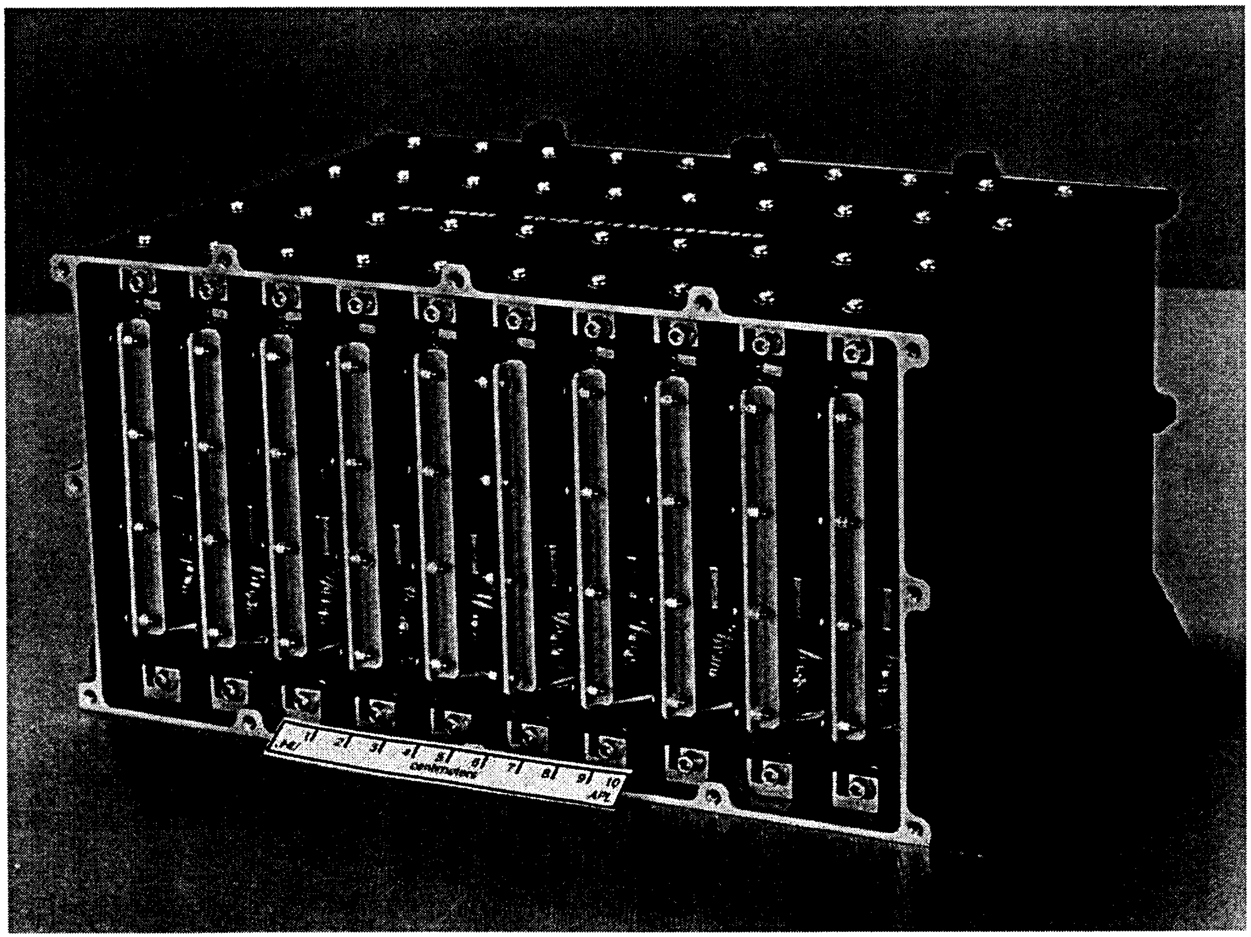
POWER SYSTEM BLOCK DIAGRAM



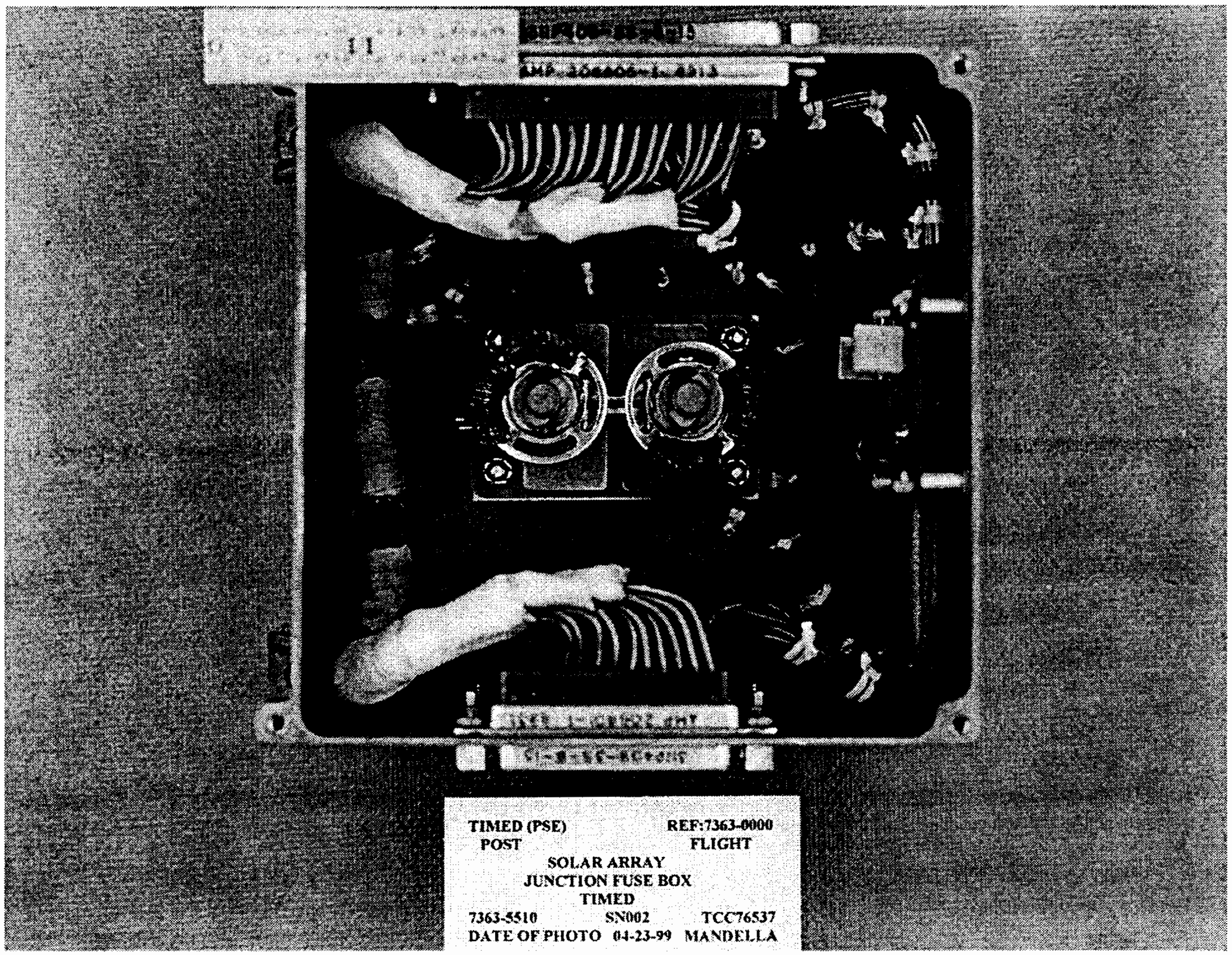
POWER SYSTEM ELECTRONICS / DISTRIBUTION UNIT



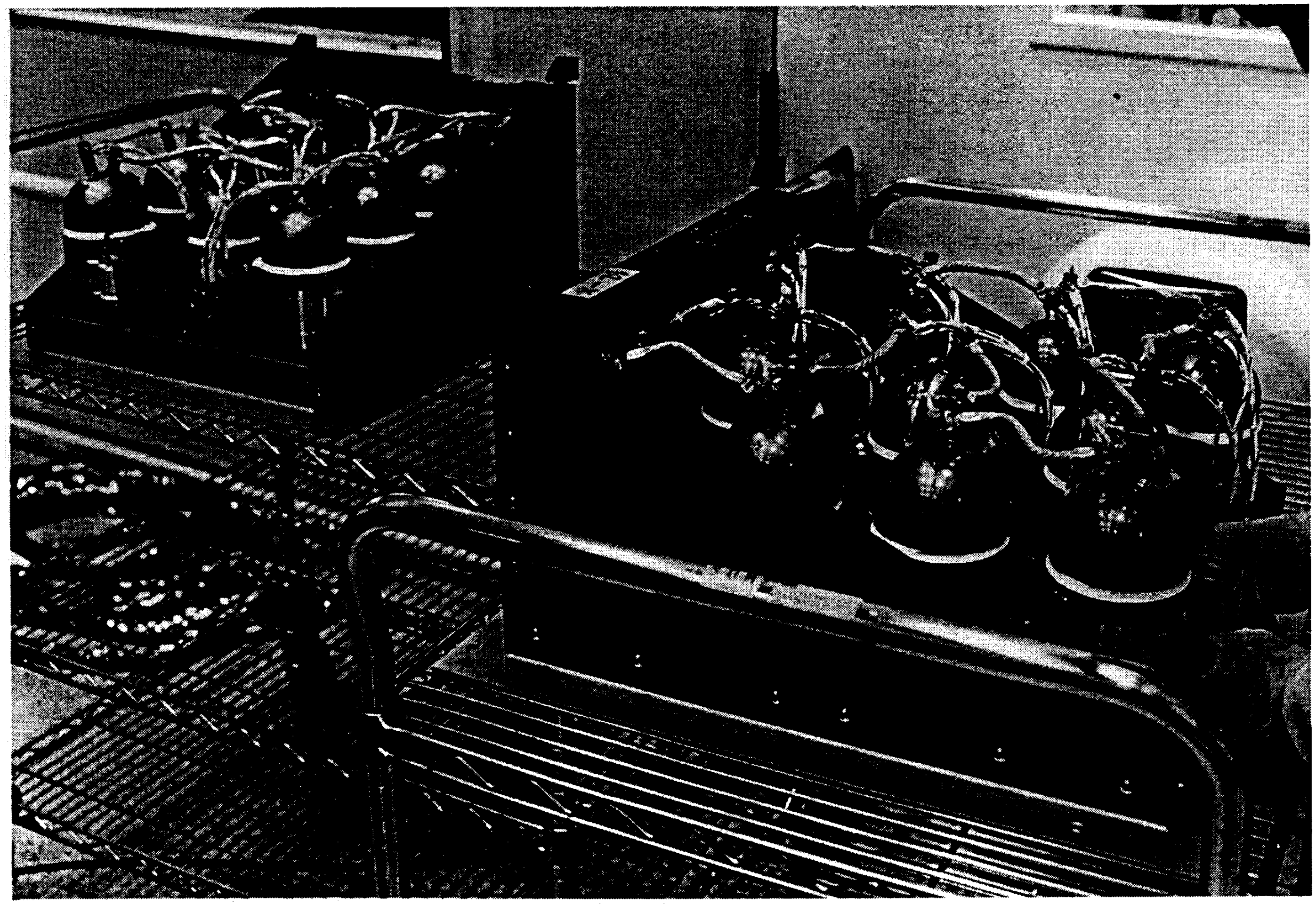
PEAK POWER TRACKER



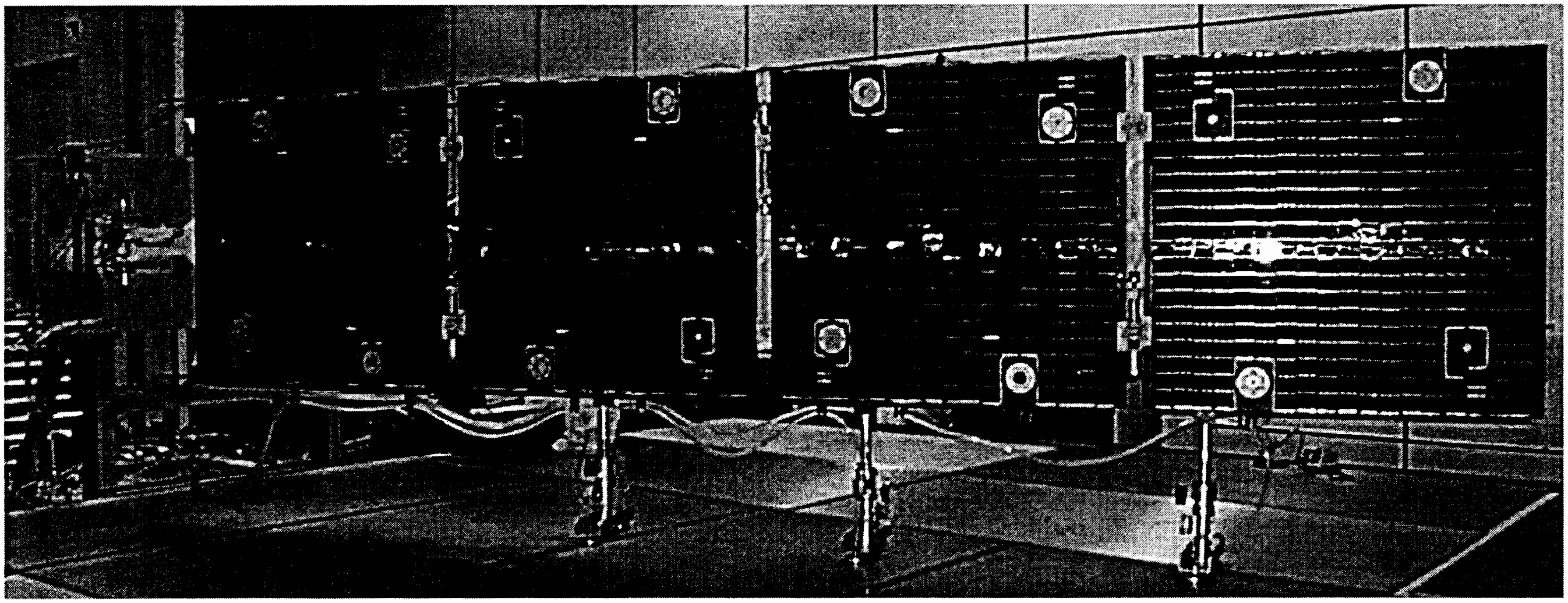
SOLAR ARRAY JUNCTION BOX



BATTERY



SOLAR ARRAY WING



Power System Engineering Design Review

The power system EDR covered the battery, solar array, peak power tracker, power system electronics/distribution unit, power system telemetry, low battery state of charge protection, and power system GSE.

Held: November 21, 1997

Reviewers:

A. Santo	JHU/APL	D. Stott	JHU/APL
R. Moore	JHU/APL	A. Mattheiss	JHU/APL
J. Kroutil	JHU/APL	P. Schwartz	JHU/APL
Dr. Ed Gaddy	NASA/GSFC	T. Yi	NASA/GSFC
D. Keys	NASA/GSFC	A. Hernandez-Pellerano	NASA/GSFC
R. Sullivan	Consultant		

RTR Question: 1,2

Power System Engineering Design Review

The TIMED Power system Design Review Action Items were listed in SEA-97-106 as summarized below.

Action Item	Assignee	STATUS
1. Failed row and/or column drivers can result in an unexpected relay being energized. Consider relay matrix coordinate assignments which optimize spacecraft fault tolerance.	Panneton	CLOSED, SEE-00-0059
2. Consider increasing the PPT converter module switching frequency to reduce the size and mass of the magnetic elements and capacitors.	Carlsson	CLOSED, SEE-00-0059
3. There is now no way to trace the fault of an invalid relay command. Consider the addition of a telemetry bit to indicate the status of the last command.	Temkin	CLOSED, SEE-00-0059
4. No spare non-latching relay is available. Investigate changing one of the spare latching relays to a non-latching relay.	Temkin	CLOSED, SEE-00-0059

RTR Question: 9

Power System Engineering Design Review

The TIMED Power system Design Review Action Items Continued

Action Item	Assignee	STATUS
5. Investigate adding ground test capability to terminate the power system heartbeat to aid in system level autonomy testing. This test feature should not add possible failures into the flight design.	Williams, R.	CLOSED, SEE-00-0059
6. Verify that there are no failure modes where LVS could be triggered indefinitely. Consider non-automatic re-enableing LVS after bus recovery, but waiting for ground reset.	Kusnierkiewicz	CLOSED, SEE-00-0059
7. When intgrated for system level testing the power system solar array simulator (SAS) is controlled by the MOC. Define validity checks to be performed on th MOC commands before being executed buy the SAS. Determine any conditions where errant SAS commands sent by the MOC could damage flight hardware.	Nguyen	CLOSED, SEE-00-0059
8. To improve interface testability, consider porting the C&DH flight code to the power system ground test equipment.	Butler	CLOSED, SEE-00-0059

RTR Question: 9

Power System Engineering Design Review

The TIMED Power system Design Review Action Items continued

Action Item	Assignee	STATUS
9. Consider moving the protection diodes from the back of first solar array panel to the fuse/shunt units to protect against harness shorts during ground testing or consider placing an extra set of diodes at the PSE.	Butler	**CLOSED, SEE-00-0059**
10. TECSTAR is known to have wide variations in their weld pull strengths. Consider changing from welding to soldering to make cell connections.	Butler	**CLOSED, SEE-00-0059**
11. Define bus voltage transient requirements and provide bus transient profiles.	Carlsson	**CLOSED, SEE-00-0059**
12. Verify that upon C&DH power-up or reset the default coulometer count is such that it does not generate a software based load shed.	Butler	**CLOSED, SEE-00-0059**
13. Consider whether there are any conditions that could result in power system lockup, ie battery discharge during sunlight conditions.	Dakermanji	**CLOSED, SEE-00-0059**
14. Investigate the effect of a possible out-of-specification battery thermal design on the power system performance.	Dakermanji	**CLOSED, SEE-00-0059**

RTR Question: 9

SOLAR ARRAY DESIGN REVIEWS

Design Reviews Held at Laydown Vendor

•PDR	**19 February 1998**
•CDR	**9 April 1998**
•MRR	**27 August 1998**
•PSR	**10 December 1998**

Review Team:	G. Dakermanji	JHU/APL
	M. Butler	JHU/APL
	G. Cameron	JHU/APL
	L. Mastracci	JHU/APL

SOLAR ARRAY

BEND TEST COUPON INSPECTION AND TEST SEQUENCE

a)* Intermediate sequence, defined by the following:
- Visual Inspection
- Cell Adhesion Check (as required)
- Wiring Continuity Test
- Insulation Resistance Test
- Power Output Test (+80°C)

b) Bend test
c)* Intermediate sequence
e) Final Visual Inspection

Comment: Bend panel tests exceeded substantially TIMED flight panel bend requirements

RTR Question: 3

SOLAR ARRAY

Qualification Panel Inspection and Test Sequence

a)* Intermediate sequence, defined by the following:
- Visual Inspection
- Cell Adhesion Check (as required)
- Wiring Continuity Test
- Temperature Sensor Functionality
- Insulation Resistance Test
- Power Output Test (+25, +80°C)

b) Damage and Repair of two cells
c) * Intermediate Sequence
d) Thermal Vacuum Cycles (8)
e) * Intermediate Sequence
f) Thermal Ambient Cycles 1 - 500
g) * Intermediate Sequence
h) Thermal Ambient Cycles 501 - 1500
i) * Intermediate Sequence
j) Thermal Ambient Cycles 3501 - 5000
k) * Intermediate Sequence
l) Thermal Ambient Cycles 5001 - 7000
m) * Intermediate Sequence
n) Panel Weight Measurement
o) Final Visual Inspection

Comment: Qual panel met TIMED requirements

RTR Question: 3

SOLAR ARRAY

Flight Panel Inspection and Test Sequence

a) * Intermediate sequence, defined by the following:
- Visual Inspection
- Cell Adhesion Check (as required)
- Wiring Continuity Test
- Temperature Sensor Functionality
- Insulation Resistance Test
- Bypass Diode Check
- Power Output Test

b) Ambient pressure 50° and 90°C Bakeout 24 hours
c) * Intermediate Sequence
d) Thermal Vacuum Cycling (8 cycles)
e) Thermal Vacuum Bakeout
f) * Intermediate Sequence
g) Panel Weight Measurement
h) Final Visual Inspection

Comments:
•Power from panels meet spec requirements
•IV curves are smooth indicating no anomalies
•Remaining cracked cells were reevaluated after S/C acoustic test and replaced as needed.

RTR Question: 3

SOLAR ARRAY

Wing Level

- Deployment tests
- Vibration 3 axis
- Isolation/Continuity/Temperature Sensor/Chassis Ground/Heater Circuits Verification Testing
- Flood light test of each string with S/C
- Damper heater operation test with S/C

RTR Question: 3

SOLAR ARRAY

Solar Array Environmental Test with Spacecraft

- Integrate wings to S/C
- S/C mass properties
- S/C vibration
- Shipment to Goddard
- S/C acoustic test/Pyro Shock
- Wing removal and shipment to APL
- Rework
- LAPSS Testing

RTR Question: 3

SOLAR ARRAY

Solar Array Wing Power

	Pre-S/C Environ.	Post S/C Environ.	%Change
Wing 2 Panel S/N 001:			
Panel 1:	307.9W	304.8W	-1.0%
Panel 2:	307.1W*	300.9W	-2.0%
Panel 3:	309.8W*	305.6W	-1.3%
Panel 4:	309.1W*	305.9W	-1.0%
Wing 1 Panel S/N 002:			
Panel 1:	309.7W	310.0W	1.1%
Panel 2:	311.5W*	308.4W	-1.0%
Panel 3:	313.7W*	308.9W	-1.5%
Panel 4:	310.9W*	308.5W	-0.8%

* Note: Output Measured before Isolation diodes and without Harness loss

RTR Question: 7

BATTERY DESIGN REVIEWS

Battery Cell Design Reviews at Cell Vendor

- PDR-TIM 17 July 1997
- CDR-TIM 2 October 1997
- Plaque-TIM 11 December 1997
- MRR-TIM 26 February 1998
- PSR-TIM 12 December 1998

Review Team:

G. Dakermanji	JHU/APL
M. Butler	JHU/APL
G. Cameron	JHU/APL
L. Mastracci	JHU/APL

TIMED Battery Engineering Design Review

Held: March 26, 1998

Reviewers:

P. Panneton	JHU/APL	T. Betenbaugh	JHU/APL
M. Colby	JHU/APL	U. Carlsson	JHU/APL
D. Temkin	JHU/APL	D. Mehoke	JHU/APL
J. Jenkins	JHU/APL	P. Schwartz	JHU/APL

Action Items: None

RTR Question: 1,2

BATTERY

Battery Acceptance Tests Cell Level

Cell level at Eagle Picher:

- Capacity, 10°C, "C/2" Rate
- Overcharge 10°C
- Capacity, -10°C, "C/2" Rate
- Overcharge -10°C
- Capacity, 20°C, "C/2" Rate
- Overcharge 20°C
- Capacity, 30°C, "C/2" Rate
- High Rate Discharge, 10°C, "2C" and "C/2" Rates
- Capacity, 10°C, "C/2" Rate
- Retention of Charge
- Capacity, 10°C, "C/2" Rate
- Leak Rate Test
- Internal Impedance Test
- Electrolyte Leak Test

Comment: All cells met TIMED specifications

RTR Question: 3

BATTERY

Battery Acceptance Tests Battery Level

- Wiring continuity and ground isolation
- Thermal control circuit operation
- Capacity 10°C
- 10°C charge retention
- Electrolyte leak test
- Vibration sine and random
- Electrolyte leak test
- 10°C capacity
- 10°C capacity retention
- Thermal vacuum testing
- 10°C capacity
- 10°C capacity retention
- -5°C capacity
- 0°C capacity
- Thermal control circuit operation
- 10°C capacity
- **Battery test time 240 hours minimum**

RTR Question: 3,8

BATTERY

Fight Battery Acceptance Test Summary

- All battery test results met or exceeded the TIMED specifications.
- No anomalies observed.
- No rework required.

RTR Question: 3

BATTERY

Spacecraft Environmental tests with Battery

- Flight battery on spacecraft.
- S/C vibration with battery in launch simulation discharge
- Shipment to GSFC with battery on S/C discharged.
- S/C acoustic with battery in launch simulation discharge.
- S/C Thermal Vacuum
  - Orbital charge/discharge cycles
  - Launch simulation
  - Thermal balance
- Post Thermal Vacuum Capacity Testing and storage

RTR Question: 3

BATTERY

Test	Pre-Vib	Post-Vib	Post-TV	Post S/C Env
10°C Capacity	64.49AH	65.75AH	65.88AH	66.70AH
10°C Charge Retention	57.69AH 89.4%	58.41AH 88.8%	59.28AH 89.98%	58.90AH 88.30%

Battery DOD:

Launch to Separation:	24.5%	
Launch to Sun Safe:	49.7%	(without Solar Array Power)

ß = 0 Orbit:	20.5%
ß = 45 Orbit:	13.1%

RTR Question: 7

BATTERY

TIMED Battery Life Test

- 4-TIMED Battery Cells
- Beta = 0, Orbit Cycles @ 10°C.
- 1730 Orbit Cycles to date
- 6000 operational hours
- No anomalies have been noted

RTR Question: 3,8

POWER SYSTEM ELECTRONICS (PSE)

The PSE consist of two PPT, PSE/DIST and two S/A shunt/ junction boxes.

- ESS screening (20 unpowered thermal cycles) of all PWA's and Chassis.
- Subsystem functional testing
- Pre vibration functional and performance testing
- Post axis functional
- Post vibration functional and performance testing
- EMC/EMI Testing
- Pre TV functional and performance testing
- TV performance testing at initial and last temperature extremes
- TV functional testing at extremes except when performance testing is done
- Post TV functional and performance testing
- Post integration functional/performance testing

Total Test Time = 160 hours (prior to delivery to I&T)

RTR Question: 3,8

POWER SYSTEM ELECTRONICS (PSE)

Power System Electronics Test Verification Matrix (Acceptance Testing)

FUNCTION	PRE VIB	VIB	POST VIB	EMI/EMC CS01	EMI/EMC CE01/03	EMI/EMC RE02	EMI/EMC RIPPLE	PRE-THERMAL VACUUM	THERMAL VACUUM	POST THERMAL VACUUM
Verify Bus Regulation via each Controller:										
Fixed S/A regulation point (Vsa=38.5V)	X		X					X		X
Peak Power Tracking (1553A/B command)	X		X					X		X
VT (8 levels)	X		X					X		X
AHI (1553A/B command)	X		X					X		X
Current Limit	X							X		
Trickle Charge via pressure (4 levels)	X		X					X		X
Verify Bus Regulation for Voted Control:	X									
Fixed S/A regulation point (Vsa=38.5V)	X		X					X	X	X
Peak Power Tracking	X	X	X	X	X	X	X	X	X	X
VT	X		X	X			X	X	X	X
AHI	X		X	X				X	X	X
Current Limit	X						X			
Trickle Charge via pressure	X		X					X	X	X
Majority Voter with Simulated Failure	X		X					X		X
Orbit Simulation	X		X					X	X	X
Relay Commands (SCD A/B)										
All Relay Commands	X		X					X	X	X
Subset of Relay Commands		X		X						
Min Coil Voltage									X	
Activate All Loads	X		X					X	X	X
Subset of Loads Active		X		X	X	X	X			
Telemetry Acquisition (1553A/B)										
Relay TT	X		X					X	X	X
Analog Telemetry	X		X					X	X	X
Power System Telemetry	X		X					X	X	X
Subset of each type of Telemetry		X		X						
Hard LVS										
4 voltage levels	X		X					X	X	X
2 pressure levels	X		X					X	X	X
Check Fuse Plugs	X		X					X		X
Individual PPT Module	X		X					X		X
1553 A and B Ports	X		X					X	X	X
Heart Beat Disable	X		X					X	X	X

RTR Question: 3

POWER SYSTEM ELECTRONICS (PSE)

Power System Electronics Test Verification Matrix(I&T - S/C Environmental)

FUNCTION	S/C I&T	PRE VIBRATION	VIBRATION	POST VIBRATION	PRE-THERMAL VACUUM	THERMAL VACUUM	POST THERMAL VACUUM
Verify Bus Regulation via each Controller:							
Fixed S/A regulation point (Vsa=38.5V)	X						X
Peak Power Tracking (1553A/B command)	X						X
VT (8 levels)	X						X
AHI (1553A/B command)	X						X
Current Limit	X						
Trickle Charge via pressure (4 levels)	X						X
Verify Bus Regulation for Voted Control:							
Fixed S/A regulation point (Vsa=38.5V)	X	X		X	X	X	X
Bus /Battery Voltage Monitor	X	X	X	X	X	X	X
Peak Power Tracking	X	X		X	X	X	X
VT	X	X		X	X	X	X
AHI	X	X	X	X	X	X	X
Current Limit	X	X				X	
Trickle Charge via pressure	X	X		X	X	X	X
Majority Voter with Simulated Failure	X						X
Orbit Simulation	X	X		X	X	X	X
Relay Commands (SCD A/B)							
All Relay Commands	X						
Subset of Relay Commands	X	X		X	X	X	X
Min Coil Voltage(22V Bus)	X	X		X	X	X	X
Activate All Loads	X	X		X	X	X	X
Subset of Loads Active			X				
Telemetry Acquisition (1553A/B)							
Relay TT	X	X	X	X	X	X	X
Analog Telemetry	X	X	X	X	X	X	X
Power System Telemetry	X	X	X	X	X	X	X
Subset of each type of Telemetry							
Hard LVS							
4 voltage levels	X	X				X	X
2 pressure levels	X	X				X	X
Check Fuse Plugs	X			X	X		X
Heart Beat Disable	X					X	

RTR Question: 3,7

POWER SUBSYSTEM P/FR's

P/FR #	Component	Summary	Status
TPWR-001	Solar Array	Solar Cell Delamination Issue	**Closed**
TPWR-002	Solar Array	Deployment switch not Indicating Correct State	**Closed**
TSC-101	Solar Array	Cracked Solar Cells found Post rework	**Closed**
TSC-107	Solar Array	Cracked Solar Cells found Post rework	**Closed**
TSC-108	Solar Array	Cell Cracked During LAPSS testing	**Open**
TSC-039	PSE	SABER Current Shunts have wrong Value	**Closed**
TSC-050	PSE	Battery Pressure Simulator caused overvoltage to pressure Inputs	**Closed**
TSC-057	PSE	Serial Cmd Decoder failure during Box level Vibration	**Closed**
TSC-095	PSE	Serial Cmd Decoder Single point failure mitagation	**Closed**
TSC-092	Battery	Differential Heater Control logic reversed	**Closed**

RTR Question: 7

POWER SUBSYSTEM RESIDUAL RISK

NONE

SOLAR ARRAY

Solar Array Cell Delamination Issue and Resolution

P/FR No: TPWR-001

- **Problem Description**

  During cleaning of the solar panels at APL by blowing N_2 on the cells and suctioning the dust particles, some cells we observed to vibrate and one cracked. Detailed investigation revealed extensive delamination of solar cells from adhesive on all panels. All panels were shipped to the vendor. Complete cell lay down was made on all eight panels. All panels were inspected and tested per specification including eight TV cycles. The panel bonding after implementing contamination control steps are good and meet the TIMED bonding specification

- **Resolution**

  The vendor re-used some of the cells removed from the original bonding. Some of these cells had cracks after rebonding and TV cycling. Due to S/C schedule, the panels were accepted for shipment to APL with some cracked cells not replaced.

  After S/C vibration and acoustic test, (which typically can cause some cell cracking) the two wings will be brought back to APL. Cells will be replaced as needed. The panels were LAPSS Tested post rework.

  Since the number of replaced cells which would not have seen vacuum is larger than typical S/C programs, all panels were exposed to vacuum.

- **PFR STATUS: CLOSED**

RTR Question: 7

POWER SYSTEM ELECTRONICS (PSE)

Serial Cmd Decoder Single Point Failure Mitagation

P/FR No: TSC-095

- **Problem Description:**

  The concern is that there is potential for a single point failure in the command system internal to the PSE/DU. The serial command decoder internal to the PSE/DU has a linear regulator which steps down the 28V bus to 12V. If the 12V regulator was to fail shorted the 28V bus would appear on the CD4000 logic supply lines which would result in some relay coils being continuously energized. If this occurred, the working command system would be unable to control the corresponding relays.

- **Resolution:**

  The PSE/DU was removed from the spacecraft and changes to the design were implemented to mitigate the possibility of the occurrence of the single point failure. After rework was complete, the box underwent workmanship vibration and 3 ambient pressure thermal cycles. The PSE/DU was then reintegrated with the spacecraft and a full performance test was successfully completed.

- **P/FR STATUS: CLOSED**

RTR Question: 7

SOLAR ARRAY

Solar Array Deployment Switch

P/FR No: TPWR-002

- **Problem Description**

  During the continuity/verification testing of the solar array deployment switches on the -X solar array wing, we noted that the primary deployment switch was not indicating the proper stowed state. Further investigation revealed that the switch arm was bent causing a misalignment with the roller actuator.

- **Resolution**

  The switch was replaced and proper operation was verified.

- **PFR STATUS: Closed**

RTR Question: 7

SOLAR ARRAY

Solar Array Cracked Cells

P/FR No: TSC-101 (S/A Wing 1)

P/FR No: TSC-107 (S/A Wing 2)

- **Problem Description**

  During the LAPSS testing of the solar array wings, the power of several panels was noted to be lower than previous test. Further investigation revealed several crack solar cells. The cracked cells were caused by excessive screw length used to hold some GSE brackets.

- **Resolution**

  The cells were replaced using qualified rework process. GSE was labeled with proper screw length for the GSE application.

- **PFR STATUS: Closed**

RTR Question: 7

SOLAR ARRAY

Solar Array Cracked Cell

P/FR No: TSC-108

- **Problem Description**

  During the LAPSS testing of the solar array wing, the GSE cover handling cause the corner of a solar cell to be damaged.

- **Resolution**

  The cell will be final inspected at VAFB and replaced using qualified rework process if needed.

- **PFR STATUS: Open**

RTR Question: 7

POWER SYSTEM ELECTRONICS (PSE)

PSE/DU pressure inputs overstressed by battery simulator

P/FR No: TSC-050

- **Problem Description:**

  During PSE/DIST testing on the S/C while using the battery simulator, an anomaly occurred on the pressure circuit simulator which caused high voltage for less than 100ms to be applied at the battery pressure inputs to the PSE.

- **Resolution:**

  All affected circuit components were analyzed, breadboards as needed to simulate the transient were built and tested, and the IC manufactures contacted. Investigations verified that no components were stressed.

- **P/FR STATUS: Closed**

RTR Question: 7

POWER SYSTEM ELECTRONICS (PSE)

PSE/DU SABER Current Shunts wrong Value

P/FR No: TSC-039

- **Problem Description:**

  PSE/DIST Unit current shunts for SABER Electronics and SABER Survival heaters were built with wrong values.

- **Resolution:**

  Change software scale factor for the SABER Electronics current channel. Change SABER Survival Heater to a spare relay (Current Shunt Channel) with higher current capability, implemented via harness change.

- **P/FR STATUS: CLOSED**

RTR Question: 7

POWER SYSTEM ELECTRONICS (PSE)

Serial Cmd Decoder Failure during Box acceptance testing

P/FR No: TSC-057

- **Problem Description:**

  During vibrations testing of the power subsystem, a fault occurred on one of the Serial Command Decode/Majority Voter Circuit cards in the PSE/DIST unit

  – The fault cleared and could not be duplicated.

- **Resolution:**

  A new card was fabricated and subjected to;

  Card Level Tests:

unpowered 20 cycles (ESS)	-35°C to 90 °C
powered 6 cycles	-35°C to 60 °C
vibration to PSE/DIST box levels	

  Box level in PSE/DIST:

  Performance Tests

  Workmanship level vibration

  TV cycled as part of power system electronics

- **P/FR STATUS: Closed**

RTR Question: 7

BATTERY

Battery Differential Heater Control Relay

P/FR No: TSC-092

•Problem Description

During spacecraft thermal vacuum testing, the battery differential heater operation was verified by varying the environments on the battery radiators and waiting for an appropriate response from the battery heater circuits. During the test we noted that the command and telemetry dictionary incorrectly denoted the differential heater On/Off command and telemetry status. However, during post thermal vacuum Hard LVS testing we noted that the command sequence burned into an FPGA in the Critical Command Decoder for shedding loads contained the command to turn on the differential heaters instead of turning the differential heaters off.

•Resolution

The command and telemetry dictionary was updated to reflect proper command and telemetry status. To update the Hard LVS command sequence would require rework to both IEM's. However, the power saved by turning off the battery differential heaters at Hard LVS would be only 18W, which does not significantly impact the battery power available at Hard LVS. Therefore, the command sequence shall be "Used-As-Is".

•PFR STATUS: Closed

RTR Question: 7

GUIDANCE AND CONTROL HARDWARE

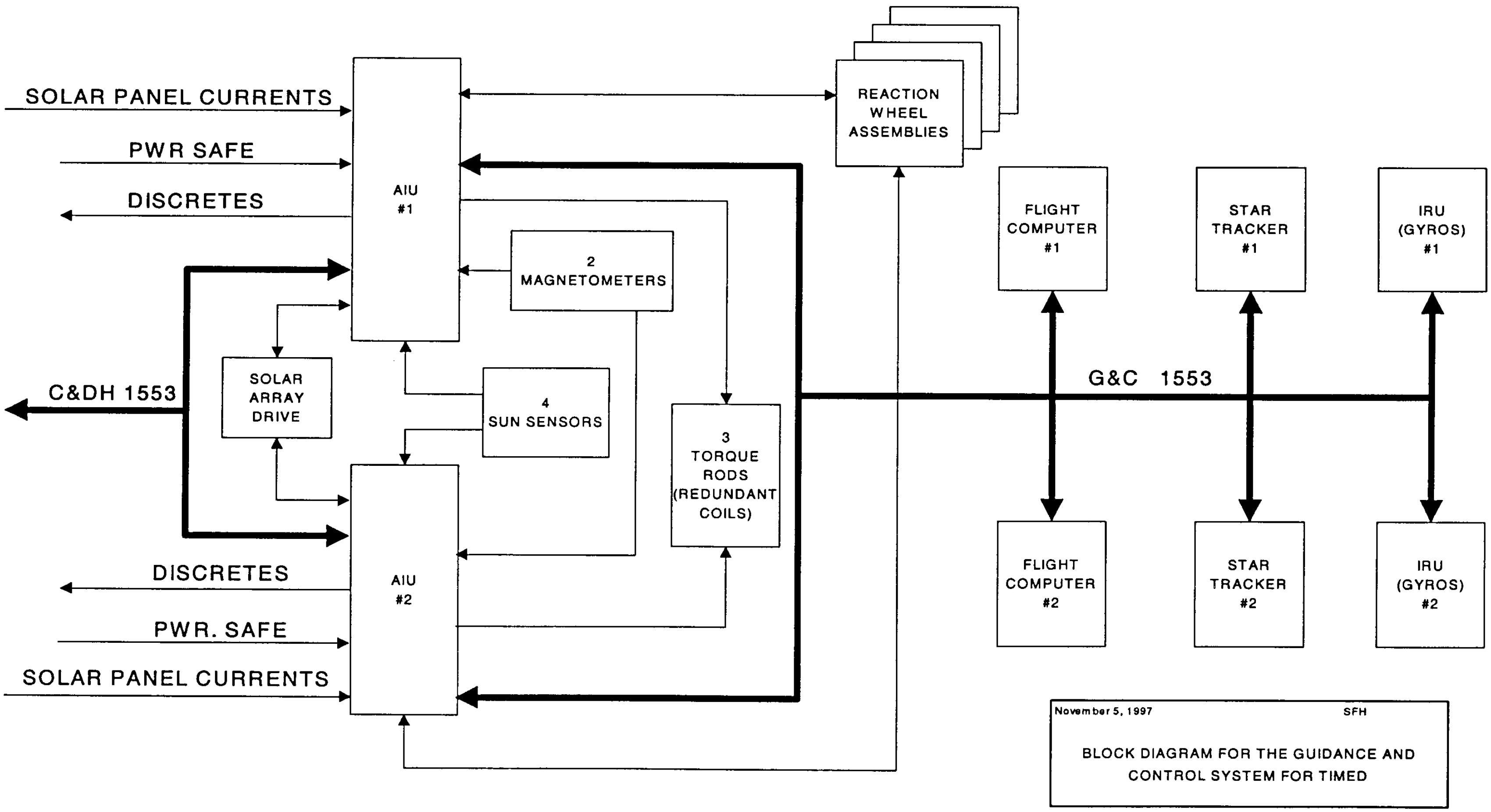
Wade E. Radford
(443) 778-5055

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Red Team Review 31 Oct. - 3 Nov. 2000

G&C BLOCK DIAGRAM



G&C COMPONENT TESTING

ITEM	VENDOR TESTING	APL TESTING					
		FUNCTIONAL	TEMP.	VIBRATION	VOLTAGE	SUB-SYS	I & T
STAR CAMERA*	X	X				X	X
WHEELS	X	X				X	X
MAGNETOMETER	X	X				X	X
IRU	X	X				X	X
TORQUE RODS	X	X				X	X
SOLAR ARR. DR.**	X	X				X	X
SUN SENSORS	X	X	X	X		X	X
AIU ASSEMBLY		X	X	X	X	X	X
MOTHER BD.		X					
1553 BD.		X					
2010 BD.		X					
ANALOG BD.		X					
DIGITAL BD.		X					
POWER BD.		X					

* See slide #5 ** See slide #7

SEE-97-0216
November 24, 1997

TO: Distribution

FROM: L. R. Kennedy

SUBJECT: Engineering Design Review of the TIMED AIU

The informal Engineering Design Review (EDR) of the TIMED Attitude Interface Unit (AIU) NEAR designs that were not reviewed include the FPGA on the 1553 board and the processor board FPGA except for the UART. Also included in the EDR package is information on interface changes made since the AIU EDR. Interface changes made include the filtering of the magnetometer and sun sensors along with the grounding of the torque rod output monitors and sun sensors.

No action items were generated from the EDR.

Larry Kennedy

Attached:
AIU Changes Since NEAR
AIU Block Diagram
AIU Power Switching (3 sheets)
AIU Low Voltage Discretes (2 sheets)
Solar Array Drive Command
AIU Test I/O
Magnetometer Inputs
Sun Sensor Inputs
Solar Array Inputs (2 pages)
Reaction Wheel Inputs/Outputs
Torque Rod Inputs
Power Distribution

Reviewers:	Mail Stop
JD Boldt	4-234
ME Fraeman	23-372
LR Kennedy	23-372
DY Kusnierkiewicz	MOD1-118
AL Lew	23-372
SF Oden	23-372
WE Radford	23-372

SEE Files

SEE-98-0094
September 29, 1998

TO: Distribution

FROM: L. R. Kennedy

SUBJECT: Engineering Design Review of the TIMED AIU Field Programmable Gate Arrays

The informal Engineering Design Review (EDR) of the TIMED Attitude Interface Unite (AIU) Field Programmable Gate Arrays (FPGA) is finished. John Boldt and Stephen Oden reviewed the designs. Only the new designs for the TIMED AIU were reviewed. These included the FPGAs for the analog and digital boards along with the Universal Asynchronous Receiver Transmitter (UART) added to the processor board FPGA. NEAR designs that were not reviewed include the FPGA on the 1553 board and the processor board FPGA except for the UART. Also included in the EDR package is information on interface changes made since the AIU EDR. Interface changes made include the filtering of the magnetometer and sun sensors along with the grounding of the torque rod output monitors and sun sensors.

No action items were generated from the EDR.

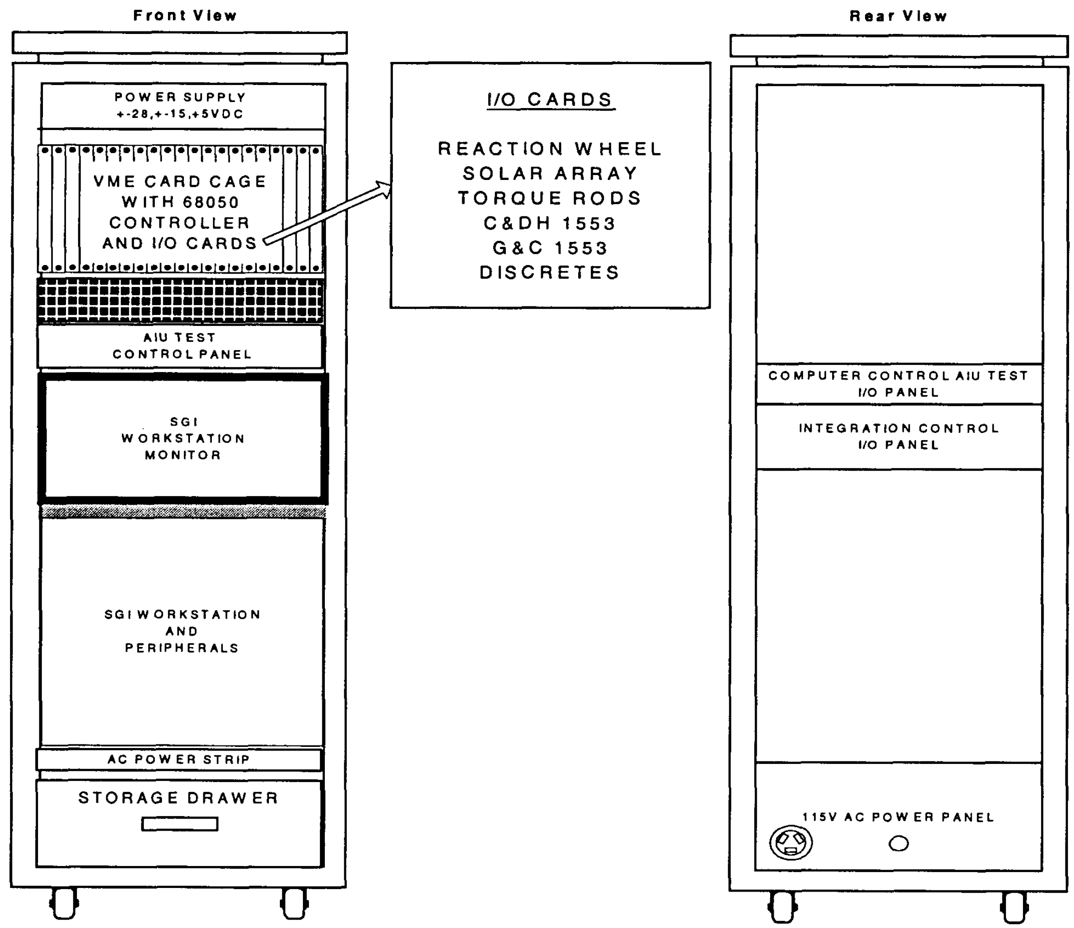
Larry Kennedy

Attachments:
(1) AIU Field Programmable Gate Array Design Review
(2) AIU Hardware Description Appendix A
(3) 7363-7005 Processor FPGA Schematic (Sheets 1-4, 11, 13, 22-24)
(4) 7363-7005 Digital FPGA Schematic (23 sheets)
(5) 7363-7007 analog FPGA Schematic (14 sheets)
(6) Timing Diagrams (11 sheets)

Reviewers:	Mail Stop	Attachments
JD Boldt	4-234	(1), (2), (3), (4), (5), (6)*
ME Fraeman	23-372	(1), (2), (3), (4), (5), (6)*
LR Kennedy	23-372	(1), (2), (3), (4), (5), (6)*
DY Kusnierkiewicz	MOD1-118	(1), (2)
AL Lew	23-372	(1), (2)
SF Oden	23-372	(1), (2), (3), (4), (5), (6)*
WE Radford	23-372	(1), (2)
SEE Files		(1), (2), (3), (4), (5), (6)*

*Distributed before the EDR.

TIMED ATTITUDE SYSTEM TEST & INTEGRATION EQUIPMENT (TASTIE)



SRH 1-19-99 t3rack.vsd

G&C COMPONENTS BURN-IN

COMPONENT	* HOURS	VENDOR	RECEIVED
AIU	37	APL	8/3/98
AFC	120	APL	9/1/98
SUN SENSOR	48	APL	7/21/98
TORQUE RODS	53	ITHACO	2/10/98
MAGNETOMETER	217	SAIC	3/10/98
IRU # 51	154	HONEYWELL	2/22/99
IRU # 52	154	HONEYWELL	3/24/99
PANEL DRIVE	58	SCHAEFFER	8/5/98
STAR TRACKER	200	LOCKHEED	8/31/99
WHEELS	>420	ITHACO	10/23/98

* Number of hours operated before delivery to the spacecraft (NO ANOMALIES)

STAR TRACKER REWORK: The Lockheed Martin star trackers #1 and #2 were reworked according to the recommendations of LMMS and GSFC.

Both star trackers were removed from the spacecraft. The power supply chassis and 1553 chassis were removed from the star trackers by a LM technician and delivered to GSFC.

The Interpoint converters were reworked at GSFC by Swales personnel per the Swales procedure SAI-PROC-821. Lid deflections on both MTR dual output converters in a vacuum before rework were measured to be 7 mils, indicating the lids were still attached to the internal magnetics. High resolution x-ray determined that the internal magnet wire clearance was 1 wire diameter on both converters, indicating sufficient strain relief. These results confirmed that both of the converters required the addition of the doubler to the lids.

20 mil doublers were bonded to the converters. The 1553 chassis above the converters were milled out to provide an additional 25 mils of clearance. Lid deflections were then remeasured in vacuum to confirm the success of the bonding process.

The power supply and 1553 chassis were returned to APL. The star trackers were re-assembled by a LM technician. New flight heaters were installed on the power supply chassis. APL performed bench tests at ambient to confirm proper operation.

Per the LM recommendation for workmanship testing, both star trackers were then subjected to an unpowered one-axis workmanship vibration. This was followed by one cold survival soak at -40 deg. C., and four powered thermal vacuum cycles between -30 and +50 deg. C. All test results indicated proper operation of the star trackers.

The star trackers were re-installed on the spacecraft on August 8, 2000.

SOLAR ARRAY DRIVE REWORK

DATE: 04/08/99

TO: Wade Radford / APL-JHU

FROM: John Lo

SUBJECT: Rework Summary for APL 4- Channel ECU, SMD 108535, SN 003

REFERENCE: 2875 / APL ECU

SMD has completed rework of the subject ECU by applying Kapton tape to provide insulation to the chassis area that are close to the hybrid chip. The actual rework instruction (Deviation Rework Record) is retained at SMD, and is available for customer inspection if required. The following is the rework summary:

PROBLEM FAILURE REPORTS

PFR #	PROBLEM	DATE	CLOSED	DATE	ENGINEER
020	IRU toggling on/off	5/20/99	New software	7/22/99	WER
041	AFC#1 not resetting	8/10/99	SPR 217	9/20/99	WER
046	Improper AIU jump to application mode	9/01/99	SPR 261	10/05/99	WER
048	Connector # missing from star trackers	9/14/99	Connectors marked	10/22/99	WER
076	-X,-Y Sun sensor damaged	12/09/99	Sun sensor replaced	09/01/00	WER
099	Interpoint converter rework	06/20/00	Units reworked	09/01/00	WER
100	Interpoint converter rework	06/20/00	Units reworked	09/01/00	WER

G&C TEST SCRIPT INDEX

SECTION	DESCRIPTION
0:	Define all variables and input arguments
1:	Assign variables and ground system global variables
2:	Set up processors
2.1:	Set up TASTIE/C&DH
2.2:	Reboot AIU and keep in boot
2.3:	Send stay in boot
2.4:	Verify currents and voltages
2.5:	Examine RAM and processor checks
2.6:	Verify software version number
2.7:	Verify AIU BCR and PSR
2.8:	Verify the select switches tell tales
2.9:	Verify application load ok
2.10:	Reboot other AIU and stay in boot
3:	Verify AIU commanding
3.1:	Send NO-OP
3.2:	Load to RAM
3.3:	Send No-Op to other AIU
4:	Test Select Switches
5:	Test AIU Relays
5.1:	Verify torque rod relays and solar array drive come up off
5.2:	Cycle power to IRUs
5.3:	Change states to the torque rods
6:	Test sensors
6.1:	Test sun sensors
6.2:	Test magnetometers
6.3	Check solar array currents
7:	Test Wheels
7.1:	Power Wheels
7.2:	Verify wheels at zero rate
7.3:	Wheel 1 test

G&C TEST SCRIPT INDEX, Continued

SECTION	DESCRIPTION
7.3.1:	Command to negative torque
7.3.2:	Allow to coast to zero and time it
7.4:	Wheel 2 test
7.4.1:	Command to positive torque
7.4.2:	Allow to coast to zero and time it
7.5:	Wheel 3 test
7.5.1:	Command to negative torque
7.5.2:	Allow to coast to zero and time it
7.6:	Wheel 4 test
7.6.1:	Command to positive torque
7.6.2:	Allow to coast to zero and time it
8:	Test Solar Array Drives
8.1:	Cycle power to solar array drives
8.2:	Verify AIUs agree in position
8.3:	SAD 1 move a little bit
8.3.1:	Verify ended at same position as started
8.4:	SAD 2 move a little bit
8.4.1:	Verify ended at same position as started
8.5:	Power down SADs
9:	Check if wheels have coasted down
9.1:	Power down Wheels
10:	Test discretes
10.1:	Change and verify input discretes from IEM
10.2:	Change and verify input discretes for PS
10.2.1:	Change and verify input discretes from PS receipt in other AIU
10.3:	Change and verify output discretes
10.4:	Change and verify output discrete on other AIU
11:	Jump to safe mode (real HW in loop)
11.1:	Verify components are not powered
11.2:	Jump to safe mode

G&C TEST SCRIPT INDEX, Continued

SECTION	DESCRIPTION
11.3:	Verify in safe mode
11.4:	Setup AIU flight parameters
12:	Move SADs from stop to stop
12.1:	Move to top stop (-z)
12.2	Move to bottom stop (-y)
12.3:	Move to up position (-z)
13:	Test other AIU on 1553
13.1:	Send other AIU to flight
13.2:	Verify other AIU answering polling
14:	Test both IRUs
14.1:	Power both IRUs (by cmd)
14.2:	Verify IRUs answering polling
14.3:	Record Body rates from primary IRU
14.4:	Turn off non-primary IRU
15:	Test AFCs
15.1:	Set primary AFC
15.2:	Power both AFCs
15.3:	Verify AFCs are answering the polling
15.4:	Send Active AFC No-Op
15.5:	Send AFC 1 No-Op
15.6:	Send AFC 2 No-Op
15.7:	Set AFC as primary
15.8:	Send Active AFC No-Op
16:	Test ASTs (Star trackers)
16.1:	Power both ASTs
16.2:	Verify ASTs are answering the polling
16.3:	Send AST 1 No-Op
16.4:	Send AST 2 No-Op
16.5:	Verify star field with stimulators
17:	Verify messages to and from AFC and AIU
18:	Power everything off

RESIDUAL RISK

Because of the overruns in cost and schedule and the high personnel turnover (both managerial and technical) at the vendor and the hardware rework for the Interpoint converter, the star tracker might be considered at risk.

Mitigation steps were taken at APL consisting of additional TV test and accuracy verification over temperature. Additionally the many hours of flawless operation during launch and orbit simulations and other satellite activities give APL confidence in the basic integrity of the hardware and software.