TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Integrated Electronics Module (IEM)

Paul Marth

The Johns Hopkins University
Applied Physics Laboratory

PHONE: (301) 953-5322
FAX: (301) 953-1093
email: paul.marth@jhuapl.edu

IEM

- Design overview
- Changes Since PDR
- PCI Bus
- 1553 Interface
- I2C Interface
- Redundancy
- Thermal Design
- Mechanical Design
- EMC Design
- Integration and Test

IEM DESIGN OVERVIEW

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

(Refer to slides 13 and 14 in this series for IEM illustrations.)

1. Command & Data Handling (C&DH) Subsystem
   - a. C&DH Processor (1 card, A2)
   - b. Solid State Recorder (SSR) (1 Card, A3)
   - c. Command & Telemetry Interface (C&T) (1 Card, A6)
   - d. Critical Command Decoder (CCD) (On Uplink Card, A8)
   - e. Downlink Formatter (On Downlink Card, A7)
2. GPS Navigation Subsystem (GNS)
   - a. GNS Receiver/Tracker (1 Card, A4)
   - b. GNS Dual Processor (1 Card, A5)
3. RF Communications Subsystem (S-Band)
   - a. Uplink (1 Card, A8)
   - b. Downlink (1 Card, A7)
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 Changes Since PDR

1. Decision not to implement SSR/1 PPS cross-strapping (IEM-to-IEM)
2. Decision to baseline design with Mongoose V processor
3. Dual rather than single processor configuration for GNS
4. Elimination of SPARE slot in IEM housing
5. Decision to use single front cover vs individual card covers

IEM - PCI BUS

1. Designed to Industry Standard

2. Sixteen Bit Bi-Directional Transfers (> 5 Mbytes/Sec)

3. Internal to IEM. Interfaces C&DH Processor to:
    a. Solid State Recorder (SSR)
        - Store/Read Data
    a. GNS Processor
        - Command Data to GNS
        - Navigation Data from GNS
    b. S-Band Downlink
        - Real Time & Stored Data for Downlink
    c. Command & Telemetry Interface
        - Cmd Packets from Uplink
        - Cmds to Power Switching via Critical Cmd Decoder (CCD)
        - Housekeeping Data from Remote Interface Units (RIU's) & IEM

IEM - 1553 Interface

1. Dual Serial Bi-Directional Bus
   - a. Bus Controller directs all I/O
   - b. One Mbit/Sec Transfer Rate
   - c. Designed to Industry Standard

2. Implemented on C&DH Processor Card using SUMMIT 1553 Controller Chip

3. Interfaces IEM to:
   - a. Instruments
   - b. Flight Attitude Computer (FAC) via Attitude Interface Units (AIU's)
   - c. S/C Power Subsystem
   - d. Second IEM

IEM - I2C Interface

1. Industry Standard Serial Bus
   100 Kbits/Sec Transfer Rate

2. Bus Controller Implemented on
   Command & Telemetry
   Interface Card

3. Interfaces IEM via Command & Telemetry
   Interface card to Remote Interface Units (RIU's)
   for collection of spacecraft temperatures.

NOTE: I2C or I^2C = Inter-Integrated Circuit

IEM Redundancy

1. Use of two IEM units on the TIMED spacecraft provides full redundancy for:
   a. Command and Data Handling (C&DH) including data storage
   b. Navigation (GNS)
   c. RF Communications (Uplink/Downlink)
   d. Power for each IEM

2. Normal dual IEM operating mode
   a. Selected primary IEM fully powered/operational
   b. Secondary IEM OFF except for Uplink Receiver with Critical Command Decoder (CCD)
   (i.e. both Uplink receivers/CCD's always ON)

3. Special operations utilize both IEM's fully powered (one as Bus Controller, BC, the other as a Remote Terminal, RT).
   NOTE: BC/RT assignment determined by relay setting external to IEM.

IEM Thermal Design

1. The central structure of an IEM card is an aluminum member serving as heat sink and mechanical support.

2. Components are thermally attached to the heat sink by: Direct contact, Thermal vias or Conductive pads thru PC board.

3. Component locations are picked to provide shortest thermal path for the highest power dissipation devices.

IEM Thermal Design (Con't)

4. Card heat sinks are clamped to the IEM aluminum chassis by full card length cam locked guides.

5. Placement of the IEMs on the +Y panel (cold side of S/C) provides optimum on-orbit thermal environment.

6. Analysis of each IEM card's thermal design indicates operation over the full IEM test temperature range while maintaining component temperatures within design guidelines.

IEM Card Testing

1. Sample cards, w/o electrical components, have successfully passed environmental stress qualification testing:
   a. Vibration
   b. Thermal Vacuum

2. Tests validated fabrication processes (Ref. TSM-97-074):
   a. Integrity of bond between PC boards and aluminum heat sink.
   b. Ability of multilayer PC boards to withstand delaminating forces.

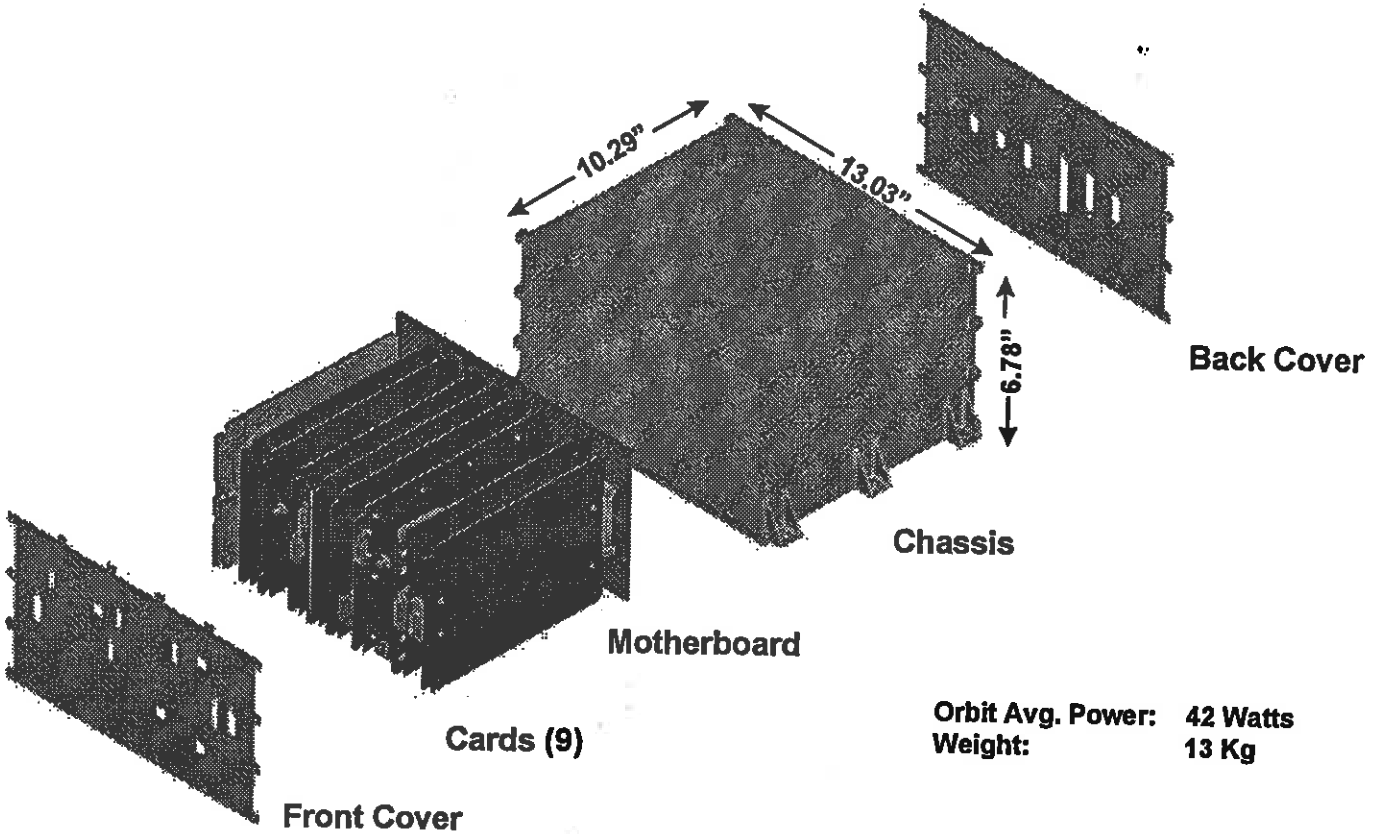
(Refer to slides 16 to 18 in this series for an illustration of card construction.)

IEM Card Testing (Con't)

3. Vibration Test (Ref. VTL-R-97-039):
   a. Random: 3 axis, 20.7 grms, 3 min/axis
   b. Sine sweep: 3 axis, 5-100 Hz, 1.5 octaves/min
   c. Ultasonic inspection after each axis

4. Thermal Vacuum Test:
   a. Three temp. ranges: 0 to +40, -10 to +55, -20 to +70 Deg. C
   b. Ten cycles each temp. range
   c. Ultasonic inspection after each temp. range

IEM CHASSIS CONSTRUCTION

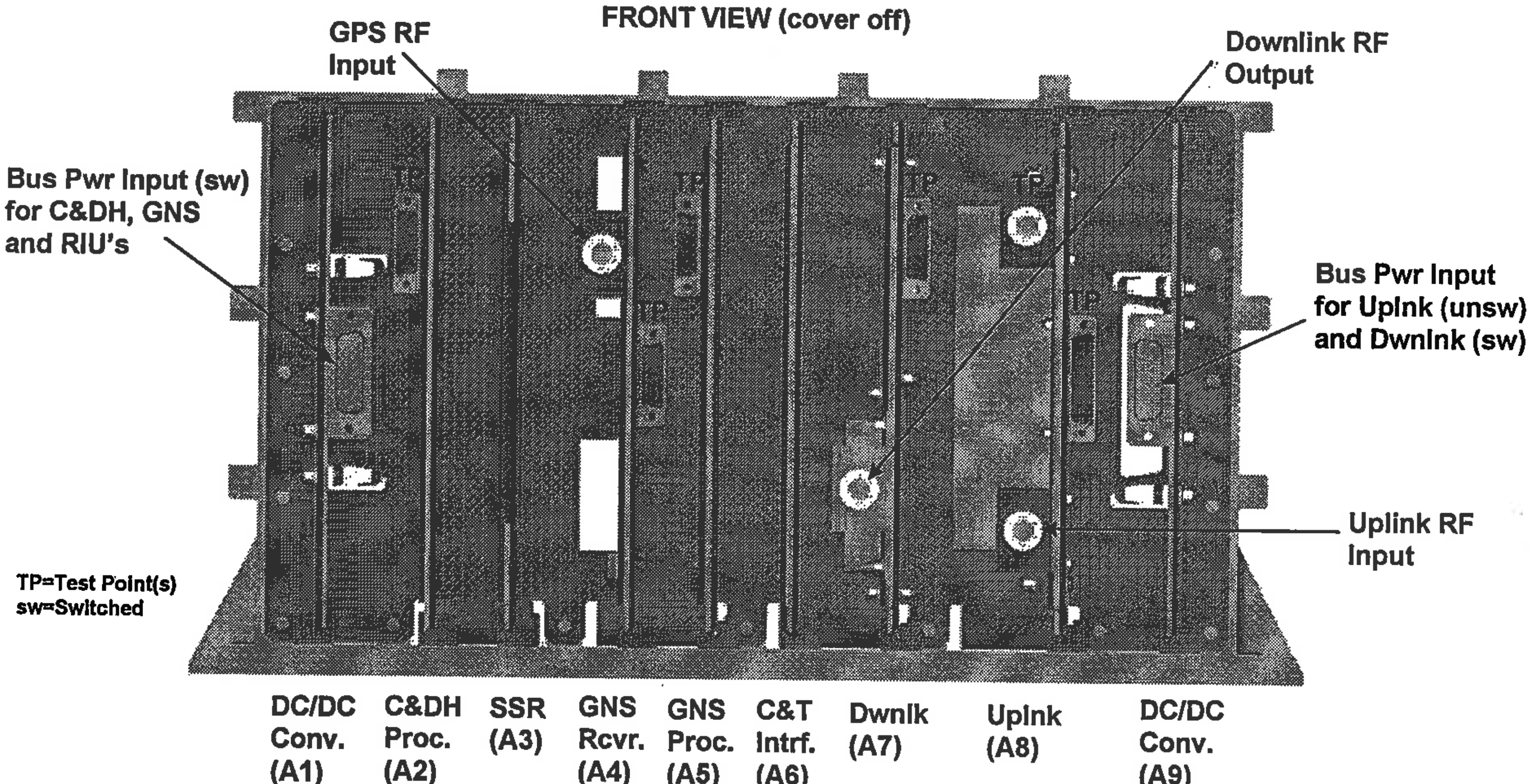


Orbit Avg. Power:	**42 Watts**
Weight:	**13 Kg**

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

IEM CHASSIS CONSTRUCTION



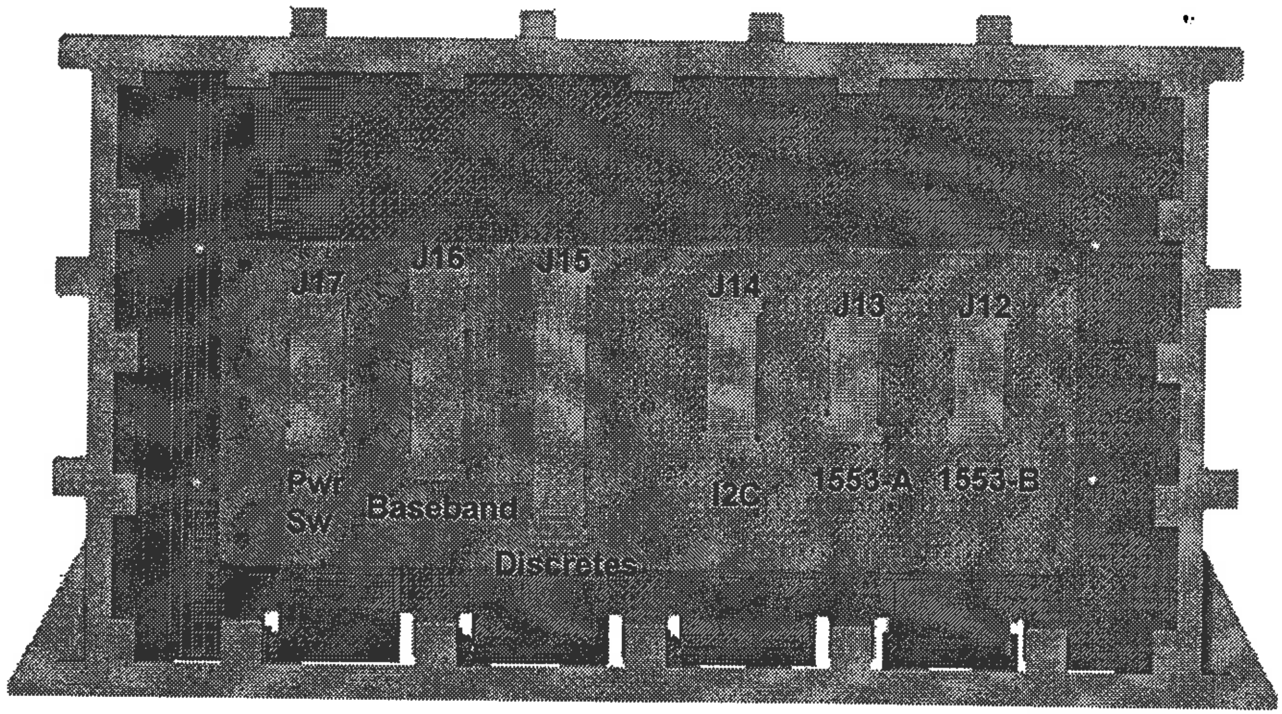
IEM-PCM-14

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

IEM CHASSIS CONSTRUCTION

BACK VIEW (cover off)

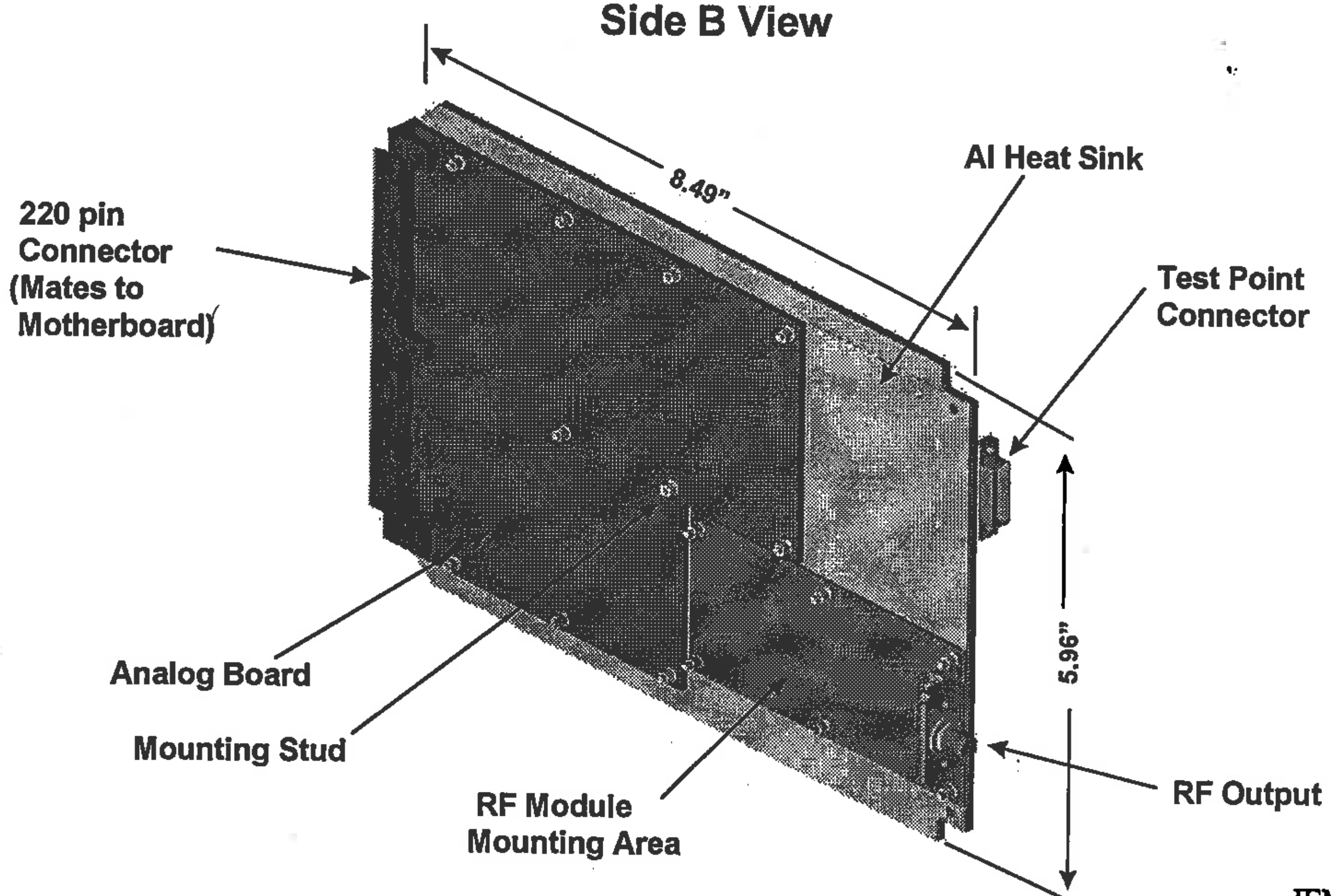


TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

IEM CARD CONSTRUCTION

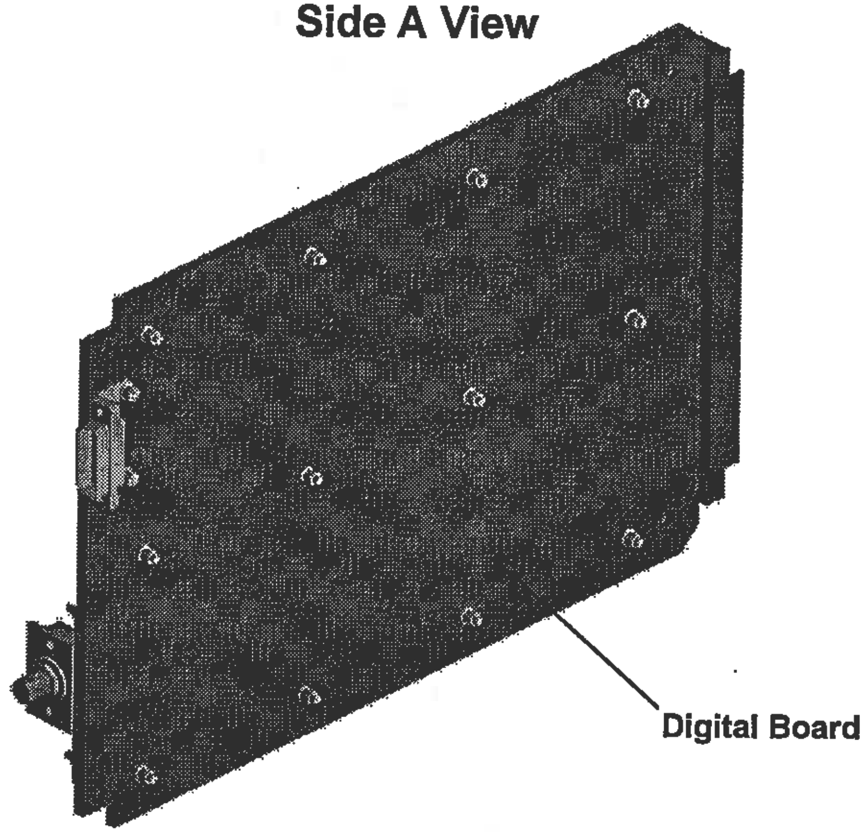
Side B View



Note: Card designed to Extended SEME standard.

IEM CARD CONSTRUCTION

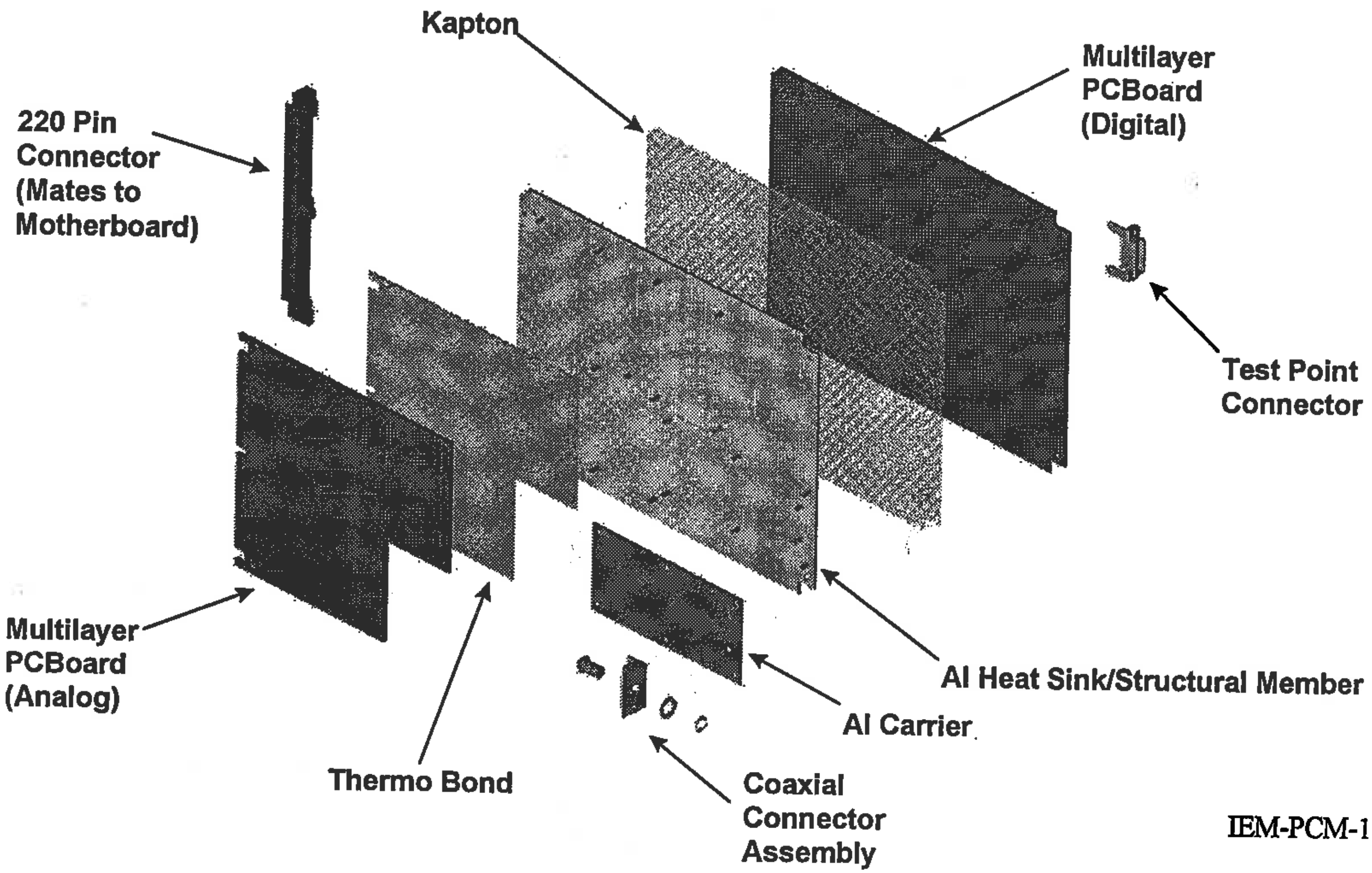
Side A View



TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

IEM CARD CONSTRUCTION



IEM EMC Design

1. The IEM Housing is designed to minimize RF leakage.

2. Alternating ground/signal PC planes are used to reduce crosstalk and control signal path characteristics.

3. Secondary grounds are referenced to the IEM chassis to prevent ground current induced interference. Primary/ Secondary power are isolated and the primary power is returned to the S/C single point ground.

4. Local shielding on RF modules is used to eliminate radiated interference.

IEM EMC Design (Con't)

5. Internal filtering and an external diplexer isolate Uplink, Downlink and GNS L1 channel. The Filter/Diplexer combination has been tested to ensure adequate isolation of Uplink from Downlink. Analysis confirms that the Downlink does not impact the GNS L1 reception even without considering antenna isolation.

6. Separate DC/DC Converter Cards supply power to Uplink/Downlink cards and other IEM subsystems (C&DH and GNS).

7. The Uplink card has been successfully tested with a DC/DC converter card and a typical digital board (all at the brassboard/ breadboard level of fabrication).

IEM Integration & Test

1. Each IEM subsystem is tested prior to IEM integration.
    a. Card level functional tests
    b. Card level Environmental Stress Screening (Flight Cards)
    c. Subsystem Functional & Performance Testing
    d. Subsystem Thermal Testing

2. Wirewrap version of IEM chassis is available for EM and Flight card checkout at IEM level prior to EM/FLT integration.

IEM Integration & Test (Con't)

3. Hardware Integration sequence:
   a. DC/DC Converter cards (A1 & A9)
   b. C&DH[1]
      - Processor card (A2)
      - Cmd & Tlm Interface card (A6)
      - Solid State Recorder (SSR) card (A3)
   c. Uplink card (A8)
   d. Downlink card (A7)
   e. GPS Navigation System (GNS)
      - Dual processor card (A5)
      - Receiver/Tracker card (A4)

1. C&DH requires Downlink Formatter (on A7) and Critical Cmd Decoder (on A8) functions to complete integration.

IEM Integration & Test (Con't)

4. Software Integration
   a. The initial C&DH and GNS software builds for EM I&T will be sufficient to support hardware testing.
   b. Later software builds will be structured to add functionality in a logical sequence leading to the final validated versions.

5. Engineering Model Testing
   a. Develop Functional and Performance tests for Flight IEM qualification.
   b. EMC (Primary Isolation, Bonding, Self Compatibility, Conducted Emissions/Susceptibility)
   c. Software Checkout

IEM Integration & Test (Con't)

6. Flight IEM Qualification Testing
   a. Baseline Test
   b. Vibration
      - Sine sweep, 3 Axis
      - Random, 3 Axis, 14.1 grms, 1 min/axis
   c. Thermal/Vacuum (6 Cycles)
   d. Repeat Baseline Test

IEM Integration & Test (Con't)

7. Spacecraft/IEM Integration Strategy
   a. Engineering Model (EM) IEM used to start spacecraft integration (10/1/98).
   b. Flight IEM #1 will be installed on the spacecraft prior to environmental qualification to check compatibility and dual IEM operation with EM (1/5/98).
   c. Flight IEM #2, fully qualified after any changes resulting from experience with IEM #1/EM, replaces IEM #1 (2/3/98).
   d. Flight IEM #1, fully qualified, replaces EM (3/12/98).

Spacecraft CDR
RF Communication System

December 3, 1997

Robert S. Bokulic

(301) 953-6409
robert.bokulic@jhuapl.edu

Requirements

NOTES:

1. The NTIA emission requirements specify that the envelope of the transmitted spectrum must fall off at a rate of at least -12 dB/octave beyond the necessary RF bandwidth. The necessary RF bandwidth for TIMED is 10 MHz.

2. The downlink bit rate and link margin requirements are per the TIMED System Requirements Document (7363-9001). To avoid confusion, both the information and the Reed Solomon bit rates are given.

3. Link margin requirements must be met over the given antenna coverage regions.

4. For the uplink and low-rate downlink, antenna coverage is specified as a percent of the volume about the spacecraft; for TIMED this is 95%. It is specified this way because the antenna pattern will be perturbed by the spacecraft structure and solar panels in ways that are impossible to predict precisely. Large dips in the pattern can occur at angles around 90° from the spacecraft Z-axis, making complete (100%) coverage impossible to guarantee. The antenna patterns in these directions are more a function of the spacecraft structure and solar panel orientation than of the antennas themselves. Based up previous experience, we believe that the 95% coverage requirement can be met; however, this should be viewed as a soft requirement because the ultimate performance of the mission is not strongly dependent on the precise coverage achieved.

Requirements

- Fully redundant
- Compatible with APL, backup, and contingency ground stations
  - Uplink and low-rate downlink compatible with all stations
  - Dump all recorder data in one <u>pass</u> to APL station; one <u>cluster</u> to backup stations
- Compatible with NTIA emission requirements
- Compatible with CCSDS recommendations
- Bit Rate Requirements:
  - High-rate downlink: 3.995 Mbps (Info.); 4.590 Mbps (Reed-Solomon)
  - Low-rate downlink: 9.018 kbps (Info.); 10.361 Mbps (Reed-Solomon)
  - Uplink: 2.0 kbps
- Link Margin Requirements:
  - High-rate downlink: $\geq$ 3 dB (P_e= 1 x 10^{-7})
  - Low-rate downlink: $\geq$ 3 dB (P_e= 1 x 10^{-6})
  - Uplink: $\geq$ 6 dB (P_e= 1 x 10^{-6})
- Antenna Coverage Requirements:
  - High-rate downlink: Must cover a $\pm$66° cone about nadir
  - Low-rate downlink: Must cover 95% of the sphere about the S/C
  - Uplink: Must cover 95% of the sphere about the S/C

This page intentionally left blank.

Changes Since PDR

- Antenna and RF switching design changed to simplify autonomy
  - "Omni"-directional antenna capability incorporated for early post-launch and sun-safe operations.
- Downlink modulation formats changed to improve performance
  - Reed Solomon coding incorporated into the downlink signals.
  - Differential QPSK (DQPSK) incorporated into the high-rate downlink to resolve phase ambiguities on the ground.
  - Randomization included on the downlink signals to break up long strings of 1^s and 0^s.

RF Communications Subsystem Block Diagram

NOTES:

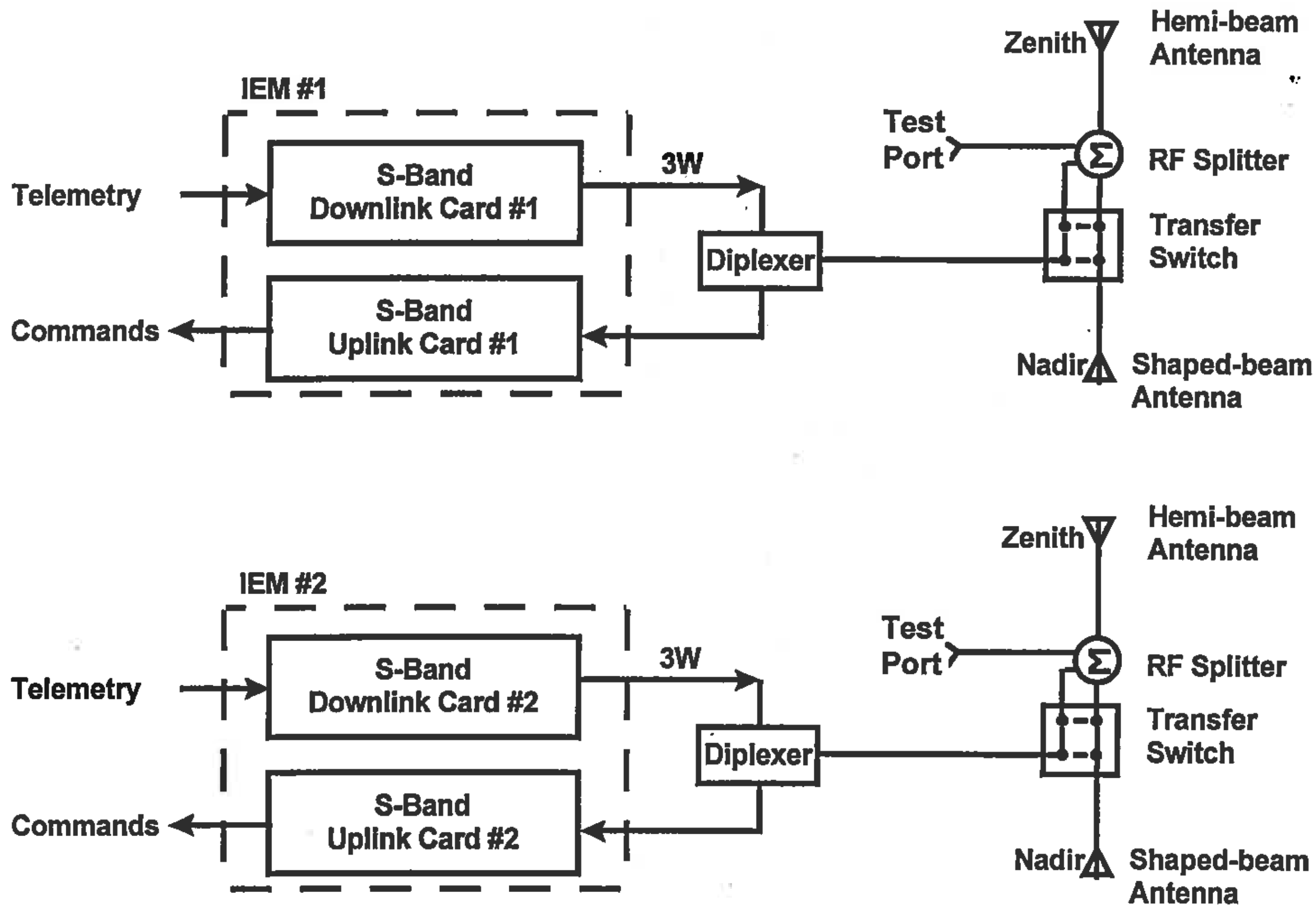
1. Both uplink cards are powered continuously (unswitched power). They remain on even when both IEMs are turned off, so real-time relay commands can always be received. The downlink card digital section is powered whenever its respective IEM is powered. The downlink card RF/analog section (including power amplifier) is powered with a separate relay command to the IEM so that the RF output signal can be controlled independently from the other switched loads within the IEM.

2. For normal operations, the spacecraft is pointed nadir and communications are accomplished via the nadir-pointing shaped-beam antenna. The pattern of this antenna is shaped to give maximum gain at approximately ±66 degrees off of boresight. Normally, we will fly with one IEM connected to its nadir-pointing antenna and the other IEM connected to its "omni" antenna (nadir and zenith summed).

3. For early post-launch and sun-safe operations when the attitude is not nadir-pointing, the transfer switches can be positioned so the the nadir and zenith antennas are summed together to form an "omni"-directional pattern. The actual pattern formed will not be uniform in all directions, but instead will have ripples due to the spacecraft structure, solar patterns, and interferometry effects.

4. The test ports (normally terminated in 50 ohms) will be used for checkout of the antennas at VAFB. They permit the antenna connections to be checked without having to power the entire spacecraft.

RF Communications System Block Diagram



RF Signaling Design

NOTES:

1. The uplink and downlink RF signal designs are CCSDS-compliant. The differential QPSK technique chosen for the high-rate downlink is identical to that used for the MSX mission.

2. Mode 2b has been included to permit the dumping of recorder data in two passes to a smaller ground station antenna such as a 3-meter dish.

RF Signaling Design

Link	Information Bit Rate[1]	Error Correction Coding[2]	Modulation Format[3]
High-Rate Downlink (Mode 1a)	4 Mbps	Reed Solomon	Randomized DQPSK
High-Rate Downlink (Mode 1b)	2 Mbps	Reed Solomon	Randomized DQPSK
Low-Rate Downlink (Mode 2)	9 kbps	Convolutional Rate ½, k=7 + Reed Solomon	Residual carrier PM. Randomized data modulated directly on the carrier in biphase-L format.
Uplink	2 kbps	None	Residual carrier PM. Randomized data modulated on 16 kHz sinusoidal subcarrier in NRZ-L format.

Notes:

(1) Information bit rates are approximate. These are the rates <u>prior</u> to error correction coding.

(2) Reed Solomon coding is 8-bit(255,223) with interleaving= 5.

(3) Downlink convolutional coding, Reed Solomon coding, and randomization will be as per CCSDS recommendation 101.0-B-3. Uplink randomization will be as per CCSDS recommendation 201.0-B-2, section 3.3.1.

Link Analysis Summary

NOTES:

1. Detailed link analysis spreadsheets are included at the end of the RF communications presentation.
2. The G/T and EIRP values assumed in the analysis are given below:

	APL 60-Foot Dish	Service Provider 5-Meter Dish	Service Provider 3-Meter Dish
G/T at 5° Elev. (dB/K):	23.2	16.5	12.0
G/T at 90° Elev. (dB/K):	23.8	17.5	13.0
EIRP (dBW):	55.2	52.6	48.2

3. Other assumptions include:

    Orbit altitude= 625 km; inclination= 74.4°

    Spacecraft transmitter power= 2.5 Watts

    Shaped-beam antenna gain at ±66° off of boresight= +3 dBic

    Negligible solar panel effects

    Implementation loss of 3 dB for the uplink and downlinks

4. The uplink and low-rate downlink margins are based upon an assumed spacecraft antenna gain of -20 dBic. This gain was achieved by the MAGSAT spacecraft for 85% of the sphere about the spacecraft when diametrically opposing antennas were summed together. For TIMED, we will have to wait until mockup antenna patterns are made in early 1998 to get a measure of the actual margins over 95% of the sphere. With the large margins shown in this viewgraph and the analytical work given in the antenna presentation, we feel that the 95% coverage specification will be ultimately be met.

Link Analysis Summary

		Link Margin at 5° Elevation (dB)		
Link	Spacecraft Antenna Coverage	APL 60-Foot Dish	Service Provider 5-Meter Dish	Service Provider 3-Meter Dish
High-Rate Downlink Mode 1a (4.0 Mbps)	Over a ± 66° cone about nadir	12.2	5.5	1.0
High-Rate Downlink Mode 1b (2.0 Mbps)	Over a ± 66° cone about nadir	15.2	8.5	4.0
Low-Rate Downlink Mode 2 (9.0 kbps)	For 85% of the sphere	20.1	13.4	8.9
Uplink (2.0 kbps)	For 85% of the sphere	16.3	13.7	9.3

Uplink Card
Block Diagram

NOTES:

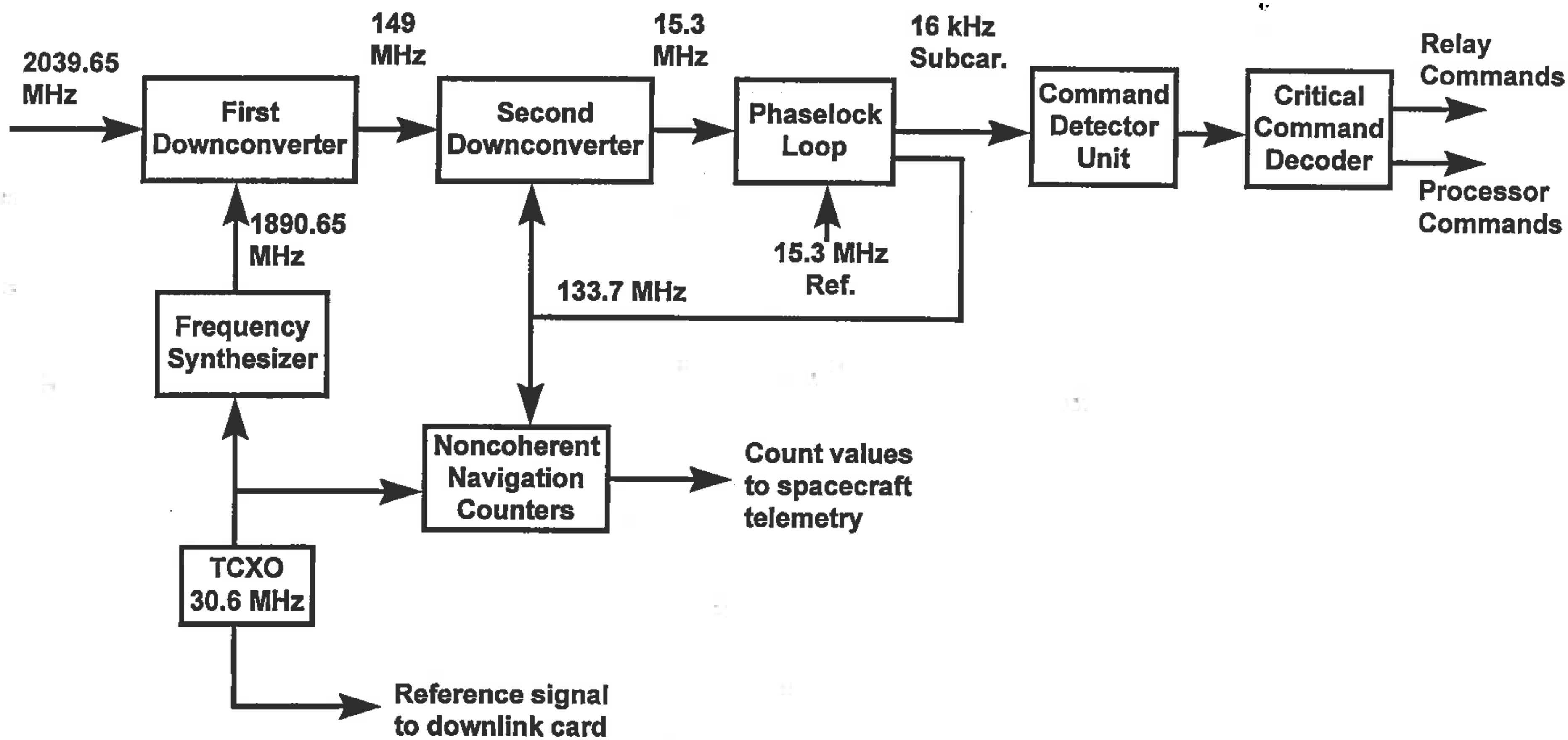
1. The RF, analog, and command detector unit (CDU) portions of the uplink card perform similar functions to those found in typical NASA command receivers. The critical command decoder (CCD) is unique to TIMED and is the subject of a separate presentation. The noncoherent navigation counters permit highly precise Doppler tracking of the spacecraft. Such tracking is not required for the the TIMED mission; however, a test of the capability is planned on-orbit.

2. A summary of the more important uplink card specifications follows:

Center frequency:	2039.645833 MHz ± 20 ppm
Acquisition threshold:	-130 dBm
Noise figure:	4 dB
Dynamic range:	80 dB
Carrier tracking loop bandwidth (B_L):	400 Hz
Tracking range:	Channel center ±150 kHz
Acquisition sweep rate:	Up to 35 kHz/s at -100 dBm input
Bit error rate:	Within 3 dB of theoretical at $P_e=1 \times 10^{-6}$
Uplink bit rate:	2 kbps
CDU acquisition time:	$\leq$ 500 bits at E_b/N_o= 10.5 dB
Real-time command capability:	128 relay commands
Mass:	Approx. 600 grams
Power:	Approx. 4.5 watts

3. EMI protection is provided with a combination of spot shielding, linear regulation of oscillator voltages, input EMI filtering, and separation of the RF/analog and digital circuitry.

Uplink Card Block Diagram



Downlink Card
Block Diagram

NOTES:

1. As indicated in the block diagram, modulation is performed directly at S-band. The output spectrum is controlled with pre-modulation filtering to meet NTIA emission requirements. The modulator supports both DQPSK and residual-carrier phase modulation formats (selectable).

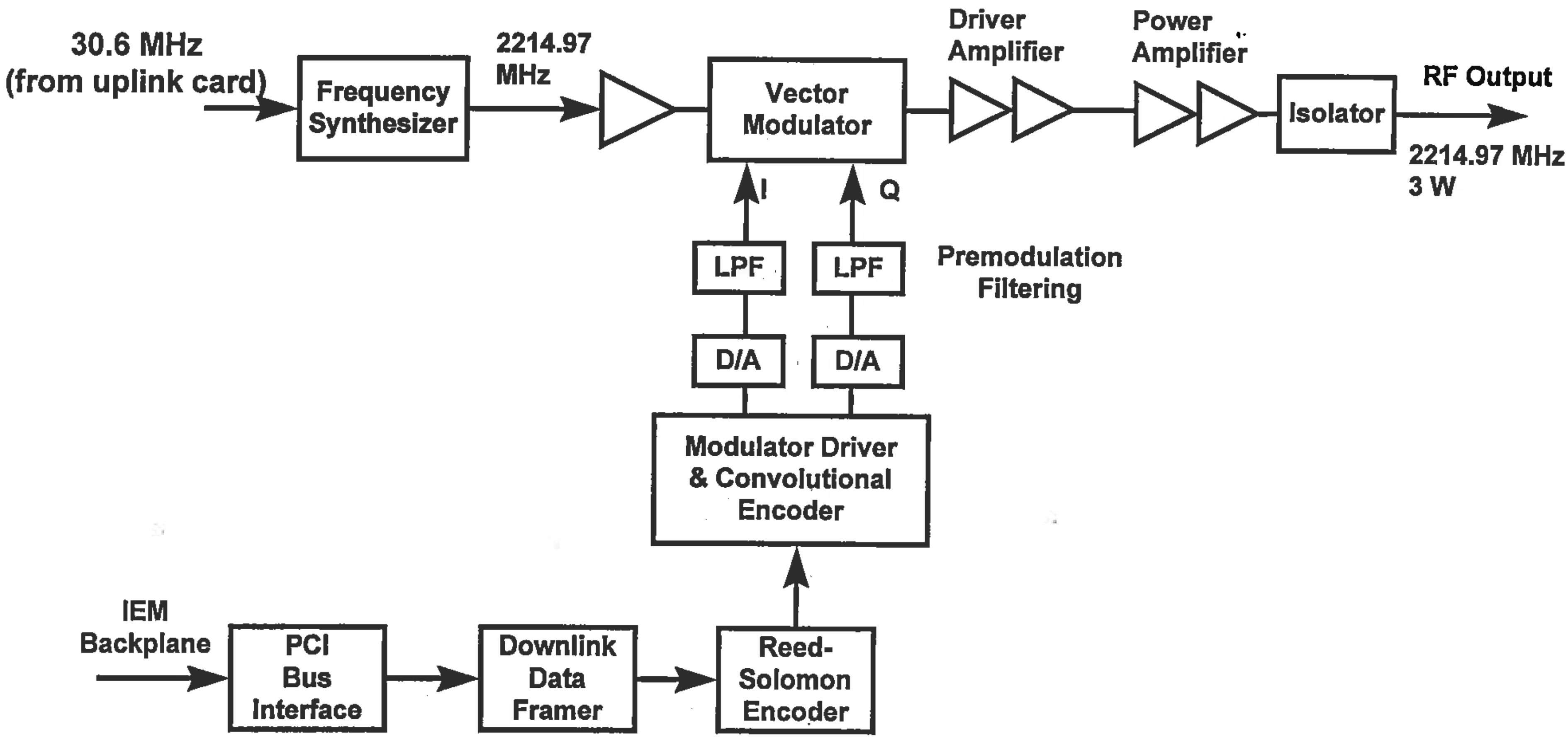
2. The output power amplification is accomplished with GaAs FET devices supplied by Fujitsu. The power amplifier output stage is protected with an isolator.

3. The downlink convolutional coding, Reed Solomon coding, and randomization are all CCSDS compliant. The PCI bus interface and downlink data framer are the subjects of separate presentations.

4. A summary of the more important downlink card specifications follows:

RF output frequency:	2214.972717 MHz ± 20 ppm
RF output power:	3 W typical, 2.5 W over temperature
Modulation formats:	-Differential QPSK
	-Residual carrier PM (mod. index= 1.2 radians) with biphase-L data direct on the carrier.
Coding:	-Convolutional, rate 1/2, k=7 (select or bypass)
	-Reed Solomon, 8-bit(255,223), interleaving=5 (select or bypass)
Mass:	Approx. 600 grams
Power:	Approx. 12.2W transmit
	Approx. 0.9 W standby

Downlink Card Block Diagram



Frequency Assignment Status

NOTES:

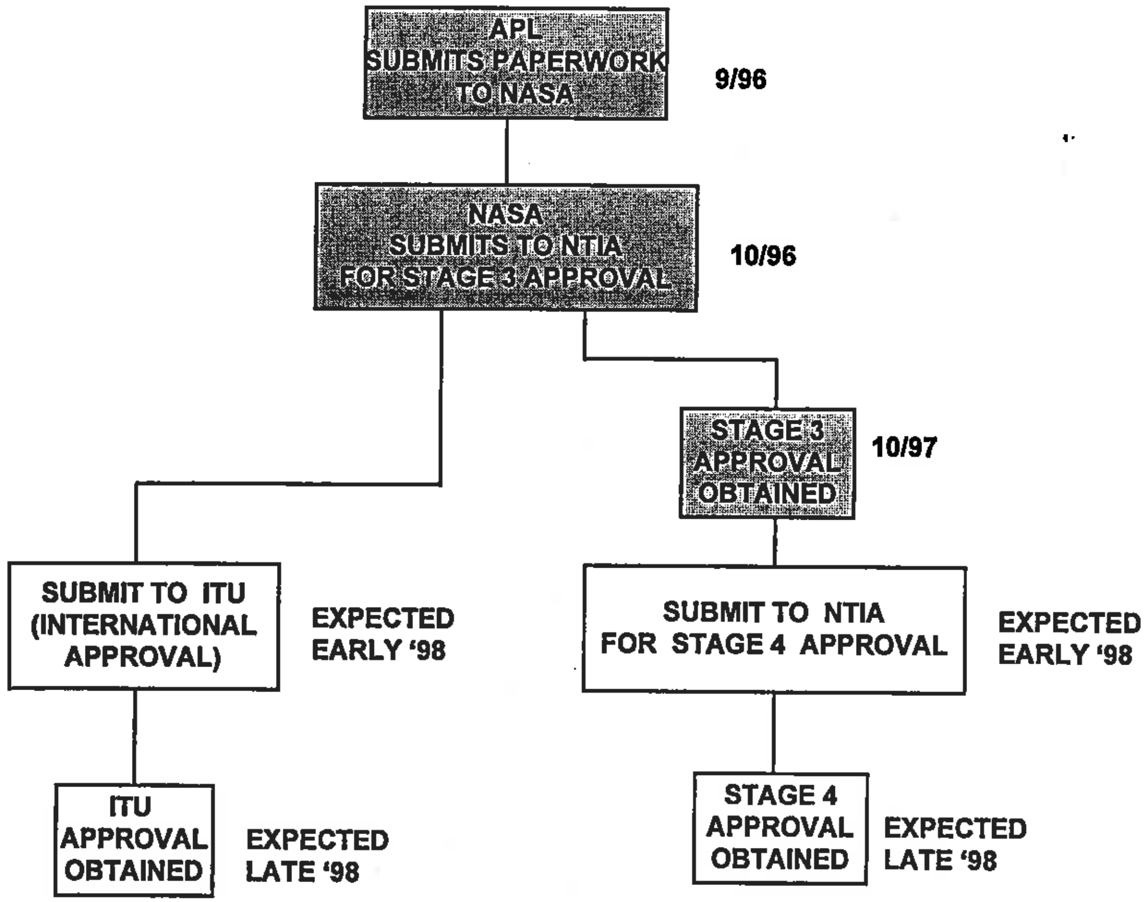
Stage 3 is for developmental systems.

Stage 4 is for operational systems.

TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Frequency Assignment Status



UPLINK ASSIGNMENT: 2039.645833 MHz
DOWNLINK ASSIGNMENT: 2214.972717 MHz
DOWNLINK NECESSARY BANDWIDTH: 10 MHz

= COMPLETED

This page intentionally left blank.

Status

- SUBSYSTEM
  - Interface PDR held on 4/15/97. All action items closed.
  - No significant issues/problems
- UPLINK CARD
  - EDR held on 10/15/97.
  - Engr. model fabrication is expected to start in 1/98
- DOWNLINK CARD
  - EDR expected in 1/98.
  - Engr. model fabrication is expected to start in 1/98
- ANTENNAS
  - Hemi-beam antenna detailed design work is complete. Engr. model fabrication is expected to start in 11/97.
  - Shaped-beam antenna electrical model is complete. Detailed design work is in progress. Engr. model fabrication is expected to start in 12/97.
- SWITCHES, CABLES, DIPLEXERS, COUPLERS
  - Procurement actions due to start in December '97

timed_60.xls Ver. 3.0, preliminary

Name: R. S. Bokulic
Date: 11/12/97

SPACECRAFT COMMUNICATIONS LINK ANALYSIS

SPACECRAFT MISSION: TIMED
LINK: Normal Operations to APL 60-Foot Dish (Nadir-Pointing)

Uplink Freq: 2.03965 GHz Wavlgth: 0.1471 meter
Downlink Freq: 2.21497 GHz Wavlgth: 0.1354 meter
Uplink Command Modulation: NRZ/PSK/PM (Data on a 16 kHz sine wave subcarrier)
Downlink Telemetry Modulation: DQPSK
Ranging Modulation: None

HIGH GAIN ANTENNA UTILITY

Spacecraft HGA Diameter: N/A m Efficiency: N/A %
Spacecraft HGA Pointing Error (+/-): N/A Deg.

Calculated Parameter	Uplink	Downlink
Spacecraft HGA Gain	#VALUE! dBic	#VALUE! dBic
Spacecraft HGA 3dB Beamwid	#VALUE! Deg.	#VALUE! Deg.
Spacecraft HGA Pointing Loss	#VALUE! dB	#VALUE! dB

LEO SPACECRAFT SLANT RANGE UTILITY

Parameter	Value	Units
Spacecraft Altitude (Enter Re or km for units):	625.0	km
Ground Antenna Elevation Angle:	5.0	Deg.
Slant Range (Assumes average Re= 6370 km):	2387.8	km

		Value	Units
Spacecraft range (enter AU, Re or km for units):		2387.8	km
UPLINK MODULATION CHARACTERISTICS			
Command data rate:		2	kbps
Command modulation index:		1	rad pk
Uplink ranging modulation index:		0	rad pk
RANGING CHANNEL CHARACTERISTICS			
Ranging channel turn-around (elbow/regenerative):		regenerative	
DOWNLINK MODULATION CHARACTERISTICS			
Entered Parameters:			
Telemetry data rate:		4000	kbps
Telemetry modulation index (enter BPSK, QPSK, or a value for PM):		QPSK	rad pk
Downlink ranging channel modulation index:		0	rad pk
Downlink telemetry waveform (square/sine):		square	
Calculated Parameters:			
S/C ranging channel bandwidth:	Br=	N/A	MHz
Pwr in fundamental component of square ranging tone:	gamma=	0.8106	
Ranging SNR at output of xpdr filter:	alphar=	N/A	
Cmd/noise ratio at output of xpdr filter:	alphac=	N/A	
Effective downlink cmd modulation index:	t1=	0.0000	rad. pk
Effective downlink ranging modulation index:	t2=	0.0000	rad. pk
Effective downlink noise modulation index:	t3=	0.0000	rad. rms

Parameter	Notes	Units	Des.Value	Adv. Tol.	Fav. Tol.	Mean Val.	Variance	PDF
Gnd Station TX Power:	0.05 kW	dBm	46.99	0.00	0.00	46.99	0.00	tri
Gnd Station TX Antenna Gain:	(APL 60' dish)	dBic	48.70	0.00	0.00	48.70	0.00	uni
Gnd Antenna Pointing Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Gnd Station Passive Loss:	(Passive loss + backoff)	dB	-10.00	0.00	0.00	-10.00	0.00	uni
EIRP:		dBm	85.19			85.19	0.00	
Uplink Path Loss:		dB	-166.19	0.00	0.00	-166.19	0.00	uni
S/C Antenna Gain:	(Shaped-beam)	dBic	0.00	0.00	0.00	0.00	0.00	tri
S/C Antenna Pointing Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Atmospheric Loss:		dB	-0.10	0.00	0.00	-0.10	0.00	uni
Polarization Mismatch Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	tri
S/C Passive Loss:	(Between antenna port and rcvr input)	dB	-3.00	0.00	0.00	-3.00	0.00	uni
Total Received Power:	(At receiver input)	dBm	-84.60			-84.60	0.00	
S/C Antenna Noise Temp.	(At antenna port)	K	150.00					
S/C Passive Loss Noise Temp.		K	288.63					
S/C Receiver Noise Figure:		dB	4.00					
System Noise Temp:	(At receiver input)	K	658.28					
System Noise Density:	(At receiver input)	dBm/Hz	-170.42	0.00	0.00	-170.42	0.00	gau
Carrier/Total Power:		dB	-2.32	0.00	0.00	-2.32	0.00	tri
Received Carrier Power:		dBm	-86.93			-86.93	0.00	
Received Pc/No:		dB-Hz	83.49			83.49	0.00	
Tracking Loop Predetection Noise BW:	40 kHz	dBHz	46.02	0.00	0.00	46.02	0.00	tri
Tracking Loop Predetection SNR:		dB	37.47			37.47	0.00	
Carrier Tracking Loop Bandwidth (BL):	400 Hz	dBHz	26.02	0.00	0.00	26.02	0.00	tri
Received Carrier/Noise in Loop Bandwidth:		dB	57.47			57.47	0.00	
Required Carrier/Noise in Loop Bandwidth:		dB	14.00	0.00	0.00	14.00	0.00	uni
Carrier Margin:		**dB**	**43.47**			**43.47**	**0.00**	
	3sigma=	**dB**					**0.00**	
Command Subc/Total Power:		dB	-4.12	0.00	0.00	-4.12	0.00	tri
Received Command Subc. Power:		dBm	-88.72			-88.72	0.00	
Subcarrier Demod. Predetection Noise B	8 kHz	dBHz	39.03	0.00	0.00	39.03	0.00	tri
Subcarrier Demod. Predetection SNR:		dB	42.66			42.66	0.00	
Command Data Rate:		dBHz	33.01	0.00	0.00	33.01	0.00	tri
Received Command Eb/No:		dB	48.68			48.68	0.00	
Required Command Eb/No:	Pe=1.0E-06	dB	10.52	0.00	0.00	10.52	0.00	uni
Implementation Loss:		dB	-3.00	0.00	0.00	-3.00	0.00	tri
Command Margin:		**dB**	**35.16**			**35.16**	**0.00**	
	3sigma=	**dB**					**0.00**	
Ranging/Total Power:		dB	#NUM!	-0.25	0.25	#NUM!	0.01	tri
Received Ranging Power:		dBm	#NUM!			#NUM!	0.01	
Uplink Pr/No:		dBHz	#NUM!			#NUM!	0.01	
S/C Ranging Channel Bandwidth:	N/A MHz	dBHz	#VALUE!	0.40	-0.40	#VALUE!	0.03	tri
S/C Ranging Channel SNR:		dB	#NUM!			#NUM!	0.04	

Parameter	Notes	Units	Des.Value	Adv. Tol.	Fav. Tol.	Mean Val.	Variance	PDF
S/C Transmitter Power:	2.5 watts	dBm	33.98	0.00	0.00	33.98	0.00	tri
S/C Passive Loss:		dB	-3.00	0.00	0.00	-3.00	0.00	uni
S/C Antenna Gain:	(Shaped-beam)	dBic	3.00	0.00	0.00	3.00	0.00	tri
S/C Antenna Pointing Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
EIRP:		dBm	33.98			33.98	0.00	
Path Loss:		dB	-166.91	0.00	0.00	-166.91	0.00	uni
Atmospheric Loss:		dB	-0.10	0.00	0.00	-0.10	0.00	uni
Polarization Mismatch Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Gnd Antenna Gain:	APL 60' dish	dBic	49.40	0.00	0.00	49.40	0.00	uni
Gnd Antenna Pointing Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Total Received Power:		dBm	-84.63			-84.63	0.00	
Gnd Antenna Noise Temp.	APL 60' dish at 5 deg. elev.	K	414.00					
Solar/Planetary Noise:		K	0.00					
Gnd System Noise Temp:		K	414.00					
Gnd System Noise Density:		dBm/Hz	-172.43	0.00	0.00	-172.43	0.00	gau
Carrier/Total Power:		dB	QPSK	0.00	0.00	QPSK	QPSK	tri
Received Carrier Power:		dBm	QPSK			QPSK	QPSK	
Received Pc/No:		dB-Hz	QPSK			QPSK	QPSK	
Tracking Loop Predetection Noise BW:	6000 kHz	dBHz	67.78	0.00	0.00	67.78	0.00	tri
Tracking Loop Predetection Loop SNR:		dB	20.02			20.02	0.00	
Carrier Tracking Loop Bandwidth (BL):	10000 Hz	dBHz	40.00	0.00	0.00	40.00	0.00	tri
Received Carrier/Noise in Loop Bandwidth:		dB	35.39			35.39	0.00	
Required Carrier/Noise in Loop Bandwidth:		dB	20.00	0.00	0.00	20.00	0.00	uni
Carrier Margin:		**dB**	**15.39**			**15.39**	**0.00**	
	3sigma=	dB					**0.00**	
Tlm/Total Power:		dB	0.00	0.00	0.00	0.00	0.00	tri
Received Tlm Power:		dBm	-84.63			-84.63	0.00	
Tlm Data Rate:		dBHz	66.02	0.00	0.00	66.02	0.00	uni
Received Eb/No:		dB	21.78			21.78	0.00	
Required Eb/No:	8bitRS(255,223); Pe=10E-7	dB	6.60	0.00	0.00	6.60	0.00	uni
Implementation Loss:		dB	-3.00	0.00	0.00	-3.00	0.00	tri
Other gain/loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Telemetry Margin:		**dB**	**12.18**			**12.18**	**0.00**	
	3sigma=	dB					**0.00**	
Rng/Total Power:		dB	#VALUE!	0.00	0.00	#VALUE!	0.00	tri
Received Ranging Power:		dBm	#VALUE!			#VALUE!	0.00	
Downlink Received Pr/No:		dBHz	#VALUE!			#VALUE!	0.00	
Tandem Pr/No (uplink and downlink):		dBHz	#NUM!			#NUM!	#NUM!	
Downlink Required Pr/No:		dBHz	0.00	0.00	0.00	0.00	0.00	uni
Ranging Demodulator Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Ranging Margin:		**dB**	**#NUM!**			**#NUM!**	**#NUM!**	
	3sigma=	dB					**#NUM!**	

timed_rt.xls Ver. 3.0, preliminary

Name: R. S. Bokulic
Date: 11/12/97

SPACECRAFT COMMUNICATIONS LINK ANALYSIS

SPACECRAFT MISSION: TIMED
LINK: Sun-Safe Operations to APL 60-Foot Dish (Arbitrary Pointing)

Uplink Freq:	2.03965 GHz	Wavlgth:	0.1471 meter	
Downlink Freq:	2.21497 GHz	Wavlgth:	0.1354 meter	

Uplink Command Modulation: NRZ/PSK/PM (Data on a 16 kHz sine wave subcarrier)
Downlink Telemetry Modulation: Biphase-L/Residual-Carrier PM (data direct on carrier)
Ranging Modulation: None

HIGH GAIN ANTENNA UTILITY

Spacecraft HGA Diameter: N/A m Efficiency: N/A %
Spacecraft HGA Pointing Error (+/-): N/A Deg.

Calculated Parameter	Uplink	Downlink
Spacecraft HGA Gain	#VALUE! dBic	#VALUE! dBic
Spacecraft HGA 3dB Beamwid	#VALUE! Deg.	#VALUE! Deg.
Spacecraft HGA Pointing Loss	#VALUE! dB	#VALUE! dB

LEO SPACECRAFT SLANT RANGE UTILITY

Parameter	Value	Units
Spacecraft Altitude (Enter Re or km for units):	625.0	km
Ground Antenna Elevation Angle:	5.0	Deg.
Slant Range (Assumes average Re= 6370 km):	2387.8	km

		Value	Units
Spacecraft range (enter AU, Re or km for units):		2387.8	km
UPLINK MODULATION CHARACTERISTICS			
Command data rate:		2	kbps
Command modulation index:		1	rad pk
Uplink ranging modulation index:		0	rad pk
RANGING CHANNEL CHARACTERISTICS			
Ranging channel turn-around (elbow/regenerative):		regenerative	
DOWNLINK MODULATION CHARACTERISTICS			
Entered Parameters:			
Telemetry data rate:		9	kbps
Telemetry modulation index (enter BPSK, QPSK, or a value for PM):		1.2	rad pk
Downlink ranging channel modulation index:		0	rad pk
Downlink telemetry waveform (square/sine):		square	
Calculated Parameters:			
S/C ranging channel bandwidth:	Br=	N/A	MHz
Pwr in fundamental component of square ranging tone:	gamma=	0.8106	
Ranging SNR at output of xpdr filter:	alphar=	N/A	
Cmd/noise ratio at output of xpdr filter:	alphac=	N/A	
Effective downlink cmd modulation index:	t1=	0.0000	rad. pk
Effective downlink ranging modulation index:	t2=	0.0000	rad. pk
Effective downlink noise modulation index:	t3=	0.0000	rad. rms

Parameter	Notes	Units	Des.Value	Adv. Tol.	Fav. Tol.	Mean Val.	Variance	PDF
Gnd Station TX Power:	0.05 kW	dBm	46.99	0.00	0.00	46.99	0.00	tri
Gnd Station TX Antenna Gain:	(APL 60' dish)	dBic	48.70	0.00	0.00	48.70	0.00	uni
Gnd Antenna Pointing Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Gnd Station Passive Loss:	(Passive loss + backoff)	dB	-10.00	0.00	0.00	-10.00	0.00	uni
EIRP:		dBm	85.19			85.19	0.00	
Uplink Path Loss:		dB	-166.19	0.00	0.00	-166.19	0.00	uni
S/C Antenna Gain:	("Omni" antenna)	dBic	-20.00	0.00	0.00	-20.00	0.00	tri
S/C Antenna Pointing Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Atmospheric Loss:		dB	-0.10	0.00	0.00	-0.10	0.00	uni
Polarization Mismatch Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	tri
S/C Passive Loss: (Between antenna port and rcvr input)		dB	-2.00	0.00	0.00	-2.00	0.00	uni
Total Received Power:	(At receiver input)	dBm	-103.60			-103.60	0.00	
S/C Antenna Noise Temp.	(At antenna port)	K	150.00					
S/C Passive Loss Noise Temp.		K	169.62					
S/C Receiver Noise Figure:		dB	4.00					
System Noise Temp:	(At receiver input)	K	640.11					
System Noise Density:	(At receiver input)	dBm/Hz	-170.54	0.00	0.00	-170.54	0.00	gau
Carrier/Total Power:		dB	-2.32	0.00	0.00	-2.32	0.00	tri
Received Carrier Power:		dBm	-105.93			-105.93	0.00	
Received Pc/No:		dB-Hz	64.61			64.61	0.00	
Tracking Loop Predetection Noise BW:	40 kHz	dBHz	46.02	0.00	0.00	46.02	0.00	tri
Tracking Loop Predetection SNR:		dB	18.59			18.59	0.00	
Carrier Tracking Loop Bandwidth (BL):	400 Hz	dBHz	26.02	0.00	0.00	26.02	0.00	tri
Received Carrier/Noise in Loop Bandwidth:		dB	38.59			38.59	0.00	
Required Carrier/Noise in Loop Bandwidth:		dB	14.00	0.00	0.00	14.00	0.00	uni
Carrier Margin:		dB	**24.59**			**24.59**	**0.00**	
	3sigma=	dB					**0.00**	
Command Subc/Total Power:		dB	-4.12	0.00	0.00	-4.12	0.00	tri
Received Command Subc. Power:		dBm	-107.72			-107.72	0.00	
Subcarrier Demod. Predetection Noise B	8 kHz	dBHz	39.03	0.00	0.00	39.03	0.00	tri
Subcarrier Demod. Predetection SNR:		dB	23.78			23.78	0.00	
Command Data Rate:		dBHz	33.01	0.00	0.00	33.01	0.00	tri
Received Command Eb/No:		dB	29.81			29.81	0.00	
Required Command Eb/No:	Pe=1.0E-06	dB	10.52	0.00	0.00	10.52	0.00	uni
Implementation Loss:		dB	-3.00	0.00	0.00	-3.00	0.00	tri
Command Margin:		dB	**16.29**			**16.29**	**0.00**	
	3sigma=	dB					**0.00**	
Ranging/Total Power:		dB	#NUM!	-0.25	0.25	#NUM!	0.01	tri
Received Ranging Power:		dBm	#NUM!			#NUM!	0.01	
Uplink Pr/No:		dBHz	#NUM!			#NUM!	0.01	
S/C Ranging Channel Bandwidth:	N/A MHz	dBHz	#VALUE!	0.40	-0.40	#VALUE!	0.03	tri
S/C Ranging Channel SNR:		dB	#NUM!			#NUM!	0.04	

Parameter	Notes	Units	Des.Value	Adv. Tol.	Fav. Tol.	Mean Val.	Variance	PDF
S/C Transmitter Power:	2.5 watts	dBm	33.98	0.00	0.00	33.98	0.00	tri
S/C Passive Loss:		dB	-2.00	0.00	0.00	-2.00	0.00	uni
S/C Antenna Gain:	("Omni" antenna)	dBic	-20.00	0.00	0.00	-20.00	0.00	tri
S/C Antenna Pointing Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
EIRP:		dBm	11.98			11.98	0.00	
Path Loss:		dB	-166.91	0.00	0.00	-166.91	0.00	uni
Atmospheric Loss:		dB	-0.10	0.00	0.00	-0.10	0.00	uni
Polarization Mismatch Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Gnd Antenna Gain:	APL 60' dish	dBic	49.40	0.00	0.00	49.40	0.00	uni
Gnd Antenna Pointing Loss:		dB	-0.50	0.00	0.00	-0.50	0.00	uni
Total Received Power:		dBm	-106.63			-106.63	0.00	
Gnd Antenna Noise Temp.	APL 60' dish at 5 deg. elev.	K	414.00					
Solar/Planetary Noise:		K	0.00					
Gnd System Noise Temp:		K	414.00					
Gnd System Noise Density:		dBm/Hz	-172.43	0.00	0.00	-172.43	0.00	gau
Carrier/Total Power:		dB	-8.82	0.00	0.00	-8.82	0.00	tri
Received Carrier Power:		dBm	-115.45			-115.45	0.00	
Received Pc/No:		dB-Hz	56.98			56.98	0.00	
Tracking Loop Predetection Noise BW:	300 kHz	dBHz	54.77	0.00	0.00	54.77	0.00	tri
Tracking Loop Predetection Loop SNR:		dB	2.21			2.21	0.00	
Carrier Tracking Loop Bandwidth (BL):	100 Hz	dBHz	20.00	0.00	0.00	20.00	0.00	tri
Received Carrier/Noise in Loop Bandwidth:		dB	36.98			36.98	0.00	
Required Carrier/Noise in Loop Bandwidth:		dB	14.00	0.00	0.00	14.00	0.00	uni
Carrier Margin:		dB	**22.98**			**22.98**	**0.00**	
	3sigma=	dB					**0.00**	
Tlm/Total Power:		dB	-0.61	0.00	0.00	-0.61	0.00	tri
Received Tlm Power:		dBm	-107.24			-107.24	0.00	
Tlm Data Rate:		dBHz	39.54	0.00	0.00	39.54	0.00	uni
Received Eb/No:		dB	25.65			25.65	0.00	
Required Eb/No:	R=1/2, k=7+8bitRS(255,223); Pe=10E-7	dB	2.60	0.00	0.00	2.60	0.00	uni
Implementation Loss:		dB	-3.00	0.00	0.00	-3.00	0.00	tri
Other gain/loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Telemetry Margin:		dB	**20.05**			**20.05**	**0.00**	
	3sigma=	dB					**0.00**	
Rng/Total Power:		dB	#NUM!	0.00	0.00	#NUM!	0.00	tri
Received Ranging Power:		dBm	#NUM!			#NUM!	0.00	
Downlink Received Pr/No:		dBHz	#NUM!			#NUM!	0.00	
Tandem Pr/No (uplink and downlink):		dBHz	#NUM!			#NUM!	#NUM!	
Downlink Required Pr/No:		dBHz	0.00	0.00	0.00	0.00	0.00	uni
Ranging Demodulator Loss:		dB	0.00	0.00	0.00	0.00	0.00	tri
Ranging Margin:		dB	#NUM!			#NUM!	#NUM!	
	3sigma=	dB					#NUM!	