Ground System Engineering

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TIMED Critical Design Review, 12-2-97

Topics of Discussion

- 1. Architectural Overview
- 2. Ground System Requirements
- 3. Design Changes Since PDR
- 4. End-to-End Data System Description
- 5. Telemetry Rate Budgets
- 6. Ground System Description
- 7. "Lights Out" Capabilities
- 8. Ground System Risk Management
- 9. Summary

  (Data Supplement)

1. Architectural Overview

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Ground System Facilities

- *Ground Stations*
  - Steve Gemeny, Lead
- *Mission Operations Center (MOC)*
  - Bill Dove, Lead
  - Walter Mitnick, Software Lead
- *Mission Data Center (MDC)*
  - Ken Heeres, Lead
  - Kevin Lyons, Software Lead
- *Science Data System (SDS)*
  - Bob DeMajistre, Manager

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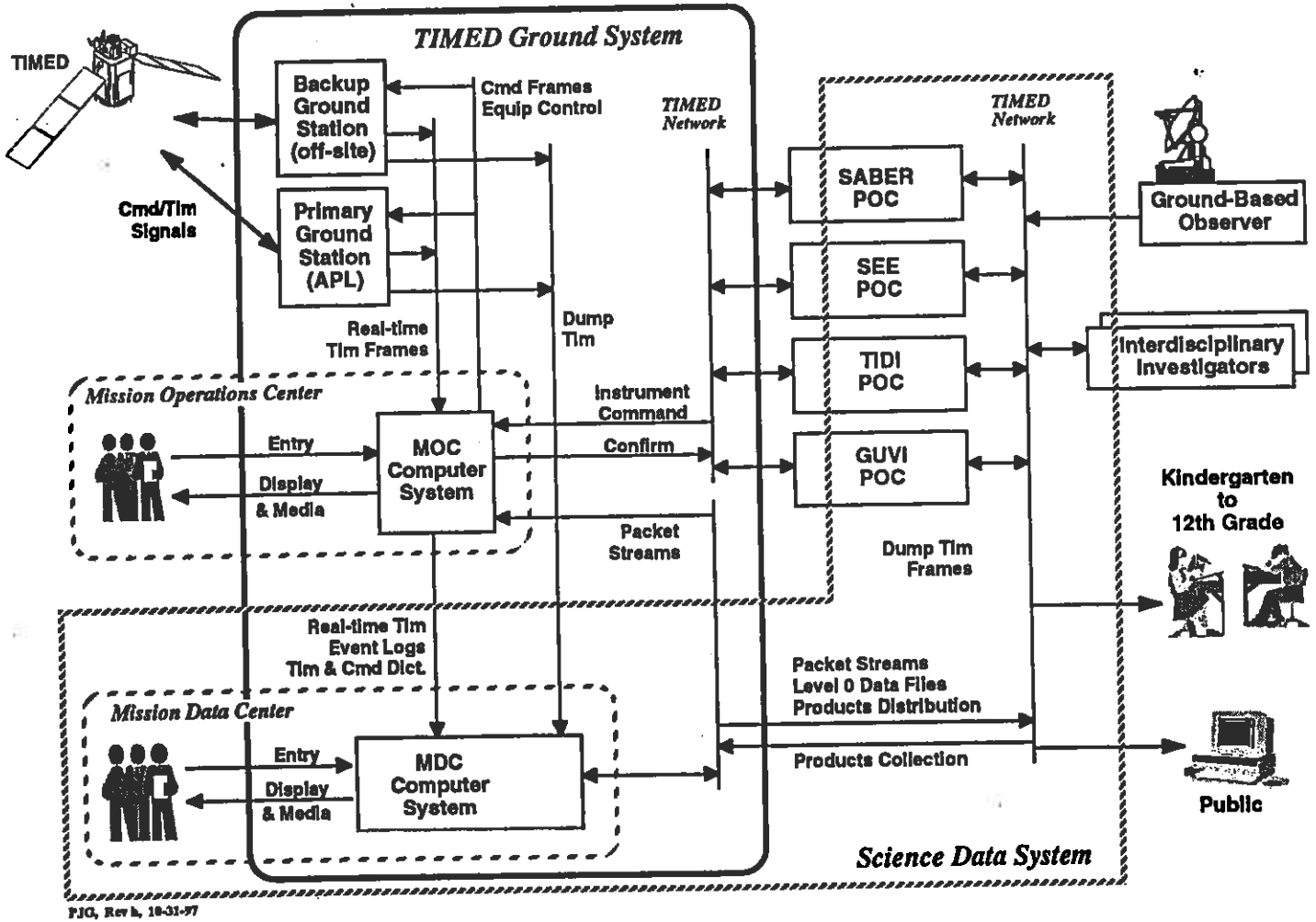
Ground System Architecture



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2. Ground System Requirements

from the System Requirements Document, Rev B

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End-to-End (Instrument-to-POC) Requirements

- System Availability
  - **95%*** 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: 1×10^{-3}
  - Fraction of Source Packets delivered with undetected errors: 1×10^{-10}

*** Underlined and Bold indicates a changed requirement**

End-to-End Requirements (cont'd)

- Data Accumulation Capacities on Spacecraft
  - Daily Average Housekeeping Data Rate: **5,500 b/s** (was 3,595 b/s)
  - Daily Average Instrument Data Rate: 16,954 b/s
  - Spacecraft Solid State Recorder (SSR) Capacity: **2.5 Gb** (was 2 Gb)

Space-Ground Interface

- High Rate downlink
  - to dump a 1-day accumulation in a single pass at the Primary Ground Station
  - Required information rate capacity = 3,994,862 b/s (was 3,936,000 b/s)
- Intermediate Rate downlink (if needed)
  - to dump a 1-day accumulation in a single cluster of passes at the Backup Ground Station
- Low Rate downlink
  - to downlink real-time engineering housekeeping telemetry to a remote station
  - for Launch and Early Operations Phase (LEOP) and contingencies
  - Required information rate capacity = 9,018 b/s (was 8,608 b/s)

Space-Ground Interface (cont'd)

- Redundancy
  - The TIMED Ground Station shall have a backup
- Command and telemetry protocols
  - per CCSDS Recommendations
- Uplink Data Rate: 2,000 b/s

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Mission Operations (MO) Support

(Applies from launch to end of mission)

- Commands:
  - Instrument command uploads shall be prepared at the POCs
  - Spacecraft [bus] commands shall be prepared in the Mission Operations Center (MOC)
  - [The MOC] shall collect instrument commands from POCs, and transmit them to the instruments
  - [The MOC] The shall generate spacecraft bus commands and transmit them to the spacecraft bus.

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MO Support (cont'd)

- Telemetry:
  - Collect all [spacecraft bus and instrument] raw telemetry [in the MDC]
  - Analyze spacecraft bus telemetry [in the MOC]
  - Forward all raw telemetry data [to the Science Data System] for processing and distribution to POCs
  - Forward all science telemetry data to the instrument POCs
- The MOC shall support planning and assessment

Integration & Test (I&T) Support

(Applies from arrival of first subsystem to launch)

- Support commands as indicated for MO
- Support telemetry as indicated for MO
- Maintain spacecraft command and telemetry dictionaries

Data Analysis (DA) Support

- 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
  - Serve all data products necessary to support the TIMED mission
  - Support transfer of data to long-term archive at the end of the mission

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General Ground System Requirements

- Cost-Related Constraints
  - The Primary TIMED Ground Station shall be selected to keep operations costs low
  - The Mission Operations Center location shall be selected to keep operations costs low
- The Ground System shall include primary and backup voice and data networks for inter-facility communications during launch operations

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3. Design Changes Since PDR

New Look at Ground Stations

- Selections were revisited immediately after the PDR and the NAR (Non-Advocate Review)
  - issues of cost, RF interference at APL, and need for off-site support
- Separate requirements were established for four types of support
  - ***Primary:*** All telemetry and command, 1 contact/day
  - ***Backup:*** All telemetry and command, 1 cluster/day support
  - ***Contingency:*** Low-rate telemetry and command
  - ***Early Launch:*** Low-rate telemetry, command if possible
- Several APL and off-site assets were considered

New Ground Station Arrangement

- Primary Ground Station is at APL
  - Supports all command and telemetry
  - Based on 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 is removed to remote site, provided by a commercial service
  - Supports all commanding
  - Supports dump telemetry at High or Intermediate data rate
  - Available for contingency support at Low data rate
  - Fixed fee per pass, up to several passes per day

Modified Telemetry Modes

Modulation Mode	Information Rate (approx.)	Coding	Modulation Format	Required G/T
1a. High Rate (note 1)	4 Mb/s	Reed Solomon (note 3)	Randomized DQPSK (note 2)	16.3 dB/k
1b. Intermediate Rate (note 2)	2 Mb/s	Reed Solomon (note 3)	Randomized DQPSK (note 2)	12.9 dB/k
2. Low Rate	9 kb/s	Reed-Solomon & Convolutional rate 1/2, k=7 (note 4)	Residual Carrier PM modulated directly on the carrier in biphase-L PCM	12.9 dB/k

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Notes: 1. Sub-modes of the Mode 1 from PDR

2. Randomization of Codeblock only, per CCSDS 101.0-B-3 (added since PDR).
   Changed since PDR from Offset QPSK to Differential QPSK (DQPSK).
   Differential Coding identical to MSX scheme (added since PDR).
3. Convolutional Coding has been deleted since PDR
4. Reed-Solomon coding has been added since PDR

New Services to POC

- Commands from POC to MOC
  - Every POC Command Message is now acknowledged with two receipts
    - » **Authentication Return Receipt**
    - » Command Return Receipt
- Telemetry from MDC to POC
  - Three Stream Services are now available
    - » Telemetry Packets
    - » **POC Telemetry Packets**
    - » Supplemented Telemetry Packets

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4. End-to-End Data System Description

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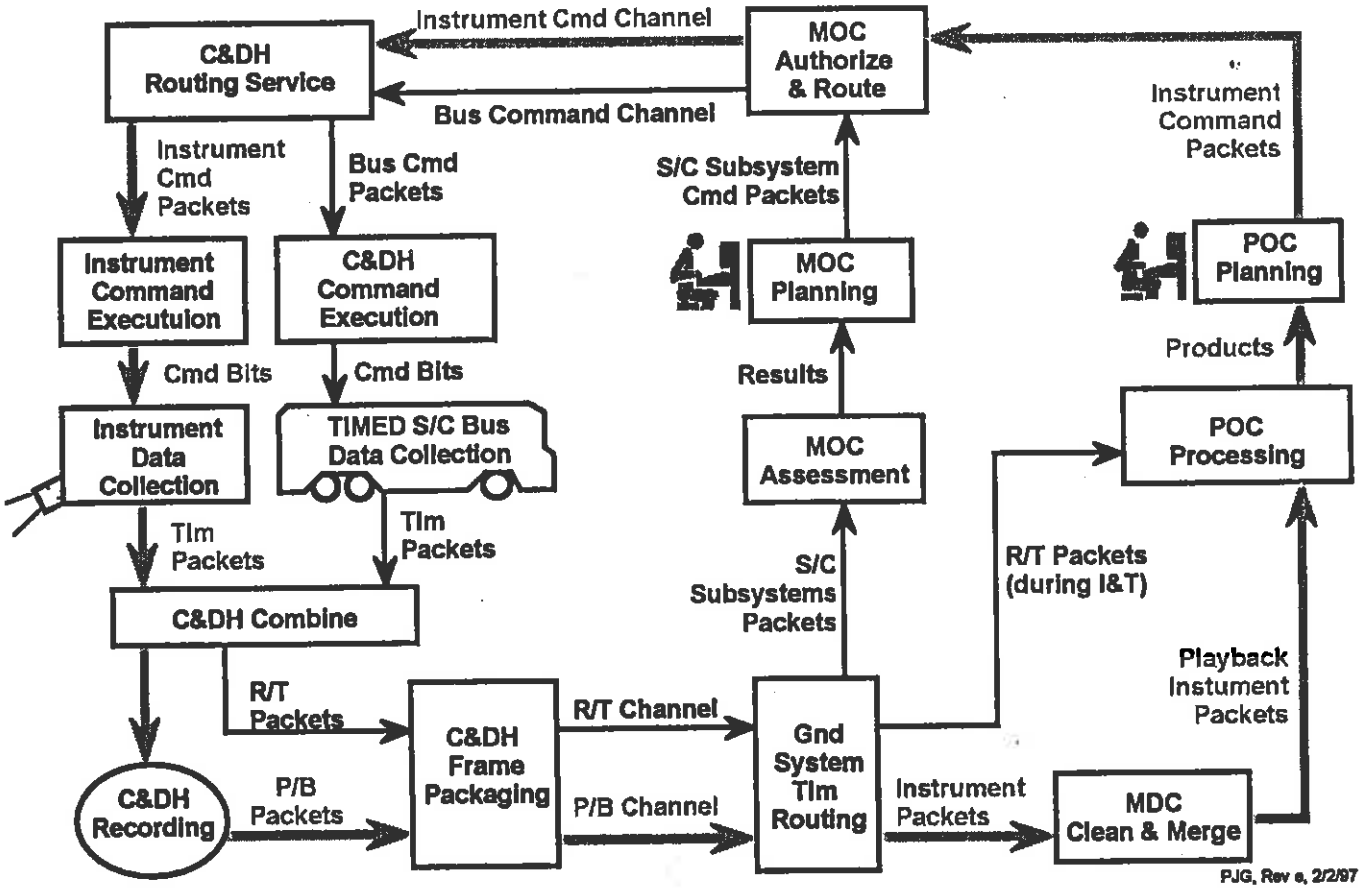
-->> TIMED Mission Data Flow -->>



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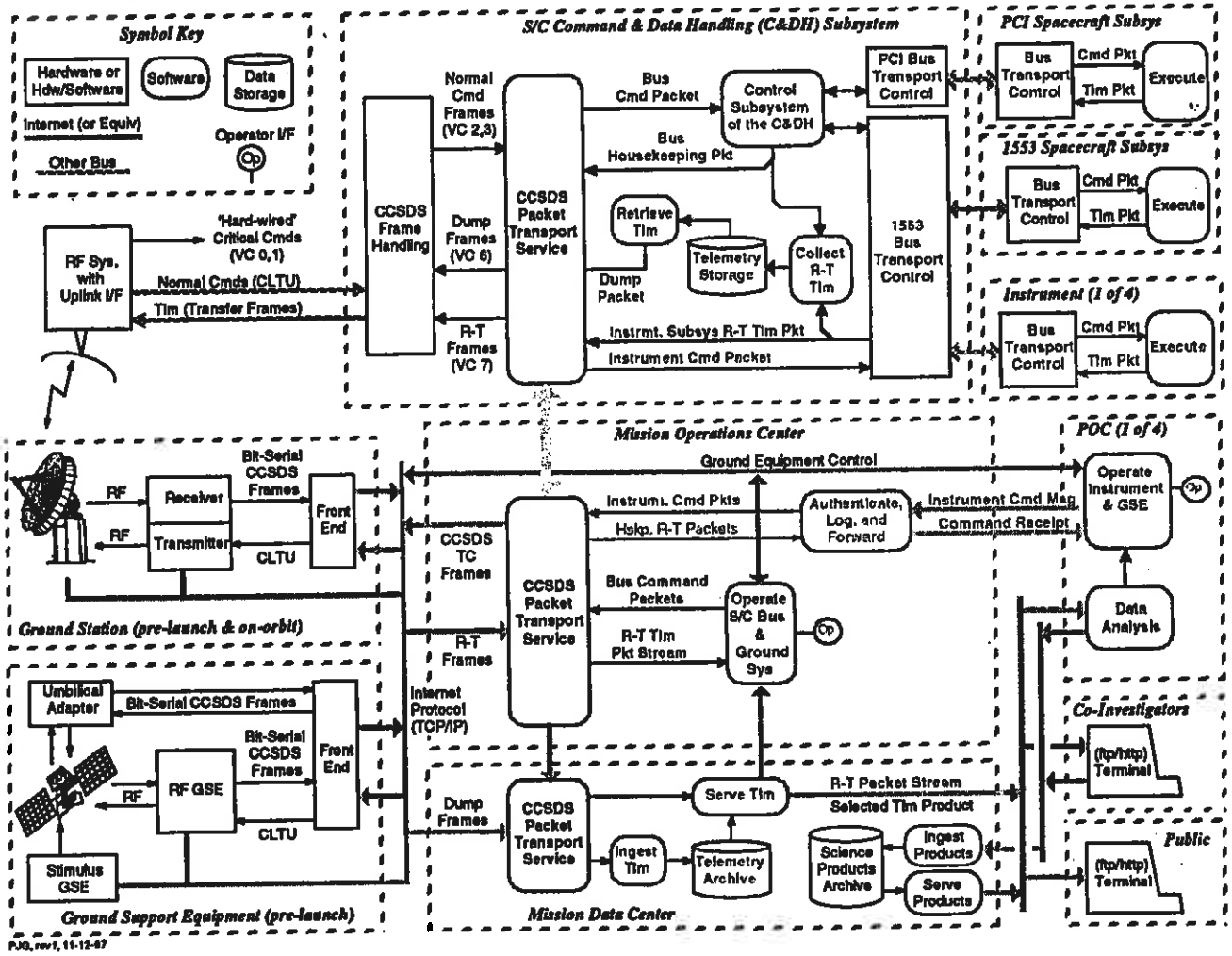
TIMED End-to-End Data System



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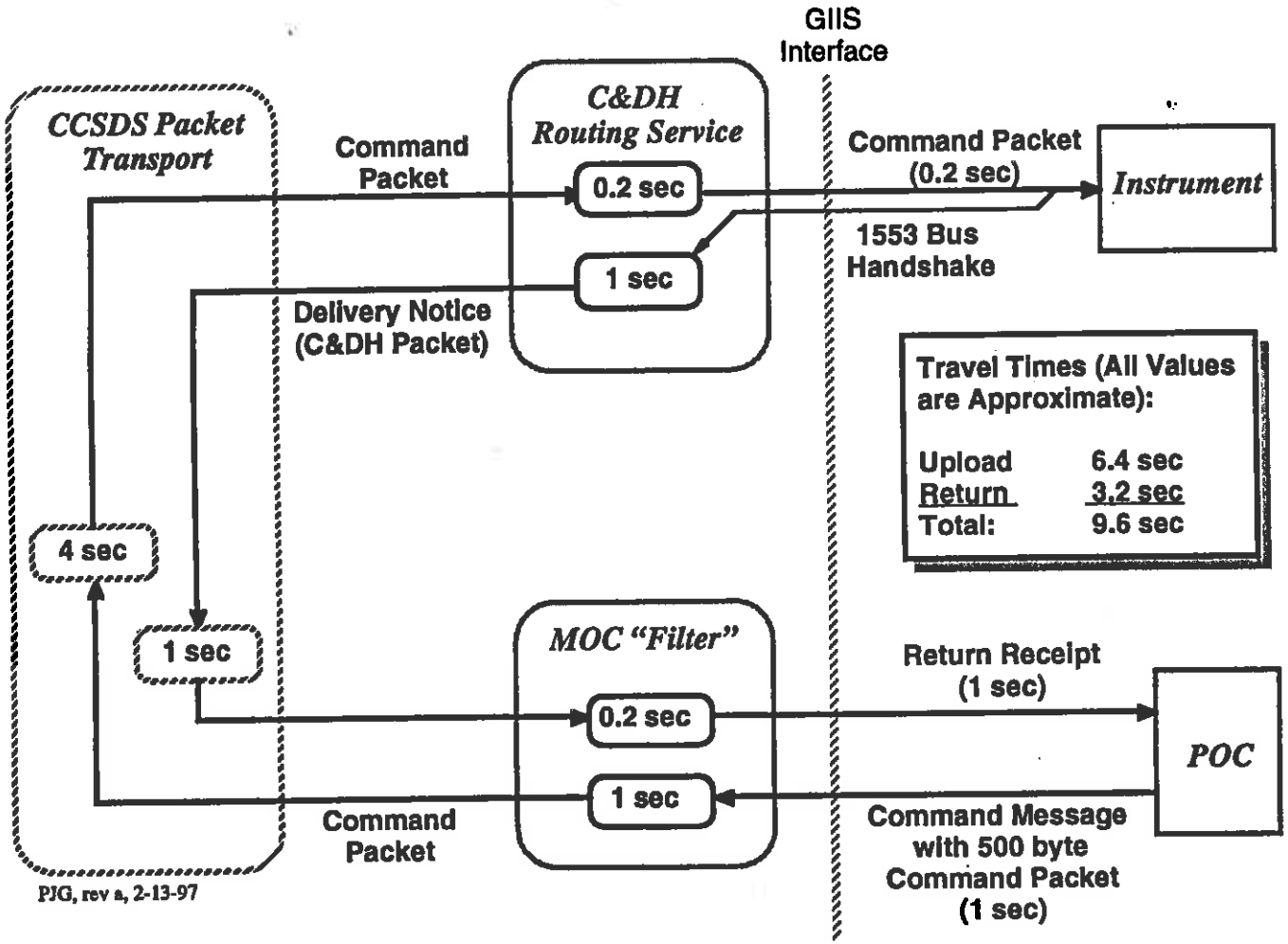
Command Loop and Timing



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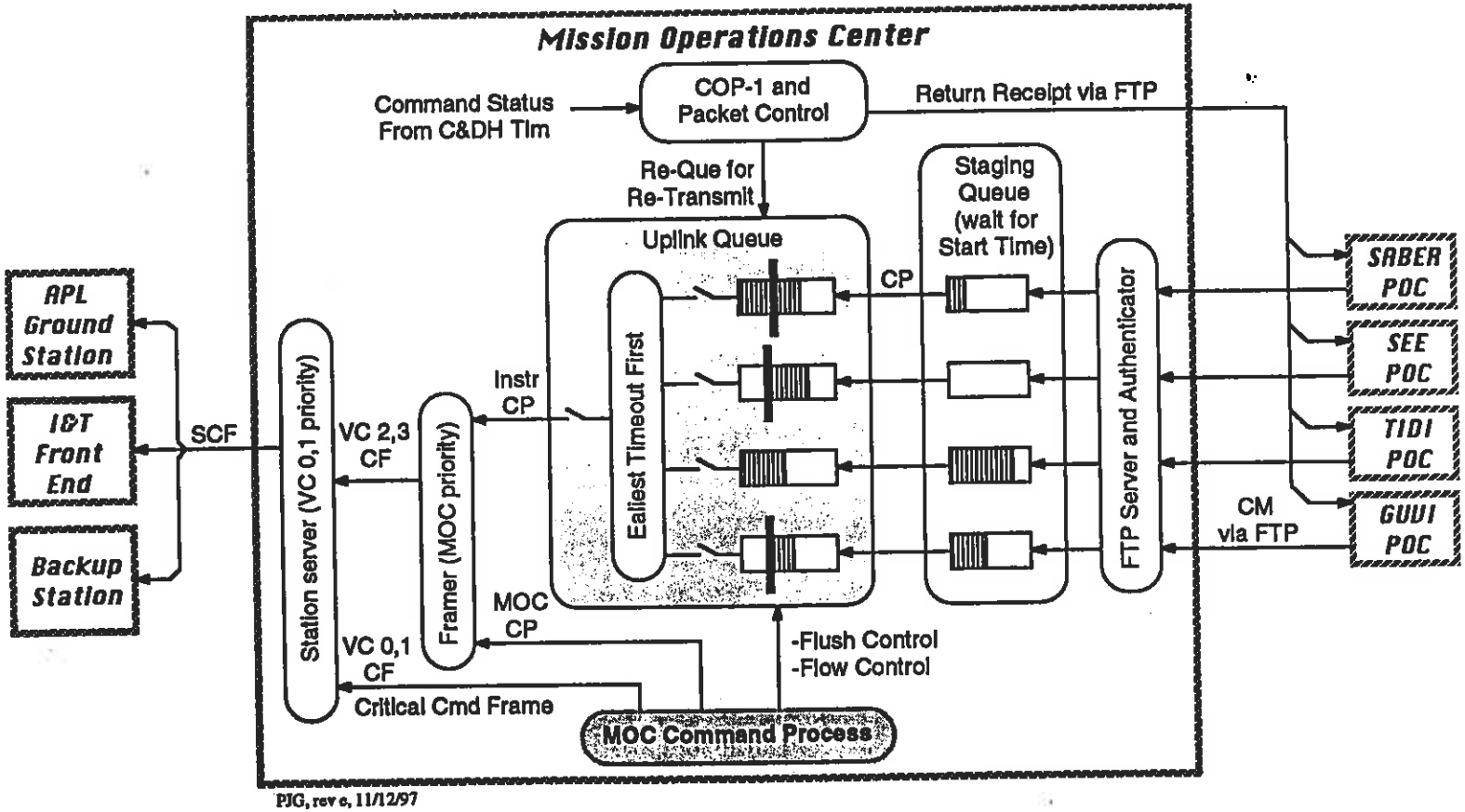
Command Data Flow



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Command Message Types

- CM = [POC-MOC] Command Message
- CP = Command Packet
- SCF = Supplemented Cmd Frame
- CF = Command Frame

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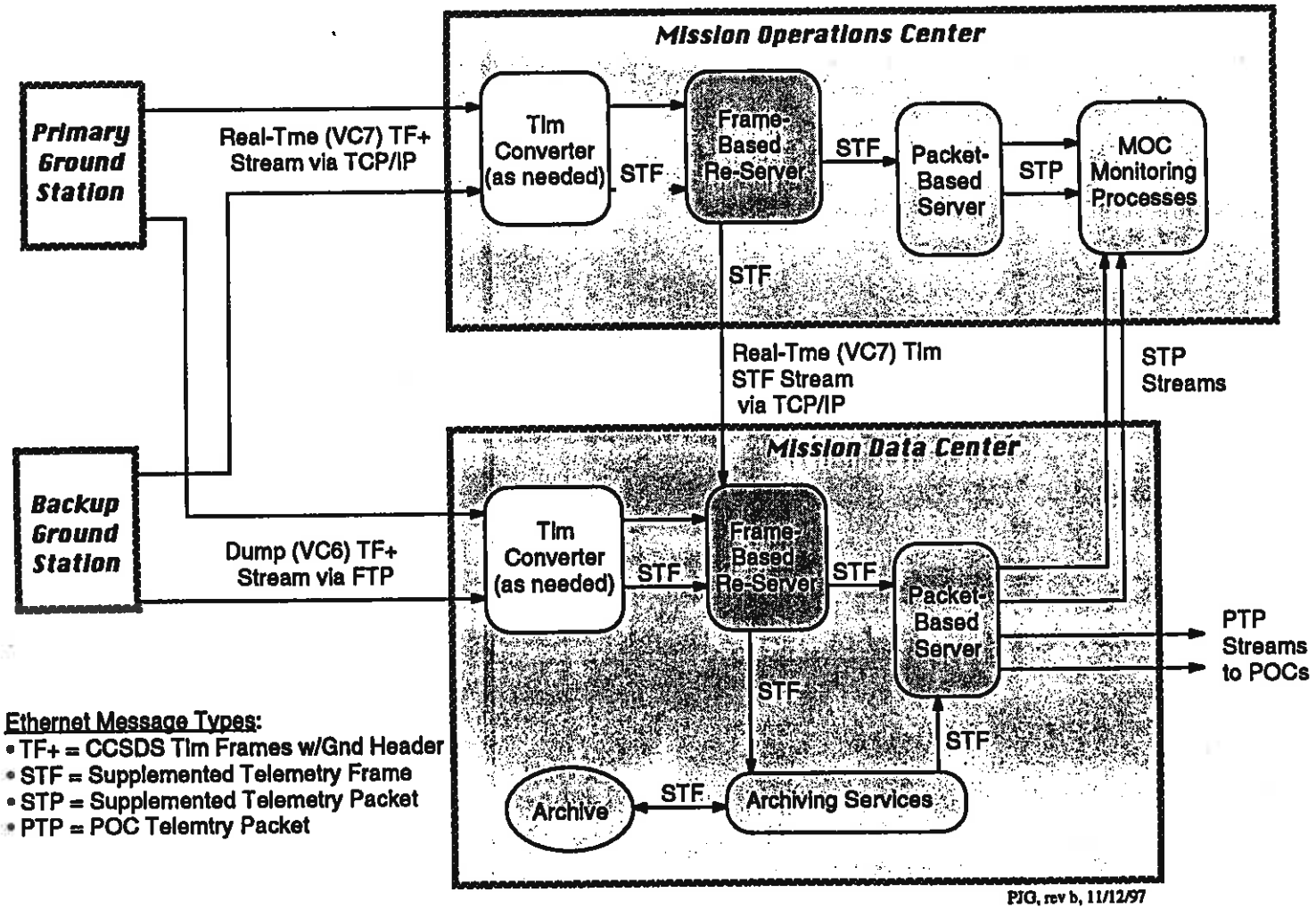
Telemetry Data Flow



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

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TIMED Message Structures

Command Message Structures

CP = Command Packet

CCSDS Telecommand Packet (6-4006 Bytes)

CM = Command Message [POC to MOC]

Header			
PI's Signature	Enable time Time-out	Command description	CP

CF = Command Frame [inside MOC and C&DH]

CCSDS Telecommand Transfer Frame			
Frame Header	CP	CP	CP

or

CCSDS Telecommand Transfer Frame	
Frame Header	One Telecommand Segment

or

CCSDS Telecmd Transfer Frame	
Frame Header	One Critical Command

SCF = Supplemented Cmd Frame [MOC to Gnd Station]

Ground Sta Header	CF

Telemetry Message Structures

TP = Telemetry Packet

CCSDS Source Packet (262 bytes)

TF = Telemetry Frame [inside C&DH and MDC]

CCSDS Telemetry Transfer Frame					
TF Headers	TP	TP	TP	TP	TF Trailers

STF = Supplemented Telemetry Frame [Inside MDC]

Ground Receipt Header	CCSDS Telemetry Transfer Frame					
	TF Headers	TP	TP	TP	TP	TF Trailers

STP = Supplemented Telemetry Packet [MDC to MOC]

Ground Receipt Hdr	TF Headers	TP	TF Trailers

PTP = POC Telemetry Packet [MDC to POC]

Ground Receipt Hdr	TP

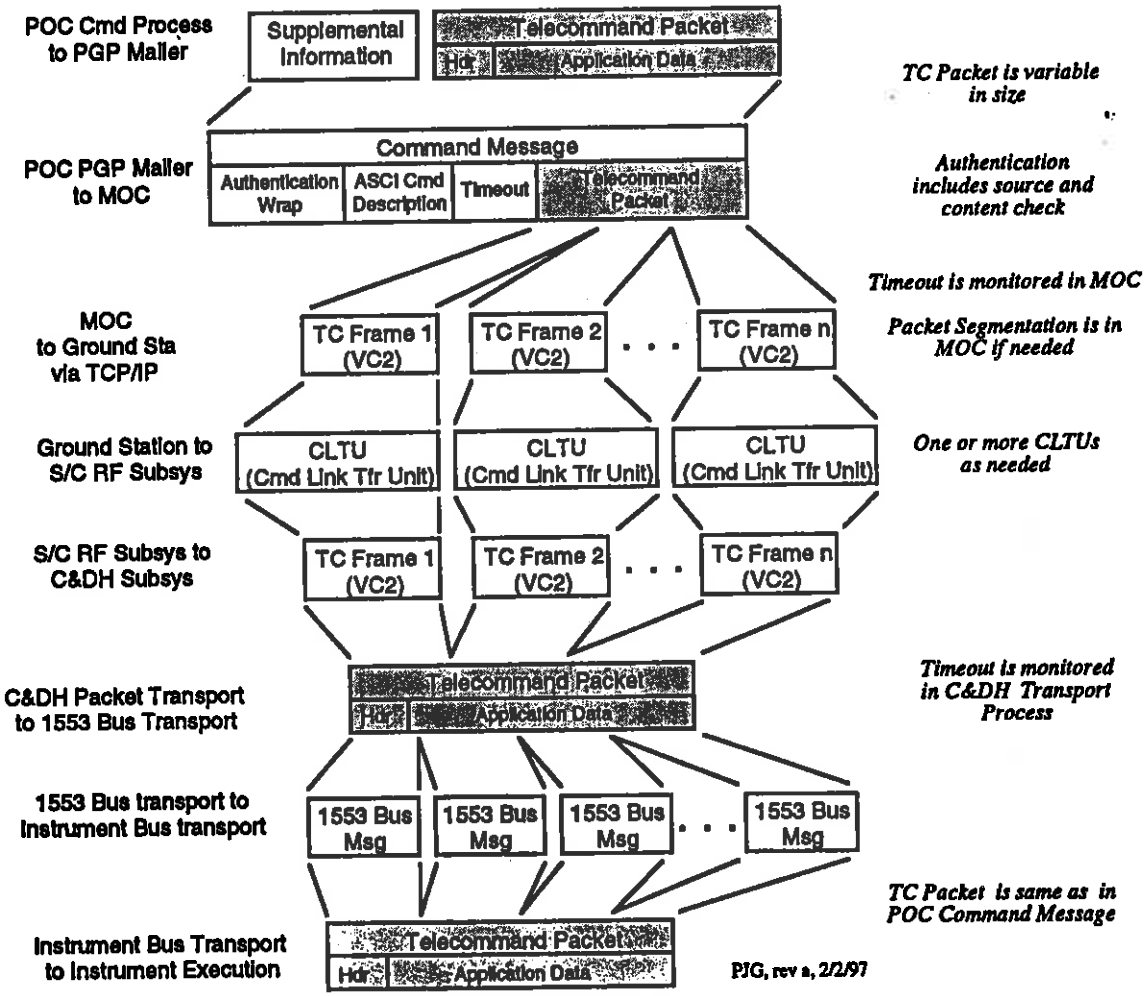
Table 6. TIMED POC Telemetry Packet (PTP) Structure

	Net Lengths (Bytes)	Portion of Total Length	Rollup lengths (Bytes)	Portion of Total Length
• **Ground Receipt Hdr [see Table 3]**	**22.000**	**7.7%**	**22.000**	**7.7%**
• **Transfer Frame Data Field excerpt:**				
> ***Source Packet (any one of 4)***			***262.000***	***92.3%***
Packet Primary Header	6.000	2.1%		
Packet Data Field:				
Packet Secondary Header:				
Spacecraft Time	4.000	1.4%		
Time Vernier [1]	2.000	0.7%		
Source Data	250.000	88.0%		
PJG, 11/12/97 **Totals:**	**284.000**	**100.0%**	**284.000**	**100.0%**

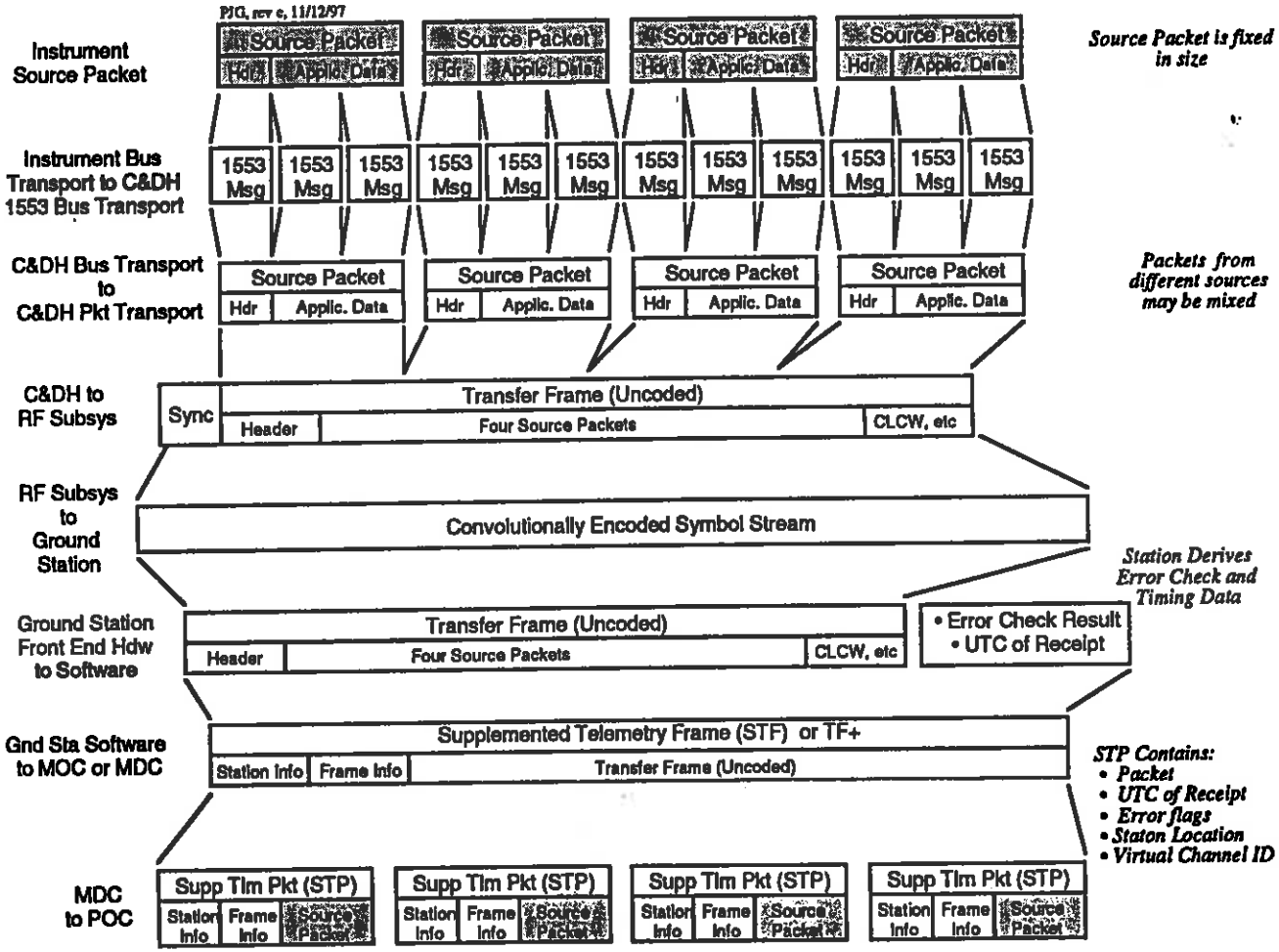
[1] Optional; add 2 Bytes to Source Data if not present.

(For the other data structures,see the Data Supplement at the end of this section)

Command Packet Transformations

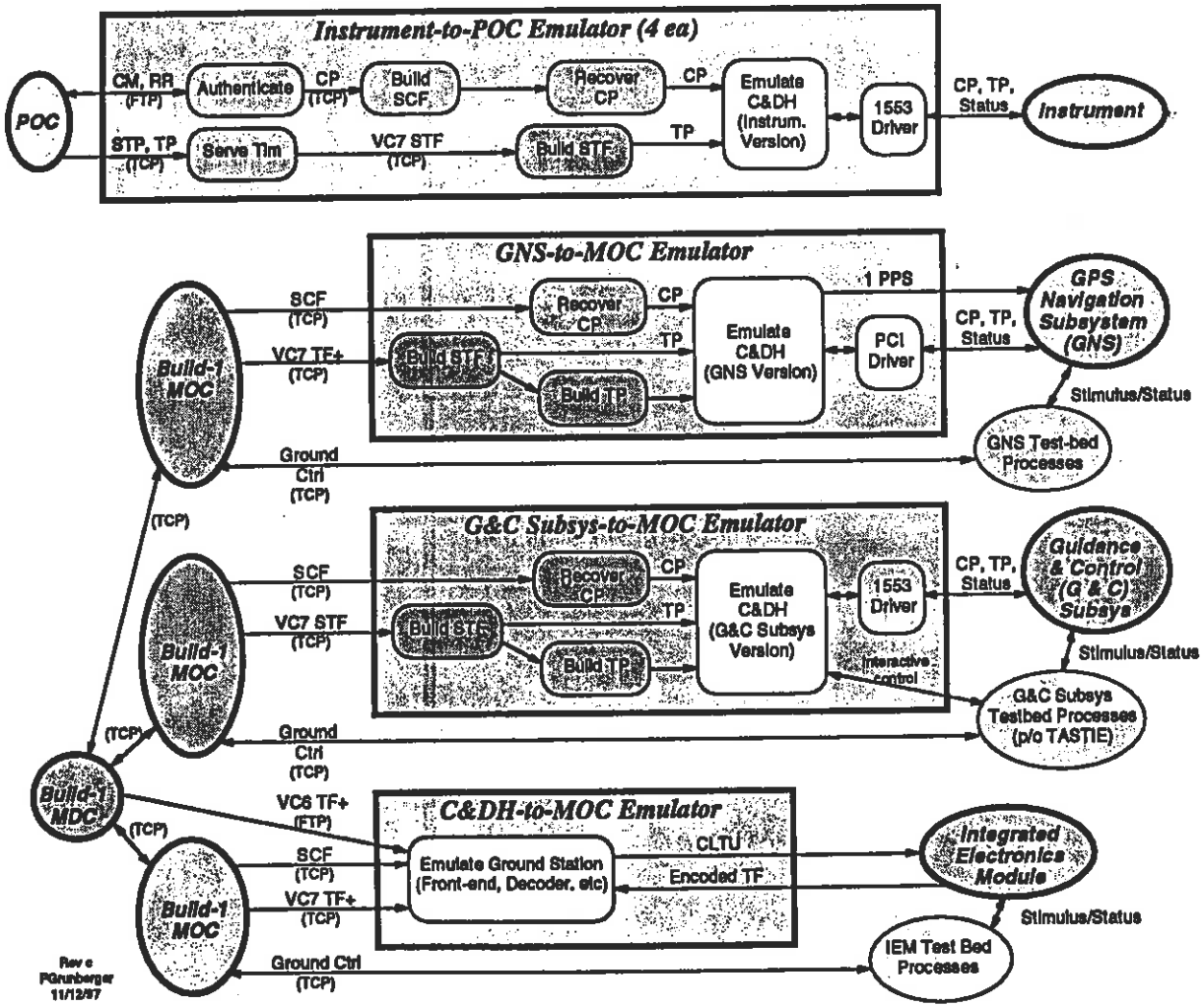


Telemetry Packet Transformations



[POC can also order a bare Packet (TP) stream, or a POC Telemetry Packet (PTP)]

Data System Emulators for Bench Testing



End-to-End Data System Features

- Fully compliant with CCSDS Packet Telemetry and Telecommand Recommendations
- Telecommand error control:
  - Frame-Delivery (COP-1) protocol operates between MOC and C&DH subsystem
  - Triple-Error Detection for all commands (was Single-Error Correction)
- Telemetry error control
  - R-S encoding, Frame Error Control Field
  - 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

5. Telemetry Rate Budgets

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Daily (24.25 Hour) Telemetry Data Volumes and Rates

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Expected Values. Includes Entire Packets				Margin Calculations	
Item	Total Dump Data to SSR in 24.25 Hrs (Mb)	Avg Record Data Rate (b/s)	Fraction of Total	*Allowed Accum. Rate* (b/s)*	Margin as of 11/12/97
G & C Telemetry	24.397	279	1.41%		
GNS 12-hour Packets	0.025	0	0.00%		
GNS 30-second Packets	67.093	769	3.87%		
GNS 1-Hz Data	91.490	1,048	5.28%		
C&DH	240.162	2,751	13.85%		
Spacecraft Memory Dump Data	18.874	216	1.09%		
HOUSEKEEPING SUBTOTAL, H =	442.042	5,063	25.50%	*5,500*	7.9%
SEE	19.905	228	1.15%		
GUVI	707.526	8,105	40.81%		
SABER	346.555	3,970	19.99%		
TIDI	217.726	2,494	12.56%		
INSTRUMENT SUBTOTAL, S =	1291.712	14,796	74.50%	*16,954*	12.7%
PACKET TOTALS, H + S =	1733.754	19,860	100.00%	22,454	11.6%

** Numbers in Italics are constrained by TIMED System Requirements Document*

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Solid State Recorder (SSR) Margins

a. SSR Capacity Margins for Daily Dumps

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24.25 Hour Volumes	Amount (Mb)
Dump Data from Previuos Table	1,734
G & C Orbit Diagnostic Data (Not dumped)	101
TOTAL ACCUMULATION	**1,834**
*Required SSR Capacity**	*2,500*
MARGIN vs REQUIRED CAPACITY	**26.6%**
Actual SSR Capacity	**2,540**
MARGIN vs ACTUAL CAPACITY	**27.8%**

**** Numbers in Italics are constrained by TIMED System Requirements Document***

b. Available SSR Record Time

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Parameter	Value
Actual SSR Capacity (Mb)	2,540
- G & C Orbit Diagnostic Data (Not dumped)	101
= Net SSR Capacity for Dumps (Mb)	2,439
+Dump Data Accumulation Rate from prior table (b/s)	19,860
= AVAILABLE RECORD TIME (hrs)	34.12

High-Rate (Mode 1a) Downlink Information Rate

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Item	Expected Values	*Required Minimum Link Capacity**
Dump (VC6) Packets, Daily Total Volume from Prior Table (Mb)	1,733.754	
+ available dump time (min)	7.940	
= Dump (VC6) Data Rate (b/s)	**3,639,282**	
+ Real-Time (VC7) Housekeeping Pkts, worst case (b/s)	37,728	
+ Real-Time (VC7) Instrument Pkts, worst case (b/s)	23,056	
= PACKET SUBTOTAL (kb/s)	**3,700,066**	
x Framing factor	1.025	
= INFORMATION RATE* (b/s)	**3,791,861**	***3,994,862***
x R-S Coding Factor	1.149	1.149
= R-S ENCODED SYMBOL RATE (b/s)	**4,356,757**	**4,590,000**
ACTUAL MODE 1a DOWNLINK SYMBOL RATE, R1a (b/s)**	**4,590,000**	**4,590,000**
Available Rate Margin	**5.1%**	

** The number in Italics is constrained by the TIMED System Requirements Document*

** locked to spacecraft oscillator: R1a = 30.600 MHz x 3 / (5 x 4)

Low-Rate (Mode 2) Downlink Information Rate

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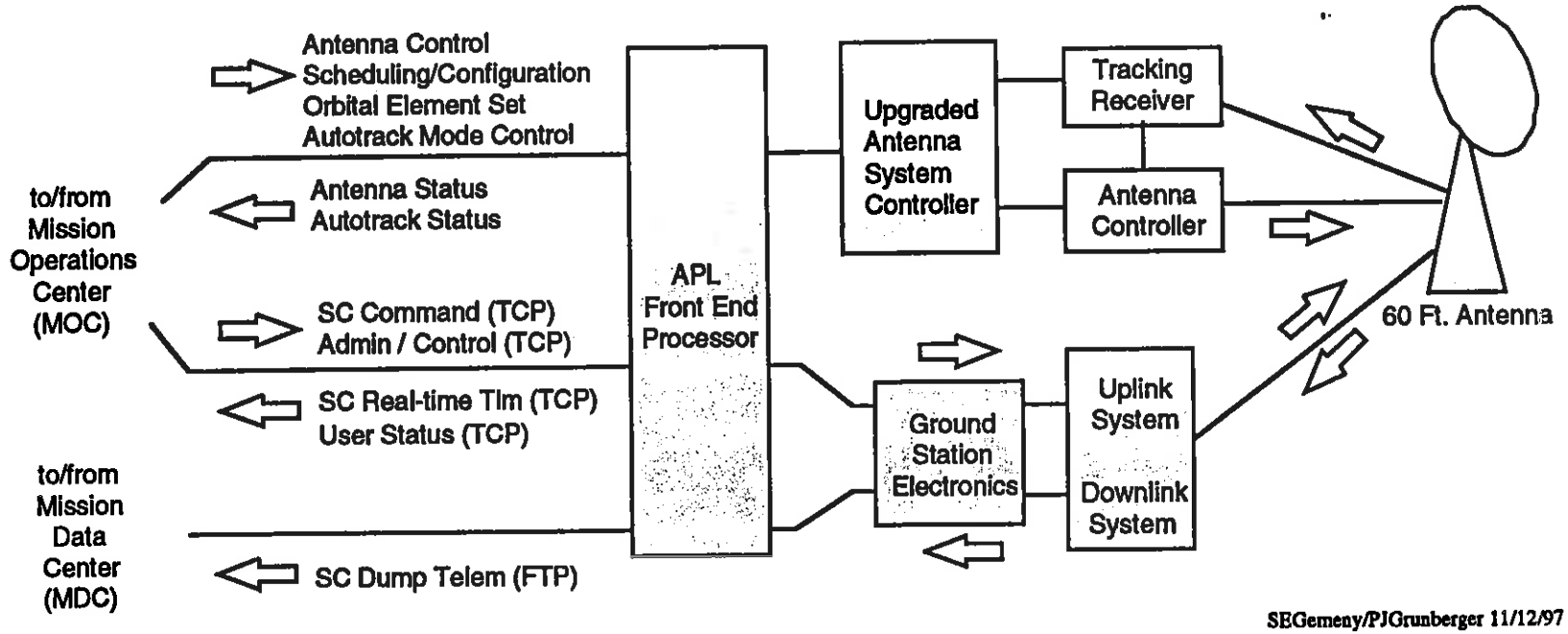
Item	Expected Rates (b/s)	*Required Minimum Link Capacity* (b/s)*
Real-Time (VC7) Packets, at 4 packets/s	8,384	
x Framing Factor	1.025	
= *INFORMATION RATE**	8,592	*9,018*
x R-S Coding Factor	1.149	1.149
= R-S ENCODED TOTAL	9,872	10,361
x Convolutional Coding Factor	2.000	2.000
= TOTAL SYMBOL RATE NEEDED	19,744	20,722
ACTUAL MODE 2 DOWNLINK SYMBOL RATE**, R2	20,722	20,722
Available Rate Margin	4.7%	

** The number in Italics is constrained by the TIMED Sys. Rqmts. Doc.*

** locked to spacecraft oscillator: R2 = 30.600 MHz x 3 / (5 x 886)

6. Ground System Description

Primary Ground Station



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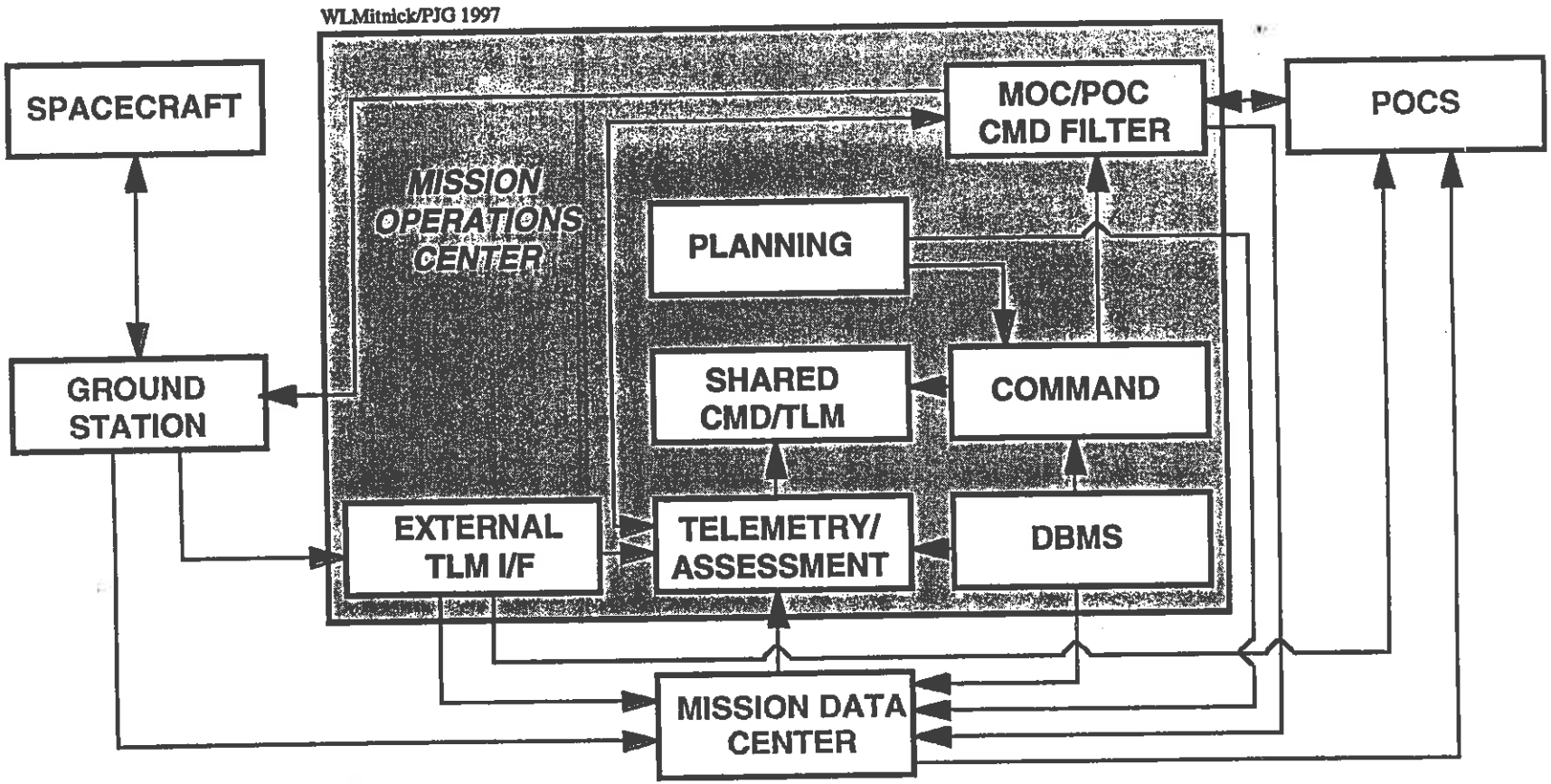
Ground Station Features

- 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:
    - » 1.54 Mb/s via Internet Service Provider, leased line or GSFC
    - » Dial-up Modem for contingency

Mission Operations Center (MOC)



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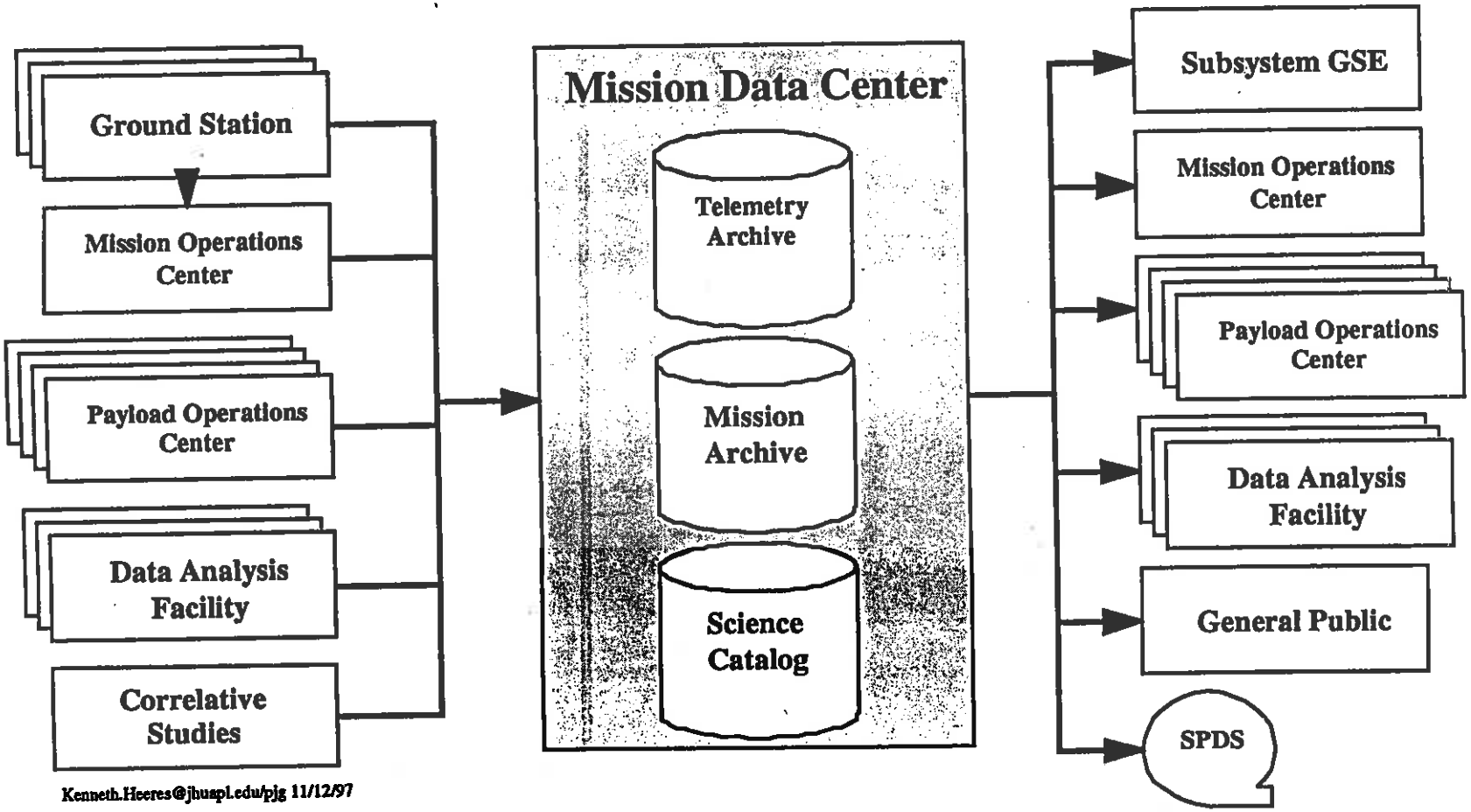
MOC Design Highlights

- Built around COTS software
- Supports independent commanding by MOC and POCs
- Supports real time or store-and-forward commands from POC
- Uses same design for
  - Mission Operations
  - Integrate & Test
  - Bench Test ("Mini-MOC")
- Operator-configurable monitoring displays
- Memory management tools for spacecraft processors
- Compiler for spacecraft autonomy rules
- Unattended operation

MOC Design Changes since PDR

- Core Software now based on EPOCH 2000 Version 2 (was Version 3)
  - no change in performance
- CCSDS Command Operation Procedure (COP-1) is implemented in MOC (rather than Ground Station)
  - more development work for MOC, but better control of process

Mission Data Center



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MDC Major Processes

- Telemetry Server
  - Builds Archive
  - Serves all Streams (TP, STP, PTP)
- Mission Database
  - Spacecraft attitude, ephemeris
  - Science product catalogs
- Data Product Production and Distribution
  - 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

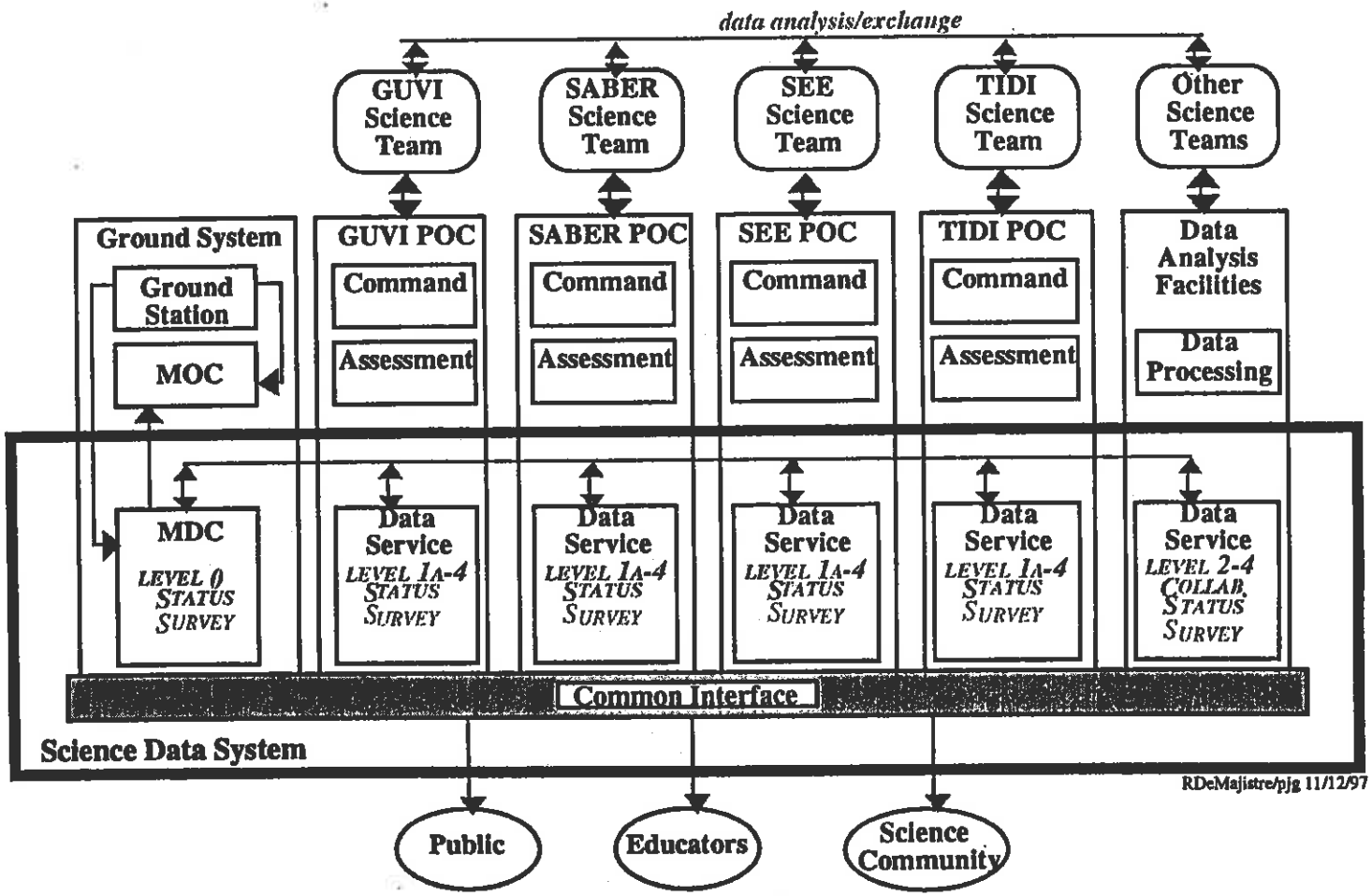
MDC Highlights

- Unattended operation
- 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
    - » Archived stream - reliable data service (no skips)
  - File-based WWW service
- Other MDC Processs
  - See Science Data System

MDC Design Changes

- NASA/Goddard's Data Distribution System (DDS) is the core software for cataloging the SDS archives
- C++ replaces the Java language for coding telemetry services

Science Data System



SDS Design Highlights

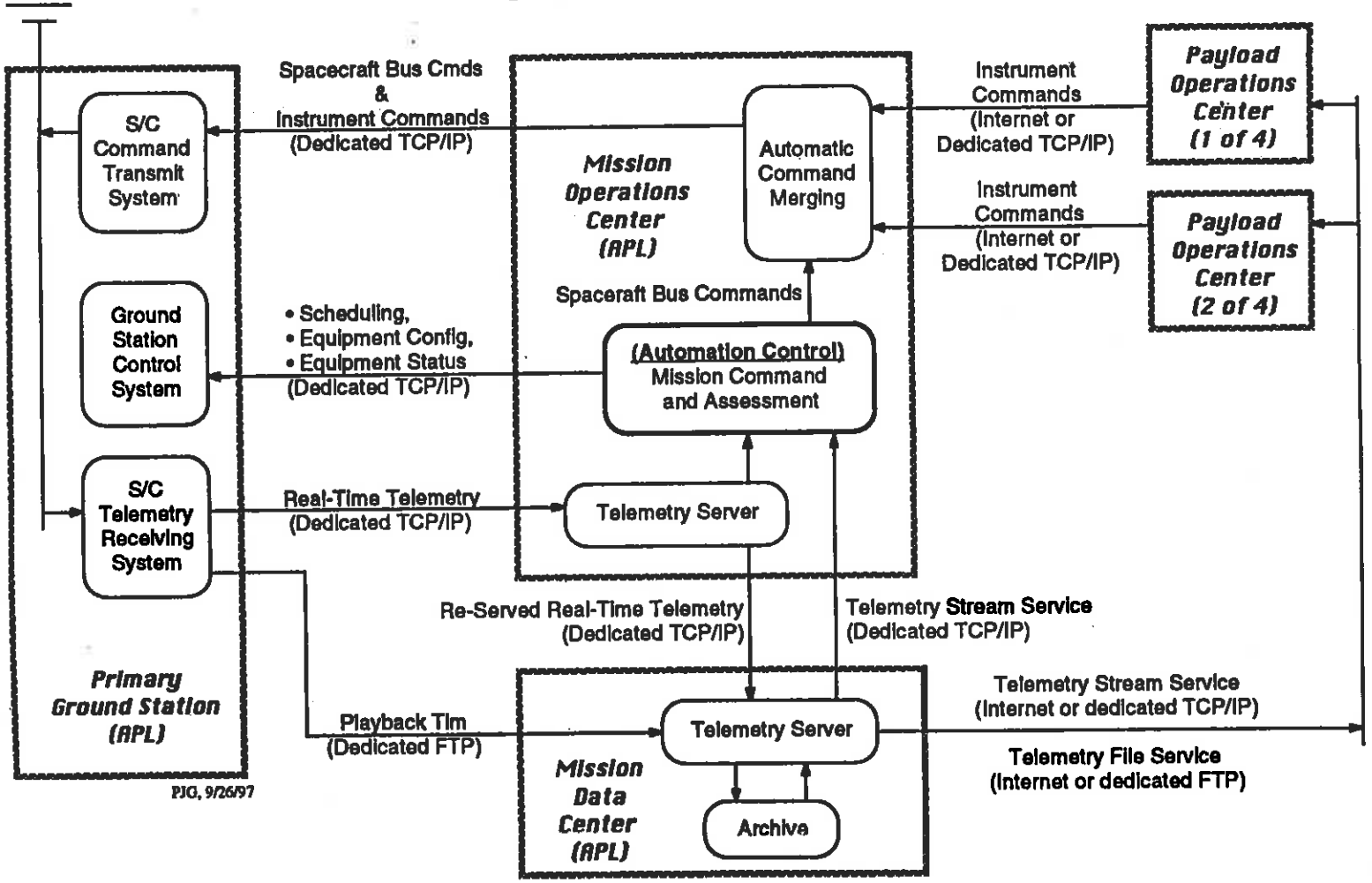
- Established by TIMED Project Data Management Plan (APL doc. 7363-9330)
- Distributed archive and network for product exchange
- Configuration management for products
- Telemetry (level-0) stream service from MDC
- Higher-level products produced at investigator facilities
- World-Wide Web service from MDC
  - Central catalog for all TIMED higher-level products
  - Accepts orders and subscriptions for SDS products
  - Educational products and activities
  - Planning tools
    - » coverage maps
    - » orbit projections for 8 weeks

7. Lights-Out Capability

Ground System Automation Design

- Primary Ground Station can be scheduled and configured from the MOC
- Unattended contacts are under control of MOC
  - Events can be monitored by "telemetry" from spacecraft, Ground Station, or any ground equipment
  - "STOL" command script language supports WAIT, DO WHILE, and contingency action triggered by an Event
- Delivery of instrument commands can be entirely automatic

"Lights-Out" Data Flow



On-Orbit "Lights-Out" Scenarios

- Early-mission contacts will require operator actions
- In mid-mission, routine daytime contacts will be conducted automatically from the MOC by STOL scripts
  - some checkpoint monitoring by operators
- Later in mission, night-time contacts will be automated to
  - monitor spacecraft health.
  - demonstrate recorder dumps, but all unattended dumps would be redundant.
- Automatic responses to abnormal events:
  - close out the contact in an orderly way
  - notify the Mission Ops Team

8. Risk Management

- Launch and Early-Orbit Support
  - Planned ground stations provide very little coverage during first three orbits
  - Risk: early loss of spacecraft due to deployment or attitude problems
  - Mitigation:
    - » Locate an existing ground station (or place portable station) in a suitable area to cover the first three orbits
    - » Establish a TCP/IP interface there, if not already available, for early-orbit coverage
- Backup Ground Stations
  - Selected vendor has not yet initiated pass-support service for any customer
  - Risk: Vendor fails to perform.
  - Mitigation: Continue pursuing NASA/Wallops (LEO-T) support through MRR/DMR until vendor is established

9. Summary

- The Ground System meets all TIMED system requirements
- Risks are under control
- The Primary Ground Station upgrade is ready for fabrication
- Backup and Contingency Stations have been selected
- The Mini-MOC/MDC has started to support bench tests
- The SDS is defined by a Data Management Plan

Data Supplement

(Telemetry and Command Data Structures)

Table 1. TIMED Telemetry Packet (TP) Structure

	Net Lengths (bits)	Portion of Total Length	Rollup Lengths (bits)	Rollup Lengths (Bytes)	Portion of Total Length
• Source Packet [Note 1]:					
> Packet Primary Header			48	6	2.3%
Version Number	3	0.1%			
Packet Identification Field:		0.0%			
Type Indicator	1	0.0%			
Packet Secondary Header Flag	1	0.0%			
Application Process Identifier	11	0.5%			
Packet Sequence Control Field:					
Grouping Flags	2	0.1%			
Source Sequence Count	14	0.7%			
Packet Data Length Field	16	0.8%			
> Packet Data Field			2048	256	97.7%
Packet Secondary Header					
Packet Secondary Header Time Code Field					
CCSDS Unsegmented Time Code [2]	32	1.5%			
Time vernier [Note 3]	16	0.8%			
Source Data	***2000***	***95.4%***			
PJG, 10/24/97 **Totals:**	**2096**	**100.0%**	**2096**	**262**	**100.0%**

[1] A TIMED Telemetry Packet (TP) is a specialization of the Source Packet defined in CCSDS 102.0-B-4.

[2] aka "Spacecraft Time". P-Field only (see CCSDS 301.0-B-2, ¶2.3.2). Epoch is 00:00 hrs, January 6, 1980.

[3] Optional; add 2 Bytes to Source Data if not present.

Table 2. TIMED Telemetry Data Format

	Modes 3a, 3b [Note 4]	Mode 2	Modes 1a, 1b			
Approximate information rate(s)	4, 2 Mb/s	9 kb/s	4, 2 Mb/s			
Reed-Solomon coding?	no	yes	yes			
Convolutional coding?	yes	yes	no			
	Itemized lengths (bits)	Itemized lengths (bits)	Itemized lengths (bits)	Rollup 1 (bits)	Portion of total length	Rollup 2 (bits)
What goes to convolutional encoder [Note 2]:						
•Attached Sync Marker	32	32	32	32	0.3%	32
•Transmitted Codeblock:						8560
>Transfer Frame [Note 3]						
Transfer Frame Primary Header				48	0.5%	
Transfer Frame Version Number	2	2	2			
Transfer Frame Identification Field						
Spacecraft ID	10	10	10			
Virtual channel ID	3	3	3			
Operational Control field	1	1	1			
Master channel frame count	8	8	8			
Virtual channel Frame count	8	8	8			
Transfer frame Data Field Status						
Transfer Frame Secondary Headr Flag	1	1	1			
Synch. Flag	1	1	1			
Packet order Flag	1	1	1			
Segment Length ID	2	2	2			
First Header Pointer	11	11	11			
Transfer Frame Secondary Header [Note 3]				80	0.8%	
Transfer Frame Secondary Header ID:						
Transfer Frame Secondary Header Version No (="00")	2	2	2			
Transfer Frame Secondary Header length (="00 1001")	6	6	6			
spare bits	8	8	8			
Transfer Frame Secondary Header Data:						
Spacecraft Time (unsegmented count, GPS epoch)	32	32	32			
spare bits	16	16	16			
SSR playback error flags (format TBD)	16	16	16			
Transfer Frame Data Field:				*8384*	*84.9%*	
Source Packet (1 of 4)	2096	2096	2096			
Source Packet (2 of 4)	2096	2096	2096			
Source Packet (3 of 4)	2096	2096	2096			
Source Packet (4 of 4)	2096	2096	2096			
Operational Control field	32	32	32	32	0.3%	
Frame Error Control Field [Note1]	16	16	16	16	0.2%	
>**Reed-Solomon Check Symbols**	none	1280	1280	1280	13.0%	1280
PJG, 11/12/97 **Totals:**	8592	9872	9872	9872	100.0%	9872

[1] This field was added as a requirement for TIMED on 9-26-97 to permit the use of Modes 3a and 3b. CCSDS considers this field optional when Reed-Solomon coding is present, but mandatory otherwise.
[2] or, to Convolutional Encoder Bypass
[3] Transfer Frame length is 8560 b =1070 B. A multiple of 5 B is preferred by formatter card designers for R-S interleave of 5, although it may be possible to remove this restriction with no penalty.
[4] Modes 3a and 3b are available by design, but not now planned for use in TIMED
[5] This is a new length. It was modified on 9-26-97 to maintain TF length at an even multiple of 5 B.

TIMED

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Table 3. TIMED Supplemented Telemetry Frame (STF) Structure

	net lengths (bits)	Net lengths (Bytes)	Portion of Total Length	Rollup 1 Lengths (Bytes)	Rollup 2 Lengths (Bytes)	Portion of Total Length
• Ground Receipt Header [Note 1]:					22	2.0%
> generic fields:				4.750		
Size [of STF]	16	2.000	0.2%			
Data Type	8	1.000	0.1%			
spare bits	8	1.000	0.1%			
GRH Version ID	6	0.750	0.1%			
> mission-specific fields:				17.250		
Spacecraft ID	10	1.250	0.1%			
Ground Receipt Time	32	4.000	0.4%			
Ground Receipt Time Vernier	32	4.000	0.4%			
Frame Source Type	4	0.500	0.0%			
Frame Source Index	4	0.500	0.0%			
Path	4	0.500	0.0%			
Front-End Identifier	4	0.500	0.0%			
Reed-Solomon Decode Flag	1	0.125	0.0%			
Reed-Solomon Error Status	1	0.125	0.0%			
Reed-Solomon Error Count	7	0.875	0.1%			
CRC Flag	1	0.125	0.0%			
CRC Error Flag	1	0.125	0.0%			
Master Channel Sequence Checked	1	0.125	0.0%			
Master Channel Sequence No. Error	1	0.125	0.0%			
Frame Sync Mode	2	0.250	0.0%			
Frame Quality Flag	1	0.125	0.0%			
Frame Sync Pattern Errors	4	0.500	0.0%			
Frame Sync Bit Slips	4	0.500	0.0%			
spare bits	24	3.000	0.3%			
• Attached [Frame] Sync Marker	32	4.000	0.4%	4.000	4	0.4%
• Transfer Frame					1070	97.6%
> Transfer Frame Primary Header	48	6.000	0.5%	6.000		
> Transfer Frame Secondary Hdr [2]	80	10.000	0.9%	10.000		
> *Transfer Frame Data Field* [2]	*8384*	*1048.000*	*95.6%*	*1048.000*		
> Operational Control Field				4.000		
Command link Control Word [3]						
Control Word Type (="0")	1	0.125	0.0%			
CLCW Version Number (= "00")	2	0.250	0.0%			
Status Field	3	0.375	0.0%			
COP in Effect (="01" for COP-1)	2	0.250	0.0%			
Virtual Channel ID	6	0.750	0.1%			
spare (="00")	2	0.250	0.0%			
Flags						
No RF Available	1	0.125	0.0%			
No Bit Lock	1	0.125	0.0%			
Lockout	1	0.125	0.0%			
Wait	1	0.125	0.0%			
Retransmit	1	0.125	0.0%			
FARM B Counter (for Type B Frames)	2	0.250	0.0%			
spare (="0")	1	0.125	0.0%			
Report Value (for Type AD frames)	8	1.000	0.1%			
> Frame Error Control Field	16	2.000	0.2%	2.000		
rev. 11/12/97 Totals:	8768	1096.000	100.0%	1096.000	1096	100.0%

[1] Title is modified as of 10/17/97. See TIMED SDS WWW page for detailed definitions
[2] Contents are detailed in Table 2
[3] as defined in CCSDS 202.0-B-2, §4.2.2

Table 5. TIMED Supplemented Telemetry Packet (STP) Structure

	Net Lengths (Bytes)	Portion of Total Length	Rollup Lengths (Bytes)	Portion of Total Length
• Ground Receipt Header [See Table 3]	**22.000**	**7.1%**	**22.000**	**7.1%**
• Attached [Frame] Sync Marker	**4.000**	**1.3%**	**4.000**	**1.3%**
• Transfer Frame non-data-field excerpts:			**22.000**	**7.1%**
Transfer Frame Primary Header	6.000	1.9%		
Transfer Frame Secondary Header	10.000	3.2%		
Operational Control Field	4.000	1.3%		
Frame Error Control Field	2.000	0.6%		
• Transfer Frame Data Field excerpt:				
> Source Packet (any one of 4)			***262.000***	***84.5%***
Packet Primary Header	6.000	1.9%		
Packet Data Field:				
Packet Secondary Header:				
Spacecraft Time	4.000	1.3%		
Time Vernier [Note 2]	2.000	0.6%		
Source Data	250.000	80.6%		
PJG, 11/12/97 **Total :**	**310.000**	**100.0%**	**310.000**	**100.0%**

[1] Optional only when Reed-Solomon coding is present, mandatory otherwise

[2] Optional; add 2 Bytes to Source Data if not present.

Table 7. Command Packet (CP) Format

	length (bits)		Rollup Length (Bytes)	
	min	max	min	max
• **Telecommand Packet** [Note 1]:				
> Primary Header			6	6
Packet Identification:				
Version number	3	3		
Type	1	1		
Secondary header Flag	1	1		
Application process ID	11	11		
Packet Sequence Control:				
Sequence Flags	2	2		
Packet Name or Sequence Count	14	14		
Packet length	16	16		
> Application Data [Note 2]	***8***	***32,000***	***1***	***4,000***
Total:	**56**	**32,048**	**7**	**4,006**

PJG, 11/12/97

[1] A TIMED Command Packet (CP) is a specialization of the Telecommand Packet defined in CCSDS 203.0-B-1, ¶5.2.

[2] Any included Secondary Header is non-CCSDS defined; See CCSDS 203.0-B-1, ¶5.2.2 The maximum length here is limited by the TIMED program. A higher limit of 65,532 bytes is allowed by CCSDS 203.0-B-1, ¶5.2.1.3.

Table 8. Command Frame (CF) for Software-Decoded Commands (Virtual Channels 2 and 3)

	lengths (bits)		Lengths (Bytes)		Rollup Lengths (Bytes)	
	min	max	min	max	min	max
• Telecommand Frame [Note 1]:						
> [TC] Transfer Frame Header					5	5
Version Number	2	2	0.250	0.250		
Bypass Flag	1	1	0.125	0.125		
Control command Flag	1	1	0.125	0.125		
spare	2	2	0.250	0.250		
Spacecraft ID	10	10	1.250	1.250		
Virtual channel ID	6	6	0.750	0.750		
Frame Length	10	10	1.250	1.250		
Frame Sequence Number	8	8	1.000	1.000		
> Transfer Frame Data Field					5	1017
Telecommand Segment						
Segment Header						
Sequence Flags	2	2	0.250	0.250		
Multiplexer Access Point	6	6	0.750	0.750		
Segment Data Field [Notes 2, 3]	***8***	***8128***	***1.000***	***1016.000***		
> Transfer Frame Error Control Field [4]	16	16	2.000	2.000	2	2
PJG, 11/12/97 **Totals:**	**72**	**8192**	**9.000**	**1024.000**	**12**	**1024**

[1] A TIMED Command Frame (CF) is a specialization of the Telecommand (TC) Transfer Frame described in CCSDS 202.0-B-2, ¶4.2.1. Software-Decoded Command Frames are uplinked using Triple Error Detection (TED).

[2] This can be a portion of one TC Packet, one TC Packet, or multiple TC Packets.

[3] The indicated maximum of 1016 Bytes is the limit given by CCSDS 201.0-B-2. Table 10 shows that a maximum of1014 Bytes makes more efficient use of uplink capacity.

[4] This was included for use with Single-Error-Correction (SEC) as recommended in CCSDS 200.0-G-6, Annex D-5 SEC was abandoned in favor of TED, which does not need this field; however, it is to be retained.

Table 9. Command Frame (CF) for Critical Command Decoder (CCD) Commands (Virtual Channels 0 and 1)

	Req'd Value [Note 1]	lengths (bits) itemized	lengths (bits) rollup	Lengths (Bytes) itemized	Lengths (Bytes) rollup
• **Telecommand Frame** [Note 1]:					
> **[TC] Transfer Frame Header**			**40**		**5.000**
Version Number	"00"	2		0.250	
Bypass Flag [Note 2]	"1"	1		0.125	
Control command Flag	"0"	1		0.125	
spare	"00"	2		0.250	
Spacecraft ID	"01 1110 0011"	10		1.250	
Virtual channel ID	"00 000x"	6		0.750	
Frame Length	"0000 0000"	10		1.250	
Frame Sequence Number	"0000 0000"	8		1.000	
> ***Transfer Frame Data Field***			***16***		***2.000***
CCD Command [Note 3]		16		2.000	
PJG, 11/12/97 **Totals:**		**56**	**56**	**7.000**	**7.000**

[1] A TIMED Command Frame (CF) is a specialization of the Telecommand (TC) Transfer Frame described in CCSDS 202.0-B-2, ¶4.2.1[1]. CCD Commands are uplinked using Triple Error Detection (TED). No Transfer Frame Error Control Field is present.

[2] MSB is transmited first

[3] CCSDS 202.0-B-2, ¶3.3.1 defines this as a "User Data Unit". (This is not a TC Packet.)