Telemetry Processor Software

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Changes since PDR

- **Reduced from many interrupt sources to a single interrupt source (1 msec heartbeat)**

- **Added Safe Mode**

- **Added automatic EEPROM-based command sequence (Bootlist) as part of maintenance mode operation. Can be used to automatically exit maintenance mode**

- **Added command linked-list feature to resolve absolute, delayed, and immediate command execution**

Telemetry Processor Software Requirements

- **Mode Specific Operations**
  - Scan mirror control and detector processor readout synchronization to support imaging and spectrograph modes
  - Pseudo-logarithmic data compression
  - Telemetry packet preparation

- **General Operations**
  - Receive and validate spacecraft commands for immediate, delayed, or absolute time execution
  - Provide analog monitor safeguarding for spectrograph, SIS, and ECU electronics
  - Provide telemetry processor and detector processor software upload capability
  - Provide watchdog capability and automatic return to science data acquisition in case of watchdog timeout (conditional)

Mode Transition Diagram
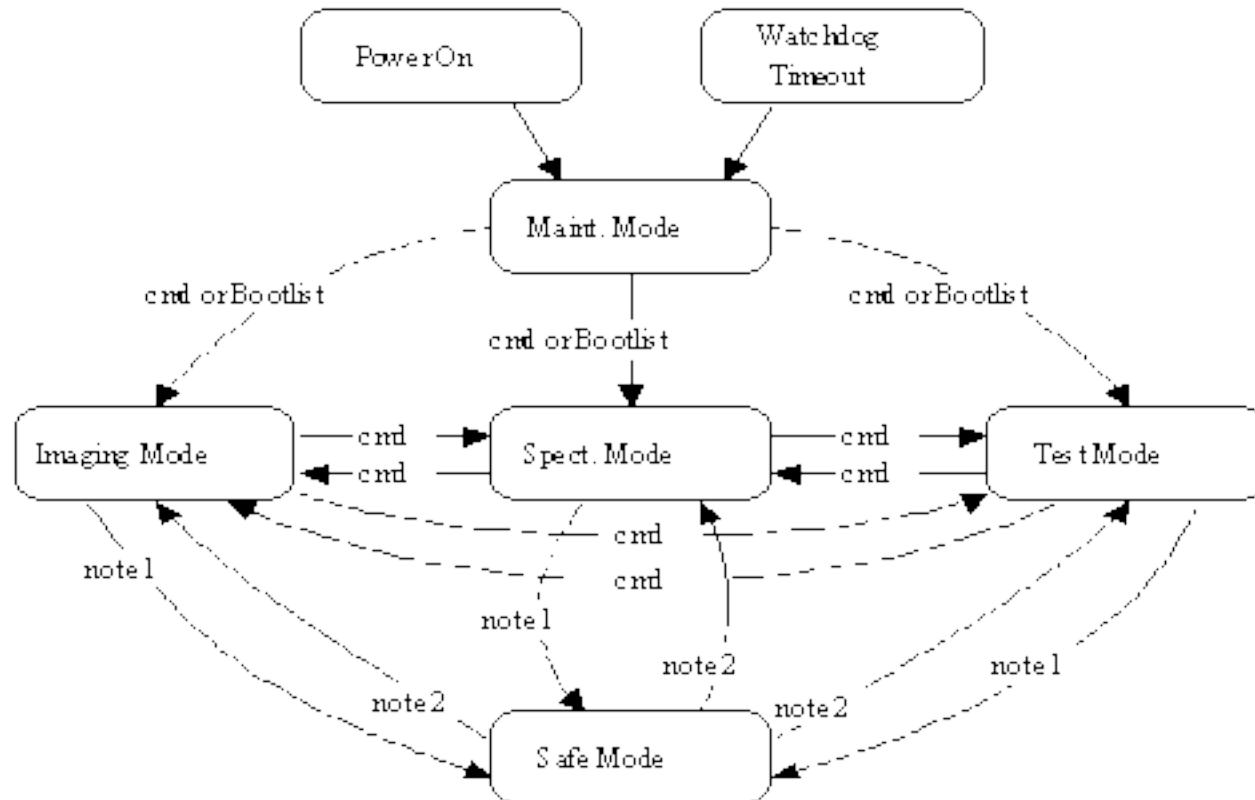
note 1: cmd, sun event, yaw maneuver, red limit violation or GUVI powerdown
note 2: cmd or yaw maneuver complete

Maintenance Mode

- **PROM-based software is executed in response to watchdog timeout or power on event**

- **High voltage is safed, scan mirror is stowed upon entry**

- **After 5 minutes in maintenance mode, EEPROM is checked for valid boot-up command list (Bootlist) of memory load or operational commands**

- **Telemetry Proc. (TP) and Detector Proc. (DP) maintenance**
  - **TP and DP software are downloaded from PROM to RAM during boot**
  - **Depending on Bootlist, RAM images for TP and DP may be partially or completely overwritten from EEPROM**

- **Exited by ground command or Bootlist**

- **Command subset accepted during maintenance mode**

- **Maximum 2 packets transmitted per second (HK and dump)**

Imaging Mode

- **Consists of three regions covered in 15 seconds**
  - **Limb Scan**
    - 32 pixels over 1.088 seconds (34 ms / pixel)
    - integration occurs over last half of each pixel
  - **Earth Scan**
    - 159 pixels over 10.812 seconds (68 ms / pixel)
    - integration occurs over 2 mirror step positions
  - **Flyback**
    - reverse steps through 349 steps in 3.1 seconds
    - at 8 msecs / step, requires 308 ms delay at end
    - if mode change required (except Safe), only occurs during flyback

Imaging Mode (continued)

- **Mirror stepping and integration start/stop are controlled from software 1 msec interrupt**

- **One test mode event is read per pixel integration time; up to 30 test events are stored to the housekeeping packet**

- **Read data deadtime (assuming detector processor adds zero)**
  - **2.8 msecs (worst case) of 68 msecs**
  - **4.1% deadtime**

- **Outputs 57 imaging mode packets and 1 housekeeping packet every 15 seconds**

Imaging Mode - Timing
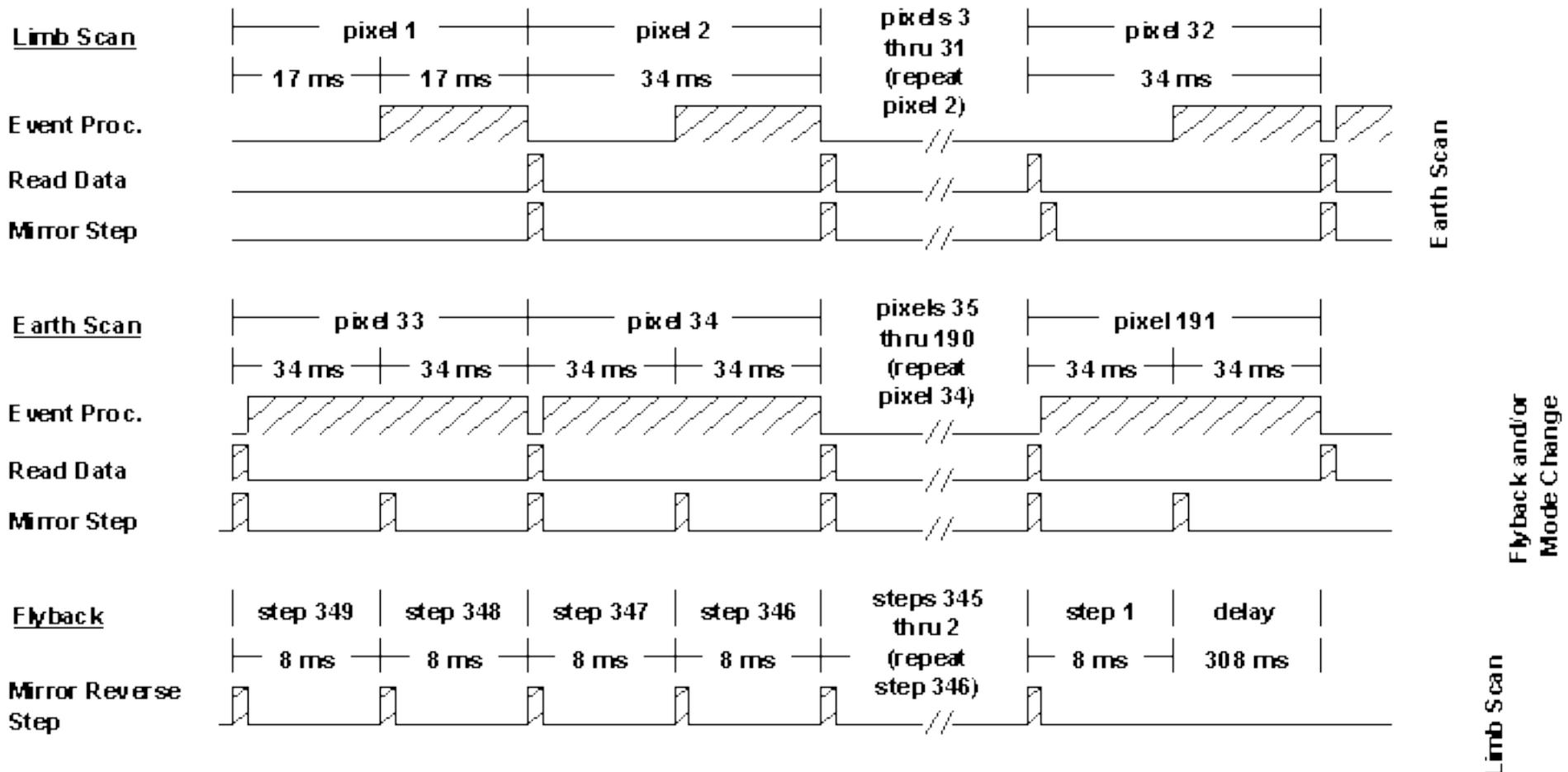
Spectrograph Mode

- Scan mirror position set, according to ground command, prior to first integration

- If mode change required (except Safe), can only occur at end of integration

- Outputs 10 spectrograph packets and 1 housekeeping packet per 3 seconds

- Read deadtime (assuming detector processor adds zero) is

  - 46.1 msecs of 3 seconds

  - 1.48% deadtime
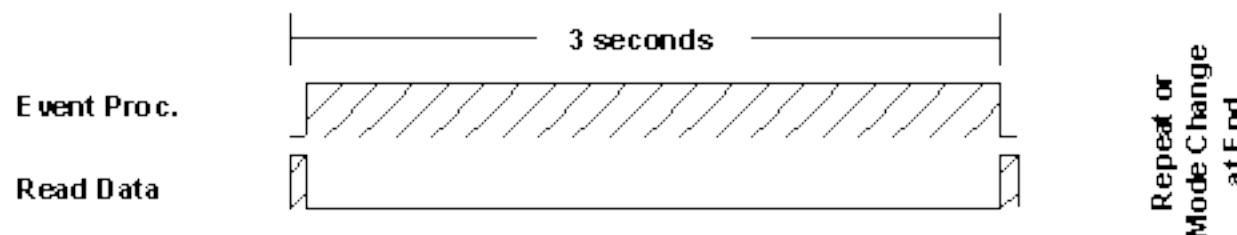
Test Mode

- Detector Processor performs "pass-thru" operation, passes digitized W, S, I signals to Telemetry Processor

- Allows for verification of Detector Processor algorithms and proper operation of front-end electronics

- Detector Processor interface checked every msec for new available event; first 120 stored

- Outputs 2 test mode and 1 housekeeping packet per second

Safe Mode

- Marker bit (Safe Mode Enabled) set in fault status indicates that Safe Mode active; Safe Mode overrides any other data acquisition mode

- If entered because of yaw maneuver broadcast, exits back to previous mode when maneuver completes

- HV and scan mirror are in safe position during execution

- Only collects housekeeping data

- Housekeeping safeguards are in effect (red limit checking)

- Outputs 1 housekeeping packet per second

Special Operations

- **High Voltage Activation/Deactivation**
  - Command requests final value of high voltage setting
  - Telemetry processor raises/lowers high voltage according to maximum rate of change to avoid breakdown
- **Yaw Maneuver (see Safe Mode)**
  - Spacecraft broadcasts warning of upcoming yaw maneuver (60 second warning)
  - Telemetry processor safes high voltage and mirror
  - Continues science operations upon yaw maneuver completion
- **Boot List**
  - Automatically resumes science operations in case of watchdog timeout

Command Overview

- GUVI will utilize telecommand packets with lengths from 262 bytes to 4000 bytes

- A 16-bit CRC checksum is included within each telecommand packet and is checked prior to command execution

- Command macros including timetagged commands and delayed commands will be built into single telecommand packets.

- Command are received into linked-list structure; execution occurs on 1 second boundaries (execute 1 or many as appropriate according to timetags)

- Timetagged commands with times earlier than the current time will execute immediately

Command Packet Overview

	Start Byte	End Byte	Bits	Contents
Primary Header				
	Start Byte	End Byte	Bits	Contents
	0	0	7:5	Version Number (=0)
	0	0	4:4	Type Indicator (= 1)
	0	0	3:3	Secondary Header Flag (=0)
	0	1	10:0	ApID (= 480H)
	2	2	7:6	Group Flags
	2	3	13:0	Source Sequence Count(incremented for each command packet)
	4	5	15:0	Packet Length (minimum = 249, maximum = 3993)
Source Data				
	6	7	15:0	Packet checksum
	8	3999 max	all	GUVI Timetagged Commands (Command Blocks)

Command Block Detail

Position	Size (bytes)	Contents
1	1	Timetag select defined as:
		=0: invalid time, terminates command list
		=1: time (position 2) indicates seconds delay from previous command
		=2: time (position 2) indicates CCSDS time for absolute time execution
2	4	Timetag (see above, most significant byte first)
3	1	Command opcode
4	0 - 3986	Command arguments

Command Linked List

- Consists of 2 elements:

  - CmdList contains absolute timetags, command length, and address offset into command Bulk Memory. CmdList commands are always in time sequence

  - Bulk Memory (BulkMem) contains the command bytes including opcode and any parameters of each command

- When a command packet is received, each command is assigned an absolute time, then

  - all command bytes are copied to the BulkMem after a suitable memory block is allocated

  - the CmdList is searched for the command insertion point based on timetags, then all following elements are moved down to make room for insertion

  - at the new insertion point CmdList receives the command's timetag, BulkMem address, and length

Command Linked List (continued)

- When a new command is being inserted near a command with the same absolute execution time, the new command always goes behind the existing command

- At time of command execution, any command found with a time earlier than the current time is executed immediately

- On each 1 second boundary, following execution of all current commands, the CmdList is shifted up to remove all commands just completed

- Once per hour, the BulkMem is compressed to put all queued commands at the bottom of memory and free the largest block to unused

Command Linked List - Example

Example	CmdList (<= 100 cmds)
3	CmdsInQueue (1 byte)
1/2/00 9:30	Timetag 1 (4 bytes)
107	AddressPtr 1 (2 bytes)
3	Length 1 (2 bytes)
1/2/00 9:35	Timetag 2 (4 bytes)
110	AddressPtr 2 (2 bytes)
3	Length 2 (2 bytes)
1/2/00 9:40	Timetag 3 (4 bytes)
200	AddressPtr 3 (2 bytes)
3	Length 3 (2 bytes)
	Empty

Bulk Memory (8K bytes)

0 - 106:	Empty	
107 - 109:	23 01 80	DET_HV, 1, LVL=80H
110 - 112:	30 02 02	SET_SLIT, MED, 2
113 - 199:	Empty	
200:	72	MODE_DAYIMAGE
201 - 7999:	Empty	
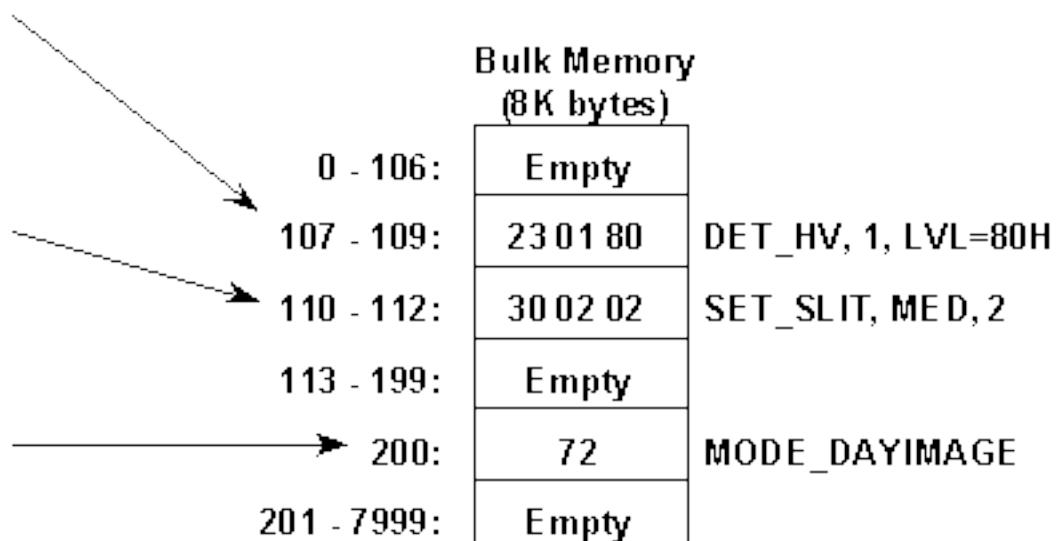
Bootlist Detail

Bootlist CRC (16 bits)
Length of Bootlist (16 bits)
command block #1
command block #2
command block #3
command block #4
etc.

- **Starting just after the Bootlist CRC, the Maintenance Mode process computes the CRC for the length specified**

- **If the computed CRC matches that provided in the first word, then execution can commence**

- **Command block can contain delayed time sequences only (absolute timetags are not supported)**

- **The Bootlist is terminated if an unknown opcode is encountered**

GUVI Mode Word

Start Bit	No. Bits	Parameter
63	1	GUVI Alive Indicator (Counts on two second boundary)
62	1	Autonomy Bit (not used)
61	3	Command Receipt Counter
58	3	Command Reject Counter
55	2	Operating Mode
53	1	Primary Detector Power
52	1	Secondary Detector Power
51	1	Narrow Slit Position
50	1	Medium Slit Position
49	1	Pop-up Mirror Position
48	1	Scan Motor Drive
47	1	Cover Closed Indicator
46	1	Cover Full Open Indicator
45	1	Sun Sensor Trip
44	1	Yaw Maneuver Indicator
43	12	Mirror Position
31	8	Last Command Sequence No. (bottom 8)
23	8	Fault Status Word
15	8	Detector High Voltage Monitor
7	8	SIS Temperature Monitor

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Telemetry Queue

- **Written by BuildTM, read by PollAll1553**

- **Circular buffer with capacity of 80 complete packets**

- **Control variables include: TPutIndex, TGetIndex, and TNumItems**
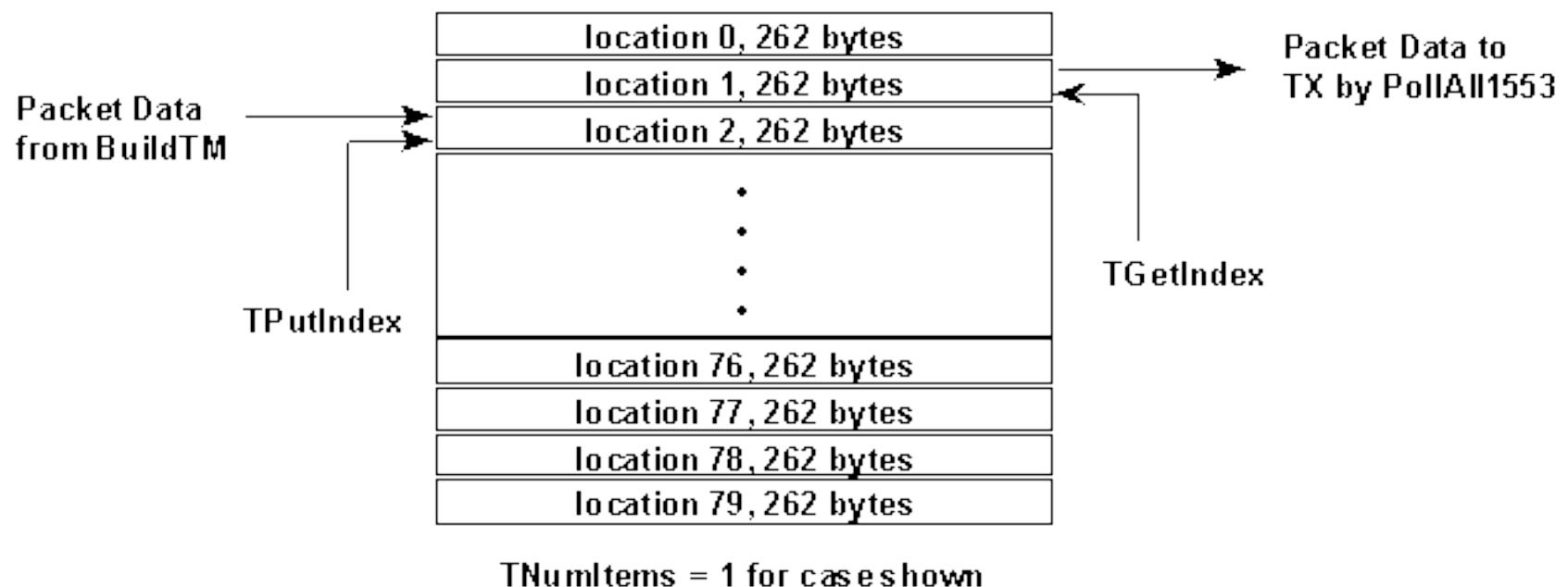
Packet Data from BuildTM

| location 0, 262 bytes |
| location 1, 262 bytes |
| location 2, 262 bytes |

Packet Data to TX by PollAll1553

TPutIndex

TGetIndex

| location 76, 262 bytes |
| location 77, 262 bytes |
| location 78, 262 bytes |
| location 79, 262 bytes |

TNumItems = 1 for case shown

Telemetry Readout Timing

- Assumes C&DH reads packet in 2.1 msecs (262 bytes X 8 bits per byte @ 1 MHz rate) after detecting packet buffer ready during poll
- To ensure all GUVI packets are available when polled (250 msecs), tally all components of interpacket latency
  - C&DH read following successful poll: 2.1 msecs
  - Telemetry reload time: 1.5 msecs
  - Assume collision with detector processor readout: 47 msecs
  - Latency of 50.6 out of 250 msecs is adequate timing margin
- Telemetry bandwidth requirements:
  - Imaging Mode (58 packets in 15 seconds): 8.2 Kbps
  - Spectrograph Mode (11 packets in 3 seconds): 7.7 Kbps
  - Test Mode (3 packets in 1 second): 6.3 Kbps
  - Maintenance Mode (3 packets in 1 second): 6.3 Kbps

Telemetry Packet Description

|	Start Byte	End Byte	Bits	Contents
Primary	0	0	7:5	Version Number (=0)
	0	0	4:4	Type Indicator (=0)
	0	0	3:3	Secondary Header Flag (=1)
	0	1	10:0	ApID:
				480H=Housekeeping Data
				481H=Imaging Mode Data
				482H=Spectrograph Mode Data
				483H=Test Mode Data
				484H=Maintenance Mode Data
	2	2	7:6	Group Flags:
				01=First packet of message
				00=Continuation of message
				10=Last packet of message
	2	3	13:0	Source Sequence Count (incremented for each packet output)
	4	5	15:0	Packet Length (=255)
Secondary	6	9	31:0	CCSDS Unsegmented Time Code
	10	11	15:0	Time Vernier (fine time, res=1msec)
	12	12	7:6	Message Type:
				00=Imaging
				01=Spectrograph
				10=Test
				11=Maintenance
	12	12	5:0	Subpacket Number
	13	13	7:0	Checksum - computed as the bytewise XOR of packet
				bytes in secondary header and source data
Source Data	14	261	all	Source Data Field (248 bytes)

1553 Response Time Requirements

| Subaddress	Max Response Time	Comment
R1-R4 and R6-R9 (Command Buffers)	125 msecs	Refer to R11 to know when to read R1-R4 and R6-R9
R11 (Cmd Buffer Status)	125 msecs	
R19 (Time Distribution)	2 msecs	Refer to T19 to know when to read R19
R20 (Spacecraft Status)	125 msecs	
T1-T5 and T6-T10 (Telemetry Buffers)	250 msecs	
T11 (T/M Config. Word)	125 msecs	Tells C&DH when Telemetry Buffers are available
T12 (Instrument Status Word)	500 msecs	Status word written once per second
T19 (Time Distribution Fiducial)	2 msecs	Tells when T19 should be read

Boot Operations

PowerOn or Watchdog

→ Download T/M Proc. Code ((EE)PROM) to RAM

→ Maintenance Mode Ops

→ Download Det. Proc. Software

→ Enable Watchdog Timer*

→ Initialize Control Variables

→ Setup interrupt vectors, enable interrupts

→ Data Acquisition (background task)

→ 1 msec Interrupt Service Routine

*Watchdog Timer disabled by hardware on boot-up

PROM Execution → RAM Execution → RAM Execution
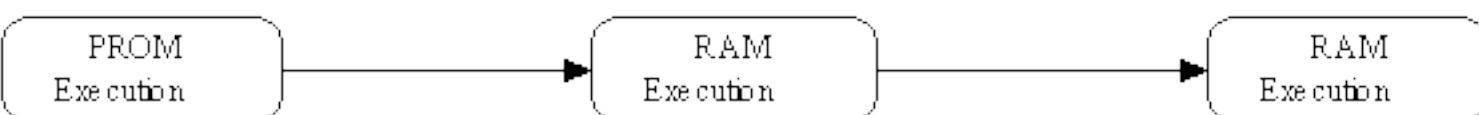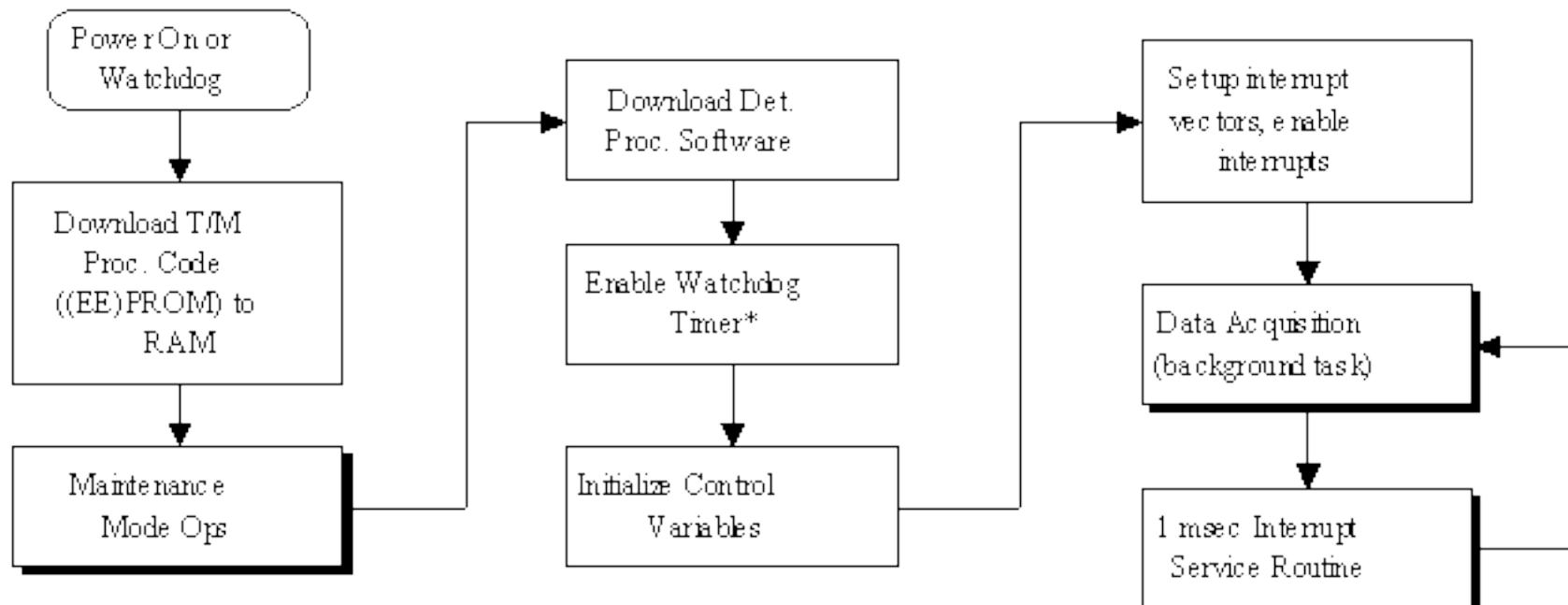
Data Acquisition / 1 msec Interrupt
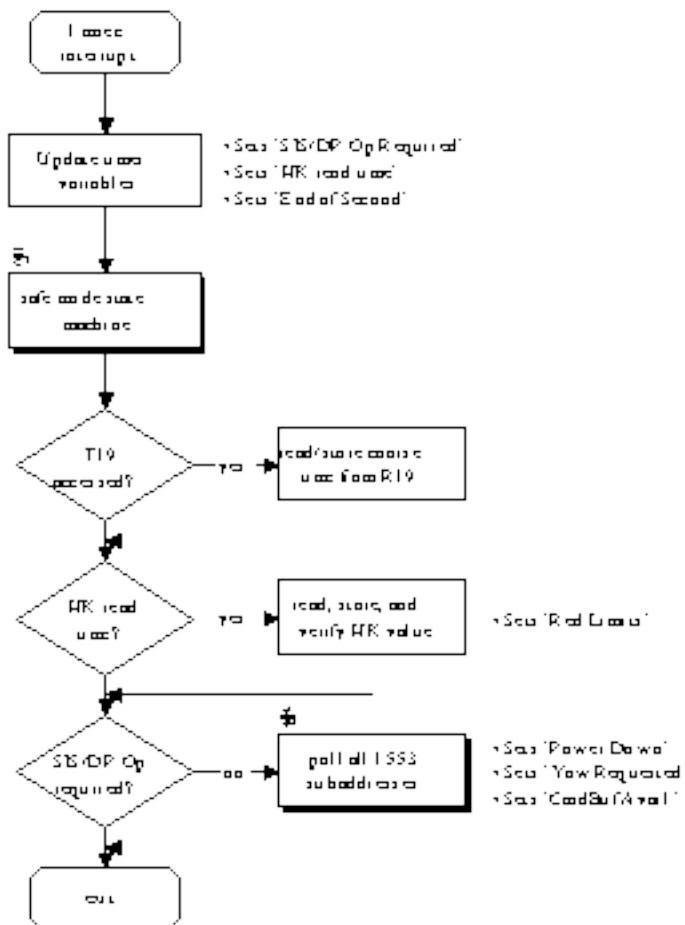
- Timer variables exist to track delay interval, integration, step interval, 25 ms (HK), 1 sec, 3 secs, and 15 secs

- Safe Mode state machine is called every msec to check transitions in and out of Safe Mode

- T19 checked every msec to ensure packet timetags accurate to within 3 msecs (S/C uncertainty = 2 msecs)

- A new housekeeping (HK) value is digitized every 25 msecs; they are checked against Red Limit table to see when automatic shutdown is needed

- Polling of 1553 ports is skipped when time critical access to SIS or DP is needed

1 msec ISR - Safe Mode State Machine
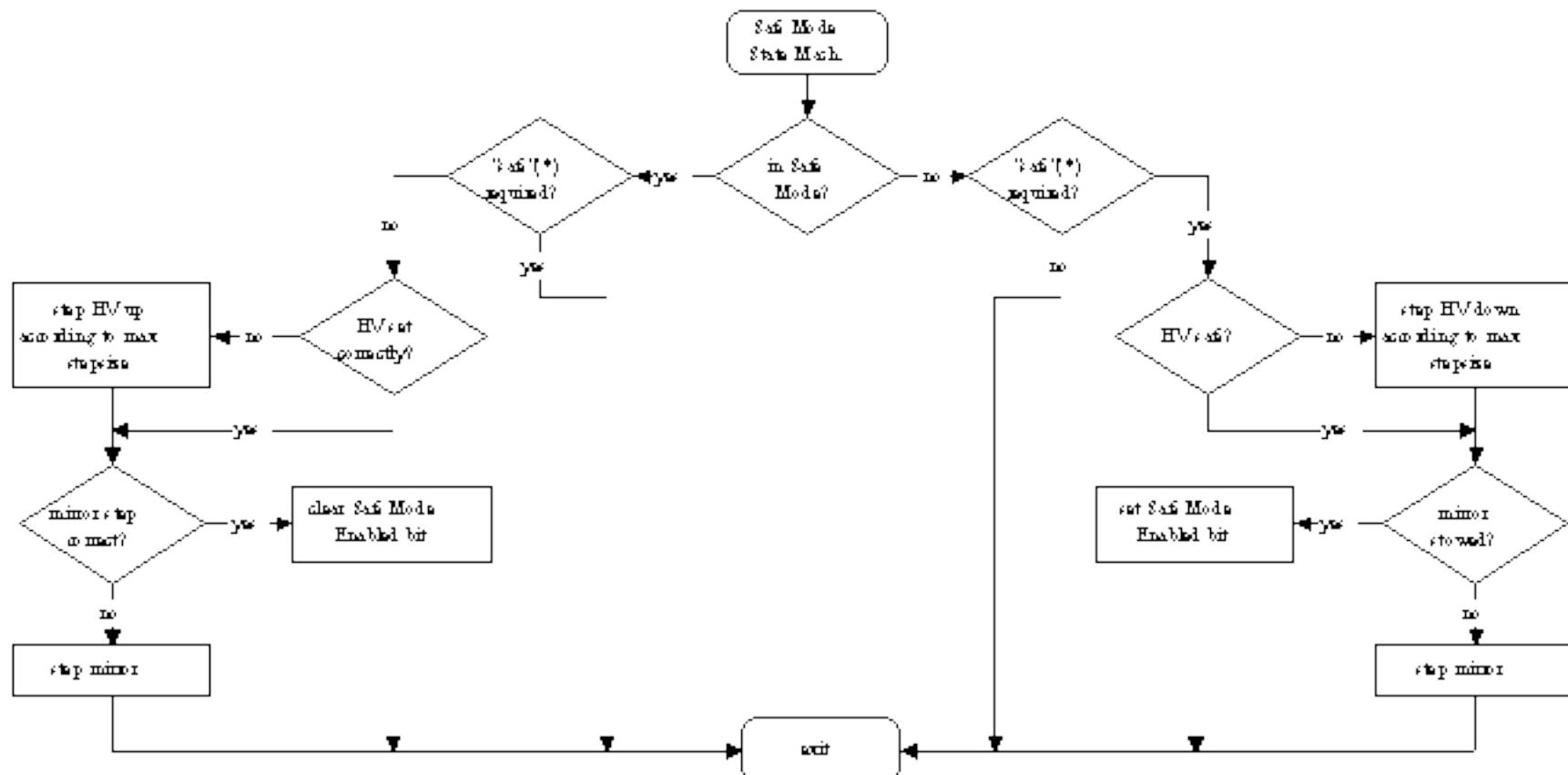
(*) safe required when any of (1) sun event, (2) yaw request
(3) power down request or (4) rad limit violation occurs.

Data Acquisition / Poll all 1553
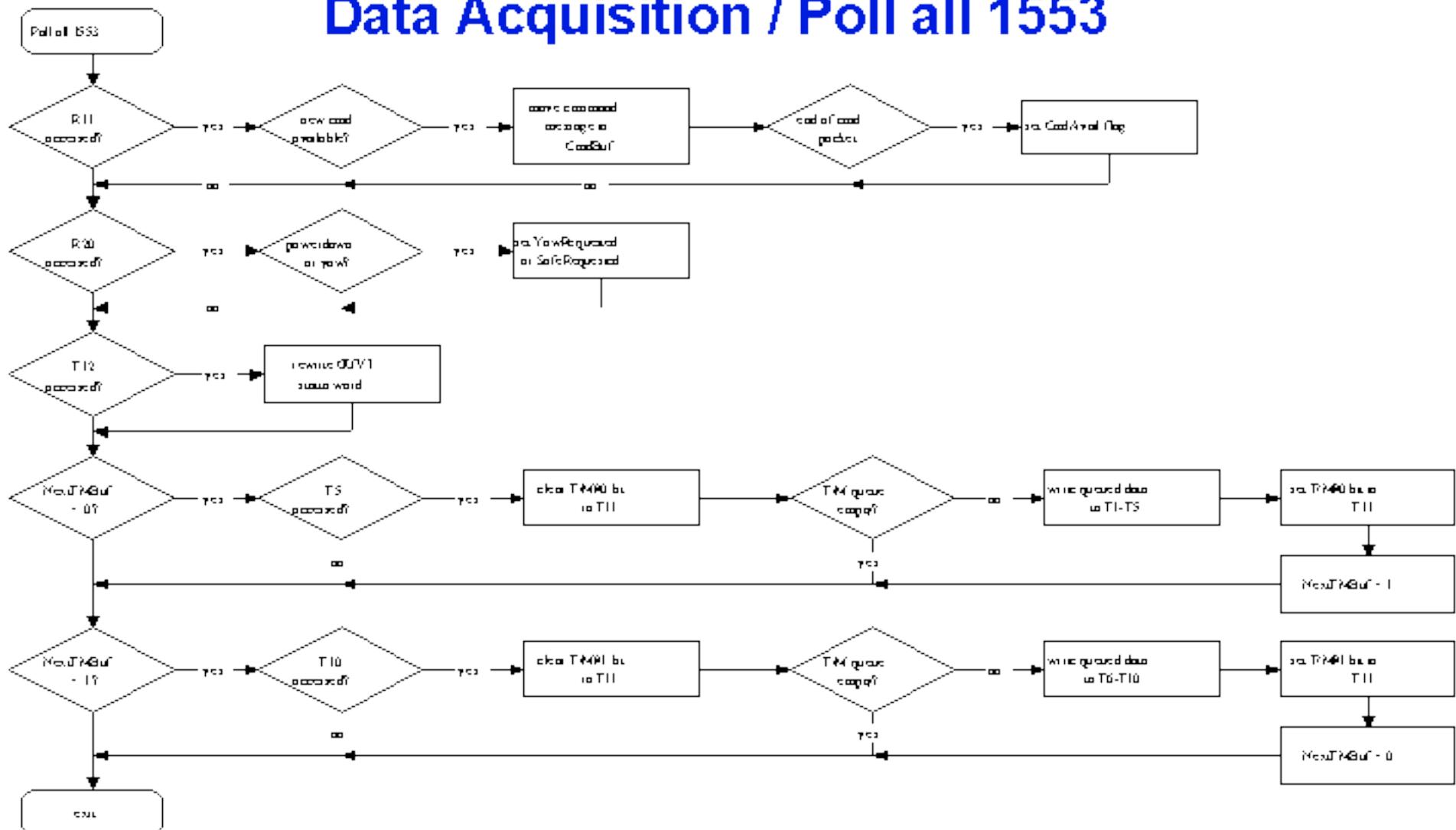
Poll-all-1553 Detail

- Interrupt Log List in 1553 chipset is not used

- "Block accessed" bits within each subaddress' control word are polled to determine when a subaddress has been accessed by the C & DH

- Not time critical, however must be controlled to complete within 1 msec

- T19 polled separately to minimize delay caused by background accesses to detector processor and scan mirror

Data Acquisition / Background Task
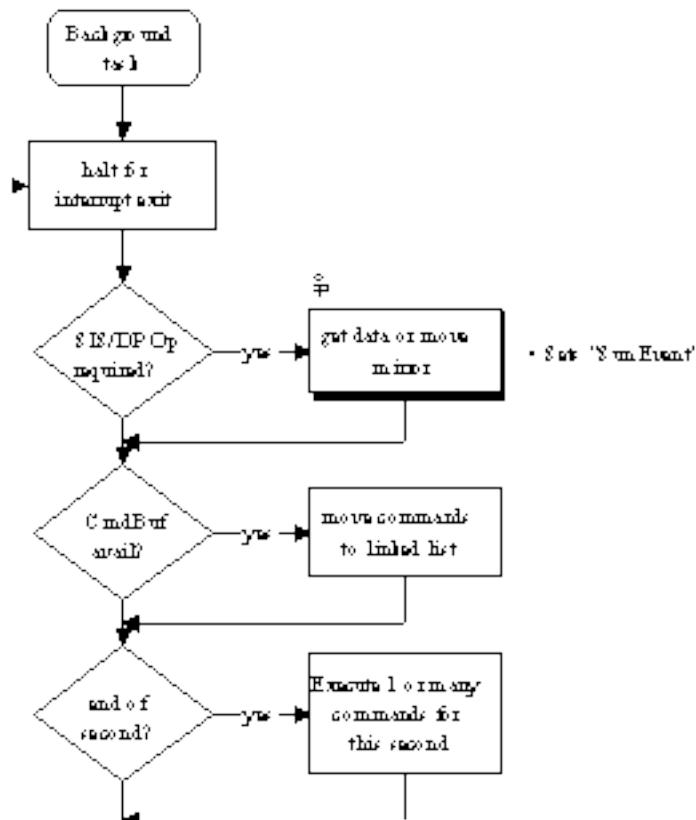
- detector processor (DP) data retrieval operations and scan mirror movement are highest priority

- Command linked list is "fixed up" whenever a new command packet is available

- Commands are executed on a 1 second boundary; many commands can be executed back-to-back

- Combined total execution time for linked list command insertion and command execution must be less than 17 msecs (smallest SIS/DP interval)

Data Acquistion / Get Data & Move Mirror

- Routine handles time critical accesses to detector processor for data collection and SIS for scan mirror movement

- Upon reading the detector processor input rate, the "Sun Event" flag is set if it appears that GUVI is looking at a bright object. Programmable options include threshold and number of suscessive sectors above threshold required to trigger "Sun Event"

- Mirror movement is synchronized to "step interval" which is decremented by 1 msec interrupt

- When data acquisition for a particular mode completes, BuildTM is called to create all packets

Telemetry Packet Creation

Instrument Mode	Packet Type				
	Memory Dump	Housekeeping	Imaging (57 each)	Spectrograph (10 each)	Test (2 each)
Maintenance	Follows HK packet if cmd requested dump	Packet created when C&DH accesses T19	N/A	N/A	N/A
Imaging	N/A	Follows generation of 57 imaging packets	Packets created after pixel step #191	N/A	N/A
Spectrograph	N/A	Follows generation of 10 spect. packets	N/A	Packets created after 3 second read interval	N/A
Test	N/A	Follows generation of 2 test packets	N/A	N/A	Packets created at 1 sec.boundary per 1ms ISR
Safe	N/A	Packet created on 1 sec boundary per 1ms ISR	N/A	N/A	N/A

Background Task - BuildTM

- **Inputs:**
  - Word PixelData [191 x 5 x 14]
  - Byte RateData [191 x 2 x 2] x 2 (double buffered)
  - Word EventData [137 x 3]

- **Outputs:**
  - CCSDS Packets into Telemetry Queue
  - If telemetry hardware (1553) idle, writes data to both hardware buffers (T1-T5 and T6-T10)

- **Time Constraints:**
  - Worst case preparation of Imaging Mode telemetry must complete during flyback period: < 3.1 seconds

- **Time Estimate:**
  - Imaging Mode telemetry preparation: 76 msecs (262 bytes per packet X 58 packets X 5 us per byte)

Memory Usage versus Allocation (TM Proc.)

- **RAM Requirement: 138.8K bytes**
    - Queues: 52.5K bytes
    - Cmd Linked List: 9K bytes
    - Data Bufs: 28.3K bytes
    - Lookup Tables: 32K bytes
    - T/M Proc. Code: 16K bytes
    - Variables: 1K bytes
- **EEPROM Req: 80K bytes**
    - Det. Proc. Code: 32K bytes
    - T/M Proc. Code: 16K bytes
    - Lookup Tables: 32K bytes
- **PROM Req: 16K bytes**
    - T/M Proc. Code: 16K bytes

- **RAM Available: 320K bytes**

- **EEPROM Available: 256K bytes**

- **PROM Available: 48K bytes**

Memory Allocation (S/C Interface)

Subaddress	Buffer	Size (bytes)	Addresses	Subaddress	Buffer	Size (bytes)	Addresses
Descriptor Table		512	0 - 1FF	T1	T1A	256	1800 - 18FF
R1	R1A	256	200 - 2FF		T1B	256	1D00 - 1DFF
	R1B	256	600 - 6FF	T2	T2A	256	1900 - 19FF
R2	R2A	256	300 - 3FF		T2B	256	1E00 - 1EFF
	R2B	256	700 - 7FF	T3	T3A	256	1A00 - 1AFF
R3	R3A	256	400 - 4FF		T3B	256	1F00 - 1FFF
	R3B	256	800 - 8FF	T4	T4A	256	1B00 - 1BFF
R4	R4A	256	500 - 5FF		T4B	256	2000 - 20FF
	R4B	256	900 - 9FF	T5	T5A	256	1C00 - 1CFF
R6	R6A	256	A00 - AFF		T5B	256	2100 - 21FF
	R6B	256	E00 - EFF	T6	T6A	256	2200 - 22FF
R7	R7A	256	B00 - BFF		T6B	256	2700 - 27FF
	R7B	256	F00 - FFF	T7	T7A	256	2300 - 23FF
R8	R8A	256	C00 - CFF		T7B	256	2800 - 28FF
	R8B	256	1000 - 10FF	T8	T8A	256	2400 - 24FF
R9	R9A	256	D00 - DFF		T8B	256	2900 - 29FF
	R9B	256	1100 - 11FF	T9	T9A	256	2500 - 25FF
R11	R11	256	1200 - 12FF		T9B	256	2A00 - 2AFF
R19	R19	256	1300 - 13FF	T10	T10A	256	2600 - 26FF
R20	R20	256	1400 - 14FF		T10B	256	2B00 - 2BFF
R30*	R30	256	1500 - 15FF	T11	T11	256	2C00 - 2CFF
				T12	T12	256	2D00 - 2DFF
TMC0	TMC0	256	1600 - 16FF	T19	T19	256	2E00 - 2EFF
TMC31	TMC31	256	1700 - 17FF	T30*	R30	256	1500 - 15FF
*R30=T30 to implement wrap-around					total	12288	(of 64K)

Software Development Tools

- **Software Development**
  - **Microsoft C, Assembler, and Codeview Debugger**

- **In-circuit Emulator**
  - **Applied Microsystems' CodeTAP-XA emulator**
  - **Paradigm CT/XA-Debug real-time debug kernel**

Configuration Control (CC)

- Prior to CC, documentation regarding software configuration will be maintained in development notebooks

- Telemetry Processor Software will undergo configuration control following instrument-level integration at APL

- Following activation of CC, software changes will require approval of the Principal Investigator (or his designee) and the GUVI System Engineer

- All versions released following activation of CC will be separately archived

Verification and Validation

- Routines of significant complexity will be single-stepped to validate functionality under all boundary conditions

- Test steps and results will be maintained in development notebooks

- Ground Support Equipment (GSE) simulators will be provided to simulate the detector processor, SIS electronics, FPE electronics, and spacecraft functions. The GSE will serve as the testbed for the telemetry processor software development