TIMED

Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

G&C Software Development

Presented by Shane Hutton

December 4, 1997

Excludes Stand-alone Simulations
(Performed by Analysts)

G&C Software

- **Flight Software**
  - **Attitude Interface Unit (AIU)**
    - » **Boot Program**
    - » **Application Program**
  - **Attitude Flight Computer (AFC)**
    - » **Boot Program**
    - » **Application Program**
- **TIMED Attitude System Test and Integration Equipment (TASTIE)**

TASTIE

- **TASTIE provides a test environment for testing G&C flight hardware and flight software. The test environment changes as flight software and hardware development progresses.**

- **TASTIE Features Include**

  PC based Host

  WATCOM C/C++ V11.0 compiler tools

  MKS Source Integrity Software Tools

  Motorola MVME-177 68060 Processor "RTOS" real-time component

  OS-9 Operating System

TASTIE Configurations

1) Partial testing of the AIU as a stand-alone system.

2) Partial testing of the AFC as a stand-alone system.

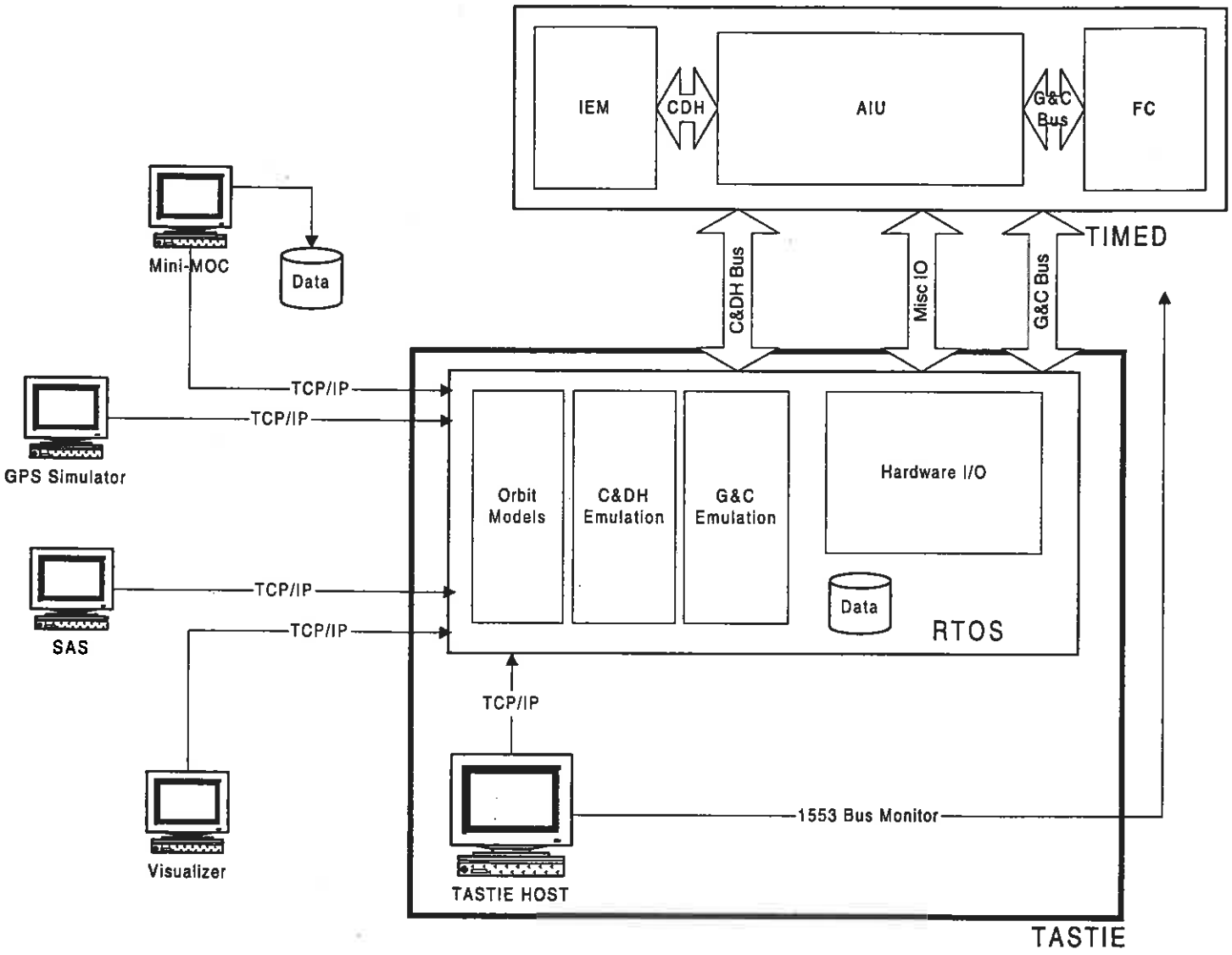
3) Hardware tests of AIU and sensors and actuators.

4) Closed-loop simulations

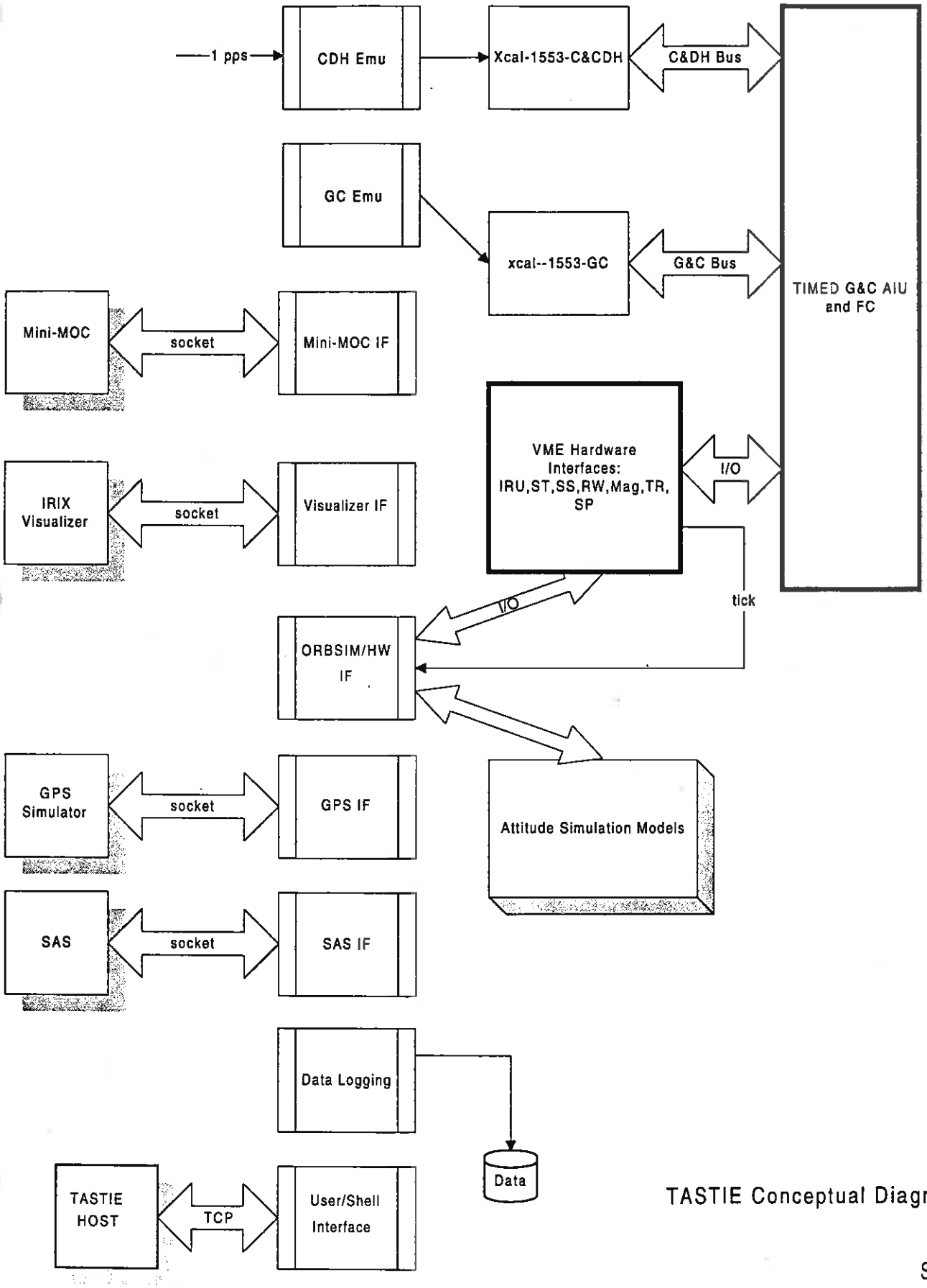
5) Spacecraft integration

6) TIMED OPerations Simulation system (TOPS)

TASTIE Conceptual Diagrams



Tastie Conceptual Diagram



TASTIE Conceptual Diagram

AIU Stand-alone Tests

- **TASTIE simulates the C&DH interface to the AIU**
- **TASTIE sends**
  - **1) Command Messages**
  - **2) CUC Time Message**
  - **3) 1553 bus mode codes**
  - **4) Data wrap-around test data**
  - **5) the GNS Message**
  - **6) LVSS discrete values**
- **TASTIE pulls**
  - **1) Normal Telemetry Messages**
  - **2) Housekeeping Messages**
  - **3) Attitude Diagnostic Messages**
  - **4) Spacecraft Attitude/Pos. Msg**
  - **5) 1553 bus mode code response**
  - **6) Data wrap-around test data**
- **TASTIE reads the AIU discretes**

AFC Stand-alone Tests

- **TASTIE simulates part of the AIU interface to the AFC**
- **TASTIE sends**
  - **1) Command Messages**
  - **2) AIU-to-AFC high-rate Message**
  - **3) 1553 bus mode code**
  - **4) AIU-to-AFC low-rate Message**
- **TASTIE pulls**
  - **1) Normal Telemetry Messages**
  - **2) AFC-to-AIU high-rate Message**
  - **3) Attitude Diagnostic Messages**
  - **4) AFC-to-AIU low-rate Message**
  - **5) 1553 bus mode code**

AIU Hardware Tests

- 1) Digital inputs, via A/Ds, for the wheel speeds, sun sensors, solar arrays, and magnetometers. The data is logged to disk.
- 2) wheel torques logged to disk.
- 3) torque rods - turn on and off primary and secondary relays and set polarity. Simulated loads are provided by TASTIE hardware.
- 4) On G&C 1553 bus, IRU and Star Tracker canned messages.
- 5) S/C (C&DH) 1553 bus simulated traffic.

G&C Subsystem Tests

- **IRU - rotate box to check all 3 axes. Log data**
- **Star Trackers - point light sources provided.**
- **Sun Sensors - light sources provided. Control each individual light.**
- **Torque rods - turn on and off primary and secondary relays and set polarity.**
- **Magnetometers - measure mag field from rods**
- **Wheel torques - torque and speed values logged.**
- **Solar array position control - drive real drive and read back position**
- **Solar array current - SAS used**

Closed-loop Simulations

1) C&DH Simulation

2) Truth Models

   a) S/C orbit state b) S/C attitude state

   c) Earth's magnetic field d) Solar position

   e) External torque

3) Models Representing Hardware

   a) gyros b) star trackers c) solar arrays

   d) wheels e) torque rods f) magnetometers

   g) GNS h) sun sensors

4) Tools - real-time telemetry, visualizer, plot & report packages

Spacecraft Integration

- **Hardware Checkout**
  - **1) IRUs (earth's rotation) 2) Star trackers (point light sources)**
  - **3) Sun sensors (lights) 4) Magnetometers (rods)**
  - **5) rods (compass confirm polarity)**
  - **6) Solar array position (dial indicator on drive)**
  - **7) Solar array current (SAS)**
  - **8) Wheels (command torques; provide torques and speeds in TLM)**

Closed-loop Simulations

- **1) Real wheels will be running**
- **2) RT on G&C 1553 bus: provide sensor data; receive actuator data**
- **3) GPS simulator used and GNS used**

TASTIE Features for TOPS

1) Support closed-loop simulations:

a) using real IEM

b) using real G&C processors

c) without real G&C sensors or actuators

d) with and without GPS simulator

2) TASTIE will not simulate:

a) C&DH interface

b) AIU interface

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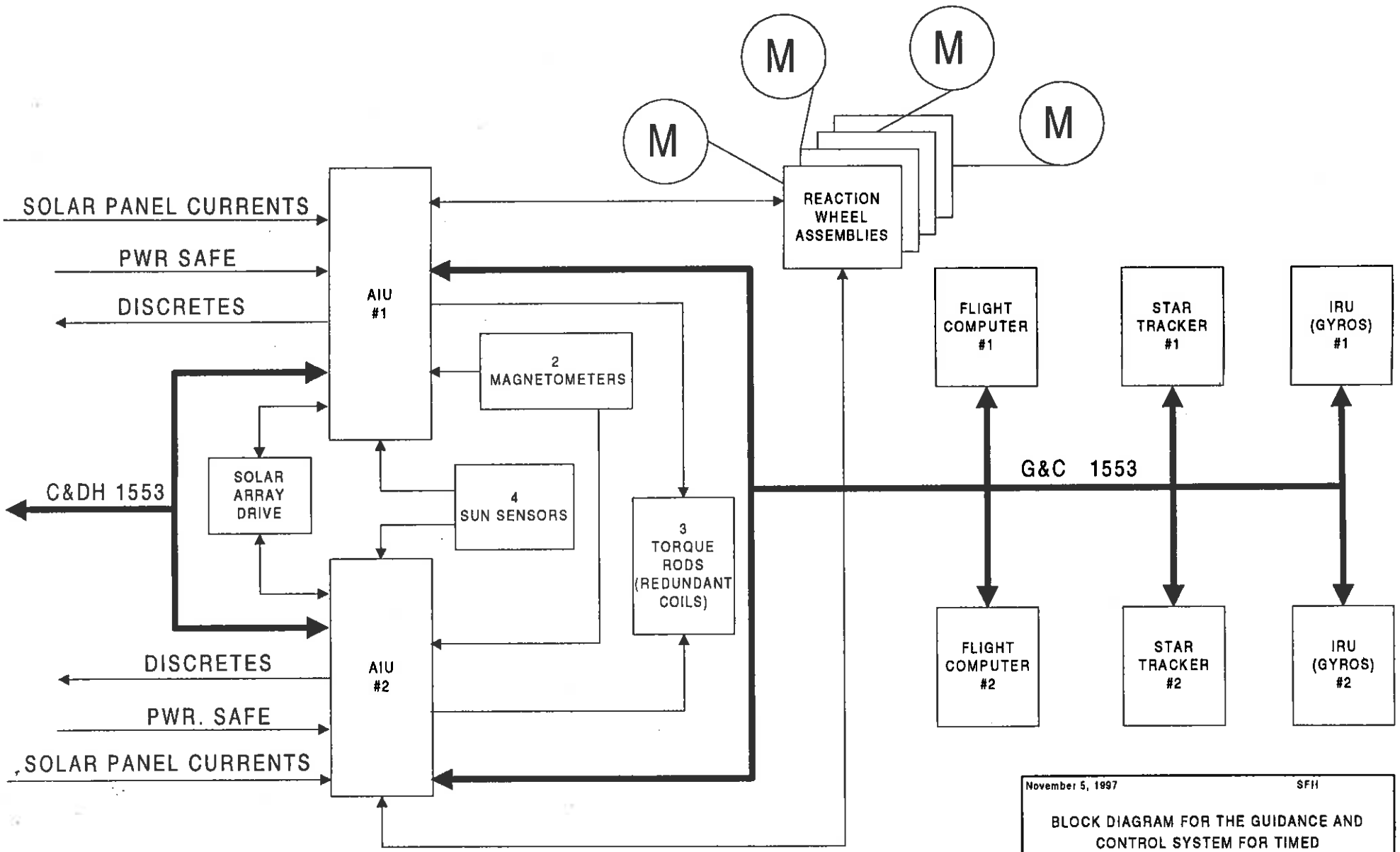
TASTIE Documentation/Review

- **TASTIE Software Requirements Document** **(8/22/97)**
- **TASTIE Functional Configurations Document** **(8/22/97)**
- **TASTIE Design and Implementation Document**
- **TASTIE Hardware Interfaces Document** **(9/17/97)**
- **TASTIE VISIO Drawings**
- **G&C Software Requirements (describes models)** **(10/1/97)**
- **Requirements Review 8/27/97**
- **Functional Configurations Review 8/27/97**

TASTIE Tests

- **Mini-MOC / TASTIE Interface**
  - **Commands**
  - **Telemetry**
- **TASTIE / AIU Interface**
  - **1553 Bus**
  - **Discretes 11/30/97?**
  - **Waiting for TASTIE hardware to test A/D & D/A interfaces**
- **TASTIE Host / RTOS Commanding**



November 5, 1997 SFH

BLOCK DIAGRAM FOR THE GUIDANCE AND CONTROL SYSTEM FOR TIMED

AIU

- **Redundant Processors - 1 is a Backup in Case of Failure**
- **RTX2010 - NEAR Heritage**
- **Interfaces - excluding G&C 1553B Bus**
  - **1) RT on S/C 1553B Bus**
  - **2) Solar Arrays**
  - **3) Torque Rods**
  - **4) Wheels**
  - **5) Magnetometers**
  - **6) Sun Sensors**
  - **7) Discretes**
- **G&C 1553B Bus**
  - **1) BC 2) FCs 3) ASTs 4) IRUs 5) Backup AIU**

AIU Boot Program

- **Requirements Document (8/4/97); Design Document (8/4/97)**
- **Requirements and Design Review 8/11/97**
- **Software Written; Test Plan and Scripts Written;**
- **MOC Command and Telemetry Database Populated**
- **Commands Supported**

1) Memory Load	**2) Clear Memory Load Bit-map**
3) Memory Dump	**4) Abort Memory Dump**
5) CRC all EEPROM Cells	**6) Calc CRC on one EEPROM Cell**
7) No Operation	**8) Reboot**
9) Read Memory Word	**10) Jump to Application**
11) Jump to Address	**12) Stay in Boot Program**

AIU Boot Telemetry Format

- Header
- Program Version Number
- Test Results
- Program Load Results
- System Block Parameters
- Command Processing
- Contents of Hardware Registers
- A/D inputs

The AIU "Boot Format" Packet has the following format:

Words 0-2: Standard Primary Header
Words 3-5: Standard Secondary Header

Word 6: PROM Version Number (the check value burned in PROM)
Word 7: PROM Checksum Result, should be 0x0000 if all is well

Word 8: Number of RAM Bank #0 failures
Word 9: Address of last RAM Bank #0 failure, if any

Word 10: Number of RAM Bank #1 failures
Word 11: Address of last RAM Bank #1 failure, if any

Word 12: TLM Anomaly Counter (cnt of unexpected 1553 TLM pulls)
Word 13: CMD Anomaly Counter (cnt of unexpected 1553 CMD recvs)

Word 14: App ID Loaded (from BCR), 0x0000 if none
Word 15: Expected Number of Cells (from BCR)
Word 16: Num Cells Loaded Successfully
Word 17: Num Cells That Failed CRC
Word 18: Last cell (0-127) that failed CRC, if any

Word 19: Command Counter (total commands (not cmd_pkts) seen)
Word 20: Command Reject (num of above that we rejected)
Word 21: Queue Index (0-9), next slot to fill
Words 22-31: Command History Queue, indexed by above.
Holds last 10 Command-ID's processed; msb shall be set
if the command was rejected, else msb is left zero.

Words 32-42: Offset words 0 through 0xA of the boot control record (BCR). The BCR starts at MAT word 128. The BCR values are read at STARTUP_TIME. [Any changes made via a mem load command will NOT be reflected here]. Note a value of 0xFFFF means the word could not be read (ie, no vote agreement).

Word 43: Magnetometer Channel 4 (X)
Word 44: Magnetometer Channel 5 (Y)
Word 45: Magnetometer Channel 6 (Z)
Word 46: Magnetometer Channel 7 (R)

Words 47-54: Offset words 0xF through 0x16 of the BCR.

Words 55-59: Available. Currently contains Offset words 0x17 through 0x1B of the BCR.

Words 60-61: Offset words 0x1C through 0x1D of the BCR.

Words 62-63: Available. Currently contains Offset words 0x1E through 0x1F of the BCR.

Note: BCR word offsets 0xB-0xE contain the LC_APP_LENGTH for program IDs 11-14 (B-E), and word offsets 0x17-0x1A contain the LC_ENTRY_ADDRESS for program IDs 11-14. Word offsets 0x1B, 0x1E, and 0x1F are spare.

Word 64-79: Memory Load Bit-Map, for up to 256 block-ids. See "Clear Memory Load Bit-Map", "Memory Load", and "CRC All EEPROM Cells".

Word 80: RPA_pg,
Word 81: RPA_address,
Word 82: RPA_Value. The "Read Physical Memory Address" Command allows for the 1Hz reading of a single memory location. That location and it's value are reported here. Note that if the spec'd address is for the first 16K of page 0 then the read will be from PROM, not RAM.

Word 83: CRC Cell Number,
Word 84: CRC Value. The "Calculate Cell CRC" command causes the boot to compute the CRC on a specified EEPROM cell. The cell's number and it's computed CRC result (should be 0x0000) is reported here.

[The following are direct reads of the HW registers]

Word 85: Processor Status Register -- PSR Bit Assignments:
msb bit 15: SEU 1=single event upset in FPGA register
bit 14: TRT2 0=have control of torq rod 2, 1=other AIU
bit 13: TRT1 0=have control of torq rod 1, 1=other AIU
bit 12: WHL4 0=have control of wheel 4, 1=other AIU
bit 11: WHL3 0=have control of wheel 3, 1=other AIU
bit 10: WHL2 0=have control of wheel 2, 1=other AIU
bit 9: WHL1 0=have control of wheel 1, 1=other AIU
bit 8: TIN Test_In input discrete
bit 7: DSO3 Discrete Output #3
bit 6: DSO2 Discrete Output #2
bit 5: DSO1 Discrete Output #1
bit 4: DSO0 Discrete Output #0
bit 3: DSI1B Discrete Input #1 - Side B
bit 2: DSI0B Discrete Input #0 - Side B
bit 1: DSI1A Discrete Input #1 - Side A
lsb bit 0: DSI0A Discrete Input #0 - Side A

Word 86: Processor Configuration Register -- PCR Bit Assignments:
msb bit 15: EWRD 0=EEPROM Writes Enabled, 1=Disabled
bit 14: WDBOOT 0=Reset Caused By WD, 1=Power-up
bit 13: SWUNLK 0=RAM Swap Locked, 1=Unlocked
bit 12: RAMSW 0=RAM 1/0 Swapped, 1=Normal
bit 11: WDUNLK 0=WatchDog Locked, 1=Unlocked
bit 10: WDDIS 0=WatchDog Enabled, 1=Disabled
bit 9: UIMSK 0=UART In Interrupt Enabled, 1=Disabled
bit 8: UOMSK 0=UART Out Interrupt Enabled, 1=Disabled
bit 7: ANGMSK 0=Analog Interrupt Enabled, 1=Disabled
bit 6: DIGMSK 0=Digital Interrupt Enabled, 1=Disabled
bit 5: MERMSK 0=Machine Error Int Enabled, 1=Disabled
bit 4: ANGINT Analog Interrupt
bit 3: DIGINT Digital Interrupt
bit 2: CODINT Code Interrupt
bit 1: EWRINT EE Write Interrupt
lsb bit 0: TOINT Time-Out Interrupt

[the following words are direct reads from the corresponding A2D Converter]
Word 87: A-to-D Converter error counter. Num times a2d failed
Word 88: Wheel 0 Speed
Word 89: Wheel 1 Speed
Word 90: Wheel 2 Speed
Word 91: Wheel 3 Speed

Word 92: Solar Panel 0 Current
Word 93: Solar Panel 1 Current
Word 94: Solar Panel 0 Position
Word 95: Solar Panel 1 Position

Word 96: Magnetometer Channel 0 (X)
Word 97: Magnetometer Channel 1 (Y)
Word 98: Magnetometer Channel 2 (Z)
Word 99: Magnetometer Channel 3 (R)

Word 100: Sun Sensor Channel 0
Word 101: Sun Sensor Channel 1
Word 102: Sun Sensor Channel 2
Word 103: Sun Sensor Channel 3
Word 104: Sun Sensor Channel 4
Word 105: Sun Sensor Channel 5
Word 106: Sun Sensor Channel 6
Word 107: Sun Sensor Channel 7

Word 108: Torq Rod 0-Primary
Word 109: Torq Rod 0-Secondary
Word 110: Torq Rod 1-Primary
Word 111: Torq Rod 1-Secondary
Word 112: Torq Rod 2-Primary
Word 113: Torq Rod 2-Secondary

Word 114: Torq Rod Enable Relay, Side 0
Word 115: Torq Rod Enable Relay, Side 1

Word 116: OTHER AIU's +15v Power
Word 117: OTHER AIU's -15v Power
Word 118: OTHER AIU's +5v Power

Word 119: Cmd Packets Total
Word 120: Cmd Packets Rejected (due to wrong dest_id)

Word 121: Sun Sensor Channel 8
Word 122: Sun Sensor Channel 9
Word 123: Sun Sensor Channel 10
Word 124: Sun Sensor Channel 11
Word 125: Sun Sensor Channel 12
Word 126: Sun Sensor Channel 13
Word 127: Sun Sensor Channel 14
Word 128: Sun Sensor Channel 15

Word 129: Reboot Count

Word 130: XOR Checksum of the previous 130 words

AFC Boot Program

- **Requirements Document 10/24/97; Requirements Review 10/30/97**
- **Mongoose V Common Boot Features Design Document; Review Sept-Oct 97**
- **Test Plan In Progress; Software Being Developed; Console Boot Done;**
- **Commands Supported**
  - **1) 13 Flash Memory Management Commands**
  - **2) Bit-map Clear (for loads, cell checksums within segments, Flash segment/RAM compare)**
  - **3) Memory Dump**
  - **4) Abort Memory Dump**
  - **5) Memory Read**
  - **6) Memory Write**
  - **7) RAM Memory Load**
  - **8) Memory Scrub Enable/Disable**
  - **9) No Operation**
  - **10) Soft Reset**
  - **11) Jump to Application**
  - **12) Jump to Address**
  - **13) Stay in Boot Program**

AFC Boot Telemetry Format

- Header
- Program Version Number
- Boot Type & Cause
- Flash Memory Segment Status
- System Boot Block Parameters
- Test Results
- Program Load Results
- Critical RAM location
- Command Processing
- Contents of Hardware Registers
- Memory Scrub Status

4 Telemetry:

A telemetry packet consists of 262 bytes, 12 of which contain CCSDS packet header information. One of the telemetry packets provided by the AFC boot program is the "normal boot telemetry" packet. The format of the "normal boot telemetry" packet is as follows:

Bytes	0 - 5:	Standard Primary Header (lower 7 bits of App ID are zero)
Bytes	6 - 11:	Standard Secondary Header
Bytes	12 - 15:	Boot Program ID (Flash program checksum)
Bytes	16 - 19:	Flash Boot Program Checksum Test results (pass/fail).
Byte	20 - 21:	Boot Type (hard or soft) and 5 Actel bits (Address line 28 zero, PON reset, watchdog timer reset, EDAC double-bit error, Master reset bit)

The information in bytes 22-43, 50-53, 60-69, 72-79, 94-103, and 208-215 is from the "system boot block" cell.

Byte	22 - 23:	Tests Selected (bits 1 through 4, and one bit identifying whether there is a valid value)
Byte	24 - 25:	Action to take based on test results (bits 1, 2, 3, 4, 12, and 13,)
Byte	26 - 27:	Decode of Actel Boot Cause Register (bits 1, 2, 3, 4, and 12)
Bytes	28 - 31:	Starting address of Hard Reset RAM to test
Bytes	32 - 35:	Ending address of Hard Reset RAM to test
Bytes	36 - 39:	Starting address of Soft Reset RAM to test
Bytes	40 - 43:	Ending address of Soft Reset RAM to test
Bytes	43 - 47:	Address of last RAM test failure - 0 if none
Byte	48:	Number of RAM test failures
Byte	49:	Type of Last RAM Test that failed (identifies address test or specific data pattern)
Byte	50:	Application Program ID loaded, 0 if none
Byte	51:	What to do with program
Bytes	52 - 53:	Expected number of cells to load
Bytes	54 - 55:	Number of Cells successfully loaded
Bytes	56 - 57:	Number of Cells that failed checksum
Byte	58:	The segment number of the last cell that failed checksum, if any
Byte	59:	Last cell that failed checksum, if any
Bytes	60 - 67:	Flash Memory Segments Status - have a code representing the value of the header word(s) to reduce telemetry locations used. For example: 4 bits per segment: segment 0 contains boot program 0 = Segment not programmed 1 = Started programming Program Segment; 2 = Finished programming Program Segment; 3 = Parameter Block Segment - started programming 4 = Parameter Block Segment - finished programming 5 = Application Specific Segment - started programming 6 = Application Specific Segment - finished programming 7 = Segment not valid 8 = Boot segment 9 = erase in progress 10 -15 reserved for Second word of Header identifying segment type

Bytes 68 - 69: Address offset of system boot block parameter dumping (dumping the same location in both system boot blocks reporting
Bytes 70 - 71: Reserved = 0
Bytes 72 - 75: Contents of parameter in first system boot block
Bytes 76 - 79: Contents of parameter in second system boot block

Bytes 80 - 83: Location of last single-bit error detected
Bytes 84 - 87: Location of last single-bit error detected in flash memory
Bytes 88 - 91: Location of last single-bit error not corrected
Byte 92: Count of single-bit errors detected
Byte 93: Count of single-bit errors not corrected

Bytes 94 - 95: Size needed of critical RAM area
Bytes 96 - 99: Starting address for critical RAM search
Bytes 100 - 103: Ending address for critical RAM search
Bytes 104 - 107: Starting address of Critical RAM area selected

Byte 108: Total commands processed
Byte 109: Total number of commands rejected
Byte 110 - 111: Index into queue of last four commands processed identifying most recent command
Bytes 112 - 143: Last four commands processed - first two words of each command
Bytes 144 - 147: Status of last four commands - accepted/rejection code
Bytes 148 - 155: Last command rejected - first two words of the command
Bytes 156 - 159: CUC Time last command was rejected
Bytes 160 - 161: Reason command was rejected

Byte 162: Status (last action) of RAM Buffer for flash
0 = no action taken with buffer (initial state)
1 = clearing RAM buffer bits to 1's (initializing)
2 = cleared RAM buffer: all words = 0xFFFFFFFF
4 = transferring data from flash to RAM buffer
8 = completed transfer from flash to RAM
16 = transferring data from RAM buffer to flash
32 = completed transfer from RAM to flash
64 = "flash RAM buffer load" command processed
Byte 163: Reserved = 0

Bytes 164 - 179: Memory Load/Checksum Check Bit Map - 128 load IDs/cells

Byte 180: Count of errors writing to flash memory
Byte 181: Count of errors not corrected with rewrite

Bytes 182 - 183: checksum cell Number
Bytes 184 - 187: checksum value

Bytes 188 - 191: First Physical address value is read from
Bytes 192 - 195: Contents of physical address selected
Bytes 196 - 199: Second Physical address value is read from
Bytes 200 - 203: Contents of physical address selected

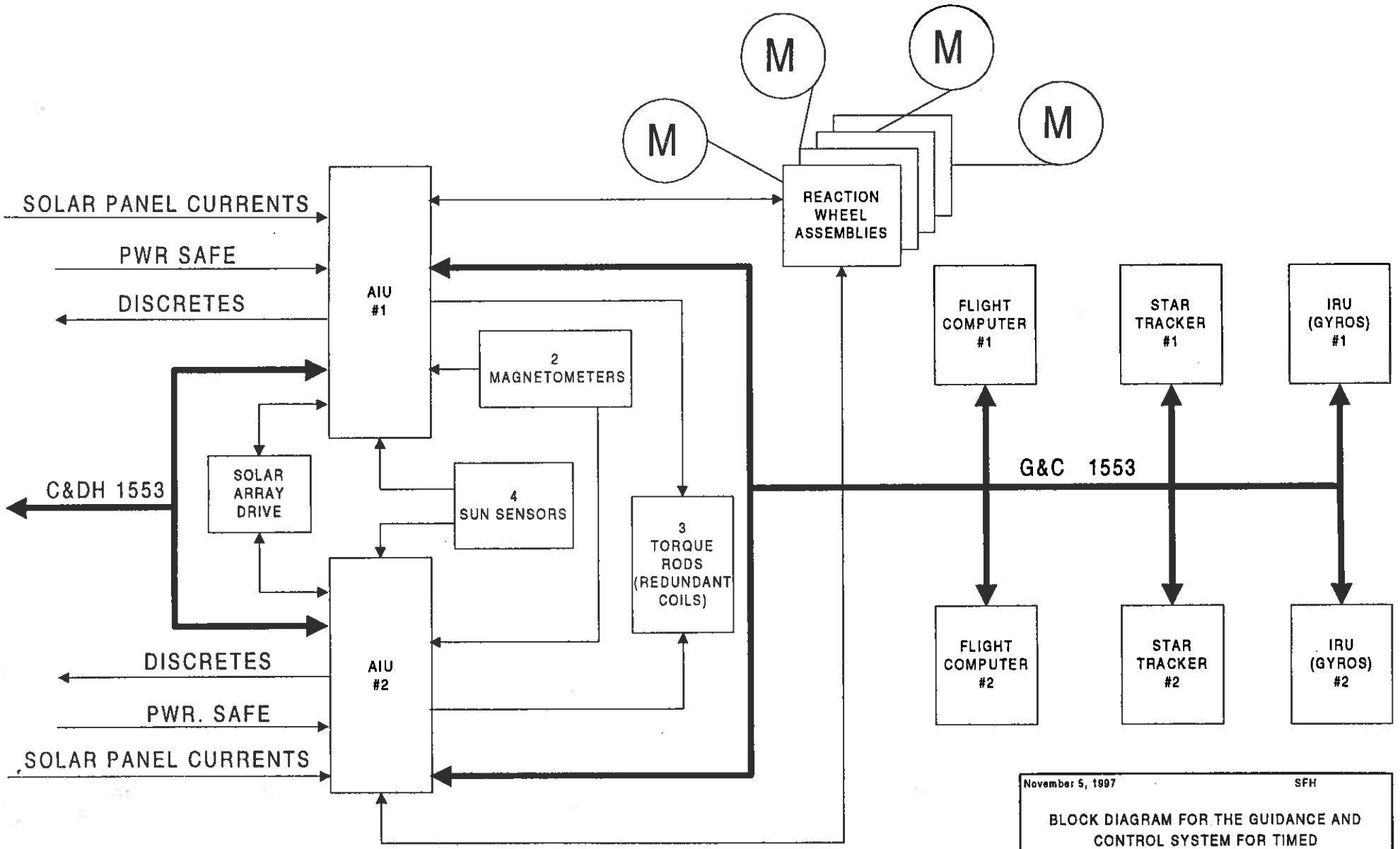
Byte 204: Memory scrubbing - Number of times scrubbed memory range selected
Byte 205: Reserved = 0
Bytes 206 - 207: Last block scrubbed
Bytes 208 - 211: Starting Address of memory to scrub
Bytes 212 - 215: Ending Address of memory to scrub

Internal registers in Mongoose V
Bytes 216 - 219: Exception Status Register
Bytes 220 - 223: Exception Cause Register
Bytes 224 - 227: Exception Program Counter

Bytes 228 - 235: Reserved for other common boot telemetry

Subsystem specific telemetry - AFC specific telemetry
Bytes 236 - 255: Reserved for other subsystem specific telemetry
Byte 256: Count of command message gaps
Byte 257: Telemetry Packet Pull Anomaly Counter
Bytes 258 - 259: Reboot Counter

Bytes 260 - 261: 16-bit XOR checksum



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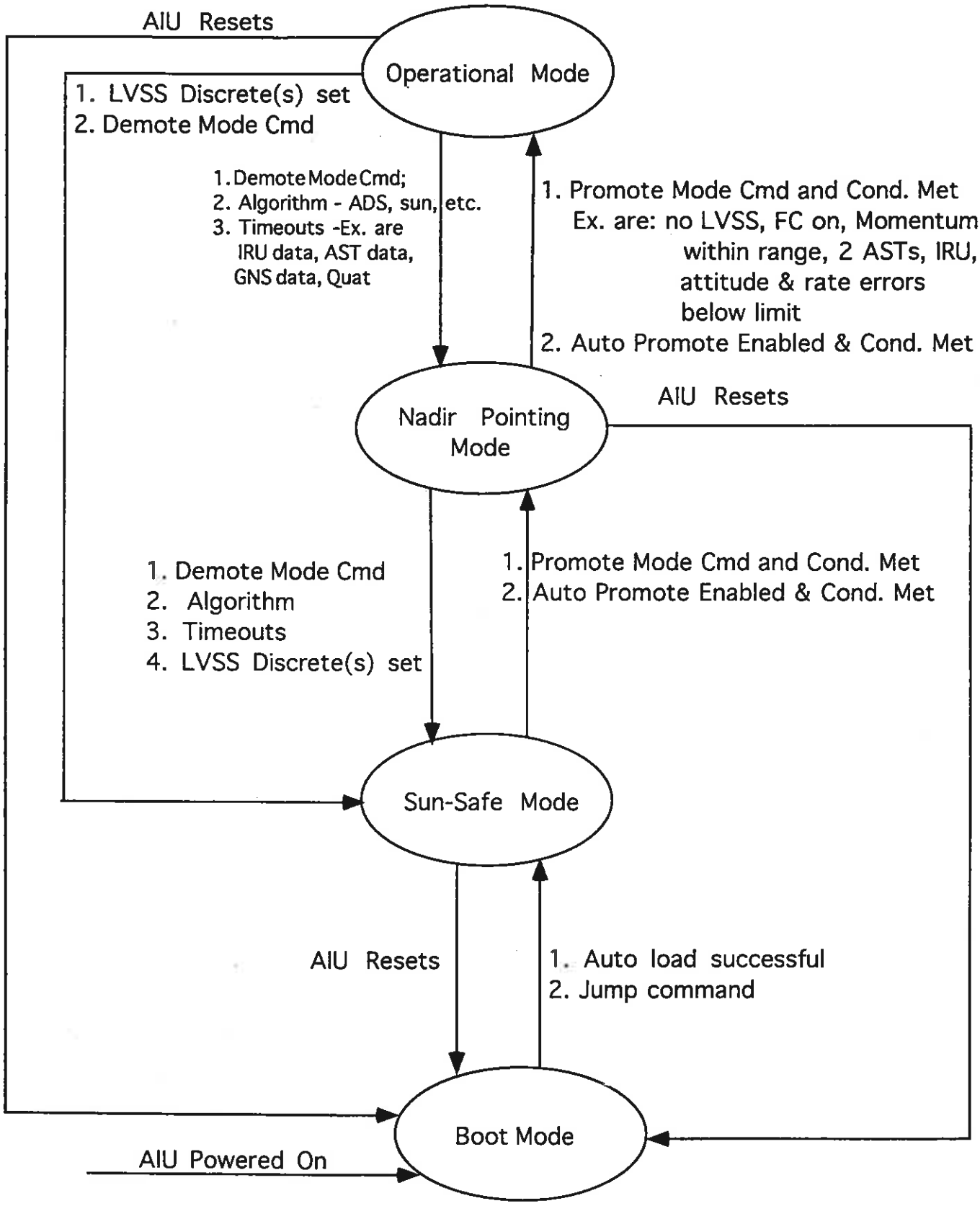
BLOCK DIAGRAM FOR THE GUIDANCE AND CONTROL SYSTEM FOR TIMED

TIMED Attitude Modes



Note: Mode changes are evaluated once a second

G&C Modes

1. **Operational Mode -**
   The S/C +Z axis will be pointed in the nadir direction.
   The S/C +X axis lies in the orbit plane and points either in the ram or wake direction.
   The S/C +Y axis will be normal to the orbit plane on the opposite side of the orbit plane from the sun (cold side).
   Attitude Control: 0.5 degrees, each axis, 3 sigma
   Attitude Knowledge +- 0.03 degrees, each axis, inertial, 3 sigma
   Jitter and stability per graph

2. **Nadir Pointing Mode -**
   Same pointing direction as operational mode, but attitude control and knowledge, and S/C jitter and stability are relaxed.

3. **Sun-safe Mode -**
   Stabilizes the S/C attitude.
   Points the S/C along the direction of an uploadable unit vector towards the sun.

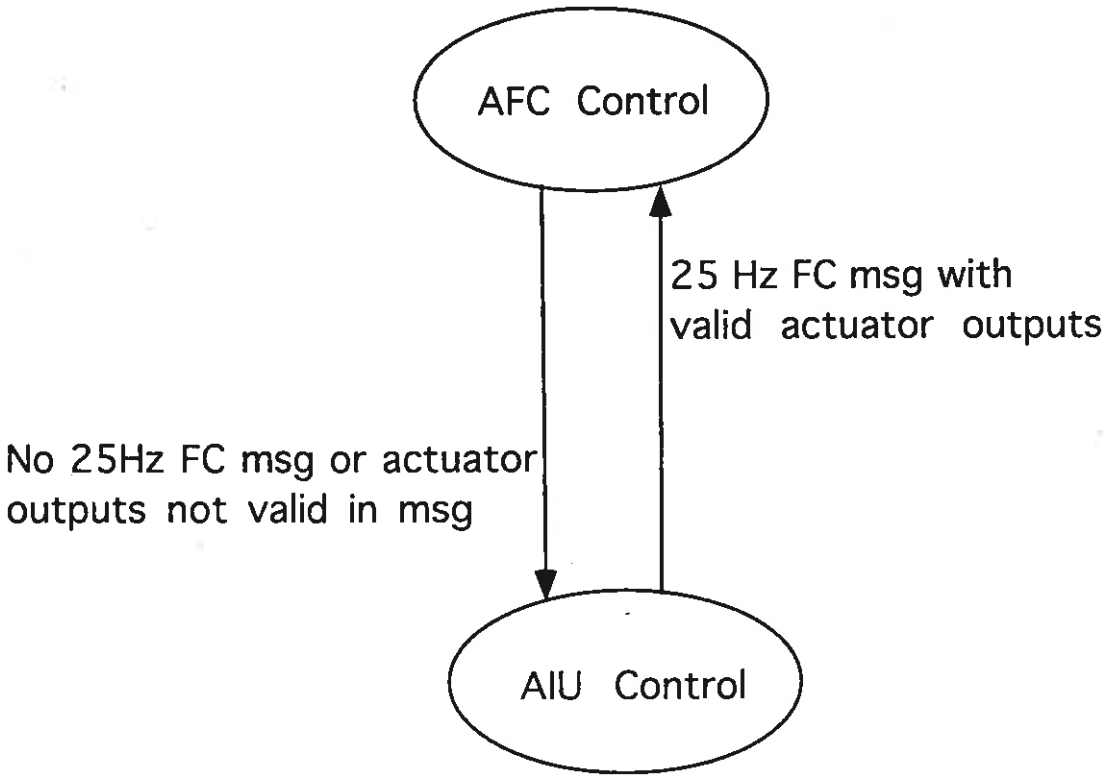
4. **Boot Mode**
   A separate program, in PROM, executes that tests RAM, zeroes the wheel torques, loads the application program and transfers control to the application program. If there is a problem with the load process, commands are supported to identify and correct/bypass the problem.

G&C States

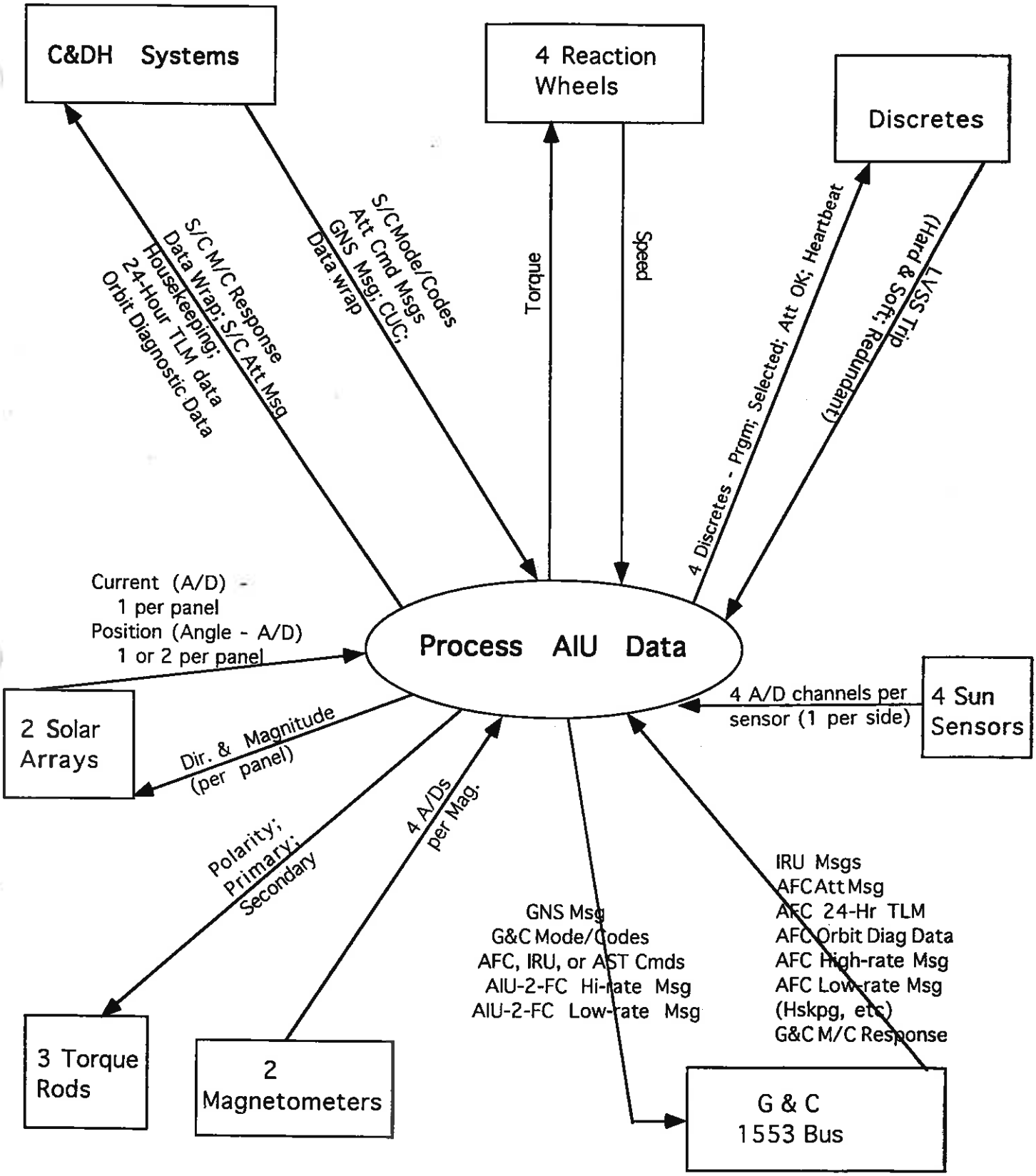
1. **AFC (Attitude Flight Computer) Control State**
   The AFC is a Mongoose V and has the complex G&C algorithms
   If the AFC is providing valid actuator outputs, the desire is to use AFC data.

2. **AIU (Attitude Interface Unit) Control State**
   The AIU is a smart interface with safe mode algorithms
   It can propagate the attitude for short periods in operational and nadir pointing modes.

TIMED Attitude States Within Application Program Modes (operational, nadir pointing, sun-safe)



Note: For sun-safe mode, if the G&C system is in AIU control state for longer than a time limit, then a command to re-enable automatic transitioning to AFC control must be sent or a resume FC override command must be sent before state transitioning can resume.



TIMED AIU Context Diagram

G&C Subsystem PDR Overview

- Terminology
- C&DH to AIU Messages (overview)
- AIU to C&DH Messages (overview)
- Messages Allocated to Subaddresses
- Messages Allocated to Minor Frames
- Formation of S/C Status Message
- S/C Attitude Msg
- GNS Msg
- Vector Word Msg
- Examples of AIU Command Msgs
- Examples of AIU Data Structures
- Examples of FC Command Msgs
- Examples of FC Data Structures
- Housekeeping Msg
- G&C Normal Telemetry
- G&C Diagnostic Telemetry
- Time Msg (CUC)
- Interrupts
- Discretes
- Recorded Data
- Telemetry Downlink

C&DH to AIU Messages

- GNS Msg
- Command Msgs
- CUC Time Msg
- Data Wrap-around Test
- 1553 Bus Mode Codes
  - Sync with Data Word (Time Code Sync)

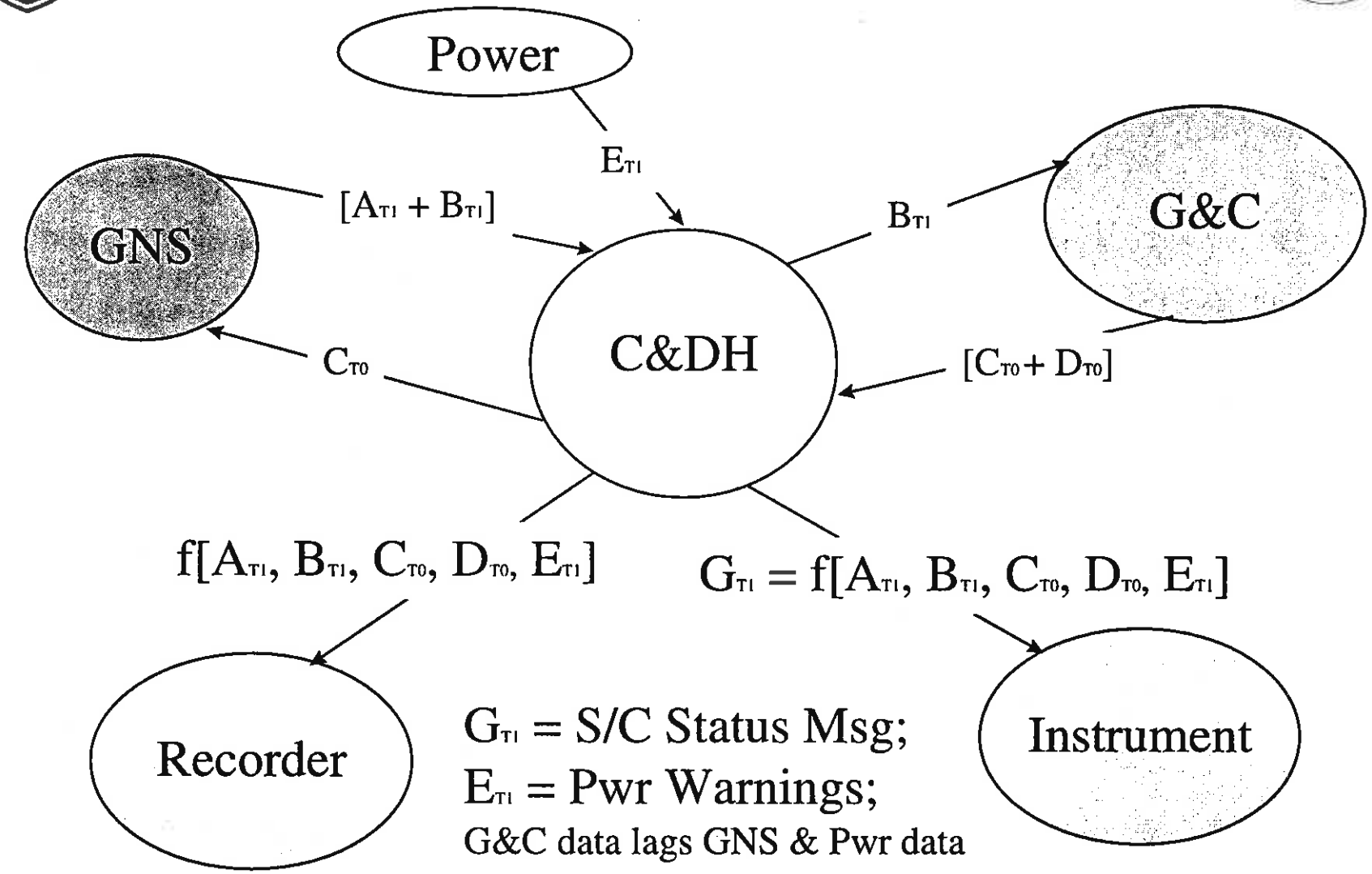
AIU to C&DH Messages

- Normal Telemetry Msgs
- Housekeeping Msg
- S/C Attitude Msg
- Attitude Diagnostic Msgs
- Data Wrap-around Msg
- 1553 Bus Mode Codes (Transmit vector word, etc.)

1553 Bus Mode Codes Supported

Function	Mode Code	T/R	Data Word
Transmit status word	00010	T	No
Initiate self test	00011	T	No
Transmitter shutdown	00100	T	No
Override transmitter shutdown	00101	T	No
Inhibit terminal flag bit	00110	T	No
Override inhibit terminal flag bit	00111	T	No
Reset remote terminal	01000	T	No
Transmit vector word	10000	T	Yes
Synchronize with data word	10001	R	Yes
Transmit last command	10010	T	Yes
Transmit BIT word	10011	T	Yes

Formation of S/C Status Msg



G_{T1} = S/C Status Msg;
E_{T1} = Pwr Warnings;
G&C data lags GNS & Pwr data

GNS → G&C
Pos, vel, sun unit vector

S/C Attitude Message

- Warnings/Data Validity
- Position - Lat., Long., Height
- Velocity - East, North, Up
- G&C Time - CUC & Vernier
- Sun Vector
- Roll, Pitch, Yaw (to Inst. Only)
- S/C Attitude Quaternion
- S/C Body Rates (attitude)
- Wheel Speeds
- Wheel Torques
- Sun Sensor Data
- Solar Panel Angle
- Solar Panel Current
- Solar Panel Command
- Magnetometer Data
- Torque Rod States

Discretes

- 4 Output Discretes per AIU. They are:
- 1) Attitude OK (1); not (0).
- 2) AIU Flight Application Program Loaded (1); not (0)
- 3) AIU selected to control actuators and G&C bus; not (0)
- 4) Heartbeat: toggling = OK; not toggling = problem

- 4 Input Discretes to each AIU (includes cross-strapping).
  - 2 Hard LVSS Discretes; 2 Soft LVSS discretes

Recorded Data (Rates and Quantity)

- Active AIU Housekeeping Data - all 16 16-bit words are recorded once a second
- Inactive AIU Housekeeping Data - the first 8 16-bit words are recorded at 0.125 Hz
- Along with housekeeping data, discrete values are recorded in C&DH packets at 1 Hz
- The Quaternion, rates, wheel speeds and torques, and associated time from the S/C Attitude Msg is recorded once a second. The entire message is recorded once every 8 seconds (excluding roll, pitch, yaw).
- G&C Normal Telemetry - up to four packets per second can be recorded. This consists of up to one message from each FC and each AIU. The normal allocated rate on the tape recorder is 8 packets per minute for 24 hours. Recorder space has been allocated for a memory dump of up to 1MBytes in addition to the 8 packets per minute.
- G&C Diagnostic Telemetry - up to 8 packets per second for an orbit can be recorded. A circular buffer is used that contains the latest 12.5MBytes of data sent.

G&C 1553 Bus Messages

- Transmit Status Word (M/C)
- AIU-to-AFC High-rate Msg
- AIU-to-AFC Low-rate Msg
- AFC-to-AIU High-rate Msg
- AFC-to-AIU Low-rate Msg
- GNS-to-AFC Msg
- Quaternion Msg to AIU
- S/C Attitude/Pos Msg for C&DH
- AFC Normal Telemetry
- AFC Diagnostic Telemetry
- Command Msgs to AFC
- IRU Incremental Angle Data
- IRU Status and Telemetry Data
- Time Broadcast to IRUs
- AST Primary Output Packet
- AST Auxiliary Output Packets (atttitude, 2 short diagnostics, long diagnostics, data download)
- AST Commands (Control, Cal/Ops, Upload Data)
- Sync with Data Word Mode Code

G&C 1553 Bus Message Rates

- **25 Hz**

1) IRU Inc. Angle Data

2) AIU/AFC High-rate Msgs

- **5 Hz - AST 1 & 2 Primary Packet**

- **Non-periodic Messages**

1) IRU Status and Tlm Data

2) Command Msgs for AFC

3) AST Auxiliary Output Packets

4) AST Commands

- **AFC Normal Tlm - Max 1 Hz; typical is 6 pkts/minute.**

- **1 Hz**

1) Transmit Status Word (per RT)

2) AIU/AFC Low-rate Msgs

3) GNS Msg

4) Quaternion Msg

5) S/C Att./Pos Msg

6) Time broadcast to IRUs

7) Sync with data word (per AST)

- **AFC Diagnostic Tlm - Max 8 Hz; typical 6 Hz; can be turned off**

IRU Incremental Angle Data

- Time Tag of Day (32 bits)
- Frame Timer 200 Hz
- Frame Counter 1 Hz
- IRU Status
- Incremental Angle X
- Incremental Angle Y
- Incremental Angle Z
- Ave X Gyro Delta Temp
- Ave Y Gyro Delta Temp
- Ave Z Gyro Delta Temp
- Ave Sensor Block Temp
- Checksum

- LS bit of time tag is 40.96 microseconds
- Frame Timer word includes bits for PLC reset active for each gyro and angular rate threshold exceeded flags for each gyro.
- IRU Status has critical monitor bits for SEU, I/O, processing, gyros, and start-up and a Go/NoGo bit.
- Incremental Angle LS Bit = 1 micro radian.

AST Primary Output Packet

- AST ID / Pkt Type / Msg Counter
- Center Of Integration Time
- Sync-referenced Time Stamp
- AST Status
- Quaternion (12 bytes)
- Attitude Uncertainty each axis
- RMS star position error
- Angular increment (X, Y, Z)
- Effective focal length
- Total # of stars used | # in CCD half 1
- Total # guide stars FOV | CCD half 1
- Total # stars extracted | CCD half 1
- CCD temp | # stars IDd Stage 1
- # of bright pixels / CCD half indicator
- Threshold | # of blobs/4
- Video offset | Ave background level
- Min background | Max
- Stage 1 brightness error | overall
- HK & Internals
- Faintest Star Magnitude
- Command Indicators
- Checksum

AIU Software

- **Modifiable Software - Application Program Exists in EEPROM**
- **Uploadable Data Structures**
- **Basic S/W Modules**
  - **Command Processing**
  - **Telemetry Data Gathering and Reporting**
  - **G&C 1553 Bus Controller**
  - **Safe Mode Processing**
  - **Attitude Control**
  - **Momentum Management**
  - **Health Monitoring**

AFC Software

Modifiable and supports uploadable Data Structures

Basic S/W Modules

- Command Processing
- Telemetry Data Gathering and Reporting
- Attitude Estimation

  Using AST data, Gyro Measurements, Magnetometer Measurements, Sun Sensors, and Solar Array Current
- Attitude Control
- Guidance (orbit integration)
- Health Monitoring