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Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Mission Autonomy System

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Topics of Discussion

- Types of Autonomy and examples
- Levels of Autonomy and examples
- System Safing Scheme
- Rule Based Autonomy Design
- Results of Red/Blue Team Review
- Test Plan Philosophy
- Summary

Types of Autonomy

- **Embedded Autonomy**
  - **Hardware and Software based processes designed within subsytems, processors, and components.**

- **Rule Based Autonomy**
  - **Functionality designed within the C&DH which allows for specification of rules used to monitor housekeeping telemetry and execute commands based on pre-defined boolean functions.**

Examples of Autonomy

- **Embedded Autonomy Examples:**
  - Hard LVS
  - Safe mode demotion
  - Operational attitude mode promotion
  - Watchdog Timers
  - other self-checks and safing within subsytems/components
- **Rule Based Autonomy examples:**
  - Other methods of safing
  - 2 levels of Soft LVS
  - Heartbeat checking on processors
  - Safing of systems/components outside operational ranges
  - Various routine operations

Levels of Autonomy

- **System Safing** - safeguard from anything which could potentially bring down the entire S/C or a major component.

Examples:

- Sun Safe attitude mode in G&C; performed by AIU (embedded)
- Monitoring for failed AIU and autonomous switch (rule)
- 3 Levels of LVS - 2 soft; 1 hard - gradual powering down of major components to eventually only essential loads (both)
- Heartbeat checking of critical components (especially AIUs) (rule)
- Instrument Safing - checking of power req. from bus (rule)
- Subsystem Safing - checking of power, temp., and other HSKP which may indicate trouble (rule)
- I&T S/C Shutdown sequence - "quick, pull the plug" (rule)

Levels of Autonomy (cont)

- **Routine Operations** - autonomy to detect required routine operations and execute them appropriately (embedded and rule based)

Examples:

- Turn-on of Transmitter for Ground Station Contact (rule)
- Battery Charge control (embedded in C&DH and PSE/DU)
- Solar Array positioning (embedded in G&C)
- Separation Sequence (rule based on sep. switches)
- Others not yet defined, but will be implemented within the rule based system, such as:
  - » Dump autonomy rule history buffer to SSR when full
  - » When GNS indicates "this" perform "that"

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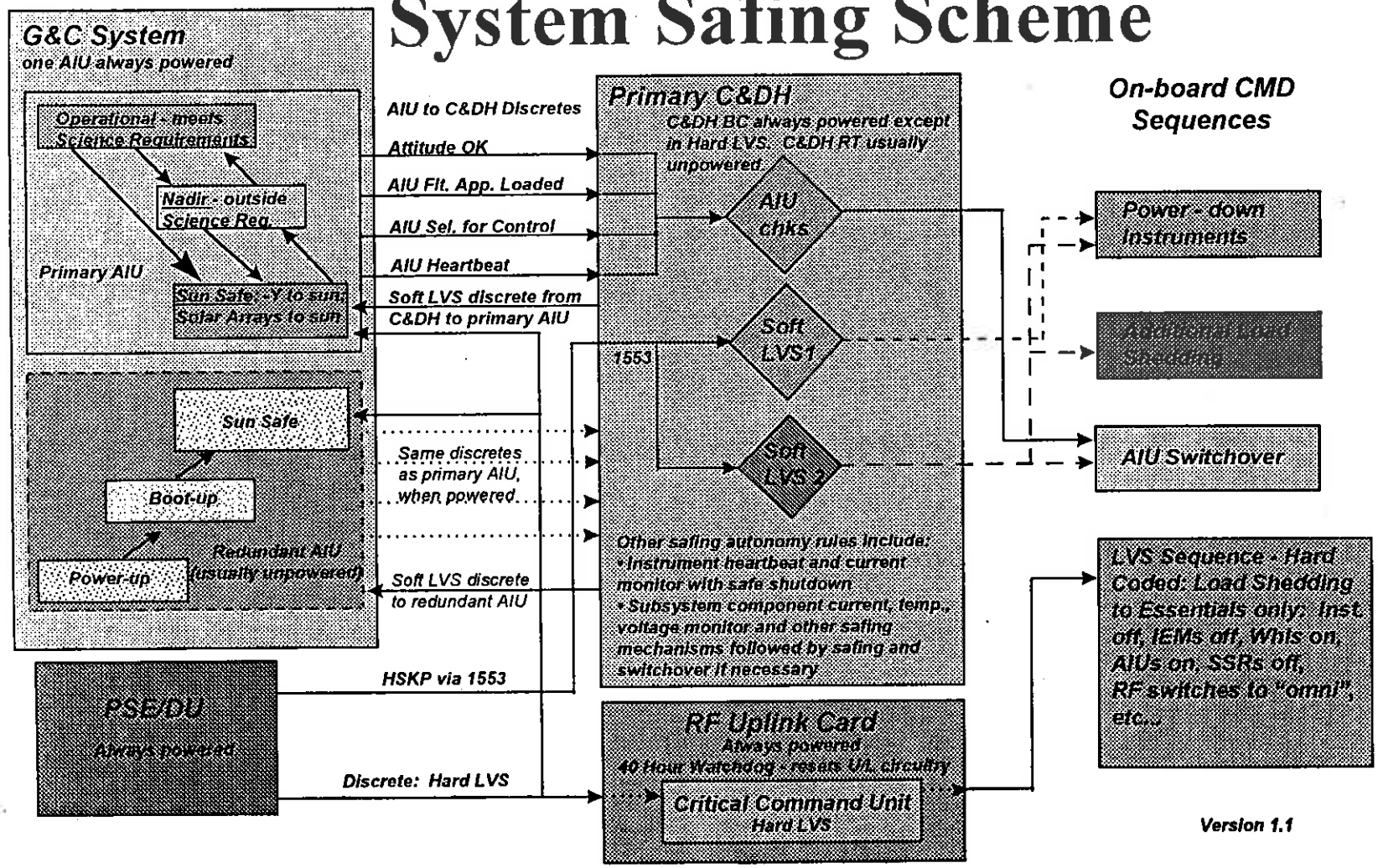
System Safing Scheme



System Safing Scheme (pg2)

- G&C has 3 attitude modes:
  - Operational: nadir pointing meeting science requirements
  - Nadir pointing: outside science requirements
  - Sun Safe: inertially fixed with -Y to sun
- AIU demotes until Sun Safe mode, under conditions within itself when timeouts of data occur or lack of data altogther (i.e no star tracker data, mag. data, etc...)
- In Sun Safe, AIU maintains panels to the sun
- Uploadable parms to AIU specify state vector to sun for Sun Safe
- 4 discretes from AIU to C&DH indicate problems and causes switch to redundant AIU through rules
- Discretes do not require the 1553 bus
- 3 LVS levels: 2 soft in C&DH perform gradual power down, 1 hard powers down most components including both IEMs (C&DHs)
- Both RF antennas to "omni" configuration

Rule Based Autonomy Design

IF *logical expression*

FOR *n* times within the next *m* seconds

THEN execute a single command (could be a macro)

logical expression **in form:**

check1 [AND,OR] check2 [AND,OR], … check4

checks are in form:

x&M=A, x&M/=A, x&M<A, x&M>A; x = telemetry, M is a mask, and A is a constant

- **Arithmetic checks may be defined for inclusion into rule definition (result may act as additional TM point)**
  - **ex. *IF result of (ST #1 current)(battery voltage) = ST #1 power is greater than 100 W for 10 of the next 15 seconds, then turn off ST #1.***

Rule Based Autonomy Design (cont)

- Rules are checked once per second
- 512 Rules per C&DH
- Normally only 1 C&DH powered
- Default state bit determines status upon reboot
- Can be loaded, enabled, disabled, and aborted via command or command macro
- Rules are prioritized (1 to 31) (R/T commands = 0)
- Rules do NOT execute simultaneously
- Lower priority rules' execution is suspended and resumed upon completion of higher priority rule execution.
- Overwriting safeguards - enabled rules are write-protected - protection must be disabled, rule disabled, cleared, and then overwritten
- 2 Groups of Rules - Fault Recovery and Routine Maintenance

Red/Blue Team Review

- **Purpose - determine if current design is sound and flexible enough to allow for incorporation of the required operability and safing.**
- **Red Team was independent; Blue Team was the TIMED Engr. Team.**
- **Implementation of autonomy was not complete and therefore could not be complete review.**
- **Series of 4 meetings weeks apart allowed good data exchange back and forth; answers prompted more questions…**

Red/Blue Team Review (cont)

- **Results:**
  - many good suggestions based on previous experience
  - good recommendations for things to re-consider
  - good advice on testing
  - because of development status, many of reviewers points could not be analyzed fully
  - rule based design was found to be very good
  - implementation will require well thought-out logic and testing
  - final report due in mid-November to include number of things to keep in mind as our development of the entire system progresses.

Autonomy Testing Philosophy

- **Embedded Autonomy**
  - TINTS - TIMED INTegration Simulator - includes simulators and stimulators of spacecraft components for I&T
  - Spacecraft
- **Rule Based Autonomy**
  - IEM Testbed - equivalent to IEM breadboard which contains a C&DH, where rules can be loaded and tripped
  - TOPS - TIMED OPerations Simulator - ground based S/C simulator - contains a single string of engr. units and/or breadboards of S/C subsystems.
  - Spacecraft

Embedded Test Philosophy

- **Embedded autonomy to be tested within subsystems where they reside. In addition, some system level testing will be required.**
  - **TINTS - will allow for system level testing when only one string is required.**
    - **» must be used when testing particular failures (ex. simulate failure of one star tracker).**
  - **Spacecraft will be required to test certain types of embedded autonomy in conjunction with particular rules which command multiple strings.**
    - **» Safe mode simulations of all 3 LVS situations require switching to redundant AIU.**
    - **» Some testing may be done piecemeal if full-up is impractical.**

Rule Based Test Philosophy

- **Rule Based autonomy to be tested in various phases**
  - **IEM Testbed**
    - » **Test the format, syntax, construction, and logic of rules**
    - » **Testbed allows changing of telemetry values to cause triggering of rules**
    - » **Only allows testing of command sequences to extent that the commands executed from the C&DH properly**
    - » **Does NOT allow for command sequence validation because S/C subsystems are not present**

Rule Based Test Philosophy (cont)

- **TOPS - Ground based S/C simulator**
  - **Incorporates S/C Subsystem Engineering Units and or bread boards**
  - **IEM Testbed incorporated to allow for Telemetry parameter tweaking**
  - **Allows for testing of Autonomy Rule construction, logic, and Single String command sequences without instruments**
  - **Does NOT allow for multiple string command sequence validation**
  - **late in I&T phase, but useful post-launch**

Rule based test Philosophy (cont)

- Spacecraft
  - to be used for checkout of rules to extent possible
  - must be used to fully validate command sequences requiring primary and redundant units
  - require that S/C components be placed into proper configuration (only way to tell if seq. has desired effect)
  - requires that rule be modified such that it will trigger when enabled. These will have been tested on the IEM Testbed or TOPS.
  - unmodified rules to be used on S/C in T-V (temperature, pressure, power related rules)
- Full up mission simulations to be run with autonomy system enabled for full-up compatibility testing

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Summary

- **TIMED Mission Autonomy System uses a combination of hard coded embedded autonomy and a rule based system.**
- **Includes both Autonomous System Safing and certain routine operations.**
- **Red/Blue Review pointed out areas to reconsider but did not uncover any show stoppers.**
- **Design is felt to be robust and flexible enough to provide safing and operability requirements as more develop.**
- **Thorough and complete Test plan being developed to fully validate the Mission Autonomy System.**