TIMED

MISSION OPERATIONS REQUIREMENTS DOCUMENT

Document Number 7363-9021

October, 1996

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1. Overview

1.1 Top Level Requirement

The TIMED Mission Operations Center (MOC) shall include the ground resident hardware and software needed to integrate, test, and operate the TIMED spacecraft.

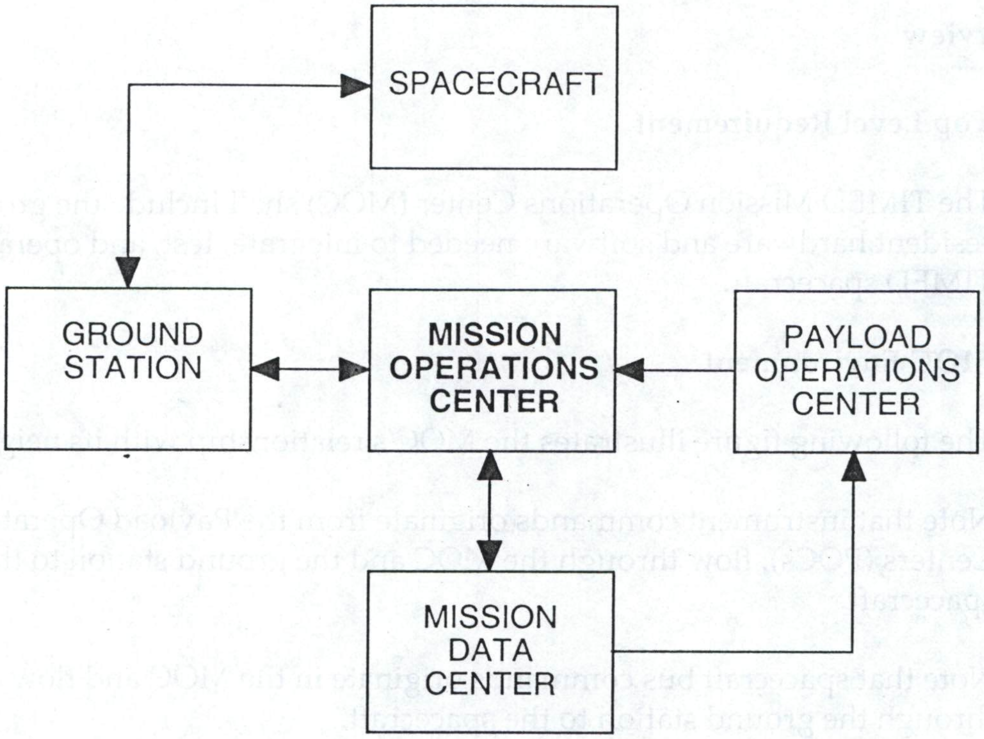
1.2 MOC Environment

The following figure illustrates the MOC's relationship with its neighbors.

Note that instrument commands originate from the Payload Operations Centers (POCs), flow through the MOC and the ground station to the spacecraft.

Note that spacecraft bus commands originate in the MOC and flow through the ground station to the spacecraft.

Note that telemetry flows from the spacecraft through the ground station to the MOC where it is displayed in real-time. Telemetry also passes from the MOC to the Mission Data Center (MDC). The MDC archives the telemetry and serves it to the MOC and the POCs.



(During portions of I&T, ground support equipment will be substituted for the ground station.)

1.3 TIMED System Requirements

The following requirements, which are found in the TIMED System Requirements Document, 7363-9001, 12/1/94, pertain to the Mission Operations Center. For each requirement, the appropriate chapter or chapters of this document is or are referenced.

1.3.1 Command the spacecraft (Chapter 2, Commanding)

1.3.2 Maintain command and telemetry dictionaries (Chapter 2, Commanding; Chapter 3, Telemetry; Chapter 6, System Administration)

1.3.3 Process and evaluate all telemetry during I&T (Chapter 3, Telemetry; Chapter 5, Miscellaneous Items)

1.3.4 Collect and archive all raw telemetry (responsibility of MDC, Appendix A, MOC-MDC Interface)

1.3.5 Transmit all science telemetry data to the instrument Ground Support Equipment (responsibility of MDC, Appendix A, MOC-MDC Interface)

1.3.6 Coordinate with the instrument providers to assure the capability of the instruments to perform as required (Appendix B, MOC-POC Interface)

1.3.7 Collect, process, and transmit instrument commands from the TIMED instrument Ground Support Equipment to the instruments (Chapter 2, Commanding; Appendix B, MOC-POC Interface)

1.3.8 Maintain and operate the Ground Station including a contingency capability (Appendix C, MOC-Ground Station Interface)

1.3.9 Plan and execute effective Mission operations in accordance with the science objectives of the TIMED program (All Chapters)

1.3.10 Collect, process, and transmit instrument commands from the TIMED instrument Payload Operations Centers to the instruments (Chapter 2, Commanding; Appendix B: MOC-POC Interface; Appendix C: MOC-Ground Station Interface)

1.3.11 Process all health and status telemetry data (Chapter 3, Telemetry) and maintain spacecraft (All Chapters)

1.3.12 Assess spacecraft performance and adapt operations to changes (Chapter 3, Telemetry; Chapter 5, Miscellaneous Items)

1.3.13 Transmit all science telemetry to the TIMED Data System for processing and distribution (Appendix A, MOC-MDC Interface)

1.3.14 The I&T Operations Team shall require a primary and backup voice network joining the Spacecraft Processing Facility (SPF), I&T Operations Control Center (ITOCC), and MOC during all operations at the launch site (Chapter 4, Hardware)

2. Commanding

2.1 Top Level Requirements

2.1.1 The MOC shall be capable of generating all commands needed to integrate, test, and operate the TIMED spacecraft.

2.1.2 Commands shall be generated for ground support equipment as well as the spacecraft.

2.2 TIMED Command Language

The MOC shall include a Command Language (TIMED Command Language, TCL).

2.2.1 TCL shall include the capability to send individual commands as well as commands grouped into scripts.

- Command scripts shall have the capability of calling other command scripts.
- Individual command entry shall make use of editing features such as command line recall, cursor movement, overstrike mode, insert mode, etc. to facilitate data entry.

2.2.2 Although most TCL statements shall be either spacecraft commands or telemetry checks (tchecks), TCL shall include wait statements and programming language-like features such as decision constructs and variables.

- A WAIT-UNTIL or WHILE construct must be available to allow the TCL script to wait until a telemetry mnemonic is in a specified range before continuing execution.
- While a script is in an absolute wait (i.e. wait for n seconds), a count-down clock shall display the number of seconds left until the wait is over.

2.2.3 TCL variables shall be either local (i.e. valid only in the current command script) or global (i.e. valid over all command scripts.)

2.2.4 TCL shall include the capability of assigning a variable to a telemetry value.

2.2.5 An IF-THEN-ELSE construct shall be included in TCL. It shall include a test of a condition. The test may include telemetry mnemonics, variables, or constants.

- Operators shall include equals, not equals, less than, greater than, less than or equal to, and greater than or equal to.

- The test may be based on either the raw or the engineering value of a telemetry mnemonic.

- The test may include multiple conditions concatenated with an AND or an OR.

- TCL shall include the capability to write comments into the event log, so that the status of an IF-THEN-ELSE statement may be recorded.

2.2.6 TCL scripts may call other TCL scripts with arguments.

2.2.7 TCL shall include the capability to prompt the operator.

- The prompt capability shall include a prompt string.

  The prompt capability shall include a variable in which the operator's response is stored.

2.2.8 TCL execution errors should be handled gracefully and should produce meaningful error messages.

2.2.9 One possible TCL command argument shall be a filename. When executing a TCL statement with such an argument, the contents of the file shall be substituted for the argument.

2.2.10 TCL shall allow variable length commands. These commands may include a length field which shall be computed automatically.

2.2.11 TCL shall include command mnemonics which map to part of a command, all of a command, or to multiple commands.

For example, if the command
Relay 20 A
means turn the star camera on,
STARCAM_ON
could be a mnemonic for this command, while
STARCAM ON
could be a mnemonic for "Relay 20" with an enumerated parameter for "A", while
SENSORS_ON
could be a mnemonic for the commands
Relay 20 A and
Relay 21 A.

2.2.12 TCL shall include a WRITE command which allows values to be put into the command log (described below).

2.2.13 The information needed to build spacecraft commands from TCL statements shall be maintained in a command dictionary (rather than hard-coded).

2.3 Script Building, Testing, and Execution Environment

The MOC shall include an environment for building, testing, and executing command scripts.

2.3.1 The MOC shall include an editor for building command scripts. The process for creating new command scripts and modifying existing command scripts shall be user-friendly.

2.3.2 The MOC shall include an input line for executing individual TCL commands or calling up TCL scripts.

2.3.3 The MOC must include a command verification utility.

- This utility must perform syntax checking on all commands before they are sent to the spacecraft.
- This utility shall include the capability for the user to define command usage rules, which shall include command argument range constraints, command sequence constraints, and other TBD constraints.

- This utility shall include a test mode which shall allow for syntax checking of scripts without routing the commands to the spacecraft. This checking shall be performed using the simulator described in section 5.

2.3.4 The MOC shall include a utility to print a merged listing of a script. The merged listing includes script line numbers. Also, if the script calls another script, the called script is included in the listing, etc.

2.3.5 The MOC shall include a script viewing utility.

- The script viewing utility shall provide a window of a script as it is executing, with the current line highlighted.

- The lines shall have line numbers.

- A TCL GOTO command shall allow the operator to branch in the script based on line number or label. Note that the operator shall not be allowed to branch into blocks such as IF-THEN-ELSE and FOR-NEXT loops.

- The window shall include a script nesting stack.

- The window shall contain a minimum of n (TBD) lines as well as vertical and horizontal scroll bars. The script viewing utility shall also include a method to return focus to the current line if it has been scrolled off the page.

- The utility shall allow this window to be viewed by any workstation in the MOC or at a POC. Each workstation shall have control over its own vertical and horizontal scroll bars. However, when a new command is executed by the workstation controlling the script (the "master"), all "slave" workstations shall be synched to the "master", ignoring local scrolling.

- A TCL STEP ON command shall put the script into step mode, i.e. when the operator sends the TCL CONTINUE command, the script shall wait after each command line.

- A TCL STEP OFF command shall put the script into normal mode, i.e. when the operator sends the TCL CONTINUE command, the script shall execute commands until a WAIT of some sort is executed.

- The script viewing utility shall display the substituted value for TCL variables as opposed to the variables themselves.

2.3.6 A time-tagged event log shall record commands as they are sent from the MOC.

- This log shall include the bits associated with each command which went out in addition to the command itself.
- Spacecraft acknowledgment (or rejection) status of the command shall also be included in this log.
- This log shall be saved with a filename which includes a date/timestamp.
- This log may be viewed from any MOC workstation in real-time.
- The event log display shall include horizontal and vertical scroll bars.

2.3.7 The MOC shall have the capability to verify execution of commands which have telltales in telemetry. The command/telltale mapping shall exist in the command/telemetry dictionary.

2.3.8 The MOC shall be able to manage a pass autonomously. Specifically, the MOC shall be able to execute a script of commands at a given time and take actions contingent on telemetry without real-time operator action.

2.4 Command Security

The MOC shall include command security.

2.4.1 The MOC shall filter commands based on their source and destination.

- Commands originating within the MOC shall be able to address all of the ground support equipment and all of the spacecraft.

- Only one workstation at a time shall be able to command the spacecraft. The test conductor shall control which workstation may command at any given time.

- Commands originating at instrument POCs shall be able to address only the appropriate instrument or its supporting ground support equipment.

- Commands with unauthorized source-destination pairs shall be alarmed, audited, and rejected.

- Command counters for each spacecraft source and destination as well as a counter of rejected commands shall be available as telemetry in the MOC.

- The MOC shall control a switch (via TCL) to enable or disable spacecraft commanding from any POC. There shall also exist a TCL command to flush the command queue for any POC.

- The status of the commanding enable/disable switch for each instrument POC shall be visible within the MOC as ground telemetry.

- POC GSE commands shall always be enabled.

- A time-tagged log of all spacecraft commands sent shall be maintained in the MOC. Note that POC commands may only be stored as bits. Also note that it is a goal to include MOC GSE commands in this logging, but not POC GSE commands.

- MOC commands shall take priority over POC commands.

2.4.2 The MOC commanding function shall be password protected.

2.4.3 Normally, each command sent to the spacecraft shall wait until the previous command has been authenticated by the spacecraft.

However, there shall also be a bypass mode in which commands do not wait for spacecraft authentication.

2.4.4 The capability to lock critical spacecraft commands (i.e. require an "are you sure" prompt) shall be included in the MOC.

There shall be a way to enable and disable the lock capability (for all commands treated as a whole) via TCL.

2.5 Types of Spacecraft Commands

MOC commanding shall include real-time commands, time-tagged commands, and processor loads.

2.5.1 "Time-tagged commands" are commands which are the same as real-time commands with the addition of:

- a command processor memory address in which the command is stored, and
- a UTC command execution time.

2.5.2 There should be a general and consistent method for converting any real-time command into a time-tagged command.

2.5.3 Processor loads are commands which include a processor ID, a starting address to load, a load length, and data.

2.5.4 The MOC shall include the capability to break processor loads into units of delivery.

2.6 Command Format

2.6.1 The MOC shall be able to generate CCSDS telecommand packets. These packets shall be stuffed into frames. These frames shall be generated for a designated virtual channel.

2.6.2 The MOC shall be able to generate embedded commands.

For example, the TIMED spacecraft includes a command and data handling system (C+DH) which routes commands over a 1553 bus to the Attitude Interface Unit (AIU). The AIU in turn routes commands over the attitude 1553 bus to the Star Camera. Therefore, Star Camera commands may be embedded in AIU commands which may be embedded in C+DH commands.

- The command dictionary must allow for embedded command definitions.

- TCL must allow for embedded command syntax.

- The MOC must be able to block embedded commands into the fixed-size CCSDS command packets.

2.6.3 The MOC must be able to include TBD CRCs and checksums for every command, including embedded commands.

3. Telemetry

3.1 Top Level Requirements

3.1.1 The MOC must be capable of decommutating, displaying, and alarming all TIMED spacecraft telemetry.

3.2.2 The MOC shall be able to ingest telemetry from both the spacecraft and the ground support equipment.

3.2 Telemetry Display

3.2.1 Telemetry shall be viewed in workstation windows.

- These windows may be in tabular, plot, or graphical format. The graphical format shall include the ability to display switches, red/green lights, and user-defined graphics such as representations of tape recorder reels and system schematics.
- The telemetry may be displayed in raw or engineering units.
- Raw telemetry may be viewed in binary, decimal, or hexadecimal.
- The window shall include telemetry mnemonics, values, units, and comments.
- Alarmed values shall be highlighted in some fashion.
- Stale values, i.e. telemetry mnemonics which have not received a valid value within TBD seconds, shall be highlighted in another fashion.
- A "Snap" utility shall allow the operator to output a copy of a display window to the printer. Snaps should be triggered by a single mouse click. Snap output should include the contents of the display window as well as the hostname of the workstation which created it.
- The color of a telemetry mnemonic on a display shall be specified in the telemetry database.

- Telemetry displays shall automatically include header information such as the display name, UTC, and data source (such as spacecraft VC0, simulator VC3, etc.)

3.2.2 The MOC must include a utility for building telemetry displays.

- It should allow for cutting and pasting from a list of telemetry mnemonics.

- Invalid telemetry mnemonics on a display must be flagged when the display is invoked.

- The process for creating and modifying telemetry displays shall be user-friendly.

3.2.3 Telemetry displays shall be able to keep up with a full workstation screen of telemetry which is updating once per second.

3.2.4 The MOC shall be able to display telemetry from multiple input sources on one screen, and shall be able to access telemetry from multiple input sources from one TCL script.

3.3 Telemetry Decommutation

A telemetry decommutation process shall describe the structure of telemetry.

3.3.1 It shall include telemetry mnemonics, engineering conversions, alarm information, formatting information, units, and other information for each item.

3.3.2 Telemetry decommutation shall be provided for subcommutated values.

3.3.3 It shall be possible to generate derived values using an arbitrary function based on actual telemetry values. This derived telemetry shall be treated the same as actual telemetry values for the purposes of displaying, alarming, etc.

3.3.4 Engineering units may also be based on polynomial equations, lookup tables, and state definitions.

3.3.5 The information needed to decommutate telemetry shall be maintained in a telemetry dictionary (rather than hard-coded).

3.3.6 Telemetry engineering conversions may be modified independently on a workstation by workstation basis. These changes are temporary and do not affect the telemetry dictionary. There shall be a method of restoring the conversions to the telemetry dictionary values via operator command.

3.3.7 Telemetry decommutation and display shall include a command processor command history display and an autonomy rule status display.

3.4 Telemetry Alarming

The MOC shall include telemetry alarming.

3.4.1 Alarm conditions may be based on a logical combination of arithmetic expressions. For example, alarm telemetry point A if telemetry point A is greater than 10 engineering units AND telemetry point B is less than 50 raw counts.

3.4.2 Alarm information in the database shall include these conditions as well as red low, yellow low, yellow high, and red high limits and messages.

3.4.3 Alarm information in the database shall contain an enable/disable flag and a trigger count. A trigger count of 3 means that the alarm condition must be satisfied on 3 consecutive evaluations of the alarm's conditions.

3.4.4 Alarms shall enabled or disabled individually or as a whole via TCL.

3.4.5 Alarms shall keep displaying in an alarm status window until an acknowledge action is executed and logged.

3.4.6 An alarm status window shall display all unacknowledged alarms. Each alarm shall include the time it occurred, the out-of-limit value, the limit which was exceeded, and the alarm message.

3.4.7 Alarms shall be included in a time-tagged event log.

3.4.8 Alarm limits may be modified through TCL.

3.4.9 The information needed to alarm telemetry shall be maintained in a telemetry dictionary (rather than hard-coded).

3.4.10 Alarms may be modified independently on a workstation by workstation basis. This includes the ability to enable and disable individual alarms. These changes are temporary and do not affect the telemetry dictionary.

3.5 Telemetry Archiving

The MOC requires that all spacecraft telemetry is archived, either locally or within the TIMED Mission Data Center.

3.5.1 Data must be archived beginning with the start of integration.

3.5.2 Access to archive telemetry shall include reports based on telemetry mnemonic and time range.

- Archived telemetry shall be available no later than 10 seconds after it is initially received by the MOC, and must be retained for at least 10 years.
- Telemetry values may be either raw or engineering units.
- Values shall be displayed either in tabular or plot form.
- Tabular formats should include an option to be output as a report or as a file designed for input into a spreadsheet. Up to 7 telemetry points shall be included on a tabular report and up to 100 telemetry points shall be included on a file designed for input into a spreadsheet.
- Plots may include up to 5 telemetry points per plot. Plots shall include ground UTC or spacecraft time on the dependent axis, as designated by the user.
- The telemetry access utility shall be user friendly.
- A hex dump capability shall allow the user to view up to 10 bytes of data on a tabular report. The input to this capability shall be a

time, a packet application identifier, and up to 10 byte offsets. The output shall be in hex.

3.5.3 The MOC/MDC shall include a telemetry playback feature which allows the replaying of telemetry to one or more workstation based on time. The replay user interface shall use a VCR paradigm, with stop, pause, forward, reverse, fast-forward, rewind, and a variable speed slider control. It shall also include a step mode (forward or reverse).

3.5.4 The time base for archive telemetry access and playback should be either ground receipt time (UTC) or spacecraft time (either UTC or mission elapsed time).

3.5.5 Telemetry access should be speedy. Specifically, it shall take less than 1 minute to produce a report of 7 or less telemetry points in engineering units for the period of one hour, as long as the data is recent (within the past 48 hours).

3.6 Telemetry Unwrapping and Wrapping

The MOC shall be able to accept CCSDS telemetry frames and to extract packets and relevant frame information. This information is then packaged into TBD Standard Telemetry Units.

4. Hardware

4.1 Hardware Elements

4.1.1 The hardware shall consist of a network of workstations (or PCs) connected together by ethernet. There shall also exist printers and backup devices.

4.1.2 The hardware shall include integration and test specific equipment such as the Blockhouse Control Unit (BCU), Tower Interface Unit (TIU), Solar Array Simulator (SAS), and other TBD equipment.

4.1.3 The hardware shall include a command bit stream monitor between the ground station front end and the BCU or RF gse.

```.4 The hardware shall include a TBD voice communications capability, including a network of headsets.. This capability shall be between the instrument POCs and the MOC. During the Integration and Test (I&T) phase of this mission, this capability shall also be needed between the MOC and the current location of the spacecraft, whether it is at APL, GSFC, or VAFB.

4.1.5 The hardware shall include routers.

4.1.6 The hardware shall include a 1553 monitor which includes a 24 hour archive capability.

4.1.7 The hardware shall include an internet monitor.

4.1.8 The hardware shall include an IRIG time code reader/generator.

4.1.9 The hardware shall include an AOS/LOS clock.

4.1.10 The MOC shall have the capability to project computer screens onto a wall. Specifically, it is envisioned that a top-level spacecraft status diagram, an attitude status diagram, and an orbit track diagram may be projected in the mission operations center.

## 4.2 Hardware Performance

4.2.1 The hardware must be able to handle peak command and telemetry rates.
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4.2.2 The hardware must be able to handle the Ground Station interface requirements.

4.2.3 The hardware must be able to handle the POC interface requirements.

4.2.4 Whenever feasible, hardware shall accept remote commanding via an ethernet link.

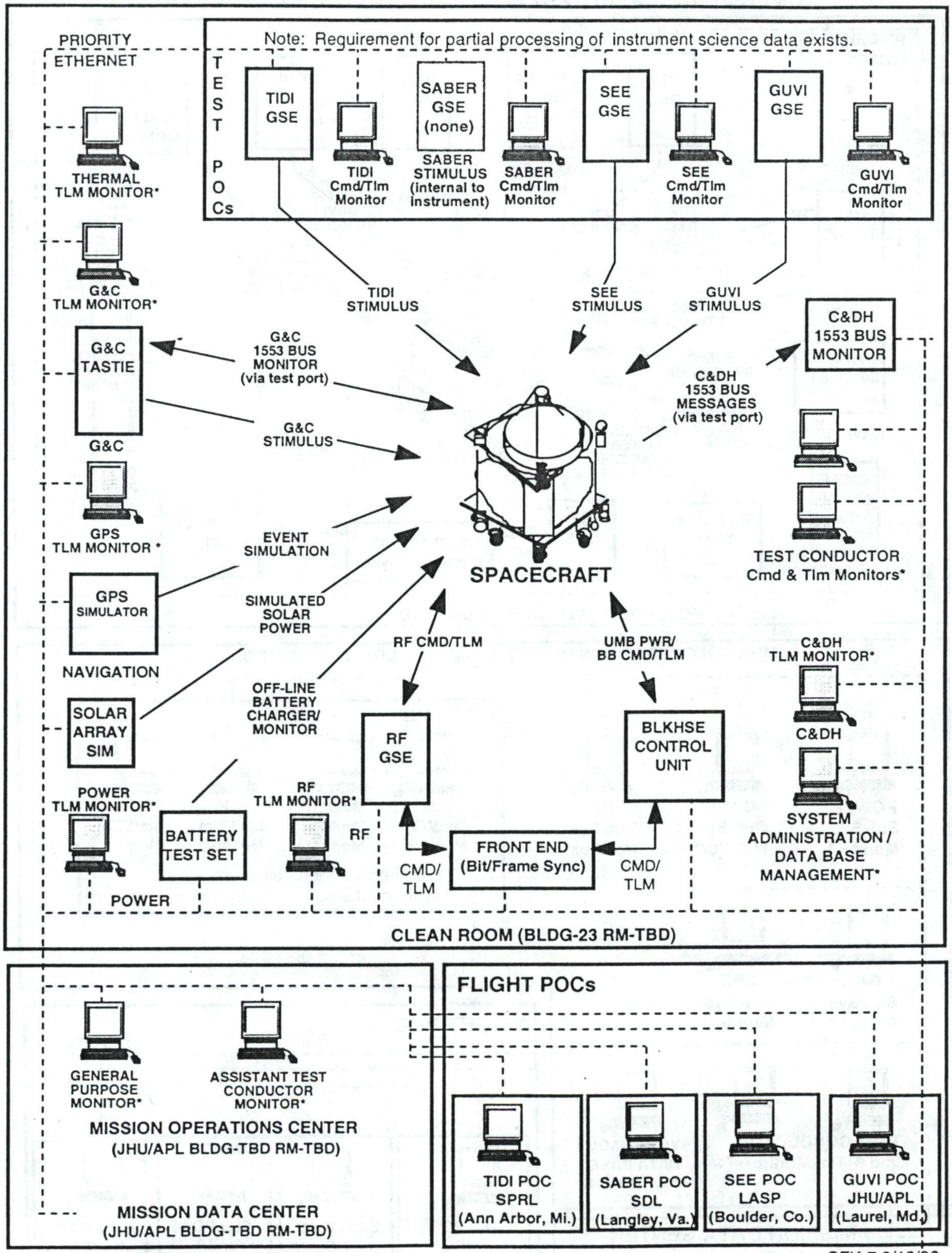
4.2.5 During I&T, data links between the MOC and the current location of the spacecraft, whether it is at APL, GSFC, or VAFB, shall be highly reliable, highly available, and of a uniform delay.

4.2.6 If instrument time critical commands need to be executed from an instrument flight POC, the datalink between the POC and the MOC shall be highly reliable, highly available, and of a uniform delay.

4.2.7 The MOC shall be protected against unwanted and/or unauthorized network access or traffic.

4.2.8 The MOC shall accommodate the configurations shown below for testing when the spacecraft is at APL, and for testing when the spacecraft is at GSFC or VAFB. Note that the post-launch configuration (not shown) will be similar to the NASA-GSFC/VAFB configuration except that the "NASA-GSFC(BLDG-7/10)/VAFB (BLDG-TBD)" box will be eliminated, and there will be 3 additional workstations in the Mission Operations Center.

TIMED SPACECRAFT TEST CONFIGURATION (JHU/APL)



(*) JHU/APL provided monitors

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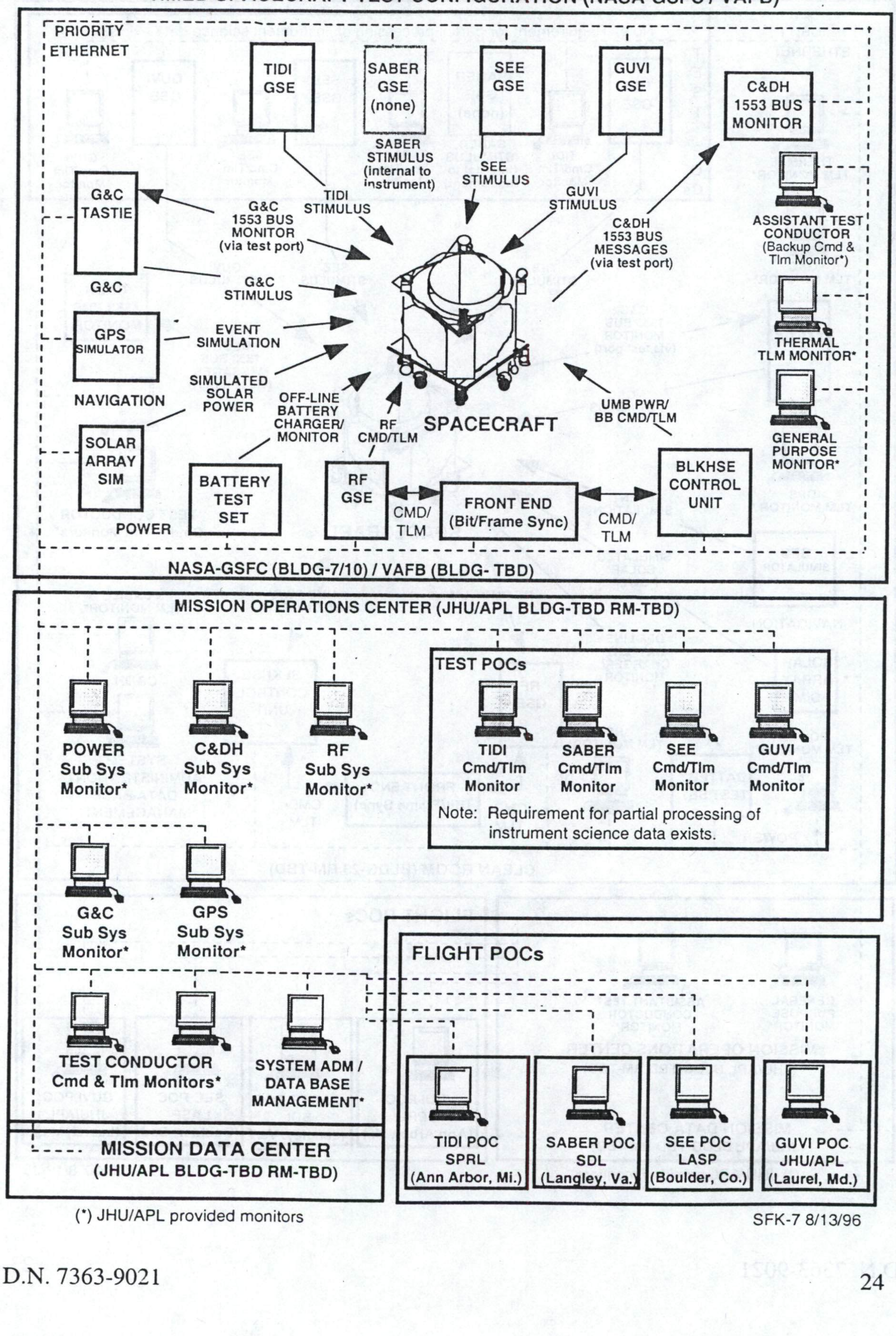
TIMED SPACECRAFT TEST CONFIGURATION (NASA-GSFC / VAFB)



(*) JHU/APL provided monitors

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5. Miscellaneous Items

5.1 Processor Load and Dump Software

5.1.1 This software shall include an expected image and an actual image for each processor, as well as a compare utility.

5.1.2 The output of the compare shall be differences.

5.1.3 Other output shall be contents of either the actual or expected image.

5.1.4 All operations may be specified for a range of physical or logical memory.

5.1.5 Logical memory relates to the APL data structures concept.

A data structure is a logical area of memory associated with a data structure name. The logical to physical memory mapping is only known to the spacecraft processor. Therefore, in order to perform memory comparisons for data structures, the ground software must:

- Know (from a database) the name and size of each data structure,
- Recognize commands that load data structures in order to build the expected image, and
- Recognize dumps of data structures in order to build the actual image.

5.1.6 The compare utility shall be invoked by TCL as well as from a menu. A script which contains a compare statement shall halt unless the compare returns zero differences. In any case, the number of differences is included in the event log.

5.1.7 The option to output a specified range of actual or expected memory shall be invoked from a menu.

5.1.8 The capability to recognize whether differences in memory are opcodes or data is desirable.

5.2 Simulator

5.2.1 The MOC shall include the capability to generate a simulated telemetry stream. The simulator shall allow for the capability to set telemetry points to a constant, to an arbitrary function, or to react to commands in a prescribed way.

5.2.2 The simulator shall be used for command verification as described in section 2.

5.2.3 The simulator software shall also be used to check out the overall hardware/software system in the absence of the spacecraft. For example, after moving from APL to GSFC, the MOC would be checked out using the software simulator.

5.2.4 The simulator shall be able to respond realistically to attitude commands.

[Ideally, it would be desirable to simulate operational performance of the entire spacecraft bus (and instrument, too) given initial conditions (a sample of an entire spacecraft housekeeping frame), the stored (on-board) time-based and event-driven command 'scripts' and the planned (to be uplinked) command messages. This, and access to operating rules and constraints as well as the predicted orbital environment of the spacecraft, would provide a complete simulation of performance of the on-orbit spacecraft. The simulator, in addition to providing a simulated flow of spacecraft downlink housekeeping data to be captured and evaluated by the MOC, would also alert the MOT of any violations to acceptable spacecraft operational behavior. This simulator must have a 'throttle' to control the operating 'speed' so as to provide for a real-time or and accelerated (time-times real time or more) of spacecraft operation.]

5.3 Spacecraft Resource Models

Note: This requirement may be satisfied in part by the afore-mentioned simulator.

5.3.1 These models shall account for the status of the data recorder, processor memory, autonomy rules, downlink, battery, momentum, and other resources. The model shall track these resources in response to planned events, i.e. maintain current and projected status for these resources.

5.4 Run-time Processing Software

5.4.1 The software shall include the capability to produce a report which includes the daily and cumulative on-time for boxes on a spacecraft, i.e. box_a has been on for 256 hours since the start of integration. Parameters shall be based on a combination of telemetry conditions, i.e. box_a_on is a parameter which is on if box_a_power is on AND box_a_current is greater than .5 amps.

5.4.2 The software shall include the capability to produce a report which includes the daily and cumulative number of relay switches for relays on the spacecraft, i.e. relay_5 has been switched 322 times since the start of integration.

5.5 Trending Report Capability

5.5.1 The capability shall exist to produce a report which includes the daily and cumulative minimum, maximum, and mean values for given telemetry mnemonics. Telemetry mnemonic data may be screened by a combination of telemetry conditions, i.e. only consider box_a_current for trending purposes if box_a_current is greater than .5 amps AND box_a_current is less than 1.5 amps. Note that the report shall include a date/timestamp associated with each minimum and maximum value.

5.6 Orbit Position Display Capability

An Orbit position display capability (also called ground trace or orbit tracker software) shall show the satellite's position relative to a map of the earth. Predicted ground trace as well as coverage areas of the Ground Station network is required.

5.7 Autonomy Rule Generation Software

Autonomy rule generation software shall provide the capability to define an autonomy rule in an English-like manner, and have it translated into TCL. (This capability becomes more or less important depending on the design of the TBD C&DH autonomy capability.)

5.8 Orbit Analysis Tools

The MOC must have the capability to propagate the spacecraft orbit forward given either Keplar elements, state vector (spacecraft position, velocity and time of applicability) or a two-line NORAD element set. Predicted orbit files are to be provided to the Mission Simulator (a TBD facility) to support mission simulations.

The capability must exist to generate a 'seed' of the on-board (spacecraft) orbit predictor as a backup contingency to the on-board autonomous GPS processor.

This capability should also predict pass times.

5.9 Operational Timeline Tool

A graphical representation of the spacecraft's planned operational timeline is required. Such a product must illustrate the planned/predicted operational status the spacecraft bus subsystems (an equivalent representation of the instrument operational status is considered desirable but is not required). This product must also include scheduled ground station contact periods. The product should provide a timeline of anticipated spacecraft operations over a period of one day on-orbit.

5.10 Ground Station Simulator

Normal operations between the MOC and the on-orbit spacecraft occur via the Ground Station Network. However, during the pre-launch test phase the Ground Station Network, itself, must be simulated in order to validate the MOC operational capabilities. A simulator, capable of emulating an actual Ground Station Network is required to support this test phase. The simulator, when replacing the Ground Station Network must be 'look and act' like a Ground Station with respect to the MOC interface as well as the spacecraft interface. During this test phase, the Ground Station Network Simulator will be placed between the MOC and the rf and/or baseband interfaces to the spacecraft.

5.11 Merge Capability

The MOC shall have the capability to merge ascii command and telemetry event logs from the POCs and the MOC into unified command and telemetry logs.

6. System Administration

6.1 Backup and Restore

The MOC shall include the capability to backup data and programs to tape. The MOC shall include the capability to retrieve data from backups.

6.2 Configuration Management

6.2.1 MOC software releases shall be subject to a configuration management system.

- New releases of software shall include a description of changes.
- While new releases are being accepted, the capability shall exist to roll back to the old release.
- Software shall be password protected.

6.2.2 MOC TCL scripts and display windows shall be subject to a configuration management system.

6.2.3 TCL scripts and display windows shall be password protected.

6.3 Time Synchronization

All MOC and POC computers shall be synchronized to UTC within one tenth of a second.

6.4 Network Outage Tolerance

The MOC shall not go down for more than 30 minutes due to network problems when the spacecraft is in the field, i.e. at GSFC or VAFB.

Note that this requirement could be met in one of two ways:

1. Guarantee a reliable network which is never down for more than 30 minutes, or
2. Include redundant commanding and telemetry decommutation capabilities, with one copy at the MOC and the other one in the field.

6.5 Database Management System

A database management system (dbms) shall be used to maintain the command and telemetry dictionaries. This dbms shall be robust.

6.5.1 The dbms should include an SQL interface.

6.5.2 The dbms should include a forms capability.

6.5.3 The dbms should include a programming language interface.

6.5.4 The dbms shall be required to produce command and telemetry reports sorted by subsystem.

6.5.5 The dbms shall be password protected.

6.5.6 Dictionary reports should be generated in a timely fashion. Specifically, no report shall take longer than one hour to generate. This shall include the generation of any ascii files which serve as input to the real-time telemetry decommutation or command generation modules.

7. Acronyms

7.1 APL: (Johns Hopkins University) Applied Physics Lab

7.2 CCSDS: Consultative Committee for Space Data Systems

7.3 Flight POC: POC physically located at instrument home facility.

7.4 GSE: Ground Support Equipment

7.5 GSFC: Goddard Space Flight Center

7.6 I&T: Integration and Test

7.7 ITOCC: I&T Operations Control Center

7.8 MDC: Mission Data Center

7.9 MOC: Mission Operations Center, (which does not include the MDC, POCs, Ground Station, or the spacecraft.)

7.10 POC: Payload Operations Center

7.11 SPF: Spacecraft Processing Facility

7.12 SQL: Structured Query Language

7.13 TCL: TIMED Control Language

7.14 Test POC: POC physically located at the instrument home facility.

7.15 TIMED: Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

7.16 UTC: Universal Time Coordinated

7.17 VAFB: Vandenberg Air Force Base

8. Definition of Selected Terms

8.1 Instrument: refers to SABER, GUVI, SEE, or TIDI.

8.2 Spacecraft bus: refers to all of the spacecraft except for the instruments.

8.3 Test conductor: MOC test leader. There is only one test conductor at a time.

Appendix A: MOC-MDC Interface

Telemetry Data to MDC

The MOC shall provide the following telemetry packet streams to the MDC

Real-Time Telemetry as received by the MOC during a pass

Composite Downlink (Real-Time plus Dump) as received by the MOC during or after a pass

In response to a request by the MDC within 72 hours of the pass, the MOC shall replay the Composite Downlink from the Ground Station via the MDC to the MOC

Every packet in the stream shall include (or be associated with) CCSDS frame-related identification information, including

Virtual channel ID

TBD Time Tag(s)

Flag indicating whether un-correctable error was detected

Other relevant frame information

Command Data to MDC

MOC shall provide a copy of all control messages issued by the MOC at the message transport interface. These shall be UTC-tagged.

Message sources shall include MOC and POCs. Messages from the MOC shall include spacecraft telecommand packets and Ground System Control Messages (including those for GSE) Messages from the POCS shall consist of authenticated telecommand packets Inclusion of command messages from the POC to the POC-controlled GSE is TBD.

Telemetry Dictionary

The MOC shall provide the MDC with access to telemetry dictionary, so that MDC can identify telemetry data items and convert them into engineering units.

Historic Stream Service from MDC

The MDC shall provide packet stream service based on a start and selection of packets by packet types(s) and virtual channel(s). Requests of data from 10 seconds to two years old shall be honored.

Start time and order of delivery shall be either by UTC at time of receipt at TBD location, or by MET [UTC at time of origination?]

Service of up to 50 concurrent streams to processes in all facilities (MOC, POCs, and other users) shall be honored

The minimum rate of data delivery to MOC users shall be TBD.

Summary Reports to MDC

The MOC shall provide TBD daily summary reports to MDC.

Summary Reports to MOC

The MDC shall provide historic summary of all time-tagged raw commands to MOC.

MDC shall provide a historic summary of all telemetry to the MOC.

Data Base Service

The MDC shall provide the MOC with relational database access to all spacecraft bus data including C&DH housekeeping packets and subsystem packets.

Queries shall be by SQL.

Database contents and access instructions shall be fully documented.

Served data shall be in engineering units.

Data shall be organized by ground UTC and TBD spacecraft time.

Appendix B: MOC-POC Interface

• The MOC shall not be able to command the instruments other than to send the instrument relay commands.

• The MOC shall be able to enable/disable the individual instrument POC ground command links.

• The only instrument telemetry available to the MOC shall be instrument relay status (ON/OFF), instrument current monitor reading, external instrument temperature monitors (PT103's) and a 16 bit instrument status word, (or possibly 2 to 4/16 bit instrument status words).

• The MOC shall have the ability to receive and display the instrument 16 bit status word(s) whenever the instrument is powered.

• All GSE must have the capability of being remotely computer controlled. Additional manpower must be provided for GSE support in the field if this requirement is not implemented.

• The instrument Test POC would execute approved test scripts on their particular terminal.

• For all instrument tests, instrument Test POCs will be required to partially reduce on-line their instrument science data acquired in the Mission Data Center. Sufficient instrument science must be processed to verify operation of the instrument.

• Remote viewing in the MOC of instrument script execution and telemetry displays is required. Incorporating this capability will provide the MOC the ability to closely coordinate and monitor testing between the instrument and the spacecraft.

• An alarm indication in the instrument housekeeping telemetry will be communicated to the MOC from the instrument POC.

• Each instrument would be responsible for maintaining a "Flight POC" located at the respective instrument facility. During S/C testing, specific test periods would be defined, whereby, a particular instrument Flight POC would take control over from the instrument Test POC and perform that particular instrument test. Confidence in the Flight POCs command capability, science data processing and voice communication link checkout would be increased.

• The POCs must provide a method to produce time-tagged engineering logs of their uplinked commands and of all their downlinked telemetry for troubleshooting.

• The POCs must provide the capability to electronically transfer time-tagged command and telemetry engineering logs to the MOC, as requested.

• The MOC must provide a utility for merging S/C and instrument command and telemetry engineering logs for troubleshooting purposes.

• All facilities (MOC, POCs, NASA-GSFC, VAFB) must be synchronized to UTC.

• The MOC must log all C&DH 1553 bus monitor activities for a TBD (~24 hour) period.

• The Test Conductor and Assistant Test Conductor command terminals must have the capability to bring the entire S/C power-down in an orderly fashion. This also includes commanding the instruments to a safe condition prior to powering them off.

•• Instruments will be required to initiate an instrument safing sequence after instrument safing command is issued

• If instrument time critical commands need to be executed from the instrument flight POCs, high reliability, high availability, uniform delay command and telemetry links will be required from the POCs to the MOC.

•• Minimize delays in testing

•• Meet latency requirements

• Remote facilities (Flight POCs, NASA-GSFC, VAFB) must be interconnected to the MOC via a reliable voice communication link.

• If it is deemed necessary to isolate a possible instrument problem anytime in the field (JHU-APL, NASA-GSFC or VAFB), instrument personnel and instrument ground equipment must be available to support an instrument stand-alone test.

• Confirmation of proper receipt, by the spacecraft, of transmitted commands must be determined and relayed back to the transmitting POC.

Appendix C: MOC-Ground Station Interface

Ground Station Network

- A primary and a backup ground station (GS) must be suitably located to provide the necessary daily contact support (a primary contact and a backup contact to occur within a four hour time window) and interconnected to the MOC via communication circuits capable of supporting real-time command and health monitor operations (must convey the 2kbps command messages as well as housekeeping telemetry in real-time).

- Real-time housekeeping data (**TBD** kbps), received by a GS are to be forwarded, in real-time, to the MOC. In addition this housekeeping data are to be stored at the GS for subsequent retrieval by the MOC.

- 'Playback' (stored on-board the spacecraft) data (**TBD** Mbps) are to be stored at the GS for subsequent retrieval by the MOC. This data must be retrieved at a rate so as to assure that the entire playback data set from the spacecraft data buffer (**TBD** Mb) may be retrieved within one hour of the real-time downlink of this data to the GS..

- Transfer of data stored at the GS will be retrieved by the MOC under MOC control (that is, the MOC will initiate all data transfers of this data). A file transfer mechanism must be devised to support efficient transfer of this data and must provide the capability to retransmit sub-sets of the total mass of data when transmission errors are detected. Data stored at the GS are to remain in storage until this storage is released via MOC command.

- Total storage capability at the GS must include the capacity to store a total of three days of spacecraft downlink data (**TBD** Mb).

- The command link (MOC to spacecraft via the GS) is expected to always occur in real time (i.e. no GS storage). The capability to store command messages at the GS for later and autonomous transmission to the spacecraft is considered as desirable (but is not levied as a requirement).

- Control functions necessary to operate and maintain the GS will originate at the MOC. These functions will include station contact schedules, station data buffer control, station data acquisition parameter selection. etc. [Will depend on the actual GS employed to support the TIMED mission.]

- GS housekeeping telemetry will be accessed by the MOC. Included data will include all necessary measurands required to convey complete GS status relative to the operational support rendered to the TIMED spacecraft. Information will include scheduling data, environmental data, storage status, readiness status. If the GS has the capability to autonomously sample and record GS telemetry measurands, then this stored data must be retrieved also. It is not expected that such data will be of high priority so retrieval time is not particularly important. [Will depend on the actual GS employed to support the TIMED mission.]

- A self-test capability is required to support pre-pass readiness testing as well as remote troubleshooting. Testing must include data flow (command and telemetry), and self-diagnostic tests. Sufficient self diagnostic testing must be accomplished so as to determine when maintenance service is required.

Command Control (Ground Station Network)

Autonomous Ground Station Network operation is desirable - that is, without required operational personnel. In this case, the Ground Station Network then must be controlled from a remote (to the Ground Station) facility; presumably the MOC. To accomplish the necessary control will require the ability of the MOC to initiate and transmit control commands to the Ground Station Network. Therefore the Ground Stations themselves, must support remote control via the communications link connecting the MOC and the Ground Stations.