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Mission Operations Center Software

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Topics

- **Review of Mission Operations Center (MOC) Software Architecture**
- **What is the Mini-MOC?**
- **EPOCH 2000**
- **MOC Builds**
- **Mini-MOC Screen Samples**
- **Documentation, Reviews, Development Environment, Languages, Testing, and Configuration Management**

This is the "Mission Operations Center at the center of the universe" diagram.

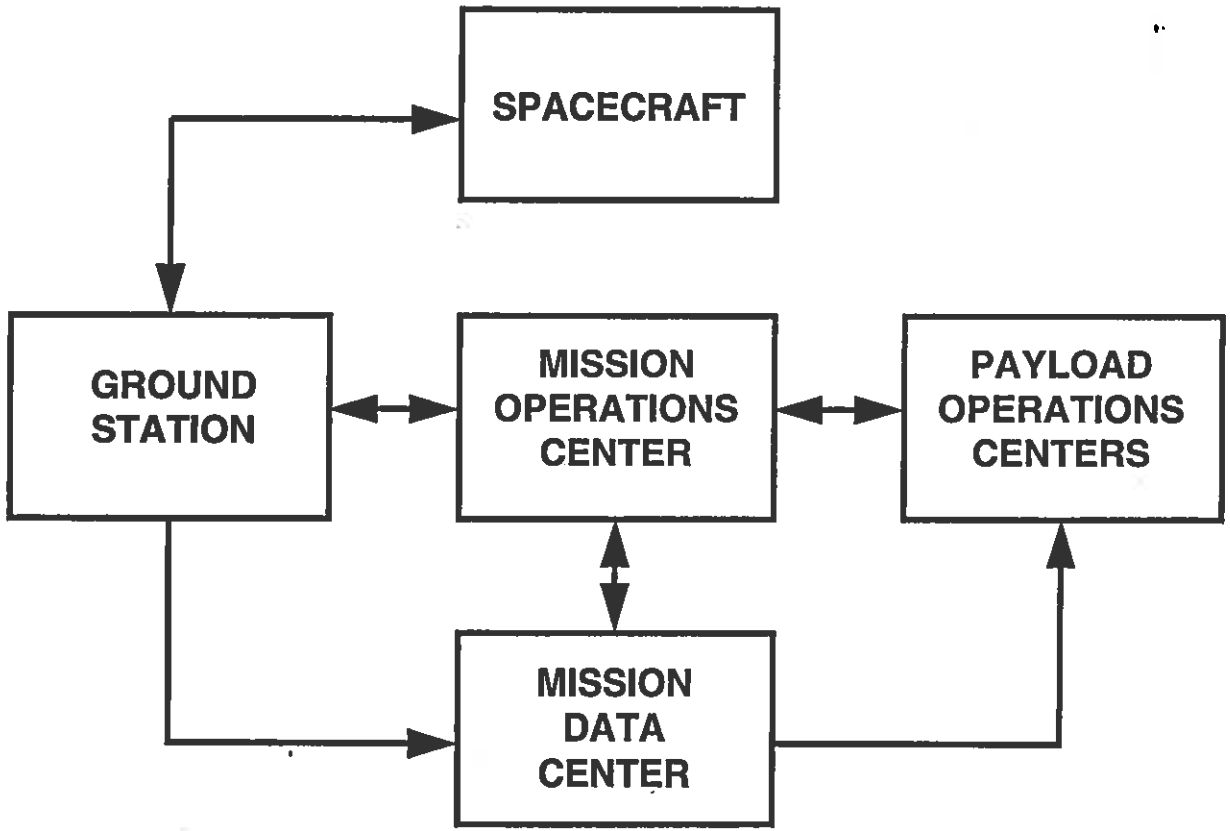
Instrument commands originate from the Payload Operations Centers (POCs) and flow through the MOC and the ground station to the spacecraft.

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

Telemetry flows from the spacecraft through the ground station to the MOC where it is displayed in real-time. The telemetry is also supplied to the MDC, which in turn supplies it to the POCs.

The MDC archives all telemetry. The MDC supplies archived telemetry to the MOC and the POCs.

MOC Architecture



This diagram is similar to the previous one except that the MOC module has been blown up to show its Computer Software Configuration Items (CSCIs).

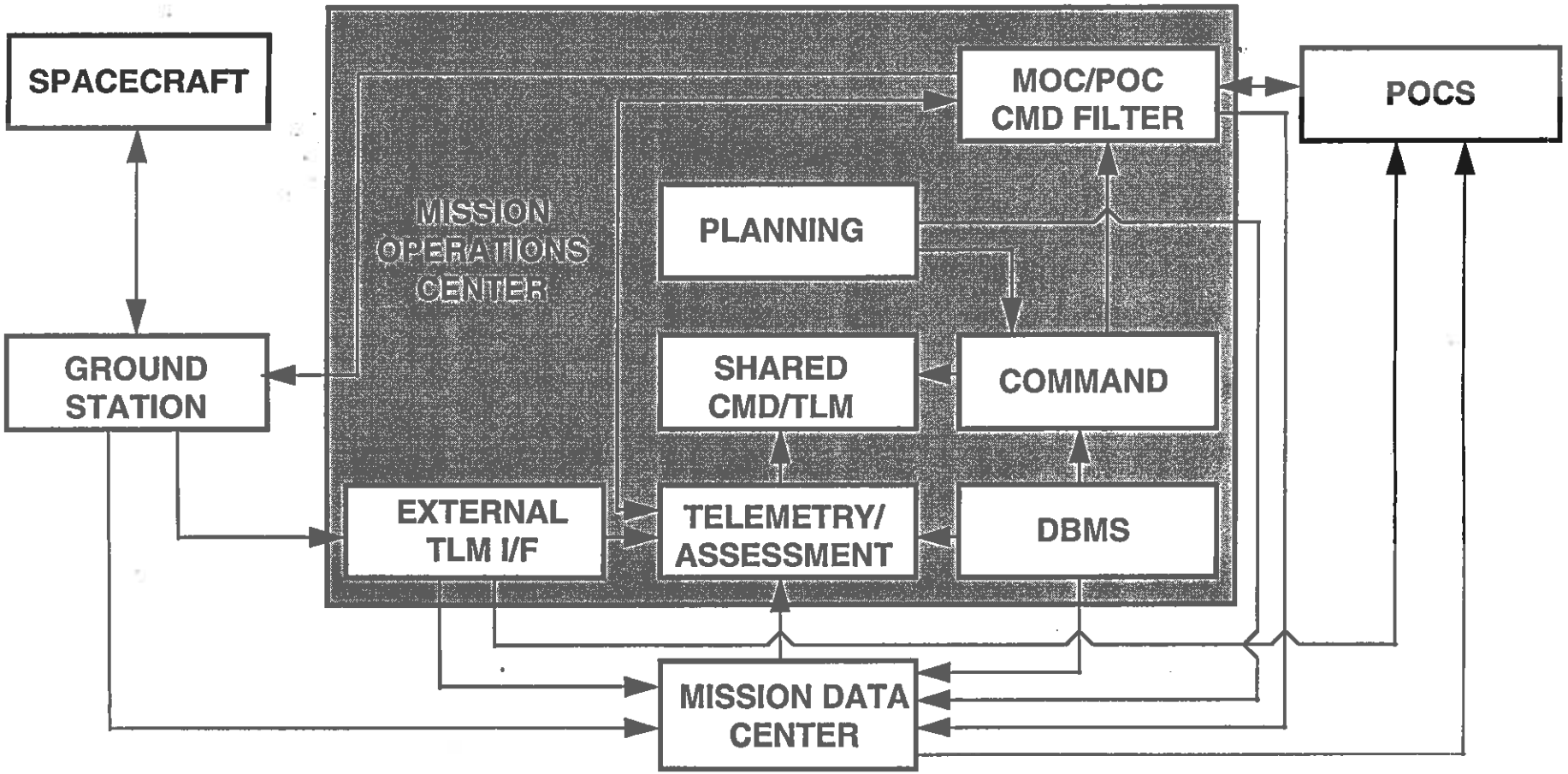
The NASA Software Documentation Standard, NASA-STD-2100-91, describes a CSCI as "a collection of software elements treated as a unit for the purpose of configuration management."

The MOC CSCIs include the:

- Command
- Telemetry/Assessment
- Database Management System
- MOC/POC Command Filter
- External Telemetry Interface
- Shared Command/Telemetry Tools
- and Planning Tools CSCI.

(This diagram highlights spacecraft commanding and telemetry. GSE commanding and telemetry is left out for simplicity.)

MOC Computer Software Configuration Items (CSCIs)



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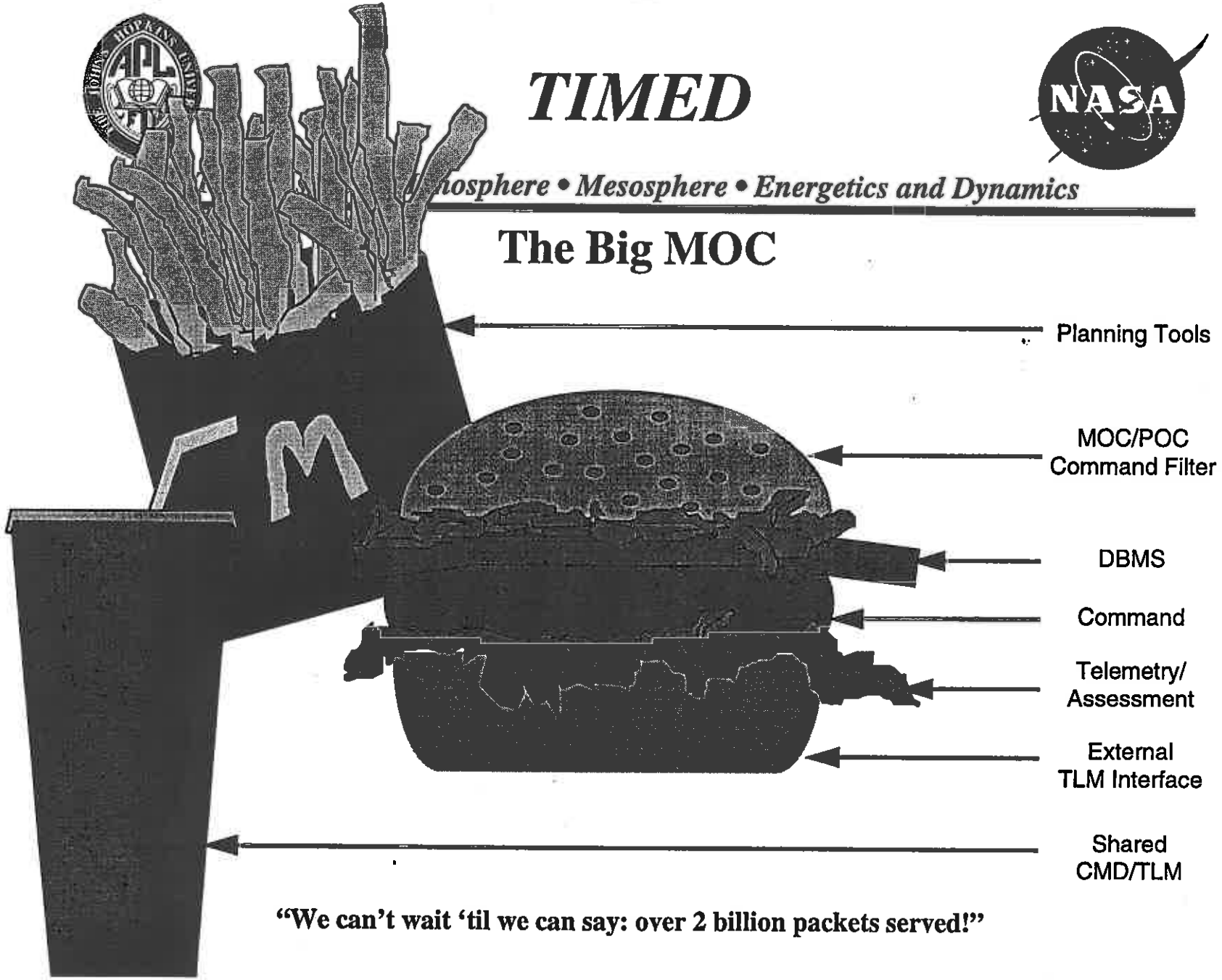
The Big MOC



"We can't wait 'til we can say: over 2 billion packets served!"

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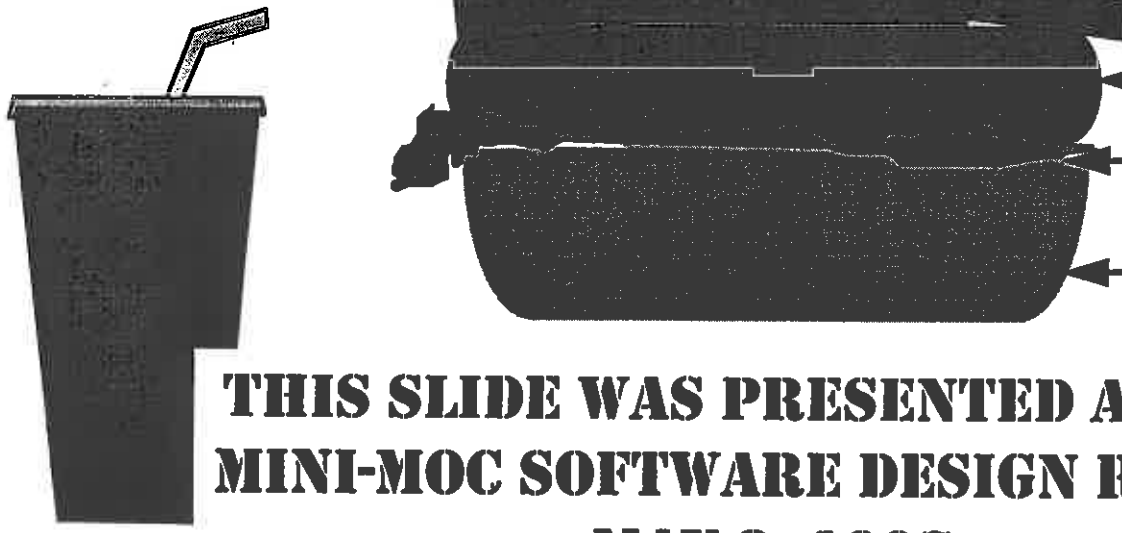
The Mini-MOC

To a Workstation Near You!



No Planning Tools

MOC/POC Command Filter

DBMS

Command

Telemetry/ Assessment

GS/MOC/MDC TLM Interface

Shared CMD/TLM

THIS SLIDE WAS PRESENTED AT THE MINI-MOC SOFTWARE DESIGN REVIEW MAY 8, 1997

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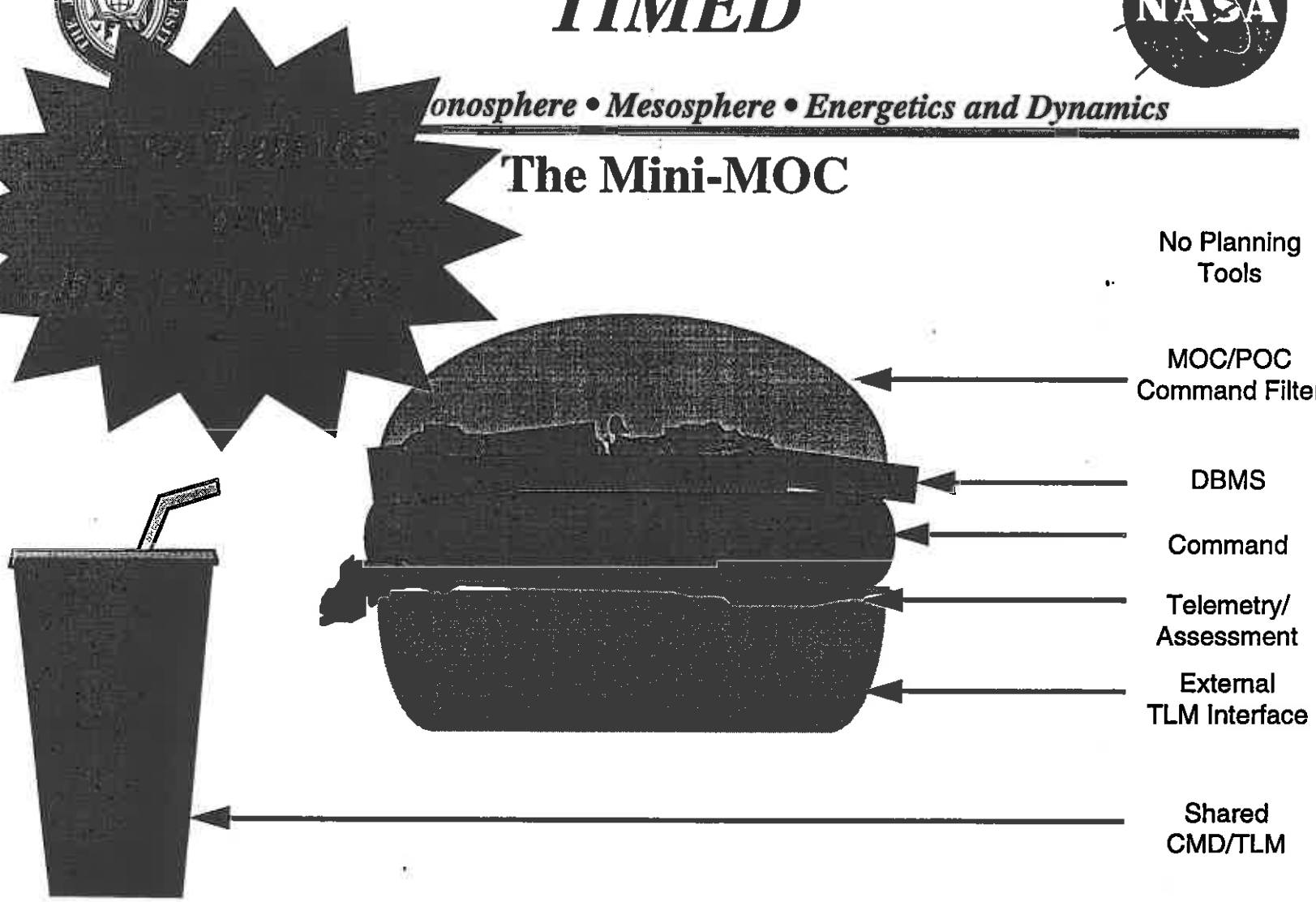
The Mini-MOC



"Limited Edition: Only 6 are being made, and then they're history!"

What is the Mini-MOC?

- **The Mini-MOC is a stripped-down version of the MOC, available early in the program, for use in subsystem testing.**
- **Although hidden from the user, the Mini-MOC includes an early version of the MDC.**
- **The Mini-MOC includes the capability to send both GSE (Ground Support Equipment) and spacecraft subsystem commands.**
- **It includes the capability to receive, decommutate, display, alarm, and archive both GSE and spacecraft subsystem telemetry.**

What is the Mini-MOC? (continued)

- **It uses the same command and telemetry dictionaries, command procedures, and display pages as the MOC.**

What are the benefits of the Mini-MOC?

- **The subsystems save money on the development of their ground systems.**
- **Command procedures, display pages, and command and telemetry dictionaries developed at the subsystem level may be re-used during spacecraft integration and testing.**
- **The Mini-MOC allows both subsystem, integration and test, and mission operations engineers to become familiar with the MOC early in the program.**

What are the benefits of the Mini-MOC? (continued)

- The Mini-MOC eases the transition from subsystem level testing to spacecraft level testing.
- Bugs in the system are discovered and fixed early in the program, providing a more stable environment for integration and test and mission operations.

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This diagram explains what the Mini-MOC can do for subsystem testing, and how the subsystem test-bed, which includes at least one computer plus other GSE, can perform certain tasks which the Mini-MOC cannot perform for itself.

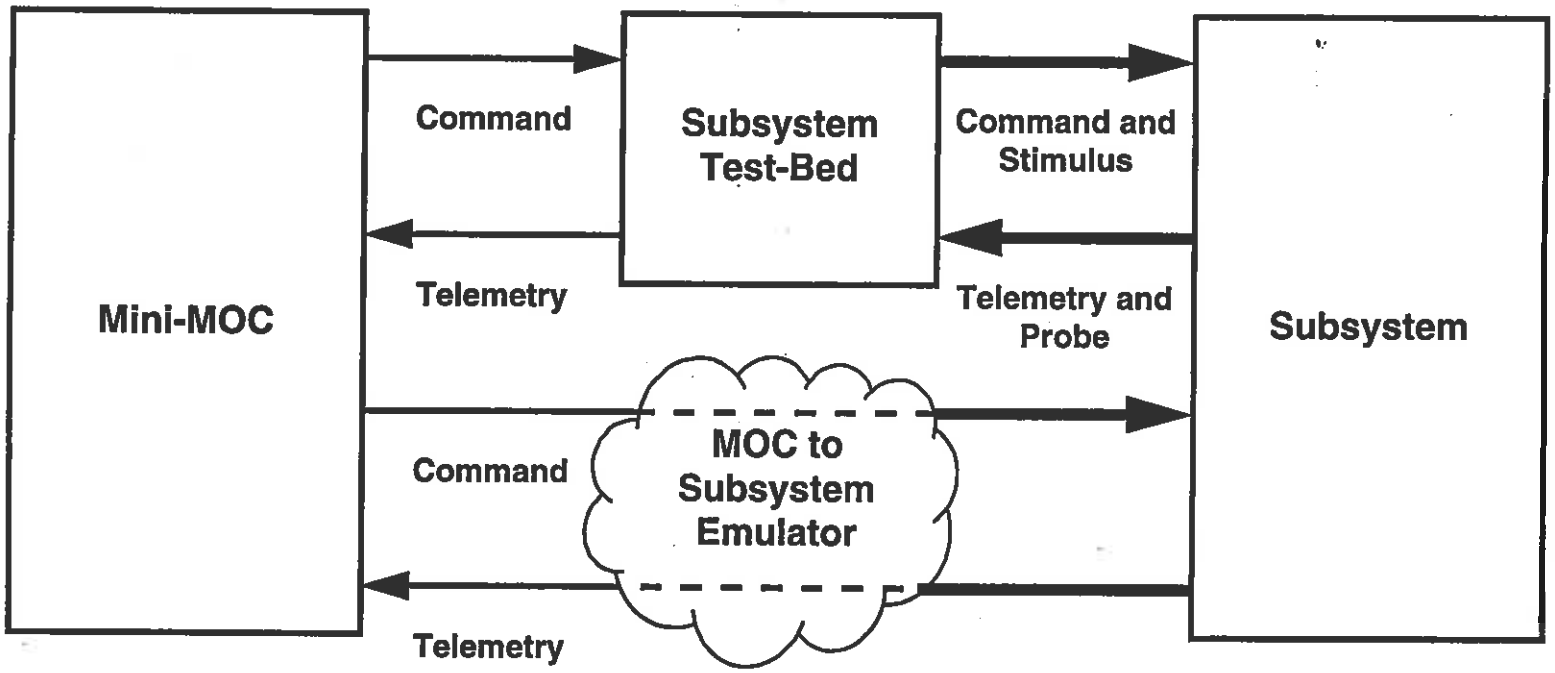
(For the purpose of this discussion, the MOC to Subsystem Emulator, which simulates whatever is between the Mini-MOC and the subsystem, is a pass-through device.)

The Mini-MOC sends commands to the subsystem or the subsystem test-bed. The Mini-MOC receives telemetry from the subsystem or the subsystem test-bed. These command and telemetry links are over ethernet using TCP-IP sockets, shown as a thin arrow.

The subsystem test-bed sends commands to the subsystem and can stimulate the subsystem. The subsystem test-bed receives telemetry from the subsystem, or it probes the subsystem for data. These links are shown with a thick arrow.

The Mini-MOC cannot stimulate or probe the subsystem. It cannot communicate with the subsystem in any way which requires accuracy of less than a second. If necessary, the test-bed can.

What is the Mini-MOC and what it is NOT

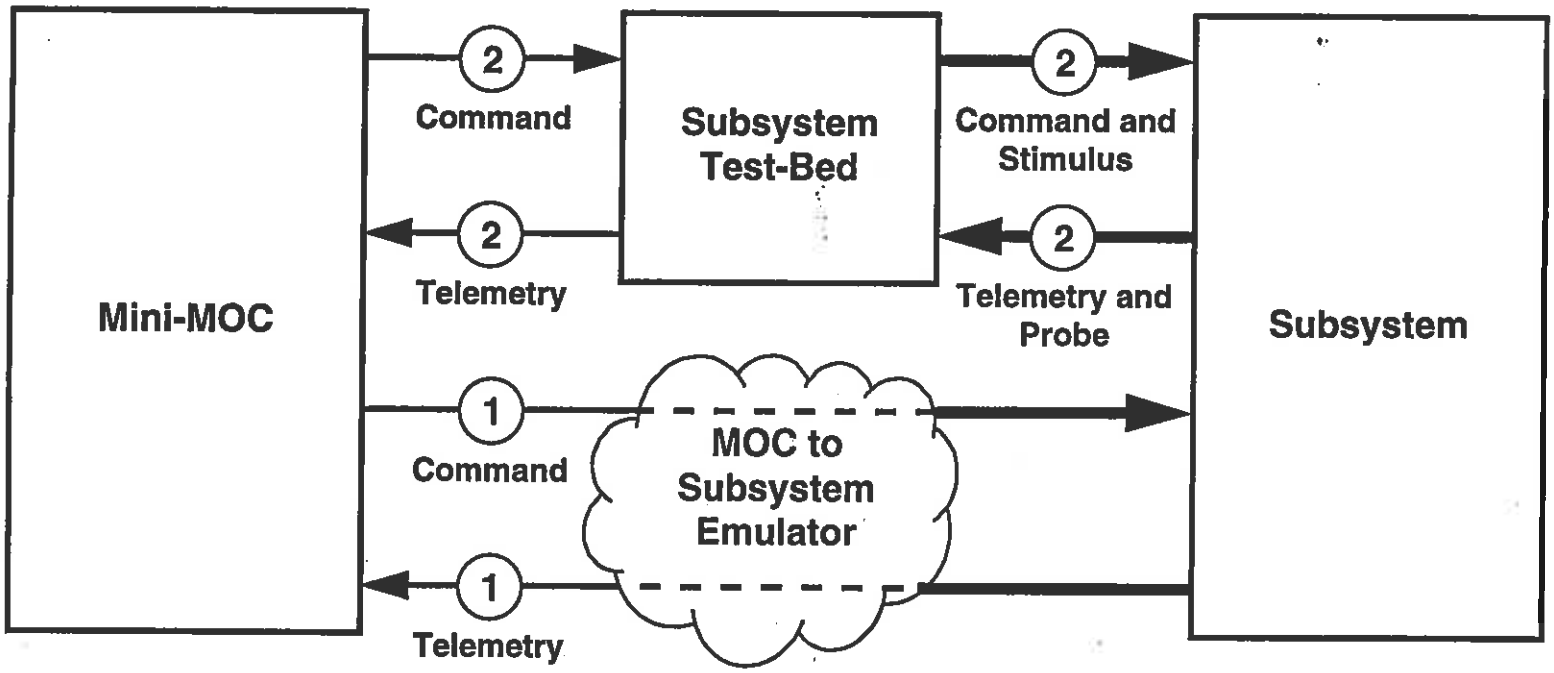


Key:
TCP/IP socket over ethernet ——————
Hard-wired ——————

This arrangement includes four command and telemetry path permutations:

1. The MOC commands the subsystem; the subsystem sends telemetry to MOC.
2. The MOC commands the test-bed; the test-bed stimulates (or sends commands to) the subsystem; the test-bed probes (or receives telemetry from) the subsystem; the test-bed sends telemetry to the MOC.

What is the Mini-MOC and what it is NOT



Key:

TCP/IP socket over ethernet ————

Hard-wired ▬▬▬

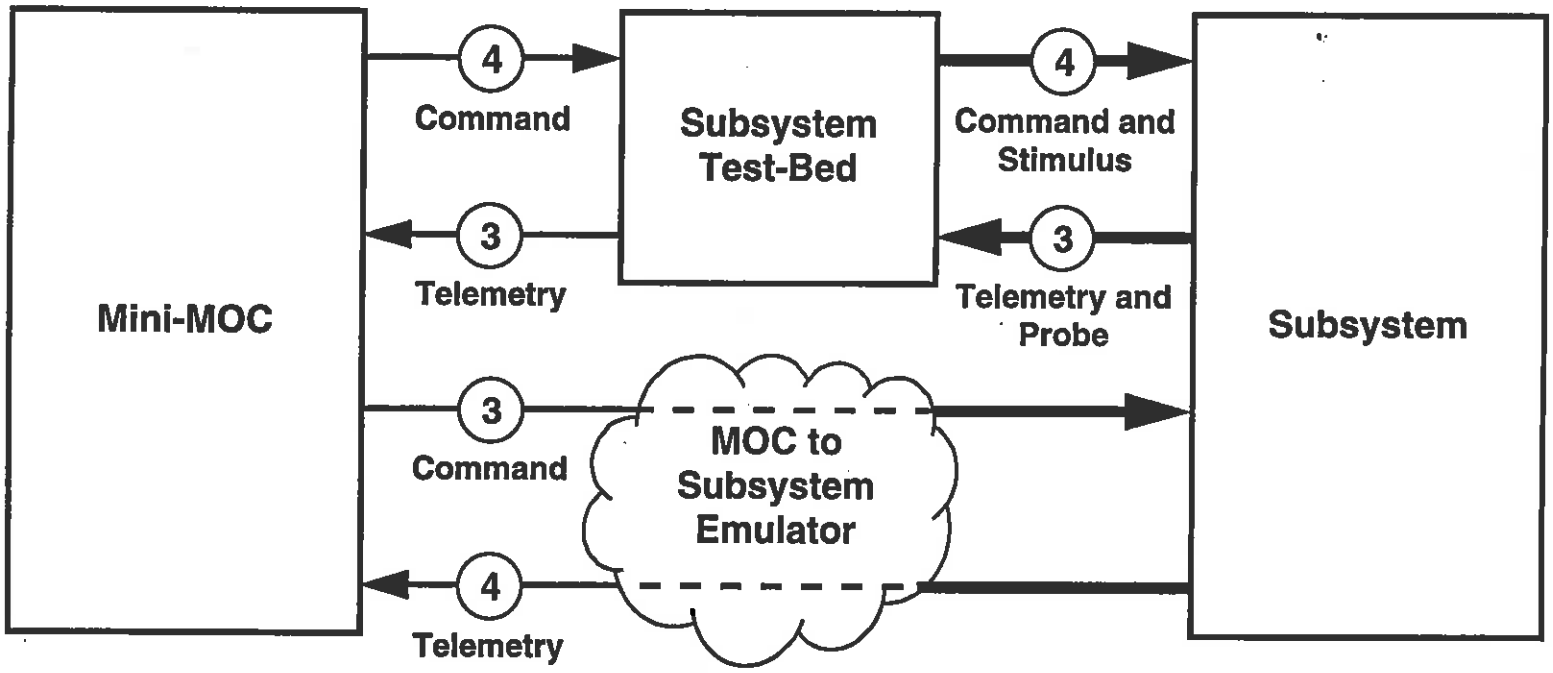
This arrangement includes four command and telemetry path permutations (continued):

3. The MOC commands the subsystem; the test-bed probes (or receives telemetry from) the subsystem; the test-bed sends telemetry to the MOC.
4. The MOC commands the test-bed; the test bed stimulates (or sends commands to) the subsystem; the subsystem sends telemetry to the MOC.

The testing of the C&DH subsystem uses both paths 3 and 4 above.

As another example of the power of this arrangement, consider how we send bad (i.e. intentionally flawed) commands to the C&DH for testing error paths. The MOC is configured to send only good commands, so the test-bed performs this assignment. The MOC triggers this activity by sending a command to the IEM test-bed which includes a filename. The IEM test-bed sends the contents of the file to the C&DH subsystem. The MOC looks in C&DH subsystem telemetry for a bad command status.

What is the Mini-MOC and what it is NOT



Key:

TCP/IP socket over ethernet ———

Hard-wired ▬▬▬

EPOCH 2000

- **EPOCH 2000 package from Integral Systems, Inc. selected via RFP-9895 in January, 1997**
- **Product selection process was discussed at the PDR**
- **EPOCH 2000 is used in the NEAR MOC**
- **Version 2 of EPOCH 2000, customized for the TIMED MOC, was delivered in July, 1997**
- **Originally planned to use EPOCH 2000 version 3, but we have abandoned those plans since:**
  - **V2 satisfies our requirements as well as V3**
  - **V2 is stable, and**
  - **V3 will be available too late**

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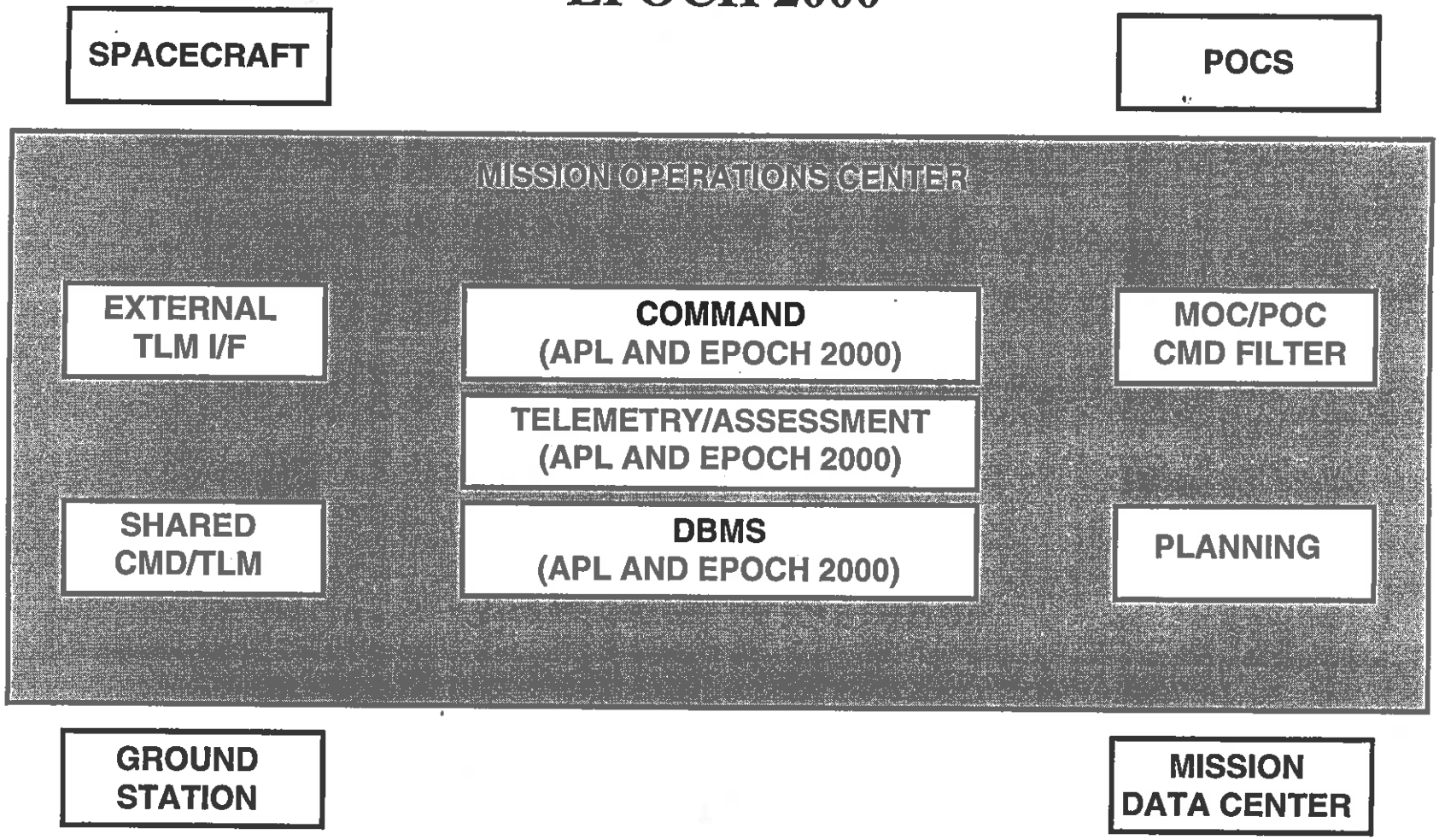
EPOCH 2000



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MOC Software Builds

- **Build 1.0: The Mini-MOC, delivered 9/97**
- **Build 1.5: Mini-MOC plus COP-1*, 12/97**
- **Build 2.0: The Integration and Test Build, needed before the start of I&T, 7/98**
- **Build 3.0: The Mission Operations Build, needed before mission simulation testing, 2/99**

*** Command Operations Procedure-1, described in the Consultative Committee for Space Data Systems (CCSDS) Blue Book 202.1-B-1**

MOC Software Builds (continued)

- **Each module includes a source:**
  - **[MOC] if it is supplied by the MOC software team,**
  - **[MDC] if it is supplied by the Mission Data Center software team,**
  - **[T] if the source is TBD,**
  - **[E] if it is supplied by EPOCH 2000,**
- **Each module includes the build number(s) which include new versions of the module**

- Directive Execution Environment [E] (1.0): Includes the ability to enter either individual commands or commands included in STOL procedures.
- Script Building Environment [E] (1.0): An editor used for inputting STOL procedure.
- Remote Script Viewer [E] (2.0): A way to view a STOL procedure which is executing on a remote workstation.
- Low-level Directive Processing [E] (1.0): Includes command input syntax and range checking; communicates with the APL CMDIF program described below.
- APL/EPOCH Command Interface [MOC] (1.0, 1.5, 2.0): Also called CMDIF, this program accepts commands from EPOCH 2000, forms them into packets, sends them either to the MOC/POC Command Filter or to GSE, and returns status to EPOCH 2000.

Command CSCI Modules

- **Directive Execution Environment [E] (1.0)**
- **Script Building Environment [E] (1.0)**
- **Remote Script Viewer [E] (2.0)**
- **Low-level Directive Processing [E] (1.0)**
- **APL/EPOCH Command Interface [MOC] (1.0, 1.5, 2.0)**

- Display Building Environment [E] (1.0): Allows user to build telemetry displays.
- Display Execution Environment [E] (1.0): Allows users to launch telemetry displays.
- Telemetry Decommutation Utility [E] (1.0): Changes telemetry from raw to engineering units.
- Alarm Processor [E] (1.0): Alarms telemetry.
- Build Telemetry [MOC] (1.0): Accepts GSE telemetry and forms it into packets and transfer frames for display, decommutation, alarm, and archival.
- APL/EPOCH Telemetry Interface [MOC] (1.0): Also called TLMIF, gets telemetry from the MDC and gives it to EPOCH 2000.
- Telemetry Playback Utility [MOC] (1.5): Tape recorder user interface to play archived telemetry through the EPOCH 2000 viewer.
- Engineering Dump Utility [MOC] (1.5): Allows user to get engineering units for selected telemetry points over a time range. Output is to the screen or to a file suitable for loading to a spreadsheet.
- Merge Capability [MOC] (2.0): Merges MOC telemetry and alarm logs with similar products from the POCs.

Telemetry/Assessment CSCI Modules

- **Display Building Environment [E] (1.0)**
- **Display Execution Environment [E] (1.0)**
- **Telemetry Decommutation Utility [E] (1.0)**
- **Alarm Processor [E] (1.0)**
- **Build Telemetry [MOC] (1.0)**
- **APL/EPOCH Telemetry Interface [MOC] (1.0)**
- **Telemetry Playback Utility [MOC] (1.5)**
- **Engineering Dump Utility [MOC] (1.5)**
- **Merge Capability [MOC] (2.0)**

- Serve Telemetry User Interface [MOC] (1.5): GUI user interface to TLMIF described above.
- Ad-Hoc Query Utility [MOC] (3.0): Allows users to use the industry standard SQL query language against a database telemetry points stored in engineering units.
- Run-Time Processing Utility [MOC] (2.0): Assessment tool which calculates how long certain boxes have been powered on the spacecraft based on telemetry.
- Trending Report Capability [MOC] (2.0): Assessment tool which reports min, max, and mean of key telemetry points.

Telemetry/Assessment CSCI Modules (continued)

- **Serve Telemetry User Interface [MOC] (1.5)**
- **Ad-Hoc Query Utility [MOC] (3.0)**
- **Run-Time Processing Utility [MOC] (2.0)**
- **Trending Report Capability [MOC] (2.0)**

- Command and Telemetry Table Definition [E] (1.0): ORACLE database of command and telemetry definitions.
- Manual Input Environment [E] (1.0): ORACLE forms input program for command and telemetry definitions.
- Telemetry Spreadsheet Input Environment [MOC] (1.0): Excel spreadsheet for inputting telemetry definitions.
- Telemetry Spreadsheet Output Environment [MOC] (1.0): Excel spreadsheet for outputting telemetry definitions.
- Command Packet and Format Description Tables [MOC] (1.0): File used to tell APL written command generation code how to package commands.
- Report Capability [MOC] (2.0): Enhanced command and telemetry dictionary reports.
- MDC Interface [MOC] (3.0): Telemetry decommutation algorithms will be furnished to the MDC if needed.

Database Management System Modules

- **Command and Telemetry Table Definition [E] (1.0)**
- **Manual Input Environment [E] (1.0)**
- **Telemetry Spreadsheet Input Environment [MOC] (1.0)**
- **Telemetry Spreadsheet Output Environment [MOC] (1.0)**
- **Command Packet and Format Description Tables [MOC] (1.0)**
- **Report Capability [MOC] (2.0)**
- **MDC Interface [MOC] (3.0)**

- Authenticate [MOC] (1.0, 2.0): Validates POC commands.
- Command Return Receipt [MOC] (1.0, 2.0): Furnishes return receipts for POC commands.
- Build SCF [MOC] (1.0): Builds supplemented command frames (SCFs.)
- COP-1 [MOC] (1.5): Implements CCSDS COP-1 protocol.
- Command Logging [MOC] (1.0): Logs commands to a time tagged ASCII event log.
- Queue Flow and Flush Control [MOC] (2.0): Administers POC instrument command queues.
- MDC Command Logging Interface [MOC] (2.0): All SCFs which are sent to the spacecraft are also sent to the MDC for archival.
- Recover CP [MOC] (1.0): A Mini-MOC only module which extracts packets from SCFs.

MOC/POC Command Filter Modules

- **Authenticate [MOC] (1.0, 2.0)**
- **Command Return Receipt [MOC] (1.0, 2.0)**
- **Build SCF [MOC] (1.0)**
- **COP-1 [MOC] (1.5)**
- **Command Logging [MOC] (1.0)**
- **Queue Flow and Flush Control [MOC] (2.0)**
- **MDC Command Logging Interface [MOC] (2.0)**
- **Recover CP [MOC] (1.0)**

- Build TP [MOC] (1.0): Accepts non-packetized GSE telemetry and builds it into packets. Part of the Build Telemetry program
- Build STF [MOC] (1.0): Accepts packetized telemetry and builds it into supplemented transfer frames (STFs). Part of the Build Telemetry Program.
- Serve Tlm [MDC] (1.0, 2.0): Accepts STFs and serves supplemented telemetry packets (STPs) to the MOC.
- TF+ to STF Translator [MDC] (1.0, 2.0, 3.0): Translates a transfer frame including a non-APL header into one with an APL header.

External Telemetry Interface Modules

- **Build TP [MOC] (1.0)**
- **Build STF [MOC] (1.0)**
- **Serve Tlm [MDC] (1.0, 2.0)**
- **TF+ to STF Translator [MDC] (1.0, 2.0, 3.0)**

- Orbit Position Display [T] (3.0): An Orbit position display capability shows the satellite's position relative to a map of the earth.
- Orbit Analysis Tool [T] (3.0): An orbit analysis tool such as the Satellite Tool Kit.
- Autonomy Compiler [MOC] (3.0): Autonomy rule generation software provides the capability to define an autonomy rule in an English-like manner, and have it translated into STOL.
- Operational Timeline Tool [T] (3.0): Produces a graphical representation of the spacecraft's planned operational timeline.
- Resource Modeling Utility [T] (3.0): This software accounts for the status of various spacecraft resources.
- Orbit Element to Antenna Interface [MOC] (3.0): Orbit Elements, derived from telemetry, are sent to the antenna control software.
- Planned/As Flown Timeline Generation [MOC] (3.0): as described in the GIIS, section 8.
- Contact Plan Generation [MOC] (3.0): Produces contact plans.

MOC: Planning Tools Modules

- **Orbit Position Display [T] (3.0)**
- **Orbit Analysis Tool [T] (3.0)**
- **Autonomy Compiler [MOC] (3.0)**
- **Operational Timeline Tool [T] (3.0)**
- **Resource Modeling Utility [T] (3.0)**
- **Orbit Element to Antenna Interface [MOC] (3.0)**
- **Planned/As Flown Timeline Generation [MOC] (3.0)**
- **Contact Plan Generation [MOC] (3.0)**

- Processor Load and Dump Utility [MOC] (2.0): Accepts spacecraft bus processor loads and produces a STOL load procedure and an expected image. Builds actual image from dump telemetry. Includes a expected vs. actual comparison.
- CMD/Telemetry Graphical Extension [T] (3.0): Graphic package to enhance EPOCH 2000 telemetry display capabilities.
- Command/Telemetry Event Logger [E + MOC] (1.0, 2.0): Logs all events to an ASCII time-tagged log. May trigger actions such as dialing somebody's beeper.

MOC: Shared Command/Telemetry Tools Modules

- **Processor Load and Dump Utility [MOC] (2.0)**
- **CMD/Telemetry Graphical Extension [T] (3.0)**
- **Command/Telemetry Event Logger [E + MOC] (1.0, 2.0)**

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Mini-MOC Screen Samples

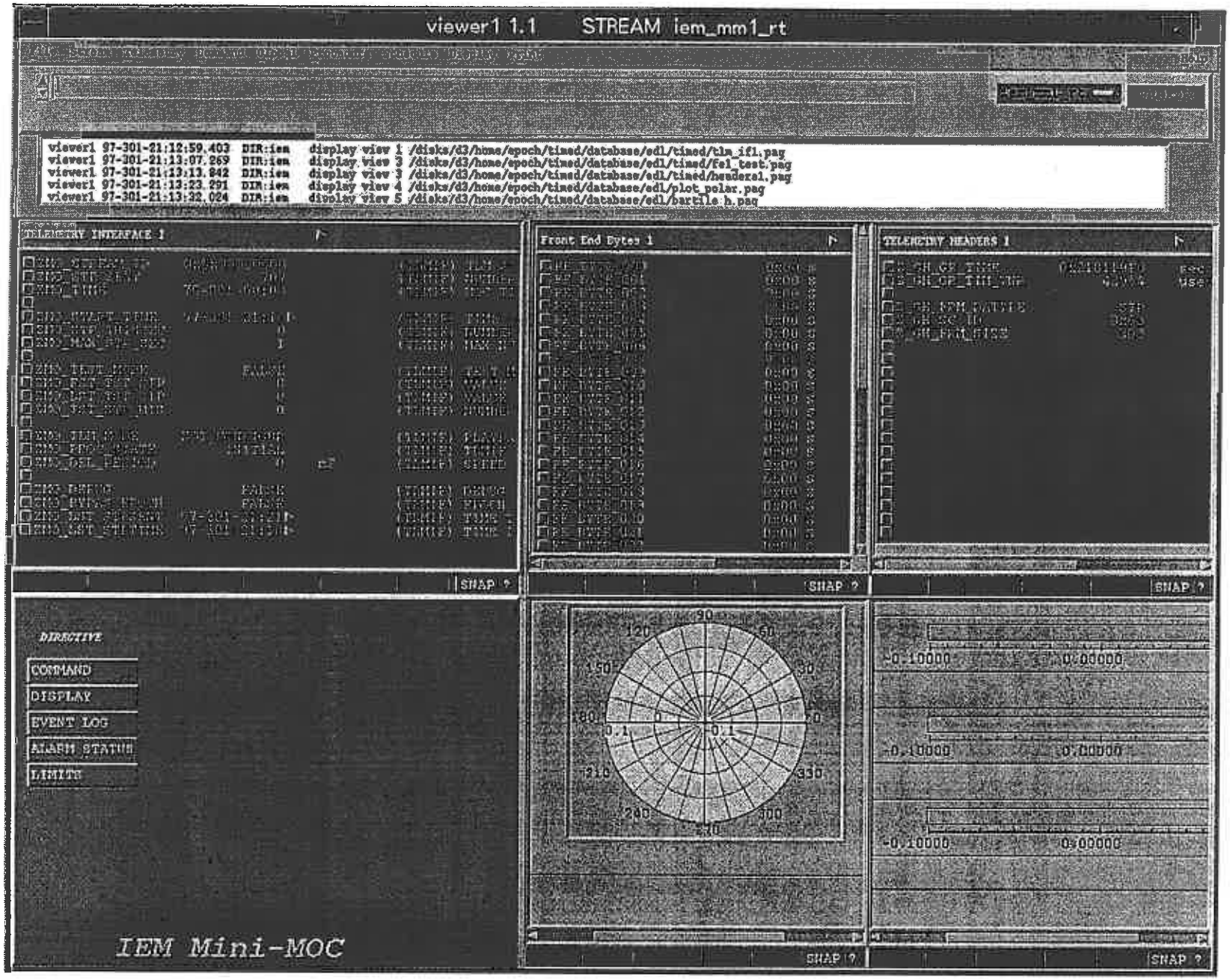
- **Mini-MOC Viewer Sample**
- **Mini-MOC Command Window Sample**
- **Mini-MOC Event Log Sample**

This slide shows the EPOCH 2000 Viewer. The viewer may be customized by the user.

The rectangle with the text "IEM Mini-MOC" includes buttons which can send directives, bring up telemetry displays, launch UNIX shell scripts, or launch UNIX programs.

Telemetry displays may be free floating or attached to a viewer. The displays on this viewer are attached.

Telemetry displays may be in tabular, plot, bar, or other formats.


viewer1 1.1 STREAM iem_mm1_rt
viewer1 97-301-21:12:59.403 DIR:iem display view 1 /disks/d3/home/epoch/timed/database/edl/timed/tlm_if1.pag
viewer1 97-301-21:13:07.269 DIR:iem display view 3 /disks/d3/home/epoch/timed/database/edl/timed/fel_test.pag
viewer1 97-301-21:13:13.842 DIR:iem display view 3 /disks/d3/home/epoch/timed/database/edl/timed/headers1.pag
viewer1 97-301-21:13:23.291 DIR:iem display view 4 /disks/d3/home/epoch/timed/database/edl/plot_polar.pag
viewer1 97-301-21:13:32.024 DIR:iem display view 5 /disks/d3/home/epoch/timed/database/edl/bartile_h.pag
TELEMETRY INTERFACE 1
Front End Bytes 1
TELEMETRY HEADERS 1
SNAP ?
DIRECTIVE
COMMAND
DISPLAY
EVENT LOG
ALARM STATUS
LIMITS
IEM Mini-MOC
-0.10000
0.00000

WLM-23

This is shows the Command Procedure pop-up window.

Single commands may be generated from the command line which is located in the upper left hand corner of the viewer, below the word Stream.

The Procedure pull-down menu allows the user a choice of STOL procedures to execute. Once a procedure is selected, this pop-up window appears. The window can be resized or moved if necessary.

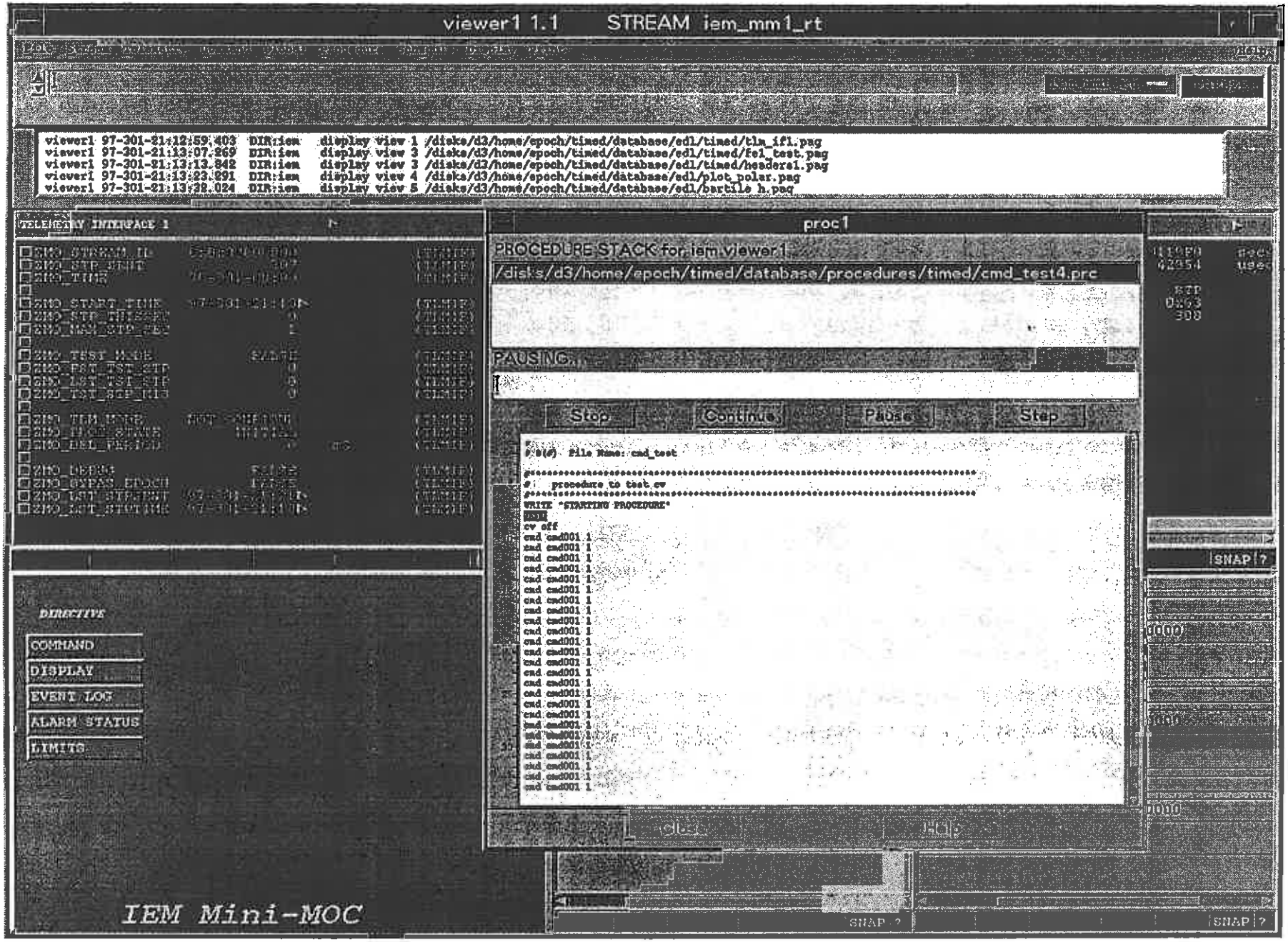
The user may continue through the procedure or single step through the procedure.

The current line of the procedure is highlighted.

The user may go to a line number.

One procedure may call another procedure.

The user can stop a procedure.

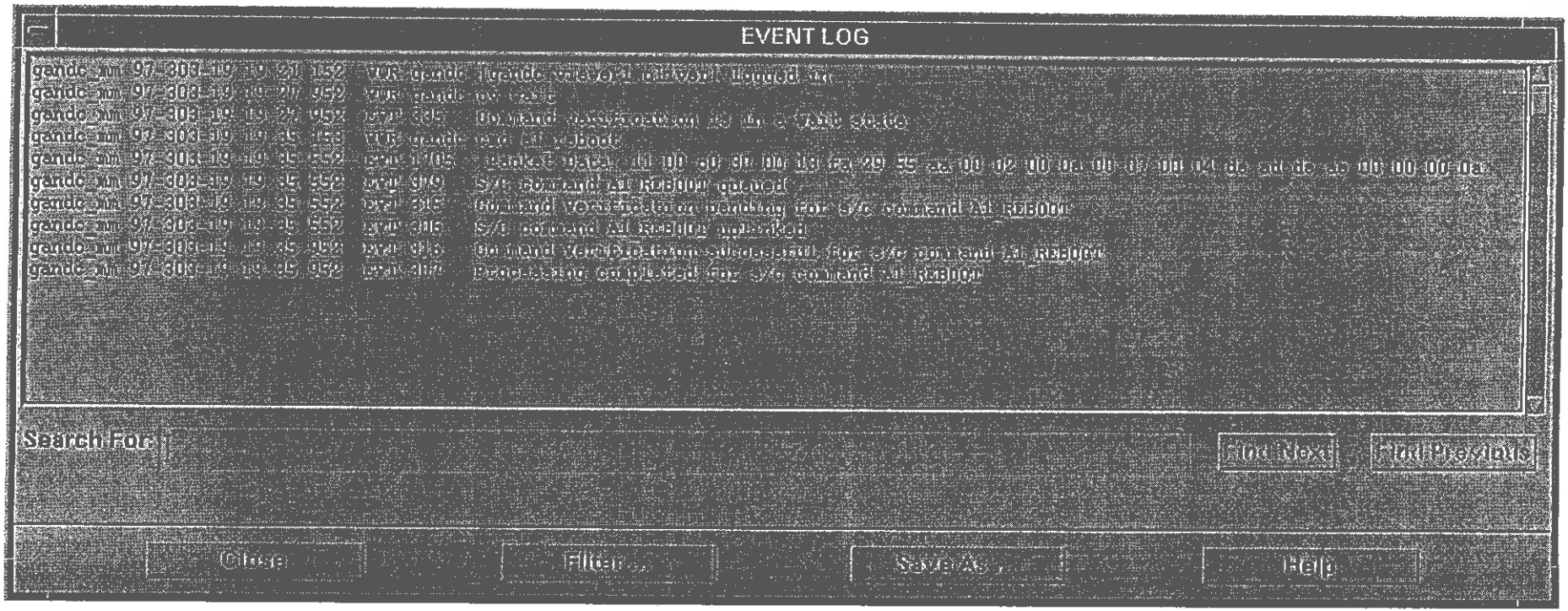

viewer1 1.1 STREAM iem_mm1_rt
viewer1 97-301-21:12:59.403 DIR:iem display view 1 /disks/d3/home/epoch/timed/database/edl/timed/tlm_if1.pag
viewer1 97-301-21:13:07.269 DIR:iem display view 3 /disks/d3/home/epoch/timed/database/edl/timed/fel_test.pag
viewer1 97-301-21:13:13.842 DIR:iem display view 3 /disks/d3/home/epoch/timed/database/edl/timed/header1.pag
viewer1 97-301-21:13:23.091 DIR:iem display view 4 /disks/d3/home/epoch/timed/database/edl/plot_polar.pag
viewer1 97-301-21:13:28.024 DIR:iem display view 5 /disks/d3/home/epoch/timed/database/edl/bartile_h.pag
TELEMETRY INTERFACE 1
proc1
PROCEDURE STACK for iem_viewer1
/disks/d3/home/epoch/timed/database/procedures/timed/cmd_test4.prc
PAUSING...
Stop
Continue
Pause
Step
DIRECTIVE
COMMAND
DISPLAY
EVENT LOG
ALARM STATUS
LIMITS
IEM Mini-MOC
SNAP ?

WLM-24

This is an example of a Mini-MOC event log. This example shows the events which were generated by sending the a1_reboot command.

There are several points to be made with this example:

1. Events may be generated by either EPOCH 2000 or APL code. In this example, event 1705 was generated by the APL written Command Interface Program, CMDIF. The other events were generated by EPOCH 2000.
2. The event which says that a command is queued is generated when CMDIF accepts a command from EPOCH 2000.
3. The event which says that a command is uplinked indicates that the command has been sent from the MOC/POC Command Filter to the Ground Station Front End. (Simulated in the Mini-MOC.)
4. The event which says that a command verification is successful indicates that a spacecraft packet was successfully delivered based on the C&DH packet history buffer in telemetry. (Simulated in the Mini-MOC.)


EVENT LOG
Search For:
Find Next
Find Previous
Close
Filter...
Save As...
Help

MOC Software Documentation

- **Mission Operations Center Software Development Plan, Document Number 7363-9035, January 17, 1997**
- **Mission Operations Requirements Document, Document Number 7363-9021, October 1996**
- **Mission Operations Center Preliminary Software Design Specification, Document Number 7363-9036, November 8, 1996**
- **Build TP and Build STF Interface Control Document, Rev 3, Document Number 7363-9305, August 6, 1997**

MOC Software Documentation (continued)

- **MOC/POC Command Filter and Recover CP Interface Control Document, Document Number 7363-9306, October 17, 1996**
- **APL/EPOCH 2000 Command Interface Program Document, Document Number 7363-9307, November 6, 1997**
- **MOC Functional Software Design Specification, Mini-MOC Version, Document Number 7363-9304, November 21, 1997**
- **Future documentation will be produced as described in the MOC Software Development Plan**

MOC Software Development Environment and Languages

- **MOC Software runs on Sun UltraSparc Workstations running the Solaris (UNIX) Operating System.**
- **The Sun Visual C++ Workshop development tool is used as a compiler and a debugger.**
- **Most MOC software is written in C++. C is used for EPOCH 2000 interfaces and ORACLE interfaces.**

MOC Software Reviews

- **MOC Software Build #1 Design Review, May 8, 1997**
- **MOC Telemetry Dictionary Load and Dump Program Code Walkthrough, July 22, 1997**
- **MOC Telemetry Service User Interface Program Code Walkthrough, October 17, 1997**
- **Future reviews will be held as described in the MOC Software Development Plan**

MOC Software Testing

- **Testing for each build includes:**
  - **unit testing performed by the developers,**
  - **an integration test plan administered by the the MOC Software Lead Engineer for Build 1 and by the Ground System Segment Engineer for Builds 2 and 3, and**
  - **acceptance testing performed by the users.**

MOC Software Configuration Management

- **MOC software team is following the TIMED Ground System Software CM Plan.**
- **The team plans to incorporate the SRS group recommended MKS product into MOC Builds 2.0 and 3.0.**

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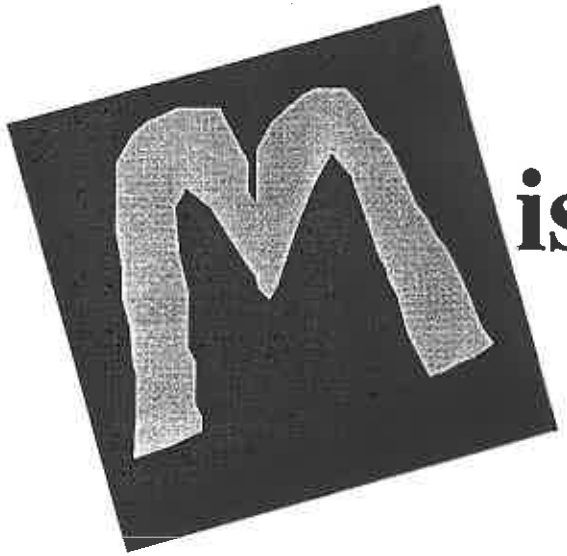

ission Operations Center Software

Any Questions?