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MULTIMISSION GROUND DATA SYSTEM SUPPORT
OF
NASA'S PLANETARY PROGRAM

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ABSTRACT

NASA funds the Multimission Operations Systems Office (MOSO) at the Jet Propulsion Laboratory to design, develop, and operate the Advanced Multimission Operations (AMMOS) multimission ground data system capabilities that are used to control operational spacecraft and process data returned from a variety of planetary missions. The AMMOS design is based on use of modular, networked capabilities and industry standard hardware and software. Individual missions adapt multimission tools and services to support ground data processing during spacecraft development and operations. Utilization of a multimission core capability significantly reduces the cost of development and operation of ground data systems for each individual project. This paper describes the AMMOS system, and the general purpose set of AMMOS multimission capabilities, services and tools that are used to support the NASA planetary program. These capabilities include mission planning and analysis tools, sequence

generation tools, command processing, ephemeris generation and optical navigation capabilities, real time engineering and science data processing, monitor and display functions, spacecraft analysis systems, science instrument data processing and photoproduct generation capabilities, data acquisition and distribution services, and tools for production of archival science data records. The system is used to support multiple missions that are operating simultaneously.

INTRODUCTION

MOSO was established at JPL to provide operational capabilities, services and tools that are common to all NASA planetary exploration missions. The MOSO program office supports design, development, operation, and maintenance of the AMMOS system, a distributed ground data system incorporating Unix-based workstations. MOSO also supports continuing evolution of AMMOS to achieve the cost benefits of integrating new technology into the existing system.

Development of AMMOS was initiated in 1985, in response to recommendations from NASA's Solar System Exploration Committee. The committee recommended implementation of a multi mission support capability to minimize operations costs. AMMOS was designed to utilize a distributed workstation based architecture, with maximum utilization

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of industry hardware and software standards.

The remainder of this paper describes the organization of mission operations activities into functional areas of activity at JPL, provides an overview of the AMMOS system architecture, and shows examples of selected multimission tools now in use supporting the planetary exploration program.

MULTIMISSION GROUND DATA SYSTEM OVERVIEW

Figure 1 is an overview of the functions involved in supporting flight operations of a planetary spacecraft. The various functional elements include:

Mission Planning.

Development of an overall plan for conducting a space mission, including development of spacecraft trajectories, an overall data acquisition strategy, etc.

Sequence Development.

Generation of detailed sequences of spacecraft and instrument events, including maneuvers, data acquisition and data transmission to the ground. Constraint checking to insure conflict-free sequences.

Mission Control. Generate and validate detailed command sequences. Monitor spacecraft and instrument health and safety.

Data Transport and Delivery.

Supports acquisition and decoding (if necessary) of telemetry returned from the spacecraft, separation of data into science instrument and engineering data sets, and delivery to users for higher level processing,

Navigation. Produces spacecraft trajectory information, instrument pointing information, and ephemerides data for science observations.

Spacecraft Planning and Analysis. Allocation of science

and engineering resources, monitoring spacecraft performance and resources during operations. Analysis of spacecraft engineering data.

Science Planning and Downlink Analysis. Planning for science instrument observations, determination of instrument parameters for specific observations, conflict resolution between science requests.

Payload Data Processing.

Conversion of science instrument data from telemetry to physical units, preparation of higher order science data products,

Archiving. Produces archival data records containing the permanent set of spacecraft engineering, navigation, science and other project data.

AMMOS supports operation of a set of multimission tools within a distributed networked workstation environment. The functional elements described above are supported by a set of tools designed for use by multiple missions. Tools supporting the functions listed above can be provided within single workstations dedicated to supporting single functions, or multiple functions can be supported by integrating several tools into a single workstation. Functional elements can be supported by subnetworks that are linked with a backbone Local Area Network (LAN).

Figure 2 shows the current AMMOS configuration. Data is received from NASA's Deep Space Network (DSN), via two gateways (SFOC G/W 1, SFOC G/W 2) shown in the upper left hand portion of the diagram. A series of subnetworks is linked by a central I. AN, the MGDS (Multimission Ground Data System) LAN. Individual projects are allocated a subnetwork for their project specific activities, and workstations are linked to the project subnetworks that contain multimission tools adapted for use by each individual project. "The Magellan,

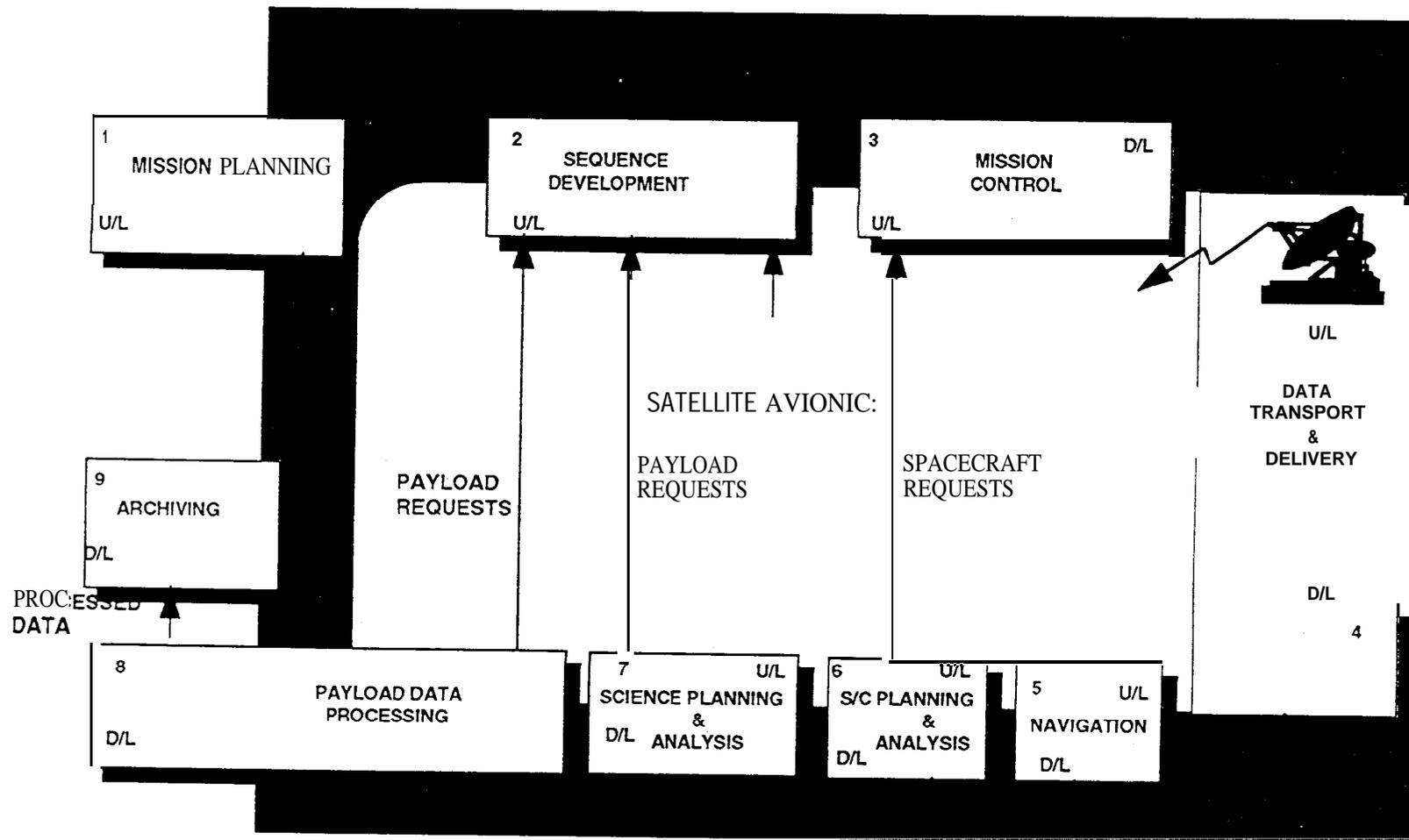


Figure 1
 Fractions Supported by the AMMOS System

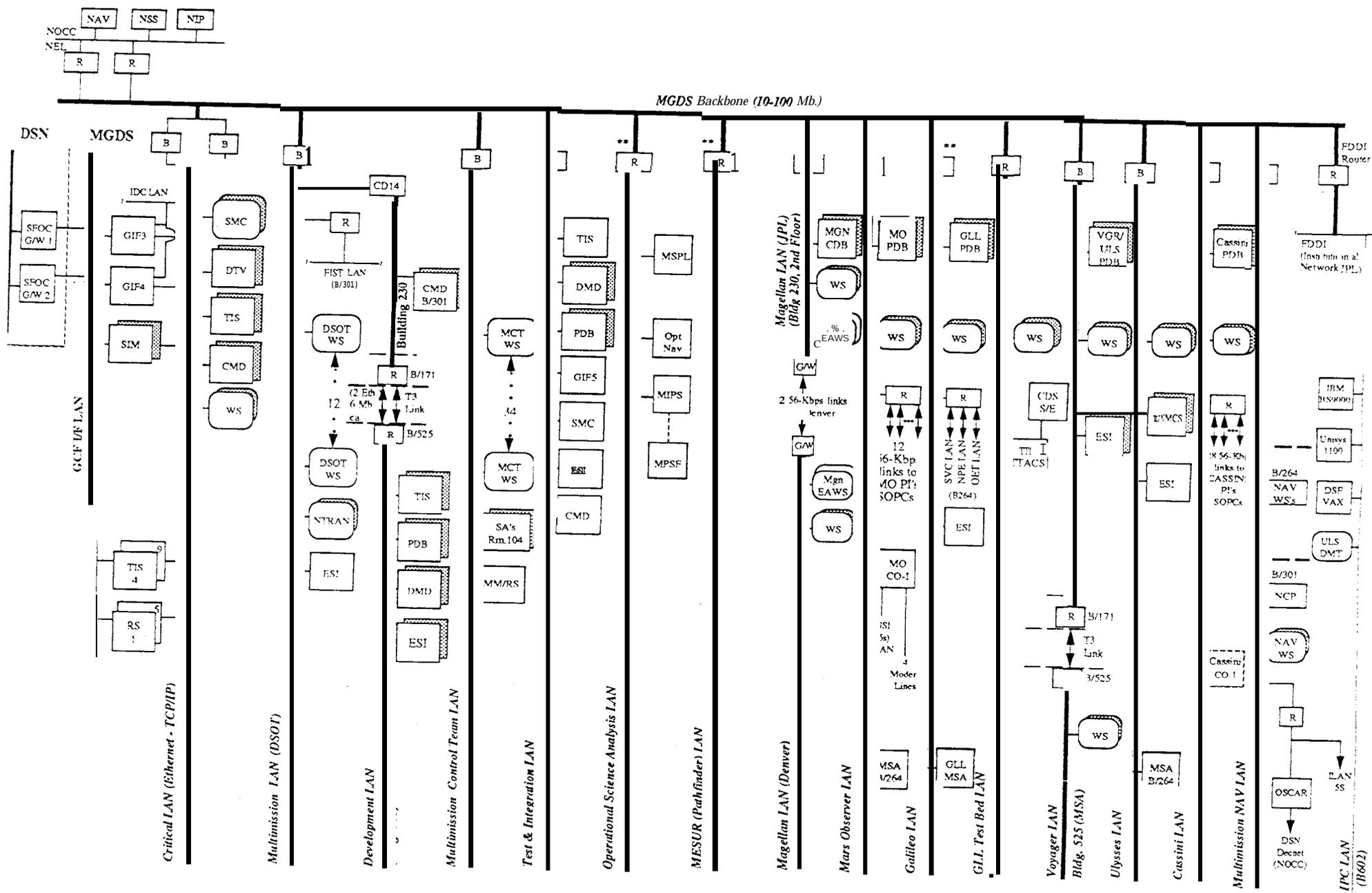


Figure 2
 Multimission Ground Data System Network Configuration

Mars Observer, Galileo, Ulysses and Voyager LAN's are typical of project subnetworks.

Functional activities are also supported via subnetworks. The Operational Science Analysis and Multimission NAV (Navigation) LAN are typical examples. There are also separate subnetworks supporting software development (the Development LAN) and integration and test activities (the Test & integration LAN). Network topology, and the software installed in each workstation, are also configurable based on operations requirements.

EXAMPLES OF MULTIMISSION TOOLS

Science Instrument Data Processing-- The VICAR Software System

The Operational Science Analysis (OSA) Functional Area processes science instrument data, and generation of photographic and digital archival products. OSA utilizes a software system that has been evolving at JPL for over twenty years to process and display science data acquired by planetary spacecraft. This software system is called VICAR (Video information Communication And Retrieval). VICAR includes an executive for overall process management, a user interface including a display manager, and over 200 science instrument processing programs. A core set of multimission software can be adapted to support individual mission requirements for sensor signal processing, information display, and production of specialized products including mosaics, color composite reconstructions, motion vectors derived from multiple imagery of planetary atmospheres. The system includes many routines specifically designed for planetary exploration science analysis that are not found in commercially available or public domain software.

An example of VICAR processing is shown in Figure 3. The figure shows one of the standard

photoproducts generated in support of the Galileo mission to Jupiter. The image was acquired during the second fly-by of the earth in December 1992. Image data is formatted for playback on high precision film recording equipment using general purpose subroutines. The subroutines support functions such as adding text annotation to the imagery, adding gray scales for use in quality control of photoproducts and data interpretation, adding graphics annotation, and adding picture element scales around the image. Photoproducts for a specific mission are designed using the general purpose subroutine set to annotate images with information selected by the science teams for each instrument. In Figure 3, spacecraft navigation and engineering data selected by the Galileo Solid State Imaging Science Team can be seen in the area surrounding the actual image.

Mission Planning and Sequencing Tools

A variety of tools are available within AMMOS that support mission planning and sequence generation of detailed spacecraft sequences. SEQ_POINTER is used as an interactive tool to design remote sensing sequences. The user varies parameters associated with passive remote sensing observations of a particular target by a particular instrument. The program displays the instrument field of view for a particular observation, and can display a series of observations (e.g. a mosaic resulting from a planned mission sequence).

SEQ_POINTER uses spacecraft and planetary ephemeris information, as well as data on the physical characteristics of the spacecraft and detailed information on the specific instrument to generate a display of the results of a particular observation sequence. The user typically iterates, modifying parameters to obtain the sequence of observations required to meet science or mission objectives. The final desired sequence can then be input

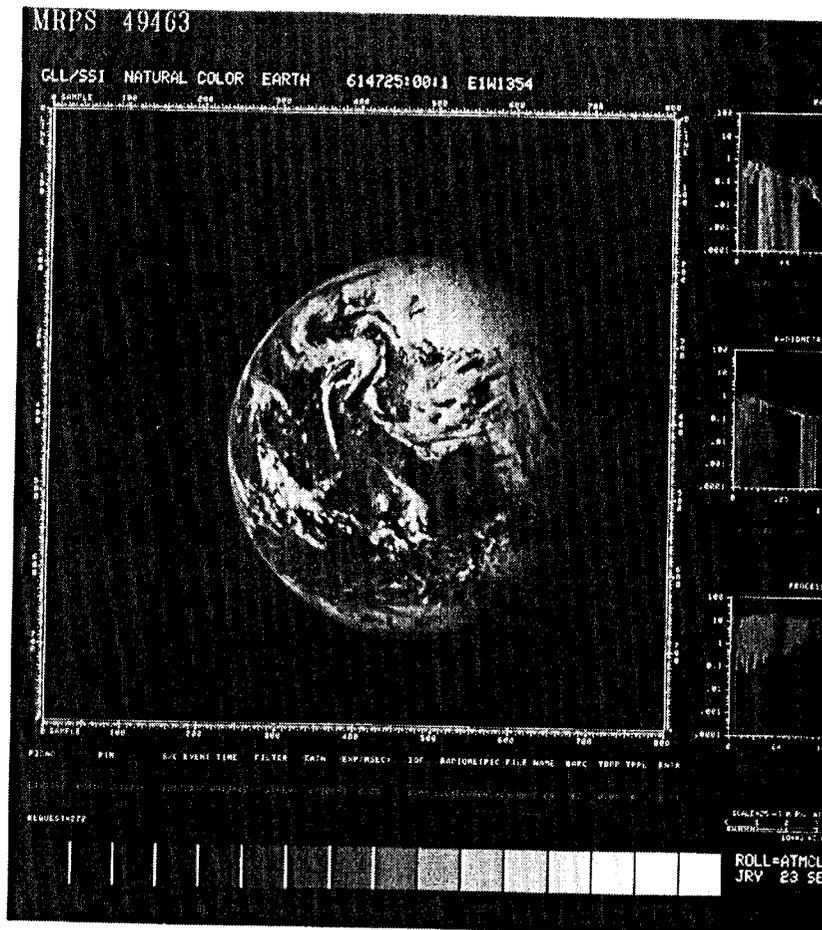


Figure 3
 Example of Photo-product_Generated Using VICAR

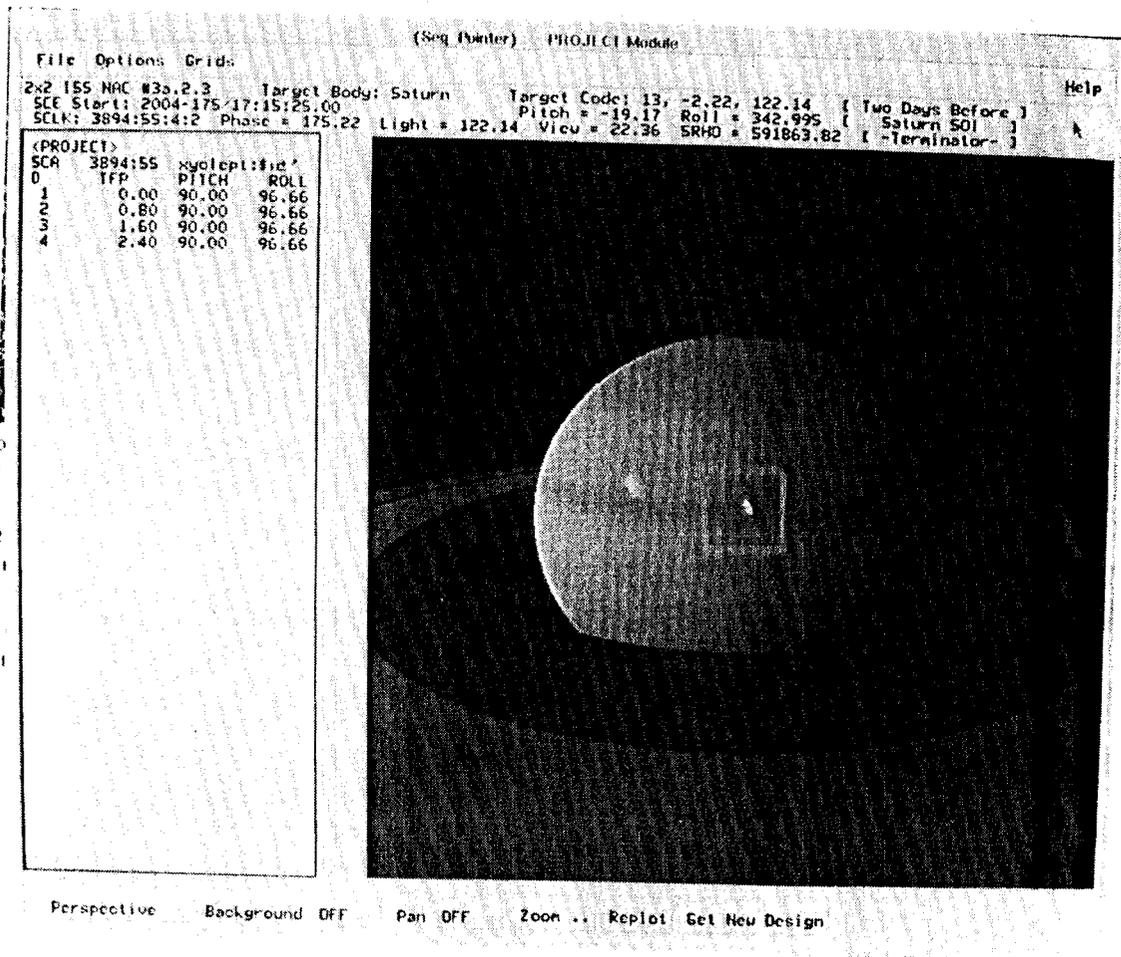


Figure 4
 Mission Planning Display from SEQ-POINTER

into the next step in the uplink process that ultimately produces the actual spacecraft and instrument commands that are sent to the spacecraft to acquire the desired data.

A typical output display from SEQ_POINTER is shown in Figure 4. This is a display of a planned image to be acquired by the Cassini spacecraft at Saturn during flight operations that will commence in 2004. The footprint of the image is shown as an overlay on a graphical representation of the planet. The user can vary the perspective and scale of the graphics display as desired.

Data Analysis Tools

A variety of multimission tools are available for use in real time viewing and analysis of data returned by planetary spacecraft. These tools operate in a Unix workstation environment, under X-Windows.

The Data Monitor and Display (DMD) subsystem is the primary tool for analysis of spacecraft engineering data channels. Figure 5 shows a screen from a typical DMD session. The graphical user interface to DMD is shown in the window on the right hand side of the display. On the left side are plots of two different engineering data streams, from two channels of engineering data selected for analysis by the user. A mission clock tool is located in the upper right hand corner of the display. A third party software tool called xrooms is used to create virtual workspaces that can contain other DMD displays and displays from other sources, as shown in the upper left portion of the display. Mission controllers can view displays from more than one mission, if two or more missions are being supported simultaneously by a multi mission control team.

AMMOS also supports a client-server architecture that enables science and mission operations users to obtain telemetry data streams specific to their needs. The Telemetry Output Tool (TOT) is a graphical client interface to a telemetry storage and delivery server.

The TOT user interface is shown in Figure 6. Users select and attach data types, data transformations, and data sinks by creating data flow definitions as illustrated in the central portion of the display. This figure shows a Galileo mission example. A resource definition file approach is used to insure that the client interface is highly configurable for individual missions,

SUMMARY

MOSO has developed and is operating a modular, scaleable ground data system that supports planetary exploration mission requirements. The system utilizes a Unix workstation based distributed architecture to insure adaptability to future mission requirements at minimal cost. A large class of multimission tools is available that can be configured to support user needs on future missions with minimal effort,

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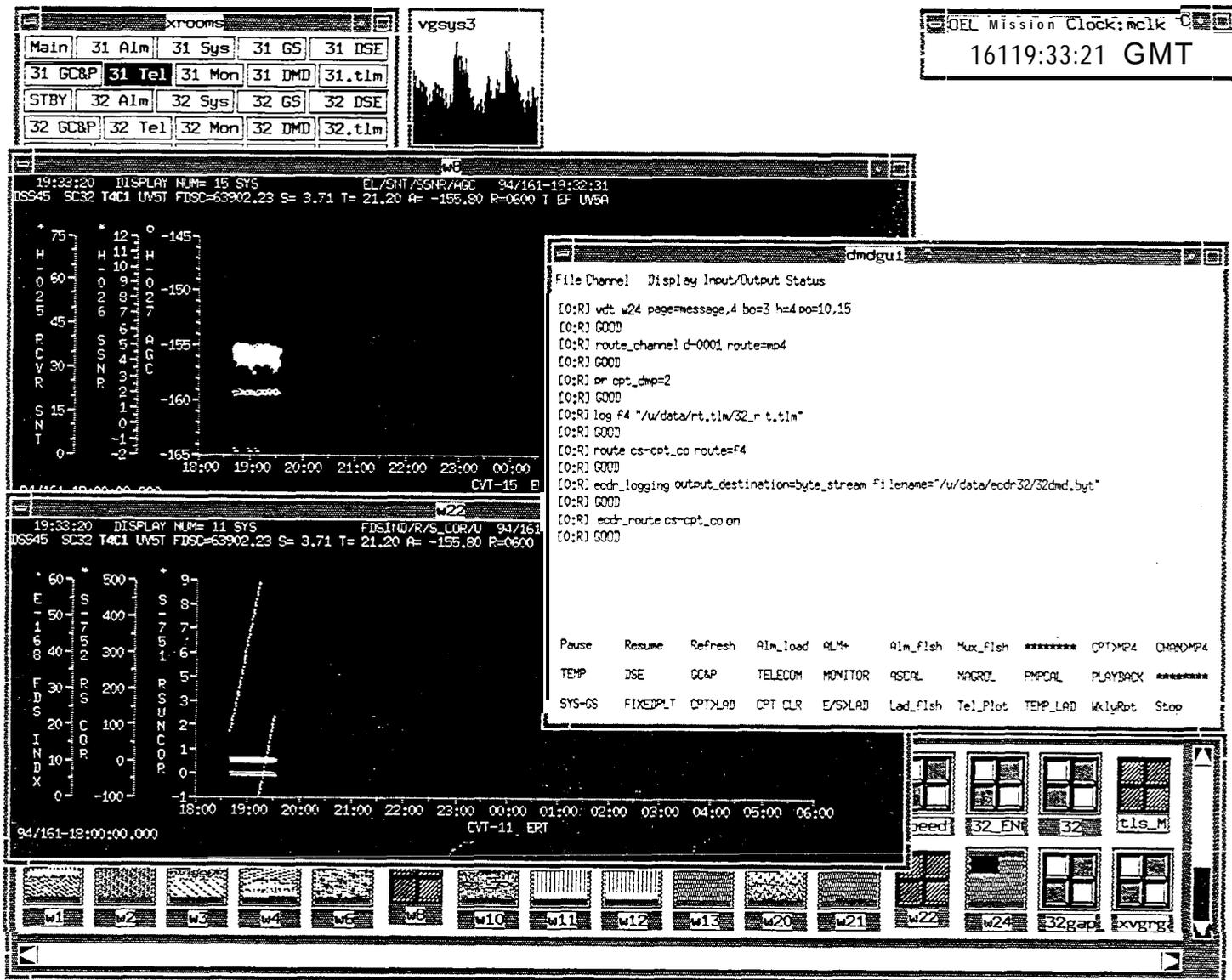


Figure 5

Output from Data Monitor and Display Tool

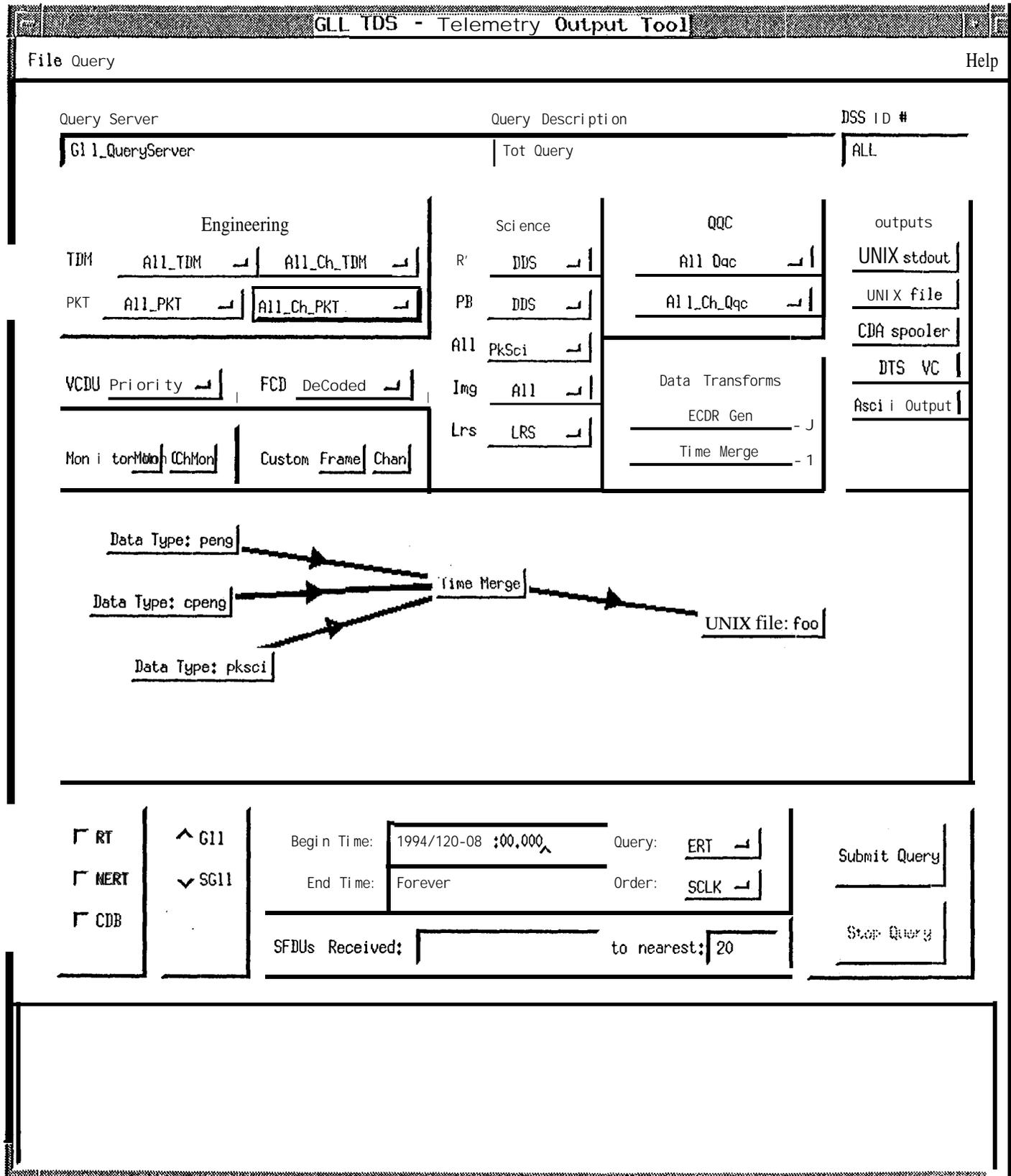


Figure 6
Telemetry Output Tool User Interface