

THE MARS MAPPER SCIENCE AND MISSION PLANNING TOOL*

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ABSTRACT

The Mars Mapper Program (MOM) is an interactive tool for science and mission design developed for the Mars Observer Mission (MO). MOM is a function of the Planning and Sequencing Element of the MO Ground Data System. The primary users of MOM are members of the science and mission planning teams. Using MOM, the user can display digital maps of Mars in various projections and resolutions ranging from 1 to 256 pixels per degree squared. The user can overlay the maps with groundtracks of the MO spacecraft (S/C) and footprints and swaths of the various instruments on-board the S/C. Orbital and instrument geometric parameters can be computed on demand and displayed on the digital map or plotted in XY-plots. The parameter data can also be saved into files for other uses.

MOM is divided into 3 major processes: Generator, Mapper, Plotter. The Generator Process is the main control which spawns all other processes. The processes communicate via sockets. At any one time, only 1 copy of MOM may operate on the system. However, up to 5 copies of each of the major processes may be invoked from the Generator.

MOM is developed on the Sun SPARCStation 2GX with menu driven graphical user interface (GUI). The map window and its overlays are mouse-sensitized to permit on-demand calculations of various parameters along an orbit. The

program is currently under testing and will be delivered to the MO Mission System Configuration Management for distribution to the MO community in 3/93.

Key Words: Mission planning software, digital map display, groundtrack, instrument swath

1. INTRODUCTION

The Mars Mapper Program is an interactive tool for science and mission design developed for the Mars Observer Mission. MOM is a function of the Planning and Sequencing Element of the MO Ground Data System. The following is an overview of the MO Mission to provide the context in which the Mars Mapper is used.

The goal of the MO Mission is to study the martian surface, atmosphere, and gravitational and magnetic fields. To achieve these scientific objectives, the MO S/C will be placed in a sun-synchronous orbit at roughly 400 Km altitude during the Mapping Phase. This is a near-circular, near-polar orbit with repeating groundtracks typical of mapping missions. The MO S/C is currently on its way to Mars and will reach Mars in August of 1993. The Mapping Phase will begin in 12/93 and will last approximately 2 years.

The MO science payload consists of 7 instruments and the Radio Science Investigation (RS). The instruments are: the Gamma Ray Spectrometer, the Magnetometer/Electron Reflectometer, the MO Camera, the MO Laser Altimeter, the Pressure Modulator Infrared Radiometer (PMIRR), the Thermal Emission Spectrometer (TES), and the Mars Balloon Relay. During the Mapping Phase, the MO S/C is nadir pointed. With the exception of PMIRR and TES, the MO instruments are not pointable. Both PMIRR and TES use scanning mirrors to alter the pointing of

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the instrument view. PMIRR is able to point along-track as well as across-track. TES is able to point along-track only. Both instruments are used to point at the planet limb for atmospheric analysis.

2. FUNCTIONAL REQUIREMENTS SUMMARY

The functional requirements for MOm are described in Sec. 4.2.4.11 of the MO Mission Operations Specification Document, Vol 2 (Ref. 1) and are summarized here:

- ◆ MOm shall provide instrument and mission geometric data generation capabilities to support the science mission planning and sequencing activities of the MO Project.
- ◆ MOm shall generate trajectories, instrument footprints, and planetary and solar geometry-dependent information to be displayed in text and in graphical formats as hardcopy or electronic displays.
- ◆ MOm shall read the JPL Navigation Ancillary Information Facility (NAIF) Kernel files and use the NAIF Toolkit to generate all ephemeris and instrument geometry parameters.
- ◆ MOm shall display mission geometric data as vector overlays on digital mars maps produced by the US Geological Survey.
- ◆ MOm shall plot mission geometry data as XY-plots.

Although a GUI is not required by the original functional requirements, due to the graphical nature of MOm and the availability of GUI builders, a GUI was added to the functional design. Refer to the MOm Functional Design Document (Ref. 2) for additional information on the functional requirements and design of MOm.

3. PROGRAM DESCRIPTION

The Mars Mapper assists the scientists and mission planners of the MO Mission by providing both visualization of and values for various mission parameters and instrument geometry parameters during the orbital Mapping Phase of the MO Mission. The user interacts with the MOm through the GUI which is completely menu-

driven. MOm consists of 3 major processes: the Generator, the Mapper, and the Plotter. The Generator is the main control process which spawns all other processes and is the engine which produces all of the mission data of which there are two classes: overlays and parameters. The overlays are data to be displayed by the Mapper such as the S/C groundtrack, instrument footprints and swaths, day/night terminators, planet limb at a point along the orbit, sites, orbit events along the orbit such as the rise/set of the earth, sun, and DSN stations. The parameters are the mission parameters generated at each time step such as sun angles, S/C range, the local hour angle, etc. which can be plotted against time or one another by the Plotter. Close to 200 mission parameters are available to the user. The parameters are selectable by the user and only those selected by the user are computed, displayed, and sent to the Plotter.

The Mapper and Plotter are the visualization tools of the Mars Mapper Program. The Mapper can display digital maps in various projections and overlay the digital maps with groundtracks of the S/C or instrument footprints and swaths provided by the Generator. The overlays are grouped into segments which can be selectively erased, plotted, saved or deleted. This approach is derived from the segment concept of the GKS graphical standards. Similarly, the Plotter displays XY-plots of parameters produced by the Generator. The data generation and display are interactive: the data is displayed by the Mapper and the Plotter as soon as it is computed by the Generator. The plot data may also be directed to a file by turning on a Writer in the Generator. Files created by the Writer are readable by the Plotter for XY-plots.

MOm also has an "Interactive Mode" which sensitizes the mouse to the S/C groundtrack on the Mapper. Depending on the options selected, by clicking the left mouse button at a point along the groundtrack, MOm can display the instantaneous day/night terminator, limb, and the mission parameter values at that point. Thus the user may examine the parameter values along the orbit interactively.

Figure 1. below is the main menu of the Generator Process. The menu bar at the top provides pull down menus which allows the user to set the

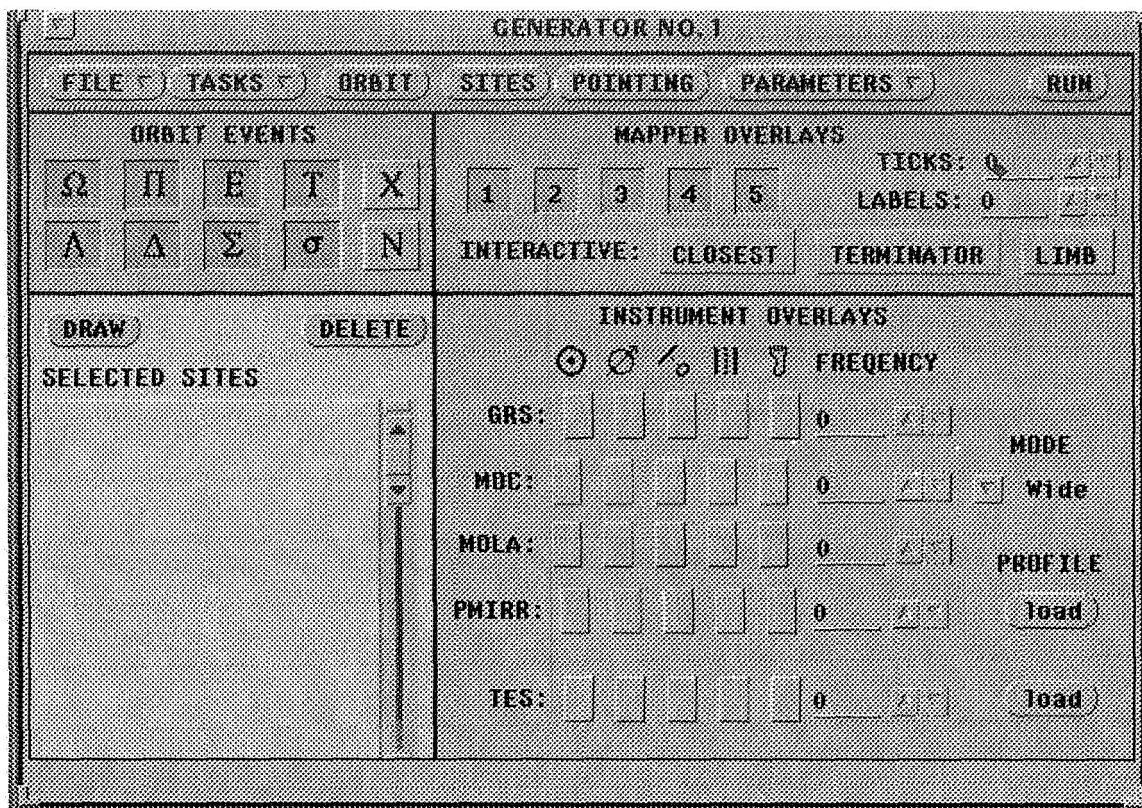


Figure 1. Generator Menu

orbit, invoke Mapper, Plotter, Writer and additional Generator tasks, load and search site databases, analyze instrument pointing, and select and display parameters. The rest of the menu lets the user define the overlay interface between this Generator and the various Mappers. The ORBIT EVENTS Panel at the top left corner just under the menu bar allows the user to select orbit events to be plotted along the groundtrack on the Mapper. The SELECTED SITES List just below the ORBIT EVENTS allows the user to display or delete sites on the Mapper. The MAPPER OVERLAYS Panel lets the user connect this Generator to 5 different Mappers. Here is where the INTERACTIVE Mode buttons are set to sensitize the mouse to the groundtrack for the display of instantaneous terminators, limbs, and parameter values. The INSTRUMENT OVERLAYS Panel allows the user to customize the instrument overlays.

4. ARCHITECTURE AND OPERATIONAL CONCEPT

The 3 major processes of the MOm are the Gen-

erator, the Mapper, and the Plotter. The Generator is the main control which spawns all other processes. The processes are independent and communicate via sockets which provide very efficient two-way interprocess communications. The main advantage of this design is that both the Mapper and the Plotter are independent of the Generator and of the MO Mission. Thus, these programs can be used for other projects without modification. By loading earth maps, the Mapper can display earth orbits. By loading star maps, the Mapper can display orbits on the celestial sphere for skyward pointing missions. In particular, the user may develop his/her own programs to display his/her data in conjunction with that generated by the Generator. Since each Mapper/Plotter is uniquely identified by its socket port number, any process on the network can communicate with the Mapper/Plotter to display data.

This design also enables the use of multiple copies of the Mapper or Plotter. At any one time, only a single copy of MOm may operate on the system. But, within each MOm, the user can in-

voke multiple copies (up to 5 each) of the Generator, Mapper, and Plotter. For example, if the user wishes to have a global view and a close up view of an orbit track, this can be achieved with 2 Mappers connected to a single Generator. Or, if the user wishes to compare the groundtrack of orbits separated by 100 days, this can be achieved by using 2 Generators plotting to the same Mapper. However, the program is not designed to operate at full capacity where all possible processes are invoked. This will push the system resources beyond their limits. The intent is to give the user as much flexibility and control as possible and let the user manage the system resources.

The socket interface to the Mapper is very simple; all Mapper overlays are drawn by using 5 Mapper commands: LINE, TEXT, TICK, SYMBOL, INPUT. The first four are self evident, the last command, INPUT, enables the user to input Mapper commands stored in files. The commands have various parameters which are described in Sec. 7 of the MOm User's Guide (UG, Ref. 3). Each command can also be given a segment name of an arbitrary ASCII string. This enables the Mapper to group the commands into segments which can then be manipulated. This feature enables the user to selectively erase or delete, save and reload overlays.

Similarly, the socket interface to the Plotter is also very simple. The Plotter expects a list of parameter names to be followed by the data in column form. The exact format is described in Sec. 8 of the MOm User's Guide (Ref. 3).

Typically, when the user runs MOm, the Generator Menu (Fig. 1) pops up. The user sets the orbit parameters and the start/stop times and step size under the ORBIT Button. The user may turn on a few instrument footprints or swaths. Then the user brings up a Mapper, Plotter, and Writer under the TASKS Button. The user needs to load a digital map into the Mapper and specify the parameters to be generated under the Generator PARAMETERS Button. Then the user must set the Plotter to plot the parameters just selected. Finally, when every thing is set, the user clicks the RUN button and data generation begins. Groundtracks and instrument tracks appear on the Mapper and plots appear on the Plotter. The socket interfaces are completely transparent to

the user who notices only the different windows popping up processing and displaying the data as he/she specified.

This architecture separates the mission analysis code from the graphics code. This has several advantages. Clearly, the mission-independent graphics code can be reused as-is for any other mission. Completely separating these two very different tasks requiring very different skills, simplifies the software management and maintenance. However, success depends on a simple and well defined interface between the processes.

5. SOFTWARE DEVELOPMENT METHODOLOGY

The MOm software development follows the JPL software standard practices. This includes the functional design review and the combined software requirements and specification design review. Normally, the requirements design review and the specification design review are separate. Due to resource constraints, a waiver was obtained from the project to combine these reviews. For the same reasons, peer review and inspection were not instituted. The resultant requirements and design are documented and described below.

During the functional design phase, the goal was to understand what the MOm does without specifying how the MOm performs these tasks. External interfaces were identified, functional blocks were identified, some new requirements were added and obsolete requirements were deleted. This is documented in the MOm Functional Design Document (Ref. 2).

During the software requirements and specification development phase, the goal was to describe in greater detail what the MOm does. Emphasis was placed on the architectural design and the external interface definition. Extensive functional and data flow diagrams were constructed to review the software architecture and design and to identify possible flaws. At the same time, the GUI was being built. Since there is a close correlation between the various menu items and functionality, the GUI was a design driver and turned out to be an excellent design tool. The resulting

design is documented in the MOm Software Design Document (Ref. 4). Coding began early in the software requirements/specification phase due to schedule constraints. The test version delivery for October 1992 was met.

6. OPERATING ENVIRONMENT

The Mars Mapper Program Version 1.0 has been developed on a Sun SPARCStation 2GX under SunOS V. 4.1.2 and Openwindows V. 3.0. The following programming languages and tools were used for the development:

F77	V. SC1.0
C	SunOS V.4.1.2
DevGuide	V. 3.0
XView	V. 3.0
Codebase	V. 4.2
NAIF Toolkit	V.17.2
PDS Toolkit	
PGPlot	V.4.9

Due to resource constraints, a waiver was obtained from the project to use Sun's Openwindows instead of MOTIF which is the MO Project standard window manager. We had inherited code from previous prototypes which used DevGuide and XView. At the time, the MOTIF GUI builders were expensive and not as easy to use as was DevGuide which was free. We also had little experience with MOTIF and could not have met our tight schedule with the additional time required for the MOTIF learning curve. For additional information, refer to Appendix B of the MOm Functional Design Document (Ref. 2).

The Mars Mapper should be operated on a color workstation. However, it will function with a black and white monitor where the digital map displays are dithered. It can also be brought up under MOTIF although some of the Greek fonts used are replaced by Roman fonts under MOTIF.

7. APPLICATIONS

Although MOm was developed with science and mission planning in mind, it can be equally useful for the analysis of actual and archived data so long as the necessary ephemeris data is in the

NAIF format. The Mars Mapper can also be easily adapted to other planetary missions. Although the instrument footprints and swaths are specific to the MO mission, they can be readily changed to accommodate other missions. The Mapper and Plotter are completely independent of the Generator and the MO mission; they are generic tools. By changing the digital map, the Mapper can display missions for any other planetary body. In fact, we have been using the Mapper to analyze observatory missions such as SIRTf and COGEX. Thus, if a new Generator needs to be developed from scratch, the visualization tools are already available.

8. ACKNOWLEDGEMENT

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9. REFERENCES

1. Hammer, F. et al. 1991, Mars Observer Mission Operations Specification Volume 2: Data System, Launch Phase Final, JPL 642-315
2. Lo, M. 1991. Mars Mapper Functional Design Document, JPL 642-3501-MAP-E.
3. Lo, M. et al. 1992. Mars Mapper User's Guide Version 1, JPL 642-3505-MAP-E.
4. Lo, M. 1991. Mars Mapper Software Design Document, JPL 642-3511-MAP-E.