APPENDIX C

Medium Explorer Ground System and Operations

1. GENERAL

The standard ground system architecture and its functional capabilities as defined for the MIDEX program are described in this Appendix. The elements of this architecture are proven, and currently support a variety of NASA missions including the Small Explorer (SMEX) missions. By providing an architecture based on proven building blocks, maximum flexibility to adapt to specific mission needs is achieved while preserving the cost saving features of maintaining common elements from mission to mission. The fundamental capabilities of these elements are based upon the Consultative Committee on Space Data Systems (CCSDS) standards and can support a wide range of implementations. Investigators may propose an implementation independent of the functions or capabilities defined in this Appendix, although the associated costs must be identified and included in the proposed instrument cost. It is expected that the implementation details necessary to satisfy specific mission needs will evolve in conjunction with the spacecraft and instruments during the definition phase in order to ensure a cost effective approach.

To the greatest extent possible, MIDEX missions will be supported from a common Mission Operations Center (MOC). Taking a multimission approach to the MOC allows MIDEX to share pre- and postlaunch resources for integration and testing, nominal operations and anomaly resolution. The sharing of resources, as demonstrated by the SMEX program, can result in considerable savings to the missions. During the definition phase, a cost effective plan for utilization of MIDEX mission operations resources will be developed. The cost associated with the day to day operation of the MOC (i.e., starting 31 days after launch) by the Flight Operations Team will be included in the MO&DA costs.

In keeping with the philosophy of the program, MIDEX ground operations are structured to balance cost and science return. Proposed investigations should assume that 90% of the science data will be delivered to the Science Operations function. This means that, although unlikely, the equivalent of up to 1 to 2 days of data may not be delivered in a given month. Such an accommodation allows for simpler, more autonomous implementations, with longer response times allowed for anomalies. Examples of anomalies are spacecraft safe hold and communication line outages.

Figure C-1 illustrates the MIDEX ground system functional architecture. The architecture has three parts: Networks, Mission Operations and Data Handling, and Science Operations. Within the bounds of the capabilities advertised in this Appendix, and allowing for some minor mission unique enhancements, the Network and Mission Operations and Data Handling functions will be configured by NASA at no cost to the proposer. The Science Operations function is expected to be provided and costed by the proposer. If a proposer seeks to use an implementation independent of, or with major deviations from, the functions or capabilities defined in this Appendix, the costs associated with such an implementation must be identified and included in the instrument cost. Examples of minor mission unique enhancements are customization of the

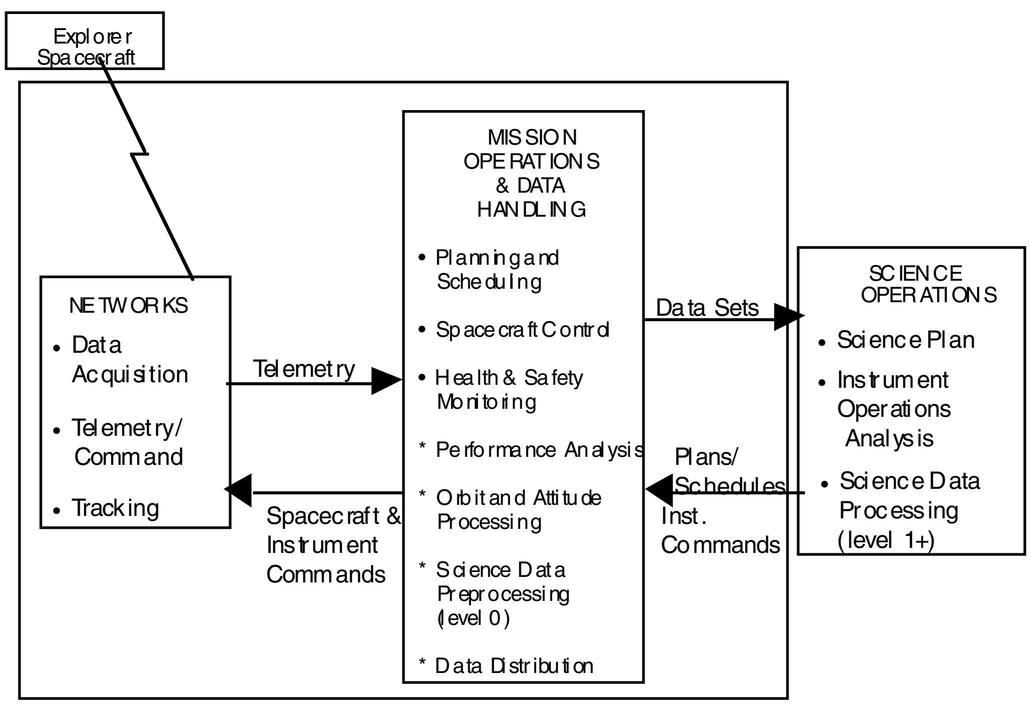

FIGURE C-1 MIDEX GROUND SYSTEM AND OPERATIONS planning and scheduling system for the mission unique resources, adaptation of attitude processing for the mission specific sensors, and definition of data set sizes. Examples of major deviations are the use of other than CCSDS standards for command or telemetry formats or orbit determination on the ground using other than standard tracking data.

2. NETWORKS

Networks are the interface between the spacecraft and the rest of the ground system. The networks acquire telemetry data from the spacecraft, send up-link commands, and track the spacecraft orbit if required. Telemetry and command transmission will use the international CCSDS Advanced Orbiting System (AOS) and Telecommand standards. Additional information can be obtained from the Explorers Project Library (see Section VIII.H in the body of this AO).

A standard set of launch and normal operations ground stations are available to a new mission. Potential sites include the Deep Space Network (DSN), the NASA Wallops Flight Facility (WFF), and high latitude ground stations such as the stations in McMurdo, Antarctica, and Fairbanks, Alaska. Optional implementations such as a Transportable Orbital Tracking Station (TOTS), a low cost ground station at the investigator's site or at another location connected to the investigator's site by communications links, or the Tracking and Data Relay Satellite System (TDRSS) may be made available, at no cost to the proposer, on a case by case basis. Since other developmental and/or operational costs may be incurred in the implementation of any of these options, requirements and capabilities trades during the definition phase will determine the most cost effective approach for the selected mission. Therefore, for proposal purposes only, the standard set of capabilities can be guaranteed at no cost to the investigator. Network support outside this envelope must be costed separately by the proposer. The MIDEX Program will act as the broker for the standard network commitments. The capabilities of the standard network elements are summarized in Table C-1. A lightweight TDRSS transponder/antenna will typically support about 2 Mbps of telemetry data and 2 kbps of command data.

TABLE C-1 STANDARD NETWORK ELEMENT CAPABILITIES

Networks	Contact Duration	Contact Frequency	Maximum Downlink Data Rate	Maximum Communi-cations Rate to U.S.	Maximum Uplink Rate	Comments
WFF	~10 minutes for LEO	One per day to one per orbit, depending on orbit	2.5 Mbps	~1.4 Mbps	2 kbps typical	
TOTS-"like"	~10 minutes for LEO	One per day to one per orbit, depending on orbit	2.5 Mbps	~1.4 Mbps (current capability)	2 kbps typical	High latitude site, local site
DSN	~10 minutes for LEO	One per day to one per orbit, depending on orbit	2.4 Mbps	~670 kbps	2 kbps typical	California, Australia, Spain

For low earth orbits; rates depend on spacecraft communications equipment

3. MISSION OPERATIONS AND DATA HANDLING

Mission Operations provides planning and scheduling of spacecraft operations, spacecraft control, orbit prediction, and spacecraft performance analysis. Spacecraft and network support schedules are integrated with science plans before integrated command loads are created for uplink to the spacecraft. Real-time control of the spacecraft and instruments, command verification, fault detection, and fault correction activities can be augmented with trend analyses in the event of an anomaly to assist in assessing the spacecraft and instrument health.

Normal operations facilities will be shared among missions at GSFC to lower mission operations costs. A basic Flight Operations Team is provided within the baseline ground system to provide basic planning and scheduling, real time health and safety operations around the clock, and, when needed, spacecraft analysis.

If required, orbit determination can be provided as part of the baseline ground system with accuracy dependent on frequency of contact, orbit profile, and drag (5 km accuracy is typical when there are 2 to 4 geometrically distributed daily contacts with the spacecraft). Prelaunch orbital analysis is performed as part of the ground system baseline to address health and safety issues, such as network coverage, tracking requirements analysis, and prediction of spacecraft sun/shadow cycles. Orbit analysis for science drivers (e.g., unique launch window requirements, science viewing analysis, South Atlantic Anomaly studies) are not in the baseline and should be identified and costed in the proposal.

A launch and special operations area and support are available at GSFC for initial operations. This special operations area will also be available to spacecraft subsystem specialists to work mission anomalies during the mission life. Standard components, chosen to match the spacecraft interfaces, are used for the mission operations functions and are available to support the integration and test of both the spacecraft and instruments.

Data Handling includes science data preprocessing and data transport to the science center (if required). Data preprocessing (also called level 0 processing) consists of removing communication artifacts, sorting, ordering, and assembling the data into data sets. The following performance will be available as part of the ground system baseline (larger volumes of data can be handled at additional cost):

- Up to 500 Megabytes per day will be delivered within 24 hours of receipt of a day's sets of data.
- Up to 15% of the data can be delivered within 2 hours of receipt as a quicklook data service.
- Distribution of science data will be electronic, using TCP/IP (transmission control protocol/Internet protocol), unless it is cost effective to send physical media, such as optical disks.

For some spacecraft (for example, those with long contact times and a tight coupling between science and spacecraft operations), a stand-alone spacecraft operations facility combining both Mission Operations and Data Handling and Science Operations functions is appropriate. The software and hardware designs associated with standard system components can be provided to the investigator for performing many of the Mission Operations and Data Handling functions as an alternative to having the service performed by GSFC. The location of standard elements at a user facility will be provided if demonstrated to be cost effective during definition. Operations of these components will be included in the MO&DA cost.

Other options that are available include real time control of the instrument by the investigator when communications contacts exist and rapid replanning within

2 hours for targets of opportunity and contingencies. Possible implementation of these options will be determined on a case-by-case basis during definition.

4. SCIENCE OPERATIONS

Science Operations, which are normally done at the investigator's institution, are not provided as part of the standard ground system. This function includes science data processing, data archiving, payload scheduling, and instrument anomaly resolution. The Science Operations functions should be proposed as a stand-alone system separate from the Mission Operations and Data Handling functions. There may be cost or technical advantages to integrating these functions or providing common solutions with the Mission Operations and Data Handling functions. These potential savings will be explored during the definition phase.

5. EXAMPLE SMALL EXPLORER MISSION GROUND SYSTEM IMPLEMENTATION

The Medium Explorer spacecraft will be supported by a ground system whose heritage includes the SMEX Mission ground system. The following description is included for reference and is illustrated in Figure C-2. It reflects the common capabilities used to support the SMEX Spacecraft, although some of the functions have been moved and updated to reflect the evolving ground system architecture. Each specific SMEX spacecraft has unique functions and interfaces that are not shown in this example.

The SMEX spacecraft use a ground station at the Wallops Flight Facility as the primary space-to-ground link. A Transportable Orbital Tracking Station or the Deep Space Network are used as backup stations. The spacecraft has several contacts per day for tracking, telemetry, and command. The uplink rate is 2 kbps. The downlink rate is approximately 1.8 Mbps. CCSDS formats are used for commands and telemetry. The telemetry data is captured at the ground station and selected virtual channels, including the housekeeping data, are sent in real time to the MOC at GSFC. The rest of the data is buffered and sent after the contact at a rate lower than the real time rate.

NASCOM communications are used between the ground stations and the MOC.

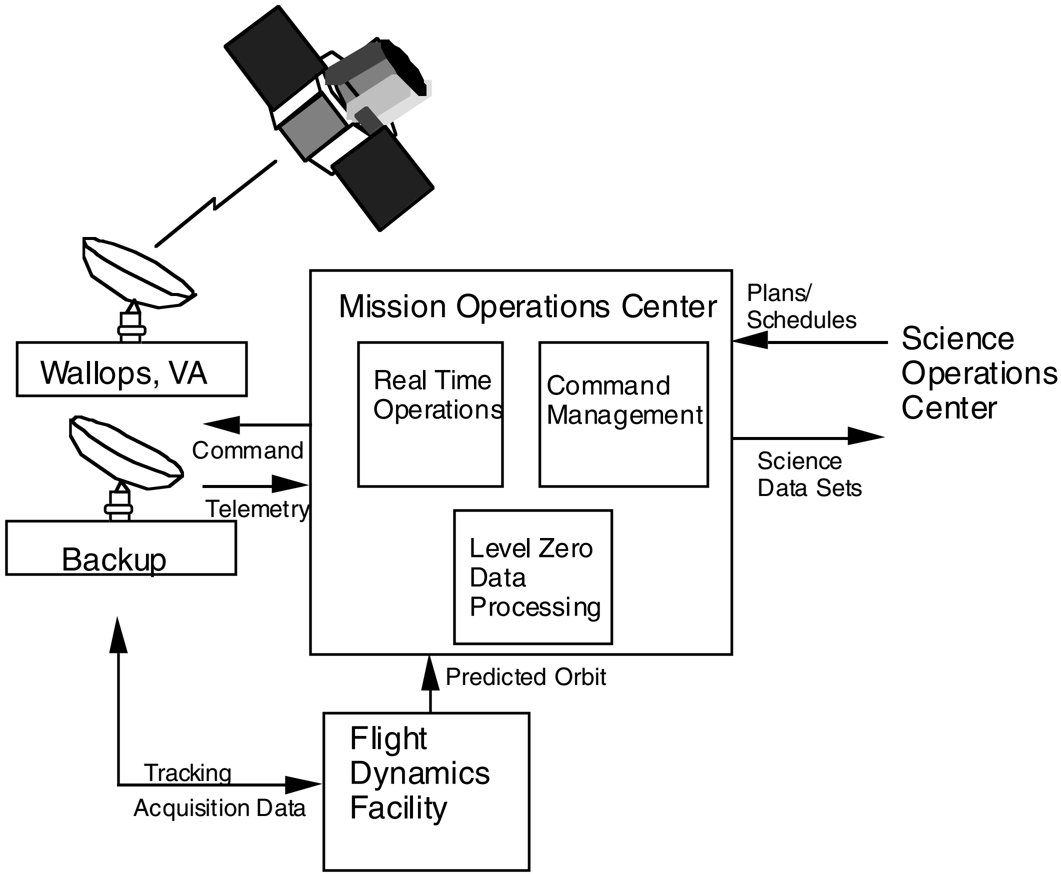

FIGURE C-2 SMALL EXPLORER GROUND SYSTEM EXAMPLE

The MOC is located at GSFC. It supports all of the SMEX spacecraft. There are sufficient equipment and personnel associated with the MOC to prevent this sharing from being a constraint on any particular spacecraft's operations. The MOC performs mission planning and scheduling, command load generation, housekeeping telemetry processing, commanding, attitude monitoring and calibration, spacecraft subsystem analysis, and level zero processing of the science data. The MOC is staffed around the clock.

The Mission Operations Center interfaces to a remote Science Operations Center (SOC). The MOC provides the SOC with planning information. The SOC provides the MOC with science schedules and command loads for the instruments. The MOC provides the SOC with science data. Science data can be provided as production data to the SOC within approximately 1 day. Production data is instrument data with the artifacts of the space to ground communications removed and quality and accounting information appended. Quick look data can also be provided. Quick look data is available within a few hours but duplicate data is not removed and less quality and accounting information can be provided.

The institutional Flight Dynamics Facility at GSFC processes the tracking data from the ground station and generates acquisition data for the ground station and predicted orbit data and other planning aids for the MOC and SOC.