DEEP SPACE PROGRAM
SCIENCE EXPERIMENT
(DSPSE)
MISSION OPERATIONS PLAN
APPENDIX A
GROUND RULES AND CONSTRAINTS
--- Draft 1.0 ---

CONTRACT NO. N00014-89-C-2023
CDRL SEQUENCE NO. A001

February 1, 1993

Prepared for:
Naval Research Laboratory
Naval Center for Space Technology
4555 Overlook Avenue
Washington, D.C. 20375

Prepared by:
Barrios Technology, Incorporated
1331 Gemini
Houston, Texas 77058-2711
1.0 INTRODUCTION

This ground rules and constraints document defines those general requirements that are largely independent of a specific test or experiment. This document is Appendix A of the DSPSE Mission Operations Plan.

1.1 Purpose

The purpose of this document is to identify the requirements, constraints, and assumptions that affect the planning and scheduling of the DSPSE Mission. In its final form this document provides the documented basis for the Mission Operations Plan. It provides the rationale for the activities and priorities scheduled on the mission timeline. In the event that the Mission Operations Plan is reworked, the document will serve as a set of ground rules for scheduling activities.

1.2 Scope

This document addresses all requirements that are to be planned for all on-orbit phases of the DSPSE mission during spaceflight. This includes the following operational phases:

- Low Earth Orbit
- Lunar Transfer Trajectory
- Lunar Orbit Operations
- Geographos Transfer Trajectory
- Geographos Flyby

1.3 Organization

Each statement or paragraph will be preceded by a classification according to the following definitions.

(R) Ground rule. This classification will be given to any statement that is clearly agreed upon by DSPSE management and participants and is supported by written documentation. An example of a requirement is the specification of Pomonkey for primary command and control until the transfer to Geographos.

(C) Constraint. Defined by any physical or operational characteristic of the vehicle, instrument, control team, or ground support equipment. Examples are sensor sensitivities to light, communication acquisition elevation angles, instrument sensing ranges.

(A) Assumptions. Any activity that is not a requirement or constraint but must be included to complete the mission planning timeline. Examples include delay time to open sensor doors to avoid contamination. These assumptions may have been gathered from informal meetings or memos and also include inferences drawn from the requirements and constraints.
2.0 APPLICABLE DOCUMENTS


[NOTE: Include User's Guides and Operations Manuals, ICD's, Safety Documents & Guidelines ]
3.0 GENERAL SPACECRAFT REQUIREMENTS BY MISSION PHASE

3.1 General Requirements

(C) Orbit adjusts have priority over all other spacecraft activities.

(A) Ground personnel must verify receipt of the downlink. If there were problems during the downlink, some of the data may need to be saved for later transmission.

(C) The maximum jitter allowed during imaging is 40 milliradians over 40 milliseconds.

(R) All cameras and the star tracker have an absolute solar exclusion angle of 5 degrees (half angle). Operations should avoid any star tracker or camera have the sun in this cone of exclusion.

3.2 Low Earth Orbit

(R) Both star trackers will be uncovered and functioning to support attitude determination.

(C) Communications from the spacecraft to the ground stations will be via omni antennas at a 128 kbps data rate.

(R) The spacecraft will downlink real-time and stored health and welfare data (telemetry log), and star tracker images during flights over the ground stations.

(R) For most of LEO, the spacecraft will be 3 axis stabilized.

(C) At insertion the angle from the orbit normal to the sun is -29°C providing 60.7% sunlight per orbit. At TTI burn the angle from the orbit normal to the sun is +33.6° providing 61.1% of sunlight per orbit.

(R) Initial acquisition activities will not be nominally scheduled until after entering sunlight (≥30 min. after insertion) and will not happen over a ground station.

(C) The spacecraft must be in sunlight to determine spin rate.

(R) The spacecraft will be spin stabilized prior to the TTI burn.

3.2 Lunar Transfer Trajectory

(R) Solar panels will be deployed only after confirming attitude control.

(R) 12 hours after the TTI burn the star trackers will be uncovered.

(A) Delay uncovering the sensors until 48 - 96 hours after TTI burn to allow residue from the TTI burn to dissipate and for outgassing.
3.3 Lunar Orbit Operations

(A) Depending on the type of ground station antenna and the orbit geometry between the ground station antenna and the onboard omni antenna 8Kbps is possible during lunar operations. Therefore real-time assume we will downlink of real-time image data for certain days and portions of the orbit.

(R) At lunar orbit insertion, the angle between the orbital plane and the sun vector will be set at 26°, so that at the beginning of mapping (5 Earth days after insertion) it will be 21°, half way through mapping it will be -4°, at the completion of mapping, it will be -31°, and at lunar departure (70 days after insertion) this angle will be -43°.

(R) There are 5 days pre-mapping readiness activities with ~ 57 Earth days lunar surface mapping (two lunar days (1 lunar day = 27.3 earth days). There will be 8 days post-mapping activities.

(C) One star tracker will have solar exposure during each lunar orbit and it should be powered off for this time.

(A) The omni antennas will likely provide poor reception above ± 70 degrees latitude so the transmitter may be powered down to save power.

(C) The current estimate to dump one orbits worth of high rate data (image and engineering data) is ~130 - 140 minutes.

(R) For high accuracy pointing mode during imaging, star tracker measurements will be needed every 10 seconds to update attitude.

(R) To maintain ±.2° pointing accuracy during high rate data dumps star tracker measurements are needed to update attitude every 60 seconds.

(A) Allow 15 in for ACS to slew to Earth pointing for the high rate data dump.

(R) The ACS system will use the reaction wheels to point the spacecraft for nadir pointing.

(A) To reduce jitter, the reaction wheels may have to be inhibited during the actual image sequences. The exact method will be determined during the first 5 days.

(A) The star tracker that is facing towards the sun should be left off and covered.

(R) The UV/Vis camera is needed to observe the limb of the moon for the autonav experiment. There will be 1 (?) observation per orbit. The Image sequence provides angular measurements used to correct the onboard state vector. NOTE: At the same time obtain 10 min. (?) of star tracker data.

(R) Begin LWIR Imaging 10° before a terminator crossing to image the thermal gradient across the terminator dark to light (and light to dark).

(R) The image sequences rates will be changed approximately every 10° of latitude.
Because of image overlap of the UV/Vis and NIR camera it is not necessary to image pole to pole. For the first month of lunar mapping the mapping sequence will be followed:

For one orbit the UV/Vis and NIR cameras will not image until -60° latitude and will continue until the north pole is reached.

The next orbit imaging will start at the south pole and continue until +60° (north) latitude is reached.

A similar sequence will take place during the second month of mapping after the periselene adjust maneuver.

(R) The HiRes camera it will be left on from pole to pole because of its narrow FOV.

(R) The laser ranger will collect ranging data at a 1 Hz rate whenever altitude is <500 km. NOTE: Ranging will take place over ~20 min.

(R) The solar panel auto track will be disabled (TBD) during imaging sequences and then enabled in between imaging sequences. This will happen every TBD° change in latitude. (A) If auto track jitter is small, auto track will be left enabled.

(A) When possible we would want to downlink real-time data (& possibly images) during the time sensors are collecting image data.
3.4 Geographos Transfer Trajectory

(C) Normal experiment operations will be performed when Pomonkey is in view, allowing real-time control of the experiment, if required.

(C) The spacecraft passes through the earth shadow twice and the moon shadow once. The first earth shadow traversal will occur \( \approx 10 \) hours after perigee and last for \( \approx 108 \) min. Second earth shadow traversal will occur \( \approx 10 \) hours after perigee and last for \( \approx 123 \) min. The moon shadow traversal will occur \( \approx 3 \) hours after swingby and last for \( \approx 114 \) min.

(R) The subsystems onboard with minimum thermal limits are warmed up for \( \approx 2 \) hours prior to entering the shadow and heaters are used to maintain temperature during shadow traversal.

(R) Batteries must be fully charged prior to entering shadow and power usage limited to \( < 15 \) amp•hrs.

(R) All non-critical systems are powered down, except those required for thermal control of heaters. The attitude control and communications systems are inactive.

3.5 Geographos Flyby

(C) To allow more flexibility in which antenna the DSN uses (34m or 70m) the spacecraft will nominally use the high gain antenna for downlink until pre-flyby phase.

(C) There is a preferred attitude for thermal and communications subsystems.

(C) Geographos is expected to be first visible in the HiRes camera between \( \approx 40 \) to \( \approx 8 \) hours and in the LWIR \( \approx 30 \) to \( \approx 8 \) hours before closest approach. At \( \approx 4 \) hours, the UV/Vis camera should begin to be able to acquire Geographos.

(R) Starting at \( \approx 5 \) hours before the flyby the spacecraft will transmit continuous omni downlink data at 125 bps (except within \( \pm 10 \) min. of the actual flyby).

(C) The distance at the closest point of approach is targetted to be \( 100 \) km with a closing velocity of \( \approx 11 \) km/sec.

(C) The best lighting occurs while receding from the asteroid, so imaging continues for 2 - 3 hours (TBD) after the closest point of approach.

(R) JPL has the responsibility to supply an accurate ephemeris for the asteroid.

(R) Images will be required every hour to define spin of asteroid.

(R) The solid state data recorder will be downloaded twice after the conclusion of the asteroid observation.
4.0 SPACECRAFT SUBSYSTEMS

4.1 Ordnance Control System

(R) The DSPSE spacecraft ordnance system provides switching and control logic for the following functions:

- Propulsion valve activation
- Solid rocket motor ignition
- Solar array deployment
- Spacecraft/Interstage separation

(R) The command to release the spacecraft from the launch vehicle is initiated by the launch vehicle.

4.2 Attitude Control System

(R) To meet the high accuracy pointing requirements, the spacecraft attitude will need to be updated every 10 seconds while imaging the Lunar surface.

(R) Attitude updates will be required every 60 seconds during high gain antenna data dumps.

(R) Attitude changes and attitude updates must be scheduled with the camera image sequences and positioning of the solar panels.

(C) Slews using the reaction wheels could take up to 30 min.

(C) The 3-axis stabilization fine pointing error is 0.05 degrees.

(R) The ACS must jitter must be less than 40 microradians over 40 microseconds.

(C) The spin stabilization attitude error is 5 degrees.

4.3 Electrical Power System

(C) During the lunar mapping phase solar panel auto tracking will be inhibited during imaging and enabled in between imaging sequences or every 10 degrees of latitude.

(C) Motion of the solar panels must be scheduled with image sequence to minimize jitter.

(R) The solar array axis (y axis) should be perpendicular to the sun vector and the solar array surface 90°±5° to the sun vector.

(C) While lunar mapping, the best angle (highest incidence angle) is the sun to spacecraft orbit normal whose absolute value varies between 52° and 90° (assuming +z axis is nadir pointing and solar arrays can move freely about the y axis).

(A) Assume the 20° null region of solar panel rotation (back of solar panels) is in the +z axis direction; front is in -z direction.

4.4 Communications Subsystem
The data rate for transmission off the omni antenna is selectable 125 bps, 250 bps, 500bps, 1Kbps, 2Kbps, 8Kbps, 64Kbps, 128Kbps. NOTE: The capability of the ground to receive the selected rate is a function of the type of the ground station antenna and the geometry (including range) between the omni antenna and the ground station.

The receiver is hard wired to the omni antennas which are also tied in with the high gain antenna so uplink can be done during periods when high gain antenna is pointing towards Earth.

Spacecraft can be commanded via the omni antennas while downlinking data on the high gain antenna. The transmitter must be turned off before switching antennas.

The transmitter should be off during periods when we are not transmitting to a ground station to save power.

The high gain antenna pointing requirement is ±7° from the vector to the center of the Earth for wide band data downlink to Pomonkey or to the DSN sites.

The best omni antenna pattern is ±70 degrees from boresight.

The transmitter needs to be powered off before switching between omni and high gain antennas.

The transmitter will be turned off when omni or high gain antenna communications not possible or not required (up to 60 minutes per orbit).

Range-rate data is available whenever either the omni antennas or the high gain antenna are supporting s-band communications.

After each lunar imaging sequence and autonomous navigation tests are complete for an orbit the spacecraft will maneuver to dump high rate (128 Kbps) data to the ground using the high gain antenna.

Preparation for the high rate data dump include:

Verify switched to high gain antenna
Turn on transmitter
Select desired bit rate
End engineering data recording using TLM Monitor Memory
### 5.0 MISSION SENSORS

#### 5.1 Star Trackers

(C) Operationing Characteristics

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>576x384</td>
</tr>
<tr>
<td>FPA</td>
<td>Full Framme CCD</td>
</tr>
<tr>
<td>Focal Length</td>
<td>17.7 mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>14 mm</td>
</tr>
<tr>
<td>FOV</td>
<td>28 x 42 deg</td>
</tr>
<tr>
<td>Solar exclusion Angle</td>
<td>63 x 75 deg</td>
</tr>
<tr>
<td>iFOV (Pixel size)</td>
<td>1.3 milliradian</td>
</tr>
<tr>
<td>Integration Time</td>
<td>0.1 to 773 milliseconds</td>
</tr>
<tr>
<td>Nominal Integration Time</td>
<td>145 to 200 milliseconds</td>
</tr>
<tr>
<td>Readout Time</td>
<td>55 milliseconds</td>
</tr>
<tr>
<td>Gain Settings</td>
<td>75, 150, 300 electrons/bit</td>
</tr>
<tr>
<td>Wavelengths</td>
<td>400 to 1100 nanometers</td>
</tr>
</tbody>
</table>

(C) The star trackers must be held at the following operating temperatures:
- CCD: -20°C to +10°C
- Lens: -20°C to +40°C
- Sensor baseplate thermal requirements -20°C to +2°C

(C) One star tracker will have solar exposure during each lunar orbit and it should be powered off for this time.
5.2 The UV/Vis Camera

(C) UV/Vis Camera Operating Characteristics

<table>
<thead>
<tr>
<th>Pixels:</th>
<th>288 x 384</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPA:</td>
<td>Frame Transfer CCD with Metachrome Coating</td>
</tr>
<tr>
<td>Focal Length:</td>
<td>90 mm</td>
</tr>
<tr>
<td>Diameter:</td>
<td>46 mm</td>
</tr>
<tr>
<td>FOV:</td>
<td>4.2 x 5.6 deg</td>
</tr>
<tr>
<td>Solar exclusion Angle:</td>
<td>40 deg</td>
</tr>
<tr>
<td>IFOV(Pixel size):</td>
<td>0.255 milliradian</td>
</tr>
<tr>
<td>Integration Time:</td>
<td>0.1 to 773 milliseconds</td>
</tr>
<tr>
<td>Nominal Integration Time:</td>
<td>5 to 20 milliseconds</td>
</tr>
<tr>
<td>Readout Time:</td>
<td>29 milliseconds</td>
</tr>
<tr>
<td>Gain Settings:</td>
<td>150, 350, 1000 electrons/bit</td>
</tr>
<tr>
<td>Wavelengths:</td>
<td>415 ± 20 nanometers (nm)</td>
</tr>
<tr>
<td></td>
<td>750 ± 5 nm</td>
</tr>
<tr>
<td></td>
<td>900 ± 10 nm</td>
</tr>
<tr>
<td></td>
<td>950 ± 15 nm</td>
</tr>
<tr>
<td></td>
<td>1000 ± 15 nm</td>
</tr>
<tr>
<td></td>
<td>400 to 950 broadband</td>
</tr>
</tbody>
</table>

(C) The UV/Vis camera electronics will be turned on 10 min. before use.

(R) During lunar mapping the UV/Vis and NIR camera images will be taken alternatively from -90° to +60° and -60° to +60° latitude (when periselene is at -30° latitude) and -60° to +90° and -60° to +60° latitude (when periselene is at +30° latitude).

(A) No need to take consecutive images of polar regions - save power.

(C) The UV/Vis camera (along with the star trackers) will also be used to collect data for autonomous orbit determination tests (limb and star images will be taken for ≥10 min. (TBD) each orbit as timeline allows).

(A) Assume that it will require 125 ms for filter wheel oscillations to die out.

(R) When not in use the opaque filter of the UV/V camera should be used.

(A) DSN tracking data will be obtained at different portions of the orbit. Assume 20 minutes at each pole and 20 at periselene. Use any DSN site that is visible to obtain Doppler data.
5.3 The NIR Camera

(C) The Near Infrared (NIR) Camera Operationing Characteristics

Pixels: 256 x 256
FPA: Cooled InSb
Focal Length: 96 mm
Diameter: 29 mm
FOV: 5.6 x 5.6 deg
IFOV(Pixel size): 0.385 milliradian
Integration Time: 11, 33, 57, 100 milliseconds
Solar Exclusion Angle: 40 degrees (half angle)
Continuous Imaging Frequency: 9.95 Hz
Gain Settings: 25 Discrete Settings
Offset Control: 500 to 3600 electrons/bit
Wavelengths: 1100 ± 15 nanometers (nm)
1250 ± 30 nm
1500 ± 30 nm
2000 ± 30 nm
2600 ± 30 nm
2780 ± 150 nm
> 4000 hrs

MTTF

(C) The NIR camera electronics will be turned on 10 min. before use.

(C) The NIR cryo cooler will be turned on 30 minutes before use.

(R) The UV/Vis and NIR camera images will be taken alternatively from -90° to +60° and -60° to +60° latitude (when periselene is at -30° latitude) and -60° to +90° and -60° to +60° latitude (when periselene is at +30° latitude).

(C) No need to take consecutive images of polar regions - save power.

(C) The UV/Vis camera (along with the star trackers) will also be used to collect data for autonomous orbit determination tests (limb and star images will be taken for ≥10 min. (TBD) each orbit as timeline allows).

(A) Assume that it will require 125 ms for filter wheel oscillations to die out.

(C) Solar illumination could damage the camera (although it may be possible to anneal out the damage to the camera) so there is a 5 degree (half angle) hard exclusion zone.
5.3 HiRes Camera And Laser Ranger

(C) HiRes (Imaging Proton Of The LIDAR System) Camera Operationing Characteristics

| Pixels:     | 288 x 384          |
| FPA:        | Frame Transfer CCD with Microchannel Image Intensifier |
| Focal Length: | 1250 mm          |
| Diameter:   | 131 mm            |
| f#:         | 10                |
| FOV:        | 0.3 x 0.4 deg     |
| IFOV(Pixel size): | 0.018 milliradian |
| Integration Time | 0.1 to 773 milliseconds (step size 94.4 μsec) |
| Solar Exclusion Angel | 40 degrees (Half angle) |
| Readout Time: | 29 milliseconds |
| Gain Settings: | 150, 350, 1000 electrons/bit |
| Microchannel Plate High Voltage | 620 to 860 volts |
| High Voltage Gate Time: | 0.01 to 699 milliseconds (step size 10.67 μsec) |
| Wavelengths: | 415 ± 20 nanometers (nm) |
|             | 560 ± 25 nm       |
|             | 650 ± 25 nm       |
|             | 750 ± 25 nm       |
|             | 400 to 750 nm broadband |
|             | Opaque            |

(C) Laser Transmitter/Range Receiver Operationing Characteristics

Laser:

| Focal Length: | 500 μm          |
| Beam Divergence (FWHM@1/e**2) | 1060 nanometers |
| Wavelength:   | < 10 nanoseconds |
| Pulse Width:  | 8 Hz Max        |
| Firing Rate   | 1 Hz Continuous |

Receiver:

| FOV:          | 0.06 degrees circular |
| IFOV:         | 1.0 milliradian      |
| Range:        | 0.640 km             |
| Resolution:   | 40 meters (14 bits)  |
| Pulse Energy: | 180 millijoules      |

(R) The high resolution (HiRes) camera will make a continuous strip of overlapping images with 5 filters along the track of the satellite on the sunlit side of the moon. Images will be taken -90° to +90° latitude.

(C) The HiRes camera electronics will be turned on 10 min. before use.
(A) Assume 125 ms for oscillations due to filter wheel changes in the HiRes camera to dampen.

(R) The laser ranging instrument will be used whenever the altitude is less than 500 km TBD (max 600 km).

(R) The laser ranging electronics will be turned on 10 min. (TBD) before use.

(C) Heaters will be turned on 15 min. prior to use to bring laser transmitter temperature up to +25°.

(C) Pulse rate will be limited to 1 Hz to keep temperatures in range.

(C) The opaque filter should be positioned if the sensor is not being used for active imaging.
5.4 The LWIR Camera

(C) The Long Wave Infrared (NIR) Camera Operationing Characteristics

- **Pixels:** 128 x 128
- **FPA:** Cooled HgCdTe
- **Focal Length:** 350 mm
- **Diameter:** 131 mm
- **f#:** 2.7
- **FOV:** 1.0 x 1.0 deg
- **IFOV(Pixel size):** 0.136 milliradian
- **Integration Time:** 0.180, 1.44, 2.88, 5.76 milliseconds
- **Solar Exclusion Angle:** 40 degrees (half angle)
- **Continuous Imaging Frequency:** 86.8 Hz
- **Gain Settings:** 25 Discrete Settings
  - 2300 to 160,000 electrons/bit
- **Offset Control:** 8 bits
- **Wavelengths:** 8.0 to 9.5 microns broadband
- **Target Temperature Range:** 250 to 400 Kelvin
- **MTTF:** > 4000 hrs

(C) The long wavelength infrared (LWIR) camera will be used to take images of thermal gradients occurring at the terminators.

(C) The LWIR cyro cooler will be on 30 minutes prior to imaging.

(C) The LWIR camera electronics will be on 10 minutes before use.

(R) LWIR images will be taken ±10° of each terminator.

(C) The LWIR camera electronics will be turned off in between terminators but the cryo cooler will remain on between north and south poles.

(C) Solar illumination could damage the camera (although it may be possible to anneal out the damage to the camera)
6.0 GROUND SUPPORT REQUIREMENTS BY MISSION PHASE

6.1 General Requirements

(A) For all ground stations, acquisition (and loss of signal) will occur at 5 degrees elevation angle for radio frequency communications purposes.

(R) NASA tracking and DSN ephemeris data will be supplied to the DMOC via Goddard Space Flight Center (GSFC).

(R) New command scripts to be sent to the spacecraft for subsequent execution will be validated using the operational test bed (OTB) prior to upload.

(R) DSN and Pomonkey can obtain tracking data while supporting high gain downlink and omni uplink and downlink communications

6.2 Low Earth Orbit

(C) During LEO communication opportunities are limited with an average duration of 3 - 4 minutes.

(R) During LEO the DSPSE ground systems network will consist of:

- Pomonkey permanent ground station - prime for command and control.
- The Deep Space Network, DSN, (Canberra, Goldstone, and Madrid)
- The Air Force Satellite Control Network (AFSCN) remote tracking station (RTS) are secondary for LEO command and control.

(R) Range resources will be used for initial orbit vectors (inter-range vectors (IRVs) for first 3 (TBD) orbits, providing vectors directly to the DMOC.

(R) Space command state vectors will be made available to the DMOC through the navy space surveillance center (NAVSPASUR).

6.3 Lunar Transfer Trajectory

(R) During LEO the DSPSE ground systems network will consist of:

- Pomonkey permanent ground station - prime for command and control.
- The Deep Space Network, DSN, (Canberra, Goldstone, and Madrid)
- The Air Force Satellite Control Network (AFSCN) remote tracking station (RTS) are secondary for LEO command and control.

(R) Pomonkey tracking support for range rate only.

a) Range rate data whenever supplying communications coverage
b) 2 days high density tracking support starting at 12 hrs after TTI burn and any trajectory trim burns
   2 hrs/day only if range data is not required
   (If range data is required, Goldstone must supply it)
c) Nominal Tracking All Other Times
15 min/day only if range data not is required
if range data is required, must schedule goldstone support

(R) • DSN tracking support: requirements for range and range rate:
   a) 12 hrs continuous tracking (CT) following the TTI SRM burn and any
      trajectory trim burn
   b) 24 hrs before any scheduled trajectory trim burn
   c) 24 hrs CT prior to lunar orbit insertion
   d) 2 Days high density tracking starting at 12 hrs after TTI burn and
      any trajectory trim burns
      3 hrs/day Canberra;
      2 hrs/day Madrid;
      2 hrs/day Goldstone (Only If Range Data Is Required)
   e) Nominal Tracking All Other Times
      15 min/day Canberra & Madrid;
      15 min/day Goldstone (Only If Range Data Is Required)

(C) Typical pass durations 10 to 13 hours, with several passes of 15 to 20 hours (during
earth flybys)

(R) Madrid and Canberra DSN sites will supply communications support for ~ 3 hrs/day
when pomonkey not in view & whenever supplying tracking data
-- goldstone will supply communications support when supplying tracking data
-- if commanding is required when dsn sites are obtaining tracking data, commands
must be routed through that dsn site
6.4 Lunar Orbit Operations

(R) Throughout the lunar mapping phase, Pomonkey will continue to be the primary command and control ground station with DSN and the AFSCN RTS sites as secondary ground stations. RTS support will be scheduled only whenever DSN support cannot be scheduled.

(R) While in lunar orbit, Pomonkey and the DSN sites will supply range rate data for orbit determination to GSFC who will compute the state vector and supply it to the DMOC.

- lunar orbit tracking scenarios:
  -- DSN will support only when Pomonkey not in view.
  -- Post insertion: Continuous tracking (CT) for 2.5 days after insertion
  -- Nominal lunar orbit support: Contacts totaling 60 min per orbit
  -- Special maneuver support:
    10 hrs CT starting 24 hrs prior to the maneuver
    10 hrs CT after the maneuver
  -- Pre departure: CT 2 days before deorbit burn

(R) During times when the DSN is tracking the spacecraft for range-rate data, all commanding will be done through that DSN site.

(C) Visibility between the moon and a given ground station averages ~13 hours; however, because of orbit geometry, there are three times when the moon will block wide band communications between the spacecraft and earth:

10 - 73 min. communication blockage for omni and hi gain antennas while over dark side of moon for ~4 days centered about full moon

10 - 40 min. communication blockage for omni antennas while on sunlit side of moon for ~8 days centered about new moon.

(R) During times when the DSN is tracking the spacecraft for range-rate data, all commanding will be done through that DSN site.
6.6 Geographos Transfer Trajectory

(R) the Pomonkey ground station will continue to be the primary command and control ground station until the spacecraft is between ≈ 1 million km from the earth (about June 3) and ≈ 2 million km from the earth (about June 16).

(R) The Air Force Satellite Control Network (AFSCN) remote tracking station (RTS) will supply secondary support for periods when DSN can not support scheduled operations

(R) DSN tracking support requirements (range and range rate):

- 12 hours continuous tracking (CT) following lunar orbit departure RCS burn and any trajectory trim burns. We also need 12 hours of continuous track starting 24 hours before any scheduled trajectory trim burn.

- 24 hours continuous tracking prior to lunar swingby

- Up to 2 days high density tracking starting at 12 hours after lunar orbit departure RCS burn and any trajectory trim burns

- 3 hours/day Canberra; 2 hours/day Madrid; 2 hours/day Goldstone (only if range data is Required)

- Nominal tracking at all other times

(R) Pomonkey tracking requirements (range rate):

- Pomonkey will supply range rate data whenever in communications with the spacecraft.

- Pomonkey will supply the following capabilities for range rate data tracking Data.

  Will support up to 2 days high density tracking support starting at 12 hours after the LUNAR ORBIT DEPARTURE RCS burn and any trajectory trim burns.

  2 hours/day only if range data is not required.

  5 min./day only if range data not is required

(C) Typical pass duration's 9 to 13 hours with one 26 hours Madrid pass.

(C) Beyond ≈ 2 million km, the DSN sites will provide all telemetry, tracking, and command communication links.
6.5 Geographos Flyby

(R) During asteroid transfer portion of the mission, DSN sites will supply range and range-rate data for spacecraft orbit determination to Goddard space flight center (GSFC) and the jet propulsion laboratory (JPL) who will compute the state vector and supply it to the DMOC.

(R) DSN tracking support requirements (range and range rate):

12 hours continuous tracking (CT) following lunar swingby and any trajectory trim burns and starting 24 hours before any scheduled trajectory trim burn.

5 days CT prior to asteroid flyby

2 days high density tracking starting @ 12 hours after lunar swingby and Any trajectory trim burns.
3 hours/day Canberra; 2 hours/day Madrid; 2 hours/day Goldstone

Nominal tracking all other times (15 min./day Canberra and Madrid; 15 Min./day Goldstone).

(C) Goldstone radar data will not be available until = 1 - 2 days prior to flyby.

(C) Visibility between the spacecraft and a given ground station averages = 9 - 12 hours.

(C) There will be no RF blockages nor sun shadow transversals.