MSI Observation Overview Document
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***************************************1**
1.0 Introduction
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The objective of this document is to provide an overview of the NEAR MSI observations. It is intended to be used as a companion document to the spreadsheets available in the eros and pre_eros subdirectories to present more detailed descriptions of observations in the context of the larger events they comprised. The information here is presented in time order from start of mission to end of mission and is divided into obvious chapters that represent the major observation events or orbital phases. Each chapter has a section which describes the historical background and one that talks about the detailed sequencing design. The historical background section provides some context for understanding why observations were planned and acquired. This may include information about spacecraft and mission events, as well as the orbital context. In the sequence design sections I try to explain more about how the detailed design of the observations attempted to satisfy the science requirements. For the orbital mission, the observations are sorted into catagories, and these observation types are described. Lists of individual observations that fall within each catagory are also given.

Some limited information about NIS data is available here, mainly regarding the earth moon flyby activities and the pre-eros calibrations. Most of the NIS observations acquired in the post-orbit insertion period and high orbits were designed as cooperative observations with MSI. Pointing control often (but not always) resided the MSI sequences, and that is described here. More information about NIS is available in the NIS browse area.

A word about the associated files. A complete list of the types of files available and the directory structure can be found in welcome.txt, eros_seq_archive.txt and pre_eros_seq_archive.txt files. Description and plot files are available for many of the observations and linked directly from the spreadsheets. There are references to many of these files in the main text of this document, but as an overview, here is what is available:

Pre_Eros:

Imagelists - Imagelists exist only for the Mathilde flyby and the Earth Moon Flyby.
They are NOT linked from anywhere on the spreadsheet, but can be found in the /pre_eros/mathilde subdirectory, and the /pre_eros/earthmoon_flyby/ subdirectory, respectively.

Sequence Files - The STOL scripts for many of these sequences are linked from the Sequence Column. Summary text descriptions are available at the top of some of these.

Detailed Description - Some individual text description files are available, linked from the Detailed Description column for some calibrations and the Earth Moon Flyby activities. Mathilde is described in this document in Chapter 3.

Plots - IDL plots for the Earth Moon flyby and Orbit simulation s/w plots for the Mathilde Flyby are linked from the Predict columns and described in the text of this document.

Orbital Info - text file overview of Mathilde trajectory linked from front page.

Eros:

Imagelists - There is an imagelist available for EACH sequence week sequence starting with week 99347. There is also a special one for Eros Flyby in week 98357. These are NOT linked from the spreadsheet. Click on the week number in the Sequence column and it will take you to the subdirectory for that week.

Sequence files - For each sequence there is a sequence file (xxxxx_final_sasf.txt) and a command expansion file for msi and nis (xxxxx.msi, xxxxx.nis). Like the imagelists, these can be accessed by going to the subdirectory for that week. (for example, /eros/00010 is the subdirectory for week starting 2000/00010)

Description Files - Individual description files exist for certain complicated sequences or observation sub-types. Many are linked from the Detailed Description column. These are all text files and they are located in the ../eros/descript/ subdirectory. A complete list of these is found in the ../eros/descript/observation_key.txt file (linked from front page).

Sorted Excel files - Also in the ../eros/descript/ subdirectory there are sorted excel files that are companions to the above .txt description files. These are subsets of the main spreadsheets. They contain only observations of a specific sub-type. They must be downloaded for use. No html versions exist. A complete guide can be found in the ../eros/descript/observation_key.txt file (linked from front page).

Predict Plots - Predict plots (plot of image fields-of-view onto a 3D model of Eros) exist for most observations. These are linked from the spreadsheet in Predict columns. See the ../eros/eros_columns.txt file for an explanation of these plots.

Plate maps of low orbit mapping coverage are available for each week that we spent in low orbit and performed 'XREQ' observations. These show total coverage for that week. They are located both in each week's subdirectory, and also in the ../eros/loworbit/ subdirectory. A list of these files can be found in ../eros/loworbit/loworbit_maps.txt. This is linked from front page. A limited number of plots exist for individual XREQ observations. These are linked from the spreadsheets and listed in ../eros/loworbit/loworbit_maps.txt.

Trajectory Plots - Sets of trajectory plots for each orbital period during the Eros orbital phase are available. For each period there are two plots: 1) Range to center vs. time, 2) Sub-s/c latitude vs. time. For the two low altitude flyovers there is also a range to surface plot. These are located in the ../eros/traj/ subdirectory, and described in the ../trajectory_plots.txt file.

Orbital Info - Text file overview of Eros orbital trajectory information, linked from main page

Information regarding EROS ORBITAL MISSION:

- Chapter 11 of this document is an overview of the orbital imaging mission

- Chapters 12 through 25 give more details for each different orbital period

- /eros/descript/observation_key.txt This file is an overview of the sorted spreadsheets and description files available in the /eros/descript/ subdirectory.

1.1 Document Outline

7.0 Eros Flyover 1998-357

8.0 Cruise Calibrations 4 1998-363 to 1999-353

9.0 Final Approach to Eros 2000-11 to 2000-45

10.0 Low Phase Flyover 2000-045

11.0 Orbital Mission Overview

12.0 Post-Orbit Insertion 2000-045 to 2000-063

13.0 200 km Orbit - North 2000-63 to 2000-102

14.0 100 km Orbit - North 2000-093 to 2000-121

15.0 50km A Orbit 2000-113 to 2000-189

16.0 35 km A Orbit 2000-189 to 2000-213

17.0 50km B Orbit 2000-206 to 2000-249

18.0 100km Orbit - South 2000-239 to 2000-294

19.0 50km C 2000-287 to 2000-299

20.0 Low Altitude Flyover I 2000-300

21.0 200km Orbit - South 2000-300 to 2000-348

22.0 35km B Orbit 2000-342 to 2001-024

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2.0 Cruise Calibrations 1   1996-051 to 1996-178
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2.1 Historical Background

This section covers the time period from launch up to just before the Mathilde encounter. Various calibrations with the MSI were performed including software validations, pointing checkouts and calibrations of the camera's radiometric response.

2.2 Sequence Design

Each observation is listed here with brief description and references to associated files.

Moon1_SW_Validation (1996-051) - First activity following launch. This is a set of calibration images of the moon. Cover had not been deployed yet. The objective was to take a set of images that would serve as a calibration baseline for cover-on imaging.

See file /pre_eros/cruisecals_1/launchmoonseq.txt
(Contains STOL, but no descriptive summary)

Hyakutake_DrkCurr_a (1996-084)
Hyakutake_Pointing (1996-084) - See /pre_eros/cruisecals_1/hyakutakeseq.txt (description
Hyakutake_DrkCurr_b (1996-084) but no STOL)

The opportunity arose to image comet Hyakutake with MSI. It was primarily used as a means for exercising the imaging and pointing capabilities. We did learn that the pointing capabilities on NEAR are excellent, and we also acquired some good images of comet Hyakutake from space.

Canopus1 (1996-120) - see /pre_eros/cruisecals_1/canopus1seq.txt (summary and STOL)
Canopus2 (1996-123) - see /pre_eros/cruisecals_1/canopus2seq.txt (summary and STOL)

The above calibrations were intended to provide info about the camera's radiometric response before and after the cover deploy.

Praesepe_GeomCal (1996-123) - see /pre_eros/cruisecals_1/canopus2seq.txt (summary and STOL)
LowSunTests (1996-178) - see /pre_eros/cruisecals_1/lowsuntestseq.txt (summary and STOL)

These calibrations were intended to provide geometric and scattered light calibrations of the camera.

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3.0 Mathilde - 1997-015 to 1997-178
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3.1 Historical Background

The Mathilde flyby was first flyby of a carbonaceous asteroid. A major constraint on aimpoint selection had to do with keeping sun on the solar panels throughout the flyby. The only trajectory which would allow us to keep the camera pointed to Mathilde throughout most of the flyby while not violating solar panel constraints was to fly due North over Mathilde (ecliptic north). The miss distance of 1200km was selected because that was the closest we could fly and still be able to turn the spacecraft fast enough to track Mathilde at closest approach. It wasn't so much a problem of maximum rate, but the acceleration needed to change the rate during the few minutes surrounding closest approach.

The two primary science experiments of the Mathilde flyby were imaging and gravity. The spectrometers would not be able to do anything useful because of the distance and speed of flyby. The magnetometer remained on, but the other instruments were turned off to conserve power and thus allow the s/c to turn farther off the sun, extending the duration of the flyby imaging. The Mathilde flyby was similar to the Gaspra and Ida flybys in that there was no on-board closed loop tracking available on NEAR. The general problem to be solved was that the ground-based uncertainties in the location of Mathilde at closest approach represented a region of sky that is huge compared to a single MSI field-of-view. The time it would take to cover that region of sky even once with a mosaic of images was larger that the time available for the entire encounter. The odds of capturing the asteroid in the image taken exactly at closest approach in that mosaic were extremely low.

To circumvent this problem we had to refine knowledge of Mathilde's location from pictures taken during last day before closest approach, and then have a mechanism for incorporating that knowledge into an on-board sequence pointing update just hours before the encounter. Opnavs were planned to be acquired at intervals of 6 hours beginning at E-42. The last set would be taken at -11 hours. The predicted uncertainty in location of Mathilde relative to spacecraft associated with these images is much smaller than the ground-based uncertainty. Plans for an optional spacecraft trajectory correction maneuver at E-24 hours were also made, although Mathilde would need to be detected in the opnavs at -36 hours in order for there to be enough time to prepare and execute a trajectory correction maneuver based on the analysis of those opnavs. It was uncertain whether Mathilde would be detected at or prior to -36 hours.

The main observation sequences were designed to cover a region of sky that represented the 2-sigma uncertainties associated with the opnavs taken at encounter -18 hours. The shape of the uncertainty region was a prolate triaxial ellipsoid, with dimensions 84 x 79 x 230 km. Long dimension was parallel to the downtrack motion of spacecraft (most difficult to determine distance from a point source along line of sight). Cross-track uncertainties, normal to the down-track, were smaller (it is easier to determine location side-to-side by comparing location of Mathilde to stars in the background). There was a 90% chance that the center of Mathilde would lie within the perimeter of this ellipsoidal region, with the most probable location at the center.

The basic plan was to try to cover this uncertainty region as many times as possible during the flyby, in an intelligent manner. After many months of evaluating the problem including the various spacecraft, operational, and geometrical constraints, we decided that the best way to get the most efficient repeated coverage was to just start at one end and continue to slew back and forth along the ellipsoid parallel to the long dimension, from one end to the other. Each pass along the ellipsoid would return on full view (or partial view) of Mathilde depending on whether the field of view was wide enough to cover the cross track dimension. It was not possible to do much cross-track slewing because of limited acceleration available on the spacecraft (and also limitations due to smear requirements). However, the only time the field of view was narrower than the crosstrack dimension was during the closest approach slew and the two following slews. For those three observations, we could not guarantee return of full disk of Mathilde. But we could guarantee partial coverage (at least a sliver, even if Mathilde were sitting at the perimeter of the 2-sigma ellipsoid).

The slew rates up and down the ellipsoid were largely constrained by smear considerations, except right at closest approach when the spacecraft acceleration was an issue. The rates were designed to limit smear to <1 pixel for the nominal exposure values. We cycled the exposures through three different values to give 500, 1000, and 2000 DN for nominal albedo of Mathilde. There was considerable uncertainty in the estimated albedo of Mathilde. This range of exposure values would guarantee return of at least one good image out of the three covering the possibility of being off in albedo by a factor of up to 8 either way. For instance, if the albedo was a factor of eight brighter than the nominal predict, the exposure calculated to give 500 DN for nominal albedo would actually return about 4000 DN (close to the limit of saturation in this case).

When the sequence was uplinked to spacecraft, these mosaics were targeted to the best known location of Mathilde at time of uplink. Uncertainty in it's location at time of uplink was basically the ground-based knowledge uncertainties quoted above. These were huge, much much bigger than the tiny mosaics centered in that region. The Mathilde sequence DEPENDED on the successful acquisition of the images taken at -18 hours AND on a successful trajectory correction at -24 hours, if one was needed. Following acquisition of the images, a new solution for location of Mathilde would be determined, and then a pointing tweak sent to spacecraft. The pointing tweak had two parts. First we would upload a revised spacecraft ephemeris. NEAR carried on-board representations of the planetary and spacecraft ephemerides and these are what drove pointing commands. The revised spacecraft ephemeris would correct for cross-track and downtrack errors in location of Mathilde. I think they kept the old Mathilde ephemeris up there, but represented any new information about location of Mathilde and/or spacecaft as a shift in the s/c trajectory only. Only a revised spacecraft trajectory would be uploaded. Since the sequence pointing was accomplished with target-relative commands, by simply uploading a revised trajectory to the spacecraft, the mosaics would automatically be centered on the new most probable location of Mathilde as known at -18 hours. The second part of the tweak was a timing update. This would correct for any error in downtrack location of Mathilde (or time of arrival at closest approach). It was decided (for a host of reasons) to simply turn the on-board clock forward or backward to correct for any improvement in knowledge of time of flight. We would also take opnavs at -11 hours, but we were not depending on them. If analysis were complete in time, preparations in the ops timeline had been made for a second tweak based on the analysis of those -11 hour opnavs. This would have the effect of better centering Mathilde within the image mosaics.

As mentioned above, the nominal sequence was dependent upon the successful execution of the tcm at -24 hours, if needed, AND a successful pointing update. If either were not successful, there was little chance that the the high and moderate resolution sequences would return any pictures of Mathilde. Therefore, as a contingency, we added an observation following the prime encounter imaging which covered a region of sky equivalent to the size of the uncertainties in Mathilde's location if NO opnavs were acquired (the ground-based trajectory uncertainties). This was included in the nominal Mathilde sequence rather than having a second separate sequence on-board, to avoid the possibility of accidentally enabling the wrong sequence.

Here's what happened. Mathilde was detected in the - 36 opnav set and it was determined that the TCM was not needed. However, the pointing tweaks were needed. We successfully performed an on-board orbit update and clock shift following the -18 hour opnavs, AND following the -11 hour opnavs. The combined effect of those updates included a 9 second clock shift, and an orbit correction of about 100km. An image of Mathilde was returned in all observations, including an image taken exactly at closest approach. The exceptional skills of the JPL navigation and APL operations teams were confirmed!

3.2 Sequence Design

Shamtilly Tests - Five in-flight (on the spacecraft) simulations were performed prior to execution of the actual Mathilde flyby. Main purposes of these tests: perform calibrations, provide operational practice for Mathilde encounter, verify slewing performance of the spacecraft (we put fake trajectories on-board which allowed a realistic rehearsal of actual encounter sequence slewing). Based on this, we tweaked the slewing in the final sequence, solved some problems, retested sequence, etc.

Some text descriptions are available in the sequence directory:

(1997-015)	Sham2CanopusEnctrSeq.txt	Darks, Canopus Cal, Encounter slewing test
(1997-015)	Sham2GeomEnctrSeq.txt	Geometric Cal, Encounter slewing test
(1997-115)	Sham3Seq.txt	This was a full-up encounter simulation
(1997-141)	Sham4Seq.txt	This was a full-up encounter simulation
(1997-150)	Sham5Seq.txt	This was a full-up encounter simulation

Opnavs- (1997-176 to 179) Point to mathilde, begin slow scan and take Seq 1 twice. Seq 1 was 8 images spaced 2sec apart, 999 ms man exp, filter 0. Therefore, each opnav acquired 16 images while slewing slowly to smear stars and Mathilde across the diagonal of a 2x2 pixel area.

Opnav1 E- 42 Hrs
Opnav2 E- 36 Hrs
Opnav3 E- 30 Hrs
Opnav4 E- 24 Hrs
Opnav5 E- 18 Hrs
Opnav6 E- 11 Hrs

ENCOUNTER SEQUENCE (1997-178):
*********>>>> An imagelist exists for the encounter sequence. See mathildeimagelist.txt in /pre_eros/mathilde/ subdirectory.

*********>>>> Plot files are also available, linked from spreadsheet. The large triaxial ellipsoid shown is the error uncertainty region. It represents the uncertainty in location of Mathilde that would be associated with analysis of opnavs taken at closest approach -18 hours. This region is the

2 sigma ellipsoid. This means, there was 90% chance that Mathilde's center would lie at the perimeter of or within that volume of space. In the second set of plots, Mathilde is shown located at the most probable position (center of uncertainty ellipsoid). Actual location following the pointing updates was not far from that shown.

MathildeHighPhase - Eight 3-exposure sets through filter 0 (clear) spaced 18 seconds apart. The three exposures were designed to give 500, 1000, 2000 DN for nominal albedo. This was a single scan across the ellipsoid starting on the far end of the ellipsoid, and ending on the near end. There is a lot of overlap between adjacent 3-exposure sets. At this point the ellipse was fat and collapsed as we were still looking more or less parallel to trajectory. Eros was captured in many of these images (all at high phase).

MathildeHiRes1 - One image every 2 seconds through filter 0 (clear) for duration of observation. Three manual exposures per time-step, to cover uncertainty in albedo of Mathilde. There are 30 3-exposure sets in this strip.

This strip was the one chance to capture Mathilde at the highest resolution possible. Notice that this strip does not cover full width of the ellipse in cross-track (normal to down-track direction). However, it did give a 90% probability of capturing at least a portion of Mathilde. We started on the near end (close to where the high phase slew terminated), and scanned along the ellipse to the far end. It was necessary to slew in this direction because it gave some small amount of relief to the overall tracking slew through closest approach. This superimposed HiRes 1 slew subtracted from the tracking slew. The timing of this observation was such that we would be pointed right at the center of the ellipse (most-probable location of Mathilde) exactly at closest approach. Turns out, Bill Owen's analysis of the opnavs was spectacular. The orbit determination solutions were nearly perfect.

We got a >95% complete global image exactly at closest approach.

Mathilde is contained in several overlapping images near closest approach in this series of images. The diameter of Mathilde is almost exactly the width of the fov in these images at closest approach.

MathildeHiRes2 - One image every 2 seconds through filter 0 (clear) for duration of scan. Three manual exposures per time-step. There are 18 3-exposure sets in this strip. During this we perform another single swath along the downtrack dimension of the uncertainty ellipse. Since the field of view width was not yet as wide as cross track dimension of the ellipse, we veered to the side a bit to cover one edge of the ellipse. This strip did return a complete view of mathilde from this observation.

MathildeGlobal1 - One image every 2 seconds through filter 0 (clear) for duration of scan. Three manual exposures per time-step. There are 10 3-exposure sets in this strip. This was another single swath along the downtrack dimension but this time we veered to the other side of the ellipse (fov still not quite covering the cross track width of ellipse. HighRes 2 and Global1 individually offered less than 90% chance of capture. But together they gave the full 2 sigma probability of capturing all of Mathilde.

MathildeGlobal2 - One image every 2 seconds through filter 0 (clear) for duration of observation. Three manual exposures per time-step. There are 9 3-exposure sets in this strip. Actually, the last image of the last set is part of the first 5-filter set in multispectral I. This is another single swath along downtrack dimension. Veer to the same side as in HighRes2.

Multispectral 1 - Still taking images once every 2 seconds but for this strip we take 15 6-filter sets. (filters 0,1,2,3,4,5; all manual exposure). See imagelist; exposure values are cycled through three sets as before. This represents another pass across the uncertainty ellipse, but the fov is quite large now relative to the ellipse and covers more than 2-sigma crosstrack dimension. The first 13 5-filter sets were taken while slewing down the length ellipse, the last two were taken while returning to nadir.

Multispectral 2 - Here we take several 7-filter sets, some of which have multiple exposures per filter. Images still being taken once every 2 seconds. Slewing is that we return to the nadir position and hold there.

No-Opnav - Still taking images every 2 seconds. Now we take 20 4-exposure sets through clear filter. Three of the exposures are 1/2 nominal, nominal and 2x nominal exposed for Eros. The fourth is a 999ms exposure for small objects. Six of the 20 4-exposure sets are taken during the first slew, and 14 are taken during the second slew (see below for slew description).

Before imaging began we repositioned to one end of the 'no-opnav' uncertainty ellipse. This is a large region of sky that represents uncertainty in Mathilde's location if we did not acquire any Opnavs. We slewed across the region once (first slew) to the other side, and then back to the starting position (second slew).

Satellite Search - Still taking images once every 2 seconds, we took several 7 filter sets and a long series of clear-filter images which was basically centered on nominal location of Mathilde. We slewed to a second position slightly overlapping the previous position in the -y direction.

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4.0 Cruise Calibrations 2 - 1997-218 to 1997-342

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4.1 Historical Background

Sorry, couldn't find the sequences for these observations. No descriptions available.
More radiometric calibration of MSI. These are similar to previous canopus calibrations preformed in cruisecals_1 section.

4.2 Sequence Design

SWUploadValidation1 - 1997_101

Canopus3 - 1997-218
Canopus4 - 1997-286
Canopus5 - 1997-342

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5.0 Earth-Moon Swingby   1998-023 to 1998-026

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5.1 Historical Background

The main purpose for the Earth Swingby was to perform a gravity assist with the Earth. The project allowed the instrument teams to perform calibrations with the Earth and Moon during the flyby. A quick overview of the observations performed with MSI and NIS follows.

5.2 Sequence Design

The spacecraft flew over the North Pole of the Earth and down across Asia, flying generally over Iran, Iraq, the Persian Gulf, Saudi Arabia, and Africa, and receding from the Earth in such a manner that allowed viewing of the South Pole and Antarctica.

Earth 1 - Observations taken of Asia and Middle East. No slewing. Pointing fixed by spacecraft solar panel constraints. Took pictures and spectra as boresight ground track passed over these regions.

Earth 2 - a. Following the Asia imaging was an Africa observation which was basically consisted of a slew that took boresight north-south along southern Africa. NIS performed mirror scans while MSI took 7-filter sets at 4 different positions along the scan.

b. After this was another MSI/NIS calibration pointed at Antarctica.

c. Then we performed a 1.5 day Earth spin movie, targeting to the South pole of the Earth. This includes 7 scattered light cal sequences (the last taken 3 days after flyby).

Moon 1 - Set of calibrations with MSI and NIS. This interrupts the Earth spin movie for about 4 hours at 23/1900.

Moon 2 - MSI/NIS Coalignment test. Follows the Earth spin movie.

********* IMPORTANT NOTE ABOUT EARTH/MOON FLYBY *****************************
The following files are available in /sequence/pre_eros/earthmoon_flyby/

Detailed descriptive summaries of both MSI and NIS observations are linked from the spreadsheet and available in:

/pre_eros/earthmoon_flyby/earth1.txt
/pre_eros/earthmoon_flyby/earth2.txt
/pre_eros/earthmoon_flyby/moon1.txt
/pre_eros/earthmoon_flyby/moon2.txt

The actual Earth and Moon sequences in STOL:

/pre_eros/earthmoon_flyby/earth1seq.txt
/pre_eros/earthmoon_flyby/earth2seq.txt
/pre_eros/earthmoon_flyby/moon1seq.txt
/pre_eros/earthmoon_flyby/moon2seq.txt

A special imagelist just for the EarthMoon swingby (note, the excel spreadsheet is easier to use):

/pre_eros/earthmoon_flyby/earthmoonimagelist.txt
/pre_eros/earthmoon_flyby/earthmoonimagelist.xls

PLOTS - numerous plots are available, linked from the Predict columns.

******NOTE - there is an ERROR in the scatz.gif plot. Where it says +Z (annotating the slew direction of frames away from moon), it should say -Z.
See moon1.txt for explanation.

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6.0 Cruise Calibrations 3 - 1998-210 to 1998-353

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6.1 Historical Background

Following the Earth Moon Swingby things were quiet for about 6 months on the spacecraft. We were busy with implementation of the SEQGEN software, developing the command macros that we needed for Eros, and expanding the capabilities of the ORBIT software for the orbital phase. The need for a single repeat capability in the MSI DPU became apparent, as well as discovery of some problems with autoexposure. The MSI DPU software was fixed and uploaded to the spacecraft. The first imaging activity following earth flyby was a test of these software fixes. This was followed by a guidance and control test. After that we began the nominal approach imaging that would lead to orbit insertion on January 10, 1999. These tests and approach imaging observations are described below.

6.2 Sequence Design

Since most of the observations and calibrations in this section were unique I have simply listed them all individually, and supplied some descriptive text.

SWUploadValidation2 - (98-210) Test of upgrade to MSI DPU software that fixed autoexposure and added the single repeat capability. Single repeat gave us a simple and cheap method of repeatedly executing the same sequence.

Point to J2000: -0.061492,+0.603155,-0.79525
Set MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,1,92,0,2000,750,0

Execute Seq 2 (8 filters, manexps 15 92 229 174 478 262 979 999, fast), followed by Seq 3 (8 filters, autoexp, fast) 2 minutes later.
Set MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,1,92,10,2000,750,0
Execute Seq 4 (filters 1 3 5, autoexp, fast)
Set MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,1,300,0,2000,500,750
Execute Seq 6 (filter 1, autoexp, fast)
Set MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,1,92,0,2000,750,4000
Execute Seq 7 (filter 1, autoexp, fast)
Set MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,0,15,0,90,750,85
Execute Seq 8 (filter 0, autoexp, fast)
Execute single repeat of Seq 9 (filter 1, manexp 92ms, fast). Three executions of seq 9, spaced 15 sec. Execute single repeat of Seq 10 (7 images through filter 1, manexp 92ms, and 1 image through filter 0 with manexp 0ms, fast). Two executions of seq 10, spaced 3 sec apart. Deliberately trying to get an error.
Set CAS_MSI_AUTO_EXPOSE,12267,2000,803,1057,385,702,188,108,10,1,92,0,2000,750,75
Execute Seq 11 (7 images through filter 1, manexp 92ms, and 1 image through filter 0 with manexp 0ms, fast) followed 28 seconds later by Seq 12 (8 filter 0 images with manexp 10ms each, fast).
Execute the MSI_CANCEL_IMAGE sequence.
Execute an MSI_DOUBLE_REPEAT CAS which is to execute Seq 13 (1 filter 6 image, autoexp, fast), followed 2 seconds later by Seq 14 (one filter 6 image, manexp 0 ms). Then repeat execution of the pair. (this was to test the only way we had at the time of doing monochrome clean observations).

SpacecraftRollTest_a and _b - (98-231) Test to check accuracy of star camera attitude information. No summary available for this, but Seq file available in 98229_msi_nis_sasf.txt; see MSI_POINTING_TEST. The last frame in this observation is OPNAV_E Test. Should have been called out separately.

OpnavTest - (98-273) Another test of Opnav_E. One clear filter manexp 999ms image. We never actually used this Opnav_E CAS again.

MonoLightCurveSeq_1a - (98-309) This observation was the first on-board light curve measurement to evaluate the state of Eros rotation and its shape. The observation executed Seq 26 (1 clear filter image, fast,autoexp) every 5 deg of rotation for 1.2 spin periods. This was followed by 2 executions of Seq 30 (1 image, clear filter, manexp 999ms, no compr).

MonoLightCurveSeq_1b - (98-313) This observation was a practice for the multispectral lightcurve that was planned to be taken just before orbit insertion. It served as a test for some complicated sequencing, but the primary objective was to test the data flow through the SDC. We did not have downlink available to perform the full multispectral rotation sequence. This one only goes for 1/3 of Eros rotation.

Seq 25 (8 filters, no compression, autoexp) is executed every 30 deg for 4 executions; in between the above we alternate between seq 20 (3 filters,fast,autoexp) and seq 24 (4 filters, fast, autoexp), every 79 seconds (equiv to 1.5 deg of Eros rotation). Three filter sequence is 1,3,4. Four filter sequence is 1,2,3,4.

MonoLightCurveSeq_2 - (98-323) This was the second real light curve measurement. Same as the first, 1 clear filter image every 5 deg of rotation for about 1.3 rotations.

Note: The following opnavs are also described in /eros/descript/opnav.txt, and also in the sequserguide.pdf

----

Opnav A1-7 - (98-324) These opnav sequences were designed to be used while Eros was subpixel. Take 16 images of Eros through clear filter while slewing slowly to smear Eros across a 2x2 pixel diagonal.

Opnav B1 - (98-324) Only executed once. Opnav B's were supposed to be used when Eros became resolved (larger than a pixel). But we decided to start them up early and interleave them with the Opnav A's. Opnav B takes 8 images of Eros (5 autoexposures for Eros, 3 man exp 999ms, all through clear). We only used this Opnav once. See description of Opnav BP below.

Opnav C1 - (98-324)This was a test of the spacecraft body fixed scanning coordinate system and did not use the real Opnav_C CAS. However, it was the same mosaic type, which was a 1x1 (single position) followed by a 2x2 mosaic, 1 clear filter, fast, autoexp at each position.

Opnav BP 3,5,6,7 - (98-348) Opnav_BP was executed several times as a part of the approach sequence. We were concerned about the design of Opnav B, that the Eros pictures were entirely dependent upon autoexposure working correctly. Acquisition of useful opnavs was critical to the mission success. Therefore, Opnav BP was created, in which 2 of the 5 autoexposures were converted to short manual exposures (4, 60ms) as back up in case we had problems with autoexposure algorithm.

MonoLightCurveSeq_3 - (98-349) Third approach light curve sequence. This time, 1 clear filter image was taken centered on Eros about every 8.7 deg of Eros rotation for 1.3 rotations.

************************************7**
7.0   Eros Flyover - 1998-357
****

7.1 Historical Background

The original mission plan for Eros orbit insertion called for a series of 4 rendevous burns beginning on Dec 20, 1998 and concluding on Jan 10, 1999 when the spacecraft would enter Eros orbit. This plan was altered when on Dec 20, 1998, Rendezvous burn 1 aborted after 1 second. The project lost contact with the spacecraft for over a day, but an intermittent signal was eventually picked up. After hasty analysis contact was reestablished. Since the burn had not executed, the spacecraft was still moving at a large velocity relative to Eros. It would fly past Eros on Dec 23, midday EDT. Project allowed a flyby imaging sequence to be built and sent to the spacecraft as this might be the only chance we would have to image Eros.

Imaging design for the flyby was dependent on knowing the uncertainty in location of Eros relative to the spacecraft. Just as in the Mathilde flyby, each time you cover this region of sky with images, you hopefully capture one view of Eros somewhere within that mosaic. Unfortunately, the size of the uncertainty region for this flyby was uncertain! Navigation only had a little bit of doppler following the aborted burn to work with. The spacecraft had been tumbling, and its trajectory was uncertain. Nevertheless, using their best estimate of the uncertainty region, together with analysis with our visualization software, we determined that a 2x2 mosaic would likely cover this region through the flyby. Turns out this was a little less conservative than should have been because Eros was actually sitting outside that region. Despite that, serendipity and geometry allowed the first half of the imaging (through closest approach) to capture Eros within the mosaics. Some time after closest approach we lost Eros in the 2x2 target region.

The images returned from this flyby allowed development of a 5 degree shape model of Eros to be constructed for the portions of Eros illuminated during the flyby. Prior to the flyby we only had the triaxial ellipsoid determined from ground-based lightcurves. Solar illumination on Eros during the flyby was southerly (sub solar latitude was -32 deg), hence, much of the north side of Eros was not visible at the time of the flyby. The model interpolated over those areas and the result was a volumne estimate that turned out to be good to about 15%.

We also got a good calibration on the spin phasing of Eros. This was a tremendous help for planning of the orbital mission that would begin in Feb, 2000.

7.1 Sequence Design

Eros Flyby Sequences performed on 1998/357 includes the following three parts. NIS data was taken simultaneously with the MSI sequences.

SatSrch1_contingency - A pre-flyby satellite search consisting of a 4x4 mosaic through the clear filter. At each position in the 4x4, four manual exp images were taken (4, 999, 999, 4 ms), fast compression. Pointing: mosaic centered on Eros' most-probable location.

MultispecRot_contingency - This was a set of observations that went on for over 5.5 hours, more than one full spin period of Eros, and was intended to repeatedly image Eros plus trajectory uncertainty region.

This main sequence began with 11 1/2 executions of the following pair of observations:

1) 7 filters with fov centered on Eros most-probable location (1x1),
2) 7-filters at each position in a 2x2 mosaic centered on Eros' most-probable location. The pair was repeated every 13 minutes.

After 11 executions of the pair, plus one additional 1x1, we scheduled a 4x4 mosaic through the clear filter. The sequence was timed to occur at the predicted closest approach time as a backup in case we had been too conservative with the uncertainty ellipse size. In other words, in case the 2x2's were not large enough, hopefully we would at least capture an image of Eros at closest approach in this 4x4.

Following the 4x4 mosaic, we resumed with the execution of the 1x1 plus 2x2 7 filter sequence pairs as above. Fourteen more pairs were executed.

SatSrch2_contingency - Immediately following the above, a post-flyby satellite search was performed, similar to the pre-flyby sat search. This consisted of a 4x4 mosaic through the clear filter. As above, 4 clear filter manual exposures were taken for at each of the 16 positions (4, 999, 999, 4 ms). (no plot available for this one, but the mosaic looks exactly like satsrch1_contingency.gif)

*********IMPORTANT NOTE about files available for Eros Flyby! *******

An imagelist, and plots are available for the above activities. They are located in
/eros/98357/erosflyby_imagelist.txt
/eros/98357/mosaicname.gif .....

The gif plot names correspond to the mosaic names as noted in the imagelist. Plots exist for all of the 1x1s, about 1/3 of the 2x2s, satsrch1, and the 4x4 at closest approach.

Please note that as these were PREDICT plots, they display Eros at its most likely location as we believed it to be prior to the flyby. We targeted the mosaics to be centered on that most probable location of Eros. Eros' actual

location was not at this point. Therefore, in the actual images, Eros will
at a different position than where these plots indicate. The rotational state of
Eros should be pretty good. Mosaic shape and frame-to-frame overlap should also be
good.

************ADDITIONAL NOTES!!*******

1) Satsrch2 looks identical to satsrch1. I did not have a satsrch2 plot so I i
linked the satsrch1 plot to Satsrch2 observation.
2) There are multiple plots for Multispecrot_contingency. Only the first plot is
linked from the predict column. You must go to directory eros/98357/ to access
the others.

8

8.0   Cruise Calibrations 4 - 1998-363 to 1999-353

****

8.1 Historical Background

About a week after the burn abort, the project was able to reschedule and successfully
execute the large burn with the main engine that eliminated most of the Eros-relative
velocity. This put the spacecraft on course for a second chance at an orbital mission 1 year
later. The spacecraft would stay within about 1 million miles of Eros for the
duration of that period (it was visible with the camera as a point source) as it chased Eros
around the sun. Gradually the distance between s/c and Eros would decrease and the second
attempt at orbit insertion would occur on Feb 14, 2000.

An unfortunate consequence of the anomaly was that during the burn abort recovery period, the spacecraft released a large percentage of the on-board fuel. Some of the by-products ended up depositing onto the camera lense and created serious scattered light problems in many of the filters. For most of this year following the Eros flyby, the science teams were allowed only a few calibrations. MSI used these calibrations to attempt to characterize the scattered light problem. In addition to the calibrations, a number of opnavs and lightcurves were performed to track the position of Eros and monitor the spin phasing of Eros.

8.2 Sequence Design

Once again, for this section the individual observations are listed with descriptive text. For a description of the Opnav sequences in this section, see notes in above section 6, opnav.txt, and the sequserguide.pdf. These opnavs were performed as a part of the post burn anomaly recovery efforts.

Opnav_A N1-N5 (98-363 to 99-007)
Opnav_C N1-N5 (98-363 to 99-007)
Opnav_BPrime N1-N5 (98-363 to 99-007)
Opnav_CA_1 - 9 (99-19 to 99-42) (these were simply a concatenation of Opnav_A and Opnav_C
as described separately)

MonoLightCurveSeq_4 - (99-45) During the year of cruise between Eros flyby and Eros orbit
insertion we attempted to monitor the state of Eros with observations
such as these. The data were used to check the shape model, the
rotation rate, spin phase (sub-s/c long), hints of albedo variation.
Reference: Clark, et al, "NEAR Lightcurves of Asteroid 433 Eros",
Icarus 145, p641-644 (2000).

This particular light curve consisted of taking 1 clear filter image every 7.1 deg of rotation for 1.1 Eros rotations. Manual exposure, 999ms, fast.

StarClusterCal_1 (99-103) - First position centered on J2000 (0.1548263,0.4880745,-0.8589599), followed by a 2x2 centered on same position. One clear filter image, manexp 999ms, fast, at each position.

CanopusCal_1a (99-103) - See /eros/descript/canopuscals.txt

MonoLightCurveSeq_5 (99-104) - One clear filter image every 5 deg of rotation for 1.1 Eros rot. Man exp 999ms.

CanopusCal_1b (99-105) - See /eros/descript/canopuscals.txt

StarClusterCal_2 (99-132) - First position centered on J2000 (0.1548263,0.4880745,-0.8589599), followed by a 2x2 centered on same position. One clear filter image, manexp 999ms, fast, at each position.

CanopusCal_1c (99-133) - See /eros/descript/canopuscals.txt

CanopusCal_2a - (99-154) See /eros/descript/canopuscals.txt

StarClusterCal_3 - (99-166) First position centered on J2000 (0.1548263,0.4880745,-0.8589599), followed by a 2x2 centered on same position. One clear filter image, manexp 999ms, fast, at each position.

CanopusCal_2b - (99-166) See /eros/descript/canopuscals.txt

MultispectralLtCrve_C1 - (99-166) Cruise light curve to monitor shape and rotational state of Eros. One set of three manual exposure 999ms images (filters 0, 1, and 5) every 7.3 degrees of Eros rotation for 1.1 rotations.

SWUploadValidation_3 - (99-181) This test sequence exercised many functions of the msi software following upload of a new flight s/w. The software changed compression Table 7 so that it would compress a throwaway image to practically nothing. Background:

During the rendezvous burn anomaly, material was deposited on the camera lense which created a very serious scattered light problem for MSI through all of the filters. To mitigate this problem, Scott Murchie devised a method of taking images which involves taking a zero exposure in addition to the normal autoexposure. The information returned in the zero exposure was used to subtract out scattered light from the normal exposure image. An observation performed in such a manner is called a 'clean' observation. For observations which use multiple filters, it was necessary to take a zero exposure frame for each different filter for which there was a regular exposure. Operationally, the only way to do this was to first take all of the normal exposures (usually, but not always autoexposure) through the various filters together as a set. After this we would take all of the zero exposures (manual) through the same set of filters. After that, however, at the end of the zero exposure set, we had to add ADDITIONAL zero exposure frame for the sole purpose of making sure that the filter wheel was in motion during the readout of the final filter of the zero exposure set. Without that additional frame the filter wheel would have been in motion for all of the other normal and zero exposures in the set, except that last filter. Calibration of that final zero exposure image would have been invalid if the filter wheel were not moving. The additional frame was of no use other than for the purpose of making the filter wheel move. We didn't need to play it back, but there was no way to not record it with the rest of the observation. Enter the new Table 7. The new table 7 was a way of compressing that 'throwaway' image to practically nothing so we did not waste downlink time on an image that was not needed.

No verbal description of this calibration. But if you want to know what happened, see /eros/99179/99179_final_sasf.txt and find the request called MSI_UploadTst. It's pretty easy to decode. (not much slewing, just a bunch of imaging)

CanopusCal_3a - (99-197) See /eros/descript/canopuscals.txt

CanopusCal_3b - (99-197) See /eros/descript/canopuscals.txt

StarClusterCal_4 - (99-197) First position centered on J2000 (0.1548263,0.4880745,-0.8589599), followed by a 2x2 centered on same position. One clear filter image, manexp 999ms, fast, at each position.

MultispectralLtCrve_C2 - (99-197) Cruise light curve to monitor rotational and photometric states and shape of Eros. One set of three manual exposure 999ms images (filters 0, 1, and 5) every 7.3 degrees of Eros rotation for 1.1 rotations.

Opnav_D through K_Tests - (99-353) These were tests of the main Opnav CASs we intended to use for orbital ops. Purpose was to make sure the slewing patterns and corresponding imaging would execute properly. Basically these opnavs take one clear filter, autoexposure, fast compressed image at each position in some mosaic pattern. The letter of the opnav determines the shape of the mosaic (see /eros/descript/opnav.txt). Pointing was to a star field.

*********************************9***
Chapter 9 - Final Approach to Eros (2000-11 to 2000-45)
****

9.1 Historical Background

Final approach to Eros occurred at a time when solar illumination on the asteroid was high on the north side (sub solar latitude +78 deg). The relative approach velocity was small and hence the range to Eros, which was only 48000 km on Jan 11, decreased slowly over this last month leading up to orbit insertion. During time period, Eros grew in size from about 7 short pixels on Jan 11, to about 100 pixels on Feb 10, 4 days before orbit insertion. In last images taken before orbit insertion, Eros was about 380 pixels across, and still fit within a single MSI field-of-view (fov).

On approach to Eros we performed many observations that prepared us for entry into orbit. Most important were the optical nav sequences which included daily monitoring (Opnav_BPs), rotation movies, and the satellite searches. Mosaicking was not necessary because Eros plus navigation uncertainties fit within one field-of-view the entire time.

NIS performed several important calibrations which are also described here.

9.2 Sequence Design

Approach Opnavs:

OPNAVBP's - Starting on January 14, 2000 we took an Opnav_BP sequence about 3 times each day.
See opnav.txt.

OPNAVBP100 through 140 (2000-14 through 2000-42)

Special Note about Opnav_BPs:

On tuesday Feb 1, Bill Owen reported that he was not able to see stars in the OpnavBPs because of scattered light through the clear filter (autoexp). He and Scott decided to change the sequence defs for OpnavBPs to make seq 29 be one manexp 150ms through filter 4, seq 9 to be four man exp 999 through filter 4, and seq 8 to be 3 autoexp through filter 4. Karl sent a real-time command Tues afternoon to make this change. Plans were made to modify seq 00038 to make the same changes to seq def file and also to modify the autoexposure setup for Opnav BPs. But this didn't happen right away. Next morning we found out that the s/c had gone into safing (see /eros/00031/NOTES.00031 regarding a problem that occurred with burn abort). We incorporated these changes to the opnav imaging into the 00033 and 00035 loads with one change from the real time command sent Tuesday. The change is that in 00033, and 00035 we went back to using clear filter for the manual 999 exp.

Summary of opnav_bp changes:

sequences	sequence

	pre-00031 rtc	00031 rtc	00033 and after
seq 29	1 man clr 999ms	1 man filt4 150ms	1 man filt4 150ms
seq 8	3 auto clr	3 auto filt4	3 auto filt4
seq 9	4 man clr (4,60,999,999ms)	4 man filt4 999ms	4 man clr 999ms

Canopus Calibrations -

MSI_Cancal4b - (11/0125) See /eros/descript/canopuscals.txt

MSI_Cancal4a - (12/0040) - See /eros/descript/canopuscals.txt

MSI_Cancal5 - (38/0610) - See /eros/descript/canopuscals.txt

Satellite Searches:

We performed three satellite searches. The first was satellite search A about 1 month before orbit insertion. Sat searches B and D were of different design and were performed closer to orbit insertion.

SatSrchA - (2000-13/0415)
SatSrchB - (2000-28/0810)
SatSrchC - (canceled because of a problem that occurred in 00031, never executed)
SatSrchD - (2000-41/0145)

Please see /eros/descript/satsearch.txt for details of these designs.

Plots available: /eros/00010/msi_satsrcha.gif
/eros/00024/msi_satsrchb.gif
/eros/00038/msi_satsearchd.gif

Approach Rotation Movies (color and monochrome):

Multiple purposes for these movies: 1) Watch Eros grow in size on approach. 2) Navigation needed the monochrome movies for establishing new landmarks at each new resolution, 3) MSI and Navigation also used them to refine shape model, determine spin phase state (this was extremely important for future sequence planning, especially for NIS low phase flyover). The color sequences were included for science (no guarantee that spacecraft wouldn't break at any time). Low resolution color data would be better than nothing. Also used for photometry, exposure determination, checks on autoexposure function.

A region representing Eros plus navigation uncertainties was smaller than the size of a single MSI frame for all of these approach movies. Normally we pointed the center of MSI fov (or NIS position 75, which is near the MSI boresight) on Eros nadir and held that position throughout the observation. No slewing.

Terminology:
- The terms 'MSLtCv' and 'MultispectralRots' stand for multispectral light curves and rotation sequences that take multiple filters every x deg of rotation.
- The term 'Movie' generally indicates a monochrome sequence where we take one filter every x deg of rotation (for nav)
- The term 'GM' is short for global morph; these are also monochrome (for nav). Same as a Movie in every way.

Please see /eros/descript/approachmovies.txt and approachmovies.xls

APPROACH ROTATION SEQUENCES

doy/hhmm	size of 35km in short pix	obs name	description
353/2115	4	MultispctrlRotSeq	- 1 clr filter, table5/fast image every .5 deg of rotation for 1.1 Eros spin period , followed by 8 filters every 10 deg for 5 iterations (50 deg of rotation)
12/0500	8	MSI_Movie 1	- 1 filter 4, table5/fast image every 1/2 deg for 1.1 rotations
13/1215	8	MSI_MSLtCv1	- 8 filters, lossless(fast) every 30 deg for 1 rotation
18/0915	10	MSI_MSLtCv2	- 8 filters, lossless(fast) every 30 deg for 1 rotation
22/0545	12	MSI_Movie3	- 1 filter 4, table5/fast image every 1/2 deg for 1.1 rotations
26/0215	16	MSI_MSLtCv3	- 8 filters, lossless(fast) every 30 deg for 1 rotation
29/0815	21	MSI_MSLtCv4	- 8 filters, lossless(fast) every 30 deg for 1 rotation
35/0635	48	MSI_NAVMovie	- 1 filter 4 table5/fast image every 15 deg for 1 rotation
37/0200	57	MSI_Movie6	- 1 filter 4, table5/fast image every 1/2 deg for 1.1 rotations
37/0831	58	MSI_MSLtCv6	- 8 filters, lossless(fast) every 5 deg for 1.1 rotations
40/0825	89	MSI_MSLtCv7	- 8 filters, lossless(fast) every 30 deg for 1.1 rotations
41/0910	112	MSI_Movie7	- 1 filter 4, table5/fast image every 1/2 deg for 1.1 rotations
42/0250	139	MSI_GM_1	- 1 filter 4, table5/fast image every 1/2 deg for 1.1 rotations
42/0830	150	MSI_MSLtCv8	- 8 filters, lossless every 30 deg for 1.1 rotations
43/0045	192-209	MSI_MSRot_1a	- 1 filter 4 image every 1/2 deg for 1.1 rotations
43/0623	201-237	MSI_MSRot_1b	- 7 filters every 13 deg for 1.1 rotations

NIS Calibrations:

The sequencing of these tests are described in detail in several text files located in /eros/descript directory, as referenced below. Both the NIS and support MSI activities, plus the pointing are described. A few plots for both instruments are also available. Only the observation names for the MSI support imaging are listed in the spreadsheet (because this is an MSI spreadsheet). Please see the NIS browse area to find associated NIS data.

1. NIS Raster Tests -

MSI_NixRasTstNarrw - (25/0345) - Support imaging for NIS Narrow Raster Test
MSI_NixRasTstWide - (25/0858) - Support imaging for NIS Wide Raster Test

The NIS and MSI sequences for these two tests are described in great detail in /eros/descript/rastertests.txt
Plots are available for the nis observations, as well as the support msi frames that were taken.

nis_nixraststnarrw.gif
msi_nixraststnarrw.gif
nis_nixraststwide.gif
msi_nixrastxtwide.gif

2. NIS Mirror Plane Test

MSI_MirrorPlaneSup - (31/1513)

The NIS and MSI activities of the NIS Mirror Plane test are described in /eros/descript/mirrorplane.txt

plots /eros/00031/nis_mirrorplanenar.gif

3. NIS Mirror Geometry Test

MSI_MirrorGeomSup1 - (31/0640)

MSI_MirrorGeomSup2 - (36/0110)

The Mirror Geom test is described in /eros/descript/mirrorgeom.txt

plots available: msi_mirrorgeomsup1a.gif
                msi_mirrorgeomsup1b.gif
                msi_mirrorgeomsup2a.gif
                msi_mirrorgeomsup2b.gif

                nis_mirrorgeom.gif - generic plot

************************************10***
10. Low Phase Flyover -   2000-045
****

Objective was to fly the s/c through zero sun line allowing NIS the opportunity to image northern hemisphere at near zero phase angle (high sun, no shadows). This would return the best data for this instrument from the mission.

These turned out to be the most complicated sets of sequences built throughout the mission. The normal instrument boresights could not be pointed to Eros during this event since this would require taking the panels 90 deg off the sun. However, built into the NIS is the capability to slew the mirror to the anti-sun direction (s/c -z direction). The exceptional guidance and control capabilities on-board NEAR allowed for some creative pointing regimes. The observations are described in detail in a section of the sequserguide.pdf.

No imaging during this time period (solar panel constraints). Closest approach occurred prior to orbit insertion.

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     /  .               |
     \                 Eros


               Eros north pole pointing roughly to sun
                     at this time
```

11*

11.0 Orbital Mission Overview

****

11.1 Historical Background

Following the successful entry in to orbit, NEAR remained in orbit about Eros for almost exactly one year. At the time of orbit insertion, the North pole of Eros (which lies roughly in it's own solar orbital plane) was roughly pointing toward the sun, and was perpetually illuminated. Sub-solar latitude was about 58 N, the most northerly it would be during the orbital mission. The south polar region was in perpetual darkness. Eros' solar orbital period is about 1.7 years. As Eros (and the spacecraft) proceeded around the sun during the one year orbital mission, the sub-solar latitude gradually moved to the south, bringing perpetual darkness to the northern hemisphere, and full illumination to the southern pole region by late summer, 2000. This diagram is a generalization. The orbital planes were not always perfectly normal to the direction to the sun.

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  left side coming out of page)
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out of page)            \xxxxxxxxxxxxxxxx/
                     |
                     |
                     V South Pole
                         shadowed
```

In the NEAR spacecraft design, the solar panels are fixed on the spacecraft. The plane of the solar panels is normal to the direction of pointing of the high gain antenna (s/c +Z). All optical instruments are boresighted together, and point in the s/c +X direction, normal to the +Z axis (which is in the plane of the solar panels). Solar panel illumination requirements demanded that the angle between the sun and the normal to the panels (+Z) be less than 30 to 45 deg. The maximum value depended on power, distance from the sun, and other considerations and varied throughout the mission. This constraint drove the mission orbital design. At any time, the spacecraft orbital plane had to be roughly normal to the direction to the sun. This is the only configuration that could allow the solar panels to satisfy illumination constraints while simultaneously allowing the instruments to view Eros. As the spacecraft proceeded in an orbit about Eros, a slow roll roughly about the direction to the sun allowed the instrument boresights to maintain viewing of Eros. Eros solar orbital period is about 1.7 Earth years. As Eros progressed in it's orbit about the sun during the year long orbital mission, the orbital plane gradually shifted to remain approximately normal to direction to sun. Mission planners put us into prograde orbits in the beginning of the mission so to avoid the need for a plane flip during the summer. By the end of the year, after going through the polar orbit period, we ended up in a retrograde orbit.

The orbital mission was divided into phases corresponding to the various orbits that were achieved. The table below (constructed with info from David Dunham and Jim McAdams, 6/21/01) shows the 25 orbit correction maneuver times and a description of each orbit. Each time indicates entry into that orbit. 'Inclination' refers to the angle between the s/c orbital plane and equatorial plane of Eros. If the number is positive it means the orbit was prograde with respect to Eros' spin. If the number is negative it means the orbit was retrograde with respect to Eros' spin.

Eros Orbital Mission Overview

Name	year	mo/day	doy	hh:mm:ss	orbit radii (km)	inclination (deg)	period (days)	# of orbits	
OIM	2000	2/14	045	15:33:05	321 x 366	35	21.8	.5	Post-Orbit Insertion A
OCM-1	2000	2/24	055	17:00:00	365 x 204	34	16.5	.5	Post-Orbit Insertion B
OCM-2	2000	3/3	063	18:00:00	206 x 203	37	10.1	2.7	200 km North
OCM-3	2000	4/2	093	02:03:20	209 x 100	55	6.7	1.5	Transition 200x100
OCM-4	2000	4/11	102	21:20:00	101 x 99	59	3.5	3.2	100km North
OCM-5	2000	4/22	113	17:50:00	101 x 50	64	2.2	4.5	100x50 Transition
OCM-6	2000	4/30	121	16:15:00	52 x 49	90	1.2	55.2	50km A
OCM-7	2000	7/7	189	18:00:02	51 x 35	90	1	6.6	50 x 35km Transition
OCM-8	2000	7/14	196	03:00:02	35 x 39	90	0.8	13.7	35 km A
OCM-9	2000	7/24	206	17:00:00	36 x 56	90	1.1	6.7	35 x 50km Transition
OCM-10	2000	7/31	213	20:00:00	52 x 49	90	1.2	6.7	50km B
OCM-11	2000	8/8	221	23:25:00	52 x 50	-75	1.2	14.1	50km B (continued)
OCM-12	2000	8/26	239	23:25:00	49 x 102	-67	2.3	4.4	50 x 100km Transition
OCM-13	2000	9/5	249	23:00:02	100 x 103	-65	3.5	10.9	100km South
OCM-14	2000	10/13	287	05:45:00	98 x 50	-50	2.2	3.5	100 x 50km Transition
OCM-15	2000	10/20	294	21:40:00	52 x 50	-47	1.2	3.2	50km C
OCM-16	2000	10/25	299	22:10:00	51 x 19	-47	0.7	1	Low Alt Flyover I
OCM-17	2000	10/26	300	17:40:00	64 x 203	-35	5.4	1.4	Transition to 200km
OCM-18	2000	11/3	308	03:00:00	196 x 194	-33	9.4	3.5	200km South
OCM-19	2000	12/7	342	15:20:00	193 x 34	-1	4.2	1.5	200 x 35km Transition
OCM-20	2000	12/13	348	20:15:00	38 x 34	-1	0.8	55.9	35km B
OCM-21	2001	1/24	024	16:05:00	35 x 22	-1	0.6	6.1	Low Altitude Flyover IIa
OCM-22	2001	1/28	028	01:25:00	37 x 19	-1	0.6	1.3	Low Altitude Flyover IIb
OCM-23	2001	1/28	028	18:05:00	36 x 35	-1	0.8	6	35 km C
OCM-24	2001	2/2	033	08:51:00	36 x 36	-1	0.8	5.5	(35km, tweak for landing)
OCM-25	2001	2/6	037	17:43:56	36 x 36	-1	0.8	5.4	(35km, tweak for landing)

EMM-1   2001   2/12   043   19:46:02   down to 6   -1 to 36   0.8-0.3   7.8   Descent
to surface   (time s/c landed)
total # orbits = 233

Science observation objectives throughout the mission were intimately tied to the effects four entities: 1) latitude of the sun, 2) inclination of the spacecraft orbit relative to Eros equator, and 3) radius of the orbit, and 4) Eros spin. It's very important to keep the definitions separate in your mind. Latitude of the sun tells you what parts of Eros may be illuminated. It varied slowly over the course of the orbital mission (from north to south). Mission observation phases such as 200km North, or 100 km South refer to times in the mission when the northern or southern hemisphere was illuminated, respectively. Inclination of the spacecraft orbit relative to the equator of Eros tells you what latitudes on the surface are viewable during each orbit. As a result of orbital inclination, the sub-s/c latitude varies sinusoidally throughout each orbit. Meanwhile the asteroid is of course spinning on it's axis once every 5.27 hours, bringing new longitudes into view at those general latitudes. 'Observation names' will often refer to 'north' or 'south' this or that. This refers to sub-s/c latitude, and hence latitudinal viewing.

To begin to get a feel for this, please check out the eros_orbital_info.txt file in the /eros directory. By scanning down the through the file, you can watch these various entities change. The sub-solar latitude will vary over the course of the year, the sub-s/c latitude will vary throughout each orbit, and the longitudes cycle through 360 deg approximately once per spin period (it varies slightly depending upon whether the orbit is retrograde or prograde).

In order to simplify operations for the mission overall, pointing control was given to individual instruments for long periods of time (one or more orbital phases). MSI/NIS was in control for the approach, low phase flyby, all high orbits (200km, 100km circular and most transitions), the two low altitude flyovers, and the landing. There were two periods of high orbits. The first was just after orbit insertion (March, April) when the north side of Eros was illuminated and provided global views of that hemisphere of Eros. The second was in in the fall (Sept, Oct, Nov) when the south side was illuminated. The s/c spent the main part of the spring and summer in 50km orbits. NLR had control the first two weeks of the 50km A, and XGRS was in control for all of the remainder of 50km orbits. In addition, XGRS controlled pointing during 35 km B and C. Navigation and gravity requirements imposed pointing control on the 35km A. Imaging data were taken opportunistically for all orbits that were not controlled by us. The exception to the above is that Optical Navigation sequences were taken on a daily basis throughout the year. MSI designed and commanded those sequences based on inputs from NAV.

The observation planning process was complicated by many challenges. The most prominent of these is the fact that often we did not always know the exact uncertainty in the accuracy the predict trajectories. This is due to a combination of factors including unmodelable uncertainties in the gravity field and thruster performance. The planning process had to take into account this continually changing array of factors. A full discussion is beyond the scope of this writeup, however I will say that we attempted at all times to be both conservative and agressive at the same time. We built in sequences that we knew WOULD work even under the worst conditions, while at the same incorporating higher risk observations that would have a higher science payoff. In general, we planned for reasonable amount of success, with backup observations in case of problems. The large amount of data downlink available made this strategy possible.

11.2 Conventions and Terminology -

Diagram of MSI field of view with spaceraft body fixed x,y,z axes shown below.

Diagram of NIS field of view shown below.

```
         537 pix
 <---------- 2.9 deg ----------->
 ---------------------------------                   ^ +y
|(0,0)       s/c +y       |  ^                   |
|           ^            | |                   |
|           |            | |                 ---
|           |            | | 244 pix           | |
```

```
|             o--------> s/c +z |  2.25deg                | |------>+z  NIS Fov
|        s/c +x into page       |  |                  ---          .76 deg x .38 deg
|                              |  |              Mirror position 75 approximately at
|                              |  |              Center of MSI fov. Mirror position
|                    (244,537) | \/                    approx .4 deg offset from one another
----------------------------------
                   (Line,Sample)

 msi pixel size .000161 microrad x .000094 microrad
(long dimension in the y direction, vertical in this
    plot)                                         NIS mirror motion in +/- z direction
                                                   mp 300 <---- 75  -----> mp 0


      94ur
      _                                                      approx s/c +x
     | |  161ur                                                  NIS 75
     |_|                                                               NIS 0
                                                              ^      _
                                                              |     /|
                                                              |30  /
                                                              |deg/
                                                              |  /
                                                              | /
                                  NIS 300  <----------------|/---------------> +z
                                   approx s/c -z          s/c +y          to sun
                                                          out of page
```

NOTE - in all the visualizations (gifs linked to spreadsheet), the MSI and NIS fields of view that correspond to the Eros view shown, will appear as in the above diagram with the upper left corner line 1 sample 1. This means sun is almost always coming from the right.

x axis is red (prime meridian - 0 lon)
y axis is green (90 East Lon)
z axis is blue (north pole)

MSI Filters

filter 0	broadband
filter 1	550 nm
filter 2	450 nm
filter 3	760 nm
filter 4	950 nm
filter 5	900 nm
filter 6	1000 nm
filter 7	1050 nm

Mosaic Sizes - given as column x row

Emission - the angle between surface normal and direction to s/c

Incidence - the angle between surface normal and direction to sun

Phase Angle - the sun/target/spacecraft angle

Eros Spin Period - 5.27 hours

Effective Spin Period - term used in this document to describe how long until same longitude reappears below s/c (it's the sum of combined effects of eros spin and orbital motion). When in prograde orbits the effective spin period is > 5.27 hours. When retrograde it's < 5.27 hours.

Sub-solar Latitude - Draw line connecting Eros center with sun. This is the latitude where that line pierces surface. This is listed in the spreadsheets. This is a general indication of what parts of Eros might be illuminated.

Sub-solar lat = -40 to -90 (or so).. south pole illuminated, north pole shadowed
Sub-solar lat = equatorial .. most of Eros illuminated at different times as it spins
Sub-solar lat = +40 to +90 (or so).. north pole illuminated, south pole shadowed

The ORBITAL PHASE names refer to SUB-SOLAR LATITUDE! For instance, 200km South refers to the orbital period in April 2000 when only the South latitudes were illuminated.

Sub-spacecraft Lat/Lon - Draw a line connecting Eros center with spacecraft. This is the lat/lon where that line pierces Eros surface. Sub-solar latitude varies over the course of each orbital period.

OBSERVATION NAMES will often refer to SUB-SPACECRAFT LATITUDES (not sub-solar latitude). For instance, SouthGlobals observation on doy 66 refers to a set of globals that was taken during the North 200km orbit (northerly illumination) but during the part of the orbit that gave the SOUTHERN view to eros (mostly shadowed in this case because the sub-solar lat was in the north).

Orbit Inclination - Angle between orbital plane and equatorial plane of Eros. When the pole of Eros was more or less pointing to the sun (beginning and end of mission) the spacecraft orbits which gave the lowest sun angles on the panels were nearly equatorial. These were also the most stable. However, the actual high orbits mission designers put us in were deliberately inclined to the equator so to give science better (lower emission) views of the illuminated territory on the polar regions. In the middle of the mission, as the sub-solar latitude passed across the equator of Eros, we were forced into more highly inclined orbits essentially to keep sun on the panels. This is why many of the low orbits were polar orbits or close to polar orbits. When in any inclined orbit, for half of the orbital period the sub-spacecraft latitudes are in the northern hemisphere, and for half the orbit the sub-s/c latitudes are in the southern hemisphere.

Each latitude on Eros within the range of the inclination is viewed twice during the orbit. Once when the spacecraft is heading 'north' in the orbit, and once when the spacecraft is heading 'south' in the orbit. The shadowing of any given region was very different depending upon which side of the orbit we were on (even though we might have been at the same latitude). This was due to Eros' irregular shape, and the fact that the pole was never pointing directly to the sun. For instance, when at sub-s/c latitude +20 on the ascending part of the orbit, the regions in shadow while viewing longitude 0 were very different from the regions in shadow while at sub-s/c latitude +20 on the south going side of the orbit at that same longitude. Keep in mind that the orbital periods were normally much longer than the spin period. So while at any given sub-spacecraft latitude we would see all longitudes as Eros spun below us.

As a result of these effects, it was important to distinguish between the ascending and descending sides of the orbit with respect to observation design and planning. In the various tables that describe 200 and 100 km observations, when the s/c was on the side of the orbit going north, I denote this by a (N), not to be confused with northern latitudes. Similarly, when on the south-going side I used an (S). Examples: 1) +35(S) means the observation was acquired when the sub-spacecraft latitude was +35 (or 35 North), but on the side of the orbit that was descending to more southerly latitudes. 2) -20(N) means the observation was taken when sub-s/c latitude was 20 South, but on the side of the orbit that was heading north. Sorry this is confusing, but this was a very complicated 3-D mission.

asteroid body-fixed coordinate system - ABF

This describes the 'right-handed' abf system used to target to Eros features during the mission. A uniform use of this coordinate system was esablished among various parts of the project including MSI team, NAV team, G&C, and Ops.

Important NOTE*** The scientists generally use West longitude when quoting lat/lons on the surface. This is not a right-handed system. Note that the +y in the abf system is at +90 East longitude which = 270 W longitude.

```
                 concave  side of Eros
     ---\       'paw'      __ /----\
    /    -- \    (90W)     /        \
   /         --------------/         \
   |                            |
Prime \ +X <----------- o Npole(+Z)         /
Meridian\           |   out of page    /
       \         /-\             /
         \---------- |  ----------/ /
                 |
                 \/+y  = 90Deg East lon
               convex side of Eros with 'saddle' at 270w
```

Terminology used to describe locations on Eros -

There are several terms which came into use that allowed us to quickly indicate general regions on Eros.

1) 'the saddle' - this is the large depression in the eastern hemisphere. Later named Himeros.
2) 'the paw crater' - later named Psyche, this is the 5.5 km crater at about 90 W lon.
3) 'nose' - This term refers to each pointy end of Eros, either at 0 lon or 180 lon.
4) 'concave side' - another term for the western hemisphere. The whole thing is concave.
5) 'convex side' - another term for the eastern hemisphere (it's convex if you exclude the big 'saddle' depression)

11.3 Sequence Design

I want to take a minute to talk about some general sequence design info that will apply through most of the orbital mission. These are generalizations. I will point out places where there are deviations.

A. Monochrome Imaging in Orbit -

In general, there were multiple overall science objectives to satisfy with the monochrome imaging throughout the mission. One objective was to obtain a low emission angle base map at each resolution, ideally at the lowest incidence possible as well. Another was to obtain good stereo coverage at reasonably low emission angles. Good viewing for morphology was moderate emission (<50) and moderately high incidence (want shadows). This was consistent also with optical nav desires. The monochrome imaging objectives were fairly easy to meet throughout the mission given the fact that spacecraft solar panel design forced us into orbits that flew generally above the terminator. Incidence angles could have been a little better for the the low emission global map, but they were good enough.

During the orbital phase we can divide the monochrome imaging into two general types: 1)movies and 2)mosaics.

1) MOVIES (movies, flyovers, and feature tracks) are observations where the camera is not slewed quickly

relative to Eros, but many images are taken with short time spacing. The frame-to-frame overlap is generally very high (>80%). If you string them together, it looks like a movie. Movies and flyovers generally point to some stable Eros-relative position, or scan slowly across the planet. Feature tracks point to a feature (asteroid body fixed position) and keep trained on that feature, watching as lighting changes.

2) MOSAICS are observations where we slew quickly from position to position with images timed to give frame-to-frame overlap of about 15-20% to give a snapshot of a region, or global view of Eros.

Monochrome mosaics of the type described here include the monochrome opnavs, any global mosaics, daily globals, low emission observations, lonscans, periapse observations, 2x2s, 3x3s, etc.

Almost all of the above named monochrome mosaics are of the 'slewing' type. This means we did not stop at each position along a column or row, but took the pictures along the way while slewing. Slew rates were slow enough to keep smear under .5 pixel usually for the estimated exposures. Reasons for this approach include commanding constraints, time efficiency (reduce distortion due to Eros rotation) and also to help make slewing more compatible with NIS needs. About 90% of the mosaic patterns slewed along the column directions, and repositioned to the adjacent frame in adjacent column (not back to the original starting side of the column). Slewing is resumed along the new column in the reverse direction. This was done because it was the most efficient way to cover territory due to the rectangular shape of fov, and also because cooperative NIS observations could be performed if the slewing was continuous in the y direction. The NIS mirror scans in the z direction, and by slewing in y we could stack mirror strips in y direction as the scan progressed.

A few notable exceptions where we scanned in the z direction include some of the lonscans in 200km orbit, and some of the global mosaics in the 100km (in the 'Periaps' series). These will be noted later. But for everything else, you can usually assume that the scanning goes in the column direction, repositions occur in the row direction.

Mosaics did not always start in the same corner. There is a numbering scheme that was occasionally used where 1 = mosaic starts in upper left, 2 = starts in upper right, 3 = starts in lower right, 4 = starts in lower left corner of the mosaic. The reason for starting in different corners had to do with minimizing pull apart caused by rotation of Eros during the mosaic. If the tip (a nose) of Eros landed on two frames of the same row, but not at the side where the reposition occurred, there could be a 6 or 8 or more minute time difference (approximately equivalent to same number of degrees of rotation) between when those two frames were taken. Usually one of the four possible mosaic patterns minimized the pull-apart.

Diagram of 4 mosaics, each starting in a different corner; applies to all mosaic types:

```
(1) |    ^---->|         <-----^     |(2)      ^    <----^           ^---->    ^
    |    |     |         |     |     |       |    |    |          |    |    |
    |    |     |         |     |     |       |    |    |          |    |    |
    |    |     |         |     |     |       |    |    |          |    |    |
   \/--->|    \/        \/     <----\/        <----\/   |(3)      (4)|    \/--->
```

There was also an alphabetical naming scheme for mosaic sizes of the type being described here.
You'll see this in the Opnav names for the 200km orbits.

colxrow
D = 2x2
F = 2x3
G = 3x2
H = 3x3
I = 2x1
J = 1x2
L = 3x4
M = 4x3
N = 4x4
O = 4x5
P = 5x4
Q = 3x5

So, for example, an Opnav_Q3 is a 3x5 (3 columns, 5 rows) that starts in lower right corner, goes up, repositions left, goes down, repositions left again, goes up for final column.

R = 2x4

Slew rates were usually on the order of .03-.04 deg/s. To simplify image commanding we used different rates for column vs. row slews in order to keep time between all images in the mosaic constant (that is, repositions as well as slews along columns). Time between images is usually between 60 and 85 sec. This was the timing which corresponded to rates that gave a reasonably low smear for the worst exposures throughout the mission, and which gave about 15% overlap in each direction.

Almost all of the monochrome imaging during orbital phase was taken through filter 4. This filter had the least amount of smear due to scattered light.

Much of the monochrome imaging was not 'clean', but some of it was. This is a term that refers to the process of taking a zero exposure immediately following the normal exposure for the purpose of removing scattered light in calibration of the normal exposure images. The spreadsheet indicates the presence of zero exposures. There were a few monochrome global morphs at the beginning of the year that were clean. Many of the flyovers feature scans, 'xreqs' (low orbit mapping sequences that rode with xgrs pointing) were clean.

B. Color Imaging in Orbit

It was a challenge to get good viewing angles for color imaging during this mission. The best color imaging requires low emission and low incidence. This was a difficult task given that we were normally in orbits because of solar panel constraints were required to fly the spacecraft roughly above the terminator. Where emission angles were low (<20), meaning viewing was directly down at the surface, incidence angles were always very high (>70), meaning low sun. We did the best we could. Sometimes we went for very low incidence (good signal) and took higher emission, sometimes we tried to balance the two with moderately low emission, moderate incidence. Color imaging at high incidence (which always came with very low emission) was worthless. The other problem was that navigation uncertainties made it difficult to predict exact timing of the better viewing on various facets. Eros' extremely irregular shape, combined with it's fast spin rate made for very short windows of opportunity for getting good viewing on these facets. We did the best we could given a difficult task. The large availability of data meant we could take more data than we needed, with the assumption that some of the data returned would not be of the best quality. Overall, the hope was that we would have enough useable good data sets on each area of Eros.

Almost all of the color imaging in orbit at Eros was 'cleaned'. This means for each filter in the sequence, a zero exposure was taken in addition to the normal exposure. Purpose for these zero exposures was to facilitate removal of effects of scattered light due to material deposited on the optics during the Rend Burn1 abort anomaly. Due to sequencing constraints, we took all the autoexposures first (through what ever different filters were being used) , they were followed by the set of zero exposures through all of the same filters. One additional zero exposure image was taken at the end so the filter wheel was moving during shutter of the previous zero exp (the last real filter). The filter wheel was moving during all previous zero exposure shutters. We put that last extra zero exposure in for consistency. EXAMPLE: For a 3-filter set, you'll first see the regular auto exposures for the first 3 filters, then a set of 4 zero exposures. The first 3 are through the matching filters, but then there is one at the end to move the filter wheel during the readout of the last real filter. For awhile at the beginning of the orbital period we were compressing that last throwaway image with lossy Table 7, but this required use of a sequence CAS that made the spacecraft unhappy (MSI_TRIPLE_REPEAT). After about week 00087 we never used the triple repeat again, instead we just compressed the throwaway image the same as the other zero exposures.

The design of the color mosaics was such that we tried to STOP at each position in mosaic pattern. Thanks are due to Matt DeMartino, an undergraduate working with us in 1998, who came up with a very clever and complicated use of the DS56 that allowed us to stop at each position in various mosaic types long enough to take all of the autoexposure and zero exposure exposures. This reduced the problems of co-registration and smear (some of the longer wavelength filters had very long exposures). Many of these mosaic types are different from the monochrome mosaics in that the repositions ARE in a zig-zag pattern. In the high orbits, this mechanism produced fairly stable sets of images that could be co-registered. In the lower orbits (50 and 35 km orbits and low alt flyovers) it was nearly impossible to command pointing in such a way that these multiple filter sets would be perfectly co-registered.

Diagram of typical 2x2 start-stop mosaic:

```
  1   3        4   2     etc.

  2   4        3   1
```

We also did 3x2's and 2x3's:

```
1  3  5       1   2

2  4  6       3   4

            5   6
```

These did not necessarily all start in the upper left corner, but the designs were all of a zig-zag type.

11.4 Organization of following chapters

Below you will find one chapter for each of the major observing campaigns. I did not call out the transition orbits separately. In the transition periods the spacecraft was put into an elliptical orbit that transitioned between the previous and subsequent circular orbits. Often we would use the transition orbits to complete observation types taken in the preceding or subsequent circular orbits. The observations contained in the transition orbits have been listed in the appropriate adjacent orbital section. For instance, observations in the 200x100 elliptical transition orbit (following OCM-5) that were acquired at approximately 200km range are included in Chapter 13 (200km north). Those taken during that transition orbit at about 100km range were put into Chapter 14 (100km north). This is why you will notice that THE CHAPTER TIME PERIODS OVERLAP.

Please see the file ../eros/descript/observation_key.txt for a list of the sorted excel tiles and description texts available for observation types. Sometimes the observation descriptions are actually better in the following text than in the description files.

12
****

12. Post-Orbit Insertion (2000-045 to 2000-063)

****
****

12.1 Historical Background

Observations described in this section fall within the following period:

	doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	Sub-Solar Lat
OIM	045	321 x 366	35	21.8	.5	Post-Orbit Insertion B	+58
OCM-1	055	365 x 204	34	16.5	.5	Post-Orbit Insertion B	+53
OCM-2	063	206 x 203	37	10.1	2.7	200 km North	+49

See /eros/traj/traj_postoi_rtc.gif   plot of range to center
/eros/traj/traj_postoi_lat.gif   plot of sub-s/c lat for nadir point (not actual pointing)

The orbit insertion burn on doy 45 occurred at a range of about 300 km from Eros center. It was designed to put the spacecraft into a large elliptical orbit that would eventually bring us down to 200km orbit over the course of 3 weeks. The mass turned out to be a little bit higher than the pre-insertion predict. Therefore the apoapse for this elliptical orbit was smaller than originally projected. The asteroid appeared larger than we had anticipated for this period. We were able to substitute larger mosaics for many of the observations at the last minute. But for some during this period, Eros is larger than the mosaics. During these first 3 weeks after orbit insertion we kept the sequences deliberately simple, making it easier to respond to unknowns.

The most important goal during this period was to acquire global images of Eros for optical navigation (for creating a new landmark data base, and for orbit determination), and acquiring global multispectral and monochome coverage for imaging. In addition to science value, the imaging team needed this data to refine the shape model. Imaging and optical navigation requirements overlapped. Due to the critical nature of this time period, we limited the number and complexity of activities. The activities can be divided into two types: 1) Global snapshots taken multiple times throughout the day (opnavs and DailyGlobals), and 2) global movies - global mosaics taken back-to-back over the course of 1 spin period.

12.2 Sequencing Design

Post-Orbit Insertion Opnavs:

Basic idea is to take a global snapshot (2x3, 3x3, 3x4, or 4x4 mosaic) once 3 times per day for this time period.
(see also /eros/descript/opnav.txt)

OPK_OIM1_3x4, OPK_OIM2_3x4 - (045/1641, 045/2041) These two observations were the first two mosaics taken after the orbit insertion burn, at about +1 hour and +4 hours, respectively. Both were 3x4 monochrome mosaics.

OPH_3 through OPH_23 - (046/0159 to 052/1723) One 3x3 mosaic for each opnav observation, three observations per day during this time period.

OPN_DOYx_KF, OPN_DOYx_KL, OPN_DOYx_H - (052 to 063) One 2x3, 3x4, or 3x3 mosaic for each opnav observations, three or four times per day.

Daily Global 46 through 63 - (046 to 63) These were slightly larger mosaics (4x4) taken once per day in case the pointing degraded.

See eros/global.txt and .xls for complete listing.

Global Rotation Mosaic Movies:

These observations were used to acquire global coverage of the lit northern hemisphere of Eros at least twice per week for opnav and shape determination. GM = Global Morphology. These are combined optical nav and imaging observations. Several were done in color. These are the first attempt to acquire global color from orbit. Note that the 2x2's did not cover the entire asteroid. We had downlink and other restrictions which limited the scope of these observations.

See eros/descript/globalmovies.txt and globalmovies.xls.

GM_3x3	47/0925	filter 4, 3x3 mosaic every 15 deg for 1.2 rotation
GM_2	50/0855	filter 4, 2x3 mosaic every 10 deg for 1.1 rotation, clean
GM_3	52/0440	filter 4, 2x3 mosaic every 10 deg for 1.1 rotation
GM_4	54/0925	filter 4, 2x3 mosaic every 10 deg for 1.1 rotation
MSRot_3	56/0910	7-filter 2x2 mosaic every 56 deg for .9 rotations, clean
MSRot_4	60/1010	7-filter 2x2 mosaic every 72 deg for 1.1rotations, clean
GM_3x3_2	62/0410	filter 4, 3x3 mosaic every 15 deg for 1.1 rotations

13*
13.0 200 km Orbit - North   2000-63 to 2000-102

****

13.1 Historical Background

Observations taken at 200km range with north illumination come from the following time period:

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	Sub-Solar Lat
Start	OCM-2	063	206 x 203	37	10.1	2.7	200 km North	+49
	OCM-3	093	209 x 100	55	6.7	1.5	Transition 200x100	+35
End	OCM-4	102	101 x 99	59	3.5	3.2	100km North	+31

See eros/traj/traj_200north_rtc.gif - plot of range to center
eros/traj/traj_200north_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

The 200 km North orbit provided an excellent opportunity for imaging the northern hemisphere of Eros. The sub-solar latitude at the start of this period was about +43, meaning the north pole and much of the northern hemisphere was perpetually illuminated, and the south polar plateau was in perpetual darkness. Ending sub-solar lat was about +31. With an orbital inclination (to equator of Eros) of 37 degrees, roughly half of each orbital period was spent looking at Eros from lower phase angles (mostly lit northern view of Eros), and half was spent at higher phase angles (mostly dark view of southern hemisphere). The highest sub-s/c latitudes would be 37 deg North and the lowest 37 deg South. Dominant change in view in the short term was due to Eros' rotation, which spins once every 5.27 hours. This is much smaller than the orbital period.

Primary goal for MSI in the first 200km orbital period was to obtain color and monochrome global coverage of the northern hemisphere of Eros. And that we did, in tremendous quantities! This was the lowest orbital radius at which a global mosaic could be obtained quickly enough so that distortion due to Eros rotation was not a problem.

Note ***>> For this orbit and all future orbits, it's a good idea to checkout the eros/eros_orbital_info.txt file. While scrolling through the pages you can watch the sub-s/c latitudes cycle up and down over the orbital period ,in this case 10.1 days. Longitudes cycle from 0 to 360 over the course of each spin period, every 5.5 hours approximately since this orbit was prograde. In other words, every 5.5 hours we get a full view of Eros as it spins beneath us, but the latitude stays approximately the same. The latitude varies slowly over the course of each 10 day orbital period. Sub-solar latitude (illumination) changes only a little overy the course of this orbit.

```
                         SUN




                                  dots show s/c orbital plane
                                   |
                          ^ North pole      |
                          |            v       X   s/c going into
                       _______|________        .          page here
                       /          \   .
                       |           |
                       |xxxxxxxxxxxxxxxxx |
                        \xxxxxxxxxxxxxxxx/
                    .     |
                 .        |
    0                      V South Pole
                              shadowed
  s/c coming
  out of page
```

here Eros spinning once every 5.27 hour
(left end coming out of page, right end going in)

Plane of this page is approximately equal to Eros orbital plane about sun.
S/c trajectory plane is normal to this page (see dots). Orbit is prograde with respect to Eros spin.

Eros shape is far from the triaxial ellipsoid we used in the pre-flyby planning. It is shaped a little bit like a bent yam, except with many bites and oddly oriented facets. The random orientations of these facets made it a challenge to satisfy the various viewing requirements for the different imaging objectives on each and every facet. How and when to get the best viewing angle combinations for a given objective was a function not only of Eros spin orientation but ALSO the spacecraft orbital position.

Sub-spacecraft latitude in the orbit determined generally what parts of Eros could be viewed at lower emission. On the northern part of an orbit, we could see the northern latitudes at low emission and pretty good incidence. On the southern part of the orbit we could see the southern latitudes (those that were illuminated) at low emission and high incidence (lots of shadow). During the northern part of the orbit we could see the northern and equatorial regions at low emission and moderately good incidence (for this mission). In reality, very low emission views (<20 deg or so) only occurred in a narrow band of about 15 deg of latitude on Eros surrounding the sub-s/c latitude. With all of that said, good incidence on the northern was not a given. It very much depended on whether we were heading north in the orbit (sub-s/c latitudes increasing with time), or going south (sub-s/c latitudes decreasing with time).
Using the below quadrant diagram to illustrate this, for the most part I found that on the ascending part of the orbit, quadrants I and III were more viewable than II and IV (which were generally shadowed). On the descending part of the orbit, the reverse was true, better viewing of II and IV, worse viewing of I and III. To get complete coverage of any latitude band required imaging from the same orbital latitude on both sides of the orbit (descending and ascending). This concept applies to pretty much all of the inclined orbits.

```
                        concave  side of Eros
        ---\           paw           /----\
      /      -- \     (90W)       /          \
     /   II       --------------     I        \
     |                                  |
Prime \ +x <-----------o Npole(+z)          /         Eros Asteroid Body Fixed (x,y,z) axes shown
Meridian\              |    out of page     /
        \  III       /-\        IV       /
          \----------|   ----------/
                     |  saddle
                     |
                    \/+y  = 90Deg East lon
                   convex side of Eros with saddle at 270w
```

Eros has a flat northern plain, a concave western hemisphere (including Psyche), and a relatively convex eastern hemisphere with a huge dent (the saddle). The sequence designs were distributed throughout each orbit in such a way as to take advantage of viewing available to these different facets from different parts of the orbit. Eros changing view was dominated by its spin. During the first part of the mission the s/c was in a prograde orbit. Therefore the effective spin (time it takes for same longitude to come below again) was a little larger than the actual spin period. It varied slightly throughout the 200km orbit but was generally a little less than 5.5 hours. We usually planned observations that were intended to cover one full effective spin in 5.5 hour time slots.
However, during any given full rotation of Eros at a given latitude, you may only get a few regions with low emission (if that is the goal). In general, for each observation type (color, global low emission mapping, etc) it was necessary to perform these observations at many different orbital latitudes

in order to capture most of the facets of Eros at the desirable viewing conditions.

Overall in this orbit, we had to contend with a large amount of uncertainty during the planning period. The fact that there were fairly large uncertainties in thruster performance, and in how much the post orbit insertion mass determination might differ from the planning mass estimate made it difficult to count on the actual trajectories looking much like the planning trajectories. This discussion is beyond the scope of this document, however, I bring the issue up to make one point. The observations in this period were designed with all of these uncertainties in mind. They are a mix of conservatism and agressive sequencing. The lonscans are repeating mosaics that would work within a fairly large range of sub-s/c latitudes (sub-s/c lat could have been 10 deg different either way). Similarly the range could be 20% higher or lower and they still would have worked. Global mosaics were tailored to return fasted snapshot possible. They might not have worked as well if we had been off in downtrack (effect is change in spin orientation, would have needed different shaped mosaic), but they still would have returned something. Since this was our only chance to get global color on the northern hemisphere, we blanketed the asteroid with a mix of generic as well as carefully targetted observations. If trajectories had been bad, chances are we would still get something due to the sheer volume of data acquired. As it turns out, a spacecraft bug caused us to lose much of the sequenced color in this orbit. A trajectory offset caused the degradation of a few of the remaining ones, but in general there is quite a bit of useful color data to work with in this data set.

13.2 Sequence Design

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MONOCHROME 200km North: |

Opnavs - Three opnav sequences were taken during each day of the 200km orbit. Usually they
------ were scheduled as follows: one following end of playback track, one just before the

next playback track, and one in the middle somewhere. Each opnav sequence consisted of a monochrome global mosaic whose shape was tailored to the view of Eros at the time of the observation.

See /eros/descript/global.txt and opnav.txt for a complete listing. (I put these in with the globals because that's what they are).

Daily Globals - Once each day, usually right after the end of the playback, and right before
-------------   the first opnav, we put in a monochrome 4x4 global mosaic of Eros. These were supposed to be a backup for opnavs in case the pointing degraded for some reason. They take a little longer to perform a 4x4 and so there will be a little more pull-apart.

See /eros/descript/global.txt and .xls.

Globals - Only one set of globals in the 200km North orbit:

See also /eros/descript/globalmovies.txt and .xls.

South Globals - This is a series of global mosaics taken back-to-back of Eros over a 5.5 hour period at a time when the sub-spacecraft latitude was -35 deg on the south going part of the orbit. (starts day 66/0300). Below is a list of the mosaic types, in order. Example: 3x5_3 is a mosaic that has 3 columns, 5 rows. The '_3' means it starts in lower right corner, goes up first, then repositions left, then down in column 2, repositions left, then up for the final column. All mosaics were taken through filter 4, not cleaned. ILLUMINATION is in the NORTH.

3x5_3 mosaic 1
3x5_3 mosaic 2
3x5_3 mosaic 3
3x5_3 mosaic 4
4x4_3 mosaic 5
4x4_3 mosaic 6
4x3_3 mosaic 7
3x4_3 mosaic 8
3x5_3 mosaic 9
3x5_3 mosaic 10
3x5_3 mosaic 11
4x4_3 mosaic 12
4x4_3 mosaic 13
4x3_3 mosaic 14
3x4_3 mosaic 15
3x5_3 mosaic 16

Lonscans -

These were intended to and did return large amount of monochrome (filter 4) stereo coverage of Eros . The idea, of a 'lonscan', short for 'longitude scan' was to take a strip of images which covered roughly a longitudinal region of Eros, let Eros rotate beneath until a new longitudinal area becomes visible and then take another strip.... repeat for a whole spin period. As mentioned before, the view of Eros varied considerably depending on what part of the orbit we were in. At high latitudes in the orbit, I mean, when the sub-s/c latitude from orbit was high on Eros either north or south, Eros would become elongated in a diagonal direction to the MSI frame. At equatorial latitudes Eros would extend in a horizontal direction (easier to image with a rectangular mosaic). This meant that the mosaic design had to be different depending on the sub-s/c latitude. For most of the different latitudes within the orbit , we could cover most of Eros with about 6 to 8 frames in a rectangular mosaic. By looping this pattern continuously for a little more than one effective spin period we could get a great deal of stereo coverage at one orbital

view. We performed these 5.5 hour observations at many places throughout the orbit. Below is a summary table of the lonscans in the 200km North orbital period.

In the table, the column (lat) tells where in the spacecraft orbit this observation was performed. For example, NorthEquatorialLon1 was acquired when the spacecraft was in the part of the orbit that was looking down at about 12 deg North latitude. This lonscan will return fairly low emission views of the north equatorial region of Eros. The (N) means we were on the ascending part of the orbit (north-going). We lost the companion (S) south-going lonscan at that latitude, but we got one at about 0 latitude (EquatorialLon4).
This may seem esoteric, however if you work with the data you will realize that the view to Eros, what territory is visible or shadowed really is quite different for same latitudes on the opposite sides of the orbit.
I tried to schedule these lonscan observations in pairs (one going north, one going south) at 6 different sub-s/c latitudes: north pole > 30, north equatorial 15-30, equatorial -15 to 15, south equatorial -15 to -30, and south pole <-30. The type of mosaic used was a function of how Eros looked throughout it's 5.5 hour spin period at these different viewing opportunities. In the equatorial part of the orbit, Eros pole lies roughly in the plane of camera field of view, and a looping horizontal mosaic covered Eros throughout the spin period. At higher latitudes in the orbit, the view of Eros elongates in a diagonal direction relative to the frame. In this case, 2x4s were better, but it was difficult to capture the whole thing mosaic throughout the spin period. Some edges slop out of the mosaic. But this is okay, because complete coverage was not the main objective. The objective was to get good stereo on parts of the asteroid that were med to low emission WITH A SIMPLIFIED LOOPING SEQUENCE that was transportable in time. We did not have enough time or sequencing uplink bits to build separate mosaics tailored to each view. Also, that would have made these observations less transportable and more sensitive to downtrack errors. I will mention that there is one north polar lonscan, NPolarLon3, that does get complete coverage throughout. This had a special asteroid body fixed circular slewing regime that follows the spin of Eros. It's the only one taken at high north latitudes that returns COMPLETE global coverage (no slopping out) for 1 full spin period.

See ../eros/descript/lonscans.txt and .xls.

Note that these are ordered by sub-s/c latitude of view (north to south).

200km NORTHERN LONSCANS
----

week	observation	sub s/c latitude	start time	mosaic (colxrow)	coverage
00066	NorthPolarLon1	+37(N)	70/1800	2x3	repeating mosaics delta 67, 288 frames
00073	NorthPolarLon2	+33(N)	80/0230	2x4	repeating mosaics, delta = 67, 288 frames
00087	NorthPolarLon3	+36(S)	91/0715	2x8	rotating diagonal mosaics, complete covg through 1 rotation
00066	NorthEquatorialLon1	+12(N)	68/1900	3x2	repeating mosaics, filter 6! (67, 288)
00066	NorthEquatorialLon2	+27(S)	72/0125	3x2	repeating mosaics (67, 288)
00087	NorthEquatorialLon3	+25(N)	89/0700	6x2	repeating mosaics, extra overlap (delta 46, 440 images)
00066	EquatorialLon1	-7(N)	67/2242	3x2	repeating mosaics (67, 288)
00073	EquatorialLon2	0(N)	78/0730	4x2	repeating mosaics (67, 288)
00080	EquatorialLon3	-10(S)	83/2236	6x2	repeating mosaics, extra overlap (delta 44, 447 images)
00094	EquatorialLon4	0(S)	99/2355	4x2	repeating mosaics (38, 434) (not quite full rotation)
00080	SouthEquatLon1	-25(S)	84/1316	2x4	repeating mosaics (67, 270)
00073	SouthPolarLon1	-36(S)	76/0600	2x4	repeating mosaics (80sec ,240 frames)
00080	SouthPolarLon2	-30(N)	86/2353	2x8	repeating mosaics, lots of overlap (30, 577)

Flyovers - These are monochrome movies in which we point to Eros, perhaps scan slowly, and take
-------- pictures frequently. I tried to distribute these to collectively cover as much of Eros as possible.

See also ../eros/descript/flyover.txt and .xls.

		sub-s/c lat	longitude coverage:	
00066	Flyover1	-27(N)	67/0300 - 0445	lat-16, lon 198 to 306 III plus saddle
00066	Flyover2	-12(N)	67/2125 - 2235	lat 0, lon 353 to 64 I
00073	Flyover3	-32(S)	75/0630 - 1125	all way around, south lats (S) (orbit going South)
00073	Flyover4	+13(N)	79/0300 - 0700	I and IV in northern hemisph
00080	Flyover5	+36(S)	81/0840 - 0950	North pole
00080	Flyover6	+36(S)	81/1100 - 1210	North pole
00080	Flyover7	+29(S)	81/2327 - 0500	all way around at mid north (S) (going South)
00080	Flyover8	+5(S)	83/0730 - 1300	all way around equator (S) (orbit going South)
00087	Flyover12	-10(N)	88/0130 - 0651	all way around, south equator (orbit going North)
00087	Flyover13	-6(N)	88/0700 - 1319	all way around , high north (orbit going North)
00087	Flyover14	+13(N)	89/0240 - 0628	ride with nlr pointing, nadir
00087	Flyover15	+37(S)	91/0155 - 0715	south polar region
00087	Flyover16	+29(S)	92/0050 - 0616	goes all over the northern hemisphere
00087	Flyover17	+25(S)	92/0635 - 1202	goes all over the northern hemisphere
00087	Flyover18	-7(S)	93/2051 - 0100	ride with nlr pointing, nadir

Feature Tracks - The feature tracks differ from flyovers in that we point to a feature on Eros, and hold the pointing
-------------- on that feature. Idea is to watch this feature for as long as possible as viewing angles change.

See also /eros/descript/featuretracks.txt and .xls.

73 FeatureTrk2 -32(S) 75/0310 - 0600 Lat/WLon (4/160) II

73	FeatureTrk3	-25(N)	77/0600 - 0730	Lat/WLon (-12/256) saddle
80	FeatureTrk4	+25(S)	82/0600 - 0725	Lat/WLon (10/349)
80	FeatureTrk5	-30(S)	85/0131 - 0330	Lat/WLon (10/349)
80	FeatureTrk6	-30(S)	85/0330 - 0430	Lat/WLon (4/331) Shoemaker-Regio, north lit
87	FeatureTrk7	+30(S)	90/0110 - 0630	Lat/WLon (37/354) tracks north side of 0 lon nose for 1 rev
87	FeatureTrk8	+30(S)	90/0630 - 1240	Lat/WLon (23/192) track north side of 180 lon nose for 1 rev; then scans across the ridge like a flyover

____
COLOR 200km North |

Four or seven filter sets were taken at STOPPED positions in variously shaped mosaics. We tried to point to and cover facets of Eros at times when the lowest emission for moderately low incidence viewing was available. Most were taken when sub-s/c latitude was in the north. These were taken in sets of observations usually over the course of 1 rotation of Eros.

How to interpret the table below, using the following line as example:

00066 (7f) HighNorth 2x2_A1 +37(S) 71/0110

This means a 2x2 mosaic was taken at time when the sub-s/c latitude was about +37 (or 37North). The (S) means that this was during the part of the orbit that was descending (heading southward) . Slewing was stopped at each position in the mosaic to acquire all normal exposure filters in the set (in this case 4 filters were taken) as well as the zero exposures.

NPolarLat1 and 2 are a little different from the others. These sit at a constant off nadir position and take periodic 7 or 4 filter sets as Eros spins below.

Quite a few of the color observations in this orbit were lost due to a s/w bug that caused the spacecraft to abort the science sequence when doing an MSI_DoubleRepeat, or MSI_Triple Repeat CAS (this is how color observations were originally commanded). This list only shows the sequences for which we acquired data.

See also /eros/descript/color200km.txt and .xls.

200 km Color

00066 (7f) NPolarLat1 +38(N) 69/2349 16 7filter sets at same off-nadir position near North pole
00080 (4f) NPolarLat2 +36(S) 81/0310 9 4filter sets on each nose, a little away from the North pole

00066 (4f) HighNorth 2x2_A1 +37(S) 71/0110 good coverage of all longitudes
(7f) HighNorth 2x2_A2
(7f) HighNorth 2x2_A3
(7f) HighNorth 2x2_A4
(7f) HighNorth 2x2_A5
(7f) HighNorth 2x2_A6
(7f) HighNorth 2x2_A7

00073 (4f) HighNorth 1x5_B1 +35(N) 80/0800 good coverage of all longitudes
(4f) HighNorth 2x2_B2
(4f) HighNorth 2x2_B3
(4f) HighNorth 2x2_B4
(4f) HighNorth 1x5_B5
(4f) HighNorth 2x2_B6
(4f) HighNorth 2x2_B7
(4f) HighNorth 2x2_B8
(4f) HighNorth 2x2_B9

00066 (4f) Mid-North 2x2_A1 +22(N) 69/0850
(7f) Mid-North 2x2_A2
(7f) Mid-North 2x2_A3
(7f) Mid-North 2x2_A4

00066 (4f) Mid-North 2x2_B1 +21(S) 72/0750
(7f) Mid_North 2x2_B2
(7f) Mid_North 2x2_B3
(7f) Mid_North 2x2_B4

00073 (4f) Mid_North 3x1_C1 +20(N) 79/0900
(4f) Mid_North 2x2_C2
(4f) Mid_North 2x2_C3
(4f) Mid_North 3x2_C4
(4f) Mid_North 2x2_C5

00066 (7f) Equatorial 2x2_A1 9(S) 73/0045
(7f) Equatorial 2x2_A2
(7f) Equatorial 2x2_A3
(7f) Equatorial 2x2_A4

00073 (4f) Equatorial 4x1_C1 -6(N) 78/0300
(4f) Equatorial 8x1_C2
(4f) Equatorial 6x1_C3
(4f) Equatorial 9x1_C4
(4f) Equatorial 9x1_C5

00087 (4f) Equatorial 8x1_D4 -5(S) 93/1500 (yes, these are out of order)
(4f) Equatorial 8x1_D1
(4f) Equatorial 6x1_D2

(4f) Equatorial 7x1_D3

*****************************14***
14.0 100 km Orbit - North   2000-093 to 2000-121
****

14.1 Historical Background

Observations taken at 100km with north illumination come from the following period:

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	Sub-Solar Lat
Start	OCM-3	093	209 x 100	55	6.7	1.5	200x100km Transition	+35
	OCM-4	102	101 x 99	59	3.5	3.2	100km North	+31
	OCM-5	113	101 x 50	64	2.2	4.5	100x50km Transition	+27
End	OCM-6	121	52 x 49	90	1.2	55.2	50km A	+24

See ../eros/traj/traj_100north_rtc.gif - plot of range to center
../eros/traj/traj_100north_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

Following the 4 weeks spent in 200km circular orbit, OCM3 put us into the 209x100 km transition orbit where we had one dip down to 100km, went back up to 200km then down to 100 again on doy

102 when the orbit was circularized at 100km. The spacecraft was in a circular 100x100 orbit from doy 102 to doy 113 (only 11 days) when we entered another transition orbit (101x50) with OCM-5 that would last 8 days. The 100km orbit observations were taken during main circular orbit period as well as both transition periods. (200km observations taken in the 200x100 transition are included in the previous section).

The inclination of this orbit to Eros equator is 59 deg, meaning we would get lower emission views of the northern hemisphere (good for morphology). Unfortunately the sun was falling southward fast, so the incidence angles would not be as good as in the 200km orbit.

Overall objectives of the 100km orbit were to get as much coverage of northern hemisphere as possible at the improved resolution while sun was still high enough to illuminate the northern plain. Originally we were going to stay in the 100km circular orbit for 6 weeks, but since we were losing sun on the north so quickly, the project decided to cut it short in order to maximize time at 50km for XGRS while the northern hemisphere was still illuminated.

14.2 Sequence Design

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MONOCHROME 100km north |

Opnavs:

All of type 'KD'. Three opnavs per day for this period.

Example: OPN_103b_KD - this is comprised of two 2x2 mosaics on different opnav landmarks.

See ../eros/descript/loworbitopnavs.xls and opnav.txt.

Global Mosaics -
----
see ../globalmovies.txt and .xls

At the 100km range, although resolution was improved, it was very difficult to capture the entire globe in a single coherent mosaic.

The first sets of mosaics taken between 100km and 135km ranges were done in week 00094, during the 200x100 elliptical transition orbit. We took 3 SETS of mosaics that each covered one full spin of Eros, each when the spacecraft was at different orbital latitudes: north, equatorial, and south view. Each set includes mosaics that cover a good portion of Eros, sometimes all of it. At this range, it is difficult to cover all of Eros with a coherent mosaic, without getting pull-apart. Global mosaics at 100km or below take so long to complete that the effect of the spin of Eros during the time it takes to complete the mosaic causes significant distortion. When the projection of Eros was too large for a single mosaic, we used two smaller ones to get the whole view.

These three mosaic sets were important for returning the first global views of Eros near the 100km range. Navigation and imaging used these to refine landmark databases, and improve shape model. Some of these mosaics use slewing patterns different from normal (3x8s go side to side)

Separate plots exist for each mosaic in each of these sets. They are linked individually from the spreadsheet.

SouthPeriaps_100 95/1338 Range to surface about 115-105 km

EquatPeriaps_100 96/0045 Range to surface about 94 to 85 km

NorthPeriaps_100 97/0108 Range to surface about 121 to 135 km

Regional Globals:

These are single mosaics taken sporadically throughout this orbit. Most of them do not cover all of Eros. Some cover most of Eros. Intent was to provide partial globals to give the larger context. These sort of took the place of the Daily Globals of 200 km orbit.

See ../eros/descript/global.txt and .xls.

MSI_RegGlobal_101 through 107

Lonscans:

Once again, goals for this observation are twofold: fill in the low emission global map at 100km, but also provide ample stereo on each part of the illuminated surface for morphology, shape model, navigation. The 100km orbit lonscans are different from the 200km lonscan. First of all, you can no longer cover the whole asteroid in a simple 2x4 or 4x2 mosaic. We went to a design that performs a reversing single strip scan for a full rotation. We oriented it so the scan slews approximately parallel to longitude lines (in spirit of the original concept). Nice thing about this design is that part of the strip (the center) would usually cross through a low emission area, and parts would wrap around the asteroid onto lower emission areas. If you repeat the observation from different sub-s/c latitudes in the orbit, then you eventually fill in a pretty good low emission map, plus you get a lot of stereo on much of the surface. The areas where you got high emission at one latitude, you eventually get at low emission in another.

Most of these were targeted near nadir. In the original plan when the 100km orbit was 6 weeks long, we had intended to do more of these targeted off nadir. Because of Eros' irregular shape, if you perform lonscans only on nadir and let Eros spin below, there are holes in the low emission coverage (4 spots at approximately 45, 135, 225, 315 lon). But since the 100km orbit was cut short, we eliminated the off nadir lonscans, and replaced them with low emission maps (next section).

See also ..eros/descript/lonscans.txt and .xls.

100km Lonscans

RTC	Solar Lat	Observation	sub s/c latitude	start time	mosaic (colxrow)	coverage
100	31	MSI_LonScan_103A	+55(N)	103/1510		reversing 1x4 scans on high north lats, nadir
		MSI_LonScan_104A	+55(S)	104/0010		reversing 1x4 scans on high north lats, nadir
		MSI_LonScan_106B	+45(N)	106/2140		reversing 1x4 scans on mid north lats, nadir
		MSI_LonScan_104B	+30(S)	104/0640		reversing 1x4 scans on mid north lats, nadir
100		MSI_LonScan_106A	+20(N)	106/1510		reversing 1x4 scans on northequatorial lats, 1hr40min at el=1, az = 0 1hr50min at el=5, az = 325 1hr50min at nadir
100		MSI_LonScan_111	-15(S)	111/1720		reversing 1x4 scans on south equatorial lats, nadir
100		MSI_LonScan_112	-51(S)	112/0555		reversing 1x4 scans on south lats, 3 deg sunward of nadir

Note about sub s/c lat:
(N) or (S) means s/c is GOING North, or going South in the orbit
the + and - indicate north and south latitude, respectively

Low Emission Monochrome Mosaics -

These observations were designed to help fill in holes in the low emission map at 100km not filled by lonscans. Some of them target specific facets of Eros and perform circular (repeating) 2x3 or 2x3 mosaics; the mosaic tracks that target. These returned much stereo data as well. Some of these observations are series of non-repeating mosaics that are targeted to what ever low emssion areas came into view as Eros rotates.

See also ../eros/descript/featuretracks.txt and .xls.

RTC	Sub-solar Lat	Observation	Start UTC	Description
99	31	MSI_South_2x3s_105	105/07:39:59	Six sets of repeating 2x3s
101		MSI_North_2x3s_107	107/04:24:59	Repeating 2x3s on single abf position for 1 rotation
100	28	MSI_2x3s_111	111/23:39:59	5 sets of repeating 2x3s on separate abf positions
83		MSI_2x3s_114	114/08:09:59	4 sets of repeating 2x3 mosaics on separate abf positions
52		MSI_2x3s_115	115/01:59:59	5 sets of repeating 2x3s on separate abf positions
93		MSI_North_2x3s_116A	116/07:04:59	Repeating 2x3 mosacis on north 180lon ridge (1/2 spin)
93		MSI_North_2x3s_116B	116/10:19:59	Repeating 2x3 mosacis on north 0 lon ridge for 110 deg of rot
100	25	MSI_LowEmissMaps_118A	118/01:07:59	- 2 sets of repeating '2x3' mosaics approximately centered on the -180 lon northern nose; 40 frames in each delta 44sec. Extra overlap in these mosaics; it takes about 12 frames to complete a normal '2x3'sized pattern.
100		MSI_LowEmissMaps_118B	118/02:35:59	- 4 3x3_3 mosaics pasted across saddle side of Eros, north view.
100		MSI_LowEmissMaps_118C	118/04:14:59	- 2 3x3's followed by 2 sets of repeating 2x3s (normal overlap,

20 frames each), followed by 2 more 3x3s

84 MSI_LowEmissMaps_119 119/23:55:00 - Mosaics of low emission areas over 5.5 hours; extra overlap in these.
Includes:
One '4x4_1' mosaic (normal 4x4 pattern, extra overlap, there are actually 32 frames)
Two repeating '2x3' mosaics,40 frames each, delta 44 sec (extra overlap, there are about 12 frames in each 2x3 pattern)
Twelve '4x4_3' mosaics. Same as above, 32 frames per 4x4 pattern.

91 North_2x3s_120 120/23:55:00 Two sets of repeating 2x3s, each has 75 frames. They are both centered on a northern 0 lon region. Whole observation goes for about 3.5 hours (250 deg of spin).

100km North FeatureTracks:

See also /eros/descript/featuretracks.txt and .xls.

RTC	Sub-solar Lat	Observation	Start UTC	Description
100	30	MSI_Feature_2x2_106	106/00:59:59	Two sets of repeating 2x2s on separate abf positions
		MSI_Feature_2x2_107	107/22:54:59	5 sets of repeating 2x2s on separate abf positions
100	28	MSI_Feature_2x2_111	111/16:09:59	repeating 2x2 mosaics pointed at single feature
72		MSI_FeatureTrack_115	115/08:09:59	lat/wlon (-23/36) 72
94		MSI_FeatureTrack_117	117/23:52:59	lat/wlon (13/107) take 100 frames, delta 39 sec
77		MSI_FeatureTrack_118	118/23:54:59	4 targets: at range = 77km lat/wlon (70/243) delta 44, 59 frames

(9/81) delta 44, 164 frames
(42/120) delta 32, 162 frames
(40,244) delta 60, 67 frames

NLR Ride Observations:

Beginning on doy 95, NLR started commanding pointing for some time periods. Normally these were pointed to nadir. These time periods were generally on the south side of the orbit when nadir was mosly unilluminated. MSI acquired some image strips along with their pointing but many of the images are dark.

MSI_Ride95a through RideNLR_120B - these were in the 200x100 transition, range varies between 100 and 200km all are nadir point, images taken in Filter 4.

See ..eros/descript/ridenlr.txt and .xls for a complete listing.

____
COLOR 100km north |

Same idea as in 200km. Take cleaned multiple filter sets at STOPPED positions in simple mosaics (2x2s and 3x2s).

See /eros/descript/color100km.txt and .xls.

RTC	Sub-solar Lat	Observation	Start UTC	Description
100	28	MSI_4Color_3x2_113	113T0110	3x2 color mosaic pointed at feature
100		MSI_Feature_4Color_1	113T0140	2x2+1x1 color mosaics pointed at feature
95		HiNorth4Color2x2s_114	114T0315	2x2 color mosaics pointed at feature
92		HiNorth4Color2x3s_114	114T0535	2x3 color mosaics pointed at feature
95		MSI_Feature4Color_116	116T0950	2x2+1x1 color mosaics pointed at feature
100		MSI_Feature4Color_118	118T0218	2x2 color mosaics pointed at feature

*******************************15**
15.0 50km A Orbit 2000-113 to 2000-189
****

15.1 Historical Background

Observations of the 50km A period were taken during the following time period:

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	Sub-Solar Lat
Start	OCM-5	113	101 x 50	64	2.2	4.5	100x50km Transition	+27
	OCM-6	121	52 x 49	90	1.2	55.2	50km A	+24
	OCM-7	189	51 x 35	90	1	6.6	50 x 35km Transition	-2
End	OCM-8	196	35 x 39	90	0.8	13.7	35 km A	-5

See /eros/traj/traj_50a_start_rtc.gif - plot of range to center
/eros/traj/traj_50a_start_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)
* These include 100x50 transition plus beginning of 50km A

/eros/traj/traj_50a_end_rtc.gif - plot of range to center
/eros/traj/traj_50a_end_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)
* These include end of 50km A plus 50x35 transition

OCM-5 on doy 113 put s/c into the 100x50 transition and then OCM-6 on 121 circularized at 50km, which is where s/c remained until day 189. This is a polar orbit (inclination to Eros equator is 90 deg). With a spacecraft orbital period of 29 hours, means s/c passes over alternate poles every 15 hours. Eros spins once every 5.3 hours, so the effect is that the ground track spirals around the planet, gradually moving from pole to pole. Sub-solar latitude goes from 24 north to about 0 during the 10 weeks of the circular orbit. Means much of the imaging on the south side of each orbit was still very high phase angle, difficult to catch illuminated surface.

Diagram of spacecraft in polar orbit during this part of the mission.

X   s/c going into page here
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.

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^ North pole

```
                                          |
                                   _______|________
                                  /       xxxxxxx \
SUN           sun roughly          |       xxxxxxxxx |
           on equator  - - >      |       xxxxxxxxx |
          (all longitudes          \________ xxxxxx/
          illuminated as it                |
          spins)                          |
                                      V South Pole
                                      .

                                      . <------  dots indicate s/c
                                                  orbit
                                      .

                                      0  s/c coming out of page here
```

Eros spinning once every 5.27 hour
(left end coming out of page, right end going in)

Plane of this page is approximately equal to Eros orbital plane about sun.
S/c trajectory plane is normal to this page (see dots). Orbit is prograde with respect to Eros spin.

Objective for MSI was to map the illuminated surface of Eros at this resolution to obtain global low emission map, and also get extra viewing angles for morphology, stereo, etc. Solar latitude was already down to about 25 north at the start of this period. It was difficult to get good incidence on the northern plain.

15.2 Sequence Design

Opnavs:

Three opnavs periods per day as before, about 35 minutes each. They were scheduled usually one before and one after the 8 hour downlink track, and one in middle of remainder of day (about a 14 hour observing period). These opnavs are of one of the following types: OPN_XXX_KD, OPN_XXX_DKD, OPN_XXX_KF, OPN_XXX_DKF, or OPN_XXX_KH. Basically we take one or two mosaics in each opnav time slot of the type indicated by letter. (H= 3x3, D=2x2, F=2x3, ignore the 'K'). Each mosaic is targeted to some optical navigation landmark. Nav requirement was to spread them out, away from nadir in opposite directions.

See ../eros/descript/loworbitopnavs.xls - for complete listing
../eros/descript/opnav.txt - for description of 50km opnavs.

NLR Ride:

Those at 50 km start with MSI_RideNLR_117A through MSI_RideNLR_136a. MSI ridealong observations, mostly pointed to nadir, MSI takes Filter 4 images while sitting at nadir. These started in the 100x50 transition orbit and were scheduled as close to 50km range as possible

see ../eros/descript/nlride.xls for full list of nlr msi ride along observations.

XREQs:

See ../eros/descript/xreqs.txt and .xls for description and listing spreadsheet.

Each day we had usually an 8 hour downlink pass with an opnav before and after each pass, and one in the middle of the observing period. These were generally 35 minute periods decicated to taking opnavs. The remainder of the time (amounted to 12 - 14 hours daily) was given over to the Eros low orbit mapping observation effort. For the first two weeks (00122 and 00129), pointing for the mapping periods was controlled by NLR and these were almost all nadir pointed (a few in 00129 were 1.5 deg off nadir). The XGRS team took over pointing control for the rest of the 50km A orbit. They generally would point between 3 and 5 deg off nadir (sunward) and hold for long periods. Occaisionally they pointed to some abf position for an hour or so. They could not tolerate high emission, hence they did not point much to the polar region. There is not a lot of 50km data of the north pole.

We scheduled MSI to ride along with this XGRS pointing during all of those mapping periods. We usually took available downlink and spaced the images evenly throughout the Eros observing periods, making sure that frame-to-frame overlap never dropped below 10-15 percent. The pointing is archived in the XGRS area. The result was spiraling strips of images. We did not try to predict when the asteroid surface would be lit or dark because of the uncertainties in navigation when we delivered these sequences. We just took frames throughout each entire observing period. Many frames are dark.

All of this data is monochrome, filter 4 but we cycled through different imaging schemes, changing compression or whether or not they were clean. This is easiest to see in the spreadsheet (SEQ ID column).

- For the first 3 weeks (00122, 00129, 00136), we used:

seq 1 - One Filter 4 image, FAST/Table 6, autoexposure

- But starting with week 00143 we varied the style, alternating between the four following regimes:

seq 30 - Two Filter 4 images, FAST/Table 5, manual exposures 103 and 0. (this is 'clean')

seq 18 - One Filter 4 image, FAST/Table 5, autoexposure
seq 9 - Two Filter 4 images, FAST/no lossy compression, manual exposures 103 and 0 (this is 'clean')
seq 8 - One Filter 4 image, FAST/ no lossy compression, autoexposure

There were usually two 'XREQ' observations per day, scheduled between the three opnav periods.

XREQ PLOTS AND MAPS:

For each week during this period there is a total coverage plate map. This is a cylindrical projection showing minimum emission angle captured on each plate imaged during the week with these observations. These are located in the week subdirectory:

/eros/00122/xreq_00122.gif
/eros/00129/xreq_00129.gif
/eros/00136/xreq_00136.gif
/eros/00143/xreq_00143.gif
/eros/00150/xreq_00150.gif
/eros/00157/xreq_00157.gif
/eros/00164/xreq_00164.gif
/eros/00171/xreq_00171.gif
/eros/00178/xreq_00178.gif
/eros/00185/xreq_00185.gif

These plots were made by projecting all of the frames from all XREQ observations during the week onto the shape model. A program written by Brian Carcich then finds each plate within each frame and determines emission and other viewing angles. Although many plates were imaged by multiple different frames, this program sorts through them all and finds the minimum emission angle achieved during that week for each plate. What is not shown is the incidence when that emission angle was captured (generally poor). But at least this gives a feel for the coverage, and where low emission is available.

There are also some orbit plots (linked from Predict column in spreadsheet) for selected groups or individual observations to give the feel for how the strips looked during the different phases. These are only moderately useful because you can only see one side of the planet, and the shadowing is only good for one of the images (the red-lined frame). There are individual plot files available for all of weeks 00136 and 00143, see 50kmA spreadsheet.

Feature Tracks and Flyovers 50 km A:

MSI only had a brief opportunity to command pointing during this first 50km orbit and it occurred during the the 100x50 transition orbit:

RTC
50km MSI_FeatureTrack_121 122/01:30:00 3 targets all near lat/wlon (1/240)
take 183 frames, delta 28 sec
50km Flyover_117 117/0625 spectacular 50km flyover that goes along limbs,
goes for almost 5 hours.

See also ..eros/descript/featuretracks.txt and .xls.

____
COLOR 50km A |

Only one color observation during this period:

MSI_Crater4Color_166 166/0113 Five positions with 4 filters at each position on Psyche.
Solarlat 7north.

See ../eros/descript/color50km.txt and .xls for complete listing of all color at 50km.

****************************16**
16.0 35 km A Orbit -   2000-189 to 2000-213
****

16.1 - Historical Background

The gravity experiment needed some time at 35 km to improve the gravity model so the project decided to attempt this lower orbit. We tried to do as much imaging as possible at the lower parts of these elliptical orbits. You will find 35 km observations during the following period:

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start	OCM-7	189	51 x 35	90	1	6.6	50 x 35km Transition	-2
	OCM-8	196	35 x 39	90	0.8	13.7	35 km A	-5
	OCM-9	206	36 x 56	90	1.1	6.7	35 x 50km Transition	-9
End	OCM-10	213	52 x 49	90	1.2	6.7	50km B	-12

See /eros/traj/traj_35a_rtc.gif - plot of range to center
/eros/traj/traj_35a_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

16.2 Sequence Design

____
MONOCHROME 35km A |

Opnavs:

Same as 50km A, two 2x2 mosaics three times per day. These are elliptical orbits so the ranges are going to vary.

Please see ..eros/descript/loworbitopnavs.xls and opnav.txt for a listing. Ranges are listed.

XREQs:

Same as 50km A, except XGRS in control during the 51x35 and 36x56 elliptical transition orbits only.

Total coverage plots in:

/eros/00192/xreq_00192.gif
/eros/00201/xreq_00201.gif
/eros/00205/xreq_00205.gif

This data is acquired during elliptical orbits at ranges to center between 50 and 35 km.

See ../eros/descript/xreq.xls to sort out which data were taken at altitudes less than 50km to center.

35 km SUN Opnavs:

During the circular 35km period the project mandated that s/c be in a guidance mode that was advantageous for the gravity experiment. The observations listed here are imaging sequences timed to be taken during the actual 35x39km period opportunistically when Eros passed beneath the FOV for that spacecraft pointing. These are filter 4 strips with overlap > 10 %.

OPN_SUN01 on 196/1700 through OPN_SUN16 on200/0543

Orbit gifs linked from spreadsheet.

See /eros/descript/loworbitopnavs.xls and opnav.txt.

____
COLOR 35km A |

We took a few color observations in this time period.

RTC	Solar Lat			
39	-8	MSI_3Color_204	204/07:29:59	Four 3-Filter Color Sets at Target 5
41	-10	OPN_209c_DKD_5Color	209/19:15:39	2x2 pointed to landmarks
41	-10	MSI_3ColorTarget_211a	211T03:42:29	Take images while XGRS controls pointing
37	-11	MSI_3ColorTarget_213	213T01:43:39	Three 3-Filter color sets at Target 3

See ../eros/descript/color35km.txt and .xls for complete listing.

17*

17.0 50km B Orbit   2000-206 to 2000-249

****

17.1 - Historical Background

This is the continuation of 50km A following the brief drop to 35 km. Time period these observations are taken from covers:

	doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start OCM-9	206	36 x 56	90	1.1	6.7	35 x 50km Transition	-9
OCM-10	213	52 x 49	90	1.2	6.7	50km B	-12
OCM-11	221	52 x 50	-75	1.2	14.1	50km B (continued)	-14
OCM-12	239	49 x 102	-67	2.3	4.4	50 x 100km Transition	-20
End OCM-13	249	100 x 103	-65	3.5	10.9	100km South	-24

See /eros/traj/traj_50b_rtc.gif - plot of range to center
/eros/traj/traj_50b_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

This is not a polar orbit but inclination is still pretty high (75 deg from equator). This is the first retrograde orbit. Solar latitude is now dropping below the equator. You will see the gradual shift in the mapping coverage southward as compared to the 50km A.

17.2 Sequence Design

____
MONOCHROME 50km B |

Opnavs :

Same as 50kmA.

See /eros/descript/loworbitopnavs.txt and opnav.xls.

XREQs:

Same as 50km A except XGRS in control the whole time.

Plots available (see 50kmA XREQ section for description of these plots):

/eros/00212/xreq_00212.gif
/eros/00220/xreq_00220.gif
/eros/00227/xreq_00227.gif
/eros/00234/xreq_00234.gif

See ../eros/descript/xreqs.txt and .xls for description and spreadsheet.

NLRide 50km B:

There are a few NLR observatons in here

MSI_SouthSupport_214, 216, and 219.

See ../eros/descript/ridenlr.txt and .xls for a complete listing.

FeatureTracks 50km B:

See also /eros/descript/featuretracks.txt and .xls.

51 -21	LowEmiss_242f	242T03:16:39	circular 2x3 mosaics at low emission
	LowEmiss_242a	242T04:41:39	circular 2x2 mosaics at low emission
	LowEmiss_242b	242T04:55:39	circular 2x2 mosaics at low emission
	LowEmiss_242c	242T05:09:39	circular 2x2 mosaics at low emission
50	LowEmiss_242d	242T05:56:39	circular 2x2 mosaics at low emission
	LowEmiss_242e	242T06:10:39	circular 2x2 mosaics at low emission
	FeatureTrack_244a	244T00:28:29	lat/wlon (34/33)
	LowEmiss_244a	244T04:49:29	circular 2x2 mosaics at low emission
	FeatureTrack_244b	244T05:16:39	lat/wlon (21/72)
55 -22	FeatureTrack_244c	244T06:53:29	lat/wlon (-39/18)
	LowEmiss_246a	246T16:40:39	circular 2x2 mosaics at low emission
	LowEmiss_246b	246T20:54:39	circular 2x2 mosaics at low emission
50	FeatureTrack_247a	247T00:04:59	lat/wlon (-22/235)
70	LowEmiss_247a	247T03:00:39	circular 2x2 mosaics at low emission
70	LowEmiss_247b	247T03:14:39	circular 2x2 mosaics at low emission

Flyovers 50km B:

See also ../eros/descript/flyover.txt and .xls.

RTC	Solar Lat	Obs Name	UTC	Descript
51	-21	Flyover_242a	242T03:34:59	images taken every 30 seconds
50		Flyover_242b	242T06:22:59	images taken every 30 seconds
50		Flyover_242c	242T07:45:59	images taken every 29 seconds
50	-22	Flyover_244a	244T19:13:29	images taken every 30 seconds

____

COLOR 50km B |

We started taking more color during this time period. Here's the list. See color50km.xls for more complete data on each observation. Note that sub-solar latitude has fallen south of equator. Still in nearly polar orbit (inclination 75 deg) so view to Eros alternates from north to south.

See also ../eros/descript/color50km.txt and .xls.

RTC	Solar Lat	Obs Name	UTC	Descript
50	7	MSI_Crater4Color_166	166T01:13:31	Five 4 Filter sets on 5.5 KM crater with clean
52	-9	OPN_207b_KD_5Color	207T11:15:39	2x2 pointed to landmarks
55		MSI_3ColorTarget_208a	208T08:02:31	Take images while XGRS controls pointing
44		MSI_3ColorTarget_208	209T01:55:21	Take images while XGRS controls pointing
46	-9	OPN_209a_K3x2_5Color	209T03:15:39	3x2 pointed to landmarks
54		MSI_3ColorTarget_210a	210T10:42:31	Take images while XGRS controls pointing 4
54		OPN_212b_KD_5Color	212T11:15:39	2x2 pointed to landmarks

50	-12	OPN_215a_KD_5Color	215T03:34:32	Color 2x2 pointed to landmarks	
50		MSI_3ColorTarget_215	215T09:32:59	Take images while XGRS controls pointing	
50		OPN_216b_KD_5Color	216T10:33:32	Color 2x2 pointed to landmarks	
52		MSI_3ColorTarget_217	217T00:14:59	Take images while XGRS controls pointing	
50		MSI_3ColorTarget_218	218T21:33:59	Take images while XGRS controls pointing	
52		OPN_220c_KD_5Color	220T18:32:32	2x2 pointed to landmarks	
51		MSI_3ColorTarget_222b	222T23:05:50	Take images while XGRS controls pointing	
51		MSI_3ColorTarget_223a	223T00:42:30	Take images while XGRS controls pointing	
52		MSI_3ColorTarget_223b	223T03:02:00	Take images while XGRS controls pointing	
51		OPN_223b_KD_5Color	223T10:14:40	2x2 pointed to landmarks	
51		OPN_224a_KD_5Color	224T03:20:00	2x2 pointed to landmarks	
52	-15	MSI_3ColorTarget_224a	224T05:50:50	Take images while XGRS controls pointing	
52		MSI_3ColorTarget_224b	224T08:28:50	Take images while XGRS controls pointing	
		MSI_3ColorTarget_224c	224T23:03:50	Take images while XGRS controls pointing	
		MSI_3ColorTarget_225b	225T07:11:25	Take images while XGRS controls pointing	
		OPN_225c_KD_5Color	225T18:32:33	2x2 pointed to landmarks	
		OPN_226a_KD_5Color	226T02:10:00	Two 2x2s pointed to landmarks	
50		OPN_226c_KD_5Color	226T17:18:00	2x2 pointed to landmarks	
		MSI_3ColorTarget_226b	226T20:46:05	Take images while XGRS controls pointing	
		MSI_3ColorTarget_228a	228T02:18:40	Take images while XGRS controls pointing	
		MSI_3ColorTarget_228b	228T05:13:40	Take images while XGRS controls pointing	
		MSI_3ColorTarget_230	230T07:07:40	Take images while XGRS controls pointing	
50	-19	MSI_XREQ01_234b	234T20:13:35	Mis-named! This should be called MSI_3ColorTarget_234b.	
50		MSI_3ColorTarget_235b	235T20:13:35	Take images while XGRS controls pointing	
50		MSI_3ColorTarget_236b	236T23:39:45	Take images while XGRS controls pointing	
50		MSI_3ColorTarget_238a	238T01:52:34	Take images while XGRS controls pointing	
50		MSI_3ColorTarget_238b	238T19:43:34	Take images while XGRS controls pointing	
50		MSI_5Color_242a	242T07:19:59	repeated 1x2 of color targets	50
50		MSI_5Color_242b	242T07:27:59	repeated 1x2 of color targets	50 -22
50		MSI_5Color_242c	242T07:36:59	repeated 1x2 of color targets	50

50	MSI_5Color_246a	246T20:26:39	1x1 of color targets 50 -23
66	MSI_5Color_247a	247T02:50:59	repeated 1x2 of color targets 70 -24

*******************************18***
18.0 100km Orbit - South 2000-239 to 2000-294
****

18.1 Historical Background

Observations at 100km South were taken during the following time periods:

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start	OCM-12	239	49 x 102	-67	2.3	4.4	50 x 100km Transition	-20
	OCM-13	249	100 x 103	-65	3.5	10.9	100km South	-24
	OCM-14	287	98 x 50	-50	2.2	3.5	100 x 50km Transition	-39
End	OCM-15	294	52 x 50	-47	1.2	3.2	50km C	-41

See /eros/traj/traj_100south_rtc.gif - plot of range to center
/eros/traj/traj_100south_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

Including the transition orbits before and after the circular 100km period, this is an extended observing period, almost 8 weeks. Inclination of this orbit is 65 deg retrograde, a little higher than the 100 km north. With sub-solar latitude between -21 and -41 latitude, the southern pole region was fully illuminated, the northern pole was mostly in darkness. This second period at 100km was scheduled into the mission plan to provide partial global views of the illuminated southern hemisphere from high orbit not possible during the first 100km orbital period in April. There was very little color imaging during the north 100km orbital period due to a s/w problem. With that problem now solved, we made an effort to do much more color imaging in this 100km South period.

18.2 Sequence Design

Pretty much same observation types as first time around except the opnavs are different.

____

MONOCHROME 100km South |

Opnavs:

Still taking three opnavs per day. All of type 'KD' (two 2x2 mosaics) as in 50 km orbit, except the KD design changed on day 241 from two single 2x2 mosaics to two repeating 2x2 mosaics. Each goes around twice now; 8 frames per mosaic.

Example: OPN_248C_DKD - this is comprised of two repeating 2x2 mosaics on different opnav landmarks (16 frames total)

Note: The opnavs in week 241 are mis-named; they are called DKH's but they are actually DKD's (2x2s). The plots are correct.

See ../eros/descript/loworbitopnavs.txt and opnav.txt (technically, these are not low orbit
opnavs but they are of that design).

Regional Globals 100km South:

These are many single mosaics taken sporadically throughout this orbit. Most of them
do not cover all of Eros. Some cover most of Eros. Intent was to provide partial globals
to give the larger context. These kind of took place of the Daily Globals of 200 km orbit.

MSI_RegGlobal_248 through about OPN_307a are rougly at 100km range.

See /eros/descript/global.txt and .xls for a complete listing.

There is one nice *global rotation set* (mosaics taken back-to-back throughout one rotation of
Eros on doy 307... MSI_RegGlobal_307a-q at an intermediate range between 100 and 200 km.

See /eros/descript/globalmovies.txt and .xls.

Lonscans 100km South:

See 100km North Lonscans for a more complete description of these observations. Same idea,
slew up and down in a little reversing strip parallel to longitude lines for 5.5 hours
as Eros rotates beneath. Perform these at multiple times during orbit when latitudinal
view is different. These complement the 100km North lonscans to fill in coverage of

southern hemisphere. Much redundant coverage of equatorial regions.

The following list is arranged by VIEW to Eros from spacecraft (north to south). For instance, Lonscan_5x1_305b begins when the sub-s/c latitude is +26 (north 26 latitude) on the side of the orbit that is increasing in latitude with time. The view in this lonscan will generally give lower emissions on regions in mid-north latitudes, and larger emission angles on regions in the south. Solar latitude is about -45 (45 south latitude) which means poor incidence (shadows) on the northern regions, but good incidence in south (high sun). We scheduled these lonscans to give good latitudinal sampling, collectively.

See /eros/descript/lonscans.txt and .xls.

RTC	Solar Lat	Observation	sub s/c latitude	start time	mosaic (colxrow)	coverage
94	-45	Lonscan_5x1_305b	+26(N)	305T14:03:29		Reversing 5x1 scans for 1 rotation on mid north lats
118	-45	Lonscan_5x1_305a	+20(N)	305T08:03:29		Reversing 5x1 scans for 1 rotation on north equat lats
101	-25	MSI_LonScan_250a	+10(S)	250T17:19:59		reversing 1x3 scans on equatorial lats
		MSI_LonScan_250b	-14(S)	250T23:12:59		reversing 1x4 scans on south equatorial lats
102	-30	MSI_LonScan_265	-68(N)	265T18:15:00		reversing 1x4 scans on high south lats

Note:
(N) or (S) means s/c is GOING North, or going South in the orbit
the + and - indicate north and south latitude, respectively

Flyovers - 100km South:

Quite a few wonderful flyovers were performed during this orbit.

See also ../eros/descript/flyover.txt and .xls.

RTC	Solar Lat	Obs Name	UTC	Descript
91	-23	Flyover_246a	246T21:39:59	images taken every 30 seconds
102	-26	MSI_Flyover_255	255T04:10:00	images every 27 sec
		MSI_LimbScan_263a	263T00:30:00	Filter 4 images taken as FOV scans across limb
101	-29	MSI_LimbScan_263b	263T03:30:00	Filter 4 images taken as FOV scans across limb
102		MSI_Flyover_264	264T02:20:00	Filter 4 images taken as asteroid moves across FOV
		MSI_LimbScan_266	266T20:55:00	Filter 4 images taken as FOV scans across limb
102		MSI_Flyover_267	267T13:15:00	Filter 4 images taken as asteroid moves across FOV, double read-down
		MSI_LimbScan_281	281T06:09:59	Filter 4 images taken as FOV scans across limb
103		MSI_Flyover_281a	281T15:39:59	Filter 4 images taken as asteroid moves across FOV
103		MSI_Flyover_281b	281T16:57:59	Filter 4 images taken as asteroid moves across FOV
104	-36	MSI_Flyover_281c	281T18:49:59	Filter 4 images taken as asteroid moves across FOV
97		MSI_Flyover_284	284T07:59:59	Filter 4 images taken as asteroid moves across FOV
		MSI_Flyover_289	289T11:26:00	Filter 4 images taken as asteroid moves across FOV
95		MSI_Flyover_291a	291T08:10:00	Filter 4 images taken as asteroid moves across FOV
96		MSI_Flyover_291b	291T18:40:00	Filter 4 images taken as asteroid moves across FOV
96	-40	Flyover_306	306T14:33:29	full rev near pole 120seq30(162 sec)

FeatureTracks - 100km South:

We performed a LOT of feature tracks at the 100km range during this part of the mission. Here is the complete list. These are the equivalent of the low emission maps of the north 100km orbit, designed to help fill in low emission viewing for global basemap.

See also /eros/descript/featuretracks.txt and .xls.

RTC	Solar Lat	Obs Name	UTC	Descript
101	-25	MSI_MonoPaw_254	254T02:36:40	4 2x2s of Paw center
		MSI_RegGlobal_254	254T03:10:00	4x4 of region
		MSI_MonoSaddle_254	254T05:10:00	4 2x2s of Paw center
102		MSI_MonoSP1_254	254T22:11:40	4 2x2s of 3 regions
		MSI_MonoSP2_255	255T02:41:40	4 2x2s of 3 regions
		FeatureTrack_255a	255T19:13:30	lat/wlon (-78/312)
		FeatureTrack_256a	256T03:38:30	lat/wlon (-49/81)
		FeatureTrack_257a	257T13:19:30	lat/wlon (2/343)
102	-28	FeatureTrack_258a	258T21:01:18	lat/wlon (-78/312)
		FeatureTrack_259a	259T02:08:30	lat/wlon (-35/200)
		FeatureTrack_259b	259T19:58:30	lat/wlon (27/345)
		FeatureTrack_260a	260T03:08:30	lat/wlon (20/216)
		MSI_MonoTarget_264a	264T10:16:40	repeating 2x2s of Targeted at region of interest
		MSI_MonoTarget_264b	264T13:21:40	repeating 2x2s of Targeted at region of interest
		MSI_FeatureTrack_26	266T04:00:00	lat/wlon (-13/15)
100	-32	FeatureTrack_269a	269T18:43:30	lat/wlon (-34/203)
		FeatureTrack_270e	270T14:06:40	lat/wlon (51/5)
		FeatureTrack_270a	270T16:21:39	lat/wlon (18,221)
		FeatureTrack_270b	270T17:32:39	lat/wlon (8,271)
		FeatureTrack_270c	270T18:35:39	lat/wlon (4,22)
		FeatureTrack_270d	270T19:38:39	lat/wlon (28,155)
		FeatureTrack_271a	271T09:43:29	lat/wlon (7/18)
		FeatureTrack_274a	274T14:58:29	lat/wlon (20/317)
		FeatureTrack_274d	274T16:11:39	lat/wlon (18/271)
		FeatureTrack_274b	274T17:20:29	lat/wlon (40/331)
		FeatureTrack_274c	274T19:36:29	lat/wlon (17/210)
104	-35	MSI_MonoTarget_278a	278T06:46:39	repeating 2x2s of Targeted at region of interest

MSI_MonoTarget_278b 278T08:56:39 repeating 2x2s of Targeted at region of interest

MSI_MonoTarget_278c 278T09:19:39 repeating 2x2s of Targeted at region of interest

MSI_MonoTarget_280a 280T02:16:39 repeating 2x2s of Targeted at region of interest

MSI_MonoTarget_280b 280T04:21:39 repeating 2x2s of Targeted at region of interest

MSI_MonoTarget_280c 280T05:41:39 repeating 2x2s of Targeted at region of interest

MSI_FeatureTrack_280 280T06:44:59 lat/wlon (-71/320)

MSI_FeatureTrack_281 281T10:39:59 lat/wlon (53/256)

MSI_MonoPawSide1_285 285T02:56:39 repeating 2x2s of Targeted at region of interest

MSI_NoseFeatFly_285 285T06:59:59 Point to ABF position on 180lon nose and take images

MSI_ScottFeat 285T15:16:39 Point to ABF position on saddle and take images

105 -38 MSI_MonoPawSide2_285 285T17:01:39 repeating 2x2s of Targeted at region of interest

MSI_MonoSad2_285 285T20:01:39 repeating 2x2s of Targeted at region of interest

MSI_MonoPawSide3_286 286T08:51:39 repeating 2x2s of Targeted at region of interest

MSI_MonoSP1_286 286T10:16:39 repeating 2x2s of Targeted at region of interest

101 MSI_MonoSP2_286 286T10:41:39 repeating 2x2s of Targeted at region of interest

MSI_MonoSP3_286 286T11:15:39 repeating 2x2s of Targeted at region of interest

MSI_MonoSP4_286 286T11:37:29 repeating 2x2s of Targeted at region of interest

MSI_MonoRidge_286 286T12:27:39 repeating 2x2s of Targeted at region of interest

98 -39 M SI_FeatureTrack_289a 289T07:08:30 lat/wlon (-26/186)

98 MSI_FeatureTrack_289b 289T09:08:30 lat/wlon (-67/359)

69 -40 MSI_FeatureTrack_292 292T07:00:00 lat/wlon (-15/17)

71 MSIMonoTargt2x2s_293a 293T01:51:40 repeating 2x2s of Targeted at region of interest

88 MSIMonoTargt2x2s_293b 293T08:46:40 repeating 2x2s of Targeted at region of interest

92 MSI_FeatureTrack_294 294T02:30:00 lat/wlon (-24/167)

NLR Ride Observations:

There are a few nadir pointed NLR observations with which we took images.
See /eros/descript/ridenlr.xls for a complete listing.

The ones for this period start with nlr_1 on doy273 through MSI_NLRide_307.

COLOR 100km South |

Quite a few color observations in the 100km South orbit. Normal type, cleaned multiple filter sets at stopped positions in 2x2's or other small mosaics.

See ../eros/descript/color100.xls and .txt for complete listings and description.

RTC	Solar Lat	Observation	Start UTC	Description
102		MSI_5ColorSP1_248	248T19:49:59	repeated 2x2 +1x1 of South Pole targets
102		MSI_5ColorSP2_248	248T22:14:59	repeated 2x2 +1x1 of South Pole targets
102		MSI_5ColorSP3_249	249T00:04:59	repeated 2x2 +1x1 of South Pole targets
101	-25.8	MSI_7ColorPaw_253	253T21:26:59	repeated 2x2 +1x1 of South Pole targets
102		MSI_5ColorSP4_254	254T23:25:00	repeated 2x2 +1x1 of South Pole targets
102		MSI_5Color_257a	257T10:03:30	2x2+1x1 of color target
102		MSI_5Color_257b	257T12:56:30	2x2+1x1 of color target
102		MSI_5Color_257c	257T14:58:30	2x2+2 1x1's of color target
102		MSI_5ColorTarget_265a	265T02:15:00	Two 2x2 + 1x1 of Southern targets
102	-29.9	MSI_5ColorTarget_265b	265T04:05:00	Two 2x2 + 1x1 of Southern targets
102		MSI_5ColorTarget_265c	265T04:55:00	Two 2x2 + 1x1 of Southern targets
102		MSI_5ColorTarget_265d	265T06:10:00	Two 2x2 + 1x1 of Southern targets
102		MSI_5Color_272a_rev	272T02:48:29	Two 2x2 + 1x1 of Southern targets
102		MSI_5Color_272c	272T03:24:39	2x2 of Southern targets
102	-32.5	MSI_5Color_272d	272T03:54:39	2x2 of Southern targets

102	MSI_5Color_272e	272T04:38:29	2x2 of Southern targets
103	MSI_5Color_275a	275T09:56:39	Two 2x2 + 1x1 of Southern targets
103	MSI_5Color_275c	275T10:32:39	2x2 + 1x1 of Southern targets
103 -34	MSI_5Color_275d	275T11:18:39	2x2 of Southern targets
103	MSI_5Color_275e	275T11:35:39	2x2 of Southern targets
103	MSI_5Color_275f	275T11:51:39	2x2 of Southern targets
102	MSI_5Color_275g	275T12:09:39	2x2 of Southern targets
101	MSI_5Color_275i	275T12:26:39	Two 2x2 + 1x1 of Southern targets
100	MSI_5Color_276a	276T01:01:39	2x2 + 1x1 of Southern targets
100	MSI_5Color_276b	276T01:20:39	2x2 + 1x1 of Southern targets
100	MSI_5Color_276d	276T03:21:39	2x2 + 1x1 of Southern targets
100	MSI_5Color_276f	276T04:16:39	2x2 + 1x1 of Southern targets
100	MSI_7Color_278	278T16:39:59	Two 2x2 + 1x1 of Southern targets
101	MSI_5Color_279a	279T08:49:59	Two 2x2 + 1x1 of Southern targets
101 -35	MSI_5Color_279b	279T10:59:59	Two 2x2 + 1x1 of Southern targets
100	MSI_7Color_282a	282T10:39:59	Two 2x2 + 1x1 of Southern targets
103	MSI_7Color_282b	282T13:14:59	Two 2x2 + 1x1 of Southern targets
105	MSI_ScottFeat_5Color	285T15:48:44	Color images of same saddle location
	MSI5ColorPawSide2_285	285T17:23:59	Two 2x2 + 1x1 of Southern targets
102 -38	MSI_7ColorRidge_286	286T07:21:39	Two 2x1 + 1x1 of ridge
86	MSI_7Color_287c	287T15:18:30	Two 2x2 + 1x1 of Southern targets
81	MSI_5Color_287a	287T16:38:30	Two 2x2 + 1x1 of Southern targets
79	MSI_5Color_287b	287T18:08:30	Two 2x2 + 1x1 of Southern targets
70	MSI_5Color_287d	287T20:53:30	Two 2x2 + 1x1 of Southern targets
98 -40	MSI_5ColorSP_289	289T08:05:00	Two 2x2 + 1x1 of Southern targets
107 -61	MSI_3ColorFlyover_344	344T02:43:19	3 Filter set Flyover

19.0 50km C   2000-287 to 2000-299
****

19.1 Historical Background

Following the 100km orbit south, there was a short period of time where we transitioned to 50km in preparation for the first low altitude flyover. Solar latitude went from -39 to -43 during this period. These orbits were only moderately inclined to Eros equator (about 50 degrees, retrograde). Polar orbits no longer possible because of Eros position around the sun. Solar latitude dropping to mid south.

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start	OCM-14	287	98 x 50	-50	2.2	3.5	100 x 50km Transition	-39
	OCM-15	294	52 x 50	-47	1.2	3.2	50km C	-41
End	OCM-16	299	51 x 19	-47	0.7	1	Low Alt Flyover I	-43

See ../eros/traj/traj_50c_rtc.gif - plot of range to center
../eros/traj/traj_50c_lat.gif - plot of sub-s/c latitude for NADIR point (not actual pointing)

19.2 Sequence Design

____
MONOCHROME 50km C |

Opnavs :

Three opnavs per day. Two repeating 2x2 mosaics on separate targets for each.

See /eros/descript/loworbitopnavs.xls and opnav.txt

XREQs:

Same as 50km A. MSI imaging strips with XGRS pointing.

Only one weekly coverage plot:

/eros/00290/xreq_00290.gif

See also /eros/descript/xreqs.txt and .xls for description and spreadsheet.

FeatureTracks 50km C:

Only one:

```
      solar
rtc    lat

69km  -40     MSI_FeatureTrack_292       292T07:00:00   lat/wlon (-15/17)
```

____
COLOR 50km C |

RTC	Solar Lat	Observation		
50km	-39	MSI_3ColorFlyover_290	290T06:10:00	Take color images as flying over asteroid

See /eros/descript/color50km.txt and .xls for complete listing of all color at 50km.

***************************************20**

20.0 Low Altitude Flyover I

****

20.1 Historical Background

Not in the original mission plan, this was an attempt to fly very close to the surface of Eros to acquire high resolution images. This first low altitude flyover would be a single pass that would take s/c from 50 km orbit down to 6 km off the surface of the asteroid then back up to 200km.

	doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start OCM-16	299	51 x 19	-47	0.7	1	Low Alt Flyover I	-43
End OCM-17	300	64 x 203	-35	5.4	1.4	Transition to 200km	-44

See /eros/traj/traj_lowalt1_rtc.gif - plot of range to center
/eros/traj/traj_lowalt1_rts.gif - plot of range to SURFACE for NADIR point (not actual pointing)
/eros/traj/traj_lowalt1_lat.gif - plot of sub-s/c latitude for NADIR point (not actual pointing)

20.2 Sequence Design

The observations were designed deliberately to be simple. There were uncertainties in the planning trajectories. Any downtrack error could cause a relative shift in timing of the observations relative to closest approach. For this reason we pointed to off nadir positions (no asteroid body fixed pointing).

Essentially the idea was to look at lit territory as it passed below and adjust the imaging rate to ensure frame-to-frame overlap. Except for two brief color observations, all of this data is monochrome, filter 3, cleaned.

The 3xn and 2xn observations were put in to capture a wider swath of area prior to closest approach when the ground track was moving more slowly. The closest approach sets are single image strips with a large amount of frame-to-frame overlap. The extra overlap was there to take into account the possibility of downtrack error which might have moved any observation closer to closest approach where territory moves at higher rate.

The color observations (only two) were 3 color single shots.

RTC	solar lat	Observation	UTC		Description
34	-43	MSI_LowAlt_Before_3xN	300T03:44:00	45	Reversing 1x3 mosaic, scan normal to grountrack
28		MSI_LowAlt_Before_2xN	300T04:42:15	44	Reversing 1x2 mosaic, scan normal to groundtrack

MSILowAltBefore3Color 300T05:39:35 3 Color set at end of above scan
22 MSI_LowAlt_Closest_1 300T05:45:00 62 Images taken during low altitude flyover
MSI_LowAlt_Closest_2 300T06:35:45 53 Images taken during low altitude flyover
19 MSILowAltAfter3Color 300T06:57:59 3 Color set after closest approach
MSI_LowAlt_Closest_3 300T06:58:44 15 Images taken during low altitude flyover
MSI_LowAlt_After 300T07:13:45 14 Zigzag mosaic (2xn) on limb

21

21.0 200km Orbit - South 2000-300 to 2000-348

****

21.1 Historical Background

Following the low altitude pass the s/c climbed up to 200 km, swung back down briefly to 65 km and back up to 200km where we stayed for 5 weeks. Sub-solar latitude during the transitions and the 200 circular dropped from -44 to -61 (south side fully illuminated now).
This orbit would return the 200km global views of the illuminated south side of Eros to complement the north side global views returned in the 200km North orbit in March.

		doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start	OCM-17	300	64 x 203	-35	5.4	1.4	Transition to 200km	-44
	OCM-18	308	196 x 194	-33	9.4	3.5	200km South	-47
	OCM-19	342	193 x 34	-1	4.2	1.5	200 x 35km Transition	-61
End	OCM-20	348	38 x 34	-1	0.8	55.9	35km B	-64

See /eros/traj/traj_200south_rtc.gif - plot of range to center
/eros/traj/traj_200south_lat.gif - plot of sub-s/c latitude for nadir point i(not actual pointing)

21.2 Sequence Design

Same concepts as designs in 200km north, except we did a lot more color, more flyovers, and more full rotation global mosaic sets.

____
MONOCHROME 200km South |

Opnavs:

Back to taking a global mosaic for each of the three opnavs per day.

OPN_307B_KL through OPN_346B_KL.

See ../eros/descript/global.txt for a complete listing.

Global Rotation Sets:

Take series of mosaics over 1 rotation while at different latitudinal views.

RTC	Solar Lat	Obs Name	Sub-s/c Lat	UTC	Descript

157to -46 MSI_RegGlobal_307a-q   -37(S)   307T06:24:59   is actually a movie, goes for 1 rotation although
165   the mosaics have separate obs names
197 -51   MSI_EquatGlobals_319   +12(N)   319T14:06:39   mosaics for 1 rot, view of equatorial latitudes
MSI_HiNorthGlob _321a   +36   321T09:38:20   mosaics for 1 rot, view of high north latitudes
MSI_HiNorthGlob _321b   321T14:55:00   (continuation of above, only 1 mosaic)
MSI_MidNoGlobals_329   +22(N)   329T12:08:20   mosaics for 1 rot, view of mid north latitudes
196 -57   MSI_HiNorthGlob_331   +33(S)   331T08:21:40   mosaics for 1 rot, view of north latitudes
MSI_HighSoGlobals_335   -34(N)   335T20:14:59   mosaics for 1 rot, view of hi south latitudes
196 -59   MSI_MidSoGlobals_337   -11(N)   337T06:23:19   mosaics for 1 rot, view of mid south latitudes

(S) and (N) refer to direction of orbit (south-going, north-going). Latitude indicated by + (north), - (south)

See ../eros/descript/globalmovies.txt and .xls.

Regional Globals 200km South:

Many single global mosaics. All of the opnavs in this period are tailored globals.
Also, see observations MSI_RegGLobal_307a through MSI_Global_347d.

See /eros/descript/global.txt and .xls for complete listing.

Lonscans 200km South:

Only three lonscans this time because we performed so many flyovers. See ../eros/descript/lonscans.xls and .txt.
See also Lonscan description in 200km North section.

RTC	Solar Lat	Obs Name		UTC		Description
195	-48	MSI_Lonscan2x4_312	10(S)	312T21:34:59	342	Repeating 2x4 mosaics for 1 rotation on equat lats 195 -48
196	-47	MSI_Lonscan4x2_309	-9(S)	309T06:39:59	280	Repeating 4x2 mosaics for 1 rotation on equat lats
194	-50	MSI_Lonscan4x2_315	-19(S)	315T06:14:59	368	Repeating 4x2 mosaics for 1 rotation on south lats 194 -50

Note: For example, Lonscan2x4_312: 10(S) means observation occurs in part of orbit 'going' south. The approximate sub-s/c latitude is 10 deg north latitude. View of asteroid is about at equator, on the south-going part of orbit. Illumination (-47) is southerly.

Flyovers 200km South:

RTC	Solar Lat	Obs Name		Start UTC	Descript
196		MSI_Flyover_310	+14(N)	310T08:33:29	south paw; 116 frames
196	-48	MSI_Flyover_311	+30(N)	311T06:53:29	full rev; 1000 frames (delta 19 sec)
		MSI_Flyover_311b	+36(N)	311T22:08:29	full rev, nadir, misses noses; 190 frames (delta 82 sec)
		MSI_Flyover_314	-11(S)	314T21:08:29	half rev; 120 frames (delta 82 sec) -x hem so of eq
		MSI_Flyover_320	+27(N)	320T09:08:30	full rev; 300 (delta 60 sec)
195	-52	MSI_Flyover_322	+29(S)	322T07:38:30	.8 rev; 250 frames (delta 60)
		MSI_Flyover_323	+15(S)	323T03:38:30	1 rev; 440 frames (delta 45 sec)
		MSI_Flyover_326	-35	326T02:50:00	20 frames (200 sec)
		MSI_Flyover_334	+18(S)	334T06:38:30	1 rev; 310 frames (delta 64 sec)

MSI_Flyover_336 -24(S) 336T08:13:29   .8 rev; 230 frames (delta 64)
197 -59   MSI_Flyover_338a +8(N) 338T03:43:29   1.1 rev; 420 frames (delta 48 sec)
MSI_Flyover_338b +25(N) 338T23:08:29   1 rev; 392 frames (delta 50 sec)
198   MSI_Flyover_339   +35   339T22:58:19   1.6 rev; 600 frames (delta 50 sec)
186   MSI_Flyover_343   -3   343T00:43:19   1.7 rev; 650 frames (delta 50 sec)
82 -62   MSI_Flyover_344   0   344T23:18:19   1.6 rev; 930 frames (delta 33 sec)

Feature Tracks 200km South:
----

197 -51 FeatureTrack_320   +30   320/1538 - 1838   180 frames (60 sec) on -x nose

NLR Ride 200km South:

There are a a number of nadir pointed NLR observations with which we took images.
See /eros/descript/ridenlr.xls for a complete listing.

The ones for this period are:
MSI_NLRide_307 through MSI_NLRide_346

COLOR 200km South |

Same concept as in 200km north. See extensive descriptions there. Basically we take multiple filter, clean sets at stopped positions with good viewing angles. Ideal color imaging is done with low emission and low incidence, not possible in this mission. We usually sacrificed emission some to get reasonably low incidence.

```
          ------\     paw        -----\
        /        -- \         /         \
       /    I         ----  -/     II      \
      |
      \                Spole -------->+x   /
        \   IV                  III     /
          \                      /
            \------------/\----------/
                       saddle
```

COLOR (everything 7 filter)

Color Flyovers 200km South:

```
--------------------------
RTC Solar    Observation          Sub-s/c   STart UTC     Description
          Flyover_333            +7(S)   333T01:00:00   +7  going south    half rev, 3-color
196  -60   MSI_3ColorFlyover_341  +27(S)  341T04:28:19    3 Filter set Flyover
182  -62   MSI_3ColorFlyover_346   -2     346T02:58:19    3 Filter set Flyover
```

Color Lat Scans 200km South:

Naming scheme different here than in first 200km, uses doy, but the idea is the same. Take n-filter sets at stopped positions in variously shaped mosaics covering regions at moderate emission, low incidence. These are arranged by coverage (south to north).

```
154  -44   MSI_5ColorScan_301     301T20:36:30         Images taken every 100 s
191  -45   MSI_5Color04_304       304T03:44:29         Scan around nose while taking images
           MSI7ColorSPoleLat_316  316T06:34:59  -33(S)  7 Filter set every 15 deg for one rotation centered on south pole

197 -55    7ColorTarget_330a      330/0750      +30     Five 7f feature tracks
                  330b                                  (6x1 mosaics on 3 of them, 4x1 on one)
                  330c
                  330d
                  330e


194 -50    7ColorSPoleLat_316     316/0625      -30     25 7f sets on so. pole, low emiss (1 full rot)
193 -54    7ColorSoPoleLat_326    326/0440      -30     13 7f sets near nadir  (1 full rot)

192 -58    7ColorMidSo_335a       335/0750      -31(S)  2x2+1 of II/III nose
                  335b                                  2x2+1 of IV/I nose (HIGH incidence!)

193 -58    7ColorMidSo_336a       336/0440      -31(N)  2x2+1 of south pole area
                  336b                                  2x2+1 of south pole area
                  336c                                  2x2+1 of south pole area


192 -54  7ColorMidSo_325a         325/0740  -20to-28(S)  2x2+1 of III, ridge to pole
                325b                                     2x2+1 of IV, sadd, whole south
```

325c 2x3 of whole, IV best
325d 6x1 of paw side ridge
325e 2x2+1 of paw side and pole
325f 2x2+1 of paw side and pole

196 -50 7ColorMidSouth_318a 318/0130 -21(N) 2x2+1 of paw side (I and II) very good
318b 2x2+1 of III (great!!)
318c 2x2+1 of east saddle wall, and IV oblique

195 -54 7ColorMidSo_327a 327/0940 -20to-15(N) 2x2+1 of III and west saddle wall
327b 2x2+1 of III and west saddle wall
327c 1x6 saddle side ridge
327d 1x4 ridge but IV in front
327e 2x2+1 of paw side (I and II)
327f 2x2+1 of paw side (I and II)

194 -49 MSI7ColorMidNorth_313 313/1740 +15(S) 2x2+1 of saddle

194 -56 7ColorMidNoLat_332 332/0715 +14(S) 13 7f set lat scan (full rotation)

198 -54 7ColorPaw_328 328/1930 +4(N) 8x1 scan across paw side
7ColorSaddle_329 329/1730 9x1 scan across saddle side

193 -57 7ColorEquat_333 333/0555 +2(S) 2x2+1 of -x nose from the side

193 -53 7ColorEquat_324a 323/2330 -0(S) 9x1 of III (scan nose I to sadd)
324b 5x1 of IV (scan sadd to II nose)
324c 6x1 of II paw side

324d 4x1 of I paw side

197 -51 7ColorEquat_319a 319/0040 0(N) 5x1 of III
319b 3x1 of west saddle wall
319c 3x1 of IV/I nose
319d 4x1 of paw side

195 -56 7Color_Equat 337a 337/1700 -5(N) 2x2+1 of II/III nose
337b 2x2+1 of saddle side
337b 2x2+1 of saddle side

22
22.0 35km B Orbit 2000-342 to 2001-024
****

22.1 Historical Background

Following the 200km south orbit we dropped directly into a 200x35kmtransfer orbit for 6 days, and then the 38x34km orbit for about 6 weeks. This was a nearly equatorial orbit (inclination only 1 deg from equator). Purpose for this was to make sure the orbit was stable leading up to the Low Altitude Flyover II. The solar latitude dropped from -64 to -83 during that time meaning there was good illumination on the south pole. However, in this equatorial orbit it was not easy to see the south polar plateau, and impossible to see it at good emission angles.

doy orbit radii orbit period #orbits orbit name sub-solar inclin. (days)   lat

OCM-19 342   193 x 34   -1   4.2   1.5   200 x 35km Transition   -61
OCM-20 348   38 x 34   -1   0.8   55.9   35km B   -64
OCM-21 024   35 x 22   -1   0.6   6.1   Low Altitude Flyover IIa   -83

See ../eros/traj/traj_35b_rtc.gif - plot of range to center
../eros/traj/traj_35b_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

22.2 Sequence Design

____
MONOCHROME 35km B |

Opnavs:

Opnav design changed from the 50km scheme. Prior to this, low orbit opnavs were repeating 2x2s. During week 00360 we changed over to a design that takes a pair of 2x4 zigzag mosaics on separate landmarks. Since the ground track moves so quickly in this orbit, this was about the only way to get a coherent 8 frame mosaic without frame pull-apart. Since most of the xgrs mapping (XREQ) sequences pointed close to the equator, we used these opnavs to try to fill in coverage of the higher south latitudes.

Every now and then we removed one of the two opnav mosaics and substituted a 5 color 4 position mosaic. These have been called out (removed from the opnavs) and given separate observation names that indicate they are color observations. The companion monochrome mosaic is changed to a 2x2 (rather than2x4).

Example: OPN_007C_DKD_5color is the color companion to the monocrhome 2x4 OPN_007c_DKD.

See ../eros/descript/opnavs.txt and loworbitopnavs.xls for the monochrome opnavs from this period.

XREQs:

Same general concept as in 50km orbits. XGRS in control, pointing a few degrees off nadir (sunward), with occasional periods fixed on abf positions. Some of these observations were made into 3 color flyovers (see below).

Plots for monochrome XREQS available (see 50kmA XREQ section for description):

/eros/00346/xreq_00346.gif
/eros/00353/xreq_00353.gif
/eros/00360/xreq_00360.gif
/eros/01001/xreq_01001.gif
/eros/01008/xreq_01008.gif
/eros/01015/xreq_01015.gif

See ../eros/descript/xreqs.xls and .txt for description and spreadsheet.

____
COLOR 35km B |

Two types of color observations in this period:

Color Opnavs 35km B:

Color opnavs as discussed above. Usually 4 positions stopped, 5 filter, clean sets at each position.

RTC Solar Lat	Observation	Start UTC	Description
34 -66	OPN_353C_DKD_5Color	353T18:13:25	2x2 mosaic pointed to NAV landmarks
34	OPN_355D_DKD_5Color	355T20:52:40	2x2 mosaic pointed to NAV landmarks
35 -67	OPN_356D_DKD_5Color	356T23:57:40	2x2 mosaic pointed to NAV landmarks
34	OPN_359C_DKD_5Color	359T18:12:40	2x2 mosaic pointed to NAV landmarks
34	OPN_360C_DKD_5Color	360T18:42:40	2x2 mosaic pointed to NAV landmarks
34	OPN_362A_DKD_5Color	362T02:31:40	2x2 mosaic pointed to NAV landmarks
34	OPN_365A_DKD_5Color	365T00:11:40	2x2 mosaic pointed to NAV landmarks
34 -71	OPN_002C_DKD_5Color	002T18:52:39	2x2 mosaic pointed to NAV landmarks
38	OPN_004C_DKD_5Color	004T18:52:39	2x2 mosaic pointed to NAV landmarks
37 -74	OPN_006A_DKD_5Color	006T02:02:39	2x2 mosaic pointed to NAV landmarks
37	OPN_007C_DKD_5Color	007T18:47:39	2x2 mosaic pointed to NAV landmarks
35	OPN_008C_DKD_5Color	008T18:52:39	2x2 mosaic pointed to NAV landmarks
34	OPN_011B_DKD_5Color	011T19:27:39	2x2 mosaic pointed to NAV landmarks
37	OPN_013A_DKD_5Color	013T01:52:39	2x2 mosaic pointed to NAV landmarks

Color Flyovers 35km B:

These were taken during the xgrs controlled periods. They are 3-filter, clean sets taken with timing planned to give some amount of frame-to-frame overlap.

36 -73	MSI_3Color_004a	004T02:56:59	Take 3-Filter imaging while XGRS controls pointing
34	MSI_3Color_013a	013T07:09:59	Take 3-Filter imaging while XGRS controls pointing
38	MSI_3Color_015b	015T21:39:59	Take 3-Filter imaging while XGRS controls pointing
36	MSI_3Color_016b	016T21:39:59	Take 3-Filter imaging while XGRS controls pointing
36 -79	MSI_3Color_016c	016T22:19:59	Take 3-Filter imaging while XGRS controls pointing
38	MSI_3Color_018a	018T04:59:59	Take 3-Filter imaging while XGRS controls pointing
34	MSI_XREQ08_019a	019T06:45:00	Take 3-Filter imaging while XGRS controls pointing
37	MSI_3Color_021a	021T01:52:00	Take 3-Filter imaging while XGRS controls pointing
37 -81	MSI_3Color_021b	021T21:15:00	Take 3-Filter imaging while XGRS controls pointing

See ../eros/descript/color35km.txt and .xls for a listing of all the color observations at 35 km.

*************************************23***

23.0 Low Altitude Flyover II 2001-024 to 20001-028

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23.1 Historical Background

After success with the first low altitude flyover, the project scheduled a more agressive second low altitude flyover period that would include multiple close passes over the course of 4 days, at lower altitudes than ever before. OCM-21 took the s/c out of the 35km circular orbit and into a 37x19 orbit that would allow low altitude viewing each time a nose (0 or 180 longitude) swung into view over the course of 3 1/2 days. There were multiple passes during this time between OCM-21 and OCM-22 and several were had images taken at ranges down to about 5-8 km range. On day 28, OCM-22 tweaked this orbit to give several passes that would go even closer. Closest images of the entire flyover II period were taken on day 28 at range to surface of about 3.0 km. Note that the places on Eros that were physically the closest during these passes were often in darkness. We tried to image the closest sunlit portions of territory available (with margin for trajectory error).

	doy	orbit radii	orbit inclin.	period (days)	#orbits	orbit name	sub-solar lat
Start OCM-21	024	35 x 22	-1	0.6	6.1	Low Altitude Flyover IIa	-83
OCM-22	028	37 x 19	-1	0.6	1.3	Low Altitude Flyover IIb	-84
End OCM-23	028	36 x 35	-1	0.8	6	35 km C	-84

See /eros/traj/traj_lowalt2_rtc.gif - plot of range to center
/eros/traj/traj_lowalt2_rts.gif - plot of range to SURFACE for nadir point (not actual pointing)
/eros/traj/traj_lowalt2_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing!!!)

NOTE: These traj files assume nadir pointing, not actual pointing. But sun pointing constraints prevented us from looking very far from nadir.

Additional files:
/eros/01022/reconstructed_ranges.txt - lists one line per image and contains range and
************************ viewing info created using the post-flyby reconstructed trajectory and ACTUAL pointing. Nice overview.
(Use SPICE data for most accurate range data).

/eros/01022/01022_imagelist.txt lists the pre-flyby predict range and viewing info.

22.2 Sequence Design

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MONOCHROME Lowalt 2 |

Opnavs Lowalt2 :

Same as in 35km orbit. Two 2x4 zigzag mosaics. We switched to using nadir sun targeting rather than abf because of downtrack uncertainties.

2xNs and 3xNs:

These are similar to those used in the lowalt 1. These are zigzag mosaics. By that I mean that we slew back and forth in direction approximately normal to groundtrack movement. This returns a swath of images 2 or 3 wide. These are monochrome filter 4 or filter 3. These were taken during times when the range was a little greater, or ground-track movement not as fast. These were not possible during lowest altitude passes (no time to slew).

these have names like...   LowAlt_2xN_028   etc

Low altitude single strips:

The lowest altitude data were strips that are one single frame wide. Time deltas between images were changed periodically along the strip to prevent keep frames from pulling apart.
The rate of territory movement through fov changes significantly as the noses swing into view.

These have names like...   LowAlt_028a, etc

Complete list of observations:

RTC Solar Lat	Observation	Start UTC	Description
	MSI_LowAlt_025a	025T02:13:35	Single strip of low altitude data in Filter 3
	MSI_LowAlt_3xN_025a	025T03:22:35	Continuous 3xN strip of low altitude data in Filter 3
	MSI_LowAlt_025b	025T04:33:35	Single strip of low altitude data in Filter 3
	MSI_LowAlt_3xN_025b	025T05:06:35	Continuous 3xN strip of low altitude data in Filter 3
	MSI_LowALT_2xN_025a	025T06:32:35	Continuous 2xN strip of low altitude data in Filter 3
	MSI_LowAlt_3xN_025c	025T07:52:35	Continuous 3xN strip of low altitude data in Filter 3
-82.8	MSI_LowAlt_025c	025T08:41:35	Single strip of low altitude data in Filter 3, while scanning on limb
	MSI_LowAlt_3xN_025d	025T09:27:35	Continuous 3xN strip of low altitude data in Filter 3
	MSI_LowAlt_2xN_026a	026T00:45:40	Continuous 2xN strip of low altitude data in Filter 3
	MSI_LowAlt_026a	026T01:12:20	Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
	MSI_MidRange_026a	026T02:28:55	2x3 Mosaic at mid-range altitude in Filter 3
	MSI_LowAlt_026b	026T02:42:30	Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST(75 images), TABLE 5 OFF NONE (175 images)
	MSI_MidRange_026b	026T03:39:50	2x3 Mosaic at mid-range altitude in Filter 3
	MSI_LowAlt_2xN_026b	026T03:53:25	Continuous 2xN strip of low altitude data in Filter 3
-83.2	MSI_LowAlt_026c	026T04:34:05	Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)

MSI_LowAlt_2xN_026c   026T05:21:05   Continuous 2xN strip of low altitude data in Filter 3
MSI_LowAlt_026d   026T06:27:45   Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
MSI_LowAlt_3xN_026   026T07:10:30   Continuous 3xN strip of low altitude data in Filter 3
MSI_LowAlt_026e   026T08:22:10   Single strip of low altitude data in Filter 3, while scanning
MSI_LowAlt_2xN_027a   027T03:57:50   Continuous 2xN strip of low altitude data in Filter 3
MSI_LowAlt_027a   027T04:48:30   Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
-83.6 MSI_LowAlt_2xN_027b   027T06:05:30   Continuous 2xN strip of low altitude data in Filter 3
MSI_LowAlt_027b   027T06:30:10   Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
MSI_LowAlt_2xN_027   027T07:11:55   Continuous 2xN strip of low altitude data in Filter 3
MSI_LowAlt_027c   027T08:13:35   Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
MSI_LowAlt_2xN_028   028T06:36:55   Continuous 2xN strip of low altitude data in Filter 3
MSI_LowAlt_028a   028T06:57:35   Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
MSI_MidRange_028a   028T08:36:55   2x3 Mosaic at mid-range altitude in Filter 3
MSI_LowAlt_028c   028T08:50:30   0 Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)
MSI_MidRange_028b   028T09:42:45   2x3 Mosaic at mid-range altitude in Filter 3
MSI_LowAlt_028b   028T10:00:00   0 Single strip of low altitude data in Filter 3 (TABLE 5 ON FAST)

COLOR Lowalt 2|

No color

24*******************************
24.0   35 km C   2001-28 to 2001-43
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24.1 Historical Background

Following the successful low altitude 2 activities we popped back up to 35 km circular for the few remaining weeks before the landing. This was essentially the same orbit as 35kmB. It was retrograde and equatorial. We were at the peak of high south latitude illumination but the orbit prevented low emission views of the polar plateau region.

Start	OCM-23	028	36 x 35	-1	0.8	6	35 km C	-84
	OCM-24	033	36 x 36	-1	0.8	5.5	35km, tweak for landing	-86
	OCM-25	037	36 x 36	-1	0.8	5.4	35km, tweak for landing	-87
End	EMM-1	043	down to 6	-1to36	0.8-0.3	7.8	Descent	-84

See /eros/traj/traj_35c_rtc.gif - plot of range to center
/eros/traj/traj_35c_lat.gif - plot of sub-s/c latitude for nadir point (not actual pointing)

24.2 Sequence Design

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MONOCHROME 35km C|

Opnavs 35kmC:

Same as 35kmB, two 2x4 mosaics at least 3 times per day. No more color.

See /eros/descript/loworbitopnavs.xls and opnav.txt

XREQS:

Same as in 35kmB, ride with XGRS pointing and take filter 4 images in strips.
Only one full week of low orbit mapping (01030) in this period. In week 01036, navigation needed as much doppler as possible which prevented Eros pointing. There is only one observation (MSI_XREQ05_039a) that has usable data. MSI_XREQ09_40c was pointed to dark sky.

Plot available:

/eros/01030/xreq_01030.gif

Sorry, no plot for 01036.

See /eros/descript/xreqs.xls for description and spreadsheet.

***********************************25***
25.0 Landing   2001-43
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The landing was accomplished with a series of 5 orbit correction maneuvers. The first maneuver, EMM1 began the decent from 35km circular orbit. The four remaining maneuvers, EMM2-5, thrusted in a direction that attempted to brake the fall of the spacecraft during the descent.

The landing site was selected to allow good imaging of lit territory all the way down, while satisfying several operational constraints. These included keeping the high gain antenna locked onto the Earth for continuous high-rate playback, and keeping solar panel illumination within limits. This eliminated the possibility of a south polar landing. Landing site was selected to be about

-37lat 278lon.

The majority of time during this period was spent either performing maneuvers, or slewing to the new maneuver positions. Mission design and navigation folks were able to design a set of maneuvers that allowed the camera boresight to be pointing down at the lit surface throughout much of the landing sequence.

25.2 Sequence Design

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MONOCHROME Descent Sequence |

Opnavs:

Following the EMM1 maneuver two 2x3 zig-zag mosaics were acquired and immediately played back.

    OPN_EMM1_DKD 32/1601

Final Descent Images:

See /eros/01036/descent_imagelist.gif for a full account of imaging and maneuver timing.

                ****

The camera boresight was off the limb for the EMM2 maneuver position. The slew to the EMM3 eventually brought the boresight onto lit territory. From that point on we acquired images all the way down until contact; we imaged during all remaining burns as well as during the s/c maneuvers that repositioned to each new burn position. To reduce smear during these repositions, we built special scan patterns that slewed at a constant rate from burn position to burn position; this was in lieu of the normal fast reposition.

A special kind of playback routine was required to buffer the images in real-time and immediately send them to the ground. Normal process was to record images during a designated observation period then playback everything during designated playback period (no data acquisition during playbacks usually). Using the new scheme, the fastest we could play back a pair of images was a little less than 65 seconds. Therefore the final imaging sequence contained pairs of images spaced 65 seconds apart. Spacing between the two images in each pair was set to be 20 seconds. The reason for this was to maintain frame-to-frame overlap between at least the members of each pair during the faster slews between burn positions. If we had set the time delta between the two frames in each pair to be something like 32 sec, there would have been no overlap at all between images taken during some of these burn transition slews. This worked out well because we at least now have little two frame mosaics from those periods.