Chapter 1 - Introduction

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Introduction to the Revised Edition

This document was originally published by the NIMS team in October 1991 as a guide to the Galileo Encounter with the asteroid Gaspra. It has been revised and corrected for inclusion on the Asteroid (5th) CD-ROM of NIMS Experimental Data Records (EDRs). Some material in the original document has been omitted.

The aim of the revised guide is to provide detailed information on the various NIMS observations and calibrations. Also included is background information on the encounter. An overview of the guide is given below. Please refer to the beginning of each chapter for a detailed list of contents.

Chapter 1 gives an introduction to the Gaspra encounter as well as a discussion of various issues that went into the design of the Gaspra encounter sequence. Chapter 2 gives an overview of the entire Gaspra encounter using various timelines. Chapter 3 contains digrams of various aspects of geometry for the Gaspra encounter. Chapter 4 summarizes the NIMS Gaspra observations in terms of a comprehensize sequence summary, PA summary and Observation Table (OBSTAB). Chapter 5 is a collection of the Detailed Observation Designs made up of OAPEL forms and POINTER plots. The Appendix contains a JPL interoffice memo describing the NAV Team's OPNAV strategy and a discussion of error ellipses.

For information on the NIMS instrument, please see the preprint of the NIMS instrument paper provided elsewhere on the CD-ROM, or refer to the published version: R.W. Carlson, P.R. Weissman, W.D. Smythe, J.C. Mahoney and the NIMS Science and Engineering Teams, "Near-infrared Mapping Spectrometer Experiment on Galileo", Space Science Reviews 60: 457-502, 1992.

ACKNOWLEDGEMENTS

The NIMS Gaspra observations in this guide were designed by Cindy Byrne and Paul Weissman with the help of Larry Soderblom, Bill Smythe and Bob Carlson. The calibrations were designed by Cindy Byrne with help from Bill Smythe. Cindy Byrne prepared the original printed guide. Frank Leader subsequently retrieved most of the original material for the CD-ROM, edited the original Postscript files for consistency and clarity, recovered missing material by scanning parts of the original printed document. Some figures from the Galileo Gaspra Encounter Notebook prepared by the Galileo Mission Design Team were incorporated into this guide. Al stevenson generated the sequence summary. Bob Mehlman oversaw the production of this guide.

Introduction

On October 29, 1991, Galileo will attempt to record the best spatial and spectral information yet available on an asteroid. 951 Gaspra will serve as the target body and will provide the opportunity for the first ever spacecraft flyby of an asteroid.

This packet is provided as a NIMS guide to the Galileo Gaspra Encounter. In the following pages, you will find some information on the asteroid itself as well as mention of some questions regarding this body which still remain; the solutions to which won't be known until after playback of the recorded sequence in late 1992. Until then, we provide only the plans for obtaining this data on October 29, 1991. There are many critical activities occuring before Gaspra Closest Approach which will affect the quality of the planned observations -- OPNAV frames to be returned, spacecraft attitude adjustments to be made, a 'tweak', etc. Each of these activities are described in the following pages.

951 Gaspra - The Asteroid

Gaspra was discovered on August 30, 1916 by G. Neujmin and was named after a Crimean resort for scientists. It is a faint object to Earth-based telescopes and little Gaspra data were gathered until it became a potential Galileo flyby target. The most recent information is available in an article authored by Goldader, Tholen, Cruikshank and Hartmann and planned for publication in the October 1991 issue of "The Astronomical Journal".

Gaspra is an S-type asteroid, one of the most common types of asteroids found at its 2.2 AU range from the Sun. S-types have moderate albedos and moderate to strong absorption features shortward of 0.7 microns and moderate to non-existent absorption features beyond 0.7 microns. Gaspra, like most S-type asteroids, is expected to have a slightly reddish color and to be composed of a combination of olivine and pyroxene silicates and nickel-iron metal, although in unknown ratios. Goldader etal. suspect that Gaspra has a high olivine/pyroxene ratio which may indicate it originated in the lower mantle of a differentiated parent body. Gaspra is similar to 8 Flora and 15 Eunomia. With data from the Gaspra Flyby, NIMS will have the opportunity to further elucidate the nature of S-type asteroids, one of the most controversial issues in asteroid science.

Gaspra is known to have a non-spherical shape which, for planning purposes, has been assumed to be a tri-axial ellipsoid with axes given below. On the following two pages, you will find more information on Gaspra's physical constants, some of which have been updated with information in the publication previously mentioned. Also included are figures from the paper "Galileo Support Observations of Asteroid 951 Gaspra", which show ground-based observations of the variation in brightness of Gaspra as a function of rotational phase and also a plot of the ground-based near-infrared normalized spectral reflectance (with the expected NIMS spectral resolution noted).

JET PROPULSION LABORATORY **INTEROFFICE MEMORANDUM**

GLL-MDT-89-230.IOM
December 13, 1990
Revision C: October 23, 1991

To: Distibution
From: Bruce McLaughlin
Subject: Physical Constants for Asteroid 951 Gaspra (UPDATE)

Concurrence: J.Ludwinski, MDT Chief — J.Dunne, S & MD Manager

To ensure Project-wide consistency in planning for the upcoming Galileo encounter with the asteroid Gaspra (currenly targeted to occur on Oct 29, 1991, 91-302/22:38 SCET - Ephemeris Time), the following data shall be used by all Project elements involved in developing planning and sequencing products based upon the physical properties of Gaspra. These data are the best estimates to date of the known constants for the asteroid. Gaspra is not a very well studied body to date, and the uncertainties can be quite large, as shown below. These data were presented and discussed at the Gaspra Aim-Point Selection Meeting held on Dec. 6, 1990 and are summarized along with historical data in a fact sheet compiled by Clark R. Chapman for the Galileo Project.

UPDATE: Due to misunderstandings and abiguities in the presentation of the original data, this update has been prepared. It has been coordinated with the Galileo Navigation Team, the Galileo Science Data Team, the Galileo POINTER Design Team and Dr. Alan Harris, JPL Gaspra Observational Astronomer. The key issues of the definitions of the epoch and prime meridian have been 'rephrased' to remove the verbal ambiguity and couched in terms of appropriate coordinate systems and absolute epochs. In addition, observations taken earlier this year provide revised estimates of some of the quantities. Clark Chapman and Alan Harris have provided these updates in a memo and unpublished E-mail which are available on request for use within Galileo Project only. These data are not for publication.

Change Control:

The coordination of updates to these values shall be the responsibility of the Mission Design Team to assure that timely and consistent values are used at each step of the planning process. Additional data taken by ground observers early in 1991 may be used to update these values and are included in the Update. Comments, corrections or updates to any of these values which occur with the passage of time should be addressed to myself or to the MDT Chief.

Asteroid 951 Gaspra - Physical Constants

Diameter: 12.5 km (range 8-20 km)

Shape: assume tri-axial ellipsoidal with axis ratios
a:b:c = 1.6 : 1.0 : 0.9
+/- 0.3 0.3 0.3
coupled with the assumed mean diameter yields:
a:b:c = 18 km : 11 km : 10 km
(12.5 km = cube root of (a*b*c))

Period: 7.0421 +/- 0.0001 hr (sidereal)

Sense of Rotation:
unknown, but for reference assume prograde
i.e., right-hand-rule about the c-axis (short axis)

North Pole Position:
assume 20 degrees ecliptic longitude, 20 degrees ecliptic latitude (uncertainty +/1 10 degrees in each direction)
(RA ~ 10.2 deg, Dec ~ +26.2 deg)

Epoch: adopt primary maximum (a-axis perpendicular to the vector between Gaspra and the spacecraft) occurs at 91-302/19:52 SCET. Maximum will occur at 91-302/21:38 SCET. This implies W0 = 251.924 deg and W-dot = 1226.906747 deg per ephemeris day (wrt EME50). W0 has an inherent ambiguity of 180 degrees, and this particular value is chosen arbitrarily.

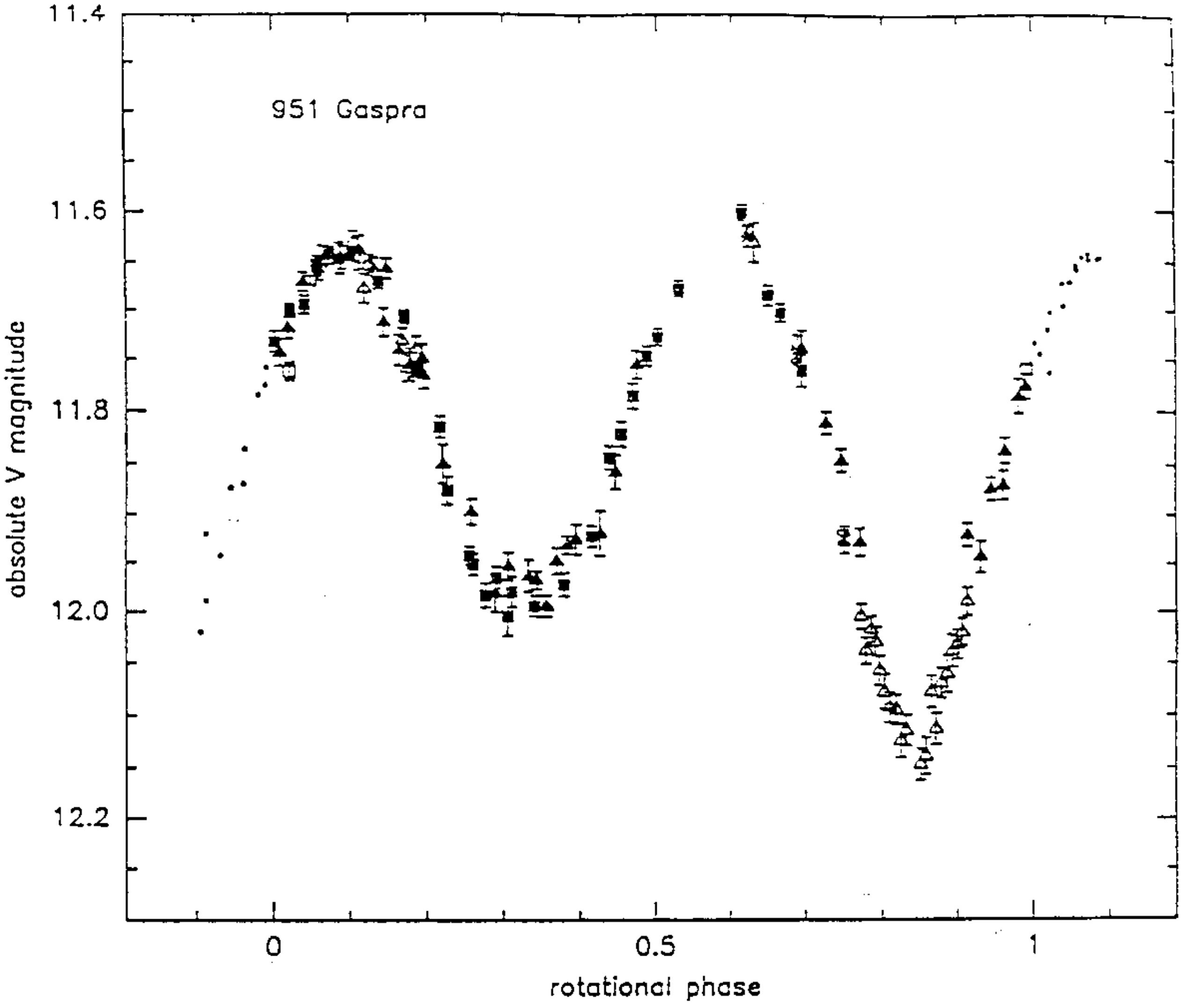
Albedo: 0.20 (range 0.16 - 0.28)

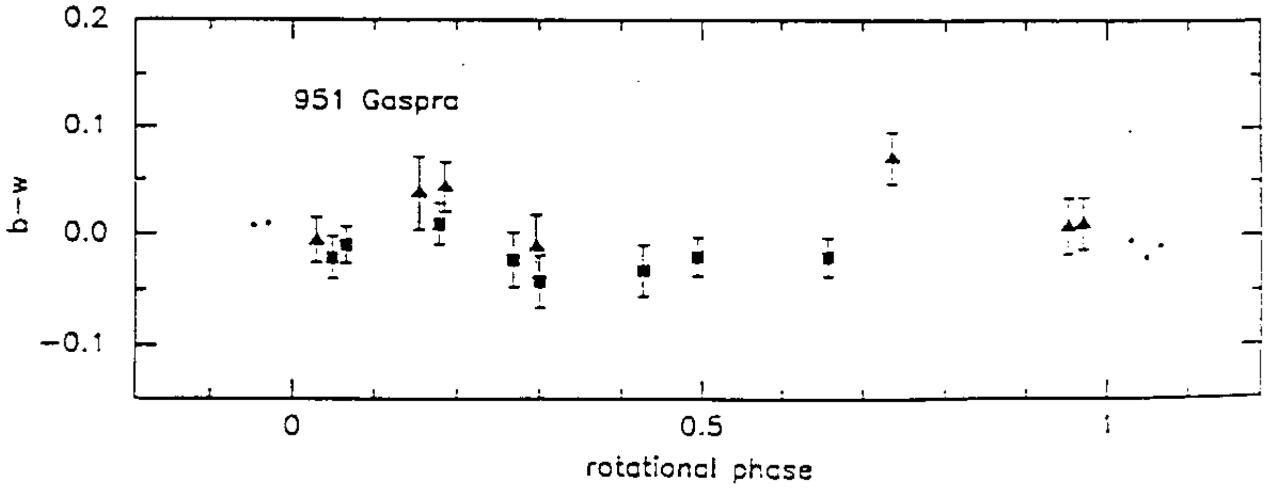
Magnitudes:
H = 11.65 +/- 0.05
G = 0.24 +/- 0.01
B(1,0) = 12.9 (absolute magnitude prior to adoption of H/G system)
U-B = 0.55
B-V = 0.87

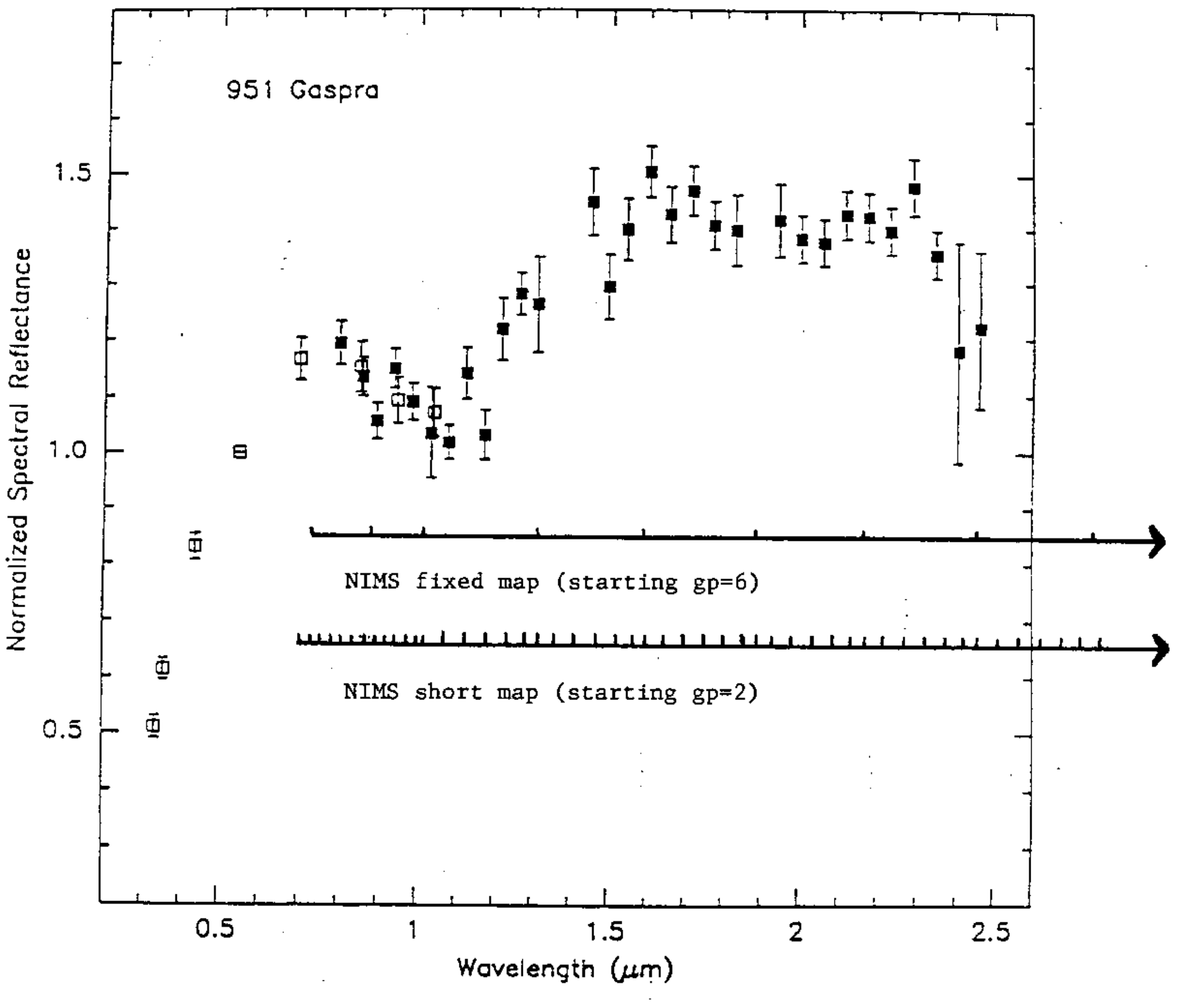
Revised Orbital Elements:
Updated merged ephemeris files in LGFIO and NAVIO format are available on Unisys tape as described in IOM 314.6-1332, Updated Orbit and Ephemeris for Asteroid 951 Gaspra, D.K. Yeomans and M.S. Keesey to W.E. Kirhofer.

The osculating orbital elements (refered to EME50) presented there are:

Epoch	1991 Dec. 10.0 TDT
T	1992 July 19.52985
q	1.8254967 AU
e	0.1738608
w	129.12909 deg.
Node	252.65713 deg.
I	4.09891 deg.


951 Gaspra
absolute V magnitude
11.4
11.6
11.8
12.0
12.2
0
0.5
1
rotational phase


951 Gaspra
b−w
0.2
0.1
0.0
−0.1
0
0.5
1
rotational phase


951 Gaspra
Normalized Spectral Reflectance
Wavelength (μm)
NIMS fixed map (starting gp=6)
NIMS short map (starting gp=2)
1.5
1.0
0.5
0.5
1
1.5
2
2.5

History of Gaspra Sequence: HGA to LGA

The original Gaspra sequence assumed use of the High Gain Antenna and a dayside, 1900 km closest approach, 60 degrees north of the ecliptic plane. On April 11, 1991, the Galileo High Gain Antenna failed to deploy and the sequence plan was changed to include tape recorded observations that could be played back at a later time at lower data rates with the Low Gain Antenna. The resulting sequence is now know as EE3 prime (EE3p). One of the drawbacks to the new sequence is that fewer OP NAV pictures can be taken and played back in time (see Appendix A for a description of OP NAV stratagies and a discussion of error ellipses). This caused the error ellipses to grow considerably and greatly reduced the probabilities of capturing Gaspra at Closest Approach. The 'time-of-flight' axis was much larger than the semi-major of semi-minor axis of the tri-axial error ellipsoid. As a result, it has been necessary to move the SSI and NIMS science observations back in time to allow an 'end-on' approach of the error ellipse.

The ultimate sequence became a darkside approach at 1600 km which met the SSI requirements of high (> 45 degrees) phase angles while Gaspra filled the largest number of pixels possible in the SSI field of view. A diagram of the phase angle (Sun-Gaspra-Spacecraft Angle) with respect to time is plotted in the Geometry Section of this guide. These high phase angles (over 45 degrees) introduce shadows on the object, which is less desirable for spectral instruments such as NIMS.

Spacecraft Orientation and Trajectory

Two obvious gains to the change to the Low Gain Antenna sequence were: 1) Galileo would be pointed Sun-pointed (the High Gain Antenna requires Earth-pointing withing 1.0 degrees) and 2) the spacecraft trajectory could nearly lie in the ecliptic plane. The first of these benefits allowed science observations outside of the spacecraft cone pole region where pointing stability is lessened. It also created an opportunity for a NIMS photometric calibration.

The second benefit mentioned above permitted science observations to be performed with almost pure cone slews, taking out the cross-cone movement which can complicate NIMS data analysis. A plot of Gaspra's and Galileo's trajectories from a sun-centerd north ecliptic pole view is presented in the Geometry Section of this guide.

Galileo off-sun angle:	3 degrees (approx)
Radial Distance:	1600 km @ Closest Approach (Darkside)
Closest Approach point:	3.9 deg north ecliptic latitude
Encounter Time:	October 29, 1991, DOY 91-302 22:37:00.702 UTC

The OPNAV Strategy and Error Ellipse Determination

Spacecraft position and velocity is well known using radio signatures from the spacecraft. This is not the case for Gaspra's trajectory. As a result, science observations must take into account a region of uncertainty in the position of Gaspra relative to the spacecraft. The resultant 'error ellipse' is a locus of possible Gaspra centers and is fixed in RA/Dec space using the most recent OPNAV information. Determination of the error ellipse size is described in greater detail in Appendix A. For planning purposes, 'Case 1, ON2' of that memo has been assumed.

It is critical that these OPNAV frames be returned and processed in time, particularly the last frame. This last frame will be used to update only the closest approach observations from 4 hours before Closest Aproach to a few minutes after Closest Approach. The process of updating parameters such as RA/Dec of Gaspra's position and scan platform slew rates which account for this new position is known as the 'tweak'.

Due to concern over lack of dual DSN coverage for this tweak activity, the Galileo Project has decided that those observations from -4 hours to -1 hours will be tweaked using realtime commands on an as-needed basis. These observations do not use Target Motion Compensation (TMC). This strategy allows postponement of the tweak window to Closest Approach - 1 hour (C/A - 1hr) when dual DSN coverage is available. Therefore, the remaining observations, all of which use TMC, occuring from Closest Approach - 1 hour to Closest Approach will be tweaked at Closest Approach - 1 hour. The NAV schedule for the Tweak is presented in the Overview section of this guide. The Science and Mission Design Office will utilize NAV inputs to determine new probabilities of Gaspra capture. These probabilities will be reported to the Project which will then give a go/no-go decision for realtime commanding.

Originally, all science teams were directed to design to a 92%, or 2.24 sigma, error ellipse. However, since return of the latest OPNAVS 1,3 and 4, the size of the error ellipse has drastically diminished. Currently, B . R = 48.3 km and B . T - 26.3 km (1 sigma). As a result, our probabilities of Gaspra capture have increased.

The NIMS designs given in a later section are designed to cover an error ellipse which includes the OPNAV information of Gaspra position uncertainty, the relative size of Gaspra and a possible scan platform error. The error ellipses appear to be 'dirigibles' if observed end-on, which is indeed the observation perspective of NIMS since the time of flight error is into the paper and in the direction of spacecraft motion. Due to limitations of the planning tools, we were unable to provide the actual orientation and shape of the error ellipse from the end-on perspective. Thus, what appears to be a circular ellipse is a tri-axial ellipsoid.

Science Priorities

The Asteroid Working Group decided on the science priorities at Gaspra, as given by the following viewgraph:

SCIENCE OBJECTIVES

Characterization of Global Properties

- o Accurate Size/Shape
- o Rotation Period
- o Pole Orientation
- o Cratering Statisitics

Characterization of Compositional Properties

- o Surface Composition (minerals, metals etc.)
  - Global properties
  - Heterogeneities
  - Stratigraphy in craters

Characterization of Surface Morphology

- o Morphology of craters as a function of diameter

Characterization of Regolith Properties

- o Stratigraphy
- o Photometric properties
- o Polarimetric properties
- o Radiometric/thermophysical properties

Asteroid Environment

- o Outgassing from asteroid
- o Dust concentrations and radial gradient
- o Search for close debris

Hopefull this will provide data for Comparative Processes with

- o Other asteroids
- o Phobos/Deimos
- o Other small planetary satellites

DB-13,14
14 June 91

NIMS Science Priorities

Using the Asteroid Working Group's Science Objectives, and information on Gaspra's size and spacecraft range, the NIMS Gaspra observations were sequenced according to the following priorities. They have been updated to reflect a small increase in tape resource discovered during the final tape useage estimates. In particular, we were able to add Fixed Map Observations (XM) to give rotational phase sampling every 15 degrees.

("Start" and "End" times are in Rims before Gaspra Closest Approach.)

Priority	Start	End	Observation
1	-23	-8	XM, 0.75 mrad/sec, 2 coverages of error ellipse for spatial resolution/phase angle trade-off
2	Broken intervals between -48	-24	SM, 0.11 mrad/sec, Low(er) phase, multicolor
3	-8hrs	-61	FM, 0.03 mrad/sec, every 90 degrees of Gaspra rotation, with a fifth FM verifying the first. SM, 0.11 mrad/sec, 30 degrees samples XM, 0.75 mrad/sec, 15 degree samples
4	After Closest Approach		PCT Calibration - 2 Rims RCT Calibration - 2 Rims

The NIMS Sequence

The following timeline shows the NIMS, SSI, UVS and PPR science observations after incorporating the above NIMS priorities with the priorities of the other teams. The description of each NIMS observation is located in the 'OAPEL Description' section which provides actual time of observation, observation objective and design detail. You will notice a "+", "-" or "*" after each Activity ID. These symbols stand for the following, respectively: 1 of 2 or more similar observations; not a joint observation; a joint observation.

The NIMS Gaspra sequence uses four NIMS modes for science observations: Long Map (LM), Full Map (FM), Short Map (SM) and Fixed Map (XM). The sequence also includes the first use of 2 special sequences (RAM modes) which allow the instrument to toggle between two different modes in one Rim. Further details on the special sequences can be found in the information on the OAPELs GASVIS01 and GASNAP01.

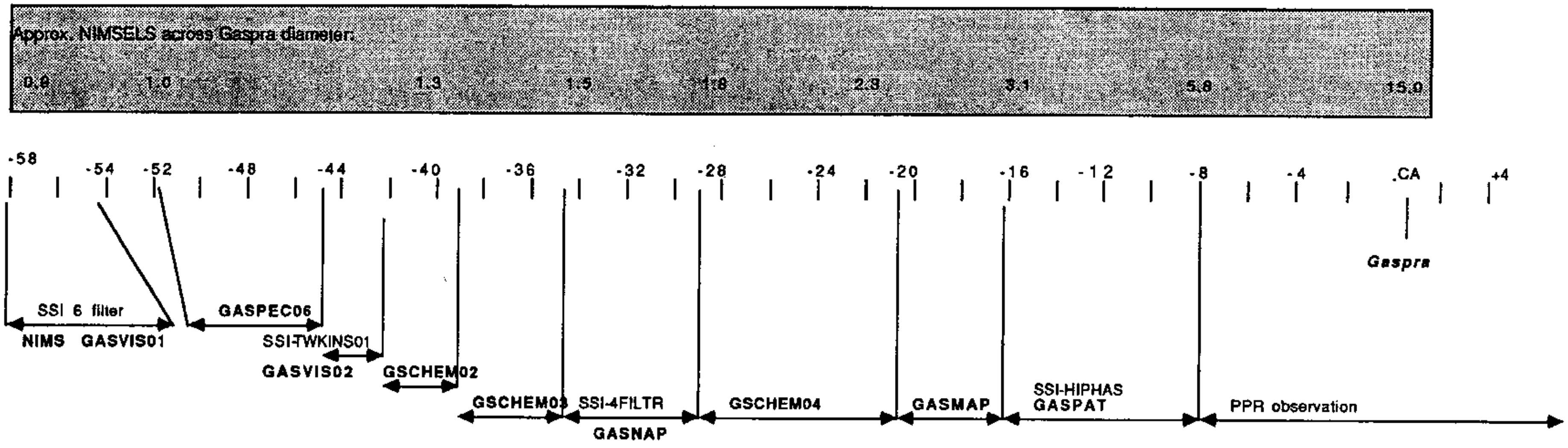
In every case, the following grating offsets are used to allow sampling of the 1.05 micron absorption band. The 1.05 micron samples maximize the scene contrast and should provide the best information on the olivine/pyroxene band.

Mode	Grating Start Position
Long Map	0
Full Map	0
Short Map	2
Fixed Map	6

GASPRA Encounter

Gaspra Closest Approach (GCA), 302/22:37:00.702

GCA-58 rims to -8 rims (1 RIM = 60.67 sec)



GASVIS01 NIMS ride-along in XM/LM Special Sequence with SSI in IM4 (2.333 sec frames).
GASVIS02 NIMS ride-along in XM with SSI in IM4 (2.333 sec frames)

GASPEC06 NIMS completes the last FM observation at LM Nyquist rate by covering lower hemisphere. GASPEC05 covers upper hemisphere.

GSCHEM02,03,04 NIMS scans each of 2 error ellipse hemispheres(02,03), and center of error ellipse (04) in SM @Nyquist rate (0.11 mrad/sec).

GASNAP NIMS ride-along in XM/LM Special Sequence with SSI in IM4 (2.333 sec frames).

GASMAP NIMS scans the error ellipse in XM @Nyquist rate. (0.75 mrad/sec).

GASPAT Joint NIMS/SSI observation, NIMS in XM @ 0.84 mrad/sec slew rates.

NIMS/SSI Gaspra Activities - Far Encounter

Gaspra Closest Approach (GCA) = 302/22:37:00.702 UTC

Approximate nimsels across Gaspra diameter		.01										.18								.41			.76	
RIMS to C/A:	473		442		407		368		337		302		263		232		197		158		127		92		64
SSI observations: [1] (every 30° of rotation)	•		•		•		•		•		•		•		•		•		•		•		•		•
NIMS observations: [1] (every 15° of rotation)	F	X	S	X	S	X	F	X	S	X	S	X	F	X	S	X	S	UVS Obs.	F	X	S	X	S	X	F

Totals

Number	Mode
12	X - Fixed Map (17 λ) (GASPER)
8	S - Short Map (102 λ) (GASCUR)
5	F - Full Map (204 λ) (GASPEC)

1 Gaspra rotation period = 7.0421 hr.

NIMS Gaspra Activity Plan Time Ordered Listing

Gaspra Closest Approach (GCA) - 91-302/22:37:00.702 (UTC)
15:37:00.702 (PDT)

Observation		Start Time (PDT)	Start Time (UTC)	Duration	Gain
Full Map-	GASPEC01	91-302/07:37:44	91-302/14:37:44	0:03:17	4
Fixed Map-	GASPER01	/07:52:01	/14:52:01	0:00:26	4
Fixed Map-	GASCUR01	/08:09:12	/15:09:12	0:01:22	4
Short Map-	GASPER02	/08:27:24	/15:27:24	0:00:24	4
Fixed Map-	GASCUR02	/08:44:35	/15:44:35	0:01:22	4
Short Map-	GASPER03	/09:02:48	/16:02:48	0:00:24	4
Fixed Map-	GASPEC02	/09:23:58	/16:23:58	0:03:41	4
Full Map-	GASPER04	/09:38:11	/16:38:11	0:00:20	4
Fixed Map-	GASCUR03	/09:55:22	/16:55:22	0:01:35	4
Short Map-	GASPER05	/10:33:34	/17:33:34	0:00:20	4
Fixed Map-	GASCUR04	/10:30:45	/17:30:45	0:01:35	4
Short Map-	GASPER06	/10:48:58	/17:48:58	0:00:20	4
Full Map-	GASPEC03	/11:10:12	/18:10:12	0:04:05	4
Fixed Map-	GASPER07	/11:24:21	/18:24:21	0:00:18	4
Short Map-	GASCUR05	/11:41:32	/18:41:32	0:01:32	4
Fixed Map-	GASPER08	/11:59:44	/18:59:44	0:00:18	4
Short Map-	GASCUR06	/12:16:55	/19:16:55	0:01:14	4
Full Map-	GASPEC04	/12:56:22	/19:56:22	0:04:20	4
Fixed Map-	GASPER10	/13:10:31	/20:10:31	0:00:18	4
Short Map-	GASCUR07	/13:27:42	/20:27:42	0:01:63	4
Fixed Map-	GASPER11	/13:45:50	/20:45:50	0:00:16	4
Short Map-	GASCUR08	/14:03:01	/21:03:01	0:01:69	3
Fixed Map-	GASPER12	/14:15:10	/21:15:10	0:00:16	3
Full Map-	GASPEC05	/14:31:24	/21:31:24	0:04:83	1
LM/FM-	GASVIS01	/14:37:52	/21:37:52	0:04:00	1
Full Map-	GASPEC06	/14:44:10	/21:44:10	0:03:38	1
Fixed Map-	GASVIS02	/14:51:35	/21:51:35	0:02:46	1
Short Map-	GSCHEM02	/14:54:28	/21:54:28	0:05:82	1
LM/FM-	GASNAP01	/15:01:07	/22:01:07	0:06:00	1
Short Map-	GSCHEM04	/15:07:12	/22:07:12	0:08:29	1
Fixed Map-	GASMAP01	/15:16:30	/22:16:30	0:03:67	1
Fixed Map-	GASPAT01 (HIPHAS01)	/15:20:55	/22:20:55	0:03:00	1
PCT CAL		/18:35:58	91-303/01:35:58	0:02:00	1
RCT CAL		/23:50:26	/06:50:26	0:20:00	1
NIMS Turn Off		91-303/18:35:58	/08:58:50		