Chapter 1 - Introduction

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Introduction to the Revised Edition

This document was originally published by the NIMS team in July 1994 as a guide to the Galileo Observations of the Impacts of the Fragments of Comet Shoemaker-Levy 9 with Jupiter. It has been revised and corrected for inclusion on the 4th CD-ROM of NIMS Experimental Data Records(EDRs). Some material in the original document has been omitted, and a chapter added describing the SL9 data actually returned to the ground.

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 SL9 encounter as well as a discussion of various issues that went into the design of the SL9 encounter sequence. Chapter 2 gives an overview of the entire SL9 encounter using various timelines. Chapter 3 contains digrams of various aspects of geometry for the SL9 encounter. Chapter 4 summarizes the NIMS SL9 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. Chapter 6 is a summary of the NIMS data return for the SL9 Impact observations.

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 SL9 observations in this guide were designed by John Hui and Paul Weissman with the help of Bill Smythe and Bob Carlson. Marcia Segura and Paul Weissman were responsible for the data return. John Hui 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 and prepared the last chapter describing the data return. Al Stevenson generated the sequence summary. Bob Mehlman oversaw the production of this guide.

Introduction

From July 16, 1994 through July 22, 1994, the Galileo spacecraft will directly observe the impact of the fragments of Comet Shoemaker-Levy 9 (SL9) with the planet Jupiter. This handbook is provided to the NIMS Team as a guide to the SL9 Impact.

Discovery of Comet Shoemaker-Levy 9

Gene and Carolyn Shoemaker and David Levy discovered Comet Shoemaker-Levy 9 on March 25, 1993 using the Palomar Mountain 18-inch Schmidt telescope. Their initial images showed multiple comet-like fragments aligned like a "string of pearls" subtending an angular extent of about 50 arc seconds (180,000 km at Jupiter’s distance from Earth) with a dust train of material associated with the comet. Astrometric observations have shown that the object is in a loosely bound, highly elliptic orbit about Jupiter and that the comet likely underwent tidal disruption during a very close Jupiter approach (~1.3 Jupiter radii) that took place on July 8, 1992. These observations also predicted that these fragments would impact with Jupiter.

Currently there are over 22 fragments, and this number may increase because some larger fragments have been splitting into two or three smaller fragments, as the original Q and G fragments have done. All fragments are predicted to impact on the dark side of Jupiter near the eastern limb (dawn terminator), as seen from Earth. The predicted impact times are still fluctuating. A table listing the best estimate of impact times for the fragments can be found on the following page. This table was provided by the Galileo Mission Design Team. The estimates were made by D.K. Yeomans and P.W. Chodas.

The expected observed phenomena from the impacts of the fragments on Jupiter are the entry flash of each fragment entering the Jovian atmosphere and beginning to burn up like a meteor, followed by the explosion of the fragment at depth in the Jovian atmosphere, likely below the visible cloud decks. The explosion will create a fireball that will rise through the clouds and become visible about one minute following the entry flash, and might last 10 to 20 minutes. Alternative hypotheses suggest that the SL9 fragments may break up prior to entry and will only produce the bright entry flashes, but not massive fireballs.

Galileo Observations

At the time of the impacts, from July 16 to July 22 of 1994, the Galileo spacecraft will be at a position to observe directly the impacts, while Earth observers will not see the impact sites until they rotate into view about twenty minutes later. The Galileo Project plans to observe the impacts with its full complement of instruments, including the remote sensing and fields and particles instruments. The remote sensing instruments will observe 18 impacts.

All of the observations will be recorded on the on-board tape recorder. There will be a two-part playback process. First, there will be a search through the data looking for the onset of the impacts using the information from the near-realtime PPR data and from the ground-based observations. Using this search information, the rest of the desired data will be returned.

Predicted Impact Times for Fragments of P/Shoemaker-Levy 9

Predict date: 11-Jul-94

SL9ET Source: D. K. Yeomans, P.W. Chodas, 314.10 - 084

IMPACT	1-sigma (min)	SL9ET (UTC)	J-S OWLT (h:mm:ss)	SCET (UTC)	S-E OWLT (h:mm:ss)	J-S-ERT (UTC)	J-E OWLT (h:mm:ss)	J-ERT (UTC)
A = 21	8.2	16-Jul 19:14:55	0:13:22	**94-197/19:28:17**	0:33:39	20:01:56	0:42:40	19:57:35
B = 20	6.8	17-Jul 02:11:21	0:13:22	**94-198/02:24:42**	0:33:42	02:58:24	0:42:42	02:54:03
C = 19	7.0	17-Jul 06:16:42	0:13:21	**94-198/06:30:03**	0:33:43	07:03:46	0:42:43	06:59:25
D = 18	7.5	17-Jul 11:02:45	0:13:21	**94-198/11:16:06**	0:33:45	11:49:51	0:42:45	11:45:30
E = 17	5.6	17-Jul 14:22:15	0:13:21	**94-198/14:35:36**	0:33:46	15:09:22	0:42:46	15:05:01
F = 16	6.0	17-Jul 23:43:51	0:13:20	**94-198/23:57:11**	0:33:50	00:31:01	0:42:49	00:26:40
G = 15	4.8	18-Jul 06:44:45	0:13:20	**94-199/06:58:05**	0:33:52	07:31:57	0:42:51	07:27:36
H = 14	4.7	18-Jul 18:43:01	0:13:19	**94-199/18:56:20**	0:33:57	19:30:17	0:42:55	19:25:56
K = 12	4.8	19-Jul 09:34:51	0:13:18	**94-200/09:48:09**	0:34:02	10:22:11	0:42:59	10:17:50
L = 11	5.1	19-Jul 21:24:04	0:13:18	**94-200/21:37:22**	0:34:07	22:11:28	0:43:03	22:07:07
N = 9	6.7	20-Jul 09:38:08	0:13:17	**94-201/09:51:25**	0:34:11	10:25:36	0:43:07	10:21:15
P2 = 8b	6.6	20-Jul 14:26:43	0:13:17	**94-201/14:40:00**	0:34:13	15:14:13	0:43:08	15:09:51
Q2 = 7b	≈15.0	20-Jul 18:48:52	0:13:17	**94-201/19:02:08**	0:34:15	19:36:23	0:43:10	19:32:02
Q1 = 7a	5.4	20-Jul 19:16:19	0:13:17	**94-201/19:29:35**	0:34:15	20:03:50	0:43:10	19:59:29
R = 6	6.2	21-Jul 04:41:04	0:13:16	**94-202/04:54:20**	0:34:18	05:28:38	0:43:13	05:24:17
S = 5	5.9	21-Jul 14:26:37	0:13:16	**94-202/14:39:52**	0:34:22	15:14:14	0:43:16	15:09:53
T = 4	13.2	21-Jul 17:22:33	0:13:15	**94-202/17:35:48**	0:34:23	18:10:11	0:43:17	18:05:50
U = 3	14.5	21-Jul 21:09:21	0:13:15	**94-202/21:22:36**	0:34:24	21:57:00	0:43:18	21:52:39
V = 2	10.3	22-Jul 03:31:22	0:13:15	**94-203/03:44:37**	0:34:27	04:19:04	0:43:20	04:14:42
W = 1	7.2	22-Jul 07:13:31	0:13:15	**94-203/07:26:45**	0:34:28	08:01:14	0:43:21	07:56:52

ACRONYMS

SL9ET	Shoemaker-Levy 9 Event Time: Impact time at Jupiter
J-S OWLT	Jupiter to Spacecraft One-Way Light Time
SCET	Spacecraft Event Time: Impact time as seen by Spacecraft
S-E OWLT	Spacecraft to Earth One-Way Light Time
J-S-ERT	Jupiter to Spacecraft to Earth Received Time: Impact time as seen by Spacecraft and monitored by the Ground
J-E OWLT	Jupiter to Earth One-Way Light Time
J-ERT	Jupiter to Earth Received Time: Impact time as seen by Earth Observers

Galileo Science Overview

Due to the large number of impacts, it was possible to assign specific fragments to individual instruments. However, PPR and UVS are also performing ride-along observations with NIMS. The following table shows the instruments, their fragments, observation descriptions and expected data return. SSI is using a new method to observe the impacts to save tape; the OCM method involving multiple exposures on the CCD chip. Also PPR is using a CDS looper to collect data into spacecraft memory buffers and then use MROs to return the data in near-realtime.

Instrument	Comet Fragment	Observation Description	Expected Data Return
NIMS	C,F,G,R	Continuous 5 1/3 sec scan 97 minutes record 64 minutes	Playback 10 2/3 secs Locate Jupiter, then Jailbar return 4 secs for G or 3.33 secs for R from each 5 1/3 sec scan for 2.8 or 3 min.
SSI	K,N	Diagonal scan 6-shutter OCM, 30 1/3 sec shuttering, 18 HCM records	Jailbar search, Jailbar return of 4 of 8 lines for half of up to 3 frames.
SSI	V	Horizontal scan 8-shutter OCM, 30 1/3 sec shuttering, 14 HCM records	Jailbar search, Jailbar return two 75-line swaths.
SSI	D,E	8x8 OCM, 8 2/3 sec shuttering, 7 IM4 records	Jailbar search, Jailbar return three 75-line swaths.
SSI	W	8x8 OCM, 2 1/3 sec shuttering, 16 IM4 records	Jailbar search, Jailbar return eight swaths.
PPR	P	Point and Stare 1 hour record LRS	Playback 10 min.
PPR	B,H,L,Q,S	Point and Stare CDS looper, collect 12 bytes/mf for 40 min	MRO CDS buffer space during event period.
UVS	Ride-along with NIMS, PPR and SSI		
PWS	All	CDS looper, collect 2 bytes every 29 mf continuously for 33 hours, repeat 9 times	MRO CDS buffer space during event period.

NIMS Observations

During the period of the SL9 impacts, July 16 to July 22, 1994, Galileo will be approximately 239 million km (~1.6 AU) from Jupiter. At this distance Jupiter is 0.59 mrad in diameter, slightly larger than a NIMS pixel of 0.5 mrad. NIMS will observe four of the SL9 fragments impacting Jupiter. They are nominally labelled C, F, G and R. In addition, NIMS will observe Jupiter three days before any of the impacts occur to get a relatively clean spectrum of Jupiter for reference. Impact C occurs on July 17 (UTC); impact F occurs at the end of day July 17; impact G occurs on July 18 and impact R occurs on July 21. Each observation has the same slew pattern. NIMS will scan in the cone direction for a distance of 3 mrad, with Jupiter in the middle of the scan. Then it will scan in the reverse direction the same distance. Each scan is 5 1/3 seconds, or 8 mf, in duration. The slew rate for this back and forth scanning is 0.92 mrad/sec. For each observation NIMS is in Fixed Map mode (XM), grating start 2, gain state 2, chopper reference mode, grating offset 4. The reference observation is 1 Rim (60 2/3 sec) in duration, while each of the four impact observations will have a duration of 96 Rims. However, NIMS will record only 64 Rims per observation, each centered on the best estimate of the impact time and updates as late as possible in the sequence design process. NIMS will not be able to return all of the observations. Two scans of the reference observations will be returned, followed by two scans each from the G and R observations. These data will be used to locate Jupiter within each scan pattern. Using this information, NIMS will return 6 mf out of 8 mf per scan for a total of 32 scans for the G observation. This corresponds to ~2.8 minutes of observing time. For the R observation, NIMS will play back 34 scans, ~3 minutes of observing time. The reference observation data will be played back on July 26, the G search data on August 03, the R search data on August 12, the G data return from September 24 to October 07 and the R data return will be in the end of October to November, 1994. This playback plan is not rigid and will most likely be modified to maximize science return using ground-based observations of the impacts.

The following is a table of the NIMS SL9 Observations:

ACTIVITY ID	Date	Start Time	Duration	Activity Title
SLNNNIMSON01	07/12/94	94-193/06:29:00	0:04:00	NIMS POWER ON
SLJNREFJUP01	07/14/94	94-195/08:04:00	0:07:00	REFERENCE SPECTRUM JUPITER BEFORE SL9
SLJNFRAGMC01	07/17/94	94-198/05:26:26	1:43:07	NIMS OBSERVATION OF SL9 FRAGMENT C
SLJNFRAGMF01	07/17/94	94-198/22:49:54	1:43:07	NIMS OBSERVATION OF SL9 FRAGMENT F
SLJNFRAGMG01	07/18/94	94-199/06:11:46	1:43:07	NIMS OBSERVATION OF SL9 FRAGMENT G
SLJNFRAGMR01	07/21/94	94-202/04:15:57	1:43:07	NIMS OBSERVATION OF SL9 FRAGMENT R
SLNNNIMSON01	07/22/94	94-203/13:39:00	0:03:00	NIMS POWER OFF

Data Playback

Due to the downlink limitations, the currenct telemetry performance is 10 bits per second. This limits the amount of data that can be returned before February 1995 when the Galileo Phase 1 software uplink is scheduled to begin. NIMS is planning to playback data from three observations; the reference spectrum observation (SLJNREFJUP01) and impacts G and R (SLJNFRAGMG01 and SLJNFRAGMR01).

For the reference spectrum, 10 2/3 seconds of continuous data will be played back, or one back and forth scan across Jupiter, in the middle of the observation. This amount of data guarantees that NIMS will see Jupiter in the data. This playback is done with one DMSMRO and this is one of the first datasets to be played back from tape.

The next NIMS playback will be the search data from the G and R observations. NIMS will use the PPR near-realtime data and ground-based observations of G and R to get precise timing of the impacts. Using these times, 10 2/3 seconds of continuous data around the impact time will be played back for each observation. These 10 2/3 seconds of data guarantee that NIMS will see Jupiter in the scanning pattern and help locate Jupiter within the scanning pattern. Hopefully, the impact is within this time also. Each search requires one DMSMRO.

For the G observation, NIMS is playing back 32 scans (16 complete back and forth scans). The first 16 scans all have the same cone slew direction, that is, playback of every other scan. The second set of 16 scans all have the reverse cone slew direction interleaved with the first set of scans played back. For each scan, NIMS is bringing back 6 mf (4 sec) of data out of 8 mf (5 1/3 sec) per scan. The playback is accomplished by using the location of Jupiter determined within the back and forth scanning pattern from the search data and is known as a jailbar search. In case the initial tape positioning is off, NIMS has the option to update the tape position after the first few scans have been returned. Total data returned is about 2 minutes, which is in 2.8 minutes of actual observing time.

The R observation data return is different from that of G's. Again, using the search data, NIMS will determine where Jupiter lies in the back and forth scans. NIMS will playback two complete back and forth scans (4 scans) of data, 21.3 seconds. This will give enough information to update the tape position, if needed. Then, 5 mf (3 1/3 sec) out of 8 mf per scan for 30 scans, or 15 complete back and forth scans, again playing back alternating scans using two DMS slews. This plan returns 34 scans, or 17 complete back and forth scans, which is about 2 minutes of total data return in 3 minutes of observing time.

Of course, the NIMS playback strategy can be modified to maximize science return based on ground-based observations of the impacts.

The flowchart on the following page is an overview of the SL9 data return process.

SL-9 Data Return Process Overview