Chapter 7 - Data Return

Contents

Introduction to Chapter 7

This chapter is a report on the NIMS data return for the E18 orbit. Due to the low downlink data rates available for Galileo Jupiter Operations and other unforeseen and unpredictable events during the E18 Encounter and Cruise, not all NIMS data recorded on the tape recorder or selected in real-time were returned. The previous 6 chapters nominally describe the planning and intention of the NIMS observations for this orbit, except the obstab section in chapter 4 which was updated to give the latest parameters for the data that were actually returned.

There were nine autonomous reloads of the NIMS RAM code from CDS during the E18 encounter, one just before each science observation. No observations were lost due to a NIMS processor halt. The approach that we are taking to avoid data loss due to processor halts has proven to be very successful.

Detectors 3 and 8 are still not functioning and are expected to be lost for the rest of the mission.

The spacecraft suffered two Despun Bus Reset Errors that safed the spacecraft, the first about 2 hours before E18 perijove and the second about 20 hours later. The perijove and outbound portions of the E18 encounter were lost.

Two Jupiter realtime observations and one recorded Jupiter observation were performed before the spacecraft safing event.

Spacecraft safing during the E18 encounter caused a portion of E17 data not to be recorded over in E18. Thus, additional E17 data were returned during E18 playback. The extra tape was used to record a NIMS star calibration during cruise.

The plots on the pages 3 and 4 show the geometry of the NIMS E18 observations using a north trajectory pole projection. The ’returned’ observations are in Bold characters and the ’non-returned’ in gray. The observations with an asterix were taken with the NIMS software halted.

The spreadsheets on pages 5 and 6 summarize the ’final’ playback model for the ’returned’ E18 and E17 data returned during E18 cruise.

The text on page 7 gives a ’recap’ of the E18 playback events which affected which observations were returned.

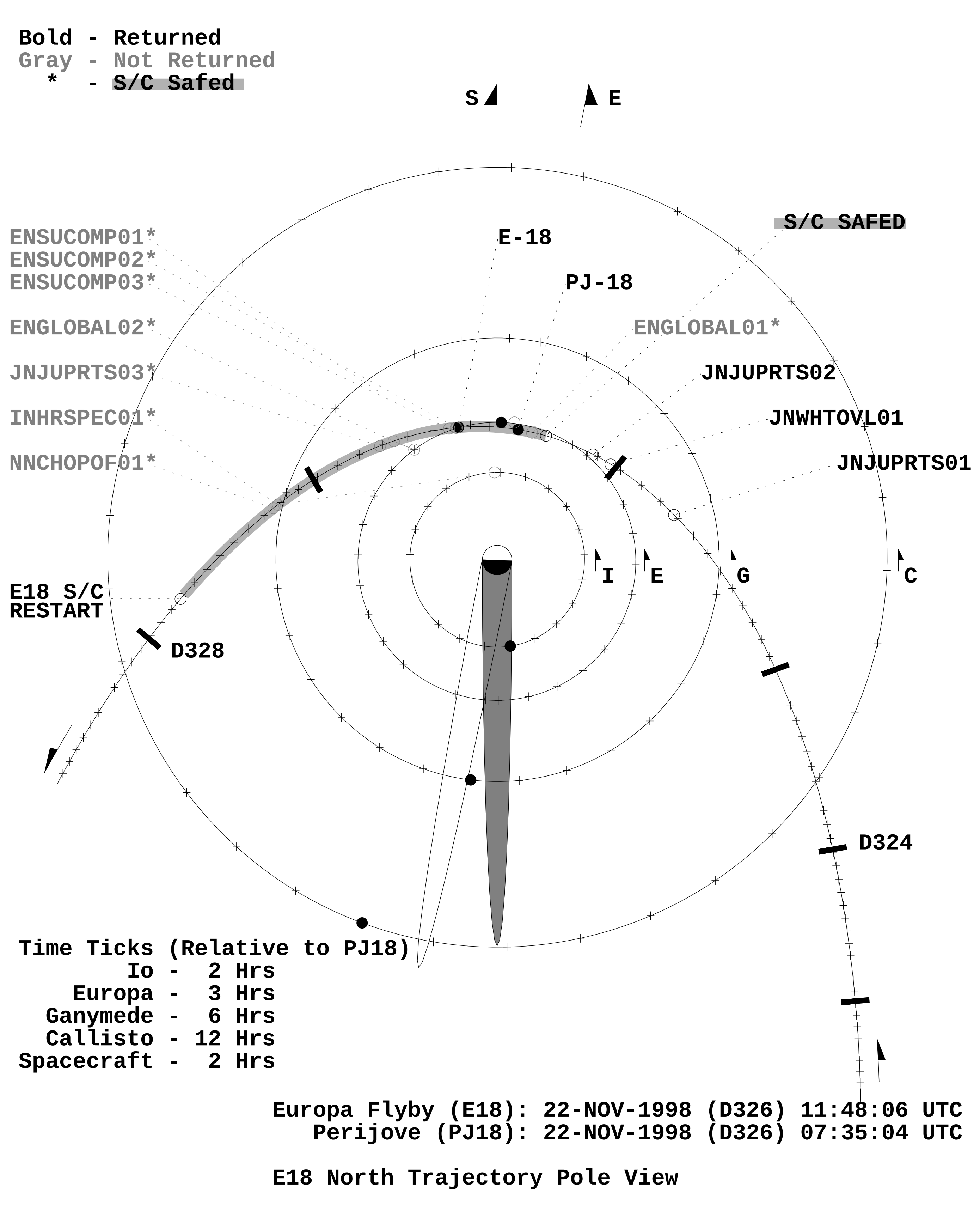
A Timeline of E18 playback events is on pages 7 through 10.

The text on page 11 describes the E18 NIMS and Spacecraft Anomalies.

The text on page 12 gives a brief discussion of the NIMS data files. Additional information about NIMS data formats, data types, data labels and data access is given on pages 13 and 14.

The text on page 15 is a guide to understanding the NIMS MASK.

NIMS E18 OBSERVATIONS



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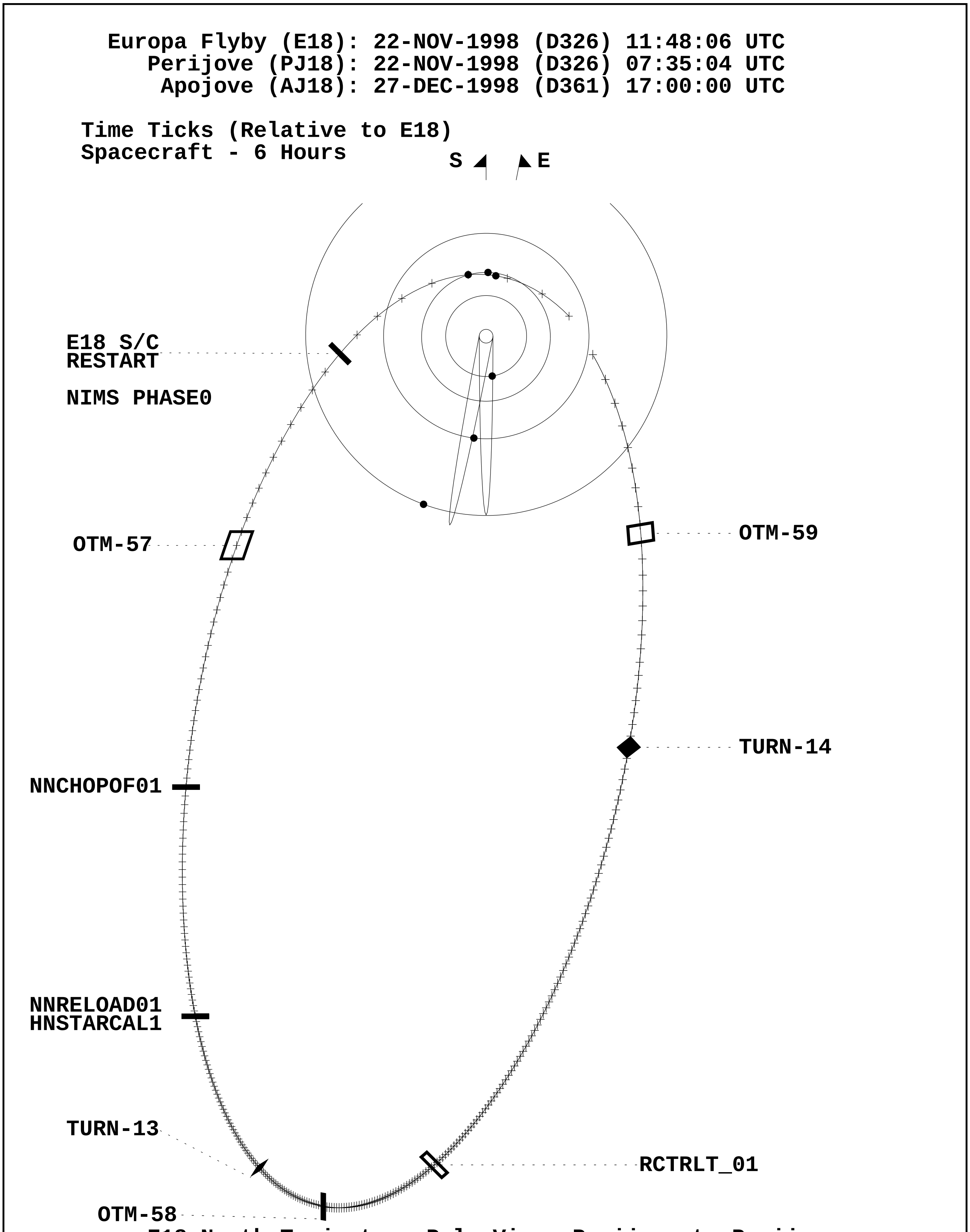
NIMS E18 CRUISE CALIBRATIONS



E18 North Trajectory Pole View, Perijove to Perijove

NIMS E18 DATA RETURN

Activity ID	Observation Title	NIMS Edit Table	NIMS PB Table	Mode	Gain	Grating Start	Grating Offset	Record Format	PSID
18JNJUPRTS01*	Jupiter Realtime Observation	E18JLM408/MB	R/T	LM	2	0	4	R/T	
18JNWHTOVL01-	Jupiter White Oval	E18JSB253B	E18JSB253B	LM	2	0	4	LPU	
18JNJUPRTS02*	Jupiter Realtime Observation	E18JLM408/MB	R/T	LM	2	0	4	R/T	
17ENSUCOMP01-gf	Europa Surface Composition	E17ELM442	E17ELM360	LM	4	0	4	MPW	
17ENSUCOMP02-gf	Europa Surface Composition	E17ELM442	E17ELM360	LS	4	0	4	MPW	
17ENSUCOMP03-gf	Europa Surface Composition	E17ELM442	E17ELM360	LM	4	0	4	MPW	
18JNWHTOVL01-	Jupiter White Oval	E18JSB253B	E18JSB253B	LM	2	0	4	LPU	
E18 Cruise Recording									
18NNSTARCL01-		E18STRCAL17	E18STRCAL15		4				
18NNSTARCL01-gf		E18STRCAL17	E18STRCAL15		4				

NIMS E18 DATA RETURN

Activity ID	Mode	Record Format	Wave- lengths Returned	Record Time (sec.)	PB Time (sec.)	Selected Bits of Tape sBOT(MBITS)	Total Bits of Tape BOT (Mbits)	Mode Cycle (sec)	Comp	Thold	RT BTG MBits	Total BTG Mbits (4% ohead)	Data Reduct Factor (sBOT/BOT)	Pass
18JNJUPRTS01	LM	R/T	360								0.16			
18JNWHTOVL01	LM	LPU	253	969	967.33	5.97	5.98	8.667	1.67	0		3.52	1.70	1
18JNJUPRTS02	LM	R/T	360								0.16			
17ENSUCOMP01	LM	MPW	360	1200	217	2.50	13.82	8.667	1.3	0		1.44	1.73	2
17ENSUCOMP02	LM	MPW	360	1020	66	0.76	11.75	8.667	1.46	0		0.39	1.95	2
17ENSUCOMP03	LM	MPW	360	1320	283	3.26	15.21	8.667	1.3	0		1.88	1.73	2
18JNWHTOVL01	LM	LPU	253	969	967.33	5.97	5.98	8.667	1.67	0		3.52	1.70	2
	XM	MPW	15	1428	1426	16.43		0.333	2.47	0		5.41	3.04	1
	XM	MPW	15	1428	68	0.78		0.333	2.47	0		0.26	3.04	2
											TOTAL	16.41		

RECAP OF E18 PLAYBACK EVENTS

The Galileo spacecraft experienced a "despun bus reset" fault in E18, similar to that which caused the loss of the E16 encounter. The results were similar. In this case, two NIMS Jupiter realtime observations and one recorded Jupiter white oval observation were performed before the safing occurred.

E18 was a relatively bit-rich orbit, with NIMS' original downlink allocation at about 44 Megabits. In the end we were able to retrieve data amounting to about 40% of that total (16.4 Mbits).

In addition to receiving our E18 data, we were able to fill many significant gaps in our E17 Europa surface composition observations. And, following playback of this data and during E18 cruise, we were able to record and play back a long (24 RIMS) star calibration.

No details of the originally planned observations or the changes in our strategy before the safing event are included here, as those observations were not executed.

The following timeline details the most signifigant events of the E18 playback period. Most of the text below is excerpted from messages issued at the time.

E18 Playback Events Timeline (11-06-98: to 01-30-99)

11-06-98: (K. Schimmels) NIMS playback bits allocation is 44.28 Megabits.

11-13-98: Today's update has produced the final pre-uplink version of the playback table.

11-22-98: (J. Erickson) 4:00 am PST: The Galileo spacecraft has experienced an anomaly just prior to it's Europa 18 encounter. It is presently in safing, and is stable. Analysis is proceeding, but appears to show that the spacecraft has experienced another despun bus reset, similar to the reset at Europa 16.
The preliminary analysis shows the reset occurred at 9:34 pm PST on November 21, approximately 2 hours prior to Jupiter closest approach, and 6 hours prior to Europa closest approach. The reset appears to have happened on both strings simultaneously (within one minor frame, two thirds of a second). After analysis confirms the sequence of events leading to the safing, a recovery plan will be developed and executed.

11-22-98: Perijove occurs at 07:35:04 UTC, followed by Europa closest approach at 11:48:06.

<u>E18 Playback Events Timeline</u> (11-06-98: to 01-30-99)

11-22-98: **(J. Erickson) 11:30 am PST: The Galileo spacecraft is still in safing, with no health or safety concerns. Recovery planning is in process, with an expected return to normal operations at approximately 5:00 pm PST on November 23. Memory readouts from the Command and Data System (CDS) have verified that the spacecraft safing was induced by a simultaneous despun bus reset on each of the semi-redundant CDS halves.**
After the spacecraft is back to normal operations, a plan will be developed to best utilize the available playback time in the Europa 18 cruise sequence. This plan will include elements of playing back the limited data taken at Europa 18, additional recovery of Europa 17 data, and real-time cruise science.

11-23-98: **(Message to project concerning uses of available E18 downlink) NIMS would like to return 18JNWHTOVL01 which was recorded on the tape successfully (as far as we know). That was a fairly large observation that will require about 3.2 Mb to return. Hopefully it was not recorded on top of 17ENGLOBAL01. We left 132 wavelengths behind on the tape there. It would require 4.3 Mbits to retrieve the rest of it. In addition we could obtain the balance of the 253 wavelengths NIMS recorded for 17JNWHTOVL01 and 02. NIMS received only 66 thermal wavelengths there. Note, these are dark-side observations. It is estimated that NIMS will need another 2.8 Mbits (total) to recover the additional wavelengths for these.**
Lastly NIMS has a very large number of significant gaps in the global observations and in 17ENSUCOMP01-03. We would like to request an initial allocation of 6 Mbits for gap fills. This number could go either up or down (but more likely down) as we find out precisely what the gaps amount to.

11-24-98: **The E18 encounter did not execute successfully due to a 'despun bus reset' that placed the spacecraft in safe mode. The cause is attributed to erroneous readings from the gyros, which indicated high rates of motion. This case is similar to the problem experienced in E16. In both cases, safing occurred some hours prior to perijove. This time we received two extended Jupiter realtime observations before safing. 18JNWHTOVL01 was recorded successfully in inertial mode before safing, and will be returned to Earth within a week or so.**
E18 activities resulted in re-recording one track of the tape recorder (track 1), leaving considerable E17 data intact. In our case, the four Europa SUCOMPs remain.
To utilize our downlink and improve E17 science we are commanding return of data that did not reach the ground successfully in E17. 17ENSUCOMP01 playback consists of the

10 sets of gap-filling commands that were included in the last E17 table. These did not execute then due to our loss of downlink allocation in connection with the Voyager 2 anomaly investigations. Likewise four sets of commands to fill gaps in 17ENSUCOMP02 are in the table, along with 5 new sets of commands to recover nearly 2 Mbits of gaps that afflicted our original playback of 17ENSUCOMP03.
We did not require gap filling for 17ENSUCOMP04. Gap fill amounts to about 3 Mbits in the current playback table.
At the request of the playback coordinator, we are playing back 18JNWHTOVL01 in full a second time, at the end of the second playback pass.
We are also requesting additional playback of AACS data from E17. As you recall we recorded most of our E17 observations in cruise mode. By having all the available AACS we may be able to reduce the pointing uncertainty.
Observations where we formerly requested only a portion of the AACS are 17ENSUCOMP01 and 02.
An open issue at present concerns the possibility of performing some calibrations during the cruise period.
We are requesting one starcal and one dark observation.

11-30-98: (K. Schimmels) Ok, here is the general info you will need for developing your E18 Cruise Recordings:
There will be an epoch defined as follows:
Epoch RDC = 98-344/15:30, set to mf 6.
OAPEL times will be as follows:
SSI: CDS RDC+5:00:0 - CDS RDC+35:00:0
NIMS: CDS RDC+37:00:0 - CDS RDC+97:00:0
MWG: CDS RDC+100:00:0 - CDS RDC+700:00:0
Tape motion commands will be from RDC - RDC+4:00:0, and after RDC+701:00:0.
We are recording on track 2, so remember the one-minute wait rule between tape commands if you have multiple SCIRECs. As for the schedule, tentatively, I would like to see the DMS commands early - so internal DMS delivery on Wed. (Dec. 2) ~ noon. If this is not possible, let me know soon so we can find a time that is. I believe the pointer files and DMS files will be due to SST Thursday, most likely EOD - again, this is tentative still.
Playback will start with E18 encounter data, at the beginning of track 2. We have one more pass through this data prior to doing the recording in cruise, so the gaps that currently exist in WHTOVAL may be filled. If they are not, Playback should start with gaps in E18 encounter data, followed by the PPR RCT Cal, and followed by the Record during cruise (RDC) data. MWG is planning on splitting their playback into multiple segments to allow updates to it. NIMS and SSI do not have that luxury due to the small amount of MB to be played back. All data will be tagged as Pass 1 in your SINGLEs. As of this time we are not planning on continuing with E17 playback again.

E18 Playback Events Timeline (11-06-98: to 01-30-99)

12-03-98: Playback of E18 data and E17 gap fills is completed.

12-08-98: The second pass playback of 18JNWHTOVL01 was successful in filling the existing gaps in that observation.
E18 playback included portions of NIMS' Europa observations recorded in E17. In E17 we were not able to fill the substantial gaps in 17ENSUCOMP01-02-03. However, our E18 playback of the gaps was successful, and thus final products for these observations will be nearly, if not 100%, complete.
E18 now continues with recorded observations that will be obtained in a few days. NIMS will record a star calibration with Sirius as the target. This is designed to obtain 24 Rims of data, one for each step of the NIMS long map grating cycle. Playback of this observation will begin soon after. The estimated downlink bits requirement is 6.2 Mbits. We are requesting 100% of the AACS data also for this period.

12-10-98: NIMS starcal is recorded (day 344, 17:43 UTC).

12-14-98: (R. Mehlman) Star and booms are plainly visible in a DN tube of the first 10 1/2 RIMs of the E18 star calibration observations.
Each observation is in fixed map mode, gain state 4, one RIM long, with the grating position changing each RIM, 0-23. But the first 10 1/2 RIMs have been processed into a single DN tube. Compression ratio was 2.47. The rest of the data should be down in a few days -- it seems to be coming down faster than expected. Only a couple of gaps so far, of 1 packet and 8 packets.

01-11-99 (K. Schimmels) We have approval to do another pass through the tape in E18, so here is the current plan:
We have ~16.2 MB capability remaining expected at the end of Pass 1. This will be allocated as follows:
SSI: 9.2 MB
MWG: 3.0 MB
Slewing: 4.0 MB

01-13-99 The availability of downlink bits has presented us with the opportunity to send up gap-fill playback commands to complete the STARCAL. The new playback table has 3 sets of singles, amounting to about 1 Rim of data, estimated to require about 0.26 Mbits to play back.
E18 playback will terminate, and the E19 encounter will begin, on January 30.

NIMS Anomaly Report - E18 Sequence

There were no NIMS processor halts detected during the E18 Encounter. Detectors 3 and 8 are still not functioning and are expected to be lost for the rest of the mission.

Also, the spacecraft suffered two despun bus resets, the first about 2 hours before E18 perijove and the second about 20 hours later. The perijove and outbound portion of the E18 encounter were lost.

Processor Halts

There were no NIMS processor halts in E18.

Spacecraft Anomaly

The spacecraft suffered a despun bus reset and safed about 2 hours before E18 perijove, very similar to the spacecraft safing that took place near E16 perojove. The spacecraft did not recover autonomously due to multiple despun bus resets to both CDS strings A and B. The anomaly was not resolved in time to recover any of the outbound protion of the E18 encounter.

NIMS Archived EDRs and CUBEs

The NIMS data are stored in EDRs (Experimental Data Records) produced by JPL-MIPS (Multi-mission Image Processing System). The NIMS Phase2 EDR is described in the NIMS EDR SIS (Software Interface Specification) Number 232-08. The same information is available in both human and machine-readable form in the PDS (Planetary Data System) structure files EDRHDR.FMT and EDRDATA.FMT in the LABEL directory of the NIMS EDR CD-ROM. Each observation has at least one EDR. The EDR file name is derived from the 12 character observation name plus a single character which allows an observation to be broken up into multiple EDRs. The EDRs have a Vicar label, followed by a PDS/ISIS label, binary header records and the data records. For archiving on CD-ROM, the Vicar labels are detached from the EDR (but kept separately on CD) and the file is renamed so as to conform to the 8.3 DOS file-naming convention. The 8.3 EDR name consists of a 2 character orbit identifier, a single character target identifier, a 3 digit counter and the suffix EDR. For example, the MIPS EDR G1GNGLOBAL01A.1 becomes G1G001.EDR. More information about NIMS EDRs can be found in the VOLINFO.TXT file on the EDR CD-ROM.

NIMS EDR data typically require considerable processing before they are readily amenable to science analysis. Normally, the EDRs are processed into spectral image cubes by one of several sets of software. MIPS systematically processes the EDRs into CUBEs (band sequential image files) and MASKs (spatial/spectral summary images) which are distributed on the NIMS CUBE CD-ROMs. Information about the structure of the NIMS CUBEs can be found in the VOLINFO.TXT file on the CUBE CD-ROM. The name of the CUBE file is derived from the input EDR filename. For archiving on CD-ROM, the CUBE files are renamed so as to conform to the 8.3 DOS file-naming convention. The 8.3 CUBE name consists of a 2 character orbit identifier, a single character target identifier, a 3 digit counter, a single character cube-type identifier, a single character data unit-type (DN, radiance or IOF) and the suffix QUB. For example, the MIPS IOF radiance cube for the observation G1GNGLOBAL01A.1 (G1G001) becomes G1G001CR.EDR. The summary MASKs on the CD-ROM have the same 6 character name as the EDR name with the suffix JPG or GIF to denote its graphics format.

NIMS Data Format - Data types - Data Labels - Data Access

Data Format

All data files have PDS labels. The raw data (EDR) file contains time-sequential, 16 bit integers. Reduced data files (TUBES and CUBES) may be viewed as images or spectra. They contain VAX real numbers, are band sequential (BSQ - the images are stacked in band order) and have geometry information appended as backplanes after the last NIMS band.

Data Types

Mask files contain summary images (3 band BSQ) and spectra of up to six selected regions that provide a quick indication of data location, data quality and spectral content. A Guide to understanding the NIMS mask is available.

Cube files contain data that have been projected and resampled. The core data are BSQ - spatial in the first two dimensions, and spectral in the third. Cubes of the satellites are projected in point-of-view, and, with few exceptions have no photometric correction applied. Cubes of Jupiter are (generally) projected as simple cylindrical. Cubes of Europa, Ganymede, and Callisto have been despiked. The cubes are available both in radiance and I/F (intensity divided by flux) form.

Tube files contain data in (almost) time order and normally have a NIMS-related 20 pixel spatial dimension (20 x n or n x 20). Projection coordinates are contained in backplanes, but the data have not been resampled. The data are in units of radiance and no despiking has been applied. All data in cubes are also available in tube form. Some data (such as spatially undersampled data) appear in tube form only.

A spike file contains a list of pixels that have been identified as spikes, but not replaced, in the tube. Spike files can be used to remove spikes from both tube and EDR files.

EDR files contain the most primitive form of the data available. They should be used only for advanced data analysis. The format is complex and the files do not form images or spectra without prior processing.

Data Labels

A data label (PDS form) is attached to the front of each file (except masks, which have an attached VICAR label and a detached PDS label). The labels are in ASCII keyword=value format and contain pointers to various data objects in the file, descriptions of the data objects and descriptions of the observation associated with the file. A history object in similar format follows and describes the processing steps that produced the file. Much of this information is necessary for understanding and viewing the cube. In particular, the label contains the offset to the cube, the dimensions of the cube, axes labels, and explicit wavelength information.

Data Access

Software for processing this data is called ISIS and is available for DEC VAX VMS, SUN Solaris, DEC Alpha Digital Unix, Silicon Graphics Unix and PC LINUX systems. The Unix versions are available from the USGS Astrogeology team. Images from NIMS cubes and tubes can be viewed with any image display program which allows an offset from the beginning of the file to the selected image. Packages tested include ISIS, VICAR, ENVI, SAO IMAGE, and NASAVIEW. ISIS and ENVI (and soon NASAVIEW) additionally display spectra. The ISIS viewer is named CV (UNIX) or QL3 (VMS).

Labels may be displayed with some editors (eg DOS edit), and with most "type" and "search" functions. Some editors do not recognize the PDS line termination conventions. The label may be listed by the ISIS function LHLIST (VMS) or LABEL (UNIX).

Software for converting EDRs to cubes exist in both ISIS (DEC VAX VMS) and VICAR (DEC Alpha VMS) versions only. A primitive list of values in an EDR may be obtained with the program EDRDMP2.

Understanding the NIMS Mask

The NIMS mask is designed to provide a quick summary of the contents of a NIMS data cube (or tube). It displays a view of both the spatial and spectral content of the data.

The mask has four regions. Starting from the upper left and proceeding clockwise: a spatial display; six or fewer representative spectra; annotation; and a spectral histogram.

The spatial display of an observation which has been projected and resampled (a cube) has a maximum size of 600x600 pixels. This is overlaid with surface coordinates and is embedded in a 700x700 grid of pixel coordinates. It is accompanied by two 1-dimensional histograms describing the raw image and the image stretched for display. The data image can range from a simple combination of up to 3 NIMS bands displayed in the RGB planes, to complicated arithmetic functions of NIMS bands displayed in the RGB planes. (The formulas appear as annotation below the histograms.) The graphics directly below the image show the input and output data histograms for the three color planes. The "shortest" color for each bin displays in front. The image also contains from one to six numbered rectangles, which show the from which averaged spectra (displayed on the right) were taken.

The spatial display of an observation in time sequence (a tube) is a graphic showing a footprint of the observation over a grid of surface coordinates on the target body. Numerals 1-6 on the graphic mark the locations of the average spectra displayed on the right.

The spectra to the right of the image may display either BDRF or radiance (or both). If both are displayed, then a vertical "radiance fence" line will appear where the breakpoint occurs. This permits display of both atmospheric data, which have significant reflectance and thermal components, and I/F satellite surface data which have strong absorptions at longer wavelengths (such as water spectra.) The spectra are labelled with wavelength in microns and location in both pixel and latitude-longitude space.

The annotation provides information about the observation, including its name, a brief description, its geometry, instrument and projection parameters. TCA is the time from Galileo's closest approach to the target body.

The 2-dimensional spectral histogram in the lower left corner shows the number of pixels at a given radiance for each wavelength. If a surface contains spatial mixtures with significantly different spatial fractions for several components, the spectra of the components will be evident in this display.