# Chapter 7 - Data Return

## Contents

## Introduction to Chapter 7

This chapter is a report on the NIMS data return for the E12 orbit. Due to the low downlink data rates available for Galileo Jupiter Operations and other unforeseen and unpredictable events during the E12 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 E12 encounter, one just before each science observation. Only 1 observation (12ENDLINEA01) was lost due to a halt, and this was due to a miscommanded NIMS reload. 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.

AACS had a gyro anomaly (ISA 11036) during E12 in which the gryos gave incorrect attitude error estimates, causing the spacecraft to loose its celestial reference. New AACS flight software was loaded to compensate for the gyro problems.

The plots on the pages 3, 4 and 5 show the geometry of the NIMS E12 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 6 and 7 summarize the 'final' playback model for the 'returned' data.

The text on page 8 gives a 'recap' of the E12 playback events which affected which observations were returned.

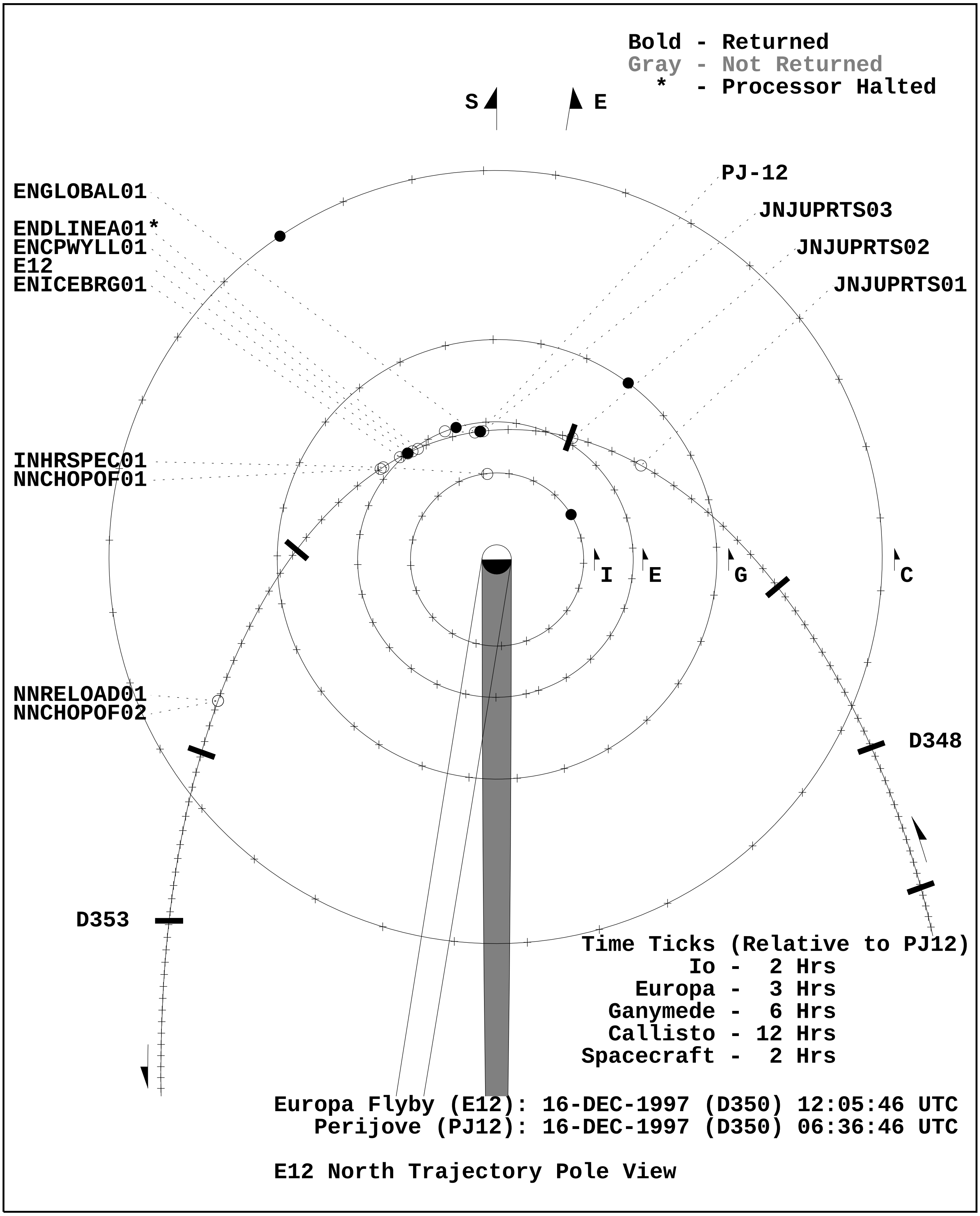
A Timeline of E12 playback events is on pages 8 through 13.

The text on pages 14, 15 and 16 describes the E12 NIMS and AACS Anomalies.

The text on page 17 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 18 and 19.

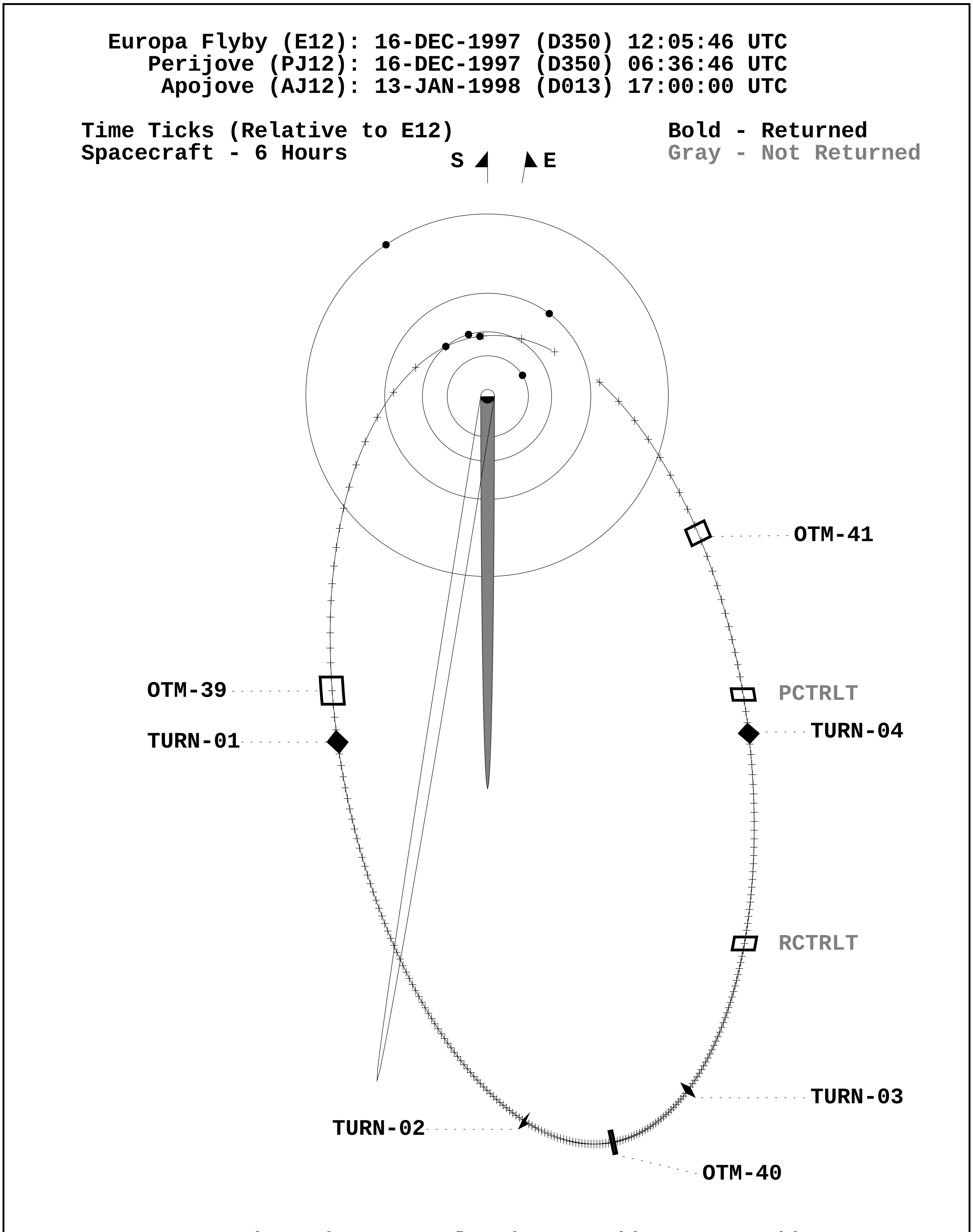
The text on page 20 is a guide to understanding the NIMS MASK.

# NIMS E12 OBSERVATIONS



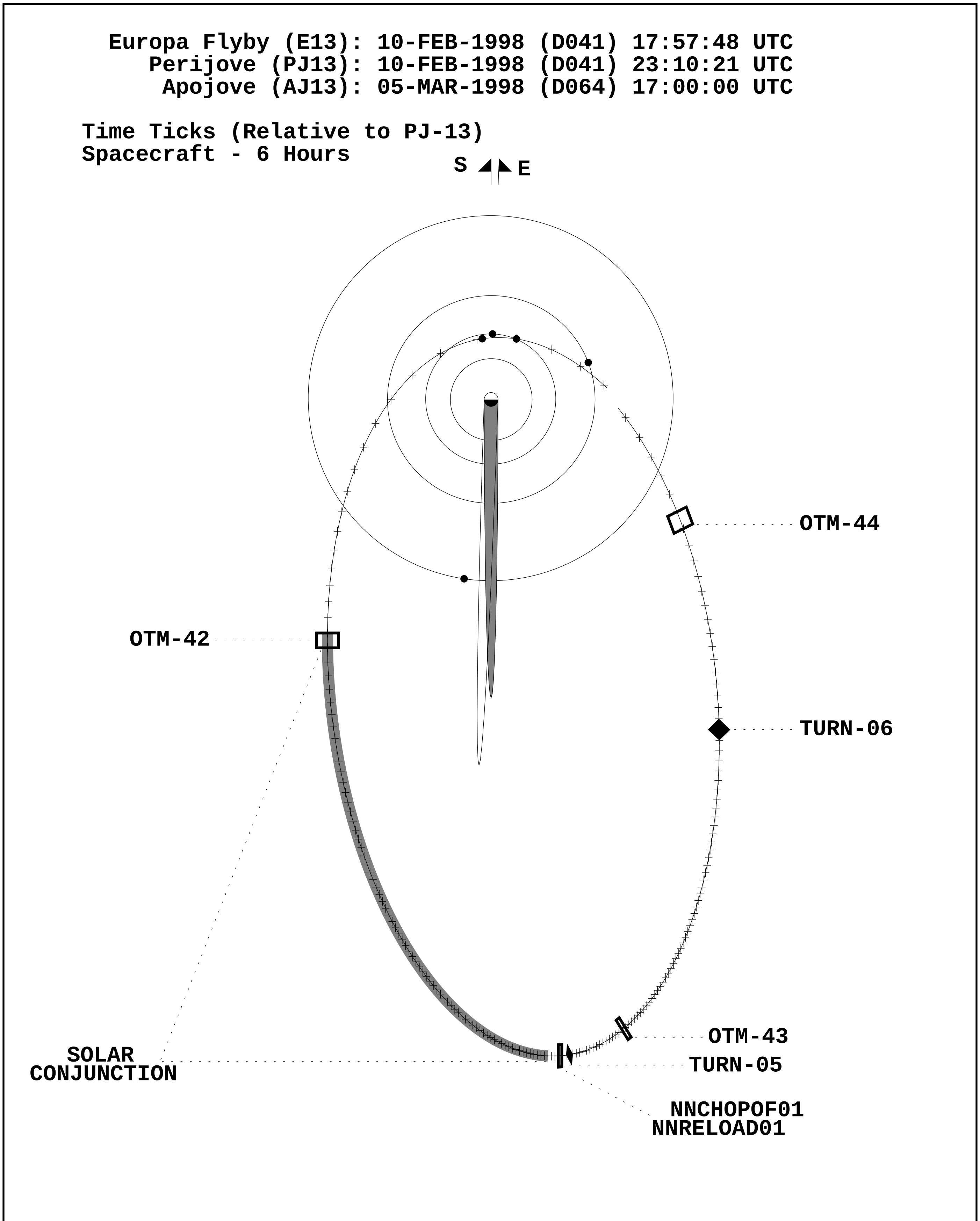

NIMS - FEL - 06/03/99

# NIMS E12 CRUISE CALIBRATIONS




E12 North Trajectory Pole View, Perijove to Perijove

# NIMS E13 CRUISE ACTIVITIES




E13 North Trajectory Pole View, Perijove to Perijove

# NIMS E12 DATA RETURN

| Activity ID | Observation Title | NIMS Edit Table | NIMS PB Table | Mode | Gain | Grating Start | Grating Offset | Record Format | PSID |
|---|---|---|---|---|---|---|---|---|---|
| 12JNJUPRTS01* | Jupiter Realtime Observation | E12JLM442/MB | R/T | LM | 2 | 0 | 4 | R/T | DA |
| 12JNJUPRTS02* | Jupiter Realtime Observation | E12JLM442/MB | R/T | LM | 2 | 0 | 4 | R/T | DB |
| 12JNJUPRTS03* | Jupiter Realtime Observation | E12JLM442/MB | R/T | LM | 2 | 0 | 4 | R/T | DC |
| 12ENGLOBAL01- | Europa Global | E12ELM442 | E12ELM228C | LM | 2 | 0 | 4 | MPW | DD |
| 12ENCPWYLL01- | Europa Surf. Comp. and Mineos Linea | E12ELM442 | E12ELM360 | LM | 2 | 0 | 4 | MPW | DF |
| 12ENICEBRG01- | Europa Surface Composition | E12ELM442 | E12ELM360 | LM | 2 | 0 | 4 | MPW | DG |
| 12INHRSPEC01- | Io Monitoring at High Spectral Resolution | E12ILM442 | E12ILM360 | LM | 2 | 0 | 4 | MPW | DH |
| | | | | | | | | | |
| 12ENGLBAL01B- | Europa Global | E12ELM442 | E12B_ELM168 | LM | 2 | 0 | 4 | MPW | DD |
| 12ENGLBAL01C- | Europa Global | E12ELM442 | E12B_ELM168 | LM | 2 | 0 | 4 | MPW | DD |
| 12ENCPWYLL01- | Europa Surf. Comp. and Mineos Linea | E12ELM442 | E12ELM360 | LM | 2 | 0 | 4 | MPW | DF |
| 12ENICEBRG01- | Europa Surface Composition | E12ELM442 | E12ELM360 | LM | 2 | 0 | 4 | MPW | DG |
| 12INHRSPEC01- | Io Monitoring at High Spectral Resolution | E12ILM442 | E12ILM360 | LM | 2 | 0 | 4 | MPW | DH |

# NIMS E12 DATA RETURN

| ACTIVITY ID | Mode | Record Format | Wave-lengths ret. | Record Time (sec) | PB Time (sec) | Sel Bits of Tape sBOT (Mbits) | Total Bits of Tape BOT (Mbits) | Mode Cycle Time | Thold | Comp | Total BTG (Mbits) (4% ohead) | Data Reduct Factor (sBOT/BTG) | Pass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| 12JNJUPRTS01 | LM | R/T | 360 | | | | | | | | | | |
| 12JNJUPRTS02 | LM | R/T | 360 | | | | | | | | | | |
| 12JNJUPRTS03 | LM | R/T | | | | | | | | | | | |
| 12ENGLOBAL01 | LM | MPW | 228 | 2030.7 | 243 | 2.80 | 23.39 | 8.667 | 0 | 1.38 | 0.96 | 2.91 | 1 |
| 12ENCPWYLL01 | LM | MPW | 360 | 442 | 122 | 1.41 | 5.09 | 8.667 | 0 | 1.34 | 0.79 | 1.79 | 1 |
| 12ENICEBRG01 | LM | MPW | 360 | 667.3 | 122 | 1.41 | 7.69 | 8.667 | 0 | 1.36 | 0.78 | 1.81 | 1 |
| 12INHRSPEC01 | LM | MPW | 360 | 509 | 269 | 3.10 | 5.86 | 8.667 | 2 | 1.68 | 1.38 | 2.24 | 1 |
| | | | | | | | | | | | | | |
| 12ENGLOBAL01 | LM | MPW | 168 | 2030.7 | 303 | 3.49 | 23.39 | 8.667 | 0 | 1.46 | 0.84 | 4.17 | 2 |
| 12ENGLOBAL01 | LM | MPW | 168 | 2030.7 | 303 | 3.49 | 23.39 | 8.667 | 0 | 1.49 | 0.82 | 4.26 | 2 |
| 12ENCPWYLL01 | LM | MPW | 360 | 442 | 333 | 3.84 | 5.09 | 8.667 | 0 | 1.35 | 2.13 | 1.80 | 2 |
| 12ENICEBRG01 | LM | MPW | 360 | 667.3 | 624 | 7.19 | 7.69 | 8.667 | 0 | 1.36 | 3.96 | 1.81 | 2 |
| 12INHRSPEC01 | LM | MPW | 360 | 509 | 316 | 3.64 | 5.86 | 8.667 | 2 | 1.61 | 1.70 | 2.15 | 2 |
| | | | | | | | | | | | | | |
| | | | | | | | 70.32 | | | | 13.432 | Total | |
| Allocation | | | | | | | | | | | 12.797 | Allocation | |
| | | | | | | | | | | | 0.635 | Over/Under | |

## RECAP OF E12 PLAYBACK EVENTS

**The first orbit of the Galileo Europa Mission (GEM) included both a new type of spacecraft hardware anomaly, and one instance of a radiation-induced NIMS software crash. The spacecraft hardware problem involved one of the gyros that are components of the AACS. Galileo's two gyros are mounted on the scan platform. One gyro began reporting ~ 10% greater motion than was actually occurring during positive sign clock and cone slews. The software when given this erroneous information attempted to correct the pointing by making adjustment slews, some of which occurred while remote sensing data was being obtained. There were two anomalous occurrences, one during the encounter, and another during a trajectory correction manuever a few days later.**

**Due to downlink bits constraints only 5 NIMS recorded observations were planned (with 3 realtime Jupiter observations). Due to a NIMS software crash, 12ENDLINEA01 was not successfully recorded. However, the two accompanying Europa high-resolution observations were returned at full spectral resolution of 360 wavelengths, as was 12INHRSPEC01. We also received a significant portion of 12ENGLOBAL01.**

**The E12 playback period was eventful, with a number of adaptations required to deal with changing conditions. The following timeline details the most significant events of this period. Most of the text is taken directly from reports generated at the time.**

### E12 Playback Events Timeline (11-04-97 to 04-02-98)

**11-04-97:** **NIMS E12 downlink allocation is 14.333 Mbits.**

**11-24-97:** **E12 will begin on 15 December. E12 playback will encompass solar conjunction, and so will last until sometime in March.**

**The playback table delivered today has realistic compression estimates and correct wavelength table selections for all observations. The situation is not good. Since NIMS received a measly 14% of total downlink in the GEM OPG negotiations, we have only 16.82 Mb to cover all our observations, whereas if we want to bring down our 5 recorded observations with all wavelengths and full spatial coverage we need about 28 Mb. If we bring back the Europa GLOBAL01 with 228 wavelengths, we still need about 5 Mb to get the high resolution Europa observations down.**

**12-04-97:** **The E12 playback plan was modified to fit within the current allocation of downlink bits as follows:**

**12ENGLOBAL01: Spatial coverage cut 50%. 40% of the observation area nearest the limb will be lost; the other 10% area cut is at or beyond the terminator, on the body. The remainder is a contiguous, complete, north to south strip, spanning longitudes 255-290 at the equator. 228 wavelengths will be returned.**

__E12 Playback Events Timeline__ **(11-04-97 to 04-02-98)**

**12ENDLINEA01: To be returned with 360 wavelengths and with full recorded spatial area coverage.**

**12ENCPWYLL01: To be returned with 360 wavelengths and with full recorded spatial area coverage.**

**12ENICEBRG01: 7 of 11 Rims recorded to be played back with 360 wavelengths centered near longitude 180).**

**12INHRSPEC01: Unchanged, full observation returned at 360 wavelengths.**

**12-15-97: E12 encounter begins at 10:45 on Monday 15 December.**

**12-16-97: First AACS-GYRO anomaly occurs at 00:21 GMT.**
**Perijove occurs at 06:36.**
**NIMS software reload error causes loss of 12ENDLINEA01.**
**This is not known until early January.**
**A software reload at 11:31 enables recording of subsequent observations.**
**Europa close approach occurs at 12:05.**

**12-19-97: Due to the AACS anomaly and the delay in initiating playback, Galileo lost 4.958 MB of capability. Worst case, that will be deducted by percentage from all teams before the first PBT update cycle.**

**12-22-97: There was an AACS anomaly last week during E12 encounter near perijove. Apparently the star scanner was affected by unusually high levels of radiation noise, causing a 'star dropout problem'. This caused CDS to command a total of 7 "mis-slews" in addition to one case in which the scan platform was safed (to 153 cone). The first of the mis-slews took place during the second Jupiter realtime observation. Although we have data from the third, which looks good, we do not know precisely where we were pointed at the time. The sequence continued to execute after these events and observations were recorded to tape as planned. However, all of our Europa observations were taken during periods when the mis-slews were occurring. The effects are unknown at present. Since playback was not started on schedule, 4.95 Mb of down-link was lost. This will result in a 14% cut to our allocation.**
**Nominal operations were restored early last Thursday morning. However, on Saturday, additional AACS "incidents" occurred. During the OTM the AACS initiated 2 attitude corrections, and then followed them up later with 4 more. The spacecraft was commanded out of inertial mode, stopping further corrections. As a result the spacecraft is pointed about 8 degrees away from the Earth-s/c direction. Work to understand this second anomaly and to get things back to normal is underway.**
**As one consequence we are sure to lose more of our playback allocation. Numbers as high as 40% have been mentioned.**

**<u>E12 Playback Events Timeline</u> (11-04-97 to 04-02-98)**

**12-23-97:** **The Galileo AACS system has locked on to a new set of stars. The spacecraft is presently pointed about 10 degrees off the Earth direction. Work to understand the anomaly and bring the orientation back to nominal continues. However, there is no estimated time for the re-orientation of the spacecraft as yet. New telemetry files have been generated with the current orientation modeled. Capability between now and 13 January is meager, about 2.5 Mb. Playback will be resumed tomorrow at about 3 pm. The first NIMS observation, 12ENGLOBAL01, will not be reached before 13 January. It is possible that activities to correct the misorientation of the spacecraft will begin before that time, but at present we cannot assume so. As a result the SPOT team estimates that we will be losing about 40% of our downlink allocation. This presently stands at 16.6 Mb; it will drop to about 10 Mb. The current allocation is distributed as follows:**

| Observation | Wavelengths | Spatial Cov | Megabits |
|---|---|---|---|
| 12ENGLOBAL01 | 228 | 50% | 4.42 |
| 12ENDLINEA01 | 360 | 100% | 2.84 |
| 12ENCPWYLL01 | 360 | 100% | 2.95 |
| 12ENICEBRG01 | 360 | 65% | 2.74 |
| 12INHRSPEC01 | 360 | 100% | 3.56 |

**The 40% reduction overall can be accomplished through cutting wavelengths or spatial coverage, or by deleting observations entirely.**

**12-29-97:** **No progress on the AACS anomaly has been reported so far. We are proceeding as if the spacecraft will continue to be mis-oriented until the next OTM on 14 January. The estimated total loss of downlink capability is 32.9 Mb, slightly less than expected. The NIMS allocation dropped to 11.76 Mb from 16.6. Early data returned by SSI undercompressed by a factor of 2, and in addition the SSI team decided that their global color Europa observation was not of the highest priority. This one has been coming down for a few days now. They requested that playback be terminated so that they could move their bits to other observations. This decision benefits us because we can now modify playback commands for the first observation in the table, 12ENGLOBAL01. We were formerly locked in to bringing down 2.2 Mb of this in pass 1. Although the cuts needed to bring us in at our allocation were serious they are not disastrous. For the Io HRSPEC01 we reduced wavelength coverage from 360 to 228 colors. The Europa global spatial coverage was further reduced by dropping the top and bottom scans from this 4-scan observation. We are now returning only 25% of the recorded area, but what we will get covers about 30 degrees of longitude (260-290) and +/- 30 degrees of latitude about the equator. We also needed to cut 1.5 Rims (of 3.5) out of our pass 1 playback of both 12ENCPWYLL01 and 12ENICEBRG01. We will still see enough of these in pass 1 to prioritize our bits spending in pass 2. 12ENDLINEA01 was not cut.**

**<u>E12 Playback Events Timeline</u> (11-04-97 to 04-02-98)**

**01-07-98:** **Playback allocations were reduced again this week in anticipation that the misalignment of the spacecraft (off-Earth pointing) will not be corrected immediately. The cost to NIMS was about 1 Mb, bringing us down to a total of 10.887. The first part of 12ENGLOBAL01 came down with a slightly better than expected compression ratio of 1.38 (predict was 1.2). This gives us about .2 Mb more to work with. No changes to the Europa observations were incorporated in this update.**
**It was remembered/recognized that the Io 12INHRSPEC01 was comprised of two overlapping scans across the body. It was originally planned to record these with different gain states, but this was not implemented in the record sequence, leaving us with redundant coverage. We will now return the first scan at 228 wavelengths as decided in Tuesday's meeting. We have about .44 Mb of "unused" capability which is presently sitting on the second scan of 12INHRSPEC01 (pass 2). This may be used later to increase spatial coverage of Europa, or to bring down more wavelengths for Io, or to get redundant spatial coverage for Io (that will help identify noise). It is possible, however, that we will face further cuts in our allocation in this orbit that will consume these bits before we can use them. SSI has deselected considerable data from their plan, and as a result we have slewed most of the way to our next observation, 12ENDLINEA01. This is likely to come down later this week. The pass 1 portion is about 50% of the spatial area, at 360 wavelengths.**

**01-12-98:** **A new sequence based on the new attitude is expected to be on-board the spacecraft by ~4 pm on Thursday.**

**01-17-98:** **Data received from playback of 12ENDLINEA01 indicates a software crash. A minimal amount of data is received, leaving much of the allocation for this observation available for use on other observations.**

**01-21-98:** **Investigation of the "AACS anomaly" now centers on one of the gyros. It appears that scan platform slews of 180 degrees may generate pointing errors of several degrees. AACS may be capable of correcting the pointing over a period of 200 seconds following the scan platform motion. No conclusions or decisions have been announced so far.**
**E12 playback continues. The next NIMS observations, 12ENICEBRG01 and 12INHRSPEC01, should be on the ground or in process next Thursday. We will see 2 Rims of the former, with 360 wavelengths, and all* of the latter, likewise with 360 wavelengths. There is no pass 2 playback of HRSPEC in the current plan. However, if there are gaps in the pass 1 data, we could fill them in pass 2. We will return all of the remaining 12ENCPWYLL01 data in pass 2, and nearly all of 12ENICEBRG01, with 360 wavelengths. Since the pass 1 portion of 12ENGLOBAL01 was very noisy beyond 3 microns, we decided to play back a larger spatial area with fewer wavelengths in pass 2. The new wavelength table selects all wavelengths for detectors 1, 2, 4, 5, 6, 7, and 9 (168 bands). Of the four**

8-Rim scans across the body, we will receive 5 Rims each from the 2 central scans, on the brightest part of the body, extending to the limb. Since the wavelength selection differs from pass 1, and since there is a small overlap in the spatial coverage, this portion is renamed 12ENGLBAL01B.

01-28-98: There has been no NIMS data playback since the last update, but we received about 0.3 Mb of new allocation due to release of 2.3 Mb from the playback slewing uncertainty bucket. After several discussions we decided to use this to bring down 2 additional Rims of data from 12ENGLOBAL01. This newest addition is from the 4th scan where we have coverage of high southern latitudes (which have not been sampled previously). The range of longitudes seen is from about 240 to about 290 degrees W. Our first data from 12ENICEBRG01 will come down overnight tomorrow and Friday morning; 12INHRSPEC should be down by noon on Saturday. Playback of 12ENGLOBAL01 (with modifications as noted above) will also begin on Saturday; this should continue until the following Thursday (5 February). Solar conjunction "begins" on Friday the 13th and "ends" on 4 March. Thus we will not see any more NIMS data until then.

01-30-98: Sometime yesterday, following Wednesday's delivery of the playback table, it was discovered that the software used to predict the playback schedule showed significantly less downlink remaining than was previously thought. Initially they drew back the .3 Mb we had gained (which we were using to get south polar coverage of Europa). Subsequently they found that the problem was significantly worse, and reduced our allocation by an additional 0.8 Mb.
The 8th segment of the PBT containing 12ENGLOBAL01 commands went up this morning, without the south polar coverage select/deselect pair. This observation will start coming down over the weekend, and drag on for most of a week.
Two observations remain in our plan that may be modified; these are 12ENCPWYLL01 and 12ENICEBRG01. We will still return all of the former and are trimming the latter to come in at our allocation. Inspection of the largescale photomosaic shows interesting bright and dark areas in the western part and a diffuse dark region in the eastern part. This area is also covered in E14 (14ENSUCOMP02). Thus this time we are choosing the westernmost area and trimming that to the east. In another development it appears that we may be able to reinstate the two realtime calibrations in the period after solar conjunction. If so then we will need to find a few more (.2 Mb) bits. These will come either from small additional cuts to the 12ENICEBRG01, or from release of office margin later on.

02-13-98: Start of Solar conjunction, no data returned.
03-02-98: End of Solar conjunction

**<u>E12 Playback Events Timeline</u> (11-04-97 to 04-02-98)**

**03-02-98** E12 playback will resume on Wednesday of this week, 3/4, early (4 AM local time). We are currently paused at the very end of Segment 9, and should be very close to finishing 12ESDKLNCL01 (SSI). Once we start playing back, we will be about 12 hours behind the schedule you recieved, titled E12PFH - Update (dated Feb. 23). The last observation was undercompressing when we entered conjunction, and the schedule could not represent this accurately. Some numbers of interest - we have recieved ~57 MB of data so far. We have lost ~ 2.4 MB. We have received about 1.4 MB of inefficiency so far. We have 22.5 MB of capability remaining post-conjunction.

**03-09-98:** A new playback table was delivered yesterday. It contains singles to play back data gaps in 12INHRSPEC01 and 12ENICEBRG01. These are the only differences from the playback table delivered previously. Also, playback of the remainder of 12ENCPWYLL01 starts today.

**03-12-98:** The project released all remaining margin this afternoon. 2.0 Mb was given to NIMS, 1.5 Mb to SSI. This is a better outcome than would have been predicted yesterday. We will return the balance of 12ENICERAF01 (about 3.5 Mb), all of the gap fills required for 12INHRSPEC01, and in addition we should receive a large portion of the second (redundant) scan over Io that was also recorded with 12INHRSPEC01.

**03-17-98:** A new E12 playback table was delivered today. It contains singles to play back the balance of 12ENICEBRG01 and most of the second (redundant) scan of 12INHRSPEC01. These are the only differences from the playback table that was delivered on March 9.

**04-02-98:** The E12 Playback was completed on Friday, March 27. We completed the return of data from the Europa ICEBRG observation at 360 wavelengths and from the Io HRSPEC observation including all of the second scan (except for the last ~13 minor frames) of HRSPEC.

**04-02-98:** E12 Playback recap:
We finished playback with 0.36 MB of capability unused. NIMS selected and received as much of their last observation (INHRSPEC) as they could, which returned data above and beyond their allocation. Since the only thing left on the tape without starting a third pass was the PPR Cooldown (which PPR did not need a second time) we got as much as we could get at the very end with only doing 2 passes through the tape. Our model predicted we would barely finish, but we did slightly better than that for one(or both) of two reasons - someone compressed better, or we didn't lose as much capability during the pause for OTM-44 as predicted, and got lucky.

Total PB data received: 75.63 MB
Total PB lost bits: 3.36 MB (radiated but not recieved)
Total Inefficient Fill received: 1.5 MB

## NIMS Anomaly Report - E12 Sequence

The NIMS processor halted once during the E12 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 some AACS anomalies during E12

---

### Processor Halts

**Facts**:

0. Between the start of the E12 Encounter and the single Halt NIMS returned 3 realtime observations and successfully reloaded NIMS from CDS 4 times. The NIMS SCLK engineering channels were continuously monitored for detecting a NIMS processor halt.

1. A NIMS processor halt was detected at SCLK 04262556 from the analysis of the NIMS SCLK engineering telemetry channels S-1931 and S-1932. This occurred about 2 hours and 40 minutes after E12 perijove. A fifth NIMS reload was planned before the next NIMS observation 1 hour and 50 minutes later, but an error in the timing of the reload caused NIMS to remain in a halted state and the NIMS observation 12ENDLINEA01 was lost. The subsequent NIMS observation (12ENCPWYLL01) had a reload that restarted the NIMS processor.

No more Halts occurred during the rest of the encounter. A table of the NIMS engineering SCLK values near the time of the Halt follows (Note that the NIMS engineering SCLK value is normally 2 Rims behind the CDS SCLK Rim when it is reported):

| NIMS SCLK | CDS SCLK | CDS SCET | GROUND ERT |
|---|---|---|---|
| 04261960 | 04261962.58 | 1997-349T23:14:20.339 | 1997-350T00:01:14.354 |
| 04262556 | 04262562.58 | 1997-350T09:21:00.317 | 1997-350T10:14:42.214 |
| 04262725 | 04262727.43 | 1997-350T12:07:40.311 | 1997-350T14:05:51.438 |

2. 1 NIMS observation was lost due to this Halt: 12ENDLINEA01.

**Timing**:

| SCLK | Comments |
|---|---|
| 04262556.00 | NIMS HALTED |
| 04262667.08 | Start Reload 12NNDLINEA01 - BAD RELOAD |
| 04262678.00 | Start NIMS Observation 12ENDLINEA01 - HALTED |
| 04262694.06 | Start Reload 12NNCPWYLL01 - GOOD RELOAD |
| 04262704.00 | Start NIMS Observation 12ENCPWYLL01 |
| 04262725.00 | Good SCLK reported. |

---

# NIMS Anomaly Report - E12 Sequence

## E12 AACS Anomaly

Two AACS anomalies occurred during E12: one near E12 perijove and another during the execution of OTM-39 5 days after perijove. The first anomaly had little effect on NIMS data taking during E12. The second anomaly resulted in poor data return conditions. The response of the spacecraft flight team to these anomalies caused the NIMS E12 PCT and RCT calibrations to be cancelled. The E12 AACS anomalies are described in detail in ISA 11036.

Extract from ISA 11036 (Shadan Ardalan, 7 pages of text plus 4 plots)

Background:

The AACS Gyro Anomaly officially began on 97-350/00:21:00, about seven hours prior to perijove during the E12 encounter, the first encounter of GEM. The indications of the anomaly in E12 were two fault monitor (FM) trips resulting in swapping to the redundant Spin Bearing Assembly (SBA) and AACS Despun Electronics (DEUCE). Five days later, during the execution of Orbit Trim Maneuver-39 (OTM-39), another fault monitor tripped resulting in swapping again to the redundant SBA; also six autonomous vernier maneuvers were executed, which moved the spacecraft away from its nominal attitude

The term "officially" is used because two scan platform science instruments, SSI and NIMS, have reported anomalous pointing in the last three encounters of the prime Galileo mission: C9, C10 and E11. The C10 and E11 cases were reported by SSI about a week before the E12 anomaly, and the C9 case was reported by the NIMS team about six months after the E12 anomaly. We believe that the seeds of the gyro anomaly are in these three instances because all display a signature consistent with what we understand to be the effects of the gyro anomaly on scan platform pointing. However, the anomalous pointing during these encounters did not result in fault monitor trips.

The gyro anomaly manifests itself in the gyro output producing a higher than nominal signal when slewing the scan platform (SBA) in specific directions. When processed by the flight software, this gyro error results in a faulty attitude estimate. But with a valid star set (at least two stars), the inertial observer (INOB) software takes out a percentage of the attitude estimate error with each spacecraft revolution. Without a valid star set, the attitude estimate error can continue to accumulate.

Testing and analysis indicates that the problem with the gyro output seems to reside in the DG181 switch, which gives the signature as if the gyro scale factors have changed. Total radiation dosage throughout the Galileo mission is the primary theory for the failure mechanism of the DG181 switch. In May 1998 (E15), additional flight software was loaded on board the spacecraft to compensate for the asymmetric changes in the gyro scale factors before the flight software determines an attitude estimate. The software has performed nominally, however the gyro scale factors continue to change per perijove pass and need to be monitored indefinitely.

# NIMS Anomaly Report - E12 Sequence

## Summary:

The first AACS anomaly at perijove caused the scan platform to "safe itself" at 153 degrees cone. The gyros remained on and the spacecraft remained in inertial mode. The rest of the E12 encounter executed without any major problems.

The second anomaly at OTM-39 caused the spacecraft to lose its inertial reference. OTM-39 was performed with a 7Burn which required closing the star scanner shutter. Attitude information during OTM-39 was maintained with gyros only, which accumulated a false attitude estimate. After the maneuver, the star scanner shutter was opened, but the Sequential Star Identifier (SEQID) could not acquire the star set. Even though the spacecraft was physically at the same attitude as it was before the closure of the star scanner shutter, the error in the attitude estimate caused SEQID to search for the star set in a different part of the sky, resulting in its inability to locate the loaded stars and determine a proper attitude.

Due to the erroneous output of the gyros, the attitude estimate error at this time was about 7.7 degrees - greater than the 5.7 degrees 'background deadband' above which the spacecraft performs autonomous atttitude corrections. Up until this point, the spacecraft's physical orientation had not changed despite the telemetry indications. After this time six autonomous and anomalous pointing corrections were executed. After the sixth pointing correction, the attitude error estimate had reached 20.5 degrees. Shortly after the sixth autonomous pointing correction, the background sequence commanded the spacecraft to cruise mode and one minute later the gyros were turned off. Throughout this period, celestial reference was never achieved, making the gyros the only source for the spacecraft's attitude. Now, with the spacecraft in cruise mode, SEQID is the only data source used to calculate an attitude, but SEQID was still unable to identify the star set. Therefore, the attitude estimate was frozen at the last position as determined based on the suspicious gyro output.

A few days after OTM-39, the AACS SSSRE buffers were read out. They contained the intensities of star pulses and the times the pulses crossed the two slits of the star scanner. From this data, the spacecraft's attitude was calculated on the ground. Real-time commands were then sent to load the actual attitude into the software and a new star set for SEQID to identify. The convergence of SEQID confirmed that the AACS team had successfully determined the spacecraft's attitude, which was 5.7 degrees away from where it started via the six autonomous vernier maneuvers.

## Direct effects on NIMS:

In response to the E12 AACS anomaly, the project deleted all scan platform activities from the E12 cruise period. NIMS had planned to perform both PCT and RCT calibrations during E12 cruise. After the initial crisis was over, the sequence team decided that they had too much work on their hands to include the PCT and RCT calibrations into the new E12 cruise load.

**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.