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Cluster-II
Master Science Plan
first constellation

prepared by Cluster-II Joint Science Operations Centre,
Rutherford Appleton Laboratory

Issue 1.1 12 January 2001

1 Preface

1.1 Document Change Record

Version	Date	Notes/remarks
Draft 1	17 Sep 2000	Draft for comment by ESTEC and JSOC
Issue 1.0	22 Sep 2000	First formal issue, MSP version 5.1
Issue 1.1	12 Jan 2000	Revised for transition into Mission Operations, MSP version 5.3

1.2 Applicable Documents

AD1 CL-EST-RS-0002/EID A. Cluster Experiment Interface Document, Part A.

1.3 Reference Documents

RD1 CL-MPE-TN-0009, Cluster Master Science Plan, Issue 3.2, 25 April 1996 Download from http://jsoc1.bnsc.rl.ac.uk/pub/msp/tn09-32.pdf

RD2 Analysis Methods for Multi-Spacecraft data, Goetz Paschmann and Patrick W. Daly (Eds), ISSI Scientific Report SR-001, 1998. Download from http://www.issi.unibe.ch/PDF-files/analysis_methods_1_1.pdf

RD3 Consultative Committee on Space Data Systems, Recommendation for time code formats, CCSDS 301.0-B-2, Blue Book, Issue 2, April 1990. Download from http://ftp.ccsds.org/documents/pdf/CCSDS-301.0-B-2.pdf

1.4 Acronym List

CSDS	Cluster Science Data System
ESOC	European Space Operations Centre, Darmstadt, Germany
GSE	Geocentric-solar-ecliptic (co-ordinate system)
ISSI	International Space Science Institute, Bern, Switzerland
JSOC	Joint Science Operations Centre, RAL, UK
MLT	Magnetic local time
MSP	Master Science Plan
RAL	Rutherford Appleton Laboratory
UTC	Co-ordinated Universal Time

1.5 Important concepts

1.5.1 Orbit number

To aid planning of Cluster-II science operations, the orbit numbers of the four spacecraft have been synchronised. This does not mean the orbit numbers are identical. Rather, it recognises that the four spacecraft are close together so that all pass perigee in the space of a few minutes (which should be compared with the 57-hour orbit period). Thus each spacecraft starts a new orbit number as it passes through perigee. This number is the same for each spacecraft for each set of closely-timed perigees. Note that this synchronised orbit number is only available in orbit data produced by ESOC and in products derived from the ESOC data (e.g. those available from JSOC and the CSDS National Data Centres). It is not available in independent orbit data such as the *Two Line Elements* produced by NORAD (e.g. see http://celestrak.com/NORAD/elements/).

1.5.2 Time code

Times in this document are represented by CCSDS ASCII Time Code A (see RD3, page 2-6) for consistency with usage throughout the Cluster Science Data System. This code is a character string of the form

`yyyy-mm-ddThh:mi:ssZ`

where **`yyyy`**, **`mm`**, **`dd`**, **`hh`**, **`mi`** and **`ss`** are the year, month, day, hours, minutes and seconds respectively. All times are presented as Co-ordinated Universal Time (UTC) and using the Gregorian Calendar.

1.6 Contacts

For further information about this document, please contact the JSOC team via Email to jsoc_ops@rl.ac.uk

2 Introduction

2.1 Purpose of the MSP

The purpose of the Master Science Plan is to schedule the acquisition of science data by the four Cluster spacecraft in a way that is consistent with both the scientific objectives of the mission and the resources available for that data collection. Those resources (on-board data storage, telemetry bandwidth, spacecraft visibility from the Vilspa ground station, the available bandwidth between Vilspa and ESOC and the computing power and disc space available at Vilspa and ESOC) are an important constraint on Cluster science operations. They are sufficient to meet the mission objective of acquiring data for approximately 50% of the time that Cluster will be operational [see AD1]. However, to achieve this it is essential to optimise data acquisition over a continuous sequence of orbits and not to treat each orbit (or set of orbits) separately. The Master Science Plan is the result of that optimisation.

Cluster data acquisition periods are targeted on regions (e.g. cusp, tail neutral sheet, etc) where we expect to observe the plasma phenomena that are the scientific objectives of Cluster. Thus to prepare the Master Science Plan we must first specify this targeting - in terms of the placement and duration of data acquisition periods on orbits which cross the target regions and in terms of the data acquisition rates[1] to used during those periods. This specification is then checked against what is possible and is iteratively revised until it is a good match with the available resources (see below for more details).

Note that the requirement to optimise data acquisition over a continuous sequence of orbits has an important implication – namely, that it is not straightforward to alter the pattern of data acquisition. For example, an ability to swap patterns on an orbit by orbit basis would aid the flexibility of missions operations. However, to do this in a straightforward manner would require the data return to be reduced from 50% to 35% of the orbit.

2.2 Scope of this release

This is the second operational version of the Master Science Plan (MSP) for Cluster-II. It covers a period of about four months from 16 January 2001 to 5 June 2001 (orbits 87 to 146). This coverage is set by constraints discussed in the next section. This release is numbered version 5.3 for consistency with previous releases.

Note that this release only specifies the data acquisition periods and telemetry rates for the period covered. It does not specify the default instrument modes to be used in

[1] Cluster supports two main data acquisition rates: a normal mode (17 kbits s^{-1}) and a burst mode (106 kbits s^{-1}). The latter yields much higher resolution data but at the cost of reducing the period over which data can be collected.

those periods. These will be set by JSOC using rules agreed by the SWT (see RD1, section 3).

2.3 Release history

Version	Description
5.1	First version for real Cluster orbit, released as Issue 1.0 of this note
5.2	Intermediate version presented at SWT #35, Nov 2000 - available as Bryant plot in report of that meeting
5.3	Version for transition into Mission Operations, released as this note

2.4 Background

This Master Science Plan is a successor to the Plan that was developed for Cluster-I [RD1]. That Plan covered a period of six months centred on the first cusp encounter. The new Plan covers a similar period and was developed by adapting the Cluster-I plan: (a) to fit the constraints of the predicted Cluster-II orbit, and (b) to fit the rules on the volume of data that can be acquired by Cluster-II. (Note that the data recovery scenario for Cluster-II is very different to that of Cluster-I – through the use of one, rather than two, ground stations – the support of partial, rather than only full, dumps from the on-board data storage.)

2.5 Acknowledgement

The Cluster-II Master Science Plan draws very heavily on the concepts developed by the late Norbert Sckopke, who prepared the equivalent Plan for Cluster-I. We warmly acknowledge the help that Norbert provided to the JSOC team.

3 Constraints

3.1 Plan Start

The start of the period covered by this release is that agreed by ESA – namely orbit 87, which starts for the reference spacecraft (Samba, s/c 3) at 2001-01-16T12:34:28Z).

3.2 Plan End

The end of the period covered by this release is when the orbits lie close to the dawn-dusk plane with their apogees on the dawn side of the Earth.

3.3 Guidelines for data acquisition

The allocation of data acquisition is constrained to follow the rules advised by ESOC:

1. 6 hours of normal mode data acquisition are equivalent to 1 hour of burst mode data acquisition
2. The data acquisition pattern is constrained by the total data acquisition is any 57-hour sliding window thus:
    - For a mixture of normal and burst mode in that window, the total data volume must not exceed 7 hours burst mode equivalent
    - But if there is normal mode only in that window, it may be completely filled, i.e. the total data volume may reach 9.5 hours burst mode equivalent
3. The duration of any period of continuous normal mode may not exceed 3 orbits (171 hours).

These guidelines have been established by ESOC following analysis of the Master Science Plan using their Windows-based Data Recovery Analysis Tool (WIN-DRAT). The guidelines will be reviewed as experience is gained during the mission.

These Cluster-II guidelines differ from the equivalent guidelines for Cluster-I in two respects:

- The total data volume for mixed normal and burst mode acquisition in a 57-hour sliding window has increased from 6 to 7 hours burst-mode equivalent.
- The maximum duration of a normal mode acquisition is now constrained.

3.4 Late commissioning activities

A few remaining commissioning activities will take place during the early part of this Plan. Those activities will be scheduled outside the data acquisitions shown in this Plan.

3.5 Eclipses

3.5.1 Short Earth eclipses

A series of short eclipses (>= 43 mins) will occur very close to perigee at the start of orbits 99 to 111. These are also the orbits in which Cluster will encounter the northern cusp near noon local time, some eight hours after perigee. It is assumed that the short eclipses will not significantly constraint the data acquisition in this Plan.

3.5.2 Long Earth eclipses

There are no long eclipses during the period covered by this release.

3.5.3 Lunar eclipses

There is one lunar eclipse on all four spacecraft. This occurs on orbit 90 about 10 hours after apogee and has a duration of about 40 minutes. A burst mode data acquisition is planned at this time.

3.6 Configuration of the tetrahedron

This release does not take any explicit account of the predicted configuration of the tetrahedron formed by the four spacecraft. JSOC is currently working to display the configuration indices developed by the ISSI working group [see RD2] in a form that is consistent with the Master Science Plan.

4 Context

4.1 Alignment with the actual orbit

The current Plan is based on material prepared long before the launches of the four Cluster spacecraft. Thus a key issue for this release has been to check the alignment of the timeline in the Plan with the timeline of region crossings that result from the actual operational orbit[2]. In particular we search for the period when Cluster crosses the northern cusp region at local noon – this being the key science target of the Cluster mission. For convenience, we take the predicted magnetic local time of the outbound (northern) magnetopause crossing as an indicator of the changing spacecraft position with respect to the cusp (and assume that Cluster will intersect the cusp at noon when it crosses the magnetopause near noon MLT).

The results are shown in Figure 1 below. There is a clear trend for the MLT of magnetopause crossing to decrease as orbit number increases. However, there is also considerable scatter (of order ± 1 hour) about that trend. The trend is a consequence of precession of the orbital plane in local time as the Earth goes round the Sun., whilst the scatter is a consequence of the diurnal rotation of the geomagnetic dipole.

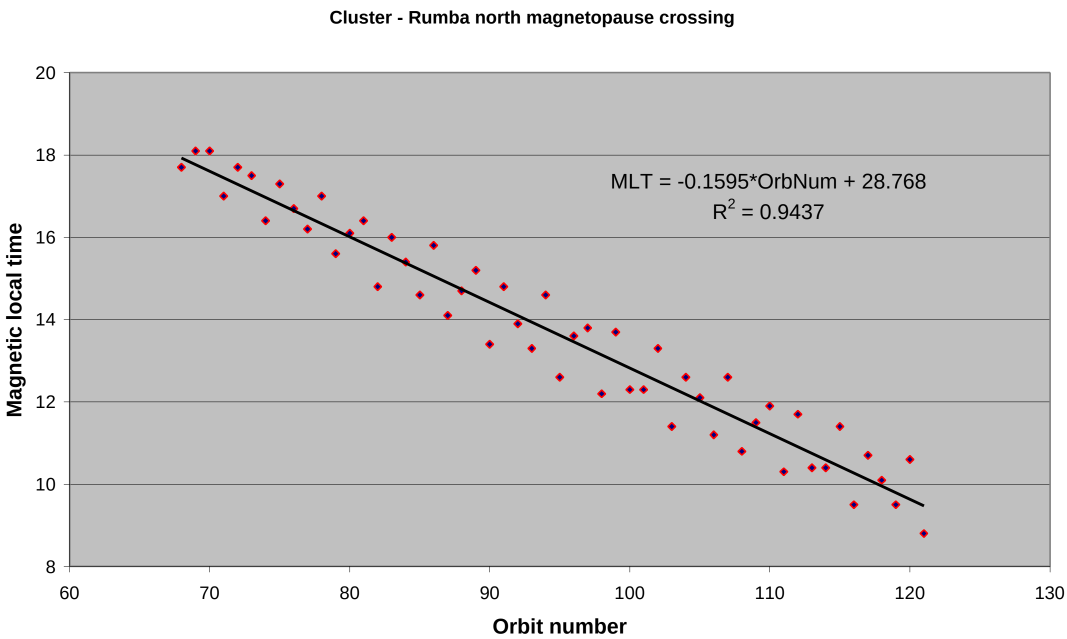

Figure 1. MLT of north magnetopause crossing

The straight line in Figure 1 is a simple regression fit to the data. It suggests that we should consider orbit 105 or 106 as the orbit in which Cluster crosses the magnetopause (and cusp) closest to noon. In practice, it was decided to use 106 as the cusp crossing as this had been used in pre-launch planning. A choice of 105 would

[2] Note that this changed several times in the last few months before launch – with the delay of the first launch from 15 June to 12 July, then to 15 July and finally to 16 July.

have necessitated extensive replanning of data acquisition on orbits close to the first set of predicted bow shock crossings (see orbits 75 to 78 in Figure 2).

4.2 Range in local time

During the period covered by this release, apogee will precess from a GSE local time of about 15 hours to about 6 hours. Thus this period will include extensive coverage of:

- the high-altitude cusp
- polar cap
- the magnetopause, magnetosheath and bow shock on the dayside and the dawn flank.
- the solar wind
- inner magnetosphere (outer plasmasphere, outer radiation belt and auroral field lines) on the nightside and duskside

4.3 Multi-spacecraft issues

The current release assumes that the same data acquisition periods and spacecraft telemetry modes will be executed on all four spacecraft.

4.4 Operation of the WBD instrument

This release takes account of initial plans to downlink data from the WBD instrument to the NASA DSN ground station network. Further work is required to co-ordinate these operations with the Plan. This is in progress at the time of writing.

The Plan does not yet contain any periods of the special BM2 operations which allow downlink of WBD data to the ESA ground station. These will be added.

4.5 Co-ordination with ground-based experiments

This release takes account of the first set of requests to co-ordinate Cluster data acquisition with ground-based experiments. These have been applied to the period up to 5 April 2001 (Orbit 120). Further analysis is planned. Information on the Plan will be delivered to the Cluster Ground-based Data Centre for use in their planning tool (see http://www.wdc.rl.ac.uk/gbdc/gbdc.html).

5 The Plan

5.1 Bryant Plot

The Plan is illustrated in the figure in Appendix B. In this "Bryant plot" format, the horizontal axis is absolute time while the vertical axis is time since last perigee. Thus each orbit is represented by a sloping line as you can see in the figure. Absolute time is shown in three forms:

- the progression of orbit number (bottom of plot)
- year and month (upper scale at top of plot)
- GSE local time of apogee (lower scale at top)

The weight of line indicates the type of data acquisition: dots for no acquisition, thin solid line for normal mode and thick solid line for burst mode. Predictions of various boundary crossings, including the radiation belts and eclipses, are indicated by coloured symbols. The legend for these symbols is at the bottom of the plot.

There is an apparent discontinuity in the timing of these events in May 2001. This is an artifact. It arises from the manoeuvre that is planned at that time to increase the spacecraft separation ready for the first tail constellation. The artifact reflects a known problem in the handling of orbit phase (i.e. fraction of orbit since last perigee). This will be fixed in order to support planning of the tail constellation.

At the lower centre of the figure, you can see a series of burst mode acquisitions targeted on the northern cusp (on the outbound leg of the orbit). Some acquisitions targeted on the southern cusp can also be seen in the upper centre. The different impact of normal and burst mode on data acquisition can also be seen well. On orbits with burst mode acquisitions, data are taken only over small segments of the orbit. Whereas, for normal data acquisition, it is possible to collect data continuously up to a limit of two to three orbits.

A "BM3 dump" is scheduled at the start of each data acquisition period and marked by an asterisk (*). These are 6-minute periods of burst mode data acquisition during which data are downloaded from the internal memory of the instruments. The content of those data is instrument-specific.

The present Plan currently contains 4 orbits (out of a total of 59) that are designated as Special Orbits. These are distinguished from the remaining 55 Baseline Orbits by allowing non-standard instrument operations designed to address special scientific questions. However, the overall telemetry rates for Special Orbits are set in this Master Science Plan - because the overall data acquisition must be consistent with that on adjacent Baseline Orbits and the guidelines presented above in section 3.3. The Special Orbits are indicated in the Bryant plot by a lower case "s" at the top and bottom of the sloping tracks that represent the orbits. Further Special Orbits will be assigned once the transition in Mission Operations is successfully completed.

5.2 MSP Tables

The Plan is also available in tabular form - see Appendix A. Each block of records indicates a data acquisition period and is separated from the next data acquisition period by a blank line. Each record indicates a period of fixed telemetry mode and comprises the following fields:

The following fields exist in all records	
START_TIME	Indicative start time
END_TIME	Indicative end time
TM	Telemetry mode • N1 = normal mode 1 • B1 = burst mode 1 • B3 = burst mode 3 (special mode during which instrument internal memory is downloaded)
DURATION	Duration of telemetry mode period in hours
The following fields exist in only in the first record of a data acquisition period	
JREF	JSOC internal reference code for the data acquisition period. Please quote this if you have a query about a particular period.
ORBIT	The orbit number of the reference event used to set the start time of the data acquisition period.
EREF	The type of reference event as follows • peri = perigee • apo=apogee • T_mp1=outbound magnetopause crossing • T_mp2=inbound magnetopause crossing • T_bs1=outbound bow shock crossing • T_bs2=inbound bow shock crossing
OFFSET	Time in hours from the time of the reference event to the start of the data acquisition period.

Note that it is (a) the fields ORBIT, EREF and OFFSET that specify the start of a data acquisition period and (b) the DURATION fields that then specify the durations of the telemetry mode periods within that period. The START_TIME and END_TIME are only indicative times based on current predictions for the relevant orbits. These times will change slightly (a few minutes) as new orbit predictions are received.

5.3 MSP statistics

MSP 5.3 contains data acquisitions covering 59 Cluster orbits (87 to 145) with apogee on the dayside. The region occupancy of Cluster for these orbits is:

Region	Total time in region (hours)
Solar Wind	1612
Magnetosheath	765
Magnetosphere	986
Grand total	3363

The telemetry durations by region, in hours, are shown in the table belowThe percentages show the fraction of the orbit from which we retrieve data. The overall total percentage is very close to the target of 50% set in the mission objectives.

Region	NM1	BM1	NM1+BM1
Solar Wind	584	23	607 (38%)
Magnetosheath	412	44	456 (60%)
Magnetosphere	459	36	495 (50%)
Overall total	1455	103	1558 (46%)

5.4 Resource Plot

As discussed in section 3.3, the Master Science Plan is subject to various guidelines - in particular, the total data acquisition in any 57-hour sliding window is constrained such that:

- For a mixture of normal and burst mode in that window, the total data volume must not exceed 7 hours burst mode equivalent
- But if there is normal mode only in that window, it may be completely filled, i.e. the total data volume may reach 9.5 hours burst mode equivalent

The figure below shows a graphical output from the tool used to check the Plan against those guidelines. It shows the total data volume in a 57-hour sliding window running over the whole period covered. The data volume is plotted as a function of orbit number at the centre of the window. The black portion of the curve indicates times when the 57-hour sliding window contains only normal mode - and the red portion, times when the window contains a mixture of normal and burst mode.

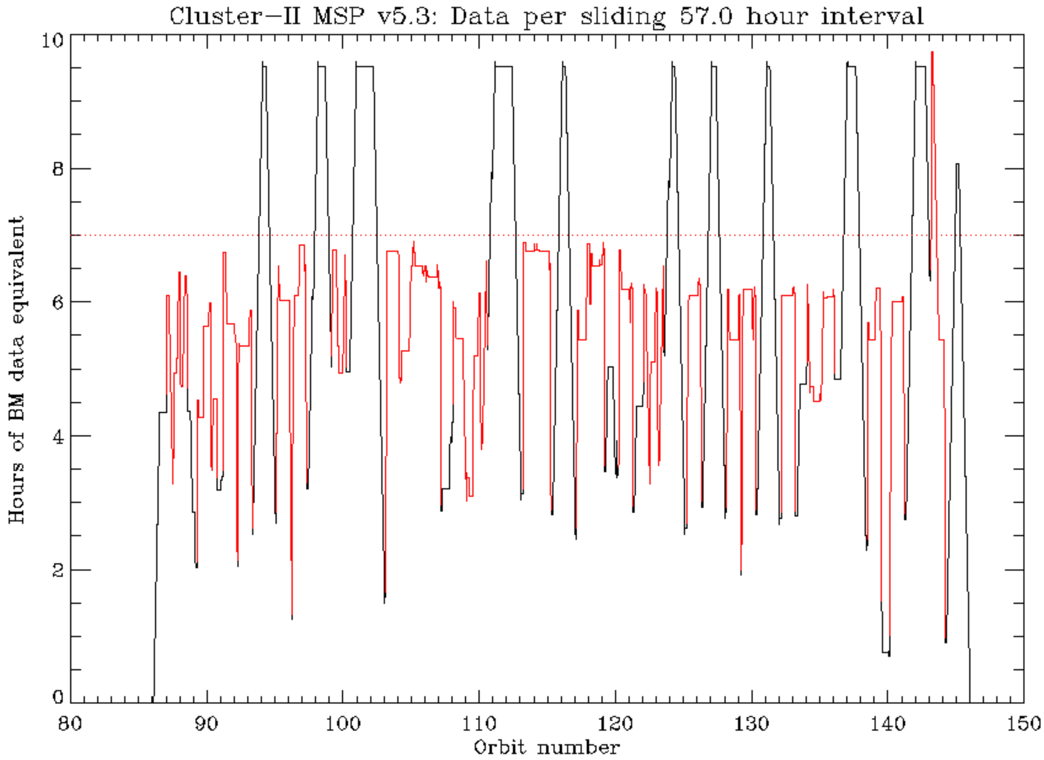

Figure 2. Data volume profile for the Plan

You can see that (with one exception discussed below) the periods of mixed normal and burst mode have been kept under the 7 hours of burst mode equivalent data - as indicated by the red dotted line. But there are ten periods of long duration normal mode data-taking in which the data volume rises to the maximum value of 9.5 hours burst mode equivalent.

You can also see that there are wide fluctuations in the data volume below these limits. JSOC has minimised these. What is left is a compromise between the need to respect the data-taking guidelines, the need to target data acquisitions on regions of interest and the staff effort required to iteratively adjust the Plan.

5.5 Open Work

Further work is planned to refine the later part of the Plan:

- To remove the evident spike in the acquisition of mixed mode data (around orbit 145 in the figure above)
- To increase the amount of data acquired in those orbits
- To take account of the refined plans for constellation manoeuvre in May 2001

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6 Appendix A. MSP tabular format

```
! Report produced from JSOC planning database
! using public_report.sql at
! 2001-01-12T15:13:36Z

START_TIME           END_TIME             TM DURATION JREF ORBIT EREF  OFFSET
-------------------- -------------------- -- -------- ---- ----- ----- ------

2001-01-16T14:37:00Z 2001-01-16T14:43:00Z N1       .1 18a     87 peri     2.0
2001-01-16T14:43:00Z 2001-01-17T16:43:00Z N1     26.0

2001-01-18T20:13:05Z 2001-01-18T20:19:05Z N1       .1 19b     88 peri    -1.5
2001-01-18T20:19:05Z 2001-01-18T21:19:05Z N1      1.0
2001-01-18T21:19:05Z 2001-01-18T22:49:05Z B1      1.5
2001-01-18T22:49:05Z 2001-01-19T06:49:05Z N1      8.0

2001-01-19T23:45:37Z 2001-01-19T23:51:37Z N1       .1 20b     88 apo     -2.5
2001-01-19T23:51:37Z 2001-01-20T01:21:37Z N1      1.5
2001-01-20T01:21:37Z 2001-01-20T02:51:37Z B1      1.5
2001-01-20T02:51:37Z 2001-01-20T04:21:37Z N1      1.5

2001-01-20T15:55:00Z 2001-01-20T16:01:00Z N1       .1 20c     88 T_mp2   -7.5
2001-01-20T16:01:00Z 2001-01-21T01:01:00Z N1      9.0

2001-01-21T08:48:20Z 2001-01-21T08:54:20Z N1       .1 21a     89 peri     2.0
2001-01-21T08:54:20Z 2001-01-22T01:54:20Z N1     17.0

2001-01-23T22:56:00Z 2001-01-23T23:02:00Z N1       .1 22b     90 T_bs1   -7.9
2001-01-23T23:02:00Z 2001-01-24T05:26:00Z N1      6.4
2001-01-24T05:26:00Z 2001-01-24T08:26:00Z B1      3.0
2001-01-24T08:26:00Z 2001-01-24T09:32:00Z N1      1.1
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2001-01-25T05:35:52Z 2001-01-25T06:05:52Z N1        .5 ecl      90 apo       9.2
2001-01-25T06:05:52Z 2001-01-25T07:17:52Z B1       1.2
2001-01-25T07:17:52Z 2001-01-25T07:47:52Z N1        .5

2001-01-26T06:01:17Z 2001-01-26T06:07:17Z N1        .1 22c      91 peri      5.0
2001-01-26T06:07:17Z 2001-01-27T01:07:17Z N1      19.0

2001-01-28T09:25:00Z 2001-01-28T10:30:00Z N1       1.1 mso      92 peri      -.8

2001-01-28T14:55:00Z 2001-01-28T15:01:00Z N1        .1 24a      92 T_mp1    -4.0
2001-01-28T15:01:00Z 2001-01-28T17:01:00Z N1       2.0
2001-01-28T17:01:00Z 2001-01-28T21:01:00Z B1       4.0
2001-01-28T21:01:00Z 2001-01-29T04:01:00Z N1       7.0

2001-01-31T00:55:00Z 2001-01-31T01:01:00Z N1        .1 28a      93 T_bs1    -8.5
2001-01-31T01:01:00Z 2001-01-31T07:31:00Z N1       6.5
2001-01-31T07:31:00Z 2001-01-31T11:31:00Z B1       4.0
2001-01-31T11:31:00Z 2001-01-31T13:01:00Z N1       1.5

2001-02-02T07:29:56Z 2001-02-02T07:35:56Z B3        .1 26a      95 peri    -54.0
2001-02-02T07:35:56Z 2001-02-05T05:35:56Z N1      70.0

2001-02-06T22:36:35Z 2001-02-06T22:42:35Z B3        .1 25a      96 peri       .0
2001-02-06T22:42:35Z 2001-02-06T23:12:35Z N1        .5
2001-02-06T23:12:35Z 2001-02-07T00:42:35Z B1       1.5
2001-02-07T00:42:35Z 2001-02-07T05:42:35Z N1       5.0
2001-02-07T05:42:35Z 2001-02-07T08:42:35Z B1       3.0
2001-02-07T08:42:35Z 2001-02-07T11:42:35Z N1       3.0

2001-02-09T14:00:00Z 2001-02-09T14:06:00Z B3        .1 29a      97 T_bs1    -7.0
2001-02-09T14:06:00Z 2001-02-09T19:06:00Z N1       5.0
2001-02-09T19:06:00Z 2001-02-09T23:06:00Z B1       4.0
2001-02-09T23:06:00Z 2001-02-10T06:06:00Z N1       7.0

2001-02-10T23:35:00Z 2001-02-10T23:41:00Z B3        .1 29b      97 T_bs2    -6.0
2001-02-10T23:41:00Z 2001-02-11T03:35:00Z N1       3.9
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2001-02-12T01:00:47Z 2001-02-12T01:06:47Z B3        .1 30a      99 peri    -49.0
2001-02-12T01:06:47Z 2001-02-15T14:06:47Z N1     85.0

2001-02-16T17:10:00Z 2001-02-16T17:16:00Z B3        .1 32a     100 T_mp1    -2.0
2001-02-16T17:16:00Z 2001-02-16T18:16:00Z N1      1.0
2001-02-16T18:16:00Z 2001-02-16T20:16:00Z B1      2.0
2001-02-16T20:16:00Z 2001-02-17T12:16:00Z N1     16.0

2001-02-18T16:06:53Z 2001-02-18T16:12:53Z B3        .1 33a     101 peri     -4.1
2001-02-18T16:12:53Z 2001-02-24T00:12:53Z N1    128.0

2001-02-26T00:30:00Z 2001-02-26T00:36:00Z B3        .1 36a     104 T_mp1    -7.0
2001-02-26T00:36:00Z 2001-02-26T03:36:00Z N1      3.0
2001-02-26T03:36:00Z 2001-02-26T09:36:00Z B1      6.0
2001-02-26T09:36:00Z 2001-02-26T10:36:00Z N1      1.0

2001-02-28T11:35:00Z 2001-02-28T11:41:00Z B3        .1 37a     105 T_mp1    -5.0
2001-02-28T11:41:00Z 2001-02-28T14:41:00Z N1      3.0
2001-02-28T14:41:00Z 2001-02-28T18:41:00Z B1      4.0
2001-02-28T18:41:00Z 2001-02-28T22:41:00Z N1      4.0

2001-03-02T07:30:00Z 2001-03-02T07:36:00Z B3        .1 37b     105 T_mp2    -3.0
2001-03-02T07:36:00Z 2001-03-02T14:36:00Z N1      7.0

2001-03-02T19:35:00Z 2001-03-02T19:41:00Z B3        .1 38a     106 T_mp1    -6.0
2001-03-02T19:41:00Z 2001-03-02T23:41:00Z N1      4.0
2001-03-02T23:41:00Z 2001-03-03T03:41:00Z B1      4.0
2001-03-03T03:41:00Z 2001-03-03T06:41:00Z N1      3.0

2001-03-04T17:05:00Z 2001-03-04T17:11:00Z B3        .1 38b     106 T_mp2    -2.5
2001-03-04T17:11:00Z 2001-03-05T00:11:00Z N1      7.0

2001-03-05T05:40:00Z 2001-03-05T05:46:00Z B3        .1 39a     107 T_mp1    -5.0
2001-03-05T05:46:00Z 2001-03-05T08:46:00Z N1      3.0
2001-03-05T08:46:00Z 2001-03-05T12:46:00Z B1      4.0
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2001-03-05T12:46:00Z 2001-03-05T15:46:00Z N1      3.0

2001-03-07T01:40:00Z 2001-03-07T01:46:00Z B3       .1 39b    107 T_mp2   -3.0
2001-03-07T01:46:00Z 2001-03-07T07:46:00Z N1      6.0

2001-03-07T14:45:00Z 2001-03-07T14:51:00Z B3       .1 40a    108 T_mp1   -5.0
2001-03-07T14:51:00Z 2001-03-08T02:51:00Z N1     12.0

2001-03-09T06:45:00Z 2001-03-09T06:51:00Z B3       .1 40b    108 T_bs2   -3.0
2001-03-09T06:51:00Z 2001-03-09T18:51:00Z N1     12.0

2001-03-09T21:14:29Z 2001-03-09T21:20:29Z B3       .1 41a    109 peri      .0
2001-03-09T21:20:29Z 2001-03-09T21:50:29Z N1       .5
2001-03-09T21:50:29Z 2001-03-09T23:20:29Z B1      1.5
2001-03-09T23:20:29Z 2001-03-10T09:20:29Z N1     10.0

2001-03-12T06:22:45Z 2001-03-12T06:28:45Z B3       .1 42a    110 peri      .0
2001-03-12T06:28:45Z 2001-03-12T07:28:45Z N1      1.0
2001-03-12T07:28:45Z 2001-03-12T08:58:45Z B1      1.5
2001-03-12T08:58:45Z 2001-03-12T16:58:45Z N1      8.0

2001-03-13T09:26:19Z 2001-03-13T09:32:19Z B3       .1 42b    110 apo     -1.5
2001-03-13T09:32:19Z 2001-03-13T11:02:19Z N1      1.5
2001-03-13T11:02:19Z 2001-03-13T12:32:19Z B1      1.5
2001-03-13T12:32:19Z 2001-03-13T14:02:19Z N1      1.5

2001-03-14T06:00:00Z 2001-03-14T06:06:00Z B3       .1 42c    110 T_mp2   -2.0
2001-03-14T06:06:00Z 2001-03-14T11:06:00Z N1      5.0

2001-03-14T21:35:27Z 2001-03-14T21:41:27Z B3       .1 43a    112 peri   -51.0
2001-03-14T21:41:27Z 2001-03-20T05:41:27Z N1    128.0

2001-03-21T20:40:00Z 2001-03-21T20:46:00Z B3       .1 46a    114 T_bs1  -10.0
2001-03-21T20:46:00Z 2001-03-22T02:46:00Z N1      6.0
2001-03-22T02:46:00Z 2001-03-22T07:16:00Z B1      4.5
2001-03-22T07:16:00Z 2001-03-22T14:16:00Z N1      7.0
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2001-03-24T05:50:00Z 2001-03-24T05:56:00Z B3        .1 47b    115 T_bs1  -10.0
2001-03-24T05:56:00Z 2001-03-24T11:56:00Z N1       6.0
2001-03-24T11:56:00Z 2001-03-24T16:26:00Z B1       4.5
2001-03-24T16:26:00Z 2001-03-24T23:26:00Z N1       7.0

2001-03-26T16:13:29Z 2001-03-26T16:19:29Z B3        .1 48a    117 peri   -54.0
2001-03-26T16:19:29Z 2001-03-29T14:19:29Z N1      70.0

2001-03-31T08:50:00Z 2001-03-31T08:56:00Z B3        .1 50a    118 T_mp1   -6.0
2001-03-31T08:56:00Z 2001-03-31T11:56:00Z N1       3.0
2001-03-31T11:56:00Z 2001-03-31T15:56:00Z B1       4.0
2001-03-31T15:56:00Z 2001-03-31T20:56:00Z N1       5.0

2001-04-02T03:30:00Z 2001-04-02T03:36:00Z B3        .1 50b    118 T_mp2   -5.0
2001-04-02T03:36:00Z 2001-04-02T11:36:00Z N1       8.0

2001-04-02T18:55:00Z 2001-04-02T19:01:00Z B3        .1 51a    119 T_mp1   -5.0
2001-04-02T19:01:00Z 2001-04-02T22:01:00Z N1       3.0
2001-04-02T22:01:00Z 2001-04-03T02:01:00Z B1       4.0
2001-04-03T02:01:00Z 2001-04-03T05:01:00Z N1       3.0

2001-04-04T12:35:00Z 2001-04-04T12:41:00Z B3        .1 51b    119 T_mp2   -5.0
2001-04-04T12:41:00Z 2001-04-04T21:41:00Z N1       9.0

2001-04-05T03:33:30Z 2001-04-05T03:39:30Z B3        .1 52a    120 peri     2.0
2001-04-05T03:39:30Z 2001-04-05T23:39:30Z N1      20.0

2001-04-07T09:41:42Z 2001-04-07T09:47:42Z B3        .1 52b    121 peri    -1.0
2001-04-07T09:47:42Z 2001-04-07T12:17:42Z N1       2.5

2001-04-07T15:45:00Z 2001-04-07T15:51:00Z B3        .1 53b    121 T_bs1   -7.0
2001-04-07T15:51:00Z 2001-04-07T20:51:00Z N1       5.0
2001-04-07T20:51:00Z 2001-04-08T00:51:00Z B1       4.0
2001-04-08T00:51:00Z 2001-04-08T05:21:00Z N1       4.5
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2001-04-09T21:48:45Z 2001-04-09T21:54:45Z B3       .1 54a    122 peri     2.0
2001-04-09T21:54:45Z 2001-04-10T23:54:45Z N1     26.0

2001-04-12T03:24:22Z 2001-04-12T03:30:22Z B3       .1 54b    123 peri    -1.5
2001-04-12T03:30:22Z 2001-04-12T04:30:22Z N1      1.0
2001-04-12T04:30:22Z 2001-04-12T06:00:22Z B1      1.5
2001-04-12T06:00:22Z 2001-04-12T14:00:22Z N1      8.0

2001-04-13T07:26:59Z 2001-04-13T07:32:59Z B3       .1 55b    123 apo     -2.0
2001-04-13T07:32:59Z 2001-04-13T09:02:59Z N1      1.5
2001-04-13T09:02:59Z 2001-04-13T10:32:59Z B1      1.5
2001-04-13T10:32:59Z 2001-04-13T12:02:59Z N1      1.5

2001-04-14T03:40:00Z 2001-04-14T03:46:00Z B3       .1 55c    123 T_mp2   -2.0
2001-04-14T03:46:00Z 2001-04-14T09:46:00Z N1      6.0

2001-04-14T21:05:57Z 2001-04-14T21:11:57Z B3       .1 56a    125 peri   -50.0
2001-04-14T21:11:57Z 2001-04-17T17:11:57Z N1     68.0

2001-04-19T11:15:00Z 2001-04-19T11:21:00Z B3       .1 58a    126 T_bs1   -9.5
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2001-04-19T19:21:00Z 2001-04-19T23:21:00Z B1      4.0
2001-04-19T23:21:00Z 2001-04-20T03:21:00Z N1      4.0

2001-04-21T19:30:54Z 2001-04-21T19:36:54Z B3       .1 59a    128 peri   -55.0
2001-04-21T19:36:54Z 2001-04-24T20:36:54Z N1     73.0

2001-04-26T13:10:00Z 2001-04-26T13:16:00Z B3       .1 61a    129 T_mp1   -6.0
2001-04-26T13:16:00Z 2001-04-26T17:16:00Z N1      4.0
2001-04-26T17:16:00Z 2001-04-26T21:16:00Z B1      4.0
2001-04-26T21:16:00Z 2001-04-27T01:16:00Z N1      4.0

2001-04-28T18:40:53Z 2001-04-28T18:46:53Z B3       .1 61b    130 peri    -2.0
2001-04-28T18:46:53Z 2001-04-28T22:46:53Z N1      4.0

2001-04-29T03:55:00Z 2001-04-29T04:01:00Z B3       .1 62b    130 T_bs1   -6.0
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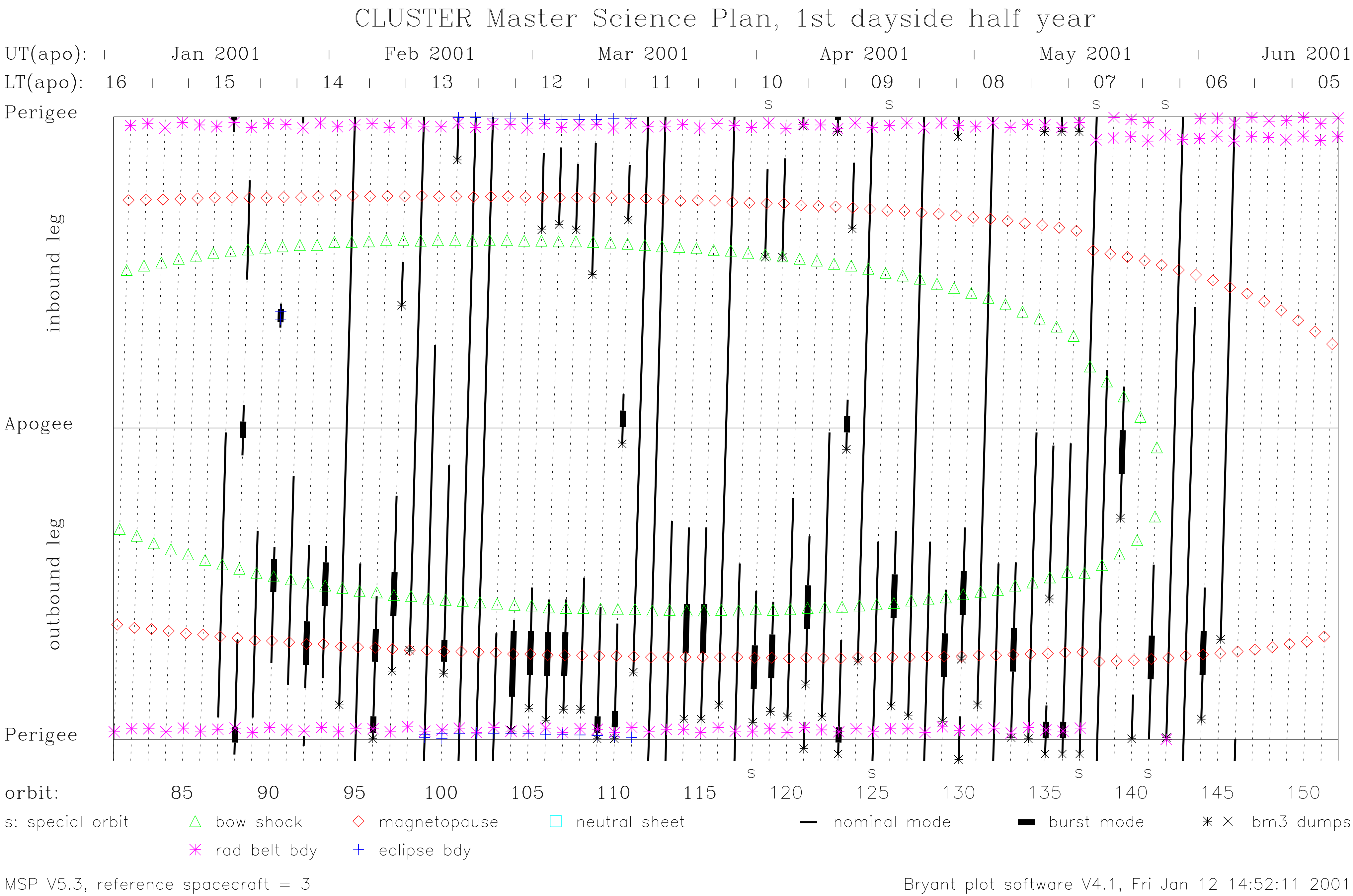
2001-04-29T04:01:00Z	2001-04-29T08:01:00Z	N1	4.0				
2001-04-29T08:01:00Z	2001-04-29T12:01:00Z	B1	4.0				
2001-04-29T12:01:00Z	2001-04-29T16:01:00Z	N1	4.0				
2001-05-01T08:55:04Z	2001-05-01T09:01:04Z	B3	.1	63a	132	peri	-54.0
2001-05-01T09:01:04Z	2001-05-04T07:01:04Z	N1	70.0				
2001-05-06T00:03:00Z	2001-05-06T00:09:00Z	B3	.1	65a	133	T_mp1	-7.7
2001-05-06T00:09:00Z	2001-05-06T06:09:00Z	N1	6.0				
2001-05-06T06:09:00Z	2001-05-06T10:09:00Z	B1	4.0				
2001-05-06T10:09:00Z	2001-05-06T16:09:00Z	N1	6.0				
2001-05-08T09:07:42Z	2001-05-08T09:13:42Z	B3	.1	66a	134	peri	.0
2001-05-08T09:13:42Z	2001-05-09T13:13:42Z	N1	28.0				
2001-05-10T16:42:15Z	2001-05-10T16:48:15Z	B3	.1	66b	135	peri	-1.5
2001-05-10T16:48:15Z	2001-05-10T18:18:15Z	N1	1.5				
2001-05-10T18:18:15Z	2001-05-10T19:48:15Z	B1	1.5				
2001-05-10T19:48:15Z	2001-05-10T21:18:15Z	N1	1.5				
2001-05-11T07:00:00Z	2001-05-11T07:06:00Z	B3	.1	67b	135	T_bs1	-2.0
2001-05-11T07:06:00Z	2001-05-11T21:06:00Z	N1	14.0				
2001-05-13T01:47:11Z	2001-05-13T01:53:11Z	B3	.1	67c	136	peri	-1.5
2001-05-13T01:53:11Z	2001-05-13T03:23:11Z	N1	1.5				
2001-05-13T03:23:11Z	2001-05-13T04:53:11Z	B1	1.5				
2001-05-13T04:53:11Z	2001-05-14T06:23:11Z	N1	25.5				
2001-05-15T10:54:03Z	2001-05-15T11:00:03Z	B3	.1	68b	137	peri	-1.5
2001-05-15T11:00:03Z	2001-05-19T08:00:03Z	N1	93.0				
2001-05-21T03:31:48Z	2001-05-21T03:37:48Z	B3	.1	73b	139	apo	-8.3
2001-05-21T03:37:48Z	2001-05-21T07:37:48Z	N1	4.0				
2001-05-21T07:37:48Z	2001-05-21T11:37:48Z	B1	4.0				
2001-05-21T11:37:48Z	2001-05-21T15:37:48Z	N1	4.0				

2001-05-22T16:22:13Z	2001-05-22T16:28:13Z	B3	.1	73a	140	peri	.0
2001-05-22T16:28:13Z	2001-05-22T20:28:13Z	N1	4.0				
2001-05-25T02:25:00Z	2001-05-25T02:31:00Z	B3	.1	72a	141	T_mp1	-7.5
2001-05-25T02:31:00Z	2001-05-25T08:01:00Z	N1	5.5				
2001-05-25T08:01:00Z	2001-05-25T12:01:00Z	B1	4.0				
2001-05-25T12:01:00Z	2001-05-25T18:31:00Z	N1	6.5				
2001-05-27T10:40:39Z	2001-05-27T10:46:39Z	B3	.1	74c	143	peri	-57.0
2001-05-27T10:46:39Z	2001-05-31T11:16:39Z	N1	96.5				
2001-06-01T07:40:00Z	2001-06-01T07:46:00Z	B3	.1	76a	144	T_mp1	-6.0
2001-06-01T07:46:00Z	2001-06-01T11:46:00Z	N1	4.0				
2001-06-01T11:46:00Z	2001-06-01T15:46:00Z	B1	4.0				
2001-06-01T15:46:00Z	2001-06-01T19:46:00Z	N1	4.0				
2001-06-03T23:00:01Z	2001-06-03T23:06:01Z	B3	.1	77a	146	peri	-48.0
2001-06-03T23:06:01Z	2001-06-05T23:00:01Z	N1	47.9				

7 Appendix B. Bryant plot

The next page shows a high resolution version of the Bryant plot discussed in Section 5.1.



CLUSTER Master Science Plan, 1st dayside half year
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Feb 2001
Mar 2001
Apr 2001
May 2001
Jun 2001
LT(apo):
16
15
14
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05
Perigee
inbound leg
Apogee
outbound leg
Perigee
orbit:
85
90
95
100
105
110
115
120
125
130
135
140
145
150
s: special orbit
bow shock
magnetopause
neutral sheet
nominal mode
burst mode
bm3 dumps
rad belt bdy
eclipse bdy
MSP V5.3, reference spacecraft = 3
Bryant plot software V4.1, Fri Jan 12 14:52:11 2001