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Cluster Joint Science Operations Centre

Notes on Cluster Master Science Plan,

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1 Document Change Record

Version	Date	Notes/remarks
Issue 1.0	11 Aug 1998	First issue
Issue 1.1	13 Aug 1998	MSP statistics added

2 Introduction

This is the first version of the Master Science Plan (MSP) to be produced for Cluster-II. It is based on MSP version 3.2, dated 25 April 1996, which was the last version produced prior to the launch of Cluster-I. The new MSP has been adapted to fit the constraints of the predicted Cluster-II orbit but should deliver identical amounts of normal and burst mode data. Like version 3.2, the new MSP covers a period of six months centred on the first cusp encounter.

3 The Cluster-II orbit

The new MSP has been fitted to the predicted orbit of Cluster supplied to JSOC by ESOC as a standard Cluster LTOF long-term orbit file (Email from J. Fischer to M. Hapgood, 22 July 1998). This LTOF was generated from the following input data:

INITIAL STATE EPOCH (UT)		2000/06/23 03:21:40.300	
J2000 SYSTEM			
STATE VECTOR	X	(KM)	= -6503.678672
	Y	(KM)	= 7262.891655
	Z	(KM)	= 34552.242660
	XDOT	(KM/SEC)	= 1.970904
	YDOT	(KM/SEC)	= -2.200979
	ZDOT	(KM/SEC)	= 2.860140
ELEMENTS	SEMI MAJOR AXIS	(KM)	= 75262.099000
	ECCENTRICITY		= 0.661017
	INCLINATION	(DEG)	= 90.000000
	ASC. NODE	(DEG)	= 131.843391
	ARG. OF PERIGEE	(DEG)	= 0.078020
	TRUE ANOMALY	(DEG)	= 74.165088
	HEIGHT OF PERIGEE	(KM)	= 19134.439944
	HEIGHT OF APOGEE	(KM)	= 118633.486056

This LTOF is stored at JSOC as LTOF_980722OAS1__________0001.CR. It contains only predicted orbit information, starts with a revolution number of zero and covers the period of one year. This LTOF has been processed through the JSOC planning sub-system to populate the predicted position and event databases - and thus to generate the various JSOC planning products used in the analysis and generation of the MSP. The magnetopause and bow-shock were predicted using a solar wind ram pressure of 2.7 nanopascals. This figure is similar to that used for MSP 3.2. For this first Cluster-II MSP it was decided to make no change in ram pressure so that all changes can be clearly attributed to changes in the launch scenario. However, the ram pressure should be reviewed, to take account of solar cycle changes, before the MSP for Cluster-II is agreed by SWT.

The new LTOF predicts that the apogee of the Cluster orbit will reach various key local times as follows:

Local time of apogee	Date reached	Orbit number	Region
18:00	5 Nov 2000	57	Dusk flank
12:00	1 Feb 2001	94	Cusp
06:00	3 May 2001	132	Dawn flank

This indicates that Cluster will encounter each of the various scientific regions at a season three months later than expected for MSP version 3.2.

4 Changes to the MSP

Version 3.2 of the MSP covered a total of 77 orbits with absolute orbit numbers from 34 to 110. These absolute numbers have changed dramatically in MSP 4.0. Thus to aid comparison between the two versions we will also use relative orbit numbers, which run from 1 to 77. Except where indicated below, the two versions have identical data acquisition patterns on the same relative orbits.

In making changes, we have attempted to respect the rules developed for the Cluster-I MSP - in particular, that for any NBN data acquisition pattern there must be no more than 36 "hour-units" of data taken in any sliding 57-hour window (see CL-MPE-TN-0009, Issue 3.2, section 2.1, rule 3). The Cluster-II data flow modelling should confirm whether those rules remain valid.

The following orbit changes apply to MSP version 4.0:

1. Orbit shift. Version 3.2 of the MSP was prepared using predicted orbit data based on a launch on 7 May 1996. These data predicted that the apogee of the Cluster orbit would reach noon local time on orbit 71. This must be shifted to orbit 94 as shown in the table above. Thus the absolute orbit numbers in the new MSP have been incremented by 23 compared with version 3.2 - and now run from 57 to 133.
2. Orbits skimming the bow shock. Cluster first encounters the bow shock in a skimming orbit near the dusk flank - and has a similar last encounter near the dawn flank. In MSP 4.0, Cluster will reach these flanks at different seasons compared with MSP 3.2. This has two effects:

a) The first and last bow shock encounters will be on different relative orbits. The first encounter is delayed two orbits to relative orbit 7 and the last encounter is advanced two orbits to relative orbit 71.
b) The orbit phase of the bow shock encounter (i.e. the time from perigee to the bow shock crossing) is changed. The first encounter will now occur after apogee and the last encounter before apogee. The opposite configuration was predicted for MSP version 3.2. This is a simple consequence of the change in launch scenario. The bow shock encounter is after apogee if it occurs during (Northern Hemisphere) winter and before apogee if it occurs during summer.

To correct for these two effects various changes have been made to data acquisition patterns in the new MSP. You may find it helpful to view the MSP Bryant plots when trying to understand these changes. See the section below on Bryant plots for information on how to access these plots via the World-Wide Web. The acquisition changes are as follows:

a) The data acquisition patterns on relative orbits 5 and 6, which both include NBN patterns targeted at the bow shock, have been swapped with those on relative orbits 7 and 8.
b) The orbit phases of the NBN patterns on new relative orbits 7 and 8 have been adjusted to maintain bow shock targeting as in MSP 3.2.
c) The start of the N pattern on relative orbit 9 has been delayed by 15 hours to ensure downlink of data from the NBN pattern on the previous orbit.
d) To compensate for this loss of 15 hours normal mode data, we have added 15 hours to end of the N pattern starting at perigee on relative orbit 4.
e) The NBN data acquisition pattern on relative orbit 73, which is targeted at the bow shock, has been moved to relative orbit 71 and adjusted to maintain bow shock targeting as in MSP 3.2.
f) The end of the 132.5 hour N pattern starting late on relative orbit 68 has been brought forward by 39.5 hours to ensure downlink of its data before the NBN pattern on new relative orbit 71.
g) The NBN data acquisition patterns on relative orbit 72, which is targeted at the outbound magnetopause crossing, has been moved to relative orbit 73 to avoid conflict with downlink of data from the NBN pattern on new relative orbit 71.
h) The short N data acquisition pattern at the start of relative orbit 73, which is targeted at the perigee, has been moved to relative orbit 72.
i) To compensate for the loss above of 39.5 hours normal mode data, we have merged the two N patterns on relative orbits 74-75 (of 4 and 53 hours duration) to form a single N pattern starting at perigee on relative orbit 74 and lasting 96.5 hours.

5 BM3 periods

Short (6-minute) periods of BM3 are required from time-to-time in order to dump the instruments' internal burst memory. These periods were not represented in MSP 3.2 but were left for addition by JSOC at a later time. This approach was adopted because of a special constraint of Cluster-I - namely the requirement to downlink data from the solid state recorder as full dumps. Thus, to avoid conflict between BM3 dumps and SSR downlink (which cannot take place while also collecting instrument data in any burst mode), it was decided to schedule BM3 outside visibility from the ESA ground-stations. Since the MSP cannot take explicit account of spacecraft visibility, the BM3 dumps were removed from the MSP. JSOC was to schedule the BM3, following rules agreed by SWT, once the spacecraft visibility was known.

Since Cluster-II will support partial SSR dumps, it is no longer necessary to schedule BM3 outside visibility from the ESA ground-stations - and thus it can be included in the MSP. This has the important advantage that the impact of BM3 dumps (generating 0.6 hour-units of data per dump) can be properly included in the modelling of the Cluster data flow.

For MSP 4.0, we have simply assigned a 6-minute BM3 dump at the beginning of each data acquisition. This seems a reasonable approach since one of the major sources of BM3 data will be the low-resolution magnetic field data obtained by the FGM-OPM9 mode between data acquisition periods. There is also an EFW mode that stores electric field data in internal memory between data acquisition periods. These data should be dumped early in each data acquisition period. There is probably a requirement to add further BM3 dumps, e.g. during long (>1 orbit) N patterns - in order to collect the high time resolution data from special events identified by the instruments and held in internal burst memories. It is planned to include a representative set of these periods in future versions of the MSP. However, they cannot be included at present because the JSOC MSP database (which provides a front-end to the MSP software developed by Norbert Sckopke) requires further development to process those cases.

We also note here that the policy on scheduling of BM3 dumps should be reviewed by SWT to take account of (a) the new Cluster-II constraints and (b) the results from the new Cluster-II data modelling (hopefully including BM3 dumps).

6 Special orbits

These have not yet been assigned in MSP 4.0. Further work is required to represent these in the JSOC MSP database. This will have no impact on the data flow modelling to be undertaken by ESOC.

7 Other minor changes

In cases where the spacecraft orbit is skimming the bow shock or the magnetopause and there is a data acquisition targeted on that boundary, JSOC will schedule the data acquisition by an appropriate time offset from apogee. Recent tests have shown that direct targeting on the predicted boundary crossing is unreliable in the case of skimming orbits - because the predicted crossing time is then very sensitive to small changes in the orbit elements. This sensitivity is not physically meaningful - in reality we would anticipate observation of multiple boundary crossings as a consequence of boundary motions. However, current boundary models cannot describe, let alone predict, this reality. To ensure stable science operations on skimming orbits, we plan to: (i) calculate the time offset from apogee that best describes the average bow shock crossing time, and (ii) use this offset time as the target. This has been done for the NBN data acquisition patterns on new relative orbits 7, 8 and 71.

Finally, please note that, in the pathological situation that the spacecraft orbit only just skims the boundary, a small change in the orbit elements could bring the orbit fully inside the boundary. This would result in the deletion of the boundary crossing from the JSOC planning database. This would, in turn, cause significant operational problems if that crossing were used as a explicit data acquisition target.

8 Bryant plots

The Bryant plots for MSP versions 3.2 and 4.0 are attached to this note. They are also available from the JSOC web server - in both GIF and Postscript formats. Please see the following URLs:

http://jsoc1.bnsc.rl.ac.uk/DOC/msp/bryant_msp_v32.gif
http://jsoc1.bnsc.rl.ac.uk/DOC/msp/bryant_msp_v32.ps
http://jsoc1.bnsc.rl.ac.uk/DOC/msp/bryant_msp_v40.ps
http://jsoc1.bnsc.rl.ac.uk/DOC/msp/bryant_msp_v40.gif

The web server also contains a copy of this note in PDF format on URL:
http://jsoc1.bnsc.rl.ac.uk/DOC/msp/msp4v0.pdf

9 MSP statistics

MSP 4.0 contains data acquisitions covering 77 Cluster orbits (57 to 133) with apogee on the dayside. The region occupancy of Cluster for these orbits is:

Region	Total time in region (hours)
Solar Wind	1741.6
Magnetosheath	1265.4
Magnetosphere	1382.0
Grand total	4389.0

The telemetry durations by region, in hours, are shown in the table below. Note that the region in which BM3 is recorded has little scientific significance. Thus we focus on the NM1 and BM1 modes.

Region	NM1	BM1	NM1+BM1	BM3	Grand total
Solar Wind	663.0	38.0	701.0 (40%)	0.7	701.7
Magnetosheath	626.3	51.2	677.5 (54%)	1.8	679.3
Magnetosphere	652.6	39.8	692.4 (50%)	5.5	697.9
Grand total	1941.9	129.0	2070.9 (47%)	8.0	2078.9