3. Projects under Development

3.1 Cluster II

Introduction

On 3 April 1997, the ESA Science Programme Committee agreed to the reflight of the full Cluster mission. Since then, the instrument teams and industry have been working hard to meet the Cluster II launch date of mid-2000. The four spacecraft will be launched in pairs by two Russian Soyuz rockets about a month apart. The spacecraft will be injected into polar orbits and a series of manoeuvres, lasting about a week for each spacecraft, will deliver them into their polar orbits with perigees of 4 R_E and apogees of 19.6 R_E. After the final orbit is reached, the commissioning phase, consisting of boom deployments and instrument checking, will be conducted over approximately 3 months. After this extensive checkout period, the mission phase itself will begin, lasting a nominal 2 years.

Each Cluster II spacecraft is cylindrical with a diameter of 2.9 m and a height of 1.3 m, and will be spin-stabilised at 15 rpm. The total mass of each is 1200 kg: 72 kg for the 11 experiments, 478 kg for the spacecraft dry mass and 650 kg for the propellant. The latter is necessary for the extensive series of manoeuvres required to reach the operational orbit and, during the course of the mission, to change the relative spacing of the spacecraft. The power allocated to the instruments is 47 W out of a total of 224 W available from the solar arrays.

The in-orbit spacecraft configuration is characterised by four 50 m experiment wire booms, two 5 m radial magnetometer booms and two axial telecommunication antenna booms.

The orbital parameters of the four spacecraft will be slightly different in order to obtain a tetrahedral configuration in the regions of scientific interest. The size of this tetrahedron will be varied from 200 km up to 18 000 km during the course of the mission. As the Cluster II orbit is fixed in the inertial system, the rotation of the Earth around the Sun will cause the spacecraft to cross the various near-Earth plasma regions, such as the Earth magnetotail soon after launch and the polar cusp and solar

Table 3.1.1. The Cluster II payload.

Acronym/Instrument	*Principal Investigator*
FGM/Fluxgate Magnetometer	A. Balogh (IC, UK)
STAFF*/Spatio-Temporal Analysis of Field Fluctuation experiment	N. Cornilleau-Wehrlin (CETP, France)
EFW*/Electric Field and Wave experiment	G. Gustafsson (IRFU, Sweden)
WHISPER*/Waves of High Frequency and Sounder for Probing of Electron density by Relaxation	P. M. E. Décréau (LPCE, France)
WBD*/Wide Band Data	D.A. Gurnett (Iowa U., USA)
DWP*/Digital Wave Processing experiment	H. Alleyne (Sheffield U., UK)
EDI/Electron Drift Instrument	G. Paschmann (MPE, Germany)
CIS/Cluster II Ion Spectrometry	H. Rème (CESR, France)
PEACE/Plasma Electron and Current Experiment	A. Fazakerley (MSSL, UK)
RAPID/Research with Adaptive Imaging Particle Detectors	B. Wilken (MPAe, Germany)
ASPOC/Active Spacecraft Potential Control	W. Riedler (IWF, Austria)

* Members of the Wave Experiment Consortium (WEC)

For further information on Cluster II, see http://www.estec.esa.nl/spdwww/cluster/html2

Table 3.1.2. Recipients of Cluster II CD-ROMs.

Country	*PIs and/or Co-Is*	*number CD-ROMs*	*Data Centre*
Austria	7	3	yes
Belgium	2	1	
China	4	2	yes
Denmark	3	3	
Finland	3	2	
France	39	8	yes
Germany	27	5	yes
Greece	2	2	
Hungary	2	1	yes
India	2	1	
Ireland	1	1	
Israel	1	1	
Italy	6	1	
Japan	3	2	
Netherlands/ESTEC	4	1	after June 2000
Norway	11	3	
Russia	4	2	
Sweden	14	4	yes
Switzerland	1	1	
United Kingdom	21	10	yes
United States	68	27	yes
Total	**225**	**81**	

wind 6 months later. All regions of interest should be crossed again during the second year, which will allow the configuration to be modified in light of the experience gained during the first year.

Cluster II will determine the physical processes involved in the interaction between the solar wind and the magnetosphere by visiting the key regions such as the polar cusps and the magnetotail. The four spacecraft will map in three dimensions the plasma structures contained in these regions. In addition, the simultaneous 4-point measurements will permit the derivation of the differential plasma quantities for the first time. For example, the current density near the four spacecraft can, under certain conditions, be derived from the magnetic field measurements using Ampère's law. The inter-spacecraft comparison requires identical experiments. This was controlled during extensive calibrations performed on-ground and will finally be verified in orbit in selected plasma regions.

Each of the four Cluster II payloads consists of a set of state of the art instruments to detect plasma fields and waves as well as particles. Table 3.1.1 lists the 11 instruments and the respective Principal Investigators (PIs). In addition, an ion emitter is carried to control the spacecraft's electrostatic charging.

Data dissemination

ESOC will distribute all mission data stored on CD-ROMs. The data are organised on a per-instrument and per-spacecraft basis, and all auxiliary data including housekeeping data of the spacecraft are also included. The CD-ROMs will be sent to the data centres and all scientific institutions involved in the mission (Table 3.1.2). On

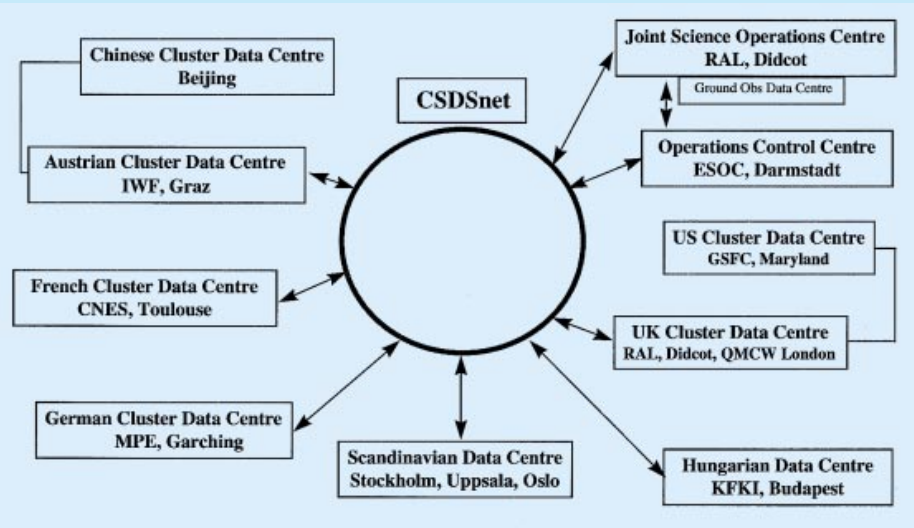

Figure 3.1.1. The architecture of the Cluster II Science Data System.

average, more than two CD-ROMs will be shipped per calendar day throughout the 2-year mission. The instrument teams and some of the data centres will have faster access to mission data by remotely retrieving data from the Data Disposition System located at the Operations Control Centre. This system offers the data shortly after reception by the ground stations but there are restrictions both to the daily data volume requested by a user and the total number of users on the system. This service is intended to provide the instrument teams with a facility to perform quick checks of their instrument's status.

Cluster II Science Data System

The Cluster Science Data System (CSDS) has been designed as a distributed system to make possible the joint scientific analysis of data from all 44 instruments (four sets of 11). The general approach is to have national data centres located near the PIs and thus near the expertise required for processing the data. One of the major tasks of CSDS is to offer, routinely, products such as the Summary Parameter Data Base and the Prime Parameter Data Base. CSDS also serves to some extent as the infrastructure for the Joint Science Operations Centre (JSOC), which is a staffed facility at the Rutherford Appleton Laboratory, Didcot (UK), to support the scientific payload operations. Mail and communications services built up for CSDS will be used by the instrument teams to send their commands to JSOC.

CSDS is a distributed system of eight nationally-funded and -operated data centres (Figure 3.1.1). In most cases, the data centres produce data products on behalf of the national PI teams. Members of the Cluster II science community wishing to access CSDS will do this via their national data centre. In those countries (Table 3.1.2) not served by a national data centre, members of the Cluster II community may contact the relevant PI to determine which data centre should be contacted. It should be noted that all data centres offer the same data products. Scientists from outside the Cluster II community will also have access to CSDS, according to the policy on data rights as agreed by the PIs. Full access can be granted to the Summary Parameters.

The scientists will interact with CSDS via the CSDS User Interface (CUI). The main purpose of the CUI is to provide the scientific community with uniform access to CSDS. For the individual data centres, it offers local file handling, distribution of

Table 3.1.3. Detailed content of the PPDB and SPDB. Bold letters represent vectorial quantities.

Instrument Acronym	*Parameter (unit)*	*Bytes*	*PPDB*	*SPDB*
ASPOC	Ion current (mA)	4	•	•
	ASPOC status word	4	•	•
	Epoch time (ms)	8	•	•
CIS	n(p), n(O^+), n(He^+), n(He^{++}), n(HIA) (cm^{-3})	20	•	•
	v(p), **v**(HIA) (km/s)	24	•	•
	v(O^+) (km/s)	12		•
	T(p), T(HIA) (eV)	8		•
	T∧ (s), $T_{\|\|}$ (s); s = p, HIA (eV)	16	•	
	CIS status word	4	•	•
	Epoch time (ms)	8	•	•
[n = number density; **v** = velocity vector; T = temperature, HIA = Hot Ion Analyser, measures most dominant ion species]				
EDI	**E**, Electric field (mV/m)	12	•	
	v(ed), Electron drift velocity (km/s)	12	•	•
	EDI status word	5	•	•
	Epoch time (ms)	8	•	•
FGM	**B**, DC magnetic field (nT)	12	•	•
	(dB2)/B2, normalised magnetic variance: total	4	•	•
	(d|B|2)/B2, normalised magnetic variance: magnitude	4	•	•
	FGM status word	4	•	•
	Epoch time (ms)	8	•	•
PEACE	n(e) (cm^{-3}), **v**(e) (km/s)	16	•	•
	T∧(e), $T_{\|\|}$(e) (MK)	8	•	•
	$Q_{\|\|}$(e), Heat flux (mJ m^{-2} s^{-1})	4	•	•
	PEACE status word	4	•	•
	Epoch time (ms)	8	•	•
[Electron density, velocity, temperature, heat flux]				
RAPID	J_{low}(s), J_{hi}(s); s = e, p, He, mass>4 (cm^{-2} s^{-1} sr^{-1})	32	•	•
	$A_{\|\|}$(e), $A_{\|\|}$(p)	8	•	•
	RAPID status word	4	•	•
	Epoch time (ms)	8	•	•
[J = particle flux, 2 energy ranges, 4 species, A = field-aligned flux anisotropy, 2 species]				
DWP	Particle Correlator Significance level (%)	4	•	•
	Particle Correlator Frequency Band (kHz)	4	•	
	Particle Correlator Energy Band (eV)	4	•	
	DWP status word	6	•	•
	WEC status word	5	•	•
	WBD status word	4	•	•
	Epoch time (ms)	2	•	•
EFW	E_{dusk} (mV/m), s_E (mV/m), V_{PS} (V), I_{probe} (mA)	16	•	•
	E power; 0.3-10, 10-180 Hz (V^2 m^{-2} Hz^{-1})	8	•	•
	EFW status word	5	•	•
	WEC status word	5	•	•
	Epoch time (ms)	8	•	•
[Dawn-dusk electric field, variations in electric field, probe-s/c voltage, and probe current]				

(continued on next page)

Table 3.1.3 (continued). This table was extracted from the *Users Guide to the Cluster Science Data System*, prepared by P.W. Daly, 1996.

Instrument Acronym	*Parameter (unit)*	*Bytes*	*PPDB*	*SPDB*
STAFF	$B_{\|\|}$, $B_{\wedge}$, 0.3-10,10-180,180-4000 Hz ($nT^2\ Hz^{-1}$)	24	•	
	B power; 0.3-10,10-180,180-4000 Hz ($nT^2\ Hz^{-1}$)	12		•
	E power; 10-180, 180-4000 Hz ($V^2\ m^{-1}\ Hz^{-1}$)	8	•	•
	STAFF status word	4	•	•
	WEC status word	5	•	•
	Epoch time (ms)	8	•	•
WHISPER	n(e) (cm^{-3}), Quality of resonance recognition	6	•	•
	E power, 4-10, 10-20, 20-80 kHz ($V^2\ m^{-2}\ Hz^{-1}$)	12	•	
	E power, 4-80 kHz ($V^2\ m^{-2}\ Hz^{-1}$)	4		•
	E variance, 2-80 kHz	4	•	
	WHISPER status word	4	•	•
	WEC status word	5	•	•
	Epoch time (ms)	8	•	•
Auxiliary Parameters	$\mathbf{R}_1$, position of s/c 1 (km)	12		•
	$\Delta\mathbf{R}_n$ = 2, 3, 4, position rel. to s/c 1 (km)	36		•
	$\mathbf{V}_1$, velocity vector of s/c 1 (km/s)	12		•
	Q_G, Q_R, min|$\Delta\mathbf{R}$ij|(km), max|$\Delta\mathbf{R}$ij| (km) [Tetrahedron quality parameters]	16		•
	Q_{SCn}, Φ_{SCn}, n = 1-4, spin axes in GSE (deg.)	32		•
	GSEfi GSM conversion angle (deg.)	4		•
	Dipole tilt angle (deg.)	4		•
	Spacecraft Status word	5		•
	Epoch time (ms)	8		•
Total number of data bytes:			**414**	**503**

validated data files to other data centres, data ordering, user administration, catalogue browsing and data manipulation functions. It allows the registered users to browse the CSDS catalogues, fetch prime and/or summary data, manipulate and display prime and summary parameters, and retrieve summary plot files. The following products will be offered:

Prime Parameter Data Base (PPDB): The parameters contained in this data base are listed in Table 3.1.3. The data files are written in the Common Data Format (CDF) and are held in physical units with an exhaustive set of ancillary information (or metadata). The PPDB will hold data from all four spacecraft with a time resolution of 4 s. The data set is accessible by all PIs and Co-Is.

Summary Parameter Data Base (SPDB): The parameters contained in this data base are listed in Table 3.1.3. These files are also written in the CDF and are held in physical units with an exhaustive set of ancillary information. The SPDB will only hold data from one of the four spacecraft with a time resolution of about 60 s. The access to this data set is not restricted.

Summary Plots: These are plots of summary parameters with 1 min resolution, which will be used by the scientists to search for interesting events. It has been agreed that the German Data Centre will produce these plots as Postscript files centrally and distribute them inside Germany and to the other data centres. The plot information is encoded in a compact form for sending it over the network. The access to the files will be either through the Cluster II User Interface or via 'anonymous FTP'. The Internet addresses of the FTP servers will be defined at a later stage.