Current and Future ESA Missions with relevance for Space Weather

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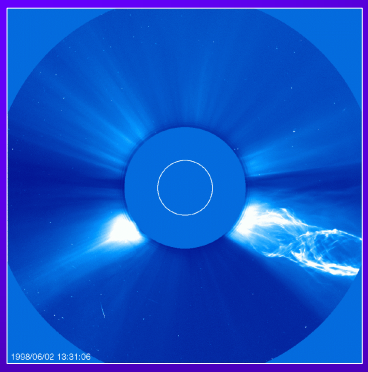
What makes a mission a good Space Weather monitor?

- Real time data
- Data rate equivalent to that needed to detect changes in the system being monitored – science missions may exceed this.
- Little/no processing time
- Data (or subset of the data) is immediately available to the public.

Measuring Changes to:

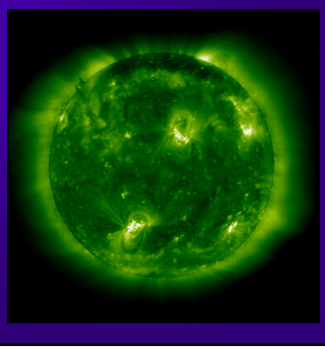
- Magnetospheric
- Interplanetary
- Solar (incl. Galactic cosmic rays & debris)



SOHO

Solar and Heliospheric Observatory

- Combined ESA/NASA mission
- Launched in 1995 into halo orbit around Sun-Earth L1 Lagrangian point.
- Near real time data downlink to DSN
- Instrumentation geared to study of the:
  1. Solar Interior
  2. Solar Wind
  3. Solar Atmosphere



LASCO coronagraph detects coronal mass ejections. Available at a rate of 20-30 minutes (2-6R_0) to 1hour(3.6-30R_0).

EUV Imaging Telescope (EIT) images the corona between 80,000K and$2x10^6$K indicating solar flare location. Images taken every 12 minutes.

Also solar wind speed and composition data from CELIAS, COSTEP & ERNE

Cluster & Double Star

4 spacecraft flying in tetrahedral formation through the Earth's magnetosphere.
Measures small scale changes in near-Earth space and interaction between charged particles in the solar wind and the Earth's atmosphere.

Each carries identical set of 11 instruments to investigate charged particles, electric and magnetic fields.

Elliptical Polar orbit: 19000 – 119000km, 57 hour period.

Aim is to understand the physical processes underlying space weather, *not* to be a space weather monitoring system. Data not available in real time.

China plans to launch a pair of spacecraft based on the Cluster design & named Double Star. ESA acting as payload coordinator.

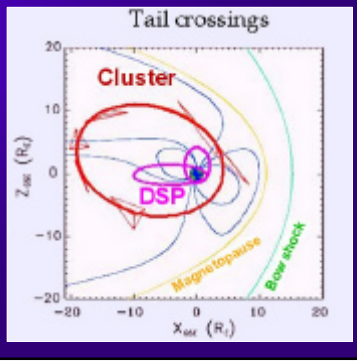
Double Star

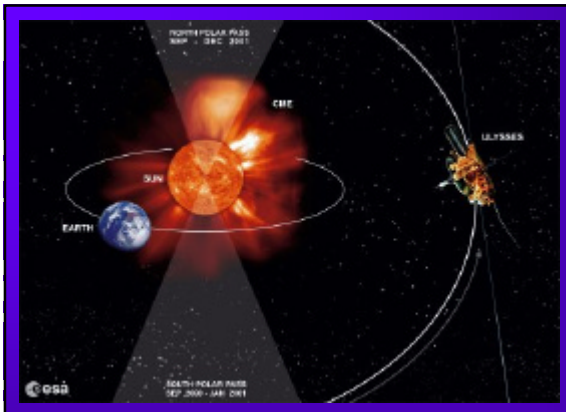
- ESA/CNSA (Chinese National Space Administration) Collaboration
- Includes 10 instruments identical to those flown on Cluster
- Additional 8 provided by Chinese institutes
- Launch predicted June 2003 & December 2003

DSP-E: Equatorial orbit 550x60000km inclined at 28.5 deg, will observe **magnetotail** regions

DSP-P: Polar Orbit 350x25000km over polar regions, will observe development of **aurorae.**

Single telemetry mode to be used - as opposed to the 'normal' & 'burst' modes used by Cluster - allowing data downlink over most of the orbit.





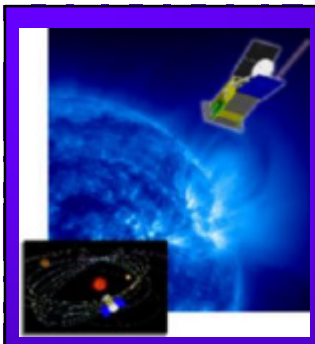
Ulysses

- Explore and define the heliosphere in 3-D
- Measure solar wind speed & composition from pole to pole
- Sun centred elliptical orbit with period of 6.2 years

Measurements:
Solar wind speed, magnetic fields, electrons, protons, ions, incl. GCRs

Figure shows location of Ulysses during an encounter with a coronal mass ejection in May 2001. Type II Radio bursts, particle density enhancement and strong magnetic field increase observed (34nT).

CME observations with Ulysses give an interesting new perspective on the nature and extent of the CME but not practical for space weather monitoring as data is collected and analysed for a period prior to general release.



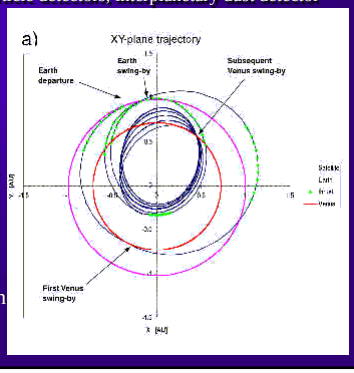
Solar Orbiter

Objectives….

- Explore innermost regions of the solar system
- Study the sun from 45 solar radii (0.21AU) distance
- Study the solar surface from a co-rotating vantage point
- Image the polar heliographic latitudes from up to 38°

Instrumentation….

1. Solar remote-sensing: EUV full sun and high-res. imager, EUV spectrometer, visible light telescope & magnetograph, EUV & visible light coronagraph, radiometer.
2. Heliospheric: solar wind analyser, radio & plasma-wave analyser, magnetometer, energetic particle detectors, interplanetary dust detector solar neutron detector.



- Particle and field measurements will be made throughout each 150 day orbit.
- High-resolution remote sensing data will be acquired during three (possibly overlapping) 10-day periods corresponding to perihelion, maximum north and maximum south heliographic latitude.

For thermal reasons, data transmission using the high-gain antenna can only take place when the spacecraft-Sun distance is greater than 0.5 AU, meaning that "real-time" data will not be available for much of each orbit

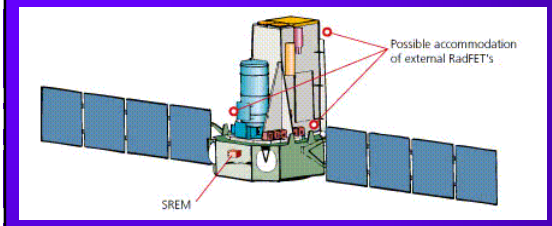
BepiColombo

- BepiColombo, the ESA Cornerstone mission to Mercury
- Proposed launch date: 2010
- Comprised of a magnetospheric orbiter, planetary orbiter and surface element

- which volatiles compose the exosphere of Mercury?
- how does the planetary magnetic field interact with the solar wind in the absence of any ionosphere?

•Magnetospheric orbiter

Acronym	Instrument	Objectives
MAG	Dual 3-axis fluxgate magnetometer	Magnetic field mapping
IMS	Ion mass spectrometer	Ambient plasma composition and energy distribution
EEA	Electron electrostatic analyser	3D electron energy distribution
RPW	Radio and plasma wave investigation	Survey of magnetospheric waves, detection of radio emission sources, solar activity monitoring
CPA	Cold plasma analyser	Low energy plasma distribution in magnetosphere
EPD	Energetic plasma detector	Energetic magnetospheric electrons and ions
SCAM	Camera	Preliminary mapping of the surface



Integral

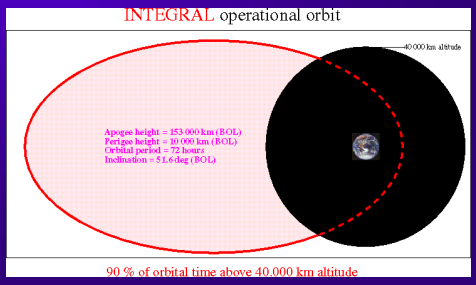
International Gamma Ray Astrophysics Laboratory

Scheduled for launch in 2002 into a geosynchronous highly eccentric orbit with high perigee.

Assessment of the local radiation environment will be carried out using SREM: Standard Radiation Environment Monitor

Initial orbital parameters are: 72-hour orbit with an inclination of 51.6 degrees, perigee of 10 000km and apogee of 153 000 km.

Spacecraft is capable of real-time data relay. SREM monitor allows real-time assessment of the radiation environment local to the spacecraft. In case of low background environment, scientific observations below 40.000 km altitude should be possible.



Proba

Project for Onboard Autonomy

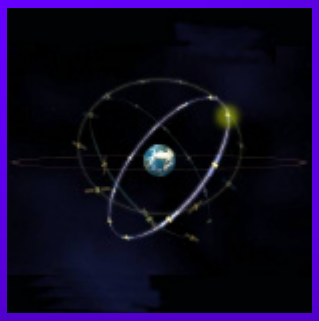
- ESA's first microsatellite (100kg) launched into an 800km orbit. Currently in commissioning phase.
- Able to operate in space virtually unaided: navigation, payload and resource management autonomous
- Carries 6 instruments, 3 of which monitor the space environment:
  1. DEBIE: Debris In-Orbit Evaluator
  2. SREM: Standard Radiation Environment Monitor
  3. MRM: Miniature Radiation Monitor

Information on sub-millimeter meteoroids & space debris can only be gained by analysis of retrieved spacecraft or by in-situ monitors.

Proba II may carry a space weather payload in the future.

Picture shows the DEBIE Digital Processing Unit (DPU) together with one sensor and the EGSE.Detection area is 10cm x 10cm per sensor.

DEBIE is designed as a *standard detector* which can be flown on different spacecraft and missions with little or no modifications.



Galileo(sat)

Global Navigation Satellite System

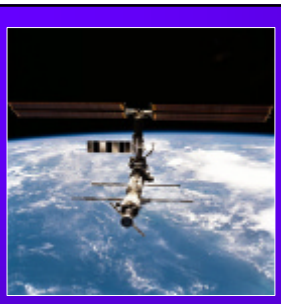
- System will Provide Global coverage
- Independent but complementary to GPS
- Performance similar to future GPS – dual frequency
- Core constellation 30 MEO satellites in 3 planes
- Enhanced SAR service

Possible synergy between Space Weather and Galileosat:

- Galileosat could employ its navigation payload to provide ionospheric data
- Could augment in-situ monitors by carrying additional space environment monitors
- Galileosat is a *user* affected by the local environment and propagation disturbances through ionospheric disruption.

ESA responsible for the first 4 satellites including the test-bed (GSTB) which will carry an SREM monitor.

Could extend this to a baseline of 1 environment monitor in each of the three planes

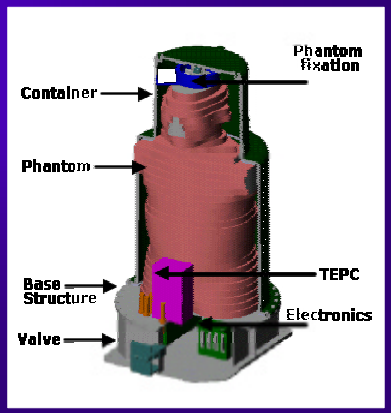


ISS

International Space Station

MATROSHKA: An ESA Facility for Radiation Measurements under EVA Conditions

Predicted launch 2003 – to be exposed for 1 year outside the Russian service module



- Allows studies of the depth dose distribution of the orbital radiation field at different sides of the organs of Spacecrew exposed during EVA.

- Consists of human 'phantom' in a sealed container.
- Made up of 32 slices containing natural bone and tissue equivalent plastics of densities corresponding to lungs, kidneys, brain, stomach, intestine.
- Monitor dose rate, particle flux and spectra & linear Energy spectra.

Earth Observation

- Earth watch missions are research oriented
- Long term sustainability is compulsory
- Two Space Weather related missions previously proposed as Earth Explorers:
  - Core Magnetometry explorer. Not selected
  - Opportunity Atmospheric Climate Explorer (ACE). Ranked 3rd in 1999 selection. Not selected for phases B, C, D but ESA authorised to continue funding in case Cryosat or Smos was cancelled. Will now go back to peer review
- ACE comprised 6 satellites in 2 planes separated by 90° longitude. 800km altitude & 75° inclination
- Proposed payload incorporated GRAS (GNSS receiver for atmospheric sounding)
- GRAS receiver will be carried by two ongoing EO programmes:
  USA NPOESS: Dedicated to Ionospheric Sounding
  Europe MetOp: Dedicated to Atmospheric Sounding
- Each will produce 100 soundings of the atmosphere/ionosphere per day

- Proposals for space weather missions possible as Earth Watch. However most Earth Watch proposals under consideration have already received strong monetary support from external sources before being proposed to ESA.

Summary: Future Missions

- Science missions: Several missions operating and planned to study the science behind Space Weather
  - SOHO, Cluster, Ulysses
  - Solar Orbiter, Bepi Columbo, Double Star (with China) (Solar-B, STEREO)
- Also hitch-hiker options: SREM and DEBIE, also GORID & MRM
  - Proba
  - Integral, Proba II, Galileosat, ISS. Ideally on all future ESA spacecraft…

Possible application of the Earth Explorer programme to Space Weather

Programme set up to advance the understanding of Space Weather physics.
No dedicated space weather monitoring missions planned by ESA currently but opportunities exist in hitch-hikers and Earth explorers.