RAL

DESIGN & DISCOVERY

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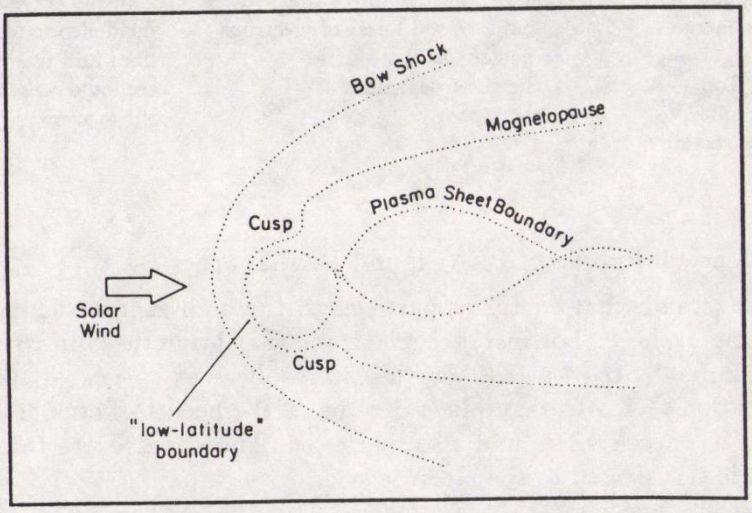
RUTHERFORD APPLETON LABORATORY

SCIENCE AND ENGINEERING RESEARCH COUNCIL

CLUSTER

The Cluster mission is one of the "cornerstones" of the European Space Agency Space Science programme. Five UK University groups, together with scientists from RAL, are involved in the mission. Four spacecraft will be launched in 1995 to fly in various formations and separations to study phenomena in ionized gases ("plasmas"). Earth-based attempts to confine and control plasmas have revealed just how prone it is to unstable, apparently disordered, behaviour. Spacecraft measurements, close to, and within the Earth's magnetosphere have also revealed such chaotic behaviour in natural plasmas, especially where there are sharp gradients in plasma characteristics. The Cluster mission is an ambitious attempt to understand the nature and causes of this chaotic behaviour. The major advance that Cluster will make is to enable us, for the first time, to construct a truly three-dimensional view of the disturbed plasma. These measurements will be made using a "cluster" of 4 spacecraft flying through plasmas of interplanetary space and of the Earth's magnetosphere.



Sketch showing the approximate locations near the Earth (smallest circle in the centre) where there are sharp gradients in the plasma characteristics, such as density and average energy. The Cluster spacecraft will measure these gradients in three dimensions, thereby enabling a comprehensive understanding of the phenomenon that determines (a) the location and form of the gradients; and (b) the response of the plasmas to disturbances, such as those caused by changes in solar wind conditions.

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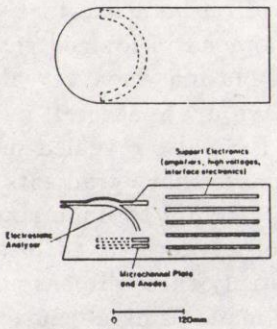
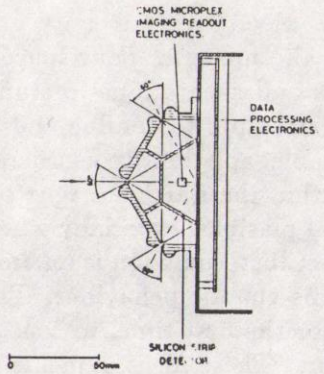
PEACE and RAPID

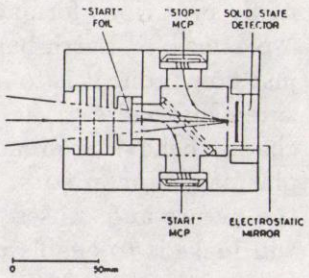
In addition to measurements of electric and magnetic fields, the four Cluster spacecraft will each use 3 sensors to measure ions within the energy range 10 eV - 1000 kev, and 3 to measure electrons within the range 0.7 eV - 400 keV. The Space Plasmas Group at RAL will help to construct 4 of the 6 sensors needed for each spacecraft. Two electron sensors will be constructed for the Particle Energy Angle and Current Experiment (PEACE), and one ion and one electron for the investigation named Research with Adaptive Particle Imaging Detectors (RAPID). The PEACE team is led by Dr A Johnstone of University College, London; the RAPID team by Dr B Wilken of the Max Planck Institute for Aeronomy in Germany. RAL will be responsible for microchannel plates, charge amplifiers, high voltage generators and the electronics that interconnect the various sensor sub-assemblies.



A sensor of the PEACE investigation. The sensor will measure electrons with energies within the energy range 0.7 - 25 keV. (Top - view from the side; Bottom - cross section from above)



The electron sensor of the RAPID investigation, showing trajectories (dashed and arrowed lines) of electrons incident at the centres the three segments of the sensor.



The ion sensor of the RAPID investigation, showing trajectoryof an incident ion (straight, arrowed, line) and trajectories of secondary electrons within the sensor.

Major science objectives of PEACE and RAPID are :-

1. to understand what energizes particles to the high energies found within the Earth's magnetosphere. For instance, electrons that leave the Sun with a speed of about 1000 km s^{-1} arrive at the Earth's atmosphere at speeds of 10000 km s^{-1}. This acceleration seems to take place in stages. We need to know how and where the electrons are accelerated, and also we need to know the source that is depleted when power is transferred to the electrons.

2. to understand how the plasma of the solar wind merges with that of the magnetosphere. It has become clear from earlier missions that the magnetosphere does not have an impervious barrier. Even though there is a gross mismatch between the density of the solar electrons that arrive at the edges of the Earth's magnetosphere and those within the magnetosphere, a combination of plasma processes such as diffusion and energization enables the plasmas to cope with this inherent mismatch and co-exist in a quasi-stable form. Even minor fluctuations in the solar wind can easily perturb the plasmas from this quasi-stability.

Gradients in the plasmas play a vital role in controlling the various energization and diffusion processes. Cluster will be the first mission in which these gradients can be measured unambiguously.