THE CLUSTER AND PHOENIX MISSIONS

edited by

C.P. ESCOUBET

Solar System Division, Space Science Department, ESA/ESTEC, Noordwijk, the Netherlands

C.T. RUSSELL

Institute of Geophysics and Planetary Physics, University of Los Angeles, USA

and

R. SCHMIDT

Solar System Division, Space Science Department, ESA/ESTEC, Noordwijk, the Netherlands

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FOREWORD

Since the earliest reports around 2500 B.C. by the Chinese, the auroras borealis have always been of great interest to mankind. Their usual manifestation is close to the geographic pole. Very active auroras, however, are sometimes visible even close to the equator. This unpredictable behaviour has attracted the interest of some of the greatest scientists in the world. Early theories explained the auroras as an evaporation of air which then became incandescent at high altitude or, alternatively, as air clouds illuminated by sunlight.

It was not until the eighteenth century that magnetic disturbances were found to be associated with auroras. This discovery marked an important step in the physics of auroras. Magnetic disturbances remain one of the main tools to characterize auroral activity today. The second major step forward in understanding auroras concerned the effect of solar activity. In the nineteenth century it was realized that there was a clear correlation between the number of sunspots and the intensity and number of geomagnetic disturbances.

Then in the twentieth century with the International Geophysical Year, the first spacecraft, carrying scientific experiments to measure electric and magnetic fields, were launched into space. These *in-situ* measurements gave an unprecedentedly detailed view of the plasma surrounding the Earth, namely the magnetosphere. All the various plasma regions, from the solar wind (the extension of the solar corona), down to the plasmasphere much closer to the Earth, were identified. The direct influence of the solar wind was also observed, with multi-point measurements made simultaneously in the solar wind and in the Earth's ionosphere. Although the global view of the magnetosphere is now quite well known, many questions remain concerning the microphysics that governs the transfer of energy from the solar wind to the Earth's magnetosphere and from the magnetosphere to the ionosphere. One major unknown in this Sun-Earth system concerns the size and shape of the small-scale plasma structures and their role in the transfer of energy. ESA's Cluster, with four spacecraft travelling together through the magnetosphere, will be the first mission to study these plasma structures in three dimensions.

Cluster is one of the two missions – the other being the Solar and Heliospheric Observatory (SOHO) – constituting the Solar Terrestrial Science Programme (STSP), the first 'Cornerstone' of ESA's Horizon 2000 Programme. The Cluster mission was first proposed in November 1982 in response to an ESA Call for Proposals for the new scientific mission. The original idea of four spacecraft in a tetrahedral configuration came from a French study (ESSAIM), the prime objective of which was to visit the magnetotail in the equatorial region. The tetrahedron idea was subsequently adopted in the proposal and a polar orbital plane was chosen in order to be able to visit both the polar cusp and the magnetotail region. Following

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an Assessment and a Phase-A Study, the Cluster mission was presented to the scientific community at the end of 1985. In February 1986 the STSP programme, combining both Cluster and Soho, was selected by the ESA Science Programme Committee. Following a joint ESA/NASA Announcement of Opportunity issued in March 1987, the eleven instruments making up the scientific payload were selected in March 1988. The launch of the four Cluster spacecraft is currently scheduled for May 1996 on the first flight of Ariane-5.

This book describes the Cluster mission and its scientific objectives, the instrumentation, which is identical on the four spacecraft, the operations carried out by the two operations centres and the data dissemination to both the Cluster and the wider scientific community. The volume begins with an overview of the Cluster mission and its scientific objectives, followed by a description of the spacecraft design and the engineering challenges of building four identical spacecraft. Each of the eleven instruments is then described in detail by their respective Principal Investigators. Seven of the instruments will measure electric and magnetic fields from static fields to high frequency fields. A further three instruments will measure electron and ion distribution functions with high time resolution. Finally, one instrument will control the potential of the spacecraft by emitting a beam of indium ions. These instrument papers are followed by a description of the mission operations undertaken by the European Space Operations Centre and the scientific operations undertaken by the Joint Science Operations Centre (JSOC). One further contribution describes the raw data dissemination, first to the principal investigators via an on-line service and later to the Cluster community on CDroms. The Cluster community, which includes the Principal Investigators and Co-Investigators, and also the wider scientific community, will have access to processed physical parameters from all instruments. The processing of the parameters and their distribution is the task of the Cluster Science Data System (CSDS). Finally, a directory of the Cluster community members is included as an Annex. A description of the Cluster mission and the latest news can be found in a World Wide Web page at http:://www.estec.esa.nl/spdwww/cluster/html/.

All contributions in this volume have been refereed by two experts, one from within and the other from outside the Cluster community. We would like to thank all the referees for their fruitful comments which will make these articles easy to read and informative for both the Cluster community and the general scientific community. We gratefully acknowledge the help of Erica Rolfe in editing the manuscripts.

Many individuals have made the challenging Cluster programme a reality. They all should be specially acknowledged for their key role. First, R. M. Bonnet, ESA director of scientific programmes, who directed the Cluster programme through all phases of the development. J. Credland, ESA Cluster project manager, and his team conducted the production of the 4 Cluster spacecraft with unrelenting efforts. M. Warhaut, ESA Cluster ground segment manager, P. Ferri, ESA Cluster spacecraft operations manager, and their team made outstanding efforts to achieve

the preparation of the ground segment. T. Dimbylow, JSOC project manager, and M. Hapgood, JSOC project scientist, together with their team worked remarkably to prepare the coordination of the science operations. The eight CSDS data centre managers and the members of the CSDS steering committee and implementation working group achieved successfully the readiness of the Cluster data system. Finally, G. Paschmann, chairman of the science operation working group, together with N. Sckopke conducted excellently the preparation of the science operations.

During the process of editing this volume, we were deeply grieved to hear of the tragic death of Les Woolliscroft, the Principal Investigator of the Digital Wave Processing instrument. He was an enthusiastic scientist and a key figure in the preparation of the Cluster mission. He was actively participating in all Cluster working groups from the Cluster Science Data System Steering Committee to the Wave Experiment Consortium Operation Working Group, of which he was Chairman. We will always remember his fundamental role in the definition of the Cluster Science Data System and his active support of the Joint Science Operation Centre. Les Woolliscroft was Reader in Physics at the University of Sheffield. He was an excellent scientist and a good friend; he will be greatly missed.

C. P. ESCOUBET C. T. RUSSELL R. SCHMIDT