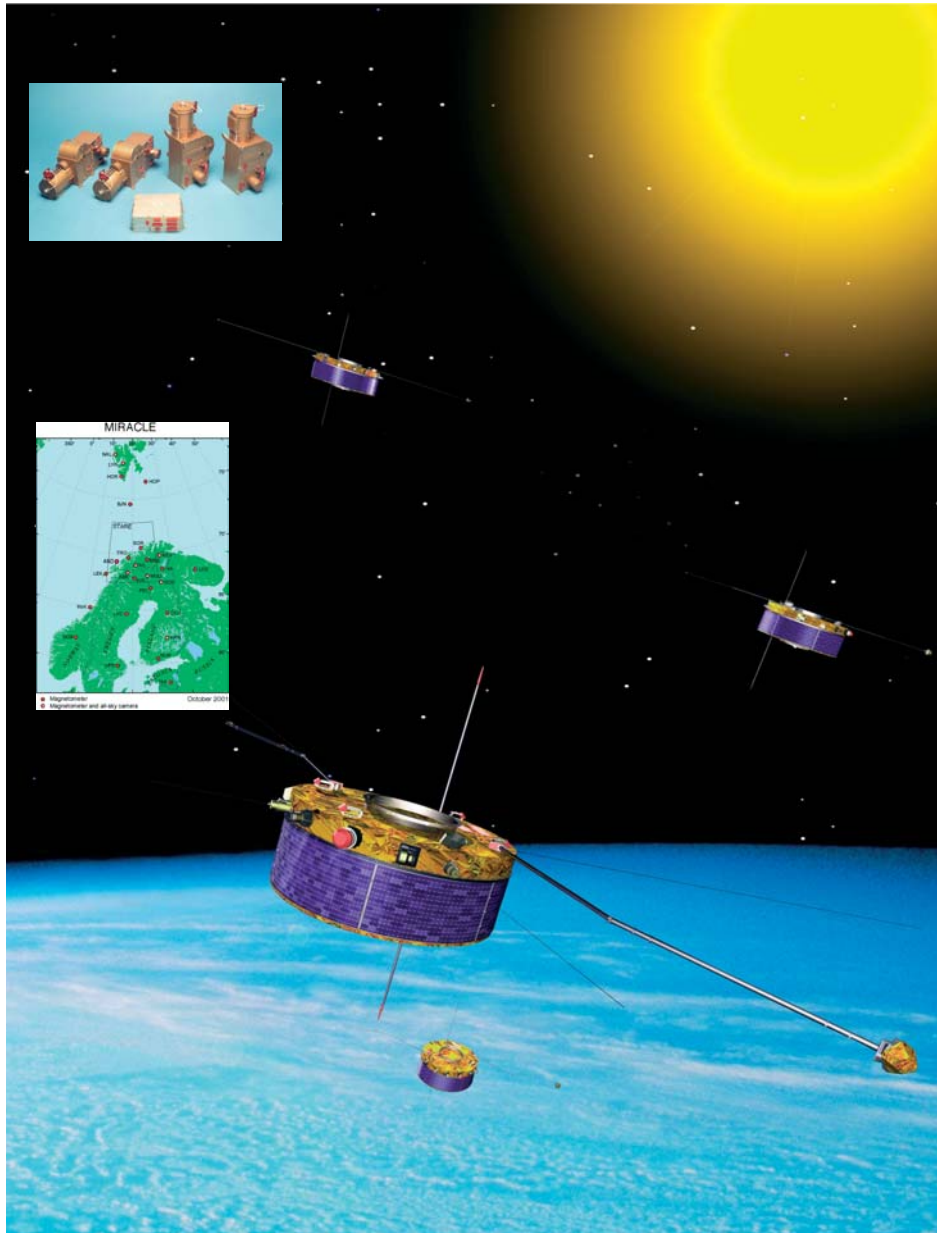


Space Research in Finland

Report to COSPAR 2002



Space Research in Finland

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Editors

Hannu Koskinen
Pauli Stigell
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COSPAR

FINNISH NATIONAL COMMITTEE



ACADEMY OF FINLAND



TEKES

National Technology Agency

Helsinki 2002

Front Cover:

The four Cluster II spacecraft were successfully launched in 2000. They comprise the second half of the First Cornerstone mission in the science programme of ESA. They study the interactions between the Sun and the Earth, in particular how the solar wind affects the Earth's magnetic environment. University of Oulu provided mechanisms for four 50-m long booms to measure the electric fields and waves. The Miracle network operated by the Finnish Meteorological Institute is an important part in the ground-based observations conducted in co-ordination of the Cluster satellites.

Photos:

- ESA
- University of Oulu
- Finnish Meteorological Institute

Back Cover:

Investigations of comets and planets provide information of the origin and evolution of the solar system. Finnish scientists participate in several ESA and NASA solar system missions, including Rosetta, Mars Express, Stardust, and Contour.

Photos:

- ESA
- NASA
- Finnish Meteorological Institute

Tekes – Your contact to Finnish Technology

Tekes, the National Technology Agency, is the main financing organisation for applied and industrial R&D in Finland. Funding is granted from the state budget.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities aim to diversify production structures, increase productivity and exports, and create a foundation for employment and social well-being. Tekes supports applied and industrial R&D in Finland to the extent of some 390 million euros annually. The Tekes network in Finland and overseas offers excellent channels for cooperation with Finnish companies, universities and research institutes.

Technology programmes – part of the innovation chain

The technology programmes for developing innovative products and processes are an essential part of the Finnish innovation system. These programmes have proved to be an effective form of cooperation and networking for companies and the research sector. Technology programmes promote development in specific sectors of technology or industry, and the results of the research work are passed on to business systematically. The programmes also serve as excellent frameworks for international R&D cooperation. Currently a total of about 50 extensive national technology programmes are under way.

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Foreword

This is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared jointly by the National Committee of COSPAR, the National Technology Agency (Tekes) and the Academy of Finland. The report describes the overall structure of Finnish space activities, the presently applied strategy, and main funding sources. The major space programmes are briefly listed. The main body of the report describes the progress during 2000–2001 in pure and applied space sciences within the domain COSPAR activities.

During the last two years some of the milestones of Finnish space activities have been the continuous exploitation of the successful observations by the SOHO (Solar and Heliospheric Observatory), and the first data analyses from the Cluster II and Odin satellites, both successfully launched in 2000. Several satellite instruments were being finalized for launches in 2002–2003 (Envisat, successfully launched on March 1, 2002, Integral, Rosetta, Mars Express, SMART-1). Also the work in the Planck satellite moved to actual design and manufacturing phase.

In 2001 a 3-year space research programme called ANTARES was initiated. The programme is jointly funded by the Academy of Finland and Tekes with a total budget of about 8.6 million euros. Almost all Finnish space science groups and several groups from the remote sensing community are involved in the 11 projects of ANTARES.

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1 Overview of Finnish Space Activity

1.1 A short history

Finnish space research utilising spacecraft began already with the first man-made satellites, whose orbital motions were used in studies of the Earth's gravitational field. The International Geophysical Year 1957–1958, which led to the establishment of the Committee on Space Research (COSPAR), also saw contributions to various ground-based space research instruments, in particular all-sky cameras whose modern successors are even today used in studies of the aurora borealis and the space physics behind this magnificent phenomenon. Finland became a member of COSPAR a few years later in 1964.

During the first 20 years of COSPAR membership Finnish space research was almost completely conducted within ground-based astronomy and ionospheric and magnetospheric physics, although sometimes in collaboration with foreign groups utilising space-borne instruments. It was not until the mid-1980s that the first space-borne instrument projects with Finnish participation were initiated. The first instrument project started in May 1985 and was a participation in the Swedish-Soviet-Finnish plasma analyser ASPERA for the Soviet Phobos mission. The project initiated a close co-operation with Sweden, and finally led to the first Finnish science contributions from *in situ* observations in space. After this initial start the activities widened already within the Phobos programme to include also other Finnish institutes as well as a wider international collaboration.

The expansion of Finnish space activities during the 1980s was extremely rapid, in particular in space science. In 1987 Finland became an Associate Member of the European Space Agency (ESA) and a full member of its Science Programme. By that time the co-operation with the Soviet Union had already broadened to include also the astronomy missions Spectrum-X-gamma and Radioastron as well as various projects involving remote sensing of the Earth.

Finnish research groups got an excellent start in the ESA Science Programme with the First Cornerstone missions SOHO and Cluster. Presently Finnish scientific institutes and high-tech companies play various roles (Principal Investigator, Co-Investigator, hardware supplier, system level contractor, etc.) in all ESA science missions. The second key line for Finland has been active participation in the Earth Observation Programme of ESA, where the Envisat mission and, in particular, its GOMOS instrument have played a central role. Today these activities cover a wide range of topics with scientific, societal, and technological interests.

Finally, in 1995 Finland became a full member of ESA. While space research itself was well-established already during the associate membership, the new status was essential to enable Finnish companies to become involved in technology programmes such as TRP and GSTP. At the same time national initiatives and co-operation with other countries and organisations have widened and strengthened.

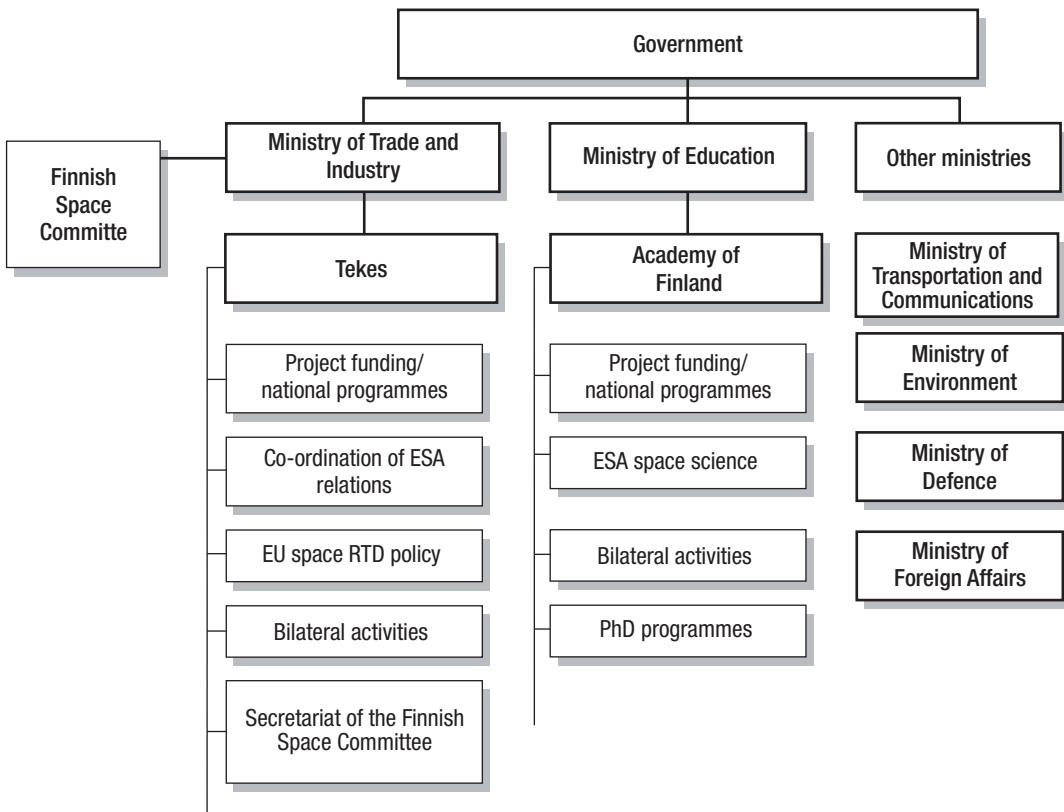


Figure 1.1. Organisation for administration of space matters in Finland.

1.2 Summary of the Finnish space policy

Space activities in Finland are administrated in a decentralised fashion mainly involving Tekes (National Technology Agency), the Academy of Finland, and the Ministry of Trade and Industry (MTI). The Finnish Space Committee acts as the co-ordinating body for Finnish space activities.

The Finnish Space Committee (established in 1985) is the co-ordinating body for Finnish space activities. The Committee makes propositions and proposals, and gives statements on matters related to space research and education as well as industrial

development, exploitation of knowledge deriving from space activities, and co-operation of Finnish partners involved in these activities.

The Committee is nominated on MTI's proposal by the Government for a period of three years. It is chaired by MTI and has members from relevant ministries and main actors in Finnish space activities. Currently, the following instances are represented in the Committee: the Ministries of Trade and Industry, Foreign Affairs, Education, Transportation and Communications, Environment, and Defence, industry, applied research, and other government sector users of space activities. The Committee meets on average eight times per year.

During 2000 and 2001 two Finnish Space Committees have held meetings. The members of the Committee that was appointed in April 2001 are (details on the 1998–2001 Committee can be found in the previous COSPAR report):

Chairman	
Timo Kekkonen	Ministry of Trade and Industry
Vice Chairman	
Risto Pellinen	Finnish Meteorological Institute
Members	
Mirja Arajärvi	Ministry of Education
Juhani Lehmusvirta	Patria Finavitec
Liisa Maunula	Ministry of Foreign Affairs
Anneli Pauli	Academy of Finland
Kari Tilli	Tekes
Advisors	
Heikki Fredriksson	Topographic Service of the Finnish Defence Forces
Heikki Huomo	Nokia
Jorma Immonen	Ministry of Trade and Industry
Antti Joensuu	Ministry of Trade and Industry
Jorma Kangas	University of Oulu
Väinö Kelhä	Technical Research Centre of Finland
Risto Kuittinen	Finnish Geodetic Institute
Raimo Kurki	Ministry of Transport and Communications
Rita Linna	Ministry of Transport and Communications
Esa Panula-Ontto	Tekes
Yrjö Sucksdorff	Finnish Environment Institute SYKE
Juha Vuorimies	Ministry of Environment
Secretaries	
Pauli Stigell	Tekes
Tuula Pitkänen	Academy of Finland
Mirja Vihma-Kaurinkoski	Academy of Finland

The secretariat of the Finnish Space Committee is run by Tekes. The science secretary of the Committee is from the Academy of Finland.

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1.3 International co-operation

As is clear from the history section above, ESA is the main international collaborative partner. The following list contains the main space organisations with whom Finland has formal co-operation agreements and the body in Finland which has the responsibility of this collaboration:

- COSPAR, Finnish National Committee
- ESA, Tekes (National Technology Agency)
- EISCAT, Academy of Finland
- EUMETSAT, Finnish Meteorological Institute
- EUTELSAT, Sonera Corporation
- INTELSAT, Sonera Corporation
- INMARSAT, Sonera Corporation
- EARSeL, Helsinki University of Technology
- SARSAT/COSPSAT, Frontier Guard of Finland

At the time of writing this report Finland has also started the final round of negotiations to become a member of the European Southern Observatory (ESO).

2 Finnish National Strategy for Space Research and Development

2.1 Vision and goals of Finnish space activities

In a society based on information, know-how, and efficient exploitation of technology, the widespread utilisation of satellites and methods from the space sector is essential. In Finland, the guiding principles in the space sector have been science and technology policy, and the desire to satisfy the needs of society using the means afforded by space technology. Despite the changes that continue to take place internationally, there is no immediate need to alter the guiding principles behind Finnish space activities.

The vision concerning Finnish space activities is defined as follows:

The needs of Finnish society shall form the main principle behind the methods from the space sector and for the development of space technology. The diversity of opportunities provided by space activities will be adopted efficiently. The benefits derived from investment in the space sector will be seen in the form of accumulation of human capital, the rise in levels of expertise, improvement in the international competitiveness of companies, expansion of business operations outside the space sector, more effective public services, and an improvement in the quality of life.

The goals pursued in Finnish space activities are:

- to collect data on our living environment and on objects and phenomena in space,
- to improve technological competitiveness in industry, in the Finnish service sector and in international business,
- to support economic growth via more efficient service provision within society and an increase in business activity, and
- to produce information for the needs of environmental monitoring, protection and sustainable development.

Strategy for Finnish space activities

A new strategy was published in June 2002 for years 2002 to 2004. The strong fluctuations in the markets for space technology applications and in the international changes taking place in science and technology policies are reflected in Finnish space activities. Strategic areas of expenditure for the public sector are space science, satellite Earth observation, satellite telecommunications, satellite navigation and positioning, and the industrial production of equipment for space vehicles. Finland has not played significant role in microgravity research, manned space flights nor in the International Space Station programme, and this will remain the case in the future. Activity in other areas is undertaken according to the needs of companies and public sector provision.

The present national space strategy is outlined in *The Space Activities in Finland, National Strategy and Development Objectives* published (in Finnish) by the Finnish Space Committee in June 2002 (to be published in English in late 2002).

The strategy for further development of space activities in the field of space science is as follows:

- The standard of Finnish space science will be maintained at the top international level by participation in the international projects concerning key research themes. The national space science and Earth observation research programme ANTARES is a major tool to achieve this goal during 2001–2004. ANTARES funded jointly by the Academy of Finland and Tekes has a budget of 8.6 M€.
- Utilisation of new satellite Earth observation methods will be increased in public sector data

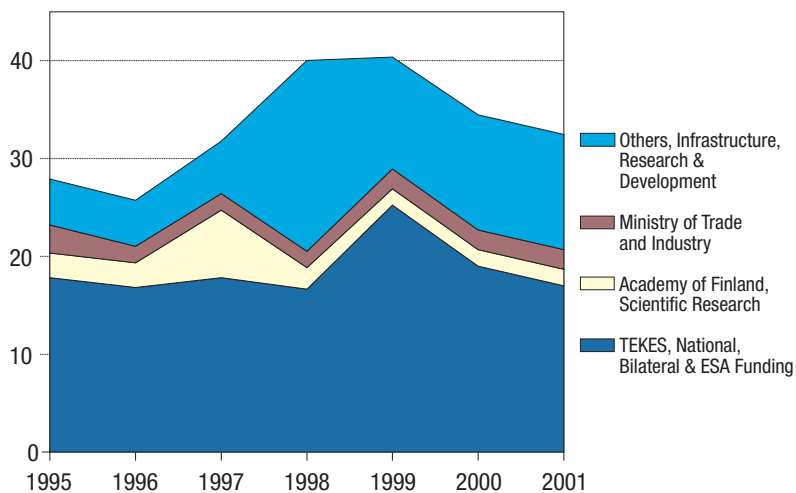
collection and in geographic information systems. Business activity will be expanded by putting public services in competition.

- International research co-operation will concentrate on ESA and EU research projects and on bilateral research projects especially with member countries of ESA, the EU and the United States.
- National projects will be used to support the wider adoption of space technology and methods, to strengthen technological competitiveness and to make effective use of international partnership projects. New ways to prepare for space technology changes and education are sought for.

2.2 Funding sources

Also the public funding responsibilities concerning space activities are divided between the Ministry of Trade and Industry, Tekes, and the Academy of Finland. In addition, several universities and research institutes provide funding to space projects from their own budgets.

Table and Graphic 2.1. Finnish Space Funding 1995–2001; in million euros (1 € = 5,94573 FIM).



	1995	1996	1997	1998	1999	2000	2001
TeKes National, Bilateral & ESA Funding	18	17	18	17	25	19	17
Academy of Finland Scientific Research	3	3	7	2	2	2	3
Ministry of Trade and Industry	3	2	2	2	2	2	3
Others, Infrastructure, Research & Development	5	5	5	20	11	12	12
Total	28	26	32	40	40	35	35

2.2.1 Tekes



Tekes, the National Technology Agency (established in 1983), is the main financing organisation for applied and industrial R&D in Finland. The funds for financing are awarded from the state budget. Tekes offers channels for co-operation with Finnish companies, universities and research institutes.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities should diversify production structures, increase production and exports, and create foundations for employment and social well-being.

Tekes co-ordinates and offers financial support for participation in international technology initiatives, including EU research programmes, EUREKA, research activities of OECD's energy organisation IEA (International Energy Agency), European Cooperation in Scientific and Technical research (COST), European Space Agency (ESA), and Nordic co-operation. Tekes also offers a network of Technology Counsellors whose aim is to increase technological co-operation between their base countries and Finland.

Technology programmes aim at gaining new technology expertise and product development options in the important business areas of the future. Technology programmes are used to promote development in specific sectors of technology or industry, and to pass on results of the research work to business in an efficient way.

Programmes have proved to be an effective form of co-operation and networking for companies and the research sector. The programmes also offer good frameworks for international R&D co-operation. During 2001, 45 national technology programmes were under way. In 2001, Tekes provided about 190 million euros to financing technology programmes. In the field of space technology, two national technology programmes that started in 1996 ended in 2000. They deepened the interactions with ESA programmes and increased the competitiveness of Finnish space technology. In 2001 Tekes and Academy of Finland started a common programme, ANTARES, on space science and remote sensing science.

In 2001 Tekes' total financing of national and international R&D programmes was about 387 million euros. From this figure, 17 million euros were provided for space activities (ESA, national and bilateral).

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2.2.2 Academy of Finland



ACADEMY OF FINLAND

The Academy of Finland is an expert organisation for research funding within the administrative sector of the Ministry of Education. The Academy has a board and four research councils, as well as an Administrative Office. The research councils are the Research Council for Biosciences and Environment, the Research Council for Culture and Society, the Research Council for Natural Sciences and Engineering, and the Research Council for Health.

The Academy's function is to improve the quality and prestige of Finnish basic research through selective, long-term funding based on competition, systematic evaluation, and relevant science policy. The Academy's development initiatives focus on developing professional researcher careers and promoting creative research environments. The various forms of support for research, such as research posts, research projects, and research grants, provide opportunities for versatile funding of research in different disciplines.

The research funding of the Academy of Finland amount to 184 million euros (1092 MFIM) in 2001, of which about 2.34 million euros (13.9 MFIM) was spent on space research. Examples of international co-operation funded by the Academy include scientific research at EU, CERN, UNESCO, and Finnish scientists participating in ESA science programmes. The Academy also funds the membership fee to European Incoherent Scatter Radar Facility (EISCAT), Nordic Optical Telescope (NOT), the European Science Foundation (ESF), the European Synchrotron Radiation Facility (ESRF), and the European Molecular Biology Laboratory (EMBL). In addition, Finland is entitled to 5% of the total observing time in the Swedish Submillimetre Telescope (SEST) in European Southern Observatory (ESO), through a special agreement between the Academy of Finland and the Swedish Research Council.

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2.3 The Finnish National Committee on Space Research

The Committee on Space Research (COSPAR) was established by the International Council of Scientific Unions (ICSU) in October 1958 to continue the co-operative programmes of rocket and satellite research successfully undertaken during the International Geophysical Year of 1957–1958. The ICSU resolution creating COSPAR stated that the primary purpose of COSPAR was to “provide the world scientific community with the means whereby it may exploit the possibilities of satellites and space probes of all kinds for scientific purposes, and exchange the resulting data on a co-operative basis.”

COSPAR is an interdisciplinary scientific organisation concerned with the progress on an international scale of all kinds of scientific research carried out with space vehicles, rockets, and balloons.

COSPAR's objectives are carried out by the international community of scientists working through ICSU and its adhering National Academies and International Scientific Unions. Operating under the rules of ICSU, COSPAR ignores political considerations and considers all questions solely from the scientific viewpoint.

The Finnish National Committee of COSPAR has participated in the international and national co-operation of scientific space research since 1964 by submitting proposals, issuing statements, arranging meetings, and keeping contact with the international COSPAR and its subcommittees.

The National Committee is an expert body nominated by the Delegation of the Finnish Academies of Science and Letters. The members of the National Committee represent the active community of space researchers in Finland.

Prof. *Hannu Koskinen*, Chairman
University of Helsinki

Prof. *Martti Hallikainen*, Member
Helsinki University of Technology

Prof. *Risto Kuittinen*, Member
Finnish Geodetic Institute

Lic. Phil. *Viljo Kuosmanen*, Member
Geological Survey of Finland

Prof. *Kari Lumme*, Member
University of Helsinki

Prof. *Kari Mattila*, Member
University of Helsinki

Prof. *Risto Pellinen*, Member
Finnish Meteorological Institute

Prof. *Pekka Tanskanen*, Member
University of Oulu

Prof. *Martti Tiuri*, Member
Parliament of Finland

Prof. *Seppo Urpo*, Member
Metsähovi Radio Observatory

Prof. *Esko Valtaoja*, Member
University of Turku (from 2001)

Prof. *Martin Vermeer*, Member
Helsinki University of Technology

Mr *Janne Lahtinen*, Secretary
Helsinki University of Technology

Note: In January 2002. Prof. *Tuomo Nygrén*, University of Oulu was elected as a new Member and Mr. *Matias Takala*, Helsinki University of Technology, was appointed as a new Secretary.

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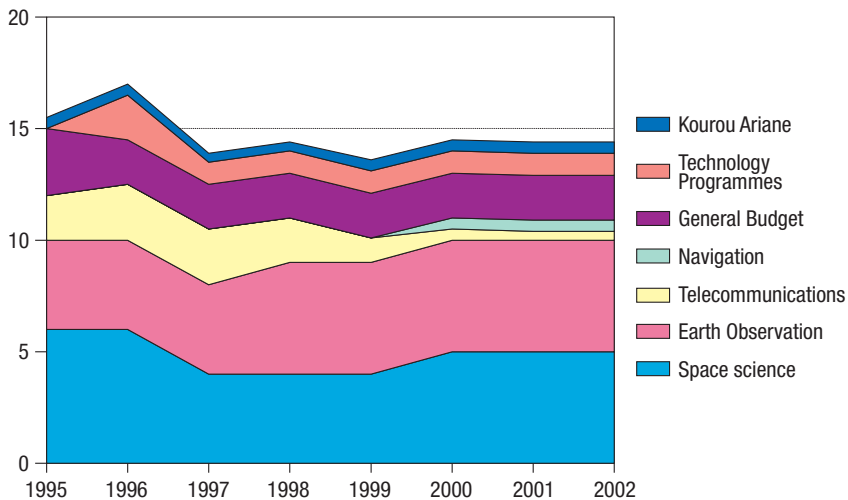
3 Space Programmes Supported by Finland

3.1 ESA programmes supported by Finland



In accordance with the Finnish national strategy for space activities, Finland participates in the European Space Agency's science, telecommunications, navigation and Earth observation programmes, and in ESA's related technology R&D programmes.

Table and Graphic 3.1. Payments to ESA Programmes 1995–2001 by Tekes and Ministry of Trade and Industry (MTI); in million euros (1 € = 5,94573 FIM).



	1995	1996	1997	1998	1999	2000	2001
Space science	6	6	4	4	4	5	5
Earth Observation	4	4	4	5	5	5	5
Telecommunications	2	2.5	2.4	2	1	0.5	0.4
Navigation	-	-	-	-	0.1	0.5	0.5
General Budget	3	2	2	2	2	2	2
Technology Programmes	2	2	1	1	1	1	1
Kourou Ariane	0.6	0.5	0.4	0.4	0.5	0.5	0.5
Total	17.5	17	14	14.5	13.5	14.5	14.5

Space science

Table 3.2 summarises the ESA space science programmes in which Finland has participated either in provision of the scientific instruments (AO instruments) or in the construction of the satellite platform equipment.

Table 3.2. Finnish AO and industrial participation in ESA space science missions.

Programme	Finnish participation	Schedule
SOHO	SWAN and ERNE AO instruments	Launched 1995
Cluster / Cluster-2	EFW AO instruments, satellite electronics	Launch failure 1996, new launch 2000
Huygens	HASI AO instrument, lander radar altimeter	Launched 1997
XMM-Newton	Telescope structure and satellite electronics	Launched 1999
Integral	JEM-X AO instrument	Launch 2002
Rosetta	COSIMA, PP, MIP AO instruments and lander CDMS, satellite structure and power electronics	Launch 2003
Mars Express	ASPERA-3 AO instrument, participation in Beagle-2-lander, satellite power electronics	Launch 2003
SMART-1	XSM and SPEDE AO instruments	Launch 2002
Herschel/Planck	LFI AO instrument onboard Planck; mirror for Herschel	Launch 2007

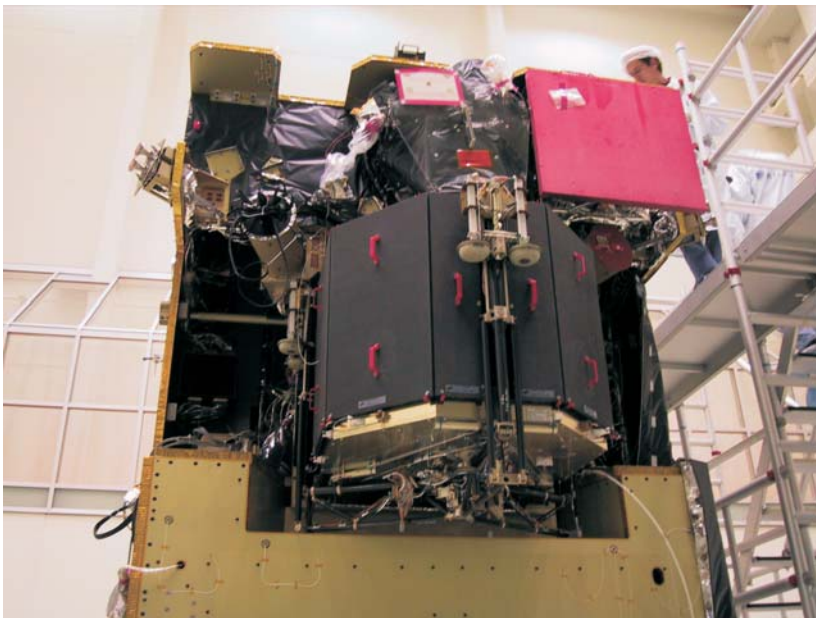


Figure 3.1. Rosetta Lander mounted in the structure of Rosetta Orbiter.

Earth observation

Table 3.3 summarises the ESA earth observation programmes in which Finland has participated either in the construction of the satellite platform or in the observation instruments.

Table 3.3. Finnish participation in ESA remote sensing programmes.

Programme	Finnish participation	Schedule
Earthnet	Pre-processing, archiving, and distribution of image data.	1979–
EOPP	Remote sensing technology programme. Several R&D activities with Finnish participation.	1986–
ERS-1 & -2 Phase E	Several data AO activities with Finnish participation.	1984–2000
MSG	Software for the satellite platform, hardware for the SEVIRI observation instrument.	1994–2002
ENVISAT-1	Software and hardware for GOMOS observation instrument.	1992–2002
METOP-1 PP METOP-1 C/D	METOP satellite series, GOME-2 instrument electronics and satellite bus S/W development	1993–
EOEP	Earth Observation Envelop Programme	1998–



Figure 3.2. Envisat was launched successfully on March 1, 2002. It carries the global ozone monitoring instrument GOMOS with significant Finnish contributions.

Telecommunications and navigation

Table 3.4 summarises the ESA telecommunication and navigation programmes in which Finland has participated.

Table 3.4. Finnish participation in ESA telecommunication programmes.

Programme	Finnish participation	Schedule
ASTP-4	Developing the competitiveness of businesses. New projects not started after 1994. Several R&D activities with Finnish participation.	–1998
DRS	Ground station for the Artemis satellite developed in Finland.	1991–2001
ARTES Element 1	Basic specifications of the systems. An extension programme to PSDE-1. Several R&D activities with Finnish participation.	1993–
ARTES Element 5 (ASTE)	Telecommunication systems and equipment programme. Extension to ASTP. Several R&D activities with Finnish participation.	1994–
ARTES Element 7	Telecommunication experiments and services demonstration. Several R&D activities with Finnish participation.	1994–1999
ARTES Element 9 and Galileosat Definition	Industry activities related to Galileo satellite navigation system definition.	1998–

Technology programmes

Technologies for ESA's future science missions are in many cases developed in the Basic Technology Research Programme (TRP) and General Support Technology Programme (GSTP). High-technology applications and continuous technology development in broad fields are an essential base for the Finnish economy. In that respect also the projects and development in the ESA R&D programmes have a great interest among the Finnish companies and research institutes. In addition to the participation in the mandatory TRP Programme financed within the general budget of ESA, Finland also decided to contribute to the optional GSTP and presently well over the nominal level.

3.2 Bilateral co-operation and programmes

Bilateral space programmes mainly in the field of space science were the first areas in which Finland became an active player in space. This started in the mid 1980's. Bilateral programmes still have an important role to play in the overall Finnish space strategy. A list of the largest bilateral programmes is given in table 3.5.

Table 3.5. The main Finnish bilateral space programmes.

Programme	Main Partners	Finnish participation	Schedule
Phobos	SU, S, D	Electronics for ASPERA instrument and test system for LIMA-D instrument	Launched 1988
Interball	SU/RUS, S	Electronics for ASPERA instrument	Launched in 1995 and 1996
Freja	S	Plasma and wave instruments	Launched 1992
Polar	USA	Mechanisms for EFI instrument	Launched 1996
Cassini	USA	Hardware for IBS, CAPS and LEMS instruments	Launched 1997
Mars-96	SU/RUS	Central electronics units, sensors and software for two landers	Launch failure in 1996
SRG	RUS	Silicon x-ray array (SiXA) for the SODART instrument	Launch TBD
Odin	S, F, CAN	119 GHz receiver and antenna measurements	Launch 2000
Stardust	USA	CIDA instrument	Launch 1999
EOS-Aura	USA	OMI instrument	Launch 2004
Space Shuttle	USA	AMS instrument	Launch 1998
Radioastron	RUS	22 GHz VLBI receiver	Launch TBD

3.3 Finnish national space programmes

Two dedicated space technology programmes were executed by Tekes in 1996–2000. These strengthened the Finnish capabilities in the areas of industrial participation, various satellite technologies and application of earth observation techniques in Finland. A new national space research programme ANTARES started in 5 April 2001. It is funded jointly between Academy of Finland and Tekes.

ANTARES, 2001–2004

The ANTARES programme (Academy of Finland and National Technology Research Programme for Space Research) addresses the Finnish space research strategy in the practical level. The programme started in 2001 and will be carried out in the years 2001–2004 consisting of extensive projects established by consortia of research groups

from universities and space research institutes. The programme is international in its nature, and many projects have relations to the programmes of ESA. ANTARES is funded jointly by the Academy of Finland and Tekes, the National Technology Agency. The focus of the ANTARES programme is in space science and in scientific environmental remote sensing.

The ANTARES programme supports especially projects which have been earlier committed to, or which are in the active development phase. In this way the continuation of long-term projects is ensured. The programme gives a possibility to analyse large data archives, as well as observations acquired in the current missions. Also developing new instrument concepts to be implemented in the future is a goal of the programme.

The ANTARES programme contains the following projects:

- Planck Surveyor Physics (PLANCK)
- High Energy Astrophysics and Space Astronomy (HESA)
- Space Based Studies of Dark Matter (DARKSTAR)
- Research of the Interstellar Medium and Star Formation (ISO-Odin)
- Space Weather in the ANTARES Programme (SWAP)
- Cluster II and MIRACLE: Mesoscale Structure of Coupled Solar Wind-Magnetosphere-Ionosphere system (C2M)
- Dust, Atmospheres, and Plasmas in the Solar System (DAPSS)
- Mars Small-Scale Weather (MSW)
- Chemical Aeronomy of the Mesosphere and Ozone in the Stratosphere (CHAMOS)
- New Modelling and Data Analysis for Satellite Based Forest Inventory (MODAFOR)
- Assimilation of Remote Sensing Data to Physical Models in Environmental Monitoring and Forecasting (ASSIMENVI).

The ANTARES programme also strengthens Finnish educational potential in space science, as most of the research groups participating in ANTARES are also active in the national Graduate School in Astronomy and Space Physics. The graduate school offers a versatile education programme with seminars and conferences. In the sense of the educational objective of the programme the seminars organised in the context of ANTARES are open also to students in space sciences.

An important goal of the ANTARES programme is to increase awareness and visibility of the space science among the public and in the schools. The visibility strategy has been prepared according to the outreach plans made within the projects of the programme, for which a special allocation of funds has been allocated in the budgets of the consortia.

The Academy of Finland has committed 4.5 million euros to the above listed projects during the years 2001–2004. Tekes will fund selected parts of these projects with 4.1 million euros during the same time period.

Space 2000 – Space equipment technology 1996–2000

The Space 2000 technology programme concentrated on the technology of space satellites and their ground support equipment. Space technology offers companies and research institutes opportunities to further apply and develop their expertise and products and to extend their markets to new, challenging fields of application. Co-operation within the European Space Agency plays a central role in the Finnish space activities. Therefore also the Space 2000 programme was closely linked with the ESA technology programmes and satellite projects.

The objectives of Space 2000 were

- Developing the international competitiveness of the Finnish space equipment industry, especially in the satellite projects of the European Space Agency.
- Intensifying technology synergy between space technology and other industry sectors.
- Transmitting the expertise acquired in connection with the development of nationally financed scientific space equipment to an industrial environment.
- Creating a functional network for space technology to enable the realisation of more extensive space technology projects in Finland.

The Space 2000 programme consisted of companies' product development projects and research-based joint projects of companies and research institutes.

Focus areas of the programme were

- Preparation of Finnish R&D project proposals for ESA's technology programmes
- Commercialisation of space technology
- Space electronics and software
- Mechanics of space equipment
- Structural technology of satellites
- Manufacturing, testing, and quality activities
- Education and training in the space sector.

The total budget of the programme was about 17 million euros, of which Tekes financed approximately 60 percent.

Globe 2000 – Remote sensing 1996–2000

The Globe 2000 technology programme helped to develop the remote sensing industry by intensifying the use of research data for operational and commercial applications and deepening the co-operation between the participants. Remote sensing is an effective tool for airborne instruments producing information about the state of the environment and changes to it with the help of satellite and airborne instruments. Satellite remote sensing is especially useful for obtaining data quickly from a wide or distant area. Combining remote sensing data from several different sources usually provides the best results. Remote sensing methods can be utilised in many ways in the information society of the future, both in Finland and on the export market.

The Globe 2000 technology programme was coordinated with the remote sensing programmes of the ESA. The success of Finnish participants in EU's and ESA's remote sensing programmes is evidence of good competitiveness.

The objectives were:

- Developing entrepreneurship in the remote sensing industry.
- Implementing operative remote sensing techniques to gain considerable economic and commercial benefits and benefits related to the monitoring of the state of the environment.
- Developing remote sensing technologies and methods that enable a technological leap forward or are related to top-level international research co-operation.

Commercial objectives were not met but scientific methods evolved into more operational remote sensing systems.

Focus areas of the projects were:

- Companies' product development projects for commercialising remote sensing methods and supporting companies' technology projects.
- Applied technological research projects for obtaining internationally significant new information about remote sensing.
- Demonstration projects for presenting a remote sensing instrument, method, or data set to the end users.
- Operative remote sensing implementation projects, during which remote sensing methods with significant economic or commercial value are implemented.

The budget of the Globe 2000 programme was approximately 9 million euros, of which Tekes finances approximately 50 percent.

4 Space Research

4.1 Ionospheric and magnetospheric research

Finnish Meteorological Institute, Geophysical Research (FMI/GEO)

The ionospheric and magnetospheric research at FMI covers a wide range of physical phenomena from space weather analyses in the heliospheric scale to detailed studies of local ionospheric electrodynamics. The research programme in the report period focussed on three key areas: Space plasma simulations, Sun-Earth connections, and Space weather. The research is conducted utilizing both ground-based and space-borne measurements, and in wide international co-operation including collaborators from Europe, the United States, and Russia. The research activity comprises the full chain of processes from instrument design, development, and construction to data taking, analysis, and interpretation using advanced data analysis tools, modeling and simulation techniques as well as theory development.

Boosted by an Academy of Finland research programme MaDaMe, the space plasma simulation work at FMI/GEO was expanded and widened in scope. The global magnetohydrodynamic simulation code GUMICS, which can resolve the solar wind – magnetosphere – ionosphere interaction using solar wind data as input, started to be developed in 1995 but is still unique in Europe with only a handful of competitors world wide. The latest version, GUMICS-4, was taken into scientific use in the year 2000. The code performance was further developed both by analysis of the MHD theory and by searching for even more efficient methods for the numerical solution. Furthermore, the code was utilized in several studies examining the dynamic processes in the magnetosphere.

The MHD theory has obvious deficiencies in describing the near-Earth plasma environment, as the observed plasma distribution functions are very complex and contain several populations with

vastly different characteristic energies. Therefore, a new approach was taken using a hybrid method, where the electrons are treated as fluids, but the ions are taken as particles with the full range of single-particle dynamics. This method allows for studies of processes and regions that change rapidly over short length scales, e.g., in the ion Larmor rotation scale. Because of the complexity of the approach, the global hybrid code has thus far been applied to the Martian and Hermean environments where the intrinsic magnetic field is much weaker. On the other hand, even at present it is possible to study limited regions of the terrestrial magnetosphere with the hybrid code, using the MHD simulation results as initial and boundary conditions.

One of the most significant highlights of the period was the successful launch of the four Cluster II spacecraft. The FMI/GEO group had prepared for the Cluster operations by combining the Scandinavian sector ground-based instruments to a single network termed MIRACLE. During the Cluster operations, the MIRACLE network provides near-real-time data from over 20 magnetometers, from 8 auroral all-sky cameras, and from the STARE bistatic coherent scatter radar system. The magnetometer network IMAGE contains stations operated by several countries, but all data are gathered and processed at FMI. The all-sky camera network has been developed at FMI, and is maintained and operated by FMI throughout the dark season; over 5 million auroral images are recorded each winter at 20-s temporal resolution. The STARE radar system is a German-Finnish radar, where FMI has accepted full responsibility of maintenance and operations from the beginning of 2002. Data from all these instruments are gathered at FMI, where quick-look plots are produced and posted on the world wide web within 24 hours of the measurements to allow for easy and rapid event identification for the entire scientific community. Full scientific data are also distributed through the internet to all interested scientists.

The combined Cluster-MIRACLE data analysis was started as soon as scientific data from the Cluster satellites became available. Initial results from this large international collaborative effort were published in the Cluster special issue of *Annales Geophysicae*, which contained several papers with FMI/GEO involvement. These and subsequent more detailed analyses have led to interesting results of the dayside auroral morphology and of the cusp dynamics. Especially, the ionospheric modeling methods developed at FMI will allow for detailed studies of the three-dimensional auroral current systems when data from four points in space and a network in the ionosphere are used as input parameters.

Space weather activities at FMI continued on many different fronts. On the programmatic side, FMI participated in a large European Space Agency study in a consortium led by the Rutherford

Appleton Laboratory investigating the European possibilities for a wider space weather program. This study was concluded at the end of 2001, and will be used as a key document when defining the future European directions in that front. Participation in this study further strengthened the FMI role as a leading institute in space weather science in Europe.

Space weather research took another step further when collaboration with the Department of Physics at the University of Helsinki brought further expertise of the solar coronal mass ejections and their consequences in interplanetary space to the group. An epitome of this collaboration is a detailed study of a strong storm that occurred in April 6–7, 2000. The study concentrating on the solar coronal mass ejection and following interplanetary magnetic cloud properties and the consequent large-scale magnetospheric activity is already in press. A high-

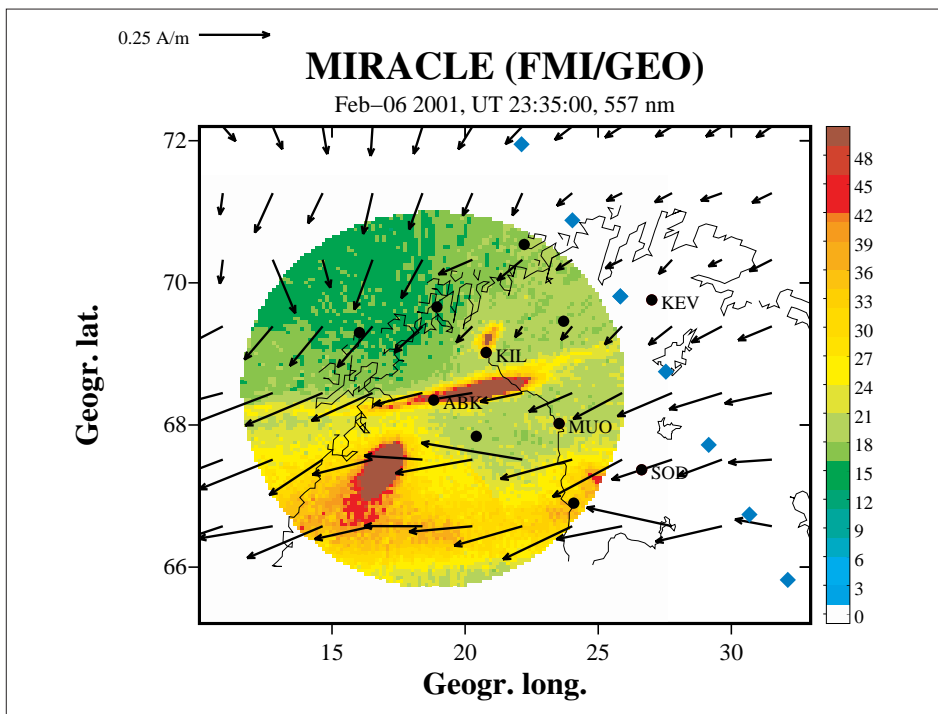


Figure 4.1. Cluster-MIRACLE co-operation. On February 6, 2001, Cluster passed over Northern Finland and Norway during an active auroral event. The auroras observed by the MIRACLE all-sky camera Abisko in Sweden are projected on the map. The magnetic footpoint of Cluster is given by diamonds and the arrows indicate ionospheric currents calculated from ground-based magnetometer observations.

resolution MHD simulation of the entire storm main phase was run, and the study submitted for publication concentrated on energy transfer from the solar wind into the magnetosphere. In this study, a completely new method to evaluate the energy transfer through the magnetospheric boundary, the magnetopause, was developed. The results were compared with an empirical estimate of the energy transfer rate: although the numerical values were different, the temporal evolution was shown to be quite similar during periods of strong energy input. This was an important step forward, giving further credibility to the simulation results as well as to the empirical formulation of the energy transfer rate. A further study concentrating on the space weather ground effects is still under way.

The studies of geomagnetically induced currents (GIC) caused by magnetospheric disturbances and their effects on manmade conductor systems such as high-voltage power lines or natural gas pipelines was tied closer to the large-scale space weather studies analyzing the dynamics of the ionosphere and magnetosphere. Several large storms that occurred near the maximum of solar cycle 23 caused several strong GIC events that were measured both by the scientific magnetometer network as well as by direct GIC recordings from the Finnish high-voltage power distribution network. The GIC properties were correlated with the type of geomagnetic storm driving the activity as well as with the detailed pattern of the electrojet currents at that time. This work together with the simulation work will further enhance our ability to predict these potentially hazardous events.

FMI continued its strong role in graduate and undergraduate education under the auspices of the national Graduate School for Astronomy and Space Physics. Being a state research institute outside the university system, FMI contributed to undergraduate and graduate classroom education by partially funding a joint space physics professorship between the University of Helsinki and FMI. Approximately 10 undergraduate students work as summer students at FMI/GEO each summer, and many of them continue toward a MSc degree during the following years under the supervision of the FMI/GEO re-

search staff. Furthermore, FMI/GEO employed over 15 graduate students at various research, space hardware, and software development tasks. These students receive their formal education mostly at the University of Helsinki and the Helsinki University of Technology, and have scientific supervision from the FMI/GEO staff.

University of Helsinki, Department of Physical Sciences

Magnetospheric and ionospheric research at the Department of Physical Sciences of the University of Helsinki (UH/PHYS) is conducted in close cooperation with the above reported activities at FMI/GEO. Graduate students employed by the University participate in studies on Space weather, theory of MHD simulations, and Auroral physics.

In space weather the UH/PHYS group is focusing on the solar and solar wind drivers of space weather, in particular on the geoefficiency of coronal mass ejections (CME) that are the main drivers of magnetospheric storms. This particular work is conducted in collaboration with scientists at Max Planck Institute for Aeronomy in Lindau, Germany, who are involved in the LASCO coronagraph onboard the SOHO spacecraft of ESA and NASA. UH/PHYS also leads the space weather consortium SWAP, with participation from FMI, and Universities of Oulu and Turku, in the ANTARES programme.

In 2000 UH/PHYS and FMI/GEO led the STORMS mission proposal in the ESA flexi-mission competition. This was the first time ever when a Finnish-led proposal for an entire satellite mission was submitted to ESA. The proposed mission consisted of three satellites on highly elliptic orbits in the equatorial magnetosphere to allow a maximal spatial coverage of the inner magnetospheric dynamics during magnetospheric storms. The proposal was well-received by the scientific community and was selected to an assessment study by ESA. At the final stage it lost against Solar Orbiter but the concept has already served in other ESA studies toward a European space weather programme and it is quite possible that the mission idea will reappear in one form or another.

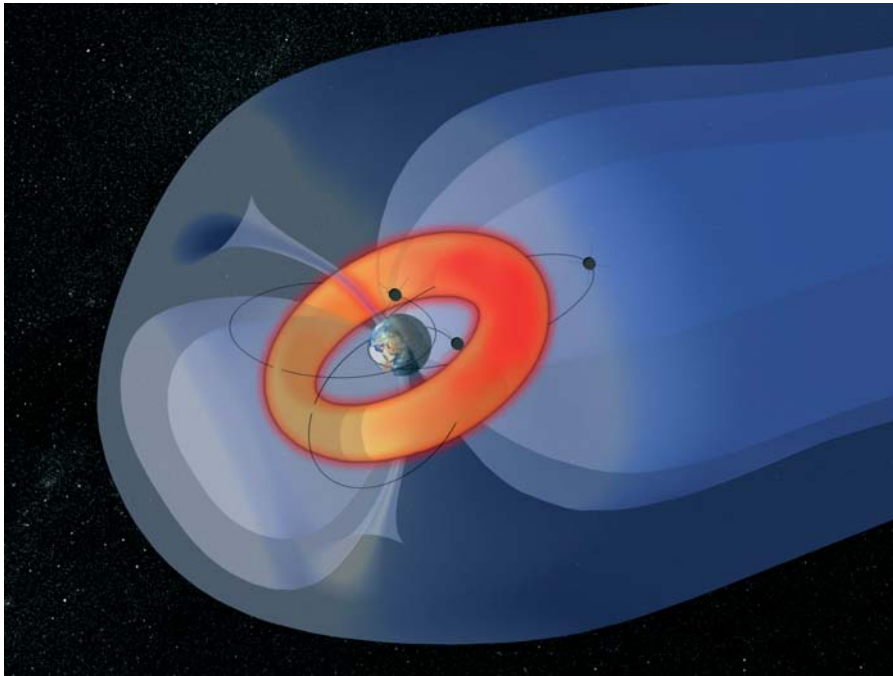


Figure 4.2. The three-satellite mission proposal STORMS to ESA for studies of space storms in the inner magnetosphere.

In the joint space physics education scheme with FMI, the University of Helsinki provides the basic education in various topics of space physics both in undergraduate and post-graduate levels. The Master and Ph.D. theses are supervised jointly by the professor in space physics and the FMI/GEO staff. All UH/PHYS space physics graduate students (presently 8), irrespective of their funding source, are enrolled in the nation-wide Graduate School in Astronomy and Space Physics.

**University of Oulu,
Department of Physical Sciences and
Sodankylä Geophysical Observatory**

The Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory of the University of Oulu (in brief: University of Oulu) have a broad research program in ionospheric and magnetospheric physics, including observations from both ground-based and satellite instruments. This program is conducted in

extensive national and international collaboration with several foreign institutes.

University of Oulu has a co-investigator status in the electric field instrument of the Polar satellite mission and in the EFW and RAPID instruments of the Cluster-2 mission. The Cluster satellites were successfully launched in 2000, and they have already provided observations that have been used in research. The group also participates in analysing data from other satellites like Astrid-II. Experiments have been designed for the Cassini satellite, which is still on its way to Saturn.

University of Oulu is engaged in continuous support and development of ground-based instrumentation. The magnetic field of the Earth is measured both in Sodankylä and the Oulujärvi site using TPM and FGE magnetometers. A network of search-coil magnetometers for pulsation research is operated with most of its instruments in Scandinavia and one on Crete. The optical equipment

consists of 4 scanning photometers, 5 auroral TV cameras and a digital all-sky camera. One of the photometers is continuously operated in the Chinese base Zong Shan in Antarctica and it was recently expanded by an extra channel. Two of the TV cameras are new highly sensitive digital instruments. The instrumentation working on radio frequencies consist of VLF receivers, an ionosonde, and a riometer chain. An imaging riometer (IRIS) installed in Kilpisjärvi by Lancaster University is operated in conjunction with Sodankylä Observatory. Construction of a meteor radar, an MST radar and a new ionosonde, as well as installation of a chain of satellite receivers for ionospheric tomography has been in progress for some time.

New ideas have been applied in the EISCAT radars. A portable receiver was developed which can be connected in parallel with the standard receiver. With this equipment the incoherent scatter signal (together with the transmission signal) can be collected for later processing. The procedure has considerable benefits; for instance the ground clutter can be eliminated more effectively than in the standard hardware. In addition to incoherent scatter work, the method was used in search for space debris. New radar modulations with 22-bit and 5-bit codes at different frequencies were tested.

Both the EISCAT radars on mainland and on Svalbard and the ionospheric heater in Tromsø were used in ionospheric and auroral research. The dynamics of auroral arcs were investigated using observations from incoherent scatter radars, optical instruments and, partly, the Cluster satellites. Three-dimensional current systems of auroral arcs were calculated. Auroral arc thickness and Pedersen conductivities were estimated and a good agreement with the theoretical prediction of the magnetosphere-ionosphere coupling model was found. The IRIS riometer were used together with EISCAT and optical measurements to study cosmic noise absorption adjacent to auroral arcs. Electron density increase in the D region was the main agent for absorption and no evidence for the role of E region plasma irregularities were found. Proton auroras were observed using the optical equipment, and they were compared with satellite-based

particle and UV observations. Green, red and blue emissions from artificial aurora generated by the ionospheric heater were observed simultaneously for the first time at high latitudes.

The ionospheric Alfvén resonator was extensively investigated by means of ground-based magnetometers, the EISCAT radar and the ionospheric heater. The heater was used for producing artificial magnetic pulsations in the resonator, and profiles of ionospheric plasma parameters given by the incoherent scatter radar allowed the calculation of the resonator properties.

VLF measurements were carried out in connection with EISCAT and ionospheric heating campaigns. Artificial VLF signals caused by the heater were observed. Data analysis is going on together with English and Russian scientist within an INTAS project.

A method was developed which allows determination of the anisotropy parameters of ionospheric irregularities from scintillation of a satellite signal observed on the ground. Comparisons with the electric field determined by the EISCAT radar indicate that the irregularities are elongated in the field direction. Irregularities most probably generated by the ionospheric heater were also observed.

Properties of the structured and unstructured Pc1 pulsations observed during 18 magnetic storms at Nurmijärvi and Sodankylä were analysed. While unstructured pulsations are only weakly affected, structured pulsations were found to nearly vanish on ground despite strong wave activity in space. The observed latitudinal similarity of structured Pc1's and the daily evolution of their frequency was found to be against the expanding plasma-pause model. Instead, the observations could be explained in terms of the ionospheric resonator and propagation conditions, which are deteriorated during the storm main and early recovery phases. Storms were divided into two intensity groups according to the Dst minimum. The great depletion of structured Pc1s on ground during the storm main and early recovery phases was found to be even more dramatic for intense storms.

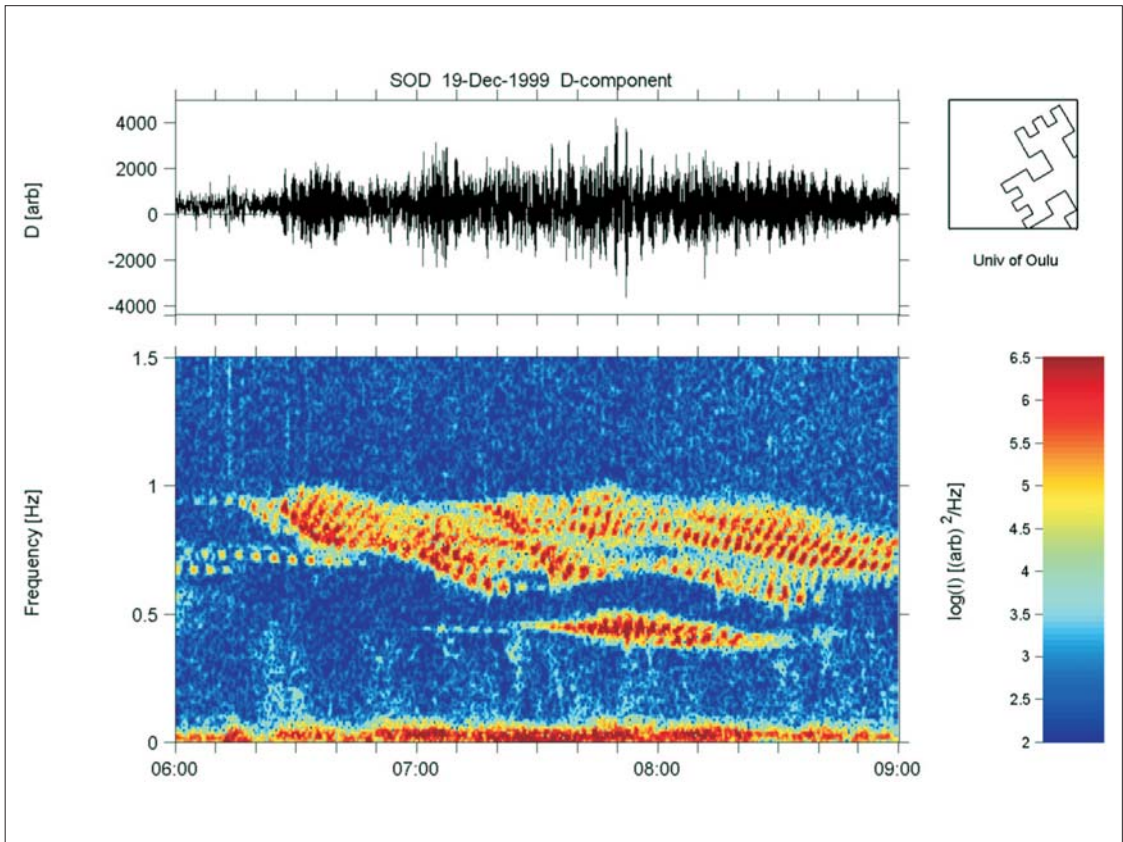


Figure 4.3. Pc1 pulsations observed in Sodankylä. The upper figure shows the recorded signal and the lower panel the spectral features at frequencies lower than 1.5 Hz.

Electromagnetic ion cyclotron (EMIC) waves were observed by the electric field instrument on Polar satellite when simultaneous Pc1 pulsations were detected at Sodankylä within ± 1.5 MLT hours. In 70% of 44 satellite passes, EMIC waves matching with ground Pc1's were observed, showing that Pc1's indeed originate at high altitudes in the magnetosphere and have their source field line within a rather limited MLT range. This also limits horizontal ducting of waves and gives a lower limit on the MLT extent of a typical EMIC wave band in space. On April 25, 1997, Polar was in a conjunction with Sodankylä and observed two EMIC wave bands matching with ground Pc1's. The lower band consisted of repetitive bursts which were observed on ground as a Pc1 pearl band. The equal repetition periods and lack of dispersion between

the two Polar bands, as well as the observed wave velocity were found to be in conflict with the bouncing wave packet model. Instead, ample evidence was found for the ULF modulation of Pc1 pearls. EMIC waves were accompanied by long-period ULF waves and plasma density variations that had a period close to the repetition period of the simultaneous EMIC bursts.

University of Oulu is in charge of the Finnish Graduate School in Astronomy and Space Physics, which is a network including all astronomy and space physics units in Finland and sponsored by the Academy of Finland. A total of 13 graduate students receive their support through the Graduate School, four of them at University of Oulu (two in astronomy and two in space physics).

4.2 Solar system research

Finnish Meteorological Institute, Geophysical Research (FMI/GEO)

The solar system exploration at FMI/GEO is focusing on the planetary atmospheres, magnetospheres and cometary research, as well as on the Sun and large scale structure of the solar wind. Exploration efforts are strongly based on accurate observations performed by sophisticated instrumentation. FMI has adopted a strategy to cover the full chain of scientific exploration starting from the instrument development and hardware building, through measurements and data analysis, to the scientific interpretation utilizing theoretical and numerical simulation methods.

During the years 2000–2001 the focus of FMI/GEO's planetary group has been in design, production and timely delivery of various instrument models associated with mission development cycles. Several of these missions will reach operational phase in the time frame of 2002–2007 begin to produce new observational data. FMI/GEO has

significant instrumentation in three ESA missions to be launched in 2003 (Rosetta, SMART-1, and Mars Express). Two cometary missions, Stardust and Contour, will provide information about the dust-plasma interactions on comets. The Huygens probe on the Cassini mission will land on the Titan moon of Saturn in 2005, and toward the end of the decade, the four NetLander surface stations to Mars will start to produce new data.

The key collaborating research institutions are The Swedish Institute Space Physics both, Uppsala and Kiruna divisions, the Jet Propulsion Laboratory of NASA, Service d'Aeronomie in France, Max-Planck-Institut für Aeronomie-Lindau and Max-Planck-Institut für Chemie-Mainz, Deutschen Zentrum für Luft- und Raumfahrt, DLR, and the Universities of Helsinki and Oulu.

A significant portion of FMI's planetary research is presently conducted through two FMI/GEO-led consortia in the ANTARES programme: The DAPSS (Dust, Atmospheres, and Plasmas in the Solar System) consortium with participation of the

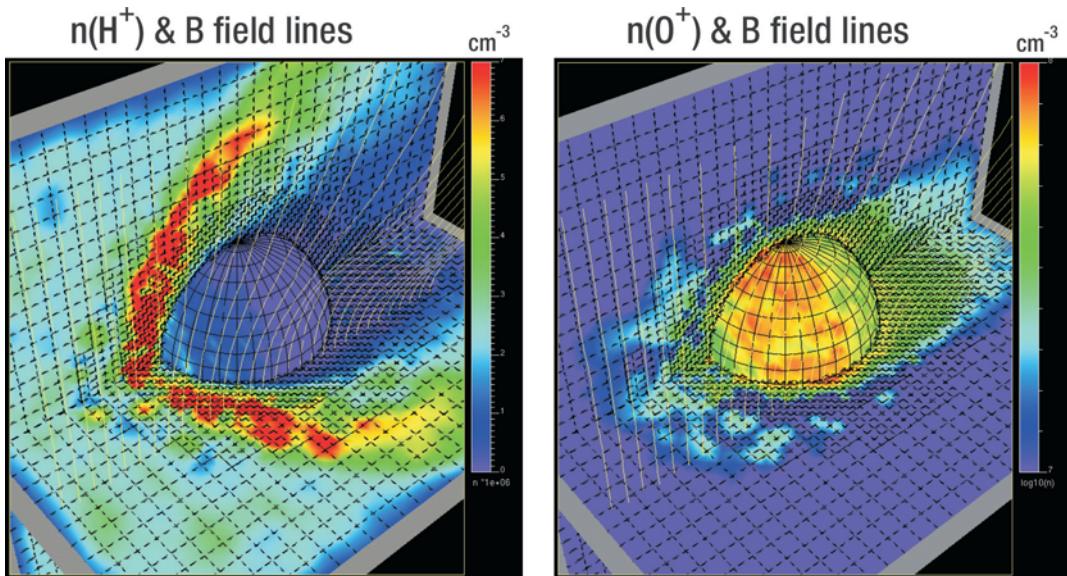


Figure 4.4. Oxygen ions escaping the Martian atmosphere. The two panes describe the density of the solar wind close to the planet (left panel), and the density of oxygen ions escaping the atmosphere (right panel). The results have been calculated by a global particle model developed at the FMI/GEO.

Department of Physical Sciences of University of Oulu and the MSW (Mars Small-Scale Weather) consortium with participation of the Department of Physical Sciences of University of Helsinki

The Martian atmosphere and its interaction with the solar wind is a focal area at FMI/GEO's planetary studies. Atmospheric modelling and instrument development have been pursued since 1988. Also studies of the dynamics of the Martian magnetosphere, and the energetic neutral atoms have a central role in FMI's investigations. Results coming from the Martian plasma environment, which is much smaller than its terrestrial counterpart, are also utilized to shed light on the physics of the terrestrial magnetosphere.

The forthcoming ESA's Mars Express Mission slated for launch in 2003 has heavily employed FMI's planetary team. FMI/GEO is responsible for a plasma physics experiment on the Mars Express Orbiter (ASPERA-3), and for atmospheric pressure observation system onboard the Beagle 2, the landing component of the Mars Express.

As of year 2000, together with University of Helsinki Division of Atmospheric Sciences FMI/GEO is implementing a 3-D Mars Local Area Model (MLAM). The MLAM is based on the weather forecast model HIRLAM in operational use, e.g., in Finland.

FMI/GEO initiated the NetLander 2007 Mars mission, which consists of four Martian landers. Each lander includes a network science payload with instrumentation for studying the interior of Mars, the atmosphere and the subsurface, as well as the ionospheric structure and geodesy. In the years 1998–2001 FMI had a key role in the Mission by being responsible for the central computer of the NetLander as well as the atmospheric instrumentation.

In the year 2000 FMI/GEO initiated a new prototyping project called MetNet with the Russian space research organisations. MetNet is a new type of minilanders for future Martian Surface aimed at atmospheric investigations. The project is co-ordinated by FMI, who will buy essential development work from the BSC (Babakin Space Center). This project will select the proper lander con-

cept out of five conceptual candidates as result of extensive trade-off analyses, and will provide the feasibility of the concept for Mars by manufacturing a full scale prototype and exposing the prototype to qualification tests.

The Cassini/Huygens spacecraft has continued its flight toward Saturn and Titan along the planned routes. The main areas of FMI interest in the mission are Saturn's atmosphere, Titan's atmosphere and surface, Icy satellites, Saturn's ring structure and Saturn's magnetosphere. The Huygens probe will descend on the surface of Titan in 2005, making in-situ measurements of the atmosphere and the surface of Titan. Onboard Huygens there is the PPI – Pressure Profile Instrument – developed by the FMI/GEO team. The PPI is part of the Huygens Atmospheric structure Instrument (HASI). It is functioning perfectly and ready for the descent into Titan's atmosphere.

FMI is the PI group of the experiment (Spacecraft Potential, Electron and Dust Experiment) in ESA's SMART-1 mission. SMART-1 is an important step towards further space exploration, where the new propulsion technique (ion thruster) and other advanced technologies will be tested. The purpose of this mission is also to collect valuable information about the Moon that could improve our understanding of the evolution of the Solar System. SPEDE will complement the monitoring system of the spacecraft surroundings and provide observations of the Lunar environment.

Cometary research at FMI utilizes the remote observations with the Lyman-alpha Solar Wind Anisotropy (SWAN) instrument onboard SOHO and near-by or in situ measurements on Rosetta, Stardust and Contour missions.

The ESA cornerstone mission Rosetta will be launched to comet 46P/Wirtanen in January 2003 and have a cruise time of about eight and a half years. The primary scientific objective of Rosetta is to study the cometary material with several instruments in order to gain unique information on primordial material and the formation of the solar system. In addition to the main payload (Rosetta Orbiter) the mission contains a landing element (Rosetta Lander) which is built by a German-lead

consortium. The Lander will analyse chemical and physical properties of the comet as well as take detailed pictures of the surface.

FMI/ GEO has several contribution in the various elements both on the Orbiter: COSIMA (Cometary Secondary Ion Mass Analyzer), MIP (Mutual Impedance Probe), LAP (Langmuir Probe), and ICA (Ion Composition Analyser), as well as on the Lander: PP (Permittivity Probe) and Lander's mass memory system (CDMS/MEM). Furthermore the group provides ground support systems for COSIMA, PP, and MIP.

The first in situ observations of interstellar matter with CIDA (Comet and Interstellar Dust Analyzer) onboard NASA's Stardust spacecraft (launched in

1999) have been analyzed. The main goal of Stardust is a flyby of comet Wild 2, where it will gather cometary and interstellar dust samples and return them to Earth. An evolution model of the CIDA will also be one of NASA's Contour mission instruments. The software of CIDA is developed by the Finnish Meteorological Institute.

The Lyman-alpha instrument SWAN onboard SOHO contributes several ways in the solar system research at FMI/GEO. During the period 2000–2001 the most striking results came from its use in cometary research. First, a comet, that was missed by all other observatories, was found in retrospect in the southern sky. Thereafter, comet S4/Linear broke in the summer of 1999 and SWAN observations were essential in determining details of the

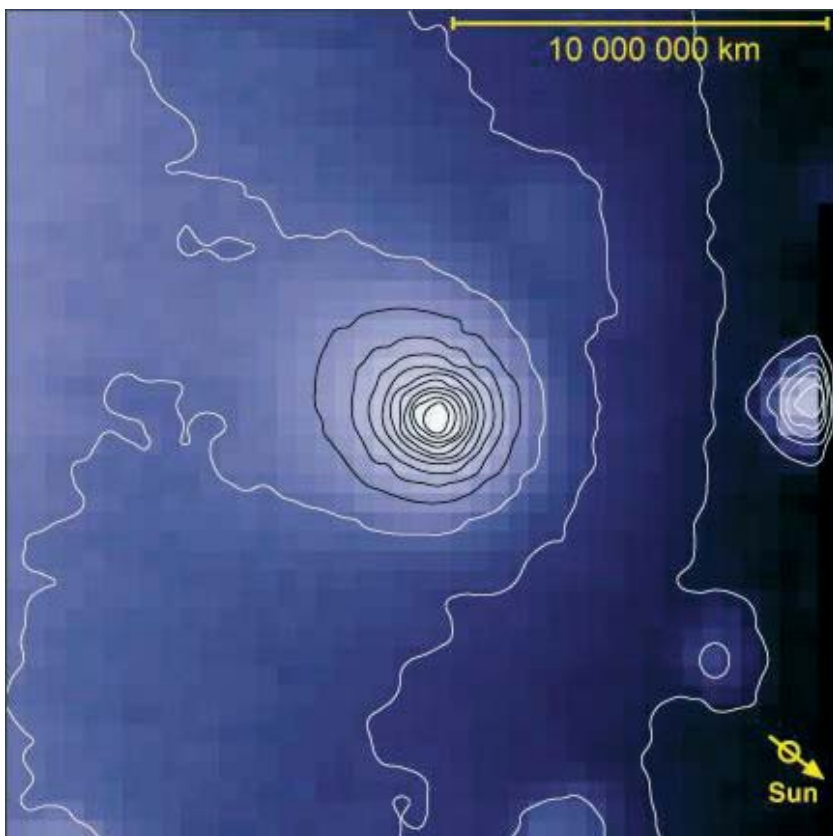


Figure 4.5. The picture (taken by the SWAN instrument) of the huge hydrogen sphere around the comet C/1999 S4, which disintegrated during the summer 1999. The varying size of the hydrogen sphere during the disintegration process gave new information about the internal structure of the comet.

process, in particular the water content of the breaking comet. These findings led to publications in the prestigious magazine Nature and Science.

SWAN's basic task is to investigate the large-scale structure of the solar wind, where it has shown, e.g., that solar wind is isotropic during the active periods of the 11-year solar cycle, but when the Sun is calm the solar wind intensity is higher at the plane normal to the Sun's rotation axis. SWAN has also demonstrated that Lyman-alpha observations scattered by the interplanetary hydrogen can be used to monitor solar activity taking place on the farside of the Sun. This is an additional piece of information that potential for intermediate-term space weather predictions.

University of Helsinki, Department of Physical Sciences (UH/PHYS)

As reported under the heading "Magnetospheric and ionospheric research" the studies of solar ac-

tivity and in particular the physics of CMEs have become one of the main research topics of the space physics group of the Department of Physical Sciences of the University of Helsinki. The reason is that to understand, and in future to reliably predict, the magnetospheric space weather we must learn more about the Sun. The first results of CME-related research of the group were communicated in several conferences of this reporting period and the first peer-reviewed article was accepted for publication in 2001. Solar physics also belongs to the teaching programme of the Department.

Another joint research line between UH/PHYS and FMI/GEO are the studies of Martian meteorology that are currently conducted under the envelope of the MSW project of the ANTARES programme reported under the FMI planetary research section above. Recently UH/PHYS has also joint the team preparing a proposal for the X-ray studies of Mercury in the ESA BepiColombo mission.

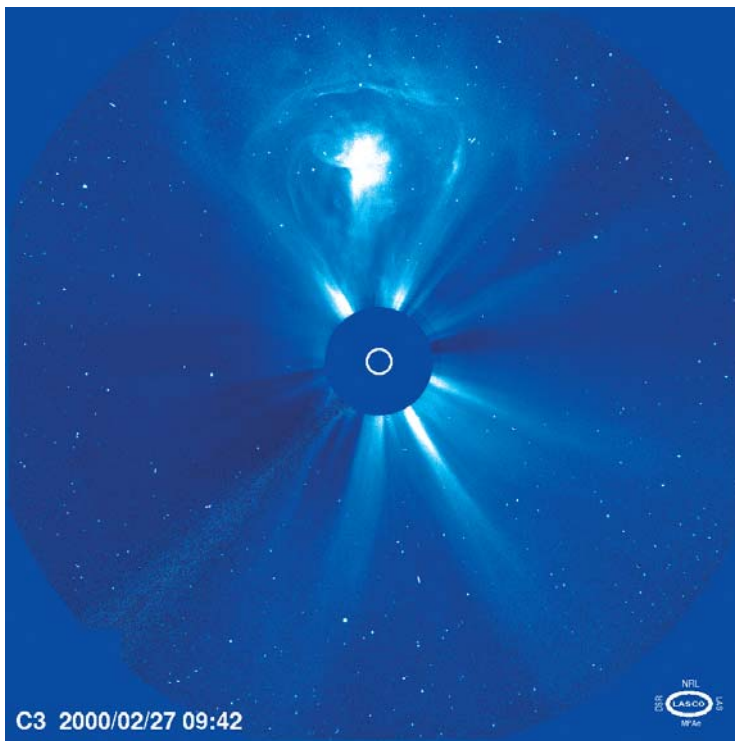


Figure 4.6. A SOHO/LASCO image of a coronal mass ejection.

**University of Turku,
Space Research Laboratory (SRL)**

Solar cosmic-ray studies have been the main field of research at the Space Research Laboratory (SRL) during 2000–2001. The ERNE (Energetic and Relativistic Nuclei and Electron) experiment on the SOHO spacecraft has been the primary instrument for observations of solar energetic particles (SEPs) associated with solar flares and coronal mass ejections (CMEs). In the beginning of 2001 the Space Research Laboratory and Tuorla Observatory joined and formed together the Väisälä Institute for Space Physics and Astronomy (VISPA). The goal of VISPA is to combine existing theoretical, observational and technical skills to attack key emerging problems in astrophysics and space science.

After more than 4 years of operation the first major science software update of ERNE was conducted in April 2000. The update introduced, among other things, three-fold increase in the resolution of the onboard measured energy spectra. This became feasible as the mass resolution of the onboard measurement had proven to be much better than anticipated and thus the corresponding telemetry was freed to other purposes. Other changes improved anisotropy measurement, heavy isotope measurement under increased particle intensities and pulse-height analyzed data packing.

Measurements of solar energetic particles with the ERNE and data from other SOHO telescopes have revealed that the lift-off of impulsive CMEs is accompanied by its coronal counterparts, soft X-ray flares and coronal shocks, and those counterparts accelerate first protons escaping into the interplanetary space. Such CME-lift-off associated acceleration creates a necessary condition (the seed particle population) for the subsequent interplanetary CME acceleration. For example, abundance of ^4He -nuclei compared to protons in the energy range up to 100 MeV/nucleon was exceptionally high during the particle events on May 27, 1998, and December 28, 1999, indicating their flare origin. There was also a prolonged enhancement of the isotope helium-3. Observations of EIT and LASCO onboard SOHO confirm that the originators of both SEP events were western hemisphere solar eruptions, flares and coronal mass ejections. The onset of the SEP release took place close to the maximum of

flares, which were triggered behind the rising CMEs. The case studies support a kind of ‘closed-chain scenario’ that is an early rise of CME triggers the X-ray flare that starts coronal wave and other processes, which in its turn initiate particle acceleration at different coronal altitudes. The coronal particle acceleration is triggered by the coronal counterparts of CME and followed by a long-term acceleration at CME in the interplanetary medium.

Statistical investigation of SEP-CME correlation by SRL team came to a conclusion that the near-Sun dynamics of CME is a significant factor contributing to the intensities of (10-MeV proton events). A typical SEP-producing CME experiences fast acceleration close to Sun in association with soft X-ray flare and coronal shocks. The joint analysis of data sets of different SOHO instruments brings out a promising direction for the SEP-CME investigations.

Theoretical research at SRL included a project “Non-linear effects in cosmic-ray acceleration and transport”, funded by the Academy of Finland. In this project the back-reaction of accelerated particles on the turbulent medium in space plasmas was studied. The project has led to an update of SRL’s existing numerical models for acceleration and transport of energetic particles, so that self-consistent transport and acceleration conditions can now be simulated. First scientific results from the numerical simulations obtained in 2001 described the coupled evolution of electromagnetic turbulence and accelerated protons in solar gamma-ray flares and around astrophysical shock waves.

Efforts to understand energetic-particle transport in the solar corona and interplanetary space led to the conclusion that energetic particle observations can give valuable constraints on the models of coronal heating and acceleration of solar wind by plasma waves. This is because precisely the same waves that heat and accelerate the solar wind plasma, also influence the propagation of energetic particles through the interplanetary medium. The first study on the subject in 2001, pointing out the connection between energetic-particle and solar wind studies for the first time, also led to a development of a wave-heating model for the solar corona.

Both the non-linear cosmic-ray transport modeling and the solar-wind modeling have been conducted in close collaboration with the Institut für Theoretische Physik in Ruhr-Universität Bochum (Germany), funded by the European PLATON network and the Academy of Finland during the year 2001.

Funded by the ANTARES programme of the Academy of Finland, a space weather research project was started in 2001 in collaboration with several Finnish institutes (SWAP). In the context of SWAP, space weather is studied by using energetic particles as the primary tool. The first goal is to identify energetic particle signatures of geoeffective coronal mass ejections based on the extensive data from the SOHO instruments. The research will then be expanded to the more general problem of energy coupling of the Earth's magnetosphere to solar-interplanetary disturbances through studies of penetration of energetic particles and acceleration of new particle populations in the magnetosphere. Dynamics of electron and proton fluxes in the inner and outer radiation belt are key aspects to be studied. For this purpose, new instrumentation capable for precise measurements of electron and proton spectra in a wide energy range in the harsh environment of radiation belts has been designed in close collaboration with a private spin-off company.

The work with building the Alpha Magnetic Spectrometer (AMS) phase II detector continued at the Space Research Laboratory. Since the AMS test flight in 1998 the main emphasis at SRL has been the co-ordination of the Finnish industry activities for AMS construction. The AMS phase II detector is planned to have a three-year flight starting on early 2004.

**University Of Oulu,
Department of Physical Sciences,
Division of Astronomy**

Planetology, especially the study of terrestrial planets including remote sensing and impact crater approaches, has become one of the main topics within the fields of space sciences at the University of Oulu. This topic is also a part of the fast-growing activities of the joined Space Institute and Sodankylä Geophysical Observatory. Consequently, the agreement between NASA and University of Oulu

for the Nordic Regional Planetary Image Facility was recently renewed.

Vice versa, the modern approaches in planetary science have been made possible through the access to the data provided by the various space missions. The co-operation between NASA and the Nordic Regional Planetary Image Facility of Oulu has ensured the availability of the detailed new planetary data sets and to provide this data for Finnish, European and Russian scientists as well as for the local schools, media, and public.

Studies of Martian photometry and tectonics has been continued with the recent (Mars Global Surveyor etc.) data sets. Participation in the Mars programme (e.g. Mars Express) also continued. The Co-I status in the Mars Express HRSC-SRC instrument group has led to various studies on Martian surface units in order to understand their history and development in details. The large Hellas Basin, for example, was found to have been especially important in the early history of Mars. It seems to provide traces of almost all Martian evolutionary elements within a rather restricted area.

Venus research using Magellan data sets was continued with studies of Venusian stratigraphy, resurfacing, tectonics, volcanism, and lithosphere. The Oulu group has also participated in the Venus Express mission (VENSIS) preparation work as well as in BepiColombo Mercury mission (HERMES-X & MEMORIS) planning.

Certain interdisciplinary topics between astronomy and geology have resulted in studies in impactite chemistry and mineralogy. The Planetology Group of Oulu, together with the Vernadsky Institute of Moscow, arranged the Nordenskiöld expedition to the Kara impact crater in the Russian arctic in the summer of 2001. The field work provided important samples and observations of this impact crater which may have been far more important in respect of the K/T boundary event than what was previously known. The Kara crater will also be studied and compared with the major Martian impact craters in order to gain additional understanding of the early Martian environment.

The Group is a part of the European Science Foundation (ESF) program “IMPACT – Response of the Earth System to Impact Processes”. Impactite rocks and minerals give information of the impact phenomena. Studies of impact craters, impact mineralogy, and impact-induced aspects on surfaces of terrestrial planets are continued.

Remote sensing studies continued to amplify different planetary approaches. They have widened the perspective by providing a possibility to adopt field true data for evaluation of the result correctness. Planetary remote sensing has increased our interest in environmental problems which have been studied over several terrestrial areas. Various remote sensing approaches have been applied to study several planetary aspects. Lunar structures, for example, have been studied using the Clementine data. Additional knowledge in geophysics has provided an insight into the Venusian crust and lithosphere, and helped to map it in order to monitor its parameters.

**University of Oulu,
Department of Physical Sciences and
Sodankylä Geophysical Observatory**

Heliospheric research of the Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory of the University of Oulu (in brief: University of Oulu) includes ground-based and underground cosmic ray measurements, long-term satellite measurements of solar wind and interplanetary magnetic field, and satellite missions. Solar research is directed to the analysis of long-term evolution of solar activity (so-called space climate), especially its periodicities at different time scales and its asymmetric structure.

The cosmic ray nucleon component has been measured continuously at the Oulu cosmic ray station since 1964. Oulu neutron monitor is one of the most stable and reliable stations of the world-wide cosmic ray network. An on-line database was created to serve the distribution and use of Oulu monitor data (see <http://cosmicrays.oulu.fi>). Galactic cosmic rays are subjected to heliospheric modulation which results in changes in the intensity and spectrum of cosmic rays detected on Earth. Thus variations of cosmic ray intensity can be used to

study the large scale changes in solar/heliospheric conditions. In order to study modulation theoretically, 1D and 2D numerical models of heliospheric transport of cosmic rays was developed which use stochastic simulation.

University of Oulu has built and installed a multi-level (0 m, 90 m and 210 m underground) muon experiment in Pyhäsalmi mine within the framework of the CUPP (Centre for Underground Physics in Pyhäsalmi) project. The experiment is intended to study the energy distribution of energetic cosmic rays up to the knee energy region. Currently, the experiment is in a test run.

The long-term evolution of sunspot activity has been reanalyzed. A persistent 22-year cyclicity with stable phase and amplitude was found in the 400-year long sunspot record and was interpreted to be due to a weak constant relic magnetic field in the Sun. It was argued that one full solar cycle was lost in late 18th century because of sparse and non-reliable observations. Including the missing cycle removes the problems related to solar evolution across the Dalton minimum. Production of sunspots was simulated by a model which can reproduce the main features of sunspot activity during both high solar activity and great minima, only changing the intensity of the dynamo field.

The long-term properties of solar wind and geomagnetic activity were studied. It was found that the annual variation in geomagnetic activity was strong during the high-activity solar cycles in mid-19th century and since 1930's. This annual variation results from a north-south asymmetry in SW speed distribution across the heliographic equator. Accordingly, the result implies that the Sun is persistently north-south asymmetric. The north-south asymmetry was found to be opposite in mid-19th century from the present suggesting for a new form of century-scale oscillation in the north-south asymmetry of the Sun. The asymmetry was explained in terms of a relic magnetic field, dislocated slightly in the north-south direction from the heliographic equator. Hence the change in the asymmetry would result from the century-scale north-south oscillation of the location of the relic field across the ecliptic.

Furthermore, the group participates in the CAPS instrument project of the Cassini mission to Saturn, with the main responsibility in the ion beam sensor (IBS). Calibration runs for the IBS-instrument were compared with simulations for the instrument performance. First measurements by the instrument were obtained for analysis and instrument calibration and testing. All CAPS sensors are functioning as expected. The Cassini probe will reach its destination in 2004.

University of Helsinki Observatory (UHO)

The planetary research at the University of Helsinki Observatory (UHO) includes both participation in observations programmes and theoretical studies on certain problems relevant to modern solar system studies.

UHO has two important contributions to the ESA SMART-1 mission: The group has a Co-PI status in the D-CIXS/XSM X-ray instrument. XSM (X-ray Solar Monitor) is the calibration instrument for the D-CIXS imaging spectrometer, and also does independent science by providing a long time series of coronal spectra of the Sun. The instrument has

been designed and built in Finland. The second contribution is in the science validation and calibration of the AMIE camera observations of the Moon (visual wavelengths).

In Mars Express UHO participates in the High-resolution spectral camera (HRSC) experiment at a Co-I-level with the goal of developing new light scattering and radiative transfer algorithms which help in assessing the properties of small particles in the Martian atmosphere. Both SMART-1 and Mars Express will be launched in 2003.

Furthermore, UHO participates in the Microgravity experiment ICAPS (Interactions in the Cosmic and Atmospheric Systems) on board the ISS. ICAPS is now under the phase A study. Microgravity enables a construction of very fluffy structures which are met in the cosmic dust particles.

In fundamental planetary physics, UHO theoretical research has been focussed on scattering and absorption of light by single small particles and by particulate media, and the celestial mechanics of the few-body problem, whereas experiments have

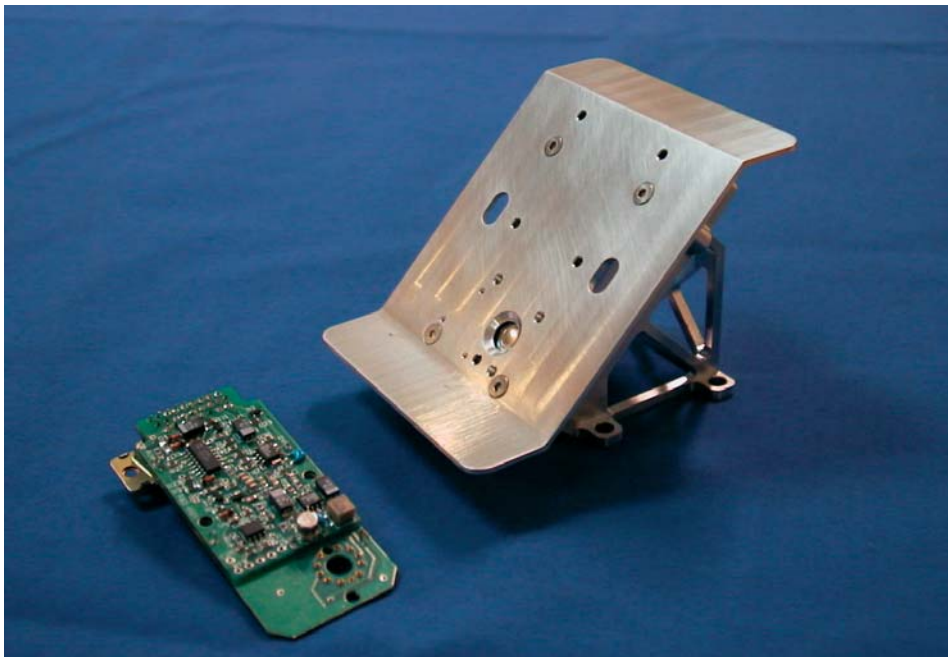


Figure 4.7. SMART-1 XSM Flight Model and the sensor unit electronics board.

been carried out to measure backscattering characteristics of particulate media (scattering laboratory at the Observatory; in connection to ISS/ICAPS). These measurements have comprised both laboratory and outdoors research (studies of snow). Recent results indicated that snow shows coherent-backscattering-type enhancement of intensity near zero phase angle (backscattering direction). Light scattering by stochastically shaped particles (in particular, Gaussian random particles) was reviewed for a cornerstone book on Light Scattering by Nonspherical Particles (Academic Press, 2000). Advances were made in light scattering by Gaussian random cylinders and wood fibers. Scattering by Gaussian random spheres was studied using the second-order perturbation series, the discrete-dipole approximation, as well as the variational volume-integral-equation approach. The years 2000–2001 have been groundbreaking in inverse light scattering problems concerning asteroids as well as small particles.

UHO has developed techniques for statistical determination of asteroid orbits, for the computation of collision probability of near-Earth objects, for the simulation of space-based search programmes, for lightcurve inversion of physical properties of asteroids (e.g., rotation and shape, microscopic surface properties), and for time-series analyses. The applications include, e.g., the impact hazard from near-Earth objects, interpretation of lunar visual and X-Ray imaging during the SMART-1 mission, time-series analysis problems, and industrial monitoring systems. For example, UHO demonstrated how the rounding of terrestrial impact crater ages introduces spurious (i.e., unreal) periodicities into such a series of time points.

UHO participated in the ASTROVIRTEL project, in which context crucial follow-up and precovery astrometric observations were obtained for the transneptunian object 2001 KX76. That object turned out to be the largest of all asteroids listed up to date. UHO has recently taken a task-leading role in asteroid orbit determination and prediction for the ESA astrometric cornerstone mission GAIA.

UHO presented new, robust methods for deducing the shapes, rotational states, and scattering properties of large irregular bodies from their lightcurves.

The results showed complete agreement with the existing space-probe images and radar-based models of asteroids. It was further shown that the dynamical parameters of an object in a complex rotational state can also be deduced from photometric data. UHO developed a new orbit integration scheme for solar system dynamics that is especially suitable for including nonconservative forces.

UHO published rigorous numerical techniques for the computation of the collision probability between asteroids and planetary bodies. In contradistinction to earlier techniques by others, the new one accounts for the full six-dimensional nonlinear probability density of the asteroid orbital elements. The technique relies on the so-called statistical ranging method of asteroid orbit determination, the only robust orbit determination method for short-arc asteroids also developed at UHO (to be applied in connection to GAIA).

Multiwavelength ground-based observations of cometary polarization are currently modelled both with irregular solid particles and fractal aggregates and very good fits have been obtained to the data. In this connection new methods have been devised to model both aggregate structures and solid particles.

A comparative, partly semiempirical study of the opposition effects for atmosphereless solar system bodies was carried out using a statistical, inversion-theoretical technique. Studies of the shadowing mechanism for the opposition effect were continued via numerical simulations. At UHO, a scatterometer was constructed for zero phase measurements of terrestrial materials, and is being used in both laboratory and field measurements. The device consists of a light source (laser or white), linear polarizers for both incident and emergent light beam, and a beamsplitter to reach the smallest phase angles. The device has been used this far for e.g. powders, sand, snow, and meteorite rocks.

Some of the planetary studies have direct applications in industrial processes. In a close connection with the National Technology Agency, Department of Physics of the University of Joensuu and

the Technical Research Centre the UHO has modelled some industrial products like paper coatings for ideal light scattering. The purpose of this work is to improve the quality of paper. Interestingly enough light scattering by coatings is close to a problem of reflection of light from planetary regoliths. Together with ABB Corporate Research, a Gaussian (or lognormal) wood-fibre model was published, including the successful estimation of the statistical parameters using angular light-scattering measurements at DLR-Stuttgart. UHO participated in extensive measurements of

scattering matrices (at the Free University of Amsterdam) for atmospheric aerosol particles and, as a pioneering achievement, contributed to a successful interpretation of the measurements using ray optics treatment for Gaussian random particles. Those two works were examples of inverse light scattering problems, where particle physical

properties are derived from laboratory measurements of their scattering characteristics. They suggest a bright future for inverse scattering problems.

**Helsinki University of Technology,
Metsähovi Radio Observatory**

A 14 metre radio telescope at Metsähovi Radio Observatory has been used for solar research. Metsähovi ground based observations at 22, 37, and 90 GHz have been used in connection with several satellite campaigns. X-ray data from GOES, Yohkoh, and GRO/BATSE satellites have been used in comparison with Metsähovi measurements.

Metsähovi has a Co-investigator status in the ERNE team in the SOHO mission of ESA. SOHO EIT instrument images have been used in the study of solar polar features at millimeter wavelengths.

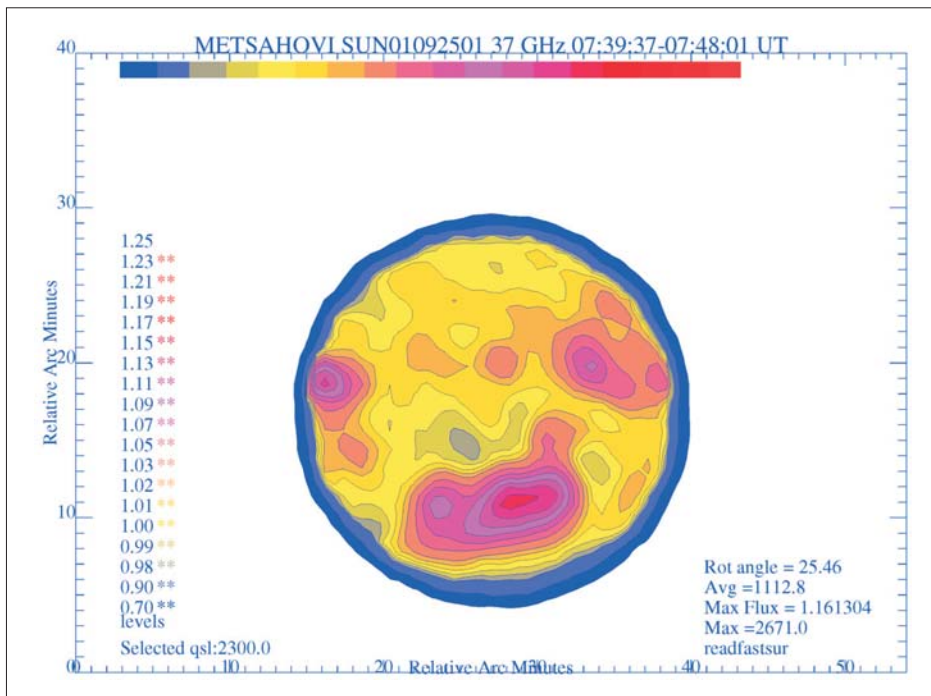


Figure 4.8. Solar radiation map at the frequency 37 GHz measured at Metsähovi Radio Observatory on September 25, 2001.

4.3 Astronomy

University of Helsinki Observatory (UHO)

The activities of the Interstellar Medium and Star Formation research group include the evolution of dust and molecular gas in interstellar clouds, the formation of protostars in dense molecular cloud cores, radiative transfer and magnetohydrodynamic (MHD) modelling of interstellar clouds, and star formation history and dust emission at high redshifts. The group is following a multi-wavelength observational approach where top-class spaceborne and ground-based infrared, (sub)millimetre, and

radio telescopes are being utilized. The two most important observational facilities have been ESA's Infrared Space Observatory (ISO) and the Swedish-ESO Submillimetre Telescope (SEST) at ESO/ La Silla. The launch of the Odin satellite in February 2001 has opened up an important new and unique research opportunity for the group. Based on its ISO experience, the group is participating since 2000 in the Planck Surveyor science projects.

Using ISOPHOT far-IR maps of several very dark patches in the sky we have been able to detect new extragalactic sources and perform galaxy counts at

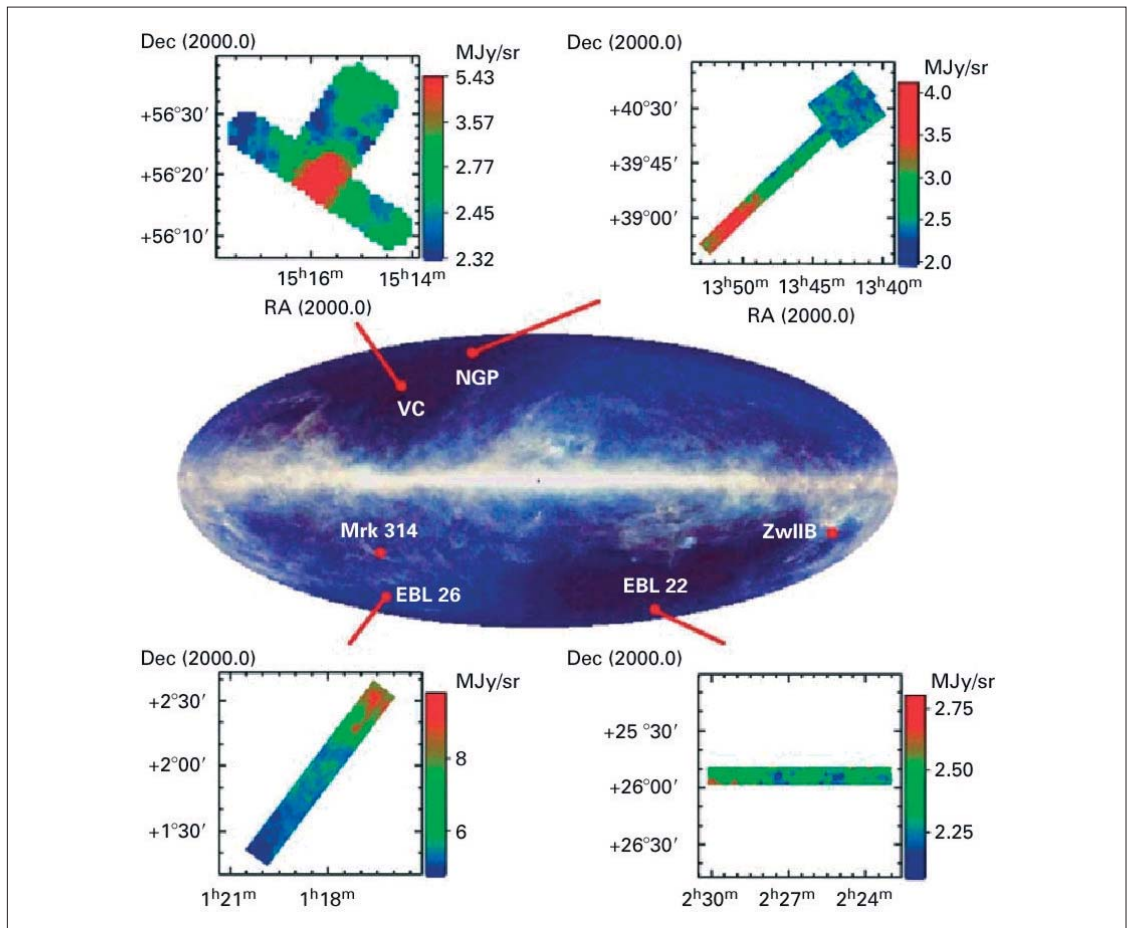


Figure 4.9. The project ISOPHOT CIRB (Cosmic Infrared Background Radiation) was carried out by Helsinki Observatory in collaboration with the Max-Planck-Institute für Astronomie, Heidelberg. Eight fields with a total area of about 1.5 square degrees have been mapped at wavelengths of 90, 150, and 180 μ m. The goal of the project was to determine the number of objects and their luminosities.

90, 150, and 180 μm . The sources already detected form a substantial part of the cosmic infrared background radiation. Extensive galaxy counts at the near-IR J and K bands have been performed in two large fields, which were included in the joint European Large Area ISO Survey (ELAIS). The ISO mid infrared galaxy counts have been used to estimate the source confusion noise expected for the NASA Space Infrared Facility (SIRTF) telescope. Based on extensive ISO far-IR mapping we have also analysed the dust properties and detected protostars and newly formed stars in several nearby molecular clouds, star formation regions, and globules. Using SEST we have carried out sev-

eral research projects which, in addition to their own scientific value, have served also as preparatory studies for the Odin satellite or as complimentary/follow up studies for our ISO projects.

The High Energy Astrophysics and Space Astronomy research group (HESA) is conducting astronomical research with existing science satellites, preparing hardware for upcoming launches, planning observing programmes for these, and developing instrumentation for future space missions. Fundamental research consists of preparing for scientific return (guaranteed time) from ongoing instrument projects (INTEGRAL, SMART-1),



Figure 4.10. INTEGRAL Flight Model at ESTEC (March 2002) waiting for launch. (F. Frontera, University of Ferrara, O. Vilhu, University of Helsinki and L. Amati, U. of Ferrara) Photo: S. Brandt.

complemented by data from satellites in orbit (e.g. XMM-Newton, Chandra, HST). The second part is a continuation to the hardware projects including research in detector and material physics, with active collaboration between several institutes.

The HESA group has studied a wide range of astrophysical topics, e.g., hard tails and superorbital periods of Low Mass X-ray Binaries, broad-band spectral modelling of microquasars and active galactic nuclei, spectral evolution and afterglows of Gamma-ray bursts, coronae and flaring in active stars and the Sun, and X-ray scattering from the lunar surface. In particular, the very broad spectral coverage (e.g. INTEGRAL) and the possibility for a very long monitoring (SMART-1 cruise phase), coupled to sophisticated theoretical modelling, are the key ingredients of our science programme.

The group has received observation time from astronomical satellites (ASTRO-E, XMM-Newton, Rossi-XTE, Chandra). The Nordic Optical Telescope (NOT) in La Palma, and MOST in Australia

have also been used by the group. On the theoretical side, genetic algorithms and mechanisms producing optical and X-ray polarisation have been studied. The coronal FeXXI 1354 line was analysed in AB Dor using Hubble data, thermal sombrero models were developed and applied for the microquasar GRS 1915+105, the 10 new sources found by BeppoSAX in the field of an X-ray transient were analysed, genetic algorithms were developed to map gas streams in close binaries and the multifrequency spectra (including COMPTON) and VLBI properties of 3C 279 were analysed in unprecedented detail and compared with models for gamma-ray production in relativistic jets.

Development of future instruments is natural continuation to the ongoing projects, where the group has gained experience, providing valuable access to the guaranteed time also in the future. The aim is to utilise advances in instrument performance carried along with bigger telescopes, larger field-of-view and decreased noise of new systems in the future plans of ESA (XEUS), individual countries

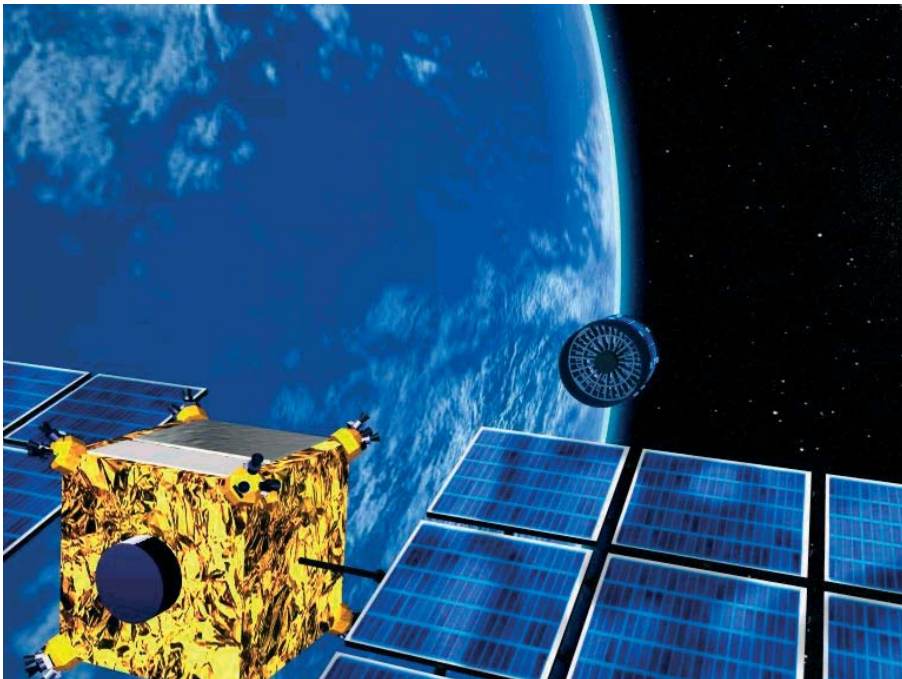


Figure 4.11. Flight configuration of the future X-ray mission XEUS (X-ray Evolving Universe Spectroscopy). The Detector Space Craft in front orbits the Earth at 50 m distance from the Mirror Spacecraft.

(Denmark, Russia, USA). The huge enhancement of sensitivity and spectral resolution with XEUS enables studies of X-ray spectra of Galactic sources with the same quality we nowadays can investigate the solar corona.

Flight Model detectors for the two units of JEM-X (X-ray monitor) of INTEGRAL have been delivered to ESA and successfully integrated to wait for the launch in October 2002. The project members are preparing within several fields of the core programme (guaranteed time) and participate in 7 AO-1 programmes. The characterization of the solar X-ray monitor (XSM) for SMART-1 is underway and the delivery will take place during 2002. XSM will offer long time series over two years of X-ray flaring, and methods to analyse the data are under development.

The design of the CDH (Command and Data handling) computers for the Danish ROEMER satellite has been finished and is waiting for the financial decision to build the flight computers as well. If successful, the project will have 2 months observing time (during 2 years) of the main MONS telescope, to observe stellar oscillations with high photometric accuracy, and to co-ordinate active star observations with the field monitor.

Development of X-ray calorimeter for XEUS has been made in jointly with at the University of Jyväskylä, Metorex International, and VTT. Progress in both areas has been achieved as planned. The ANTARES funding has been in a key role in this work. The IR-filter development work at the University of Joensuu, aiming at instrument thermal filters for XEUS, has also progressed as planned. New processing method for filter grid has been applied with success, leading to better transmission properties. Growth methods of TlBr crystals have been developed for the hard X-ray detector of XEUS. During 2002 a new travelling molten zone set-up for purification and crystal growth will be applied and characterized by X-ray powder diffraction, IR and UV-VIS spectroscopy.

Design of a GEM detector with double foil and two-dimensional readout board has been started and characterization of single foil GEM's continued. The complex gas analysis system has been re-

assembled and tested in the new laboratory of the Department of Physical Sciences (HU/PHYS) at the Kumpula Campus. The project has a Co-I status in the INSPIRE proposal for NASA/MIDEX programme (Nov. 2001), including a GEM X-ray polarimeter. Massachusetts Institute of Technology (MIT) has ordered two GEM detectors (a gas flow counter and a sealed one) from our industrial collaborator METOREX (with NASA funding).

**University of Helsinki,
Department of Physical sciences (UH/PHYS)**

The participation of UH/PHYS in astrophysical space missions has been based on specific skills in instrumentation or theory. On both sectors a close co-operation with Finnish and foreign astrophysics groups and with the Helsinki Institute of Physics (HIP) is an essential factor.

One of the leading fields in theoretical physics at UH/PHYS is cosmology and during the period 2000-2001 the cosmology group of the Division of Theoretical Physics and HIP became heavily involved in the Planck programme of ESA and the Planck consortium within the ANTARES programme is co-ordinated by UH/PHYS. In addition to the theoretical work on cosmic microwave background the group is actively participating in the development of the data analysis software of the low-frequency instrument (LFI) of Planck.

The Division of X-ray Physics and the Instrument Laboratory participate in development of various detectors used in high-energy astrophysics. These include the XSM and the GEM detectors discussed above under the HESA group of the UHO. Most recently the group has become involved in the preparation for the X-ray instrument (HERMES-X) for the BepiColombo mission of ESA.

**University of Oulu,
Department of Physical Sciences,
Division of astronomy**

The study of stellar activity as seen from surface maps has continued to be one of the main research topics of the group. We developed a new technique of stellar surface imaging from photometric observations to study the long-term behaviour of stellar magnetic behaviour. The Doppler imaging pro-

grammes at the Nordic Optical Telescope to study the cycles in several late-type stars continued.

T Tauri stars are young (age about 1 million years), solar mass stars, which are in most cases still surrounded by proto-planetary disks, and accrete matter from that disk. It was found that the T Tau star RW Aur shows non-axisymmetric accretion, most likely governed by a magnetic field. The asymmetry may be caused by an asymmetry in the magnetic field or by a small, brown-dwarf companion orbiting RW Aur.

The main observational instrument, the SOFIN high-resolution échelle spectrograph at the Nordic Optical Telescope at La Palma, Spain, has been used in many observing runs for the projects of the astrophysics group in Oulu as well as for collaborators from other universities all over the world. Several improvements made to the instruments increased the sensitivity considerably.

The development and application of a parallel 3D magnetohydrodynamics (MHD) numerical model was continued. The model is used to examine the fluid dynamics and evolution of structures at various spatial scales in a small box positioned within a magnetised astrophysical body (such as a star, a galaxy or an accretion disk). This model is currently being used to study turbulence within accretion disks, magneto-convection in stellar convection zones, and for various projects investigating turbulence, star-formation and the generation of magnetic fields in the interstellar medium.

Some late-type stars show strong water maser emission lines at 22 GHz. The research concentrated on modeling of the molecular disks around a spectacular class of stars, the so-called silicate carbon stars, and its best studied representative V778 Cyg. The proposed approach is based on the extreme sensitivity of the maser emission on the density of molecular hydrogen and the geometry of the masing material. Thus, modeling the water maser activity allows us to determine the physical parameters in the emitting region.

Gamma-ray bursts (GRBs) are the most powerful explosions in the universe. The group studies the bursts themselves as well as the faint, actively

star-forming galaxies, in which they occur. Observations from the ground as well as from the Hubble Space Telescope are used. A publicly available database containing 3906 GRBs found in a re-analysis of the BATSE data, has been created.

Black hole sources in our Galaxy are bright X-ray and gamma-ray emitters. With satellite observations and modeling, the spectra and their variations of the galactic micro-quasar GRS 1915+105 and the black hole source Cygnus X-1 have been studied.

University of Turku, Tuorla Observatory

Various studies to constrain the nature, distribution and kinematics of matter in the Milky Way, as well as the age and the chemical evolution of our Galaxy have been carried out using Hipparcos and HST data as well as computer simulations. The main results to date are that there is no dark matter in the Galactic disk and that low luminosity, low mass dwarf stars do not make up a significant fraction of the dark matter. This has allowed us also to measure the faint end of the stellar luminosity function in the disk and halo down to the hydrogen burning limit, and strongly constrained the amount of dark matter in low mass dwarf stars. This also permits the measurement of the solar vertical oscillation period which may be connected to the cratering record on the Earth. Hipparcos data has also been used for studying the kinematics and the dynamics of local galactic environment, and for calibrating the period-luminosity relation for Cepheids as part of the studies of the cosmological distance.

We have been involved in drafting the science case for the proposed ESA Cornerstone GAIA, and are now participating in the planning phases, in which the optical system will be designed and recommended to ESA. Of particular interest is the improvement GAIA will make on determination of the dark matter content of the Galaxy, both in the disk and at large Galactocentric distances. GAIA will measure the transverse motions of local group galaxies, providing new insight into the mass of the local group. Our work on galactic kinematics and dynamics will also be extended to the GAIA mission. We are also contributing to the development

of procedures and software for the German Space Agency's DIVA mission.

Accretion induced phenomena in interacting compact binaries have been studied using the XMM-Newton satellite and ground-based observations. One of the key goals is to set observational constraints on the physical properties of accretion discs in general. This requires high quality UV / optical / IR and X-ray data. In order to exploit the data fully in modelling the various systems, modern global optimisation techniques such as genetic algorithms are being developed. We have also continued to study magnetic cataclysmic variables found in the ROSAT all-sky survey with photo- and spectropolarimetric ground observations as well as with RXTE and XMM-Newton.

We are associated with the Planck LFI Consortium, our main interests being in the so-called foreground sources, including galactic contamination and active galactic nuclei. As a by-product of its main mission PLANCK will provide the first complete all-sky catalog of radio bright AGN, with several measurements of their flux densities and polarizations at frequencies between 30 and 857 GHz. Instead of the present handful of selection-biased high frequency data points we will have thousands of unbiased PLANCK measurements. The Planck Core program was formulated during 2001, with active participation and co-ordination from the Tuorla/Metsähovi AGN group. We are also collaborating with Tarto Observatory in Planck-related studies of large-scale structure in the universe and its connection to the CMB era phenomena.

The AGN researchers are also participating at various levels in a number of operational, scheduled or planned space missions. Most of the work is directed towards understanding the relationships between spectra, flux density and structural variations across the whole electromagnetic spectrum. In particular, we have studied the high-energy phenomena in relativistic jets and shocks, demonstrating that the strongest gamma-ray flares in quasars are produced by the synchrotron self-Compton mechanism. The satellites used in AGN studies include ASCA, ROSAT, GINGA, CGRO/EGRET, CHANDRA, RXTE, Beppo-SAX, XMM-Newton,

HST, and HALCA. Within an international collaboration, we have obtained observing time with INTEGRAL for a number of AGN projects. We are also contributing to the science plans of the future space VLBI satellites VSOP-2 and ARISE, and of the next gamma-ray satellite AGILE (Italy). The HST has also been used for studies of Seyferts and AGN host galaxies.

The test mirror for the Herschel (formerly FIRST) mission was produced by Opteon OY at Tuorla Observatory. The Herschel 3.5 meter mirror contract has now been awarded to Opteon OY, the only company in the world with the capability to polish large, ultralight silicon carbide mirrors.

Helsinki University of Technology, Metsähovi Radio Observatory

Data from Metsähovi monitoring programme of quasars and active galaxies have been used to select target-of-opportunity sources for X-ray and Gamma-ray satellites. Metsähovi has used data from several satellites (Compton GRO, RXTE, Rosat, ASCA, and ISO) in the study of extragalactic radio sources.

Our group has especially studied the relationship between high frequency radio emission and gamma-ray emission detected by the EGRET instrument onboard the CGRO satellite. Based on the millimeter-wavelength data we have identified some Active Galactic Nuclei (AGN) with previously unidentified EGRET gamma-ray sources, and we have also confirmed some of the identifications that were earlier considered to be of low confidence only. We have also found out that the gamma-ray vs. radio emission behavior of AGNs may actually depend on the source type and the shape of their spectral energy distribution.

Metsähovi participated in the AMS-01 mission (Alpha Magnetic Spectrometer) in 1998 and thereafter in the preparation of the next mission AMS-02 which is intended to fly by Space Shuttle to ISS (International Space Station) in 2003–2004. Metsähovi is responsible for design, construction, and operation of the High Rate Data Link (HRDL) electronics, through which all scientific data from AMS detectors are transmitted.

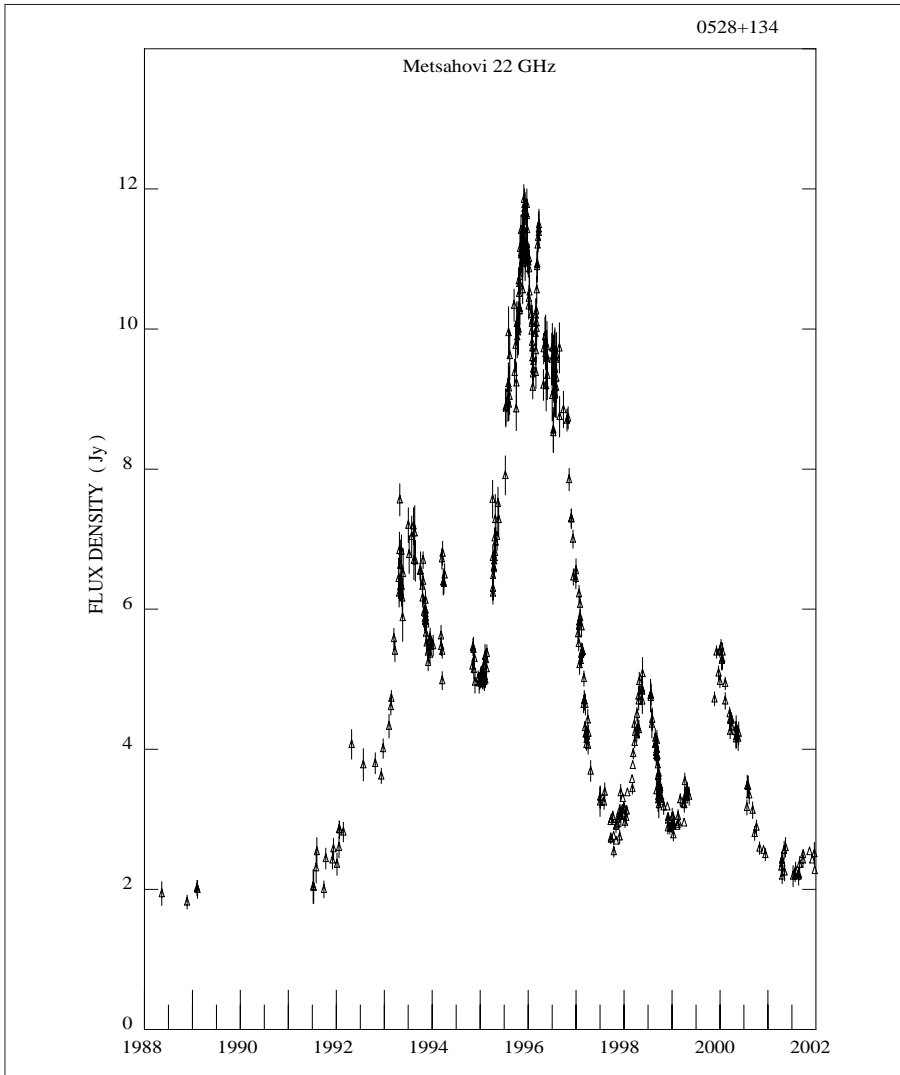


Figure 4.12. Long term monitoring of a well known gamma-ray blazar 0528+134.

Metsähovi is a member of the LFI consortium, which is building for ESA Planck satellite a set of low frequency receivers. 70 GHz receivers are built in Finland and Metsähovi is in this Finnish team. Metsähovi has participated with the Ylinen Electronics Ltd. in the design and testing of the Elegant Bread Board (EBB) model of the receiver and in the design and construction of a low temperature test system for the EBB.

Metsähovi is participating in the Planck extragalactic point source foreground science. Follow-

ing the First General Meeting of the Planck community in January 2001, the first stage of the Planck Baseline Core Programme was defined in summer 2001. The purpose of the working groups is to prepare for the mission (launch 2007) both technically and scientifically (e.g. constructing pre-launch source catalogues and modeling the variability behavior of AGNs). Our special responsibility is the development of the quick time alarm system which will detect unexpected flaring sources and trigger follow-up observations with other instruments.

Metsähovi is also participating in the science programme of the Swedish submillimetre wave satellite ODIN. The satellite was successfully launched in February 2001. The most important spectral lines to be observed in a variety of astrophysical environments are the thermal water line at 557 GHz and the molecular oxygen line at 487 GHz and 119 GHz. Metsähovi scientists are involved in several scientific teams of ODIN: photon dominated regions (PDRs) and high-latitude clouds, absorption lines, galactic centre, giant molecular clouds, star forming regions, and shocks and outflows.

Helsinki University of Technology, Radio Laboratory

The HUT Radio Laboratory has carried out research into antenna measurement techniques at millimeter and submillimeter wavelengths, especially into hologram based compact antenna test range (CATR), including its instrumentation. These studies on instrumentation serve also the development of radio astronomy receivers.

Millimetre Wave Laboratory of Finland (MilliLab)

Millimetre Wave Laboratory of Finland – MilliLab is a joint laboratory between VTT, Technical Research Centre of Finland and HUT, Helsinki University of Technology. MilliLab is also an European Space Agency Centre of Competence called *ESA External Laboratory on Millimetre Wave Technology*. MilliLab was established in 1995.

The main purpose of MilliLab is to support European space industry to meet the demands of future ESA missions, which will include an increasing number of millimetre wave instruments for astronomical and remote sensing applications.

MilliLab supplies services at millimetre wave frequencies in the field of device modeling, device characterisation, measurements, testing, research, and development. The parent organisations of MilliLab, VTT and HUT have a substantial amount experience and expertise in the field of microwave and millimetre wave technology.

A low noise receiver for the ESA Planck-mission and an antenna test method for future mm-wave space telescopes are the main development projects in MilliLab, related to space applications. In the Planck Low Frequency Instrument (LFI) MilliLab's responsibility together with Ylinen Electronic Co. and Metsähovi Radio Observatory is to design and construct the 70 GHz receivers. In order to obtain maximum sensitivity, the receiver is divided into a front-end cooled to 20 K and a 300 K back-end. The most vital parts of the receiver are the Low Noise Amplifiers (LNA) to be realised by utilising the InP MMIC technology. The use of integrated circuits is important due to the large number of receivers in the LFI. All together 12 identical back- and front-end receiver chains will be made in Finland.

At 70 GHz, the initial receiver breadboarding has been completed as well as the next step called Elegant Breadboard Model (EBB). Also, a large cryogenic tests facility has been designed and build. Presently, manufacturing of the Qualification

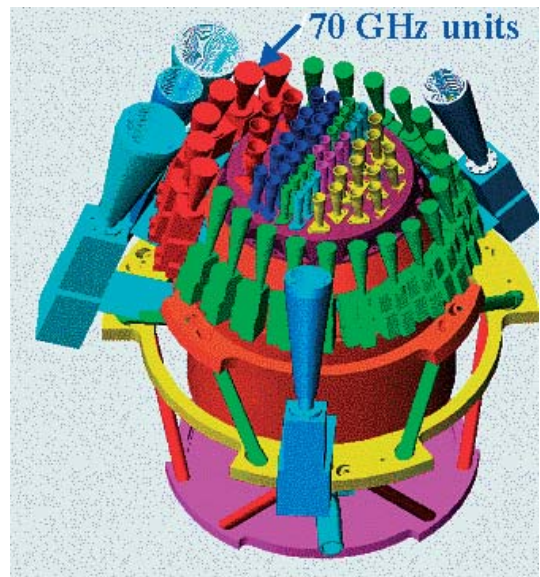


Figure 4.13. Planck spacecraft focal plane unit, including the critical parts of the Low Frequency Instrument (LFI) and High Frequency Instrument (HFI). The receivers will be cooled to 20 K and 4 K, respectively. The active parts of LFI 70 GHz channel will be build by the Finnish team.

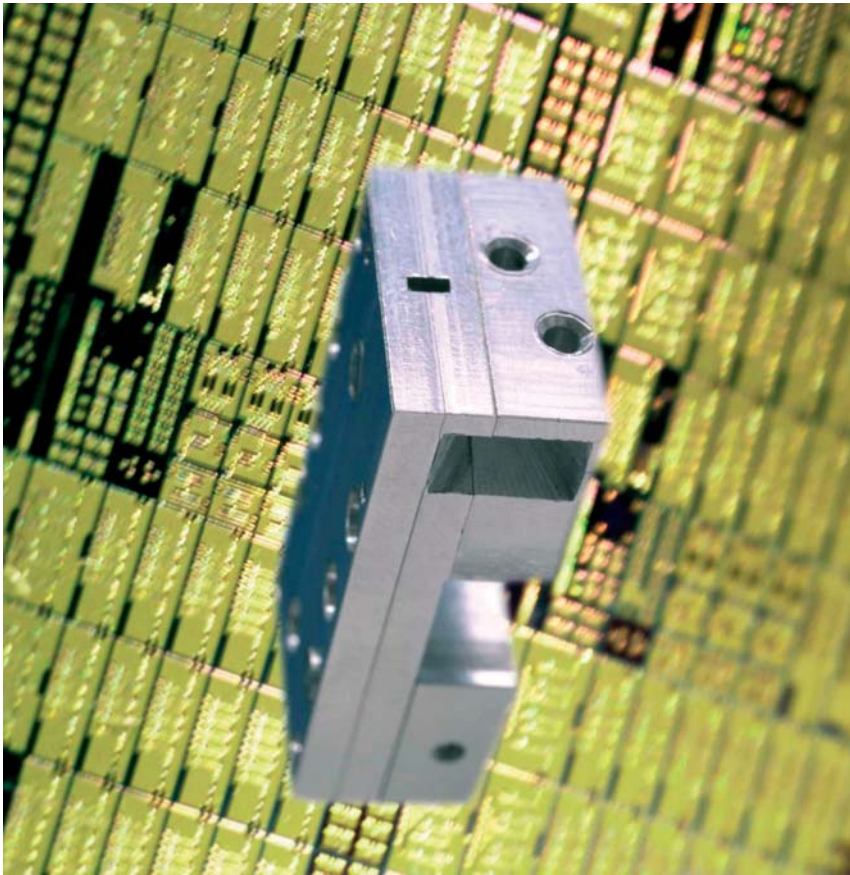


Figure 4.14. Elegant Breadboard Model of the Planck LFI 70 GHz receiver front-end module developed by MilliLab, Ylinen Electronics Co., and Metsähovi Radio Observatory. The size of this device equals to a matchbox. This will be cooled 20 Kelvin. In total, 12 of these 70 GHz receivers will be included in Planck. In the background, a wafer including 70 GHz low-noise integrated amplifiers is shown. These integrated circuits are based on Indium-Phosphide (InP) HEMTs (high electron mobility transistor) technology.

Model (QM) has been started and is expected to be completed in March 2003. With the EBB, extremely low noise temperatures have been obtained. A front-end receiver noise temperature between 20-30 K has been measured over most of the required 63-77 GHz band.

The main scientific goal for European Space Agency's Planck mission is to measure Cosmic Microwave Background (CMB) radiation anisotropy. A consequence of the unprecedented angular resolution (10 arc minutes at 100 GHz) and the measurement sensitivity of the background radia-

tion ($\Delta T/T \cong 4 \times 10^{-6}$) is the possibility to uncover the wealth of cosmological information encoded in the anisotropy pattern.

In addition to the 1.5-m telescope and LFI, the Planck spacecraft will have the High Frequency Instrument (HFI) on board. The LFI comprises receivers for 30, 44, 70 and 100 GHz frequencies. The HFI, for its part, has receivers for frequencies of 100, 143, 217, 353, 545 and 857 GHz using bolometers. Planck will be launched to the sun-earth synchronous L2 orbit in the end of 2007 together with the Herschel spacecraft.

5 Applied Space Research

5.1 Space geodesy

Finnish Geodetic Institute (FGI)

The routine operations of the permanent GPS network FinnRef of 12 stations continued on daily basis by dial-up modem line to the FGI. The FGI also has permanent GPS stations in Suurupi, Estonia, and in Xi'an, China and receives data from Svetloe, Russia. Data are archived and transferred to the international computing centres. The FinnRef is used for local studies on crustal movements as well as a reference for GPS measurements. The Finnish new reference frame, EUREF-FIN is based on ties to the FinnRef network. Determination of land uplift, but also studies on periodic effects on data, as well as deformation studies due to loading effects have been made using the permanent network.

During the year 2001, the final report of the computations and co-ordinates of the first and the second phase of the Finnish EUREF densification "EUREF-FIN" was published. The 350 new EUREF-FIN points were tied to FinnRef and to a subset of earlier (1996–1997) measured high precision EUREF-FIN points. FGI has participated in several national committees and working groups in order to advance the usage and help in practical questions of the new reference frame in Finland.

As partly funded by Tekes, a study on the usage of gravimetric satellites in Finland was made. Also, a common Nordic proposal to use the Fennoscandian area as a test field for gravimetric satellites CHAMP, GRACE and GOCE were presented in the EGS meeting in Nice, and IAG Scientific Assembly in Budapest. FGI received the co-investigator status of the CHAMP satellite, which opened the possibility to use the CHAMP data products.

The Metsähovi Satellite Laser Ranging (SLR) continued its operation. During the year 2001 a total of 544 orbits of 16 satellites (92577 single observations) were observed. The development of the SLR was continued in a co-operation with the Univer-

sity of Latvia, Riga. Preparations for daytime observations were initiated. The Metsähovi GPS station continued as a part of the Finnish permanent GPS network, FinnRef. Data were submitted to the European permanent GPS network computation as well as IGS network. Also, data from Javad/Legacy GPS/GLONASS receiver were submitted to the GLONASS data center for IGEX.

As a co-operation project with the Metsähovi Radio Research Station of the Helsinki University of Technology, preparations for geodetic VLBI installation were started. First tests are expected by the end of the year 2002.

Investigation of local crustal motions contained in a contract with Posiva Oy was continued on the candidate sites for final nuclear waste disposal. The local networks at Olkiluoto, Kivetty and Romuvaara were measured with GPS. Deformation studies at Nuottavaara/Pasmajärvi region in Finnish Lapland was continued.

A study on periodic variation on the time series of the Finnish permanent GPS stations FinnRef was made. This is in connection of the work made for the rebound studies with GPS and repeated levelling. The periodicity of GPS time series degrades the accuracy and resolution.

An international co-operation in project BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea Level and Tectonics) was continued. This is a co-operation project between the Massachusetts Institute of Technology, University of Toronto, University of Durham, Chalmers University of Technology, National Land Survey of Sweden and the Finnish Geodetic Institute for better understanding the rebound process and to constrain the lithospheric structure and ice models.

The FGI organized the IAG Symposium on Recent Crustal Movements in Helsinki. The Symposium was supported by UNSECO, University of Hel-

sinki and Ministry of Agriculture and Forestry. Proceedings to be published as a special issue of the Journal of Geodynamics is under preparation. A total of 70 participants from 18 countries attended the Symposium.

5.2 Remote sensing

Helsinki University of Technology, Laboratory of Space Technology (LST/HUT)

The Laboratory of Space Technology at the Helsinki University of Technology (LST/HUT) is specialized in microwave remote sensing. Special fields of interest are remote sensing of snow, ice, forest and water quality. The Laboratory participates in different projects which are described below.

An airborne L-band two-dimensional interferometric radiometer by aperture synthesis, HUT-2D, is under development and construction at LST/HUT in co-operation with Ylinen Electronics Ltd. The instrument will be accommodated onboard the

LST/HUT remote sensing aircraft, Short SC-7 Skyvan. The instrument will be used to support the ESA Soil Moisture and Ocean Salinity (SMOS) mission and, especially, to verify the feasibility of the interferometric measurement principle along with image quality and the chosen calibration technology. Project is funded by ESA.

The SMOS programme is currently in phase B and the satellite equipped with an interferometric radiometer will be launched in 2006. This will be the first time when L-band is used for microwave radiometry of the Earth. Only the synthetic aperture technique allows a reasonable spatial resolution to be achieved. LST/HUT is also working on the MIRAS Demonstrator Pilot Project, the goal of which is to construct the first functional airborne 2D-imaging interferometric radiometer MIRAS (Microwave Imaging Radiometer with Aperture Synthesis).

Globally the most interesting remote sensing parameters for SMOS are soil moisture and ocean salinity. As Finland is a northern country the cryospheric applications, too, are of great interest.

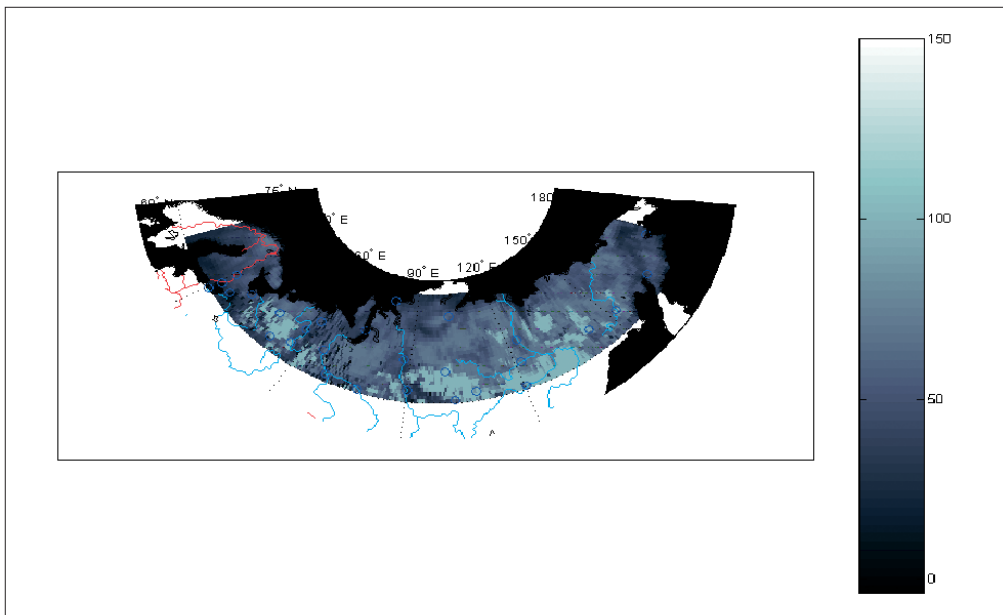


Figure 5.1. Snow map of Northern Eurasia produced by data assimilation methods using SSM/I data.

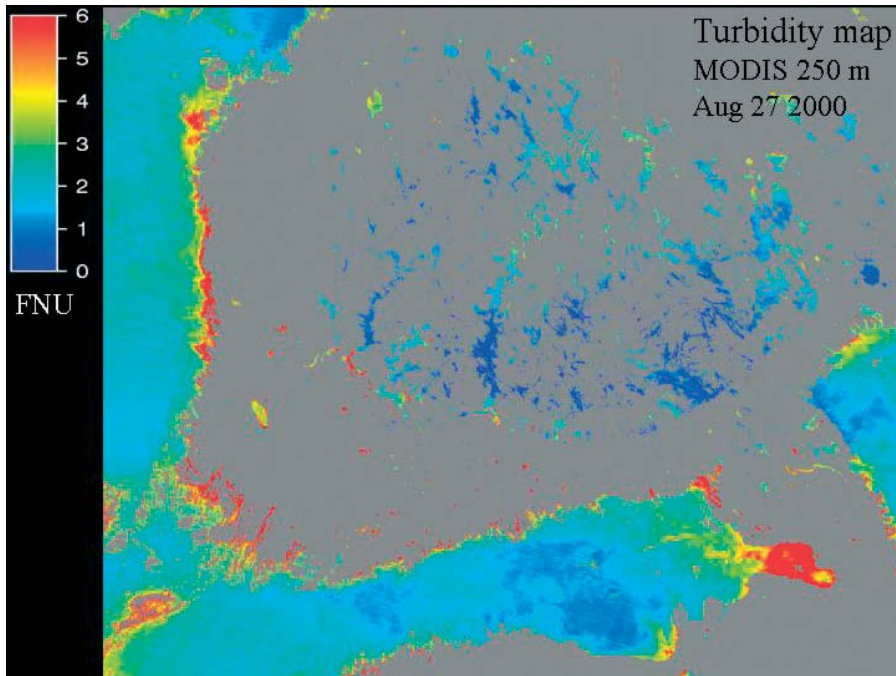


Figure 5.2. Water turbidity map of the Gulf of Finland and inland lakes produced from MODIS spectrometer data.

In this project radioemission models are developed for ocean salinity, properties of sea ice, soil moisture, and soil frost (land ice). The topics also include the effect of vegetation and its moisture, snow and roughness effects of the soil and sea surface. Other fields of interest are ionospheric effects in Northern Hemisphere (Faraday-rotation) and synergy between SMOS-data and other satellite data. The project is funded by Tekes.

LST/HUT participates in retrieval of boreal forest and surface characteristics from Envisat multi-sensor data. The objective is to develop novel methods to use space-borne remote sensing data for boreal forest ecology and forestry applications with emphasis on such Envisat-instruments as ASAR radar and MERIS-spectrometer. The specific applications include forest inventory, monitoring of soil moisture/frost, determination of the length of growing season, estimation of carbon balance and land cover classification.

In addition to Envisat instrumentation, the research is carried out using historical space-borne data, es-

pecially ERS-2 SAR observations. For comparison, extensive ground-based data are collected from selected test areas in Finland including ground/tower-based optical and microwave measurements. The main test site is the SMEAR II Station in Hyytiälä, Southern Finland, that yields continuous measurements on gas exchange, water transport and growth of trees.

In the EnviSnow project generic Earth observation based snow parameter retrieval algorithms are developed. The project is funded by the European Commission and it started in January 2002 and will end in early 2005. The main goal of the project is the development of satellite-based methods for monitoring snow cover in Europe. The EnviSnow project will contribute to future progress in hydrological modelling and water management by modifying lumped and distributed hydrological models for optimum utilization of Earth observation products.

Envisat provides researchers for the first time with simultaneous imaging capacity of the same ground

area with both optical (MERIS, AATSR) and multiparameter SAR (ASAR) instruments. This makes it possible to develop, validate and bring into operational use multisensor and multitemporal algorithms and products applicable both for regional and global mapping.

LST/HUT leads the Modafor (New Modeling and Data Analysis Methods for Satellite Based Forest Inventory) consortium in the ANTARES programme. In addition to LST/HUT the consortium involves scientists from Rolf Nevanlinna Institute (RNI), National Forest Institute (NFI) and Helsinki School of Economics. Researchers from RNI and NFI have applied a new nonparametric regression technique to forest inventory analyses based on satellite image data.

Researchers from LST selected a data set consisting of fourteen ERS-1/2 SAR interferometric images from the Tuusula test area for interferometric analysis (model validation and forest characteristics retrieval testing). Some ground-truth data have been collected for the Kirkkonummi test site and the eastern part of the site was visited. More detailed forest inventory statistics are still needed. The applicability of polarization calculation methodology for wide areas is a question to be solved.

Another participation in the ANTARES programme is in the consortium Assimilation of Remote Sensing Data to Physical Models in Environmental Monitoring and Forecasting (ASSIMENVI). The objective is to develop novel methods (1) to assimilate remote sensing data to environmental models and (2) to improve the quality of environmental monitoring information by using remote sensing data. Remote sensing can benefit environmental monitoring and modeling by providing spatially distributed information. Presently, a problem with the use of environmental models is the lack of information on the spatial distribution of model parameters and variables. The project concentrates on two promising fields of application: (1) water quality monitoring and (2) hydrological modeling and forecasting.

As remote sensing data are combined with environmental models by taking into account the stochastic accuracy characteristics of both informa-

tion sources, the combination technique can be called data assimilation. Especially, a new feature in this research project is the development of assimilation techniques that are able to eliminate the accumulative, with time propagating errors of current physical environmental models. Data assimilation also requires that the remote sensing observations are modeled as a function of environmental variables. The attached diagram illustrates the practical implementation of a data assimilation system. Additionally, the methodology development includes the development of optimal methods to combine spatially distributed remote sensing information with point-wise (or small area) information.

The expected outcome of the project is the accuracy improvement of current environmental models obtained by employing the developed assimilation techniques. The goal also includes the development of methods that are feasible for operational use and, thus, enable the implementation of new remote sensing-aided environmental forecasting/monitoring products.

The FOREMMS (Forest Environmental Monitoring and Management System) is the Information Societies Technology (IST) Programme Shared-cost RTD Demonstration project financed by European Commission under the Fifth Framework Programme. The objective of the FOREMMS project is to develop and demonstrate an advanced forest environmental monitoring and management system prototype. The operational version of the prototype will be able to monitor whole Europe, giving precise and coherent information on the environmental status and development of forests. The prototype will be demonstrated at three locations covering the three major European forest types (northern boreal coniferous forest, continental temperate mixed forest and Mediterranean dry forests).

FOREMMS relies on field measurements and advanced remote sensing methods. Automatic field sensors measure air, precipitation and soil variables continuously. Very-high-resolution airborne data are typically collected each few years in a measurement campaign supported by field personnel. The high-resolution satellite data, including at

least one node area are acquired at about the same time as the airborne and field campaign data. The medium-resolution satellite data is acquired frequently through the vegetation season. The environmental data in the system are stored in a spatial-temporal database (the three spatial dimensions and the time dimension). The system is designed to produce maps of needed parameters directly to Internet.

LST/HUT's participation in FOREMMS covers research on airborne remote sensing and some high-resolution satellite data, including responsibility for airborne data preprocessing. The laboratory has carried out airborne campaigns in Finland, Poland and Italy. Two instruments, the hyperspectral AISA spectrometer and HUTSCAT ranging scatterometer were used. HUT has processed over 20 GB raw data for FOREMMS. For image rectification and calibration an automated pipeline process has been constructed. 3 hyperspectral AISA images with 30 spectral bands between 400-900 nm with ground resolution 1 m were acquired over 110-km² area. During the summer 2002 another airborne campaign for the FOREMMS system prototype will be arranged.

European Forest Institute

In 2000-2001 European Forest Institute (EFI) in co-operation with other institutions has conducted several projects in the area of remote sensing. These projects are

- Combining geographically referenced earth observation data and forest statistics for deriving a forest map for Europe (phase 1: the EU 15 countries)
- Forest tree groupings database of the EU-15 and pan-European area derived from NOAA-AVHRR data.
- Treaty Enforcement Services Using Earth Observation (TESEO), Theme 2: Carbon.

Combining Geographically Referenced Earth Observation Data and Forest Statistics for Deriving a Forest Map for Europe was conducted during 1999–2000. The Consortium included VTT Automation, University of Joensuu and Stora Enso Forest Consulting. The funding came from the European Commission through the Joint Research Centre.

The main goal of the project aimed at combining Earth Observation (EO) data and forest inventory statistics. A methodology for producing calibrated, digital forest probability maps for different classes at the pan-European level was developed. The process applied NOAA AVHRR satellite data and forest statistics. The statistics were taken from both Eurostat 'Forestry Statistics 1992–1996' for EU15 countries and from 3 case study countries. The data for the 3 case study countries was based on national forest statistics.

Forest Tree Groupings Database of the EU-15 and Pan-European Area Derived from NOAA-AVHRR Data was conducted during 2000–2001 jointly with the University of Joensuu (co-ordinator) and VTT automation. It was also funded by European Commission through Joint Research Centre.

Earth Observation (EO) data is regarded as a cost-efficient means for locating different types of vegetation cover at the ground level. Forest inventories are commonly based on field sample plots, providing statistically sound estimates for the reference areas as for example a country or province. Data and maps represent important sources of information in the process of international agreements, policymaking and decision taking, forest planning at the local, national and international level and research. Forest data and maps find application in the fields of protection and conservation, forest resources analysis, questions on carbon storage and climate change, forest development and management scenarios and many others. Both EO and forest inventory information have fields of application. However, effort should be put into combining the two sources of information resulting in high quality data sets and maps.

Mapped forest information for the entire European continent is rather limited and often not in much detail. There are two main sources for forest resources information: EO data and statistical data based in forest inventories. The project targeted to utilise most effectively EO data and statistical forest information. A previously developed calibration method has been applied to produce comprehensive and complete European maps on forest, its sub-classes coniferous forest, broadleaved forest and mixed forest and non-forest/water at 1 x 1 kilo-

meter resolution. This was implemented at the European, the country and sub-country level. In specific the proposed project aimed at:

- computing an enhanced digital database for forest consisting of coniferous, broadleaved and mixed forest, other wooded land and non-forest in ArcView format for the region covered in the previous projects using an augmented NOAA AVHRR mosaic
- compiling country statistics at national and province level for forest and its three sub-classes coniferous, broadleaved and mixed forest (where available) and digitize the polygons
- calibrating a complete European forest map to produce an improved forest resources distribution map for forest area of the European continent.

The level of detail of the forest statistics (by forest classes and/or sub-country level statistics) relied on the data availability from the national inventory statistics. For the EU 15 countries (excluding France, Finland, Italy) the target was to collect data for the forest classes at the sub-country level. For a number of EU candidate countries (Hungary, Czech Republic, Poland), for Norway, Switzerland and the European part of Russia information was collected for the forest classes at the sub-country level. The information for the remaining European countries was based on the data from the TBFRA 2000 at the country level for the forest classes.

The study on Treaty Enforcement Services Using Earth Observation (TESEO), Theme 2: Carbon was conducted jointly with VTT Automation (coordinator), GAMMA Remote Sensing Research and Consulting AG, Stora Enso Forest Consulting Oy Ltd., and funded by ESA. TESEO Carbon is part of ESA TESEO project. The general objective of the TESEO projects is to find and develop prototype products that help in enforcing international environmental treaties. This project focuses on the carbon issues and is thus associated with the enforcement of the Kyoto Protocol to the United Nations Framework Convention on Climatic Change (1997). The Kyoto Protocol includes the Clean Development Mechanism (CDM) (or “carbon trading”). Forestation projects (e.g., afforestation and reforestation) may increase capacity of industrial CO₂ emissions and developed countries may ob-

tain emission reduction credits also by implementing forestation projects in developing countries.

The main relevance of the earth observation to the Kyoto protocol and terrestrial carbon comes thus from mapping and monitoring of forest ecosystem. Another carbon storage and possible source or sink is the peatlands, particularly in the Northern Hemisphere, which may or may not be covered by forest. The agricultural lands and grasslands also assimilate carbon but their primary production is annually released back to the atmosphere through grazing, harvesting and consumption.

The following core of demands, relevant to earth observation, can be derived from the Kyoto Protocol:

- the anthropogenic emissions of carbon dioxide shall be 5 percent below the 1990 reference year during 2008 to 2012
- the emission reduction has to be demonstrated;
- changes in land cover in general and forest cover and forest biomass in particular are taken into consideration when the net emission of greenhouse gases is estimated
- the human induced changes in land cover must be demonstrated in a transparent and verifiable manner
- observation systems have to be developed.

Remote sensing techniques can be used to provide basic information for the Treaty enforcement. Earth observation data may be the only reasonable way to derive an estimate of the global terrestrial carbon storage of the reference year 1990 as well as to monitor development of the changes in biomass and land cover at continental to global scales.

Geological Survey of Finland (GTK)

The Remote Sensing Laboratory at the Geological Survey of Finland acts as a base for mainly applied remote sensing survey projects concerning geology and environment. Those projects aim to develop remote detection and identification methods for geological mapping, mining operations, water resources, environmental contamination and natural geo-hazards. The laboratory has been equipped with high-performance workstations image processing software and a portable spectrometer covering wavelengths 400–2500 nm of electromag-

netic radiation. A dense, non-reflecting shelf is used for measuring large number of geological samples by portable imaging spectrometers. Programmable robot can steer the spectrometers to automatically follow a predefined set of steps in front of the shelf. Moving lights illuminating the samples are synchronized with the movement of the spectrometers. In addition to the laboratory measurements, several field and airborne imaging spectrometry campaigns have been organized using the Australian HyMap and the Finnish AISA imaging spectrometers from the altitudes of 1–2 kilometers. The current (most voluminous) projects at the laboratory are explained in the following.

The recently accomplished project HYDO “Hyperspectral Study of Mineral Indications and Mining Environments” has provided GTK and its partners with the methods of hyperspectral remote detec-

tion of minerals and environmental targets in four Finnish mines. Mineralogical approach of remote sensing method can be used for mining improvement, decreasing waste rock dilution and improving mineral enrichment. It has been shown that the same remote detection and identification methods work from near distance (millimeters to meters), from airborne distances (kilometers) and from satellites (hundreds of kilometers).

The laboratory is a partner to a large European project ‘MINEO’ (Assessing and monitoring the environmental impact of mining activities in Europe using advanced Earth Observation techniques). The MINEO consortium gathers seven European Geological Surveys, from Finland, Denmark, France, UK, Germany, Austria and Portugal, the Joint Research Centre of EU, two mining companies and one national environmental research insti-

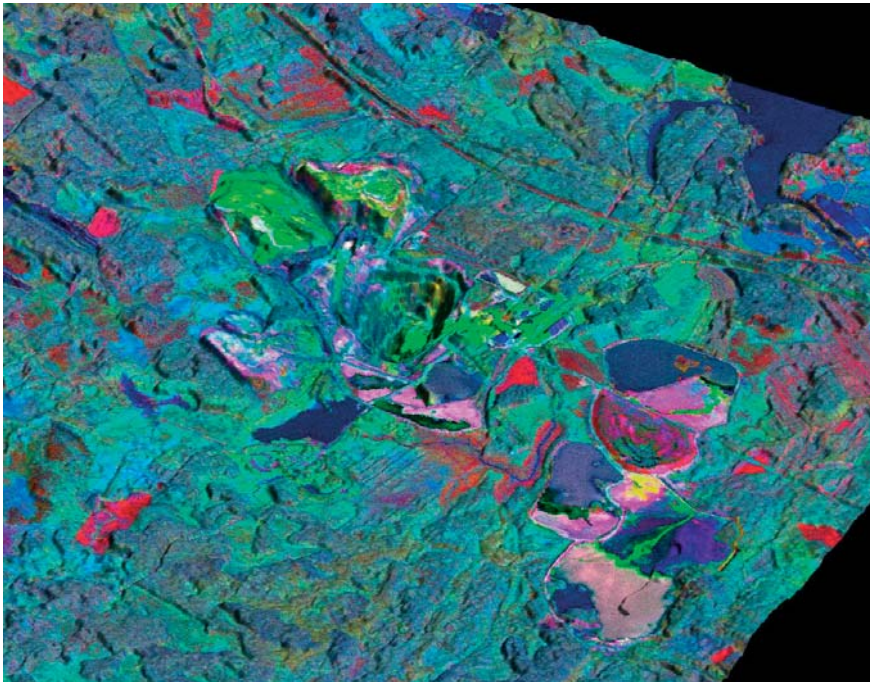


Figure 5.3. Minimum Noise Fraction transform of the 126-channel HyMap image superimposed on the digital terrain model in the Lahnaslampi talc mining area in Sotkamo, Finland. The open pit, enrichment plant and the rock piles are visible in the relief green in color indicating presence of talc mineral. Tailing sands which are mainly magnesite mineral from the enrichment process, are indicated by pink colors. Areas of sparse or dry vegetation are red. Width of the area is about 3 kilometers.

tute to assess and monitor European mining environments by modern Remote sensing techniques. The objective is to develop cost-effective and standardized methods to research the environmental impact of mining activities from hyperspectral airborne imagery, which could be further used to update the European environmental databases.

Hyperspectral images can characterize the chemical composition of the imaged ground surface (Fig. 1). This technique can reduce time-consuming and expensive field sampling. Imaging can be repeated to gather time-series data on the environments and changes due to mining. Hyperspectral imagery capabilities in mineral mapping have been proven in arid environments and used to map typical mineral assemblages responsible for pollution from mining. MINEO's goal is to transpose these applications to European vegetated environments and more global environmental concerns.

GTK is responsible for MINEO studies for the Boreal test site (Fig. 5.3, Lahnaslampi talc mine, operated by Mondo Minerals Oy), task for image processing of hyperspectral data and for development of environmental generic image processing models. The main forms of MINEO products are environmental hotspot maps, contamination maps, pollution dissemination maps and risk maps. On national levels MINEO will contribute to increasing national capability to use the advanced Earth Observation techniques in industrial environments.

Finnish Geodetic Institute, Department of Remote Sensing and Photogrammetry

Finnish Geodetic Institute, Department of Remote Sensing and Photogrammetry, was involved in the development of SAR (synthetic aperture radar) processing and applications, development of algorithms and application of laserscanning, digital photogrammetry, and modeling and analysis of BRDF effects.

Rice is the most important crop in South-East Asia, and, thus, prediction of potential yield during a growing season would be very useful for the national political decision-makers and for the international trade and aid organisations. The objective was to develop a method, to be used in Oy Finnagro

Ab, for the estimation of the rice field acreage and yield using SAR imagery. Finnish Geodetic Institute was responsible for the processing of the SAR imagery and rice mapping. The rice yield model was developed by the Laboratory of water resources at Helsinki University of Technology. The interpretation of the rice fields is based on the multitemporal SAR imagery. When several SAR images are chosen from a growing season, such as one image before sowing and another in the beginning of the growing season, it is possible to identify rice fields using numerical classification methods. The rice yield estimation is primarily based on the meteorological data, historical yield statistics and more detailed information about rice varieties. The use of SAR images in the yield estimation was also studied.

In spring 2001, Finnish Geodetic Institute ordered 20 Canadian Radarsat-1 SAR Fine Beam images from the southern Ostrobothnia. The first image was taken on the 29th April 2001 and the last one year later. The images were received in Tromsø satellite receiving station. Fast delivery of the images has provided almost real-time monitoring capability. Simultaneously with SAR acquisition, Finnish Geodetic Institute performed ground truth measurements, e.g. soil moisture and crop characterization. During the project, the factors, such as soil moisture, crop characteristics, ploughing direction and surface slope, affecting the recorded backscatter were investigated in greater detail.

Finnish Geodetic Institute participated in two airborne ESAR campaigns with DLR in August 2000 and May 2001 in Sjäkulla test site. Thematic interpretation of SAR imagery has been developed using ERS-1/2, JERS-1, Radarsat-1 and ESAR images. The research aiming at updating of topographic maps with ERS-1/2 Tandem images and ESAR images is currently under progress.

The quality and algorithms of laser scanning were studied. The reference measurements consisted of real-time GPS measurements and tachymeter measurements in Otaniemi, Masala and Kalkkinen. The DEMs obtained from the cloud of points were confirmed to deviate about 5 cm in flat areas (asphalt, concrete and grass) from the reference measurements. The height of the buildings were shown

to deviate about 6 cm. The visibility of street lamps was another research topic. It was demonstrated that the flight altitude and structure of lamps had a significant impact on the visibility.

In 2001, research aiming at automatic updating of large-scale city maps and converting them from 2D to 3D using airborne laserscanners was initiated. The test site of Otaniemi was applied. Classification method capable of separating ground, tree and building segments was developed. A classification accuracy of 97% was achieved in the study area. To estimate the accuracy of automatic building extraction from the data, corner points of buildings in the segmentation result were measured and compared with the GPS measurements, resulting in planimetric precision (standard deviation) of 31 cm.

New software (FGIAT) developed at the Finnish Geodetic Institute was brought into operation during the year 2000. With this software, the orientations of aerial and push broom satellite images can be determined using the bundle block adjustment method. In addition to traditional image and ground control observations, direct orientation observations can be utilized. In the case of aerial photography, these are the positions of the projection centres measured with GPS and the rotations of the camera observed with inertial systems. With satellite images, the direct observations are four orbit parameters and attitude observations. With aerial blocks, the most important object of development in the year 2000 was GPS/INS supported block adjustment and direct georeferencing. For the orientation observations, different kinds of observation equations can be used. In the software, the methods for calibration of the eccentricity between camera and GPS/INS devices were included. For satellite imagery, especially the utilization of direct orientation observations was elaborated. In the software, methods for robust adjustments and detection of gross errors were realized. A tool for simulation was developed in order to enable the investigations of the effects of usage of different observation groups, and their accuracy, on the quality of aerial and satellite image blocks. The general structure and user interface of the program were improved by better object oriented handling, unifying treatment of aerial and satellite images, add-

ing possibilities for editing database, and developing output routines.

Goniometer is used to measure scattered light as a function of imaging geometry. This information is needed to understand the imaging process of remote sensing instruments, and can be applied in pre-processing of aerial and space-borne imagery, as well as in recognition of target properties. Finnish Geodetic Institute has long been working in the field of bidirectional reflectance measurements. In year 2000, field goniometer was constructed in order to gather database of bidirectional reflectance distribution function (BRDF) measurements. The advantages of the new instrument, compared to other instruments in the world, is that 1) the instrument is easily transportable, 2) it only disturbs the target slightly during measurements and it is suitable for field use, and 3) it can be operated also in the laboratory environment. The structure of the goniometer is simple, it does not include movable and breakable parts and it is totally hand-operated, and operates in all conditions by one person.

Up-to-date information on the areal extent and properties of snow cover is needed e.g. in hydrology and hydropower production, especially during the snowmelt season in spring. During the last years research has been conducted at the Finnish Geodetic Institute to develop methods for satellite-aided snow mapping. Co-operation has been made with the Finnish Environment Institute (FEI) and the Laboratory of Space Technology at the Helsinki University of Technology. The research at the FGI has concentrated on interpretation of optical satellite images and combination of satellite image-derived information with that available from ground measurements. In 1999 a method was developed to estimate snow-cover percentages of drainage areas from NOAA/AVHRR images. Operational use of this method began at the FEI in spring 2000. The method developed for snow-cover percentage estimation is based on comparison of images from different dates. To achieve accurate results, it is therefore important that images acquired under different conditions are comparable with each other. One important factor that affects the reflectance values in the images is the imaging geometry, i.e. the sun zenith angle, the satellite zenith angle and the relative azimuth angle be-

tween the illumination and viewing directions. In 2000 research was conducted at the FGI to further develop the snow-cover percentage estimation method such that the effect of the imaging geometry on the reflectance values of snow could be accounted for. Results from BRDF (bidirectional reflectance distribution function) measurements of snow in the field were applied in the study.

In order to define bidirectional distribution reflectance functions (BRDF) of agricultural fields, forest and suburban areas, Finnish Geodetic Institute ordered HRSC acquisition flight from the DLR in 2001. Acquisition was performed in late July in Sjöskulla, Kuckuberg, Otaniemi and Espoonlahti. The flights were performed with two different sun angles and with 30 degrees difference in azimuth angle. The total coverage of the acquisition was 45 km². The vegetation was photographed in detail. The HRSC material was delivered to FGI in December 2001.

5.3 Atmospheric Sciences

Finnish Meteorological Institute, Geophysical Research Division

The work of the aeronomy group at the Geophysical Research Division has grown around three satellite instrument projects GOMOS on Envisat, OSIRIS on Odin, and OMI on EOS-Aura. These three instruments will provide in the coming years a wealth of new measurement data on the chemical composition and dynamics in the stratosphere and mesosphere. The main research areas of the aeronomy group are algorithm development, inversion theory, radiative transfer, data simulation, data assimilation to chemical-transport models, and solar-terrestrial effects in the upper atmosphere.

Odin was launched successfully on 20.2.2001 from Svobodny, Russia on Start-1 rocket. Odin is a Swedish satellite with participation also from Canada, France and Finland. Odin carries on board two instruments, the sub-millimeter radiometer SMR and the optical spectrograph OSIRIS. Odin divides its observational time to two disciplines, aeronomy

and astronomy. Since the launch Odin has carried out its measurement program without major technical problems. The validation work for aeronomy measurements has continued throughout 2001. FMI's aeronomy group has developed Level 2 data processing algorithms for OSIRIS and together with the Finnish industry FMI has built the level 2 processing centre in Sodankylä.

The major success for the European environmental satellite research was achieved when ESA's Envisat satellite was launched from Kourou on Ariane 5 launcher on 1 March, 2002. FMI is an original co-proposer of the GOMOS stellar occultation instrument, which is one of the three atmospheric instruments on Envisat. FMI's aeronomy group has been extensively involved in almost all areas of this project. These include mission definition and planning, instrument definition, data processing algorithm development, development of in-flight calibration and geophysical validation, and development of the ground processing facilities. FMI is one of four Envisat Expert Support Laboratories for GOMOS and FMI hosts the GOMOS Level 2 data processing facility (FIN-CoPac) in Sodankylä.

As a potential successor for GOMOS, FMI has proposed (with several Finnish and foreign partners) a small stellar occultation instrument named COALA or OLIVIA for satellite missions planned by ESA (Explorer-program) and NASDA (GCOM-program). FMI is participating in the development work of COALA instrument and is planning the scientific utilisation of the mission.

The most recent new activity is participation in the OMI-project. OMI is a Dutch-Finnish instrument that will be flown on NASA's EOS-Aura mission in 2004. FMI's role is to lead the industry participation in Finland and to co-ordinate the scientific work in Finland. FMI will be responsible for the developing a ground receiving station for OMI in Sodankylä.

In the scientific research we have continued work for inversion theory and algorithms, radiative transfer problems and solar effects in the strato-



Figure 5.4. Finnish GOMOS scientist and engineers celebrate the successful launch of Envisat on the top of Carapa mountain near the Guiana Space Centre in Kourou.

sphere and mesosphere. In the radiative transfer research the main tool is Monte Carlo simulation program Siro which calculates multiple scattered solar irradiance and its polarisation degree in the limb viewing geometry.

We have continued the development of the end-to-end simulation program LIMBO for occultation and limb measurements. The program's main use is now in the testing of new inversion approaches for GOMOS and limb measurements. The emphasis in the inversion theory work has been directed to the estimation methods that provide not only point estimates but also the whole probability distribution for the unknown parameters. The method, Markov Chain Monte Carlo, is computationally intensive but we expect it to be the method of future. We have also studied how to define the information content for measurements and what can be achieved through the use of a priori information in retrievals.

The data assimilation research has been continued. The theoretical aspects of the assimilation are under investigation in the MaDaMe-program of the Academy of Finland. The aim of the assimilation work is to provide global ozone and other trace gas maps from GOMOS, Odin and OMI measurements and also to help in the geophysical validation of these satellite measurements.

In the atmospheric research we have continued the research on the effects due to the solar corpuscular and radiative flux on the chemical balance and processes in the meso- and stratosphere. The work is based on the use and further development of the Sodankylä Ionosphere Chemistry model SIC. We will also investigate how atmospheric waves in the stratosphere can be detected by GOMOS measurements. Global data from the new satellites will foster studies of the time variation of the key constituents in the stratosphere.

5.4 Life sciences

**Kuopio University Hospital,
Department of Clinical Physiology and
Turku University,
Department of Theoretical Physics**

The Neurolab research project, with its experimental part conducted by STS-90 crewmembers in microgravity during the Space Shuttle Columbia STS-90 mission in April-May 1998, was totally devoted to neuroscience research. The science designed and realized during the Neurolab project, partly by our Finnish scientific contribution, has been considered as the most complex human life science (HLS) mission flown ever in the history of manned space missions. The 26 experiments during the pre-flight, in-flight and post-flight studies, were designed and conducted by multinational research teams from three continents.

The two Finnish co-investigators were scientists involved to study cardiovascular neural interac-

tions in space. Our research team, Autonomic Nervous System (ANS) Team, had four principal investigators (three from the USA and one from Germany). The ANS Team conducted four of the 26 Neurolab experiments. Neurolab project was the second step of our active participation in the HLS research in space after our earlier co-investigatorship in the American-Russian collaboration (Shuttle-Mir) onboard the Russian Space Station Mir (1). The Neurolab project represents a huge undertaking that has required major contribution from many scientists, collaborators, institutions and agencies in many countries.

The Finnish contribution to the Neurolab project was in the design phase of the experiments and especially the signal analysis expertise in the methods of data acquisition and analysis of numerous biosignals obtained in the pre-flight, in-flight and post-flight study sessions. The software package (WinCPRS, Absolute Aliens Oy), designed especially for the needs of Neurolab research, includes



Figure 5.5. Finnish team during inflight activities at the Neurolab control center.

sophisticated signal feature extraction methods for the various biosignals, and time and frequency domain methods to study the neural interactions of the various processed signals. The WinCPRS software package designed in Finland has been successfully utilized for several years in the laboratories of three Neurolab principal investigators in extracting and post-processing the data from the various neural interactions controlling the functions of the cardiovascular system.

The main hypothesis in cardiovascular regulation tested during the Neurolab project was that a reduced function of the sympathetic nervous system is responsible for the orthostatic intolerance exhibited by astronauts on return to Earth. Our research team succeeded to obtain direct recordings of muscle sympathetic nerve activity parallel to measuring sympathetic neurotransmitter kinetics in space. In order to monitor the sympathetic and vagal responses to various ANS stressors and to determine the effects of microgravity on the ANS, a complex set of studies including measurements of muscle sympathetic nerve activity (MSNA), utilizing also lower body negative pressure (LBNP) chamber, evaluating neural control of blood pressure, car-

diac performance and brain blood flow were carried out on the STS-90 crewmembers in a series of carefully controlled study sessions before, during and after the 16-day space mission.

The principal findings from the Neurolab project, published this far by the ANS Team in three articles (2-4), indicate that baseline sympathetic activity is preserved in space. The astronauts, our study subjects, showed normal sympathetic responses during simulated orthostatic stress induced by LBNP experiments in space, and they were able to maintain their arterial pressure at normal levels during such experiments. Accordingly, arterial pressure and sympathetic responses to Valsalva straining were augmented in space and not degraded as postulated earlier. Sympathetic baroreflex gain was normal. Thus, the postulated reduction in sympathetic function could not be confirmed.

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6 Publications

6.1 Ionospheric and magnetospheric research

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6.2 Solar system research

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