

Space Research in Finland

Report to COSPAR 2000

Editors

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COSPAR

FINNISH NATIONAL COMMITTEE



National Technology Agency



ACADEMY OF FINLAND

Helsinki 2000

Front Cover

The International Rosetta Mission is a Planetary Cornerstone Mission in ESA's long-term space science programme. The mission goal is a rendezvous with comet 46 P/Wirtanen. On its eight-year journey to the comet, the spacecraft will pass close to two asteroids. Rosetta will study the nucleus of comet Wirtanen and its environment in great detail for a period of nearly two years.

Finnish industry and research institutions are contributing main elements to the mission:

Patria Finavitec delivers the primary structure of the satellite.

Finnish Meteorological Institute participates in several AO science instruments.

Photos:

- Finnish Meteorological Institute
- Patria Finavitec Oy Systems
- Patria Finavitec Oy

Back Cover

In 2001, the European Space Agency will launch Envisat-1, an advanced polar-orbiting Earth observation satellite which will provide measurements of the atmosphere, ocean, land, and ice over a five year period. Finland has prepared to use Envisat data and has contributed to the development of Global Ozone Monitoring by Occultation of Stars (GOMOS) instrument:

Science Data Electronics package has been developed by Patria Finavitec.

Characterization of GOMOS gratings for image quality measurements: the grating in clean room in laminar flow cabin of class 100 at VTT Automation

Photos:

- ESA
- Patria Finavitec Oy Systems
- VTT Automation

Tekes – Your contact for Finnish Technology

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

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities should lead to diversified production structures, increased production 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 two billion Finnish marks, EUR 360 million, annually. The Tekes network in Finland and overseas offers excellent channels for co-operation with Finnish companies, universities and research institutes.

Technology programmes – part of the innovation chain

The technology programmes for developing innovative products and processes, is 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 are used to promote development in specific sectors of technology or industry, and to pass on the results of the research work to business in an efficient way. The programmes also offer good frameworks for international R&D cooperation. Currently a total of about 60 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 1998-1999 in pure and applied space sciences within the domain of the COSPAR.

During the last two years some of the milestones of Finnish space activities have been the exploitation of the successful observations by the SOHO (Solar and Heliospheric Observatory) and ISO (Infrared Space Observatory) spacecraft, successful launch of the XMM (X-ray Multi Mirror) satellite for which Finnish industry provided the telescope tube and satellite electronics, and, of course, intensive work in several upcoming missions, including Cluster-2, Envisat, Rosetta, Integral, Mars Express, Planck, and Odin.

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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.

However, it was not until the mid-1980s that space-borne instrument projects with Finnish participation were initiated. The first instrument project started in May 1985 and was a participation in the plasma analyser ASPERA in the Soviet Phobos mission. The project also 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 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, 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.

1.2 Summary of the Finnish Space Policy

Space activities in Finland are administrated in a decentralised way 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 overall coordinating body for the Finnish space activities.

The Finnish Space Committee (established in 1985) is a coordinating body for Finnish space activities. The duty of the Committee is to make propositions and proposals and give statements related to space research and education and industrial development, exploitation of knowledge deriving from space activities and cooperation of Finnish partners involved in these activities.

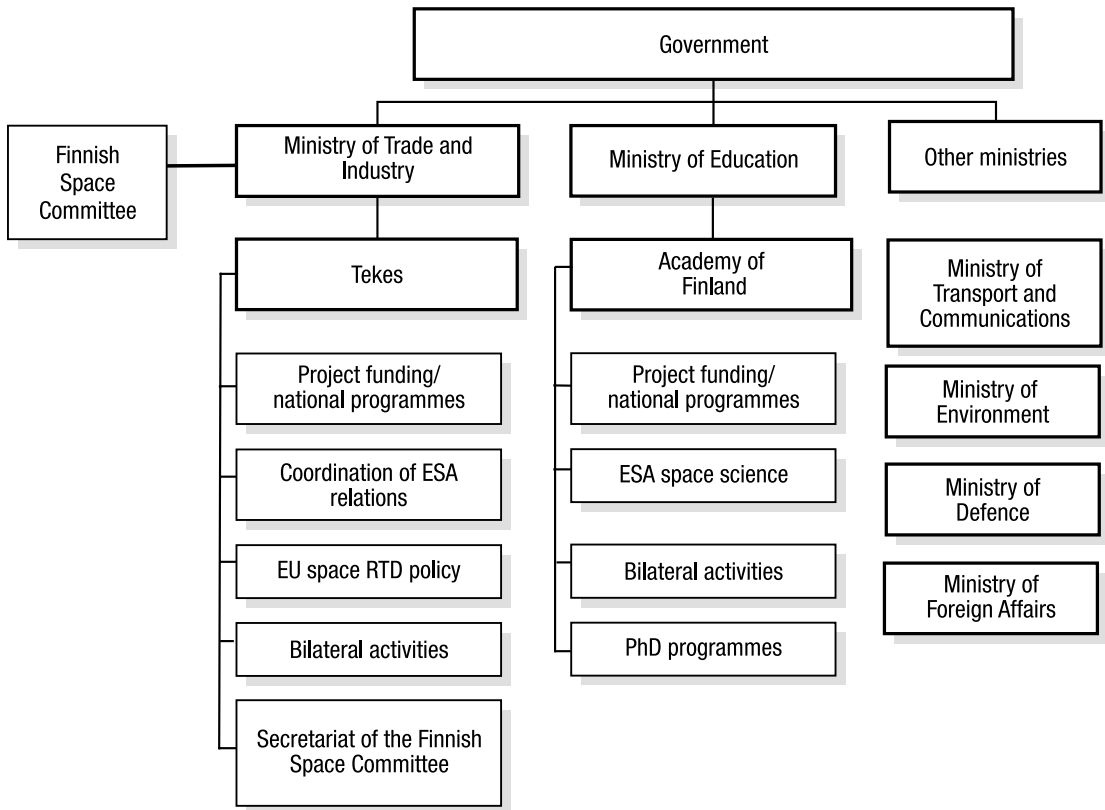


Figure 1.1. Organisation for administration of space matters in Finland.

The Committee is nominated on MTI's proposal by the government, typically for a period of three years. It is chaired by MTI and should have members from all relevant ministries and main actors. Currently the following instances are to be repre-

sent in the Committee: the Ministry of Trade and Industry, the Ministry of Foreign Affairs, the Ministry of Education, industry, applied research and other users of space activities. The Committee meets in average eight times per year.

From the year 1998 the composition of the Finnish Space Committee has been as follows:

Chairman	
Timo Kekkonen	Ministry of Trade and Industry
Vice Chairman	
Risto Pellinen	Finnish Meteorological Institute
Members	
Mirja Arajärvi	Ministry of Education
Jaakko Halttunen	Ministry of Foreign Affairs
Jorma Hattula	Academy of Finland
Kari Tilli	Tekes
Tytti Varmavuo	Nokia Corporation
Advisors	
Heikki Fredriksson	Topographic Service of the Finnish Defence Forces
Jorma Immonen	Ministry of Trade and Industry
Antti Joensuu	Ministry of Trade and Industry
Pauli Juuti	Patria Finavitec Oy
Väinö Kelhä	VTT Automation
Risto Kuittinen	Finnish Geodetic Institute
Mikael Nyberg	Ministry of Transport and Communications
Seppo Urpo	Metsähovi Radio Research Laboratory (Helsinki Univ. of Technology)
Juha Vuorimies	Finnish Environment Institute
Secretaries	
Einar-Arne Herland	Tekes
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
INTELSAT	Sonera
INMARSAT	Sonera
EARSel	Helsinki University of Technology
SARSAT/ COSPSAT	Frontier Guard of Finland

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.

Visions in space activities

The needs of Finnish society form the main principle behind the methods from the space sector and for the development of space technology. The diversity of opportunities afforded by space activities will be afforded 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.

Goals

- 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 economical growth via more efficient service provision within society and an increase in business activity
- to produce information for the needs of environmental monitoring, protection and sustainable development

Strategy

The growth in the markets for new space technology applications and in the international changes taking place in science and technology policy are also reflected in Finnish space activities. Strategic areas of expenditure for the public sector are the space science, satellite Earth observation, satellite telecommunication, navigation and positioning, and the production of space equipment. Finland has not played significant role in micro gravity, manned space flights or in the International Space Station programme, and this will remain the case in the future too. 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 by the Finnish Space Committee in January 1999.

Strategy for further development of space activities

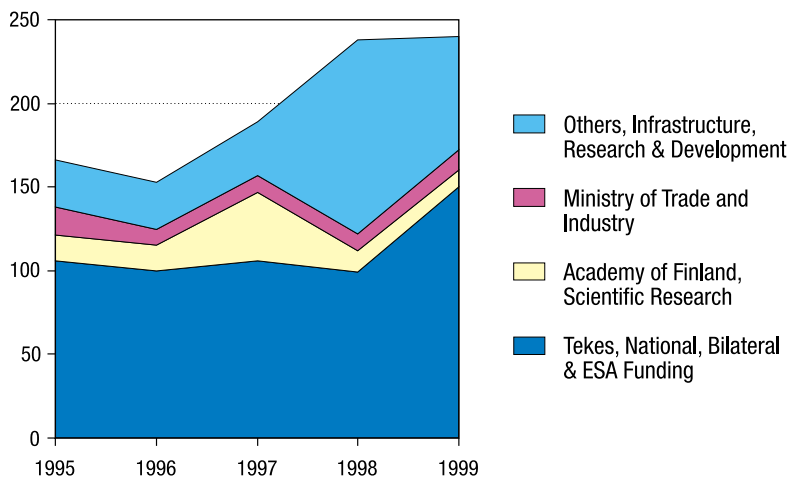
- The standard of Finnish space science will be maintained at the top international level by participation in the international partnership projects concerning key research themes in the field.
- Utilisation of new satellite Earth observation methods will be increased in public sector data collection and in geographic information systems. Business activity will be expanded by putting public services in competition.

- International research cooperation 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.

Table and Graphic 2.1. Finnish Space Funding 1995-1999; values in FIM million (1 Euro = 6 FIM).

	1995	1996	1997	1998	1999
Tekes National, Bilateral & ESA Funding	106	100	106	99	150
Academy of Finland Scientific Research	15	15	41*	13	10
Ministry of Trade and Industry	17	10	10	10	12
Others, Infrastructure, Research & Development	28	28	32	116	68
Total	166	153	189	238	240

* Mostly covers years 1998-2000



2.2 Funding Sources

As the space administration organisation is distributed in Finland, also the public funding responsibilities 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.

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 state budget. Tekes offers channels for cooperation 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 aim to diversify production structures, increase productivity and exports, and create a foundation for employment and social well-being.

Tekes coordinates and offers financial support for participation in international technology initiatives, including EU research programmes, EUREKA, research activities of OECD's energy organisation (International Energy Agency), European Cooperation in Scientific and Technical research (COST), European Space Agency (ESA) and Nordic cooperation. Tekes also offers a whose aim is to increase technological cooperation 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 cooperation and networking for companies and the research sector. The programmes also offer good frameworks for international R&D cooperation. During 2000, a total of about 60 extensive national technology programmes are under way. In 1999, Tekes provided FIM 1 100 million to financing technology programmes. In the field of space technology, two national technology programmes have been started in 1996 to increase and deepen the interaction with ESA programmes and strengthen the competitiveness of Finnish space technology.

In 1999 Tekes total financing of national and international R&D programmes was about 2 400 MFIM. From this figure, 150 MFIM was provided for space activities (ESA, national and bilateral).

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2.2.2 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 Culture and Society, the Research Council for Natural Sciences and Engineering, the Research Council for Health, and the Research Council for Environment and Natural Resources.

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 research careers and promoting creative research environments. The various forms of support for research, such as research posts, research appropriations, and research grants, provide opportunities for versatile funding of research in different disciplines.

The research appropriations of the Academy of Finland amount to 988 MFIM (166 million Euro) in 1999, of which about 10 MFIM (1.7 million Euro) 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 EISCAT, NOT, the European Science Foundation (ESF), the European Synchrotron Radiation facility 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 Natural Science 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.

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.

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.

The members of the Finnish National Committee

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. Martin Vermeer, Member	Finnish Geodetic Institute
Mr Janne Lahtinen, Secretary	Helsinki University of Technology

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3 Space Programmes Supported by Finland

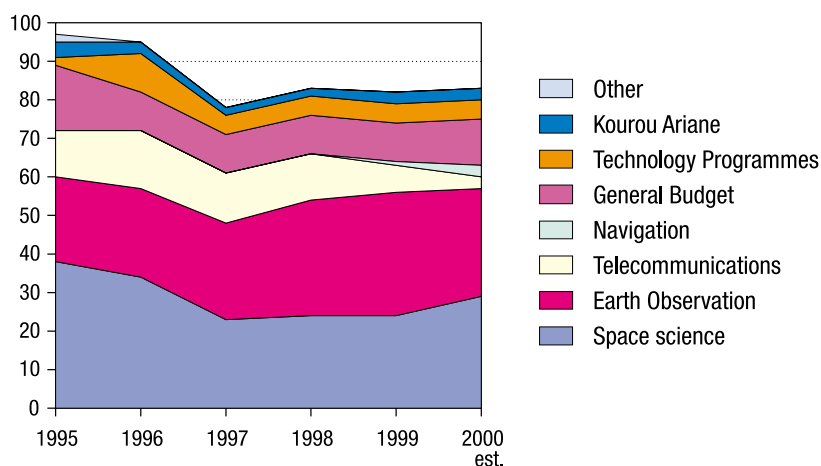
3.1 ESA Programmes Supported by Finland



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

Table and Graphic 3.1. Payments to ESA programmes 1995-2000 by Tekes and Ministry of Trade and Industry (MTI); values in FIM million (1 Euro = 6 FIM).

	1995	1996	1997	1998	1999	2000 estimated
Space science	38	34	23	24	24	29
Earth Observation	22	23	25	30	32	28
Telecommunications	12	15	13	12	7	3
Navigation	-	-	-	-	1	3
General Budget	17	10	10	10	10	12
Technology Programmes	2	10	5	5	5	5
Kourou Ariane	4	3	2	2	3	3
Other	2	-	-	-	-	-
Total	97	95	78	83	82	85



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	Telescope tube and satellite electronics	Launched 1999
Integral	JEM-X AO instrument, satellite flight software	Launch 2002
SMART-1	XSM and SPEDE AO instruments	Launch 2002
Rosetta	COSIMA, PP, MIP AO instruments and lander CDMS, satellite structure and power electronics	Launch 2003
Mars Express	ASPERA-3 AO instrument, satellite power electronics	Launch 2003
Planck	LFI AO instrument and lander CDMS	Launch 2007



Figure 3.1. Finnish participation to development of the Electrical Field and Waves instruments integrated to ESA/Cluster-2 satellite has been lead by University of Oulu.

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.

Telecommunications and navigation

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

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.	1986-2002
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.	1994-2000
ENVISAT-1	Software and hardware for the GOMOS observation instrument.	1992-2003
METOP-1 PP METOP-1 C/D	METOP satellite series, satellite electronics and S/W development	1993-2003
EOEP	Earth Observation Envelop Programme	1998-

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.	1993-2001
ARTES Element 5 (ASTE)	Telecommunication systems and equipment programme. Extension to ASTP. Several R&D activities with Finnish participation.	1994-2001
ARTES Element 7	Telecommunication experiments and services demonstration. Several R&D activities with Finnish participation.	1994-1997
ARTES Element 9 and Galileosat Definition	Industry activities related to Galileo satellite navigation system definition	1998-



Figure 3.2. In Orbit Test Station for ESA Artemis satellite, prime VTT Information Technology.

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 essential base for the Finnish economy. In that respect also the projects and development in the ESA R&D pro-

grammes 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. The most relevant technology developments to support space research during the period of 1998-1999 are listed in the table 3.5.

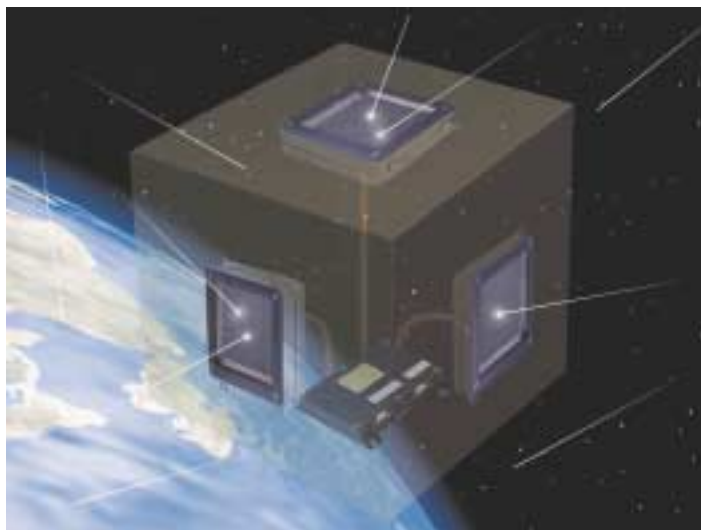


Figure 3.3. Standard In-Situ Impact Detector (DEBIE) for space debris environment monitoring, prime Patria Finavitec Oy Systems.

Table 3.5. Main activities and recent Finnish participation in the ESA technology R&D programmes.

Project	Finnish participation	Programme
Digital interface circuits	Patria Finavitec	TRP
Netlander study	Finnish Meteorological Institute	TRP
Standard in-situ impact detector (DEBIE)	Patria Finavitec, Metorex International, Space systems Finland	TRP
Hot-electron micro-bolometer technology	Metorex International, Univ. of Jyväskylä	TRP
Critical technology for millimeter wave radiometer	Ylinen, Millilab	TRP
Radiation hard data handling technology	Smartech	TRP
Sub millimeter antenna testing	Millilab	TRP
Predevelopment of cascade solar cells	Tutcore	TRP
GaN/P/GaAs cascade solar cells	Tutcore, Tampere Univ. of Technology	TRP
Micro-machined Fabry-Perot interferometer	VTT Automation	TRP
Scanning micromechanical mirror	VTT Automation	TRP
MIRAS demonstrator	Ylinen, Helsinki Univ. of Technology	TRP
Solid state detectors and arrays for X-rays	Metorex International	TRP
Measurement small size debris	Sodankylä Geophysical Observatory	TRP
Imaging micro bolometer array	Metorex International	TRP
Structural CRFP technology	Patria Finavicom	TRP
Silicon detector elements for radiation monitors	Detection Technology	GSTP-2
Struct. CRFP/honeycomb sandwich panel tech.	Patria Finavicom	GSTP-2
MIRAS demonstrator calibration system	Helsinki Univ. of Technology, Ylinen	GSTP-2
Micro-robotics for scientific applications	Space Systems Finland, VTT/Automation, Helsinki Univ. of Technology	GSTP-2
UV/Optical filters	Metorex International, Univ. of Joensuu	GSTP-2
SSS crystal fabrication	Metorex International	GSTP-2
Cloud radar LNA	Ylinen, Millilab	GSTP-2
MMICs for receiver arrays at 70-90 GHz	Ylinen, Millilab	GSTP-2
NIS chip cooling	Univ. of Jyväskylä, Nanoway	GSTP-2
Imaging LIDAR	VTT/Electronics, Univ. of Oulu, Noptel	GSTP-2
Multi-purpose rotating actuator	VTT/Automation, Rejlers	GSTP-2
DSP based application development	Space Systems Finland	GSTP-2
Development of a reference S/W validation facility	Space Systems Finland	GSTP-2
HOORA industrialisation	Space Systems Finland	GSTP-2

...Table 3.5. continues

Project	Finnish participation	Programme
Project for on board autonomy (PROBA)	Space Systems Finland	GSTP-2
Cascade solar cells	Tampere Univ. of Technology	GSTP-2
Components for high speed frame synchr. And Viterbi decoding	VTT/Electronics	GSTP-2
GaAs solar cells on Germanium by molecular beam epitaxy	Tampere Univ. of Technology	GSTP-2

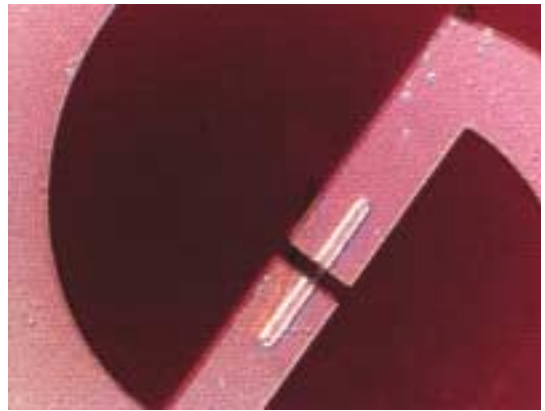


Figure 3.4. An antenna-coupled microbolometer. The antenna is sensitive to frequencies between 200 GHz up to 1 THz. Radiation power absorbed in this band heats up a microscopic niobium thermometer strip, located at the feed of the spiral antenna. Prime Metorex International.

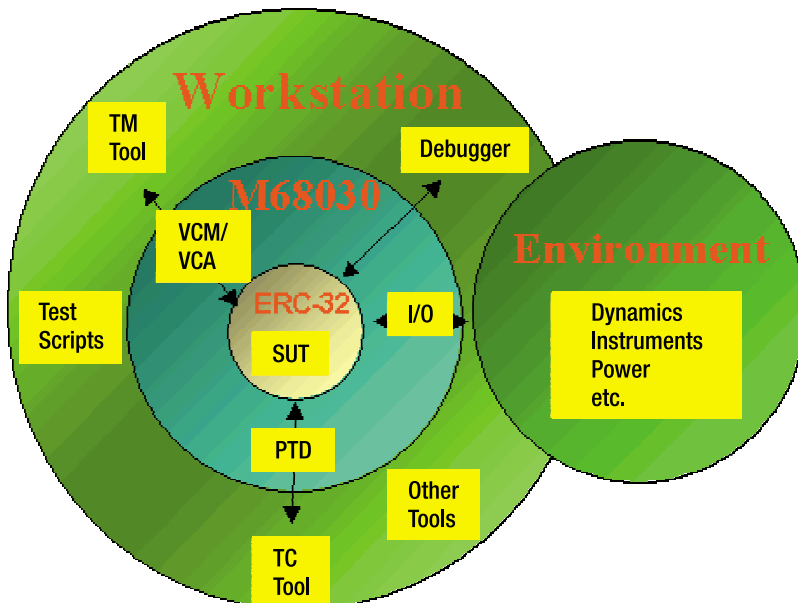


Figure 3.5. Software Validation Facility for use in the validation of satellite software developed by Space Systems Finland Oy.

3.2 Bilateral Co-operation and Programmes

Bilateral space programmes mainly in the field of space science have been the first areas in which Finland has become an active player in space. This

has started in the mid 80's and still bilateral programmes have an important role to play in the overall Finnish space strategy. A list of the largest operative bilateral programmes is given in table 3.6.

Table 3.6. The main Finnish operative 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
Freja	S	Plasma and wave instruments	Launched 1992
Interball	SU/RUS, S	Electronics for ASPERA instrument	Launched in 1995 and 1996
Polar	USA	Mechanisms for EFI instrument	Launched 1996
Mars-96	SU/RUS	Central electronics units, sensors and software for two landers	Launch failure in 1996
Cassini	USA	Hardware for IBS, CAPS and LEMS instruments	Launched 1997
Space Shuttle	USA	AMS instrument	Launch 1998
Odin	S, F, CAN	119 GHz receiver and antenna measurements	Launch 2000
SRG	RUS	Silicon x-ray array (SiXA) for the SODART instrument	Launch TBD
Radioastron	RUS	22 GHz VLBI receiver	Launch TBD

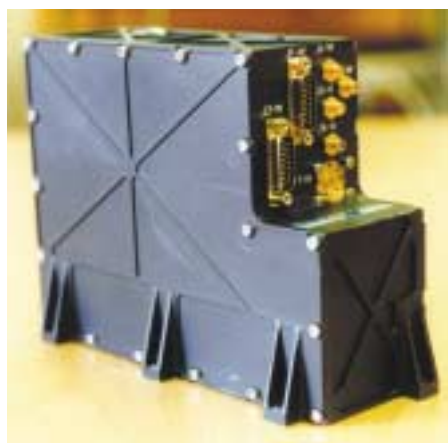


Figure 3.6. 119 GHz receiver developed by Ylinen Oy for ODIN satellite.

Table 3.7. The Finnish national space technology programmes.

Programme	Originator	Finnish participation	Schedule
Space 2000	Tekes	National space equipment technology programme	1996-2000
Globe 2000	Tekes	National remote sensing programme	1996-2000

3.3 Finnish National Space Programmes

Two dedicated space technology programmes were initiated by Tekes in 1996. These have strengthened the Finnish capabilities in the areas of industrial participation, various satellite technologies and application of earth observation techniques in Finland.

Preparation of a national space research programme for years 2001-2003 has started jointly between Academy of Finland and Tekes.

Space 2000 - Space Equipment Technology 1996-2000

The Space 2000 technology programme concentrates 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. Cooperation within the European Space Agency plays a central role in the Finnish space activities. Therefore also the Space 2000 programme is closely linked with the ESA technology programmes and satellite projects.

Objectives are

- Developing the international competitiveness of the Finnish space equipment industry, especially in the satellite projects of the European Space Agency (ESA)
- 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 consists of companies' product development projects and research-based joint projects of companies and research institutes. Many projects are closely related to ESA's future satellite projects and technology programmes.

Focus areas are

- 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 Space 2000 programme runs for five years. The total budget of the programme is estimated at FIM 100 million, of which Tekes finances approximately 60 percent.

GLOBE 2000 - Remote Sensing 1996-2000

The Globe 2000 technology programme helps to develop the remote sensing industry by intensifying the use of research data for operational and commercial applications and deepening the cooperation 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 meth-

ods 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 is coordinated with the remote sensing programmes of the ESA and the remote sensing programme of the European Union (CEO). The success of Finnish participants in EU's and ESA's remote sensing programmes is evidence of good competitiveness.

Objectives

- 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 cooperation

Focus areas of the projects

- 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 Globe 2000 programme runs for five years. The estimated budget of the programme is approximately FIM 50 million, of which Tekes finances approximately 50 percent.

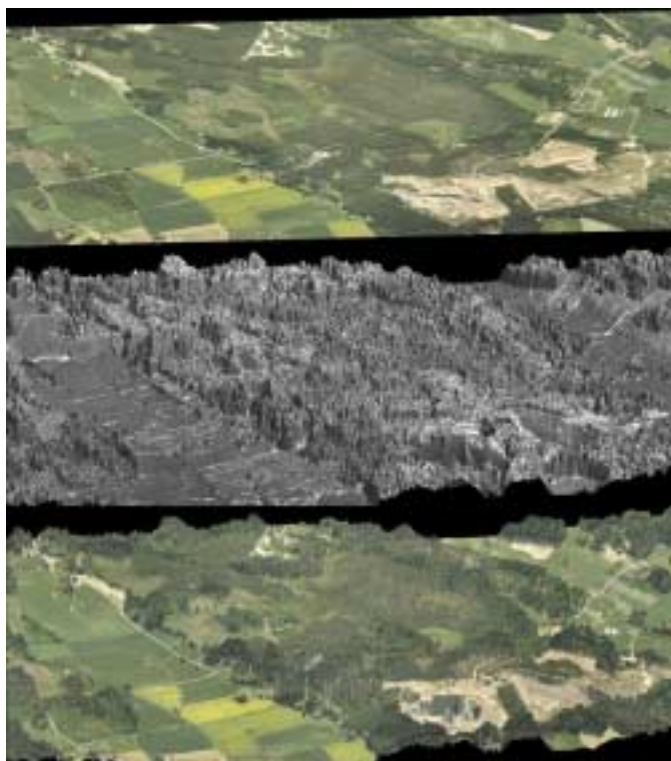


Figure 3.7. Digital image mosaic combined with terrain model. Both have been produced by means of a global reconstruction algorithm developed by VTT Automation.

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, including large-scale dynamics of the magnetosphere, storms and substorms, electrodynamic coupling between the ionosphere and magnetosphere in various spatial scales, and ionospheric and auroral physics. The research is conducted in wide international collaboration utilising both ground-based and space-borne measurements. The research activities comprise the full chain of

instrument development, design, and construction, observations and data-analysis, and interpretation utilising theoretical and modelling methods.

Development and utilisation of numerical theoretical and empirical models is an important tool in modern space physics. The global magnetohydrodynamic simulation code developed at FMI can resolve the solar wind - magnetosphere - ionosphere interaction using solar wind data as input. This is currently the only global MHD code in Europe. It is used in studies of the large-scale magnetospheric dynamics as well as in ionosphere-magnetosphere coupling studies. The simulations are under continuous development in terms of development of plasma theory as well as

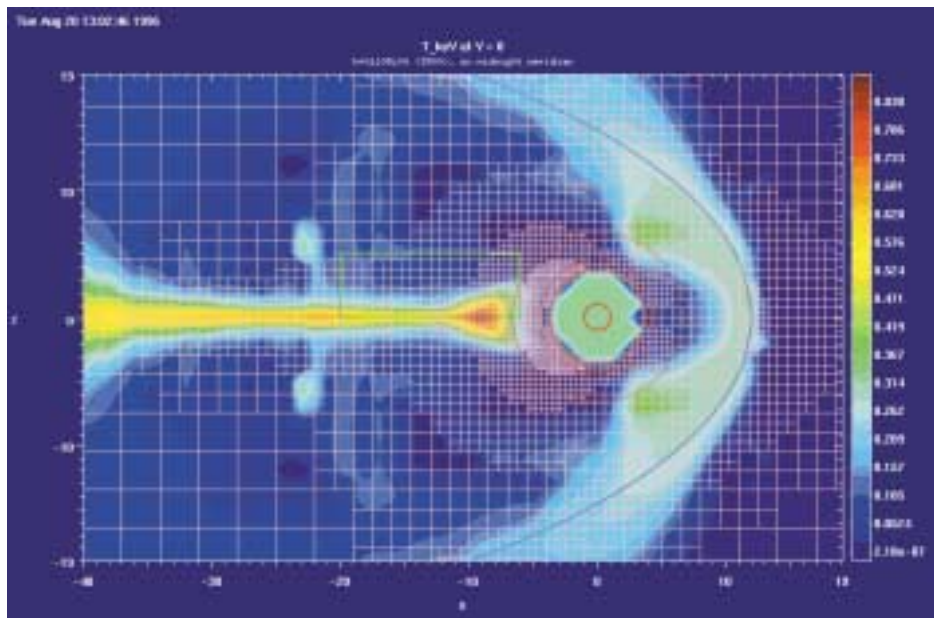


Figure 4.1. Magnetospheric temperature distribution simulated by the GUMICS-3 code. The picture is in the noon-midnight meridian and the distances along the axes are given in Earth radii. The computational grid (white grid-lines) is adaptive. The figure shows how the solar wind (coming from the right) is compressed and heated upstream of the magnetosphere and that the nightside is characterised by a plasma sheet that is hotter than its surroundings.

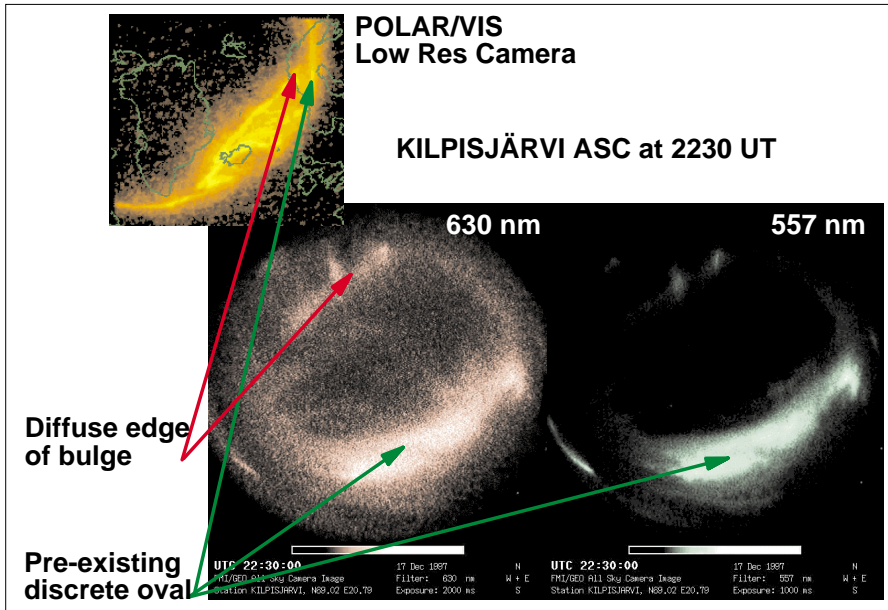


Figure 4.2. An example of the combined use of satellite-borne imager (VIS onboard Polar) and ground-based all-sky cameras (Kilpisjärvi station of the MIRACLE network). The satellite imager yields the global features of the dynamical event whereas the ground-based images provide smaller-scale details.

in terms of improved numerical accuracy and speed.

The FMI utilises the International Solar Terrestrial Physics (ISTP) programme in studies of geomagnetic storms and substorms using data from several spacecraft. During 1998-99 these included SOHO (Solar and Heliospheric Observatory) of ESA, Polar, Wind, and FAST of NASA, as well as the Japanese Geotail, Russian Interball, and Swedish Freja satellites. Many of the event analyses utilise empirical analysis modelling methods developed at FMI.

MIRACLE (Magnetometers, Ionospheric Radars and All-sky cameras Large Experiment) is a network of ground-based instrumentation, which is used to monitor the dynamic state of the ionosphere in the Scandinavian local time sector from Southern Finland to Svalbard. The network consists of the IMAGE magnetometer chain, six all-sky cameras, and the STARE twin auroral radar system. This network is used in collaboration

with the ISTP program for magnetospheric research and in various ionospheric research projects. In particular, MIRACLE has a formal agreement with the Cluster community to provide complementary ground-based observations to support the Cluster-2 data analysis. The MIRACLE Principal Investigator (PI) at FMI is responsible for data collection and distribution at FMI, development of analysis software for common display, and collaboration agreements with third parties, although some of the instruments are maintained and operated by other groups.

A central part of MIRACLE is the IMAGE magnetometer chain where FMI has also a PI role. More than 20 magnetometers provide continuous high-quality absolute field measurements at 10-s intervals. The network extends from Southern Finland to Svalbard with stations also in Sweden, Norway, and Russia. Data are distributed through the World Wide Web (WWW), for most of the mainland stations the day following the measurements.

Five all-sky cameras were maintained and operated by FMI during 1998-99. The cameras record the auroras continuously (20-s intervals) throughout the dark season at four stations in Northern Finland and Sweden, and one in Svalbard. Quick looks of these data are available through the WWW the day following the measurements; full data become available two weeks after the data taking. The FMI has a strong program in digital image processing, which aims at developing automated data analysis methods for the over 2 million auroral images recorded during a winter season.

The STARE radar was renovated and became operative at the beginning of 1998 producing measurements of the ionospheric electric fields at 20-s intervals. The radar data are transferred daily to FMI. The FMI also operates and partially maintains the UK-owned CUTLASS radar, which is a part of the SuperDARN coherent radar network. The CUTLASS observations as well as EISCAT and ESR observations are also merged with the MIRACLE data sets in joint analyses.

During last few years, space weather activities have gained a growing role in space research at FMI. In 1996-1999 the first ESA-funded investigation of European capabilities in space weather modelling was conducted in collaboration with the space physics group at the Department of Physics of the University of Helsinki. The unique expertise in ground effects of space weather, in magnetospheric modelling and simulations, and in the wide scientific approach to solar-terrestrial physics research have made the FMI one of the most important contributors to the European space weather activities.

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 is engaged in continuous support and development of a network of search-coil magnetometers and a set of optical instruments, including multichannel scanning photometers and low light-level TV cameras. A new search-coil magnetometer was installed in Crete in 1999 for low-latitude observations of magnetic pulsations and magnetic background noise, and a new photometer system was installed in the Chinese Zhong Shan base in Antarctica for observations of Aurora Australis. Preparations for an instrument measuring the vertical electric component of the Schumann field were initiated. VLF observations were made during special campaigns. Ground-based observations have been used in a co-ordinated way as a support for several satellite missions, like Polar, Astrid-2 and Interball satellites. Analyses of the measurements of the Auroral Turbulence II rocket experiment were started and first results were published.

The high-sensitivity magnetic and optical measurements, together with simultaneous satellite observations, have given several interesting results on auroras, waves, and magnetosphere-ionosphere coupling. Action of the ionospheric Alfvén resonator at auroral latitudes was experimentally verified and the possibility of artificial excitation of the resonator by periodic HF heating of the ionospheric electron gas could be demonstrated. Electromagnetic ion cyclotron (EMIC) waves were studied using both ground-based magnetic observations and magnetic and electric field data from satellites, in particular from Viking, Freja and Polar satellites. The significance of EMIC waves in magnetic storms was studied for the first time directly in space using Freja satellite observations. Also, evidence was given for an alternative model of structured (pearl) Pc1 pulsations. Magnetospheric substorms, particle injections, and particle boundaries were studied with CRRES, NOAA, and geosynchronous satellites. By studying pseudobreakups from ground, ionosphere, geosynchronous orbit, and mid-tail, it was shown that pseudobreakups are associated with particle injections, current disruptions, and magnetic reconnection in the magnetotail. Satellite radio to-

mography measurements have been carried out using a receiver chain in Scandinavia, and related tomographic methods have been developed. Amplitude scintillation was used to determine the anisotropy parameters of F region small-scale irregularities.

Finland is a member of the EISCAT (European Incoherent Scatter) Association, together with five other European countries and Japan. The task of EISCAT is to carry out incoherent scattering measurements at high latitudes for ionospheric and magnetospheric research. This is accomplished by UHF and VHF radars in the auroral zone and by the EISCAT Svalbard Radar within the polar cap. EISCAT also possesses a RF Ionospheric Heating Facility. Finnish scientists have made important contributions to radar measurement techniques and data analysis, in particular to the experiment design and analysis package GUISDAP. The EISCAT data laboratory serves scientists in problems associated with using and analysing EISCAT data. Moreover, coherent and incoherent scatter radar techniques have been developed and used in auroral and airglow studies.

The group also has co-investigator status in the Polar and Cluster-2 missions. The data from the electric field instrument of Polar were analysed and first results were published. Preparations for the Cluster-2 mission were continued, and the deployment mechanisms for the EFW (Electric Field and Waves) instrument were constructed and tested under the supervision of the Production Technology Laboratory. Flight time test software for the RAPID (Research with Adaptive Particle Imaging Detectors) instrument was further developed and used in system tests. The Astrid-2 microsatellite was launched in December 1998 and operated until July 1999.

The Graduate School in Solar-Terrestrial Physics, which started in 1995, was expanded in 1999 to the Finnish Graduate School in Astronomy and Space Physics. The school is a network including all astronomy and space physics units in Finland (University of Oulu, University of Helsinki, University of Turku, Helsinki University of Technology, and Finnish Meteorological Institute). It is sponsored by the Academy of Finland and is or-

ganised and chaired by the Department of Physical Sciences of the University of Oulu. A total of 14 graduate students receive their support through the Graduate School.

4.2 Solar System Research

Finnish Meteorological Institute, Geophysical Research (FMI/GEO)

For most of 1998-99 the ESA SOHO (Solar Heliospheric Observatory) mission continued observations of the Sun and the Heliosphere. FMI is involved in the Solar Wind Anisotropies (SWAN) instrument, which measures Lyman Alpha radiation originating in the Sun and scattered by hydrogen atoms coming from interstellar space and moving in the solar system. Its main research target is the diffuse Lyman Alpha background radiation but other objects such as comets and the geocorona can also be studied.

SWAN data has been used to determine water production rates of comets Wirtanen, Hyakutake and Hale-Bopp. A new comet was found in the 1997 SWAN observations of the whole sky. SWAN data also confirmed the earlier Lyman Alpha and Ulysses observations that near the solar activity minimum the solar wind proton flux is high in a narrow belt around the solar equator. Furthermore, SWAN has shown that the temporal development of the background radiation pattern during the solar cycle is not as simple as believed based on earlier observations. The SWAN observations of the penetration of the interstellar hydrogen atoms into the solar system were included in the list of 30 main discoveries of ESA spacecraft in 1984-1999.

The FMI-built atmospheric Pressure Profile Instrument (PPI) launched on board the Cassini/Huygens spacecraft in 1997 is in nominal condition for operations at Titan in 2004. The spacecraft has completed its Earth and Venus gravity assist manoeuvres and is en route to Saturn via Jupiter.

Rosetta is one of the ESA cornerstone missions planned to shed light on the origin of the solar system by investigating in-depth the close surround-

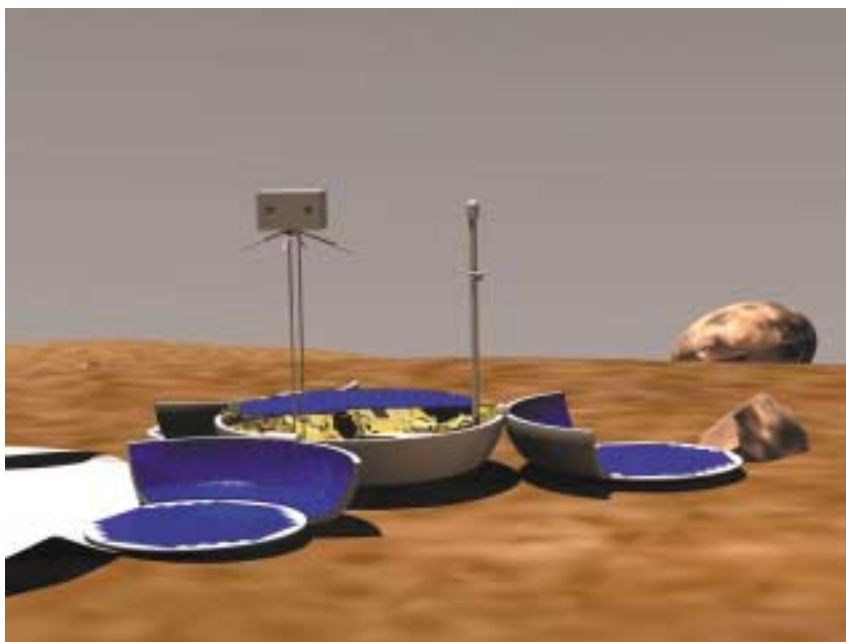


Figure 4.3. NetLander operating on Martian surface.

ing, surface properties, and structure of a short-periodic solar system comet Wirtanen. FMI/GEO participates in four orbiter and two landing unit instruments: the Swedish orbiter plasma instruments LAP and ICA, the French instrument MIP and the German dust analyser COSIMA. On the lander GEO's Principal Investigator (PI) instrument PP will analyse the electrical properties of the comet's surface material and plasma waves in its environment. GEO has also system level responsibility in the lander CDMS memory unit. During 1998, the instruments' feasibility was demonstrated by building breadboard models for each part. All engineering models were manufactured, tested and delivered for integration in 1999. The PP instrument's prototype was taken to a 1-week field test on frozen rivers and lakes in Northern Finland.

As a preliminary study, the COSIMA consortium developed a simplified version, CIDA, which was successfully launched on the NASA spacecraft STARDUST in February 1999 and has already produced valuable information about dust properties in the solar system.

In January 1999, the NASA Mars Polar Lander (MPL) was successfully launched. The MPL payload included, for example, FMI-supplied pressure devices for three-month observations of meteorology and soil volatile content. Attempts to establish communications with the lander after the landing sequence were unsuccessful and the mission was lost.

After the FMI-led European study on a Mars surface network in the second half of 1997, the NetLander proposal was submitted to ESA in early 1998. The NetLander network (four landers for observations of meteorology, surface, interior and subsurface structure, and ionosphere) was not approved by ESA, but extensive work on mission definition continued through 1998-99. The NetLander mission has emerged as a primarily French-Finnish-German mission and as a component of the French-U.S. Mars co-operation framework with a joint Ariane 5 launch in 2005 together with a Mars Sample Return orbiter. The NetLanders' landing was scheduled for August 2006 followed by surface operations for a Martian year. However, the recent reorganisation of the NASA

programme may move the NetLander launch to 2007. In the phase A study started in early 1999 FMI/GEO has assumed primary responsibilities for the Surface Module – the component operating on the surface – and the Atmospheric and Meteorological Instrument System (ATMIS).

FMI participates in the studies of solar wind interaction with the Martian atmosphere. The scientific studies have been continued based on plasma observations obtained by the ASPERA instrument onboard the Phobos mission in 1989. In 1998 the group became involved in the Mars Express (MEX) mission of ESA, which is the first ESA mission to Mars with a launch in June 2003. FMI is designing and manufacturing the data processing unit and developing the flight software for the ASPERA-3 (Analyzer of Space Plasmas and Energetic Atoms) instrument. The instrument will study the effects of the solar wind on the Martian atmosphere utilising the new energetic neutral atom techniques.

SMART-1 is an ESA technology mission in preparation for the cornerstone mission to Mercury. FMI is participating with the PI-instrument ‘Spacecraft Potential, Electron and Dust Emission Analyzer’ (SPEDE), which will monitor the effects of the new electron propulsion system on the direct environment of the spacecraft. While SMART-1 slowly spirals out of Earth orbit towards the Moon SPEDE will additionally investigate the plasma properties of the Earth’s magnetosphere and the solar wind during the transfer phase. In Moon orbit the plasma properties of the transition region into and out of the eclipse will be studied. The project started with the instrument selection in 1999, the flight hardware delivery is planned for Spring 2001 with an estimated launch by the end of 2002.

University of Turku, Space Research Laboratory (SRL)

The main scientific activities of the Space Research Laboratory (SRL) during the years 1998-99 have been the observations, data analysis, and scientific work with the Energetic and Relativistic Nuclei and Electron experiment

(ERNE) onboard the Solar and Heliospheric Observatory (SOHO). ERNE consists of two detectors, the Low Energy Detector (LED) and the High Energy Detector (HED). Both measure energetic particles of elements with $Z = 1 - 30$. Together they cover the energy range $\sim 1.5 - 500$ MeV/n.

Contact with SOHO was lost in June 1998, but due to excellent work of NASA and ESA engineers, contact satellite was re-established in August and its experiments were recovered in October 1998. Despite the long period during which the temperature onboard SOHO was very low, ERNE did not suffer any problems after the recovery, but showed the same quality as before the SOHO loss of contact.

During the period 1998-99, the solar activity increased remarkably, when solar cycle 23 developed from the solar minimum (September 1996) towards its maximum. This was also seen in the increasing number and intensities of energetic particle events. Increase of activity enabled SRL scientists to start research of intensive solar energetic particle (SEP) events, the first of which occurred in November 1997. The studies of November 6, 1997 event unveiled two particle populations with different elemental compositions.

In 1998 SRL scientists took part on the SOHO whole Sun month campaign by analysing the energetic particle events on August 1996. These studies revealed a phenomenon of solar energetic particle (SEP) storage and/or re-acceleration by a corotating interaction region (CIR). This kind of phenomenon had never been detected before, and the exact course of events has not yet been explained.

Further studies on Earth-directed coronal mass ejections (CMEs) during the first half of 1997 showed that the injection profiles of energetic particles differ remarkably from injection profiles of CME-accelerated particles during solar maximum. While the more intensive CMEs are still effective particle accelerators when they cross the Earth orbit, the injection from the weaker CMEs vanishes already at distances of some tenths of astronomical units (AU) from the Sun. Earth-di-

rected CMEs can cause magnetic storms, when they hit the Earth's magnetosphere. Magnetic storms can damage electrical power lines, telecommunications and satellites. Therefore the prediction of such phenomena is economically important. Although the prediction of the magnetic storms is one of the hot topics in the SOHO project, more observations are still needed before complete understanding of magnetic storms will be reached.

Analysis of solar energetic particle (SEP) events associated with impulsive soft X-ray flares, type II radio bursts and coronal mass ejections (CMEs) revealed a SEP acceleration process during the first 100 minutes after the flare impulsive phase, called post-impulsive-phase acceleration. The solar event of 9 July 1996 was a representative example of a well-connected event. The post-impulsive-phase acceleration association with Moreton waves was confirmed, but instead of the previously detected two-component structure, additional proton acceleration at intermediate scales between flare acceleration and interplanetary CME-driven shock acceleration was detected. This post-impulsive-phase acceleration seems to be caused by the CME lift-off.

The theoretical studies in SRL during the years 1998-99 have concentrated on the transport and acceleration of solar energetic particles. A numerical transport model taking into account adiabatic energy changes during the interplanetary particle transport has been developed. Further, models of stochastic acceleration and diffusive shock acceleration have been studied in solar coronal conditions. Both analytical and numerical methods have been employed. The key findings in these studies have been associated with effect of the diverging coronal magnetic field on the efficiency of the acceleration mechanisms, which has been shown to be considerable. In addition, diffusive shock acceleration in solar corona has been shown to be strongly modified by the large phase speed of the waves associated with the acceleration process, enhancing the acceleration efficiency above the prediction of the standard shock-acceleration theory.

University of Oulu, Department of Geosciences and Astronomy

Planetology is a part of the activities of the Space Institute of the University of Oulu. Modern approaches in planetary science have been made possible by the data provided by the notable space missions. Together with NASA the Nordic Regional Planetary Image Facility has been established to ensure the availability of the detailed new planetary data sets and to provide this data for Northern European scientists, schools, media, and public.

Various tools have been applied to study different aspects found on planetary surfaces. Some interdisciplinary topics between astronomy and geology have resulted in studies in selenochemistry and impactite mineralogy. Planetary remote sensing has led to increased interest in environmental problems. Knowledge in geophysics has provided an insight to the crust and lithosphere, and helped to monitor certain environmental parameters.

Lunar tectonics and geological development have been studied with Clementine data. Studies of Martian photometry and tectonics have been continued with more recent (Mars Global Surveyor etc.) data sets. Participation in future Mars programmes (e.g. NetLander) has been prepared. Venus research using Magellan data sets continues with studies of Venusian stratigraphy, re-surfacing, tectonics, volcanism, and lithosphere. Venusian and terrestrial impact craters have been studied by using radar imagery and field works, respectively. 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 continuing.

Remote sensing methodology studies continue and amplify different planetary approaches. They widen the perspective by providing a possibility to adopt field-true data for evaluation of the result correctness.

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

Heliospheric physics is an increasing research field in 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). Heliospheric research includes ground-based and underground cosmic ray measurements, long-term satellite measurements of solar wind and IMF, and satellite missions.

The cosmic ray nucleon component has been measured continuously at the Oulu cosmic ray station since 1964. These data are regularly sent to the World Data Center and other scientists. The CUPP project was continued in order to establish a multi-layer muon detector in the Pyhäsalmi mine. The first new muon detector elements were installed at the depth of 210 m. The effects of the Earth's magnetic field on the asymptotic directions of cosmic rays were calculated according to the modern models of the magnetic field. Solar neutrons were studied using an extensive network of cosmic rays stations at different latitudes. New methods were developed in order to analyse the dependence of cosmic rays on solar activity.

Heliospheric structure and its changes over the solar cycle were analysed using the long-term measurements of the solar wind and IMF obtained from various spacecraft. A significant annual variation of solar wind speed was detected and found to change its phase from one solar cycle minimum to another. A similar behaviour was found in geomagnetic activity, solving the long-existing problem of the origin of the annual variation in geomagnetic activity. The annual variation was related to a persistent north-south asymmetry of the solar corona.

The group is also participating as a co-investigator in the CAPS instrument project of the Cassini mission to Saturn, with the main responsibility in the ion beam sensor (IBS). A CAPS-team workshop was held in Oulu in 1998. Calibration beam runs

for the IBS-instrument were made and simulations for the instrument performance were continued. 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, Department of Physics

Space physics research at the University of Helsinki is directed toward solar-terrestrial physics and conducted by a small group consisting of a professor and of a number of graduate students who all work in close collaboration with the Finnish Meteorological Institute. The joint research in magnetospheric physics, including a leading role in European space weather activities, is reported under the section describing FMI's activities in this field.

During 1998–1999 the group became involved in solar studies in two fields. Long term solar activity was studied using 143 years of sunspot observations to study solar differential rotation and its generators. From 1999 on the group has been active in studies of coronal mass ejections and their role in magnetospheric storms using SOHO/LASCO observations together with data from WIND, IMP-8, and ACE spacecraft and ground-based storm indicators.

University of Helsinki Observatory (UHO)

The planetary research at University of Helsinki Observatory (UHO) has concentrated on some key theoretical problems relevant to modern solar system studies. The UHO is participating in the Mars Express/HRSC experiment and the Microgravity experiment onboard the International Space Station (ISS) at a Co-Investigator (Co-I) status. The activities include the analysis of dust and aerosol light scattering both from the surface and in the atmosphere of Mars and in low gravity circumstances. Photoclinometric methods devel-

oped at UHO enable one to deduce the topography of the Martian surface.

New methods and codes have been developed for light scattering by small non-spherical particles. Systematic research continues to find means of separating aggregated and solid irregular articles by using these methods. Cosmic dust permeates the solar system and, therefore, these studies form an important method in gaining more information about that dust. Results from the systematic studies of light scattering by so-called Gaussian random particles have been obtained. Quite new results about the cometary dust have been gained by analysing polarisation measurements over a wide wavelength range.

UHO published the first application of the so-called Gaussian random sphere method to the modelling of the shapes of asteroids and cometary nuclei. Intriguingly fine light curve details appeared in the calculations that partly explained the increase of the asteroid light curve amplitudes with increasing solar phase angle. UHO continued photometric and photopolarimetric observing campaigns on asteroids that are (or are likely to be) targets of space missions.

Together with the Department of Mathematics, University of Helsinki, UHO provided a maximum likelihood estimator for solving the inverse problem of deriving the statistical parameters of the Gaussian random sphere from sample shapes. By making use of existing three-dimensional shape models of asteroids and planetary satellites, UHO together with the Astronomical Observatory, Uppsala University, succeeded in describing the shapes of small solar system bodies with a small number of statistical parameters. The statistical model promises to be applicable in numerous simulations of the physics of small solar system bodies.

UHO, together with colleagues at the Astronomical Observatory, Kharkov State University, Ukraine, published a paper on the diagnostic sense of the opposition effect of solid planetary surfaces, making use of recent snow measurements. An ex-

tensive study of the shadow-hiding effect in inhomogeneous layered particulate media was completed. The results offer important insight into understanding the opposition effect of airless solar system bodies. UHO has a Co-I status in the LIBRIS space experiment that aims at lidar imaging of small-to-medium sized space debris particles in low-Earth orbit.

UHO carried out discovery and follow-up simulations for small Earth-crossing asteroids, down to the diameter of 10 m, reaching substantial conclusions about the discovery biases for various classes of near-Earth objects. These simulations will help design efficient ground-based and space-borne search programs for near-Earth objects in the visible and infrared regime of the electromagnetic spectrum.

The near-Earth asteroid 1997XF11 made the news media headlines in Spring, 1998, when it was suggested that a collision with the Earth in October 2028 could not be ruled out with the existing astrometric data. UHO participated in the vivid discussion about the collision probability and showed, using rigorous statistical methods, that the collision probability was, in fact, vanishingly small. A Finnish near-Earth object impact hazard meeting was organised in Spring, 1999.

The SMART-1 space probe is planned for launch in late 2002, aiming at an orbit around the Moon. UHO has a Co-Principal-Investigator in the D-

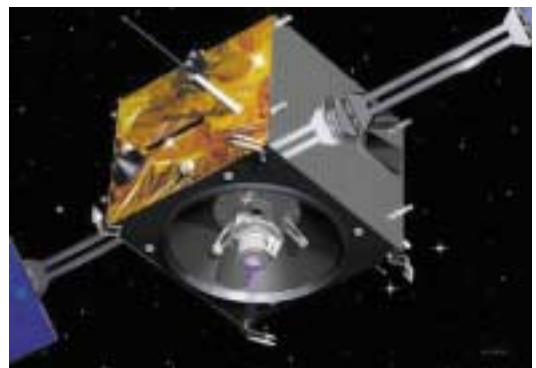


Figure 4.4. SMART-1 spacecraft that will carry the Finnish contributions SPEDE and XSM .

CIXS/XSM X-ray instrument complex and a Co-I in the SMART-1 AMIE complex. XSM (X-ray Solar Monitor) is the calibration instrument for the D-CIXS imaging spectrometer. D-CIXS will be measuring the X-ray fluorescence and monochromatic scattering of the lunar surface. In addition to the calibration task, XSM will independently produce valuable information of the solar corona and the solar flares. AMIE (Asteroid-Moon Imager Experiment) is a light-weight visual camera designed and built by a Swiss company. AMIE will provide a thorough data set of the disc-resolved opposition effect of the Moon and UHO will participate in the interpretation of the imagery using state-of-the-art theoretical models.

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 have been used in several international satellite campaigns. X-ray data from GOES, Yohkoh, and GRO/BATSE satellites have been used in comparison with the 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.

University of Turku, Tuorla Observatory

Planetary system dynamics have been studied by numerical investigations of various real and hypothetical systems, mostly in collaboration with American, Canadian, British, and Japanese colleagues. We have continued the study of the dynamics of the curious asteroidal body 3753 Cruithne, which is a new kind of companion to the Earth. Simulations of the formation of planets in binary star systems, tidal friction in multiple stars, and the dynamics of hypothetical quasi-satellites

(similar to the Cruithne) in the outer Solar System and several other systems have been conducted.

Significant new results in developing numerical methods have been achieved. New methods in the very topical field of symplectic integration of planetary orbits were invented, the most important among them a new way for regularisation and stabilisation. The superiority of our methods has been confirmed by other investigators. An entirely new method, algorithmic regularization of N-body equations of motion, was also discovered recently.

The evolution of the populations of small bodies in the solar system is very slow, and for many problems the direct orbit integration methods are too slow by several orders of magnitude. We have developed a Monte Carlo code that is about 100 times faster than direct orbit integration.

In collaboration with Swedish and American scientists we have investigated the possibility of matter transfer between planets. We have shown that smaller rocks ejected from planetary surfaces in collisions with larger meteoritic bodies have a non-negligible possibility of reaching other planets of our solar system. In particular, the transfer times between Mars and Earth are often small enough to make possible the survival of primitive life forms embedded in the rocks.

Helsinki University of Technology, Laboratory of Space Technology

The role of the Laboratory of Space Technology in the Mars NetLander 2005 project was to design a telecommunication system concept for the NetLander to Orbiter link as a part of ESA NetLander study and to participate in the telecommunication system development during the Phase A of the NetLander project. A preliminary design was produced for the Mars Express proposal and this design was further developed in the ESA NetLander study (which has ended by now) and the NetLander Phase A study (to end during Spring, 2000).

On the NetLander side the measurement data will be modulated on a carrier that is coherent with the carrier received from the Orbiter. This carrier is transmitted by the UHF transmitter (TX) to the Orbiter using a frequency of about 401,6 MHz (F_2). In addition, a coherent radio science carrier with a frequency of 2380 MHz (F_3) is transmitted by the NetLanders. This radio science carrier is implemented by two radio science experiments that will rely on Doppler measurements. On the Relay Orbiter side the command data received from the Earth will be modulated on a carrier, which is coherent with the stable reference frequency provided by an Ultra Stable Oscillator (USO) and transmitted to the NetLanders using a frequency of 437,1 MHz (F_1). The Doppler measurements (implemented by radio science experiments) will be conducted by a Data Processing Unit (DPU) onboard the Relay Orbiter. This data, along with the measurement data received from the NetLanders, will be stored by the Orbiter and sent to the Earth when possible.

4.3 Astronomy

University of Helsinki Observatory (UHO)

The general goals of the research group of the interstellar medium and star formation are to investigate the physical and chemical properties of interstellar molecular clouds and the properties and composition of interstellar dust grains in dense and diffuse clouds, and to measure the intensity of the extragalactic background radiation at optical and infrared wavelengths. The group has utilised a multi-wavelength approach where radio, infrared, and optical telescopes have been used. The observational facilities most important for the group have been the Swedish-ESO Submillimetre Telescope (SEST), the Infrared Space Observatory (ISO), and - starting in 2000 - the Odin submillimetre satellite.

The research goals of the group of interstellar medium and star formation have motivated a strong involvement in infrared space observations in the 2 to 200 micrometer bands. The group has Co-Investigator status in ESA's ISO (Infrared Space Observatory) ISOPHOT consortium.

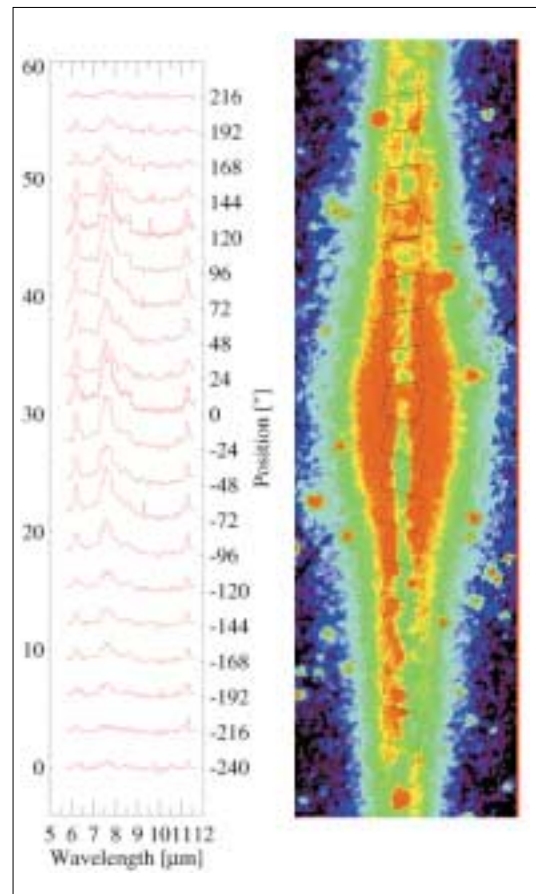


Figure 4.5. Infrared spectra along the major axis of the spiral galaxy NGC891, seen edge on. These spectra were obtained by the UHO using the ISO ISOPHOT-S instrument. On the right an optical false-colour image of the galaxy is shown with the observed 24×24 arc second areas superimposed. These spectra represent the first detection of the 'Unidentified Infrared' bands at 6.2, 7.7, 8.6, and 11.3 micrometers in the diffuse disk emission of an external galaxy. These bands are currently supposed to be caused by large numbers of Polycyclic Aromatic Hydrocarbon (PAH) molecules in interstellar space.

The space instrument design activity of the High Energy Astrophysics Group of UHO includes 3 science instruments: the SIXA X-ray spectrometer for Spectrum-X-Gamma with Principal Investigator (PI) status, the JEM-X X-ray monitor for the INTEGRAL satellite with Co-Investigator (Co-I) status, and the D-CIXS/XSM X-ray detector system for the SMART-1 space probe with

Co-Principal Investigator status. The High Energy Astrophysics Group of UHO participates actively in the hardware project management, the science data analysis software design, and the mission science preparation in all three missions. The above space missions will be launched between 2001 and 2003. Collaboration in these projects includes scientific institutes in European countries and in the USA, and space technology companies in Finland (the most important company partner being Metorex International Oy).

The scientific work includes studies of, 1) coronae of active stars and the Sun, 2) disc and pole accretion in X-ray binaries and CVs, 3) microquasars and radiation processes around black holes, 4) the galactic centre region, and 5) hot gas in clusters of galaxies. The work is based on satellite observations (ROSAT, ASCA, CGRO, RXTE, BeppoSAX, Hubble ST, EUVE and SOHO) and ground-based optical and Radio data (NOT, AAT, CAT, MOST, ATCA and SEST). Magnetic flaring and hot coronal gas are the unifying physical factors behind many of these topics.

- 1) HST observations of CIV 1550 line profiles show that microflaring is likely to be an important coronal heating mechanism. Related work is in progress to study the X-ray bright points (XBP) on the Sun using SOHO/SUMER observations. The preliminary results indicate that even smaller structures than microflares may exist, giving rise to the low level ubiquitous coronal emission on the solar surface.
- 2) Optical and X-ray light curves of X-ray binaries have been modelled using structured (warped) accretion discs and utilising genetic software algorithms. The method has been successfully applied to the black hole candidate 4U 1957+115. The results suggest the presence of vertically extended disc structure, which is difficult to explain with conventional models. Work on a more elaborated 3-dimensional code is in progress and will be applied also to MS 1603+2600 (possibly a new X-ray transient in quiescence observed at NOT) for which 50 ksec of the XMM-Newton time has been granted.
- 3) Multiwavelength (Radio-X-Gamma) observations of Galactic microquasars and theoret-

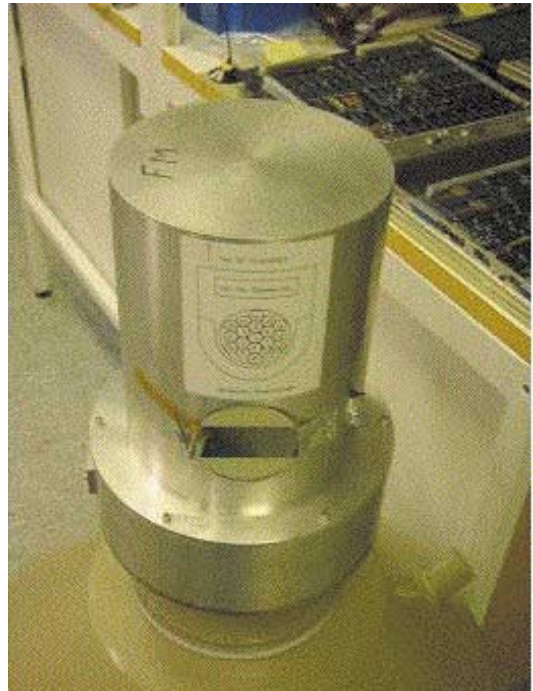


Figure 4.6. SIXA Flight Model detector in cold storage.

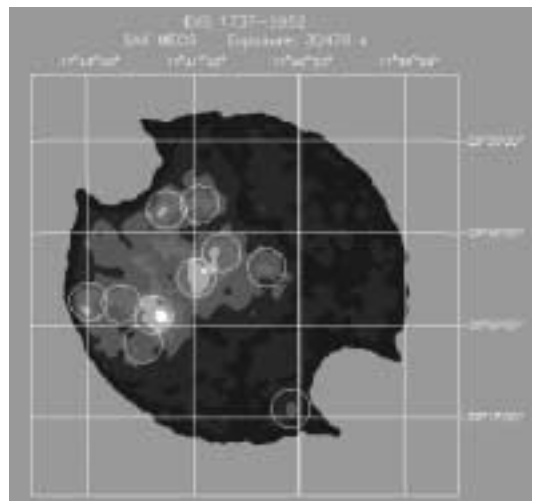


Figure 4.7. New soft X-ray sources identified by UHO observations with BeppoSAX satellite in April 1998 (Huovelin et al. 1999).

ical work on Comptonized radiation have been carried out. The work has given insight into the jet-ejection mechanisms, as well as to the disc structure under super-Eddington ac-

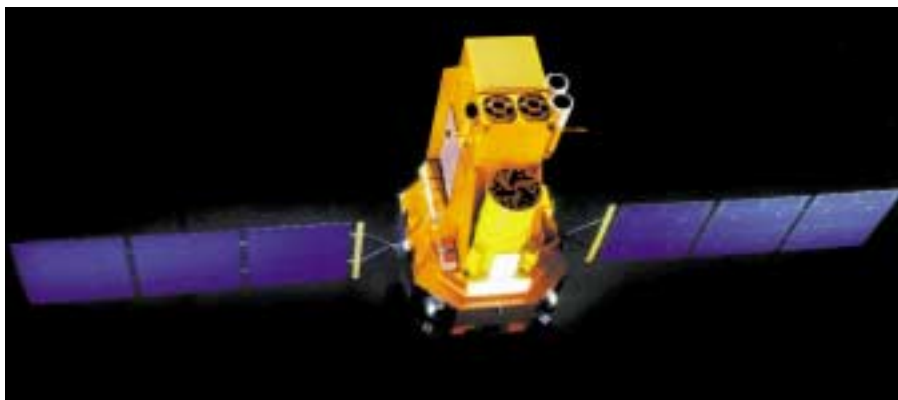


Figure 4.8. ESA's INTEGRAL-satellite, which will carry four science instruments. The double X-ray telescope JEM-X, which is partly manufactured in Finland, is located in the picture next below the large square aperture of the gammaray imager IBIS.

cretion. Modelling of the phenomena suggests that at least one of these (GRS 1915+105) is likely to be a Kerr hole with an extreme prograde rotation.

- 4) The Galactic Centre region at EXS 1737.9-2952 was observed in 1998 with Beppo-SAX to find a suspected transient. Surprisingly, ten new soft X-ray sources were discovered. Detailed study of the individual sources is being made to reveal their spectroscopic properties and possible time variability.
- 5) Hot gas, as observed in X-rays, has been studied to probe dark and baryonic matter distribution and cosmological parameters in clusters of galaxies. The results are consistent with the concept that the large scale structure of the Universe originated from primordial density fluctuations. The work will be continued with XMM-Newton and Chandra data.

University of Helsinki, Department of Physics

In 1999 scientific participation in the LFI (Low Frequency Instrument) Consortium of the Planck Surveyor Mission began at the Physics Department of the Helsinki University and the Helsinki Institute of Physics. The main interest is in the physical implications of the temperature map of the cosmic microwave background on particle physics and models of inflation. One particular

topic that has been studied is the amplitude of isocurvature fluctuations, predicted by certain types of supersymmetric particle physics models, and the possibilities for their detection at Planck. The group also participates in the data handling activities at a preliminary level.

University of Turku, Tuorla Observatory

Dark matter in the Milky Way has been studied using deep images obtained with the Hubble Space Telescope (HST). Analysis of the magnitudes and colours of the stars has enabled us to exclude the possibility that the low mass stars could provide a significant fraction the dark matter. The mass distributions, kinematics and metallicities of nearby stars have been studied using the Hipparcos data, which also helps to constrain the possible dark matter candidates. Using the Hipparcos data, Cepheid variables have been calibrated and the results applied to the study of the Hubble constant. The HST extragalactic Cepheid measurements have been utilised for calibrating the Tully-Fisher distance indicator. These and other ongoing studies, e.g., kinematics of a proposed massive black hole population and motions of the Local Group of galaxies, also pave the way for the GAIA mission.

Recently found magnetic Cataclysmic Variables and mCV candidates from the ROSAT all-sky survey have been studied optically with NOT and

CASLEO telescopes with photopolarimetric and spectropolarimetric methods. Future studies will include developing more realistic physical and geometrical models for mCVs, and their magnetic fields and cyclotron emission regions, based on new XMM satellite observations and optical studies. Other cataclysmic variables and low mass X-ray binaries have also been studied using the ROSAT and RXTE satellites and optical telescopes. Tuorla Observatory has Principal Investigator (PI) status in the forthcoming XMM study “Evolving accretion disc structure in UW CrB”, and Co-Investigator (Co-I) status in another XMM program.

Tuorla Observatory is associated with the Planck LFI Consortium, participating in the planning of the Planck Core program, to be formulated in 2001. Our main interest is in the so-called foreground sources, including Galactic contamination and active galactic nuclei. AGN researchers are also participating at various levels in other scheduled or proposed future radio astronomical missions, including the Halca (a number of PI and Co-I projects), Radioastron (Science Objectives Group), ARISE (Science Advisory Group), and VSOP-2 space VLBI (Very Long Baseline Interferometry) missions. Most of the work is directed towards understanding the relationships among the multiwavelength spectra, the total flux density variations across the whole electromagnetic regime, and the structural variations revealed by high resolution VLBI. In particular, numerous Compton/EGRET investigations (with Tuorla Co-Investigators) have revealed a close correlation between the radio and the gamma-ray regimes.

The large international OJ-94 blazar monitoring project, involving some 50 astronomers in 12 countries, has been continued. Within the project, a number of campaigns have been conducted using the Compton/EGRET, RXTE, ASCA, and Beppo-SAX satellites. In the future, the project will also incorporate multiwavelength observations with such new satellites as Integral, GLAST and AGILE.

Using the NOT, Calar Alto, Kitt Peak, NTT and VLT telescopes we have observed various sam-

ples of AGN from the Einstein Slew Survey, the ROSAT Green Bank Survey and the FIRST survey of radio sources in order to study their optical, IR and radio properties, parent galaxies and environments. We are also collaborating in a project of combining the NOT and the HST images of selected BL Lacs, and participating in the ELAIS survey of IR-luminous but optically faint galaxies detected by ISO.

New methods for manufacturing and testing of optical components have been developed. We have developed new techniques of polishing thin, lightweight carbon and silicon carbide mirrors, suitable for space applications. In collaboration with the Opteon Oy (Finland) and Matra Marconi Space (France), polishing of a test mirror for the FIRST satellite was successfully completed in 1999. The 1.35 m mirror is the largest silicon carbide mirror ever polished.

University of Turku, Space Research Laboratory (SRL)

The Space research Laboratory is actively participating in the Alpha Magnetic Spectrometer (AMS) project. AMS is a new generation particle instrument with a gathering power of three orders of magnitude higher than in previous instruments. The goal of the project is to measure the antimatter abundance in the Universe in order to probe the fundamental theories of physics. In addition, AMS searches for weakly interacting particles (WIMPs) that may partly or completely explain the problem of dark matter. The laboratory was invited to the AMS collaboration by Nobel Laureate Prof. Samuel Ting to provide the ground support system for the project. SRL also participates in tracker production.

AMS made a successful test flight aboard the Space Shuttle in 1998, obtaining a total of 107 hours of observations. SRL ground support team assisted the instrument integration in Zürich and Cape Canaveral and participated in the mission operations in Johnson Space Center during the flight. After the flight the instrument was calibrated with particle accelerators in Darmstadt and

CERN. Observations onboard the International Space Station Alpha (ISSA) will be carried out during the years 2003 - 2006.

Helsinki University of Technology, Metsähovi Radio Observatory

Metsähovi Radio Observatory continued to participate in the dedicated international space-VLBI (Very Long Baseline Interferometry) missions: Halca (VSOP) from Japan and Radioastron from Russia. Metsähovi is a member of several accepted observing programmes of Halca and the Metsähovi telescope has participated in one common VLBI session with Halca at 22 GHz.

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 in the study of extragalactic radio sources. The following satellites have been used: Compton GRO, RXTE, IUE, ROSAT, ASCA, and ISO.

Metsähovi participated in the AMS (Alpha Magnetic Spectrometer) mission. The first test flight was in June 1998 with the Space Shuttle flight STS-91. The first results from this flight were published in 1999. The next phase is 2-3 years of measurements in the International Space Station Alpha starting 2003. Metsähovi is responsible for the design, construction, and operation of the High Rate Data Link (HRDL) electronics, through which all scientific data from AMS instrument are transmitted.

Metsähovi is a member of the team that is building for ESA the low frequency set of receivers for the Planck satellite. The group is participating in the design and testing of the 70-GHz receivers. In addition Metsähovi is participating in the Planck foreground science. Metsähovi participated in the Planck CMB Surveyor instrumentation team. The Finnish team is responsible for the design, construction and test of the 70-GHz HEMT (High Electron Mobility Transistor) receivers. The Planck Phase-0, "Critical Technology for Microwave Radiometers," consists of several InP MMIC (Microwave Monolithic Integrated Cir-

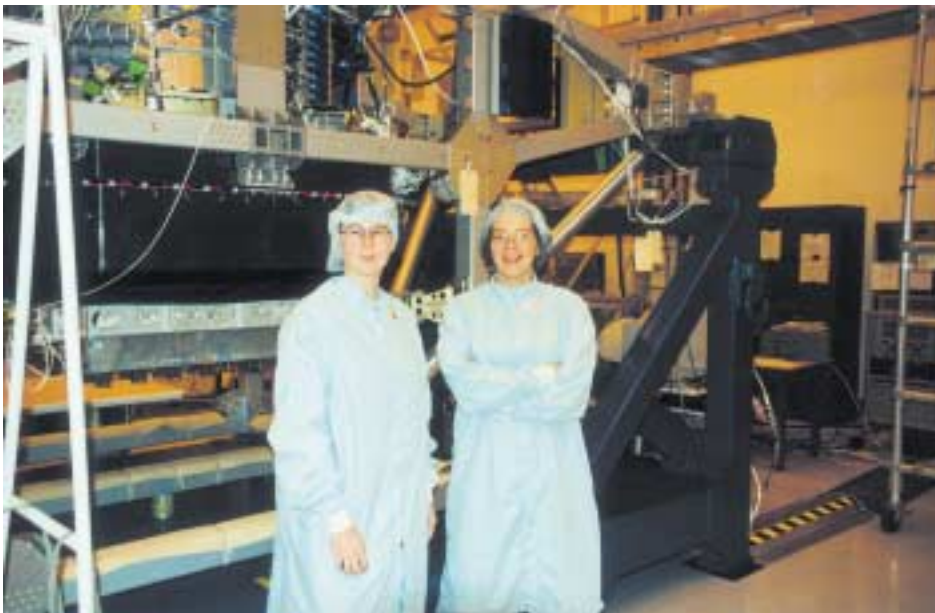


Figure 4.9. The AMS experiment being assembled at NASA Kennedy Space Center MPPF cleanroom (M. Tornikoski and K. Karlamaa, Metsähovi).

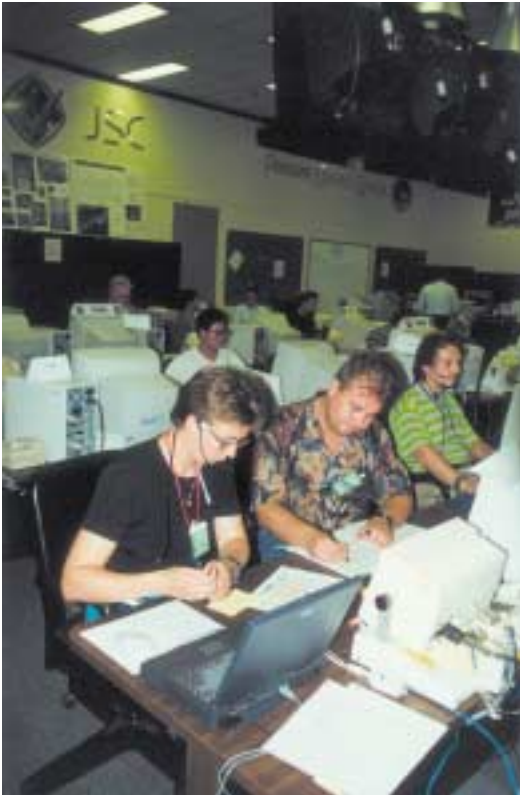


Figure 4.10. Supervising reception of HRDL data during STS-91 at NASA Johnson Space Center Mission Control Center (M. Tornikoski and A. Mujunen, Metsähovi, T. Eronen, University of Turku).

cuit) process runs at Daimler-Chrysler. An ultra-wide band monolithic hybrid divider with an operating bandwidth of 20 - 100 GHz has been designed. Two designs with alternative port orders were accepted for the latest process run. Metsähovi was the prime contractor in Planck Phase 1a, "Evaluation of the TRW MMIC process and its upper frequency limits," Tekes contract 40162 / 99. Metsähovi and VTT contributed a 3-stage LNA design to the first TRW MMIC process run. The LNA was designed for 18 dB gain and 2.4 dB noise figure.

Helsinki University of Technology, Radio Laboratory

During 1998-1999, space research activities at the Radio Laboratory were focused on research into

receiver technology and antenna measurement techniques at millimeter and submillimeter wavelengths.

The Radio Laboratory is participating in the international Odin satellite project. Odin will carry onboard a radio telescope operating at millimeter and submillimeter wavelengths for monitoring aeronomical and astronomical spectral lines. The radio telescope uses an offset reflector antenna with a 1.1-m diameter main reflector. The Finnish contribution is a cooled 119-GHz Schottky diode receiver, and the telescope antenna tests at 119 GHz.

Within the project, a compact antenna test range (CATR) based on a hologram was developed and the Odin telescope was tested at 119 GHz in Linköping, Sweden. For these tests a 2.4 m by 2.0 m hologram was designed and fabricated. The hologram consisted of seven pieces, which were connected together with thin polyester tape. The quality of the hologram for Odin measurements was assessed measuring the quiet-zone field. According to the telescope tests, the main beam was symmetric and the beamwidth met design requirements.

The European Space Agency is currently examining the use of space-based radiometric instruments to probe the atmosphere in the 200 - 1000 GHz region. The hologram CATR technique has a potential to become an economic way of testing the large satellite antennas of such instruments. In 1998-1999, the Radio Laboratory carried out a project in which the feasibility and applicability of a submillimeter wave hologram CATR was studied. A demonstrator CATR based on a 60-cm hologram was built for 310 GHz.

In 1996, ESA started a development program called KASIMIR (Key Advanced Structure Investigations for mm- and Sub-mm-Wave Integrated Receivers) in order to advance the future submillimeter receiver technology for Earth observation and radio astronomy. The goal of the project is to fabricate sensitive open-structure and waveguide type integrated 650-GHz receiver front-ends using European Schottky diode technologies in co-operation among several research



Figure 4.11. Measurement set-up for testing the quiet-zone field of the 60 cm hologram at 310 GHz.

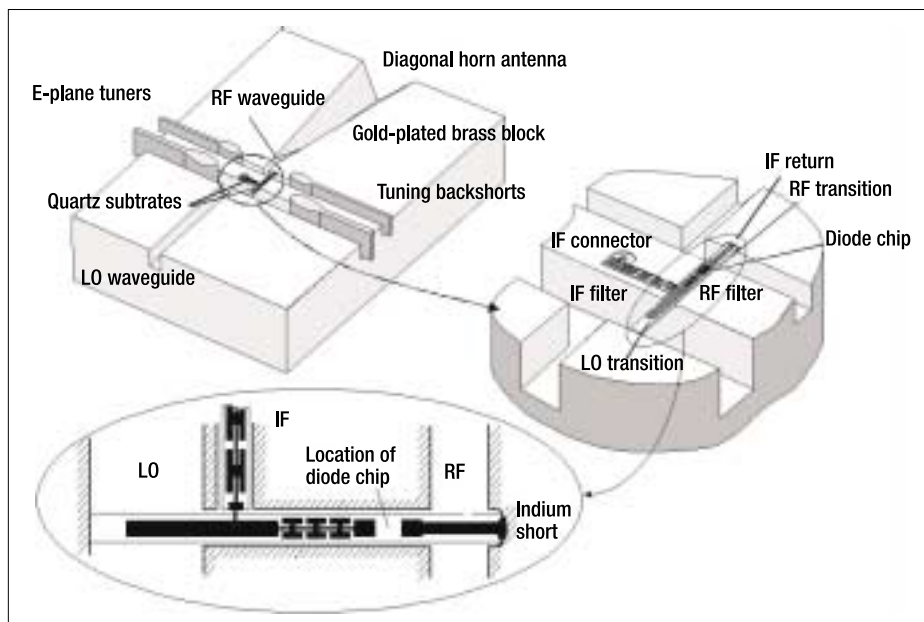


Figure 4.12. Integrated 650 GHz receiver front-end comprising a diagonal horn antenna and a subharmonic waveguide mixer utilising an anti-parallel pair of quasi-vertical Schottky diodes. Filters are made on 45 m thick quartz substrates by using microstrip techniques.

groups. All the front-ends employ so-called quasi-vertical Schottky diodes. The development and fabrication of these high quality GaAs Schottky diodes are essential parts of the project.

The Radio Laboratory is responsible for the 650-GHz waveguide type receiver front-end comprising a diagonal horn antenna and a subharmonic waveguide mixer utilising an anti-parallel pair of quasi-vertical Schottky diodes. 10- and 220-GHz scale models are designed and tested before the 650-GHz receiver front-end. During 1999, the tests of the subharmonic 220-GHz mixer were finished yielding a single sideband (SSB) noise temperature of 3500 K and conversion loss of 9.2 dB with an applied LO power of 3.5 mW. Currently, the 650-GHz mixer is being assembled.

Millimetre Wave Laboratory of Finland (MilliLab)

The Millimetre Wave Laboratory of Finland - MilliLab is a joint laboratory between the Technical Research Centre of Finland (VTT) and the Helsinki University of Technology (HUT). MilliLab is also an 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 modelling, 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. The total research personnel with experience in millimetre waves is over 25.

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. The

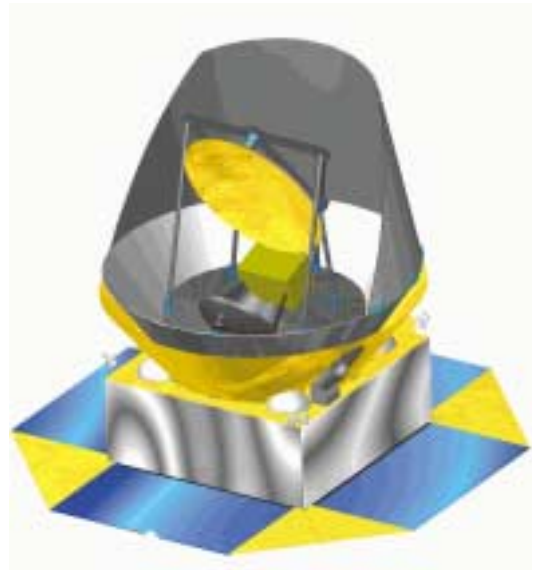


Figure 4.13. The Planck spacecraft. The active parts of the 12 receivers at 70 GHz will be built by the Finnish team.

novel antenna test method based on a radio frequency hologram has been described above in more detail under HUT Radio Laboratory.

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 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 for this project.

The main scientific goal for the 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 radiation ($\Delta T/T \cong 4 \times 10^{-6}$) is the possibility to uncover a wealth of cosmological information encoded in the anisotropy pattern.

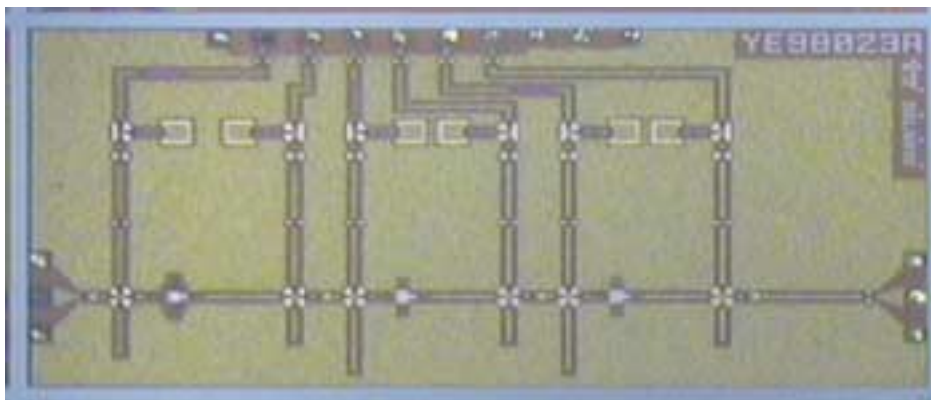


Figure 4.14. Photograph of a three-stage 70 GHz low-noise amplifier designed for Planck LFI. This integrated circuit is based on Indium-Phosphide (InP) HEMTs (high electron mobility transistor).

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 FIRST spacecraft.

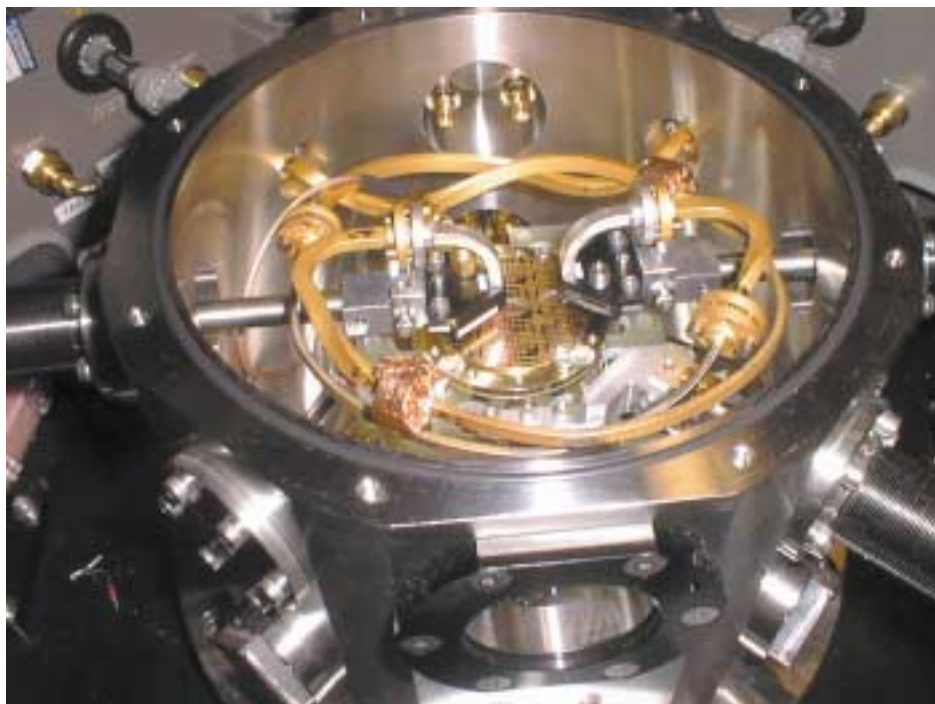


Figure 4.15. Unique set-up for testing millimetre wave integrated circuits on wafer at 20 K. This is an essential tool, e.g., in the development work for Planck-mission.

5 Applied Space Research

5.1 Space Geodesy

Finnish Geodetic Institute (FGI)

Finnish Geodetic Institute operates several pieces of powerful research equipment at the Metsähovi Space Geodetic Station (METS), such as a permanent GPS (Global Positioning System) receiver, a satellite laser rangefinder, a DORIS beacon, and a superconducting gravimeter. METS served in 1998-99 as a reference station of the IGS (International GPS Service), and was part of the FinnRef permanent GPS network. The receiver type was Turbo Rogue; during 1999, also an Ashtech Z-18 GPS-GLONASS receiver has operated in the framework of IGEX (International GLONASS Experiment).

In 1998, a new laser (7806) was approved as a part of the ILRS (International Laser Ranging Service) network. It uses a mode-locked 50 ps NdYAG laser, which produces a 25 mm single-shot accuracy. The old satellite laser (7805) produced during 1998 (January-October) 29558 observations on 356 arcs of 9 satellites (Topex, ERS-1 and -2, Stella, Ajisai, Fizeau, GFO, Starlette, Resurs). The new satellite laser rangefinder (7806) produced during 1998 54424 highly precise observations from 369 arcs of 13 satellites (in addition to the previous: Lageos-1 and -2, Geos-3, Westpac). In 1999 the number of observed satellites increased to 18 (Sunsat, Glonass-68, -72, -79, and -80, Etalon-1 being the new ones) In total, 90967 observations were produced on 566 arcs of these satellites.

The Finnish permanent GPS network (FinnRef) worked well during the report period. The stations were instrumented with Vaisala PTU200 meteo sensors with a view toward including the network in international "GPS meteorology" work. This is

a multipurpose network serving the needs of geodynamic and atmospheric research as well as those of mapping, charting, and surveying.

During 1998-99, the FGI executed a Tekes-funded research project jointly with Vaisala Oy in the field of "GPS-meteorology". In the frame of this project a one month field campaign was carried out in January-February 1998 to test the feasibility of GPS meteorology in a small area under winter conditions. Later, all permanent stations were instrumented with meteo sensors. With the aid of these sensors one can use GPS observations to determine the total water vapour content ("precipitable water vapour") straight above the station in near real time. In the frame of the project methodological research was conducted, among other things, in the effect of snow on the antennas on the ability to simultaneously estimate from GPS data both atmospheric parameters and in the height changes caused by postglacial land uplift. The FGI also participated, together with the Finnish Meteorological Institute, in the European COST-716 project, which also aims at exploiting GPS meteorology.

During 1998-99, the FGI participated, through GPS measurements, in the second phase of the EUREF Densification Project, aimed at providing an accurate realisation of the European EUREF co-ordinate system over the Finnish territory. In this second phase, 350 points were created in easily accessible locations for use by the general surveying and mapping user community. The final results of the first phase of EUREF densification, one hundred mainly first order triangulation points, were prepared in manuscript form for publication in early 2000. The choice of triangulation points allows for the easy derivation of transformation formulas between the traditional co-ordinate frames and the new EUREF-based one.

During autumn 1999 a Nordic airborne gravimetry project mapped gravity anomalies over the main basin of the Baltic Sea and the Gulf of Finland. GPS was used for positioning the aircraft in order to separate motion induced pseudo-forces from gravity; Finland participated by operating the reference GPS stations in Tuorla and Virolahti at 1-second data collection intervals.

During the gravimetric survey field operation of the FGI, the use of GPS together with the FIN95 Finnish geoid model for determination of gravimetric station heights was successfully pioneered.

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 GPS networks at Olkiluoto, Kivetty and Romuvaara were measured at half-yearly intervals.

During 1999, using satellite radar altimetric observation from ERS-1 and ERS-2, the sea surface topography of the Baltic Sea, i.e. the deviation, of decimetre class, of its surface from hydrostatic equilibrium caused by currents, air pressure and salinity variations, was studied, as were temporal variations of sea level. This work belongs to the Baltic Sea Level project.

Helsinki University Of Technology, Institute of Geodesy and Cartography (IGC)

Research project on the utilisation of GPS (Global Positioning System) in traversing, mapping and setting out measurements has been continued. For this purpose a test net in Otaniemi, Espoo, was established, measured and computed. The test net was used in studying the validity of Real Time Kinematic GPS (RTKGPS) in urban environment and in testing communication modems and data storing and handling in a rugged field computer under natural, open air, conditions. Several transformations of co-ordinates were carried out between different co-ordinate systems.

5.2 Remote Sensing

Helsinki University of Technology, Laboratory of Space Technology

Helsinki University of Technology (HUT), Laboratory of Space Technology was involved in development of space-borne interferometric microwave radiometers, remote sensing of water, forest, snow, and sea ice, and topography studies using SAR (Synthetic Aperture Radar) interferometry.

The MIRAS-Demonstrator Pilot Project (MIRAS-DP) was started in December 1998. Its objective is to design, construct and test a small-scale prototype of the space-borne MIRAS instrument (Microwave Interferometric Radiometer with Aperture Synthesis). The space-borne instrument will include altogether 85 receiver units in Y-shape geometry. The small-scale prototype will consist of four receiver/antenna units, a calibration system, an optical harness and the electrical ground supporting equipment (EGSE). HUT and Ylinen Oy are responsible for the calibration system and the EGSE, including participation in the integration and the electrical tests of the prototype. Within the project the HUT airborne synthetic aperture radiometer, HUT-2D, presently under construction, will be used to test the overall feasibility of the calibration system and the sensitivity of the selected technology to outside interference. Design of the demonstrator has been completed and the manufacturing phase has started. The project is funded by ESA and the main contractor is CASA Space Division.

The feasibility study to design and test the calibration system of the future ESA MIRAS space-borne L-band synthetic aperture radiometer (MIRAS Calibration System Experimentation, CAS-E) was conducted from November 1997 to May 1998. Several possible calibration techniques were investigated and the most promising methods for both the interferometric and total power channels were designed for implementation in the HUT aperture synthesis radiometer. One of the main conclusions from the project was that a calibration system based on distributed

noise injection can be implemented in the HUT airborne instrument for the calibration tests. The required modifications to the HUT instrument are reasonable. The project was funded by ESA.

The goal of the EU-funded SALMON (Satellite Remote Sensing for Lake Monitoring) project was to evaluate the capabilities and potential of current and future space-borne sensors for monitoring the water quality of European lakes. The project lasted for 30 months and was completed in March 1999. The project consortium consisted of eight partners from Italy, Finland, and Sweden. The evaluation was performed by analysing both airborne remote sensing data and actual and simulated satellite data. These data were compared with extensive ground truth measurements. The results of the project show that hyperspectral spectrometers operating at optical and near-infrared channels are capable of measuring water quality variables such as chlorophyll-a, Secchi depth, and turbidity with a good accuracy. The methods developed at HUT for water quality parameter retrieval in the case of Finnish lakes include empirical algorithms based on employment of optimum channel-ratios and spectrum shape feature analysis techniques. The results also indicated that some of the current satellite instruments, such as Landsat TM, are capable of measuring lake water turbidity and Secchi depth. Airborne data were also used to simulate ENVISAT MERIS spectrometer data. The simulation results indicated that MERIS is capable of measuring chlorophyll concentration and that the expected retrieval accuracy for Secchi depth and turbidity will be better than that obtained with current satellite instruments.

The goal of the “Operative Monitoring System for Coastal Waters of the Baltic Sea” project was to develop an operational monitoring system for coastal water quality using remote sensing data. Therefore, the project was closely related to the SALMON project described earlier. The project was funded by Tekes and was concluded in March 1999. The project included two partners, the Finnish Environment Institute and the Laboratory of Space Technology. During the project, a scheme

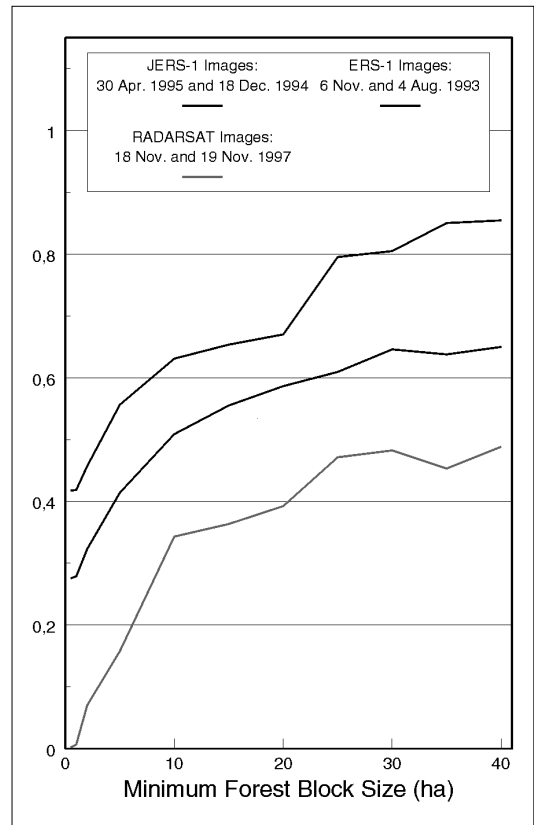


Figure 5.1. Correlation between radar-derived stem volume and ground-based stem volume vs. minimum forest block size.

for an operational water quality monitoring system was developed based on identifying suitable airborne remote sensing instruments and methods. The results indicated that currently water quality-related information from remote sensing data can be retrieved only if a large database containing simultaneous *in situ* and remote sensing measurements (or surface spectrometer measurements) from different sites and seasons is available. In coastal areas coarse-resolution satellite instruments such as NOAA AVHRR, ORBVIEW 2 SeaWiFS and ADEOS II OCTS can also be used for operational monitoring.

The EUFORA (European Forest Observations by Radars) project started in September 1996 and ended in November 1998. The objectives were to

(a) evaluate the value of the most advanced radar remote sensing research results with respect to forest information required in environment and climate studies, and forest management, (b) validate the methods and results at different European sites, and (c) define methods applicable in European conditions. The Coordinator of the study team was CESBIO from France. The project radar data sets include satellite, airborne, and ground truth data. HUT organised a joint experiment was conducted in 1997 in Finland with airborne and space-borne radars. The radar data sets for the Tuusula test site near Helsinki were analysed and the radar response to forest parameters at various frequencies (VHF-band to X-band) and polarisations was determined. The forest parameters included stem volume, basal area, height, age, and diameter. The results indicate that radar response to stem volume and other forest characteristics strongly increases with decreasing frequency. The highest correlation between the total (forest + ground) backscattering coefficient and forest characteristics was obtained in the VHF- band. Examination of the feasibility of using SAR interferometry for forest parameter retrieval was started in late 1998 in collaboration with Gamma Remote Sensing AG.

New adaptive inversion methods have been developed for active satellite-borne microwave remote sensing. The objectives of the study were biomass estimation, forest and land-cover type recognition in boreal forests. The inversion method for active sensors has been developed for forest blockwise stem volume estimation from satellite-borne radar images (e.g. JERS-1, ERS-1 SAR and RADAR-SAT). The inversion results with L-band and/or C-band SAR images have showed promising accuracies: the relative retrieval rms error varies from 25% to 5% as the size of the forest area varies from 5 to 30000 hectares (the forest stem volume varied from 0 to 300 m³/ha). The textural information of a seasonal set of satellite-borne radar images has been studied with the first and second order statistical measures. The multitemporal approach was beneficial for the textural measures in forest and land-cover type recognition. Based on the SAR image texture, the overall classification accuracy for seven land-cover types was 65% while with the SAR image intensity the classifica-

tion accuracy was 50%, respectively. In the forest type classification based on the SAR image texture and intensity, the overall classification accuracy for four forest types was 66%, while with the intensity alone, the accuracy was 4 %, respectively.

The main objective of the “Forest Inventory by Multi-Source Remote Sensing Techniques” project was to evaluate the feasibility and usefulness of single-source and multi-source remote sensing data for forest inventory. The remote sensing data set included satellite and airborne data. The reference data included three different standwise data sets. The accuracy of each data source and the use of combined data sets for forest inventory was evaluated. New methods under study included 3-D measurements over forest using laser scanner and profiling radar (HUTSCAT), the use of aerial photographs for automatic interpretation and updating of old field inventory with remote sensing techniques and growth models. The profiling radar and laser were determined to have higher accuracy than any other remote sensing data source applied for forest inventory. Optical satellite imagery was typically found to have more explanatory power than radar imagery. The project was a co-operation between several national institutes and was funded by Tekes and the Academy of Finland.

The synergy of airborne laser scanner and very-high resolution satellite data is demonstrated in the EU/CEO-funded project HIGH-SCAN (Assessing Forest Stand Attributes by Integrated Use of High Resolution Satellite Imagery and Laser-scanner). The objective is to explore and test methods for the integrated use of high-resolution satellite imagery and laserscanner data for small-area (regional and standwise) forest inventory and mapping. Methods to extract forest parameters from laser data have been developed during 1998 and 1999. The results have shown that laser-derived stand attributes are more accurate than those obtained by other data sources used in the comparisons. The HUT Laboratory of Space Technology is Coordinator of the project.

The SNOW-TOOLS (Research and Development of Remote Sensing Methods with Main Focus on

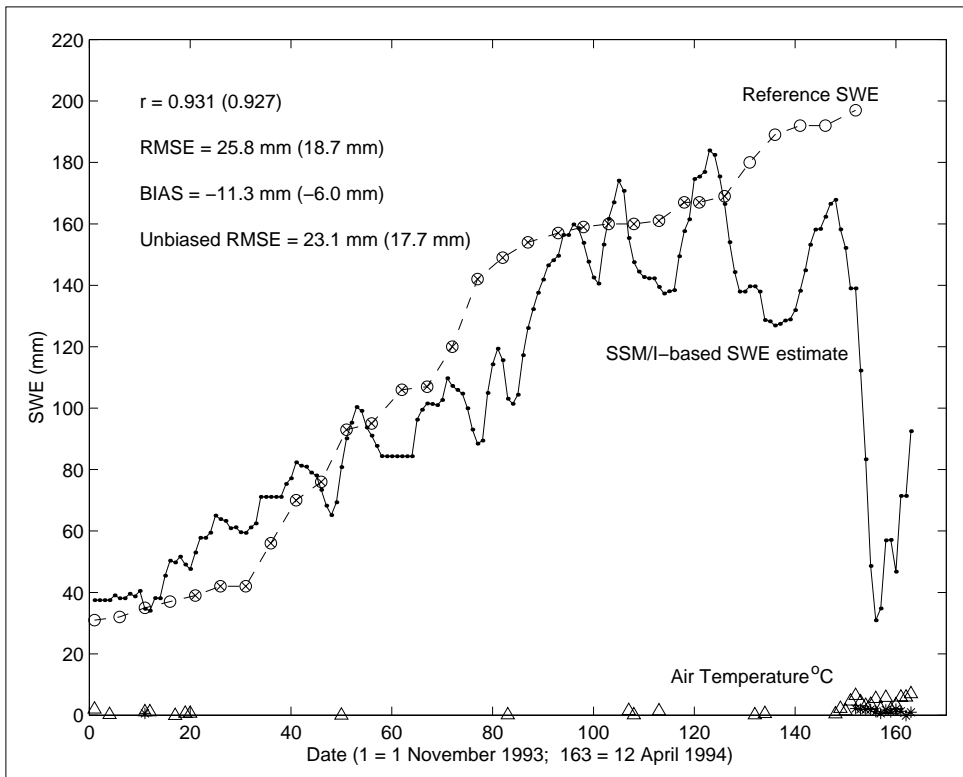


Figure 5.2. Regional snow water equivalent (SWE) estimation results for the River Kemijoki drainage. The estimates determined using the HUT Snow Emission Model-based inversion algorithm are marked by solid line, *in situ* observations-based reference values are marked by circles. The behavior of maximum and mean near-surface air temperature are marked with triangles and asterisks, respectively.

Snow Hydrology) project started in October 1996 and ended in the fall of 1999. The main objective was to develop generic methods for correction and interpretation of microwave and optical data with the main aim of (a) generating high-level products, (b) improving the information extraction from microwave and optical data, and (c) developing techniques for information extraction specific to snow hydrology. The SNOW-TOOLS Coordinator was NORUT Information Technology Ltd. with contractors from Norway, Finland, U.K., and Switzerland. LST participated in several project tasks. The transmissivity of boreal forest was derived as a function of stem volume up to 540 m³/ha. The application of remote sensing methods and products in operational snow hydrology was demonstrated at the end of the project.

The SNOW MAP (Monitoring of Snow Melt) project started in 1997 and it lasted until the end of 1998. The project was carried out with the Geodetic Institute as Coordinator and three Finnish partners. The aim of the project was to develop a semi-operational snow monitoring system that employs *in situ* measurements, GIS (digital elevation model and land-use map), and remote sensing data. NOAA AVHRR data and ERS-2 SAR images were used. The test site was the drainage area of River Kemijoki in northern Finland. The main responsibility of HUT was the development of SAR-based methods for snow monitoring. A system was developed for the retrieval of snow extent and classification of dry snow, wet snow and snow-free categories. The results show that a monitoring system can be constructed by syner-

getic utilisation of various satellite and ground-based data sources. The project was funded by Tekes.

The goal of the ESA-funded “Retrieval of Geophysical Parameters with Integrated Modelling of Land Surfaces and Atmosphere” project was to develop new forward modelling and geophysical parameter retrieval algorithms for the land applications of space-borne microwave radiometers. The project was started in 1996 and it was finished in 1998. The study team was lead by the Laboratory of Space Technology with two contractors from Switzerland. The main outcome of the project was the development of three new modelling approaches for microwave radiometry: (1) the semi-empirical HUT Snow Emission Model for describing the brightness temperature of snow-covered terrain, (2) the Microwave Emission Model of Layered Snowpacks (MEMLS), and (3) empirical Rough Soil Reflectivity Model. Additionally, a novel snow water equivalent retrieval technique was developed based on the HUT Snow Emission Model and the applicability of the theoretical strong fluctuation approach for snow microwave emission modelling was investigated.

The multinational EU-funded IMSI (Integrated Use of New Microwave Satellite Data for Improved Sea Ice Observation) project started in February 1997 and ended in May 1999. It was part of the EU Environment and Climate Program 1994-98. The overall objective was to explore and test methods for the use of new satellite Earth Observation data in sea ice monitoring and improve utilisation of these observations in a wider user community. The responsibilities of the HUT Laboratory of Space Technology consisted of studying combined use of SAR and microwave radiometer (MWR) data for classification of open water and various ice types in the Baltic Sea. LST also studied statistical properties of C-band backscattering signatures of various Baltic Sea ice types. The studies were conducted using airborne MWR and SAR data. It seems to be possible to use space-borne SSM/I data and the NASA Team and Bootstrap algorithms to derive total ice concentration in the Baltic Sea after proper modifications of

the tie points in the algorithms. Unfortunately, the amount of the combined MWR and SAR data was too small for statistically reliable classification results. The results from the backscattering signature data analysis can be used to help the development of sea ice classification algorithms for space-borne SAR data (e.g. ERS-2 and RADAR-SAT).

The most important geographical information in cellular planning is topographic (digital elevation model, DEM) and morphographic data. Morphographic classes are defined as different land types, differed, however, according to their radio wave propagation abilities, i.e. how the land use types interact with RF and microwaves. New methods to retrieve morphographic classification are studied in co-operation with Finnish industry. The project has demonstrated that morphographic classification for cellular network planning can be produced using coherence and intensity information of SAR images. The selected morphographic classes are water, open areas, forests, suburban and urban areas.

Technical Research Centre of Finland (VTT)

A comprehensive software package to process operatively data from the AVHRR instrument of NOAA satellites was developed. The package includes geometric and radiometric corrections of the imagery. The geometric corrections include utilisation of the orbital parameters of the satellites and the radiometric corrections involve atmospheric corrections and the BRDF corrections. The package is used operationally in Finland, Belgium and Japan. The project was funded by Tekes and VTT.

A methodology was developed and applied to estimate forest area and to produce forest maps. The method utilises satellite data and ground reference data. It takes into consideration the fact that a pixel rarely represents any single ground cover class. This is particularly true for low spatial resolution data. It also takes into consideration the fact that

the spectral classes overlap. First, the image was classified using an unsupervised method. Second, target variable values for the spectral classes were determined using ground sampling. Third, the target variable estimate for each pixel was computed as a continuous value by using the probability of that pixel belonging to each spectral class, and the target variable value of the classes. The method was applied over a mosaic of 49 AVHRR images acquired from the NOAA-14 satellite. A forest probability map was computed using the mosaic. The forest probability was defined to be an estimate of the forested area within a pixel. The ground reference data were taken from the CORINE Land Cover classification that covered most of central and southern Europe. The estimated forest areas were compared with those extracted from the full coverage CORINE data and with official forest statistics reported to the European Commission's Statistical Office (EUROSTAT). The forest percentage of twelve countries of the European Union was underestimated by 1.8 percentage units compared to the CORINE data, 4.2 percentage units when compared with EUROSTAT's statistics, and 6.0 percentage units when compared to FAO statistics. The largest underestimation of forest percentage (compared to CORINE) was in France, (5.9 percentage units). The largest overestimation was found in Ireland, 15.6 percentage units. This project was carried out under a contract for the Joint Research Centre of the European Commission by VTT Automation (Coordinator).

Methods of estimating forestry parameters from SAR imagery were developed in the EUFORA shared cost action project. The VTT part focused on using the low-frequency CARABAS SAR data. Other remote sensing data types included JERS and ERS SAR data and HUTSCAT ranging scatterometer data as well as laser profilometer data. New texture-based methods were developed for the data sets. The performance of CARABAS in forest biomass estimation was much higher than that of higher frequency SAR's.

Forest increment and forest characteristics, relevant to increment estimation are estimated in

GeoBIRD (Forest Increment Estimation Using Growth Models and Remote Sensing Data) project using existing forest growth models, Landsat TM, and ERS SAR images. The main methods are regression analysis and multi-temporal analysis. Texture analysis and SAR interferometry are applied to ERS images. Combination of growth models and Landsat data improved stem volume increment estimation by eight percentage units in Finland compared to the exclusive use of growth models. ERS SAR is applicable to forest mapping but does not in general case give information of forestry parameters, not even using interferometry. The study is performed for the European Space Agency. VTT is responsible for the forest growth estimation using statistical growth models.

Leaf Area Index (LAI) estimation methods were developed using Envisat ASAR data. The objective of this study is to develop new methods using the ASAR instrument onboard ESA's Envisat satellite. This study is an Announcement of Opportunity project for Envisat. The image data include ERS and RADARSAT images, and Envisat images, if available during the project, which will end in 2001. Polynomial Legendre series expansion for trees is used to develop an analytic solution to the backscattering. The relationship of LAI and the structure is used as a link between the scattered field and the LAI. The study is in co-operation with three national institutes.

In the FMERS (Forest Mapping in Europe Using Medium and High Resolution Imagery) study for the Joint Research Centre and DGVI of the European Commission, methodologies were developed for the provision of standardised geo-referenced data (maps) and statistical data of forests in Europe. The image data included Spot, Landsat, IRS-WiFS, Resurs MSU-SK, and ERS SAR imagery. The main methodologies were unsupervised classification of calibrated image mosaics (optical data), temporal back-scattering change analysis (SAR), and multistage area frame sampling. A working system for European-wide forest mapping was developed and forest maps from the bulk of the western part of Europe were made. The

study was performed by an international consortium and was co-ordinated by VTT.

A pilot forest variable estimation method at sub-stand level was developed to estimate forest stand variables using satellite and aerial imagery. In this method the estimates were computed for each pixel, thus increasing the level of details compared to the traditional forest inventory. The first step of the method is a hierarchical classification of the image data. The different data types form the hierarchy levels. The final estimates for forest variables are computed as continuous values. The study was funded by Metsäteho Oy and Stora Enso Ltd.

The main objective of the EU shared-cost action project SIBERIA (Forest Mapping Methods for Siberia) is to develop methods for wide-area forest mapping using SAR interferometric data. VTT's role is to make a reference classification using optical data. The satellite data used will be from Landsat TM, NOAA AVHRR, and Spot HRV and Spot Vegetation instruments. The same probability-based method that was developed for the pan-European forest mapping will be further developed and applied. The study will be completed by the end of 2000.

The FUEGO concept of a constellation of 12 satellites for forest fire detection and monitoring was critically evaluated by VTT, taking account of current fire-fighting practices. Enhancements to fire detection algorithm were proposed, and recommendations for a smoke detection algorithm were made. The project was funded by ESA and VTT was a partner in an international consortium. In another project, an automatic forest fire alarming system was demonstrated in an operational context in the Boreal forest zone. The method utilises data from two satellite systems: NOAA AVHRR and ERS-2 ATSR. The system detects high-temperature targets in the Mid-IR bands of the chosen sensors. An automatically generated alarm message is sent via facsimile communication to the dispatching centres. The image processing techniques are adopted and optimised for the near-real-time requirements imposed by the

application. This ESA-funded study is a joint project (co-ordinated by VTT Automation) among Finnish institutes, companies and the JRC. The project will be completed in the year 2000.

Operational software (SARDEM) to generate digital elevation model using SAR interferometry was developed for Satellite Data Centre of the National Land Survey (presently NovoSat). The system uses complex data from ERS-2 SAR.

European Forest Institute

The study "Combining Geographically Referenced Earth Observation Data and Forest Statistics for Deriving a Forest Map for Europe" is funded by JRC/EC and co-ordinated by the European Forest Institute with Finnish institutes and a company as contractors. The study started in August, 1999, and it will last until March, 2000. The objective of this study was to produce calibrated digital forest probability maps for the Pan-European area. The process applies AVHRR satellite data, forest statistics from both Eurostat and national agencies, and NUTS (Nomenclature of Territorial Units for Statistics) vector data sets organised by GISCO (Geographic Information System for the European Commission). The main purpose of the calibration was to create a program that could be used with differing numbers of input images. The automation of the process will make the calibration faster, user errors can be avoided easily, and the process can be repeated in the exactly same way. The documentation of the calibration program will also help to understand better the technical background. AVHRR satellite data are used. The deliverables include the probability databases in ArcView format for the countries of the study, AVHRR-based maps with 3 target variables (forest, other wooded land, and other) calibrated at NUTS2 level for 15 EU countries, AVHRR-based maps with 5 target variables calibrated at regional level for 3 countries, a database linking the statistics and the GIS data, and a technical report on the working package. The developed calibration method is quite well suited for its purpose and it is quite fast. The calibration of

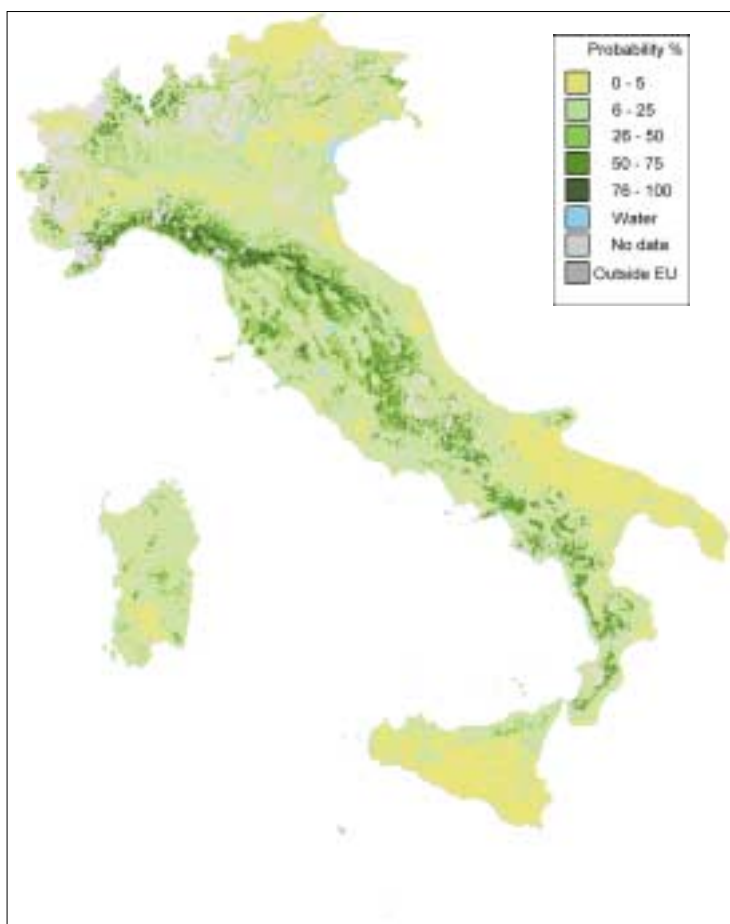


Figure 5.3. Probability of the broadleaf forests in Italy, image calibrated with country statistics.

one country takes only few minutes and the time usage depends on the number of different variables and polygons. The original forest probability maps and calibrated forest probability maps were compared to CORINE raster data, produced July 7th 1997 by the European Topic Center on Land Cover.

Geological Survey of Finland (GTK)

The Remote Sensing Laboratory – now under construction at the GTK - aims to act as a base for remote sensing of outcropped bedrock and soil,

mining activities, and environment and natural geo-hazards. The laboratory has been equipped with high-performance Unix workstations and image processing software, a dense, non-reflecting shelf and has been built for placing and imaging a large number of geological samples by imaging spectrometers. The spectrometers can be automatically moved in front of the shelf. Moving lights illuminating the samples are synchronised by a laser beam with the movement of the spectrometer. The GTK contribution to an EU- funded project 'MINEO' (Assessing and monitoring the environmental impact of mining activities in Europe using advanced Earth Observation tech-

niques') will be based on the new Remote Sensing Laboratory.

The aim of the ongoing project "Hyperspectral Study of Mineral Indications and Mining Environments" is to provide GTK and its partners with the methods of hyperspectral remote detection of minerals and environmental targets by the end of September 2001. The wavelengths normally used are 400-2500 nm. Studies of indications for ore deposits, industrial minerals and geoenvironmental contamination are based on the ability to map, for example, mineral abundances, rock types, alteration zones, and subtle changes in vegetation from a distance. The test imaging is carried out at close range, from a helicopter, from aeroplanes and – finally, in future - from satellites. The project tests the hyperspectral method in various natural circumstances and test areas: for example, discernibility of outcropped Precambrian bedrock units, and discernibility of glacial soil types. Environmental, geochemical and vegetation effects are studied near mines and especially near their waste areas. Mineralogical applications of the hyperspectral method for mining improvement, waste rock dilution and mineral enrichment are being carried out in four different mines in Finland.

Helsinki University of Technology, Institute for Photogrammetry and Remote Sensing

The aim of the research project "Digital Image Processing in Remote Sensing" (funded by the Ministry of Agriculture and Forestry) is to develop and apply different digital image processing, image analysis, and pattern recognition methods to photogrammetry and remote sensing. The actual main target has been land-use and tree species classification using airborne data (ranging scatterometer, laser) and satellite data (ERS-1/2, Landsat TM). Methods for information extraction and classification have been based on image processing methods, statistical pattern recognition, and neural networks, especially self-organizing neural networks.

5.3 Meteorology

Finnish Meteorological Institute, Meteorological Research Division

During the 1990's EUMETSAT has initiated several projects called Satellite Application Facilities (SAF) to fully utilise the potential generated by the planned geostationary MSG and polar Metop satellites to be launched in the near future. The SAF on Climate Monitoring, which started in 1999, has now submitted its comprehensive scientific and operative plans for international review. The operative system, to be completed in 2003, will collect satellite-based climatological data that will assist in analysis and diagnosis of climate parameters to identify and understand changes in the climate system on an European and global scale. The expert institutes developing the SAF are from Belgium, Finland, The Netherlands, Sweden, and Germany. The deliverables of the SAF on Climate Monitoring are: cloud parameters, components of the surface radiation budget, components of the radiation budget at the top of the atmosphere, sea surface temperature and sea ice cover, and temperature and humidity profiles. FMI concentrates on the development of the surface albedo product. During the development phase the analysis methods for surface albedo have been tested particularly for the high latitudes and the boreal sub-arctic region.

A method for estimating the instantaneous and daily solar (global) irradiance at earth's surface from AVHRR data was developed and tested. The satellite-based spatial distributions of solar irradiance, as affected by the prevailing cloudiness, were found particularly useful over regions where the station network of pyranometers was sparse, such as in the Northern Finland.

A project dealing with an operative satellite image processing system (SOKA) in co-operation with the Technical Research Centre of Finland and the Finnish Environment Centre was completed. FMI was responsible for the software for the detection of clouds. For this purpose a simple analysis scheme for cloud masking was imple-

mented. The use of the new AVHRR/3 channel to discriminate snow, cloud and sun-glint from satellite images was investigated in co-operation with the Swedish Meteorological and Hydrological Institute.

Concerning the development of operational weather forecasting, FMI has participated in the SATREP project together with ZAMG (project manager) from Austria and KNMI from The Netherlands during 1998-2000. The project is preparing a manual consisting of conceptual models on CD-ROM for the diagnosis of synoptic weather systems using satellite imagery. Two versions of the manual have already been published and the third will be available in May, 2000. The aim is to present various conceptual models in practical detail, with a multitude of examples, as well as to give the reader a quick overview of the phenomena in question. The manual can also be accessed via the www at (<http://www.zamg.ac.at>). EUMETSAT has financed the project together with participating institutes. In parallel with the method development, FMI has, jointly with ZAMG and KNMI, completed an operational system for the diagnosis of the synoptic scale weather phenomena using satellite data (Meteosat, NOAA) and outputs from numerical weather prediction models. The SATREP products, appearing three times daily, are also distributed to other interested national weather services in Europe.

Finnish Meteorological Institute, Geophysical Research Division

The work of the aeronomy group at the Geophysical Research Division has grown around the various satellite instrument projects GOMOS/Envisat, OSIRIS/Odin, and OMI/EOS Aura. Algorithm development, inversion theory, radiative transfer, data simulation, chemical-transport models, data assimilation, and solar-terrestrial effects in the upper atmosphere are the key words that explain the research activity of the aeronomy group.

FMI was one of the original co-proposers of the GOMOS stellar occultation instrument, which

will be flown on ESA's Envisat satellite in 2001. 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 will host the GOMOS Level 2 data processing facility (FIN-CoPac) in Sodankylä. FMI is participating in the Envisat data validation and data utilisation programs on a wide front.

As a potential successor for GOMOS, FMI has proposed (with several Finnish and foreign partners) a small stellar occultation instrument named COALA 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.

FMI is participating in a Swedish-led, Canadian, Finnish, and French small satellite project Odin (launch expected in 2000). FMI's aeronomy group is developing the data processing algorithms for Odin's UV-visible spectrograph OSIRIS and FMI is building together with the Finnish industry the level 2 processing centre in Sodankylä.

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 2002. FMI's role is to lead the industrial participation in Finland and to co-ordinate the scientific work in Finland. FMI will be responsible for developing a ground receiving station for OMI in Sodankylä.

In the radiative transfer research we have developed a Monte Carlo simulation program (named Siro) which calculates multiple scattered solar irradiance and its polarisation degree in the limb viewing geometry. Siro has already been used to validate other radiative transfer programs and plays an important role in the OSIRIS signal simulation. We have developed an extensive simulation program (named LIMBO) that makes

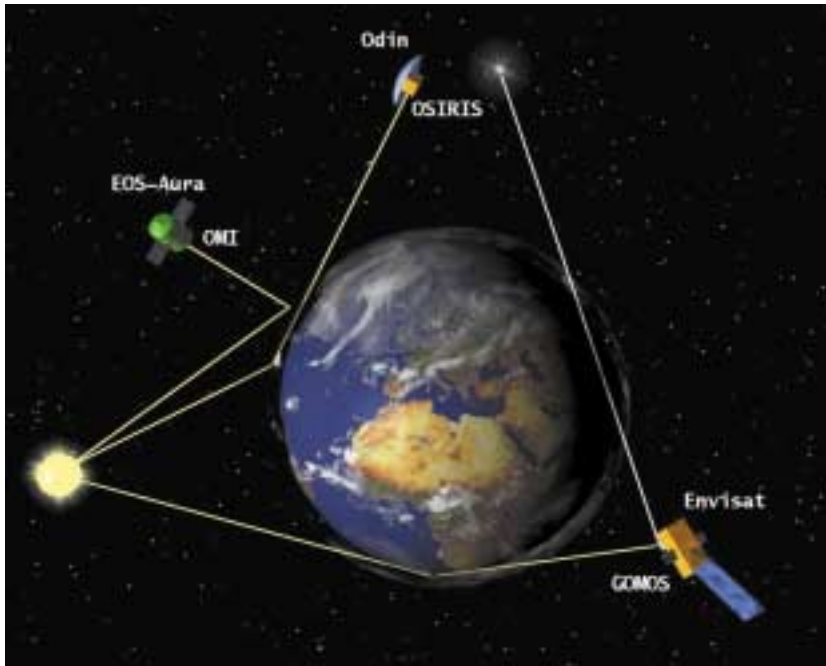


Figure 5.4. Measurement principles of GOMOS/Envisat, OSIRIS/Odin, and OMI/EOS Aura instruments utilizing solar and stellar occultation techniques as well as atmospheric scattering of sunlight.

end-to-end simulations for occultation and limb measurements. This program is being used extensively in the algorithm development of GOMOS, OSIRIS, and COALA. In the inversion algorithm development the work has responded on the needs of the satellite projects mentioned above. We have developed spectrally global, non-linear point-estimate inversion techniques. Recently we have also directed a great deal of attention to the estimation method that provides not only a point estimate but also the whole probability distribution for the unknown parameter. The method, Markov Chain Monte Carlo, is computationally intensive but we expect it to be the method of future.

The new research direction in the aeronomy group is the data assimilation research. FMI has participated in the MSDOL-project (funded by EU) to study GOMOS data assimilation to chemical-dy-

namical models. The aim is to provide global ozone maps from GOMOS measurements and also to help in the geophysical validation of GOMOS measurements. We are also starting assimilation tool development for the OSIRIS measurements.

In basic atmosphere research, which will grow in emphasis once the new satellites are functioning, we study 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 the atmospheric waves can be detected 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

Tampere University Hospital, Department of Clinical Physiology University of Turku, Laboratory of Theoretical Physics

Finnish participation in life science research in space has, thus far, been rather limited. However, the recent participation in the Neurolab research project has opened new possibilities in this potentially very important field of applied space research. The Neurolab project, partly conducted during the 16-day Space Shuttle Columbia STS-90 mission in April-May 1998, was totally devoted to dedicated neuroscience research. Neurolab has been considered as the most complex human life science (HLS) mission flown ever in the history of space research. The experiments (26 in total) had passed highly selective independent scientific peer reviews and the sophisticated in-flight experiments had met strict criteria for feasibility to be conducted in the Spacelab module logged to the cargo bay of the NASA Space Shuttle Columbia.

The Finnish team were selected as co-investigators to the Autonomic Nervous System Team with four principal investigators conducting four of the 26 Neurolab experiments. This space medical project was the second step of our participation in the HLS research after our earlier co-investigatorship in the American-Russian collaboration (Shuttle-Mir) onboard the Russian Space Station Mir. Our goals and objectives in the Neurolab project were to study the effects of microgravity on the autonomic nervous system (ANS), specifically on its role in cardiovascular regulation. In order to monitor the sympathetic 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), lower body negative pressure, blood pressure, cardiac 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.

During the Neurolab project the first direct recordings of efferent sympathetic function in space by means of microneurography were conducted by



Figure 5.5. The seven crewmembers of the Neurolab mission (STS-90) in the Spacelab module of the Space Shuttle Columbia.

our ANS team. Two STS-90 crewmembers were trained to conduct microneurography in space. The first (historical) microneurography recordings in space onboard the Space Shuttle Columbia revealed increased efferent sympathetic activity when comparing to the results obtained before the mission.

The Finnish contribution to the Neurolab project was in the design phase of the experiments and especially the 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), designed especially for the needs of Neurolab research, includes 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. During the project we worked several periods in 1998-99 in the USA, participating in the pre-flight activities and in the in-flight activities. After the mission we participated in the detailed data analysis by utilising the software package we had developed, and in documentation and publication of the results of this unique HLS research endeavour in space, dedicated totally to neuroscience research. Two scientific papers on the results of this work have been submitted to international journals in physiology. Neurolab project was retrospectively and partially supported in Finland by a grant from the Centennial Foundation of Helsingin Sanomat.

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