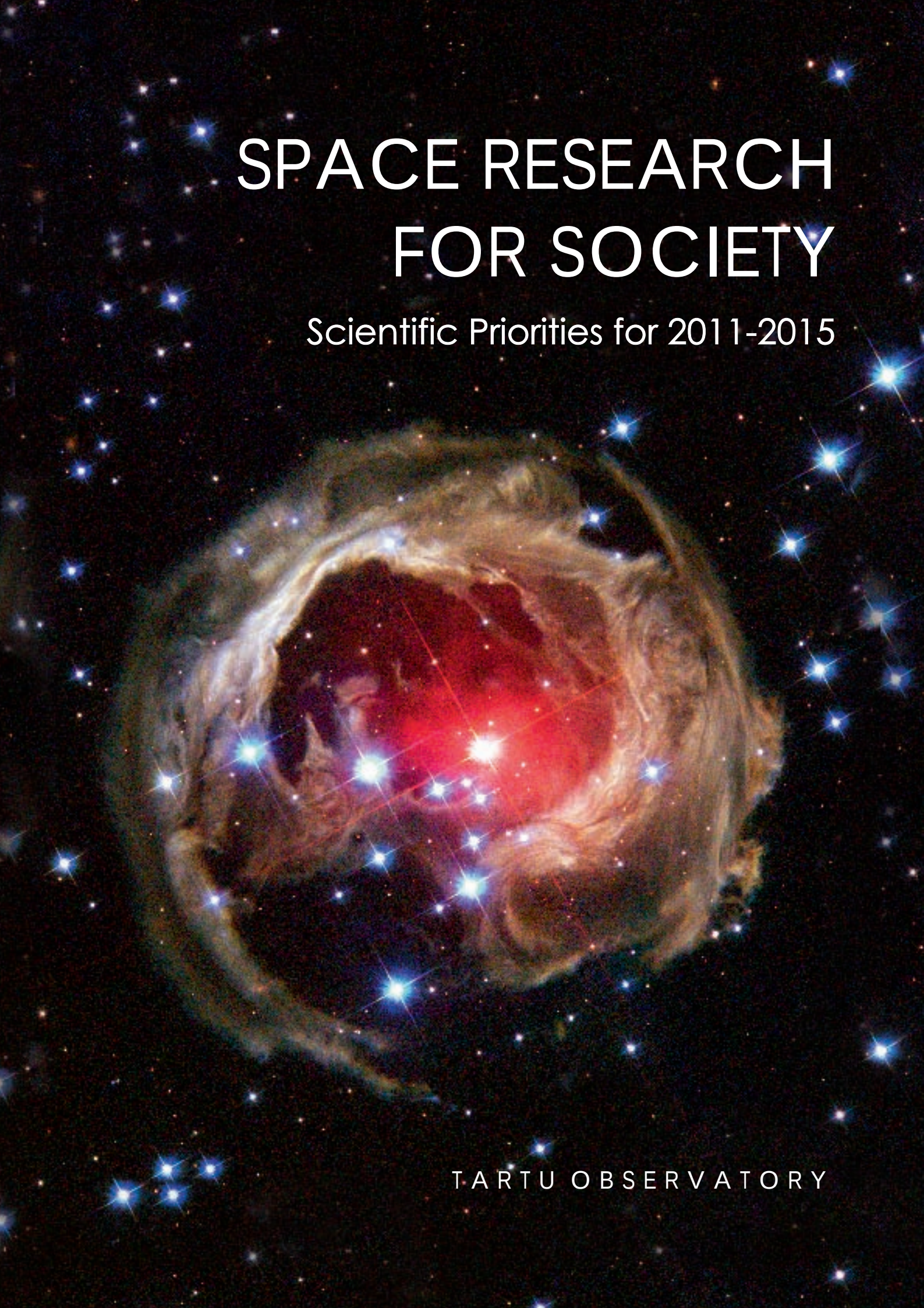
SPACE RESEARCH FOR SOCIETY

Scientific Priorities for 2011-2015



TARTU OBSERVATORY

Requests from the society for space research

Global challenges like adaptation with the changing environment, the need for effective use of energy, rapid increase of Earth population with a large variety of cultural differences forces countries to look for new and innovative technologies. Space technology has a significant role to play in meeting these challenges.

Space research is widely acknowledged as one of the most innovative fields of science, having priority with regard to the economic growth. Through the collaboration and technology transfer, space researches contribute to the increase of the innovation capacity of entrepreneurs. The development of space science and technology enables space exploration and improves our understanding of the nature of the Universe.

Space activities provide invaluable tools for environmental monitoring and protection, security, crisis management, communication and navigation. Space applications can also provide a significant pull for terrestrial technologies, e.g. advanced intelligent systems. Space inspires the young generation to start careers in science and technology, which is one of the most important factors for sustainable development of the economy.

RESEARCH

- cosmology
- stellar physics
- Earth observation
- space technology

APPLICATIONS

- environmental monitoring
- high-tech entrepreneurship
- optical calibration and radiometry
- specific hardware and software technology

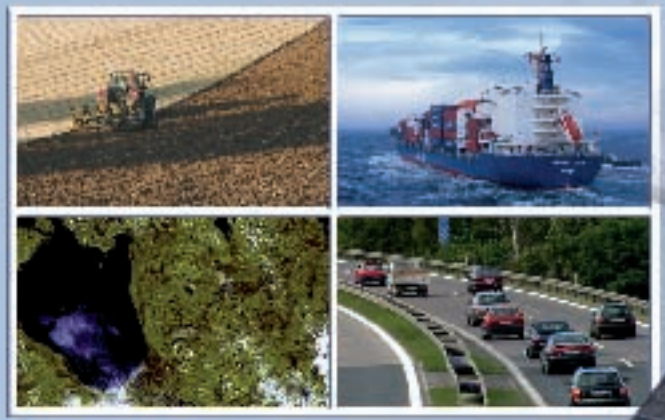
Background for the scientific goals of Tartu Observatory

In Estonia, the development of space applications and their downstream implementation is seen as the basis for future competitiveness and economic growth. On September 22nd 2010, Estonia signed a Plan for European Cooperating State with the European Space Agency (ESA) and approved the first version of the national Space Strategy.

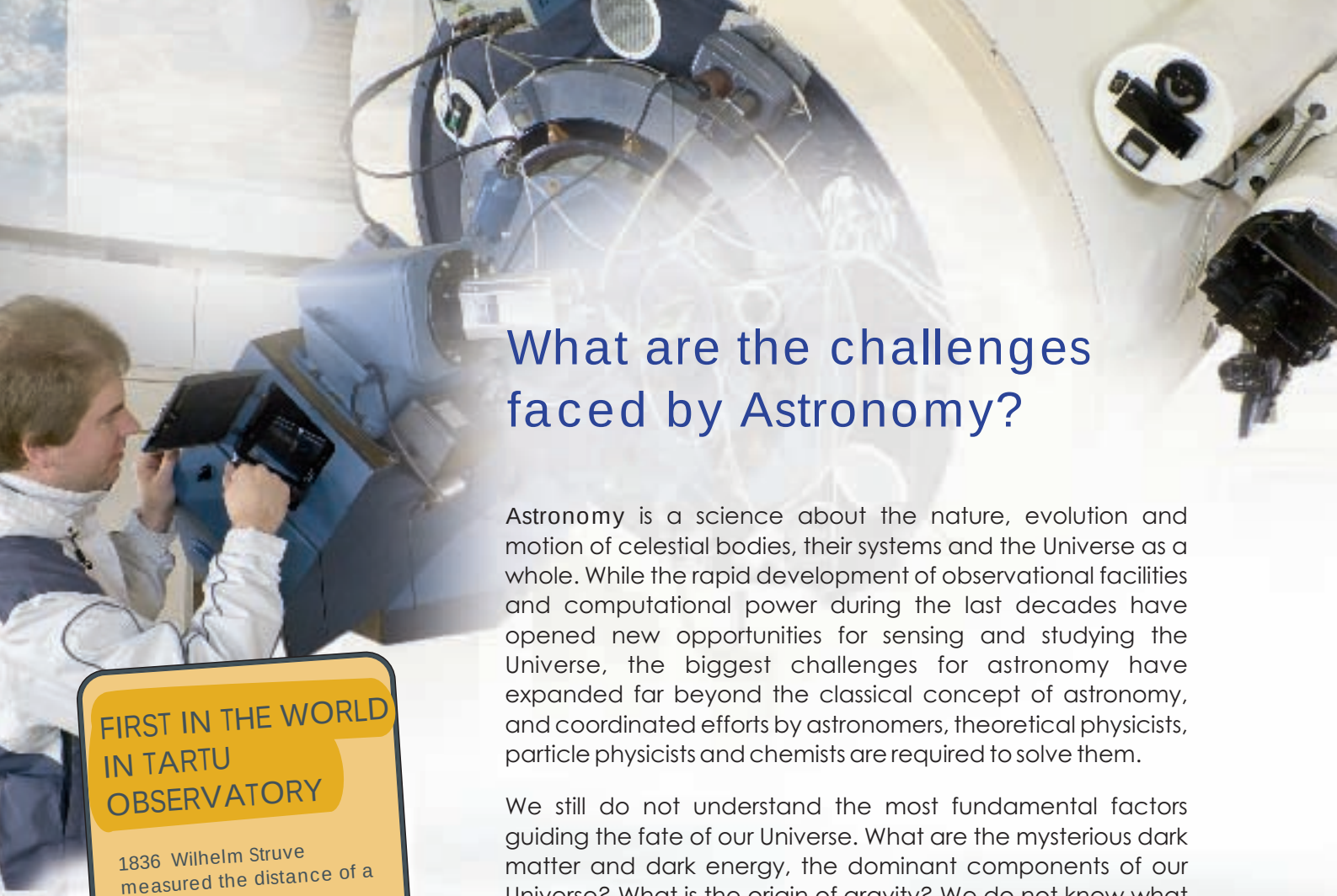
Having 200 years experience in space research, Tartu Observatory was evaluated with positive credits in each category during the Estonian Science evaluation procedure in May 2010. Tartu Observatory is the leading centre of astronomical research in Estonia, also possessing an internationally acknowledged competence in remote sensing of natural environment. Tartu Observatory research strategy brings together scientific and public goals. This enables to respond to the challenges that modern technology, political situation and economic needs create.

A cohesive strategy for Tartu Observatory space research, corresponding to the Estonian Research, Development and Innovation objectives is a key element to achieve a strong position in the international space research community and enables to meet the Estonian space strategic objectives. Scientific priorities of Tartu Observatory are focused on Astronomy, Earth Observation and Space Technology. The strategy is based on a medium-term view and its implementation is focused on scientific excellence on specific topics, identified as the strongest at Tartu Observatory, most relevant for further joint activities in European Research Area and Space community, and with the significant impact to the society.

OUTPUT TO SOCIETY



- services for public use
- expertise and consultancies
- popularisation of science
- education at school and university level



What are the challenges faced by Astronomy?

Astronomy is a science about the nature, evolution and motion of celestial bodies, their systems and the Universe as a whole. While the rapid development of observational facilities and computational power during the last decades have opened new opportunities for sensing and studying the Universe, the biggest challenges for astronomy have expanded far beyond the classical concept of astronomy, and coordinated efforts by astronomers, theoretical physicists, particle physicists and chemists are required to solve them.

We still do not understand the most fundamental factors guiding the fate of our Universe. What are the mysterious dark matter and dark energy, the dominant components of our Universe? What is the origin of gravity? We do not know what the conditions in the early Universe were, allowing for the formation of all the cosmic structures we are now witnessing. The formation and evolution of the basic cosmic objects: galaxies, stars, planets and even the variety of chemical elements and cosmic molecules, is still not clear in many aspects. And finally, how do the complex organic molecules – the bases for life - form in the Universe? Is our green planet unique?

FIRST IN THE WORLD IN TARTU OBSERVATORY

1836 Wilhelm Struve measured the distance of a star (Vega)

1922 Ernst Öpik measured the distance of a galaxy (Andromeda)

1974-1977 Jaan Einasto and colleagues showed that galaxies contain dark matter and discovered the cellular large-scale structure of the Universe

High priority research directions at Tartu Observatory

- **Questions about the fundamental physics of our Universe.** By analysing the large-scale distribution of galaxies, constraints on the properties of dark matter and dark energy can be laid. This work is carried out in large international cooperation with Tuorla Observatory (Finland), Potsdam Astrophysical Institute (Germany) and others. In collaboration with the National Institute of Chemical Physics and Biophysics, the results from the Large Hadron Collider experiment at CERN will be combined with cosmological considerations to entangle the issues of dark matter and gravity.
- **Participating in the ESA Planck mission to map the distribution of the cosmic microwave background radiation**, radiated about 300 000 years after the Big Bang and thus tracing the earliest structures in the Universe.
- **Usage of modern observational facilities for the research of stellar physics and galaxy physics.** Together with international partners, algorithms are elaborated for studying peculiar stars and the structure of our Milky Way galaxy in the framework of the ESA Gaia mission, measuring the accurate coordinates and velocities of about 1 billion stars.
- **Study of late evolutionary stages of stars, the properties of stellar populations and the structure of galaxies with modern ground-based telescopes.** The goal of joining the European Southern Observatory (ESO) has been set and cooperation with the Canary Institute of Astrophysics is being developed to promote these studies. Besides, high priority is given to modernization of the local 1,5-metre telescope, making it more efficient for observer training

What are the challenges faced by Earth Observation?

Earth observation is the gathering of information about physical, chemical and biological systems of our planet. However effects of the variations in the solar radiation and its spectral composition related to different environmental, biospheric, and health aspects as well as to atmospheric photochemistry are not well understood yet.

Studies about the Earth have revolutionised thanks to the observations uniquely available from satellites. Images of the changing planet are improving the understanding of the Earth's dynamic processes and helping the society to manage limited resources. Earth observation has become technologically more and more sophisticated – the number of satellites increases, the spectral range of passive and active sensors is extended from UV to microwave and spatial resolution is diminished to centimetres.

New challenges are now focused on linking optical signatures not only with objects, but also with processes, combing information from different sources into a system and distributing it via various services. EU and ESA are jointly developing the program Global Monitoring for Environment and Security (GMES), which is the European input to the Global Earth Observation System of Systems (GEOSS).

WE HELP TO UNDERSTAND THE GLOBAL CHANGE

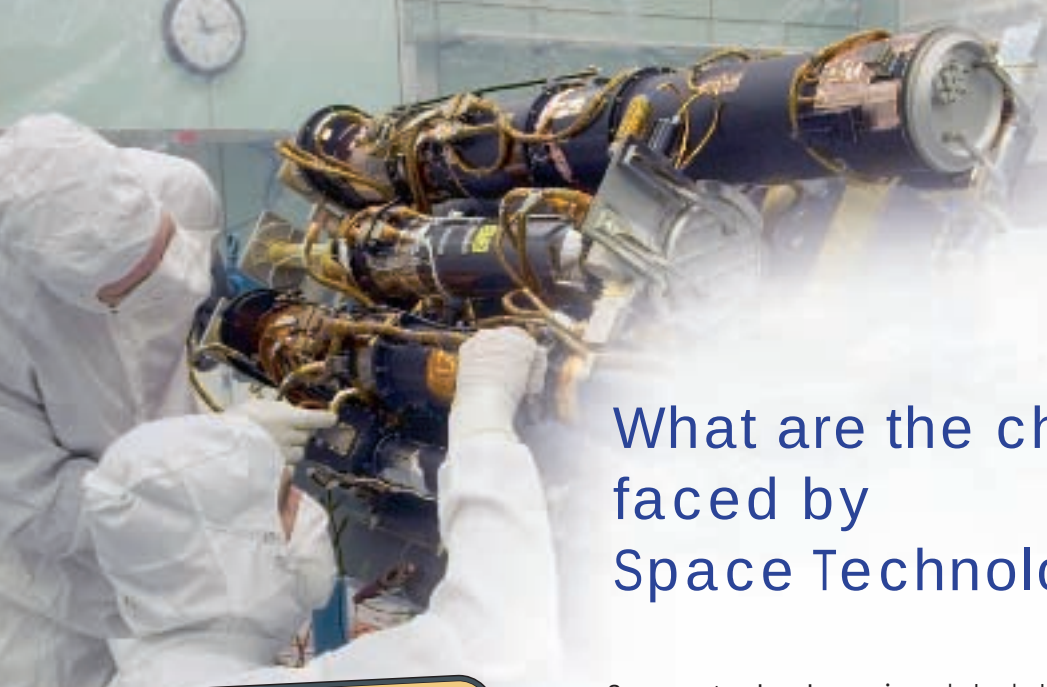
1955-.... One of the longest measured time series in the world of solar irradiance and atmospheric turbidity is collected at the Tartu Meteorological station

1963-1976 Juhan Ross and Tiit Nilson provided a theory of radiative transfer in vegetation as a basis for understanding vegetation productivity and remote sensing

2008 Andres Kuusk with his team compiled a database of forests and their optical signatures for international comparison of radiative transfer models (RAMI)

High priority research directions at Tartu Observatory

- **Development of high spatial resolution reflectance models** for forests based on detailed 3D structure and optical data to meet the needs of the new generation high resolution scanner systems. Inclusion of laser scanning and high-resolution stereo imagery into the plant canopy structure description.
- **Improved application of coarse and medium resolution satellite imagery to retrieve environmental parameters** by the inclusion of within-pixel information from high-resolution data and national public databases: elaboration of an initial version of remote-sensing-aided forest inventory system in Estonia; derivation of ecological classification of inland waters; demonstration of the practical use of the retrieved parameters and knowledge in the fields of terrestrial and aquatic ecology as well as carbon cycle science.
- **Improving methodologies for ground truth measurements** needed for the validation of satellite products through surface reflectance spectra over optically complex waters and vegetation.
- **Studying effects of UV radiation on biospherical objects** and artificial materials. Estimation of the variability in factors influencing optical properties of the atmosphere in the Baltic Sea region.
- **Support the Estonian Environmental Observatory** with solar irradiance data collections and analyses in SMEAR and GAW stations.



What are the challenges faced by Space Technology

Space technology is related to entering and retrieving information and objects from space. Applications like remote sensing, weather forecast, global navigation systems, satellite television *etc* rely heavily on space infrastructure. Modern astronomy and Earth sciences are based on measurements from the space. Because of the growing number of demanding applications there is an urgent need for space exploration to become economically feasible.

On the road to the membership of ESA, Estonia has set its focus towards the high added value industry and economic benefit from the unique and innovative opportunities in the downstream services. We can help to establish better linkages between the user needs and the innovative technology.

TARTU OBSERVATORY IN SUCCESSFUL SPACE EXPLORATIONS

1968 Participation in one of the first astronomical ultraviolet satellite Cosmos-215

1978 Arved Sapar contributed to the measurement campaign of the NASA satellite IUE – the first imaging UV Space telescope in the world

1968-2000 Building and launching instruments for atmospheric studies onboard of seven Soviet space stations

High priority research directions at Tartu Observatory

- To offer multidisciplinary research, development, verification, testing and consultation services in the field of space technology. The space technology section at Tartu Observatory is subdivided into several topics as shown in the figure.
- Earth Observation Technology benefits from the theoretical knowledge and a long experience in the development of new scientific instrumentation for Earth Observation measurements whether from the air, on the ground or on/in the water. In-house developed sophisticated optical instruments for measurement of a variety of quantities useful for remote sensing research provide a solid foundation for the development and verification of new operational downstream services. This is complemented by in-house real-time reception of remote sensing data with our ground station.
- Small satellite instrumentation development and testing. The activity is supported by engagement in several international collaboration projects under FP7, ESA and with the Baltic region.
- Adopt synergetic approach for integration of hardware and software for a higher level in reliability and performance.
- Develop high-accuracy testing, verification and calibration services for space instrumentation, optical instruments and software.
- Set up a dialog with the end users and collaborators to stay on the leading edge of space technology development. We especially focus on cooperation with the private sector for meeting the public sector request for technological achievements, services, education and consultancies.

SPACE TECHNOLOGY

Earth Observation Technology

- Development of Specialised Scientific Hardware
- Development of Novel Remote Sensing Services

Space Instrumentation

- Development of spacecraft hardware
- Development of spacecraft software
- Groundstation services

Verification and Testing

- Characterisation spacecraft hardware and software components
- High accuracy radiometric and photometric calibration

SERVICES

BENEFITS FOR SOCIETY

- Technology transfer to industry
- Increased public awareness about space applications
- Attractive education and training process
- Harmonisation of space and environmental initiatives

Tartu Observatory in numbers 2010

- Budget: 2 317 000 EUR
- Personnel: 79 researchers, engineers and officers
- International projects: 8 projects 612 000 EUR
- National research funding:
  3 target financed projects 570 000 EUR
  14 specific grants 173 000 EUR
- 6300 visitors, 18 guest researchers

Partnership in International Space Community

Helsinki University of Technology (Aalto University)
Finnish Meteorological Institute (FMI)
The Finnish Environment Institute (SYKE)
University of Turku, Tuorla Observatory
University of Helsinki
Univerisity of Jyväskylä

Ventspils High Technology Park
Ventspils International Radio Astronomy Centre
Ventspils University College

Vrije Universiteit Brussel
Royal Observatory Belgium

Centre National d'Etudes Spatiales (CNES), Toulouse
Centre de Recherches d'Avignon (INRA), Avignon

Uppsala University Ångström Space Technology Centre
Stockholm University, Department of Systems Ecology
Nano Space AB

Forschungszentrum Geesthacht GmbH (GKSS)
Max-Planck- Institute for Extraterrestrial Physics
University of Hannover, Institute of Meteorology and Climatology
Brockmann Consult
Astrophysical Institute Potsdam (AIP)
Deutsches Zentrum für Luft- und Raumfort (DLR)

Water Insight
Vrije Universiteit Amsterdam

Oslo University
Norwegian Water Research Institute

Isaac Newton Group of Telescopes
Instituto de Astrofísica de Canarias
Nordic Optical Telescope Scientific Association
Observatori Astronómic, Universitat de València

International Centre for Relativistic Astrophysics
University of Pisa
Alta S.p.A.

EC Joint Research Centre Marine Environment Unit

Polish Academy of Sciences
Toruń Centre for Astronomy

Virginia Polytechnic Institute and State University
Boston University, Geography and Environment Department
University of California, Scripps Institution of Oceanography, San Diego
University of Maryland
University of Memphis
University of Chicago
NASA

University of Tartu
Estonian University of Life Sciences
Tallinn University of Technology
Estonian Meteorological and Hydrological Institute
Estonian Ministry of Education and Research
Estonian Ministry of Environment
Estonian Agricultural Registers and Information Board
Enterprise Estonia
Archimedes
Interspectrum AS
Hohenheide AS
Metrosert AS
Regio AS

Investing in your future

European Union
Regional Development Fund

Haridus- ja Teadusministeerium

ESTSPACE

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