The Baltic Space Facilities

Competencies

A special thanks to:

"Baltics in Space"
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The philosophy of the nonprofit organisation, Baltics in Space is a nonprofit organisation that seeks INVENTORY, IDENTIFY, and INTEGRATE with a sprinkling of INSPIRATION to build space products greater than the sum of their parts. The best resource in the space business is people. With an eye to strengthening the triple helix links of INDUSTRY, EDUCATION, and RESEARCH, Baltics in Space integrates Baltics-wide space events, compiles skill-sets catalogs for prospective users, supports Baltic space project development with distributed teams, and facilitates Baltic space education.

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Investment and Development Agency of Latvia (LIAA)
European Regional Development Fund Project No. 1.2.1.2/16/I/001
"Technology Transfer Programme".

NATIONAL DEVELOPMENT PLAN 2020
EUROPEAN UNION
European Regional Development Fund
INVESTING IN YOUR FUTURE

Printed by "Dardedze hologrāfija"
Riga, 2017

Made from recycled material.

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Introduction

Welcome to the Baltic Region's Space Facilities!

From the propulsion of the E-Sail to a unique model of collaboration between government, businesses and non-profits, the Baltic space workers show an agility, fortitude, and passion for space work that deserves a wider audience.

The eight Baltic space facilities from southern Finland (FI), Estonia (EE), Latvia (LV) and Lithuania (LT),have a long history in space work to study geomagnetic variations, develop rocketry, track satellites, study the terrestrial and interplanetary climates, perform radio communications, measure stellar asteroseismic activity and late-evolution stars, and perform small planetary body observations.

In the last few decades, the Baltic Space Facilities have further developed their historical skillsets in parallel with the miniaturization of the electronics and instrumentation of the space industry.

In the realm of successful observations, we have powerful high-resolution (LT) and multi-wavelength (LV) spectroscopy of stellar objects (LT) and of terrestrial terrains (LV, EE), we have years of asteroid discoveries in real-time (LT) and in pre-coveries (LV), plus state-of-the-art asteroid orbit determinations (FI).

In the realm of successful mathematical applications, we have world-class theoretical, experimental, and numerical understanding of light-scattering off of airless planetary surfaces (FI) plus climate modeling and interplanetary space weather (FI).

In the realm of successful public engagement, we have the strong political support to be a full member of the European Space Agency (ESA) --EE, the widespread public support for the line of nanosatellite development (EE), the restoration of major Soviet era space equipment (LV), the attraction of large numbers of youth (EE, LV, LT), and a citizen-science and citizen-business rocketry effort (LV).

Each of our Facilities shows unique and strong individual competencies. At a national level, the proofs of Baltic regional space competency is visible in European Commission (EC) FP7 success rates in Space Themes: EE: 34.4%[1], LV: 35.0%[2], and LT: 37.5%[3], when the EU average success rate was 29%.

Together, our individual and national strengths represent a Baltic regional space competency that rivals other European regions.

Moreover, our Baltic Space Facilities competencies are well-positioned for 'New Space', i.e. entrepreneurial space, astropreneurship, and commercial space[4].

We hope that, as you browse through our chapters, you will find skillsets that your team is seeking. Please don't hesitate to contact staff at the addresses within with your questions and for your potential collaborations.

Welcome to this first edition,
September 2017,
of the Baltic Space Facilities booklet.

Amara L. Grapa,
Baltics in Space

Juris Žagars,
Ventspils International Radio Astronomical Center
and the Latvian Academy of Sciences

September 2017

1 Estonia (see Table 14)
http://s3platform.jrc.ec.europa.eu/documents/20182/117536/S2E_EE_national_profile.pdf

2 Latvia (see Table 12)
http://s3platform.jrc.ec.europa.eu/documents/20182/117536/S2E_LV_national_profile.pdf

3 Lithuania (see Table 12)
http://s3platform.jrc.ec.europa.eu/documents/20182/117536/S2E_LT_national_profile.pdf
The Annexes describe further how the regional space competency is delineated.

4 – Finland with E-sail propulsion, asteroid polarimetry, space weather numerical modeling, and long years of ESA full membership.

– Estonia with entrepreneurial cubesats, strong eco-system (*) of industry to support space, long working cooperation with Finland, new ESA member; can teach ESA space competencies to LV, LT.
(*) http://www.eas.ee/kosmos/en/companies-and-research-groups/companies

– Latvia with large renovated space equipment, decades of satellite tracking and radio communication, and a private, successfully-funded environmental institute (IES) from which other Baltic countries can learn.

– Lithuania is best positioned for research on 'in-space resources': asteroids, many hundreds discovered, it has the largest public astronomical observatory in Europe.

Finnish Meteorological Institute

History

The roots of the Finnish Meteorological Institute (FMI) date back to 1838, when the Helsinki Magnetic Observatory was founded to record and study geomagnetic variations. The observatory has, since then, evolved into the current Finnish Meteorological Institute—a governmental research and service agency under the Ministry of Transport and Communications. Geomagnetic variations, auroras, and space weather are still subjects of intensive study at the institute.

In 1985, FMI began to build space instruments and widened its field of study to other planets. FMI's first space project was building particle analysers in collaboration with the Swedish Institute of Space Physics (IRF) for the Soviet Phobos Mars probes. Since then, FMI has developed experiments and built instrumentation for more than 20 space missions conducted by ESA, NASA, Russia, and Sweden.

Space Mission Contributions

The CASSINI/Huygens mission to Saturn and its moon Titan was a great endeavour that included a three-hour sounding of the Titan atmosphere in January 2005. It was FMI that developed the highly successful atmospheric pressure profile instrument that was a part of the sensor package attached to the Huygens probe.

Earth's sibling planet Mars has been a prime target of planetary science investigations for decades; FMI has also participated in this trend. FMI provided atmospheric instruments for the successful Phoenix Mars Lander and Mars Science Laboratory missions, and will continue developing in situ atmospheric instruments for the NASA Mars-2020 and ESA EXOMARS 2020 missions.

FMI started developing plasma spectrometers for Martian magnetospheric studies in cooperation with Swedish research groups already in 1985 for the Russian Phobos and Mars-96 missions. One of these plasma spectrometers is presently still operating on board the ESA Mars Express mission. Another is successfully contributing to the investigations of Venus's magnetosphere aboard the Venus Express spacecraft.

FMI delivered five instruments and a mass memory unit for ESA's Rosetta spacecraft and its Philae lander, including Philae's Permittivity Probe (PP), which was used to analyse the composition of the surface material of the Churyumov-Gerasimenko comet. At present FMI is managing the development of the control and data managing units of the Imaging X-ray Spectrometer (MIXS) and the Solar Intensity X-ray and particle Spectrometer (SIXS) instruments for the ESA Bepi-Colombo mission to Mercury.

Figure 1. FMI operates the National Satellite Data Centre in Sodankylä, Northern Finland. The data centre specializes in fast delivery of remote sensing products for scientific and commercial use. The aurora borealis often lights up the sky above the two 7.3 metre downlink antennas.

Figure 2. The Finnish Meteorological Institute, Helsinki, Finland.

Finnish Meteorological Institute

Space Mission Projects in Development

A novel approach to Mars exploration is the MetNet programme, led by FMI. MetNet aims to deploy a global atmospheric observation network on Mars, consisting of several tens of small landers. The MetNet Lander concept is based on inflatable entry and descent systems that enable the deployment of small autonomous landers with a good payload mass to overall mass ratio.

FMI has also developed a numerical weather prediction (NWP) model for Mars. The Mars high-resolution Limited-Area Model (MLAM) is a Mars-customized version of the High-Resolution Limited-Area Model (HIRLAM), which has been the primary operative NWP model at the institute since 1990. From a meteorological viewpoint, Mars can be thought of as a simplified version of Earth, thus study of its atmosphere provides an interesting parallel for terrestrial meteorology.

Figure 3. Dr. Ari-Matti Harri, head of the Earth Observation unit at FMI, holding the heat shield of a life-size model of the MetNet lander. The lander is designed as a small, low-mass vehicle to carry a versatile science payload to Mars.

Additional Skillsets

An important branch of planetary science at the FMI is the development and use of plasma simulations to study the magnetospheres and plasma environments of planets, moons, and comets, in collaboration with Aalto University and the University of Helsinki.

The plasma environment of Earth is an important subject of research and service development at FMI. The institute is developing a real-time operative version of its global magnetospheric simulation. FMI also maintains a network of magnetometers and auroral all-sky cameras in Finland to monitor the effects of space weather. This observation network provides the basis for a space weather service, which is popular with auroral photographers and enthusiasts. The space weather service also includes 24/7 availability of a space weather expert and warnings to authorities in case of a large space storm.

For the future of planetary research, new possibilities are opened by the electric solar wind sail, or e-sail, invented and developed at FMI. The e-sail harnesses the feeble dynamic pressure of the solar wind to give a small but permanent thrust to a spacecraft in interplanetary space. It is especially well-suited for sending spacecraft to the outer planets, eliminating the need for large amounts of propellant, thus reducing launch mass and costs. A small probe fitted with an e-sail could reach Pluto in five years. FMI is testing e-sail technology on small satellite missions together with the University of Tartu (Estonia) and Aalto University (Finland).

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Finnish Meteorological Institute Essentials

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Figure 4. Pressure sensors being prepared for testing in the FMI space laboratory.

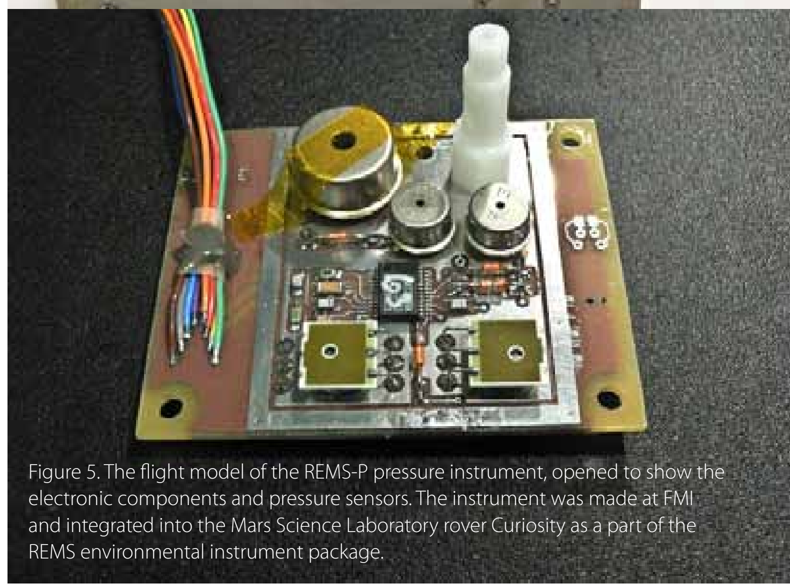

Figure 5. The flight model of the REMS-P pressure instrument, opened to show the electronic components and pressure sensors. The instrument was made at FMI and integrated into the Mars Science Laboratory rover Curiosity as a part of the REMS environmental instrument package.

University of Helsinki: Planetary Systems Research (PSR)

History

The University of Helsinki (UH), a multidisciplinary university, celebrated its 375th anniversary in 2015. UH counts about 40,000 students and staff members spread among 11 faculties. It operates on four campuses in Helsinki and nine other localities in Finland. Teaching at UH is based on research. The underlying principle is that every teacher does research and every researcher teaches. UH encourages its students to complete a Master's degree. The University has four doctoral schools, offering a total of 32 doctoral programmes. Planetary research is carried out at the Faculty of Science.

Skillsets

The planetary-system research (PSR) team possesses markedly cross-disciplinary know-how, from theoretical and experimental astrophysics to observational astronomy and planetary geology, with applied mathematics playing a major role. PSR is the home of the European Research Council Advanced Grant project *Scattering and Absorption of ElectroMagnetic waves in ParticuLate media* (SAEMPL), 2013–2018, the only such project in Astronomy in Finland. The main objective of SAEMPL is to develop a system of quantification for the scattering of electromagnetic waves at the surfaces of atmosphereless Solar System objects, such as asteroids, the Moon, Mercury, icy planetary satellites, and dormant cometary nuclei.

The PSR/SAEMPL team members focus on asteroids, comets, and meteorites, as well as on small particles in planetary regoliths and atmospheres, including the atmosphere of Earth.

Space Mission Contributions

The PSR team developed software for calculating asteroid orbits in connection to the ESA Gaia mission; the software has been operational/in the processing pipeline for the Gaia Solar-System-Object Short-Term since fall 2016.

For the Gaia mission, we have further developed algorithms for asteroid lightcurve and surface material analyses in an ESA-funded project, together with Space Systems Finland Ltd. The algorithms are to be deployed in an open computing environment called Gaia Added Value Interface for the Gaia space mission data. The lightcurve analysis, the period, pole, shape, and composition for the planetary small bodies, employs the most recent mathematical physical and numerical methods advances in radiative-transfer theory, probability distribution sampling, and inversion.

The PSR team continues to be involved in the BepiColombo mission to the planet Mercury. The team also assesses the risk of near-Earth asteroid collisions and participates in the Canadian Near-Earth Object Surveillance Satellite (NEOSSat) mission.

Space Mission Projects in Development

The PSR team is involved in the interplanetary CubeSat Asteroid Spectral Imaging Mission (ASPECT), jointly developed by UH, the VTT Technical Research Centre of Finland, and Aalto University. ASPECT is primarily developed as a payload for the Asteroid Impact Mission (AIM) / Asteroid Impact & Deflection Assessment (AIDA), a joint ESA–NASA project. Other possible applications, such as missions to the Martian moons or to the outer Main Belt asteroids, are being investigated.
For ground-based, planetary small bodies observations, the PSR team utilizes state-of-the-art sky surveys such as the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and the Catalina Sky Survey (CSS) to understand population-level properties of main-belt and near-Earth objects. These efforts have led to, e.g., a new model describing the sizes and orbits of near-Earth objects and the realization that asteroids undergo a non-trivial disruption when approaching the Sun. This latter result indicates that models describing population statistics for asteroids can be used to constrain their physical properties.

Facilities

PSR members run the Astrophysics Laboratory (APL) and the Geophysics Laboratory (GL). The APL houses highly specialised instrumentation for light measurements, including a unique spectrometer called the integrating-sphere UV-Vis-NIR spectrometer (Fig. 1) and a laser scatterometer—an instrument that measures the return of the laser light in a medium. The scatterometer has the capability to measure, with full control of position and orientation, samples of size micron- to millimeter scale,, which have been ultrasonically levitated (Fig. 2, part of SAEMPL activities, in full operation by 2018). The APL is also in the process of developing a polarimetric spectrogoniometer—an instrument to measure the polarised, spectral distribution of light at a specific angular position, and a polarimetric imaging spectrogoniometer—a related instrument used for images in backscattered light studies. Both instruments will be operational in 2018.

The GL houses a 3D laser scanner (Fig. 3) and a device called a gas pycnometer that is used to determine the density of solids using gas displacement. The gas pycnometer can measure the density and porosity of meteorites, be they regularly shaped, porous, non-porous, monolithic, or powdered. The GL has a variety of other instruments for mineralogical, geochemical, and rock magnetism studies.

Space radiation and impacts, causing 'space weathering', alter the mineral composition of asteroids by creating nano- or micron-sized iron or sulfide particles within the surface regolith materials. This, in turn, affects the spectral properties of the target bodies. The PSR laboratory runs space weathering simulations to understand in-space small body surface alterations. 'Siris'—a ray-optics light-scattering Fortran program developed at PSR—is used to model the results of laboratory experiments and observational data.

UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE

Planetary Systems Research Essentials

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Figure 1. The integrating-sphere UV-Vis-NIR spectrometer.

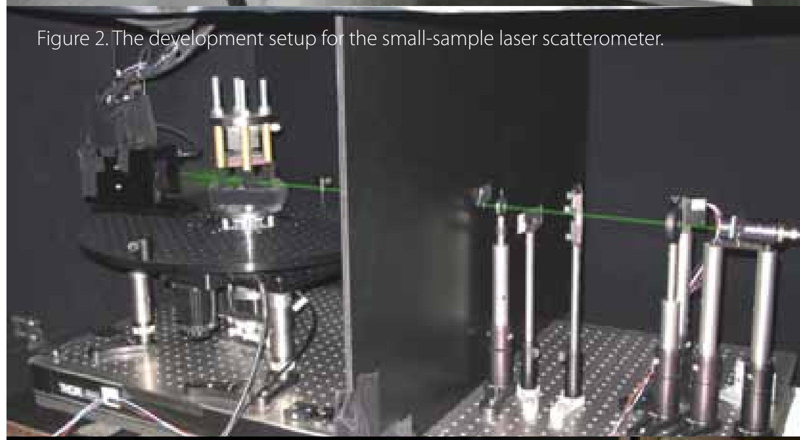
Figure 2. The development setup for the small-sample laser scatterometer.


Figure 3. 3D scanning a Chelyabinsk meteorite at the Geophysics Laboratory.


Figure 4. The AIM and CubeSats Courtesy of ESA.

Tartu Observatory

Figure 1. Tartu Observatorium (or Observatory) in Nõo Parish, Tartu County, Estonia.

Tartu Observatory ("TO", international code: 075) is the leading centre of space research and technology in Estonia. The development of space applications and their downstream services is seen as the basis for future competitiveness and economic growth of the country.

Historical Perspective

Historically, Tartu Observatory is a successor of the Tartu University Observatory, founded in 1808, and the Estonian Meteorological Observatory, founded in 1865. It is the largest astronomical observatory in Estonia. Tartu Observatory is known internationally for its connection to several notable scientists like Friedrich Georg Wilhelm Struve, Johann Heinrich von Mädler, Thomas Clausen, Ernst Julius Öpik, Grigori Kuzmin, Jaan Einasto

Our Vision

The mission of Tartu Observatory as Estonia's space research centre is to implement cutting-edge scientific research and technology in the interests of Estonia's development. We pursue, develop, and promote technology for unprecedented space missions that will enable novel fundamental scientific discoveries and address environmental and global challenges.

Our vision is to be the leading hub for space technology in the region, and to be competitive worldwide, via excellent engineering, science, education, international cooperation, outreach, and commercialisation. Its established research competence is applied to the promotion of science education, supporting entrepreneurship, and expanding the scientific understanding of the world, thus helping to find solutions for the challenges facing society.

Facilities

Our facilities include a modern laboratory complex for testing, optical calibration, and space technology development; ground station and antennas for space communication; telescopes; novel visitor centre organizing educational programmes for schoolchildren.

Laboratories

- **Environmental testing.** The laboratories for environmental testing include test stations for climatic conditions (temperature and humidity), sinusoidal and random vibration, thermal vacuum, mechanical shock, and electromagnetic compatibility in an anechoic chamber. Ground support for remote sensing measurements.
- **Optical Measurement.** Calibration and characterization of light sources, spectral responsivity of radiometric sensors, characterization of materials.
- **Space Technology.** The laboratory for development of space technology provides services for designing, assembling, prototyping as well as testing a wide range of different equipment. That includes electronic boards, controllers, radio transmitters, receivers, cameras etc. The available tools involve Altium Designer, Labview, soldering stations and microscopes. The first Estonian nanosatellite ESTCube-1, launched successfully in 2013, was designed and constructed in the laboratories of Tartu.Observatory. In cooperation with several universities and research institutes, we can provide in orbit space technology validation service on nanosattelites as a part of our upcoming future missions.

Ground-station and antennas for Space Communication

During the year 2013, a dedicated satellite communication ground station was established. Two different antenna systems have been installed on the roof of the main building: one 3.0 m diameter parabolic dish antenna and a yagi antenna array for 145 MHz and 435 MHz frequency ranges. Both antenna systems include computer-controlled rotators capable of tracking low-Earth orbiting satellites and other space objects. The receiving station is based on a solid state high performance software controlled radio (SDR) technology. Tartu Observatory is presently tracking the Swedish 2U-CubeSat: QBEE regularly. It was also one of the first to decode a packet from Latvia's first satellite: Venta-1 after its June 23, 2017 launch.

Figure 2. A technician is testing in the vacuum chamber of the laboratories of Tartu Observatory, the Lithuanian cubesat lihtuanicaSAt-2.

Figure 3. Ground station of Tartu Observatorium. This was at the time of the launch of Estcube-1.

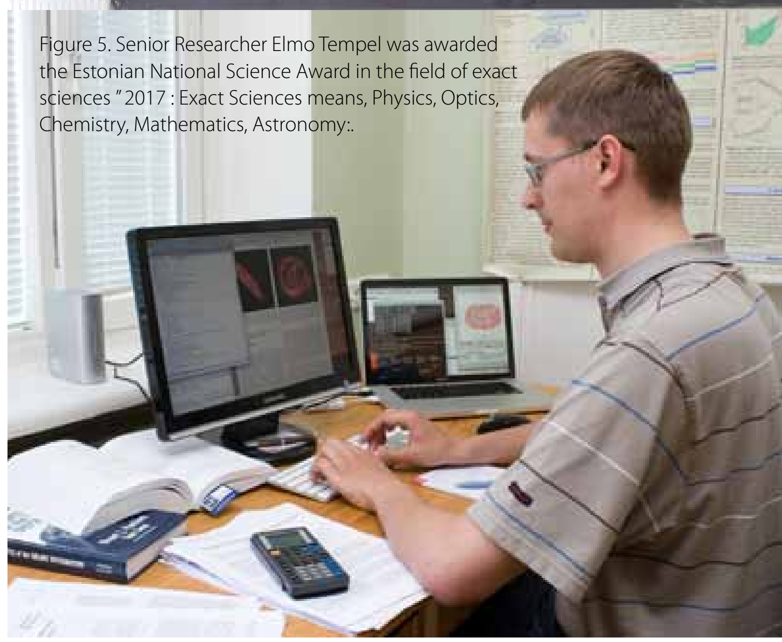

Figure 5. Senior Researcher Elmo Tempel was awarded the Estonian National Science Award in the field of exact sciences " 2017 : Exact Sciences means, Physics, Optics, Chemistry, Mathematics, Astronomy:.

Tartu Observatory

Telescopes

- A 1.5-m AZT-12 reflecting telescope equipped with a Cassegrain spectrograph enabled to register spectra from 360 to 1000 nm and dispersion up to 0.18 A/px (spectral resolution R ~ 100 – 12000).
- A 0.6m reflecting telescope Zeiss600 with a CCD photometer (2048x2048 px camera, JohnsonCousins UBVRI filters).
- A 0.3m robotic telescope PlaneWave CDK 12.5 with the CCD photometer (2048x2048 px camera, Johnson Cousins BVRI, Hα, and a set of RGB filters).

Novel Visitor Centre

TO has also strong traditions in outreach to society; it has a dedicated Visitor Centre for the popularization of space science and technology, visited by more than 5000 pupils and 1000 adults annually. The main principle of science popularization in TO is to expose the public to 'live' science – the labs, telescopes and other premises, where new scientific knowledge is created every day.
Our centre in particular offers:

- Modern conference facilities
- Active learning programmes for schools. A half-day program on-site divided in 3 parts: real scientific questions, research of those questions using practical exercises, presention of the answers. i.e. a researcher's work in miniature. The active learning is in the fields of remote sensing, satellites, and space technology.
- Summer Academy: Internships and Training.
- Hands-on Training. Year-round training provided by the TO staff. High-tech entrepreneurship mentorship.
- Stellarium. Excursions in astronomy for all ages. Open observations with the 1.5m telescope, once per month.
- Popularisation of science in partnership with ESA European Space Education Resource Office and the European Southern Observatory educational offices.

Figure 4. 1.5m telescope at Tartu Observatorium

Skillsets, research directions, applications

The main areas of activity of Tartu Observatory is the research and development in the fields of Earth Observation, Space Technology, and Cosmology and Stellar Physics.

The TO research priorities in the different fields for the period of 2016-2020 are the following.

Earth Observations – how to maintain life on Earth?

- The main research areas are as follows:
  The development of **metrology (the study of measurement) for Earth Observation** (EO) with a design and characterisation of EO instrumentation.
  This includes contributions to the **EU Copernicus programme**, and participation in the work of the Estonian Environmental Observatory and the Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) at Järvselja.
- Developing and improving methodologies for grasslands mowing detection and the identification of built-up areas.This activity employs optical and radar data for **terrestrial remote sensing**. Improving and developing methodologies for grasslands mowing detection and identification of built-up areas.
- Estimation of **water parameters**: water transparency, sediment load, phenology of phytoplankton and toxic Cyanobacteria, and carbon fluxes in water bodies for the EU Water Framework Directive via satellite data.
- Studies of the **variations in UV radiation** from the data continuously collected at Tartu Observatory.
- The study of **climatology teleconnections between the Arctic and Europe**. This activity includes investigating the absorption of Earth radiation in the atmosphere for different greenhouse gas conditions.

Space Technology – what's next after the industrial and digital revolution?

- The main research areas are as follows: We are working on miniaturising satellites (i.e. nanosatellites) and we are developing new satellite instrumentation, so that human civilization can afford to have more of them in orbit, increasing the revisit frequency and providing closely-spaced measurement points.
- One technology, which could deorbit satellites in the most populated orbits an order of magnitude faster than would happen naturally by aerodynamic drag, is the plasma brake – a charged tether dragged by the Coulomb force in the ionosphere. TO is participating in the development of the tether and the deployment system with FMI. The cost of interplanetary missions could also be decreased by launching tens of self-propelled, using **E-sail**, satellites to various planetary bodies that will return data about hundreds of objects, increasing the science output by an order of magnitude.

Cosmology and Stellar Physics – what can we learn from this?

- The main research areas are as follows: untangling the fundamental issues of dark matter, dark energy and gravity.; the evolution of galaxies; the variability and evolution of massive stars; the shells, discs and other outflows from stars; symbiotic and related binary stars; planet formation and astrobiology; computations of stellar model atmospheres and synthetic spectra; relativistic physics in the sources of gamma-ray-bursts; statistical analysis of astronomical time series; and preparations for the analysis of the Gaia data.
- Optical calibration and radiometry.

We wish to further increase the visibility and impact of our work via partnerships in large scientific collaborations for building and using state-of-the-art space research instrumentation.

Education Degrees

- Doctoral, master and bachelor degrees in
  - Space and military technology
  - Environmental physics and EO technology
  - Astrophysics - theory and observation
  - Popularisation of science in partnership with ESA ESERO and the ESO educational offices

Contributions to ESA Missions and Initiatives

- Refinement of data algorithms (Gaia, Planck, Euclid)
  - Input to mission design (Athena, PLATO)
  - Development of miniature camera systems (ESEO)
  - Participation in validation teams (ENVISAT, SENTINELS)
  - Quality assurance of measurements (FRM4SOC)
  - Partner in the ESA Business Incubation Centre.
  - Experts in European Commission and European Space Agency committees

TARTU OBSERVATORY
space research centre

Institute Essentials

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Institute for Environmental Solutions (IES)

Historical Perspective

The Institute of Environmental Solutions (IES) was established in 2008 as a result of private initiative, with the goal of creating an independent, multi-disciplinary environmental research institute in Latvia for informed, objective, and unbiased research and analysis beyond academic structures. IES's mission is to develop scientific expertise and innovative solutions for sustainably managing natural resources and the environment in a wider social and economic context.

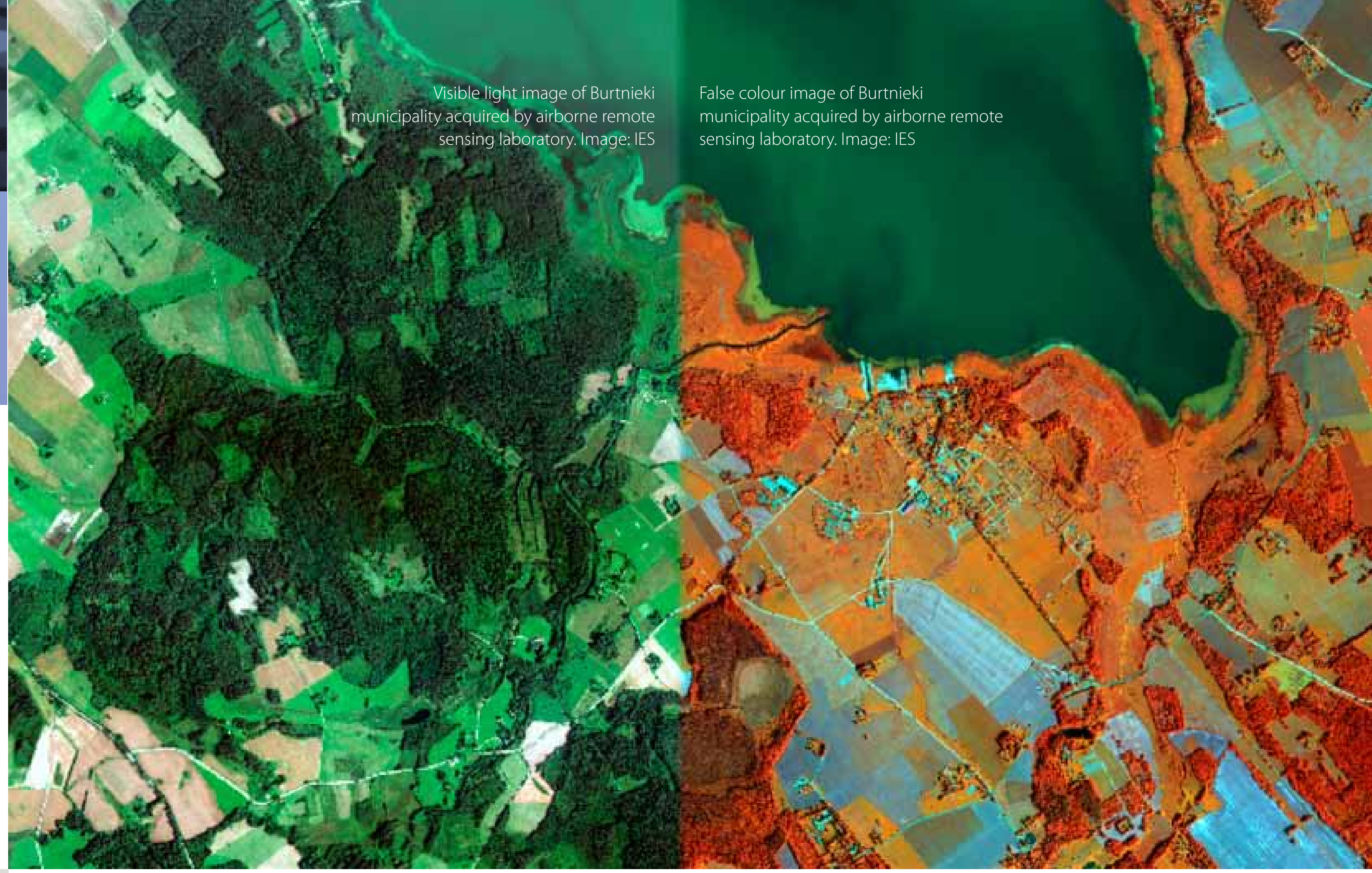
ARSENAL is a state-of-the-art airborne remote sensing technology uniquely developed by IES fusing eight mutually operable sensors that cover a wide range of electromagnetic spectrum. It integrates ultraviolet, visible, near-infrared, short-wave infrared, thermal infrared, mid-wave infrared, and long-wave infrared sensors with a light detection system and a high resolution RGB camera. The human eye can detect light in wavelengths of 390 to 750 nanometres (nm), while ARSENAL covers a spectrum of

Figure 1. The Airborne Remote Sensing and Environmental Monitoring System (ARSENAL) readying for take-off.

Facilities

In 2013, IES launched the Airborne Remote Sensing and Environmental Monitoring System (ARSENAL), which provides high quality data on terrestrial, marine, and freshwater ecosystems, their structure, chemical composition, and spatial characteristics.

280 to 1200 nm. ARSENAL can produce 454 images of a sample area in a single flight. Each of the images reflects different wavelengths. ARSENAL is mounted onto a BN-2T-4S Defender airplane, which can fly long distances in all weather conditions and take off and land on short, unprepared runways. It can fly for up to 8 hours and can collect data from up to 100 square kilometres of



Visible light image of Burtnieki municipality acquired by airborne remote sensing laboratory. Image: IES

False colour image of Burtnieki municipality acquired by airborne remote sensing laboratory. Image: IES

Figure 2. Airborne remote sensing images, which were developed during the ESA PECS project: *Simulation of Sentinel-2 images for land cover/land use monitoring using hyperspectral airborne remote sensing* (SentiSimuLat).

territory in a single hour. Furthermore, the airplane can fly comparatively slowly, which ensures a higher quality of data. Since 2015 IES has been implementing research and development projects commissioned by the European Space Agency (ESA) within the framework of the Plan for European Cooperating States (PECS).

Our Philosophy

IES is continuously challenging accepted beliefs about what the 'good life' is, and studying the rules that govern nature to gain a more nuanced understanding of our environment. IES's goal is to develop appropriate and practical solutions to prevent the depletion of the Earth's resources and preserve nature's wonders for the enjoyment of future generations.

Areas of expertise

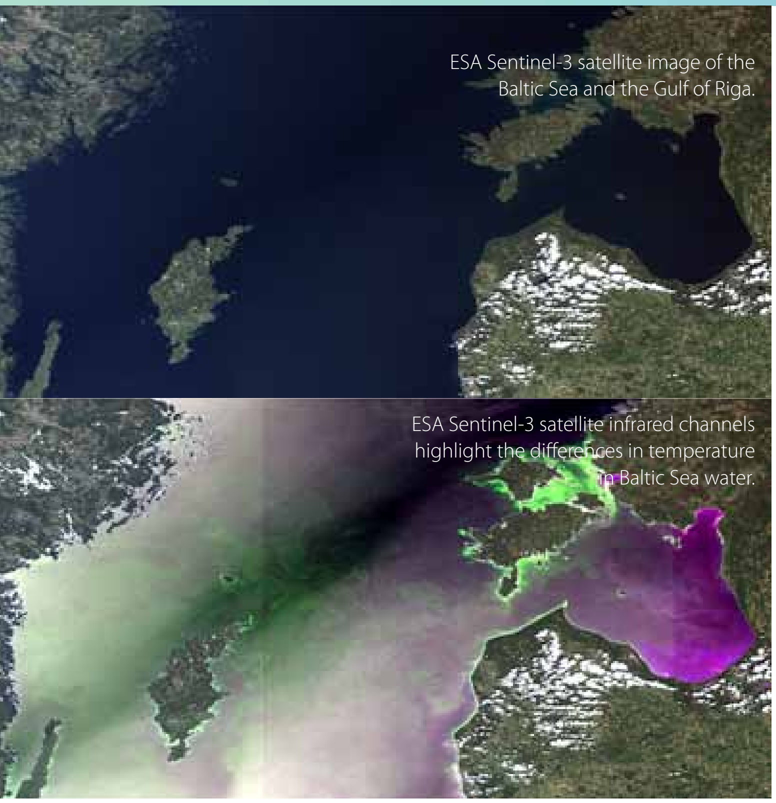
IES has world-class expertise in the field of remote sensing. The institute develops and improves the acquisition of remote sensing data as well as the methods and tools of interpreting that data; it refines environmental remote sensing applications, creates multi-sensor data fusions, and simulates satellite data using hyper-spectral airborne remote sensing.

The IES staff possess advanced degrees in forestry, biology, physics, chemistry, engineering, computer science, environmental science, geography, agronomy, and innovation management, as well as extensive hands-on experience in nature research and conservation, water ecology and management, fisheries, forest research and management, and remote sensing.

By combining the information gathered by remote sensing and in-situ methods, IES develops novel methods and approaches to forest resource inventories, forest vitality assessment, species biodiversity assessment, counting and species detection of birds and wild animals, habitat suitability modelling, land use/land cover classification, detection of archaeological heritage sites, and mapping and assessment of invasive species.

By fusing the information provided by ESA's Sentinel-2 satellite, ARSENAL and in-situ ground truthing missions, IES developed an innovative approach for land cover mapping during the ESA PECS SentiSimuLat project. Based on Latvian user-needs, IES identified 12 target classes for annual land cover/ land use classification. The results can be used for cross-checking the accuracy and veracity of available data, as well as for control activities under the Common Agriculture Policy.

Institute for Environmental Solutions (IES)



ESA Sentinel-3 satellite image of the Baltic Sea and the Gulf of Riga.

ESA Sentinel-3 satellite infrared channels highlight the differences in temperature in Baltic Sea water.

Figure 3. Satellite images that were developed during the ESA PECS project: *Simulating performance of ESA future satellites for water quality monitoring of the Baltic Sea* (SentiBalt).

Over the past four years, IES has provided research services to local municipalities and private sector entities regarding the holistic assessment of lake ecosystems, the mapping of aquatic overgrowth, the assessment of vegetation and the estimation of biomass, the estimation of water depth and sediments, the analysis of shallow coastal waters, and studies of fish migration and natural reproduction.

Currently, IES is developing an international centre of excellence where science, art, and gastronomy will be integrated to address environmental issues and challenge people to open their minds to new ways of understanding. The centre is located in the former Cēsis Old Brewery complex in the town of Cēsis.

Employees and network

IES is a network-based organisation that brings people of different nationalities together who have multi-disciplinary backgrounds and skills and are driven by their passion to improve our quality of life by solving complex environmental challenges. IES engages in partnerships with world-class scientific institutes, non-governmental organisations, universities, and public institutions, such as the European Commission, the European Space Agency,

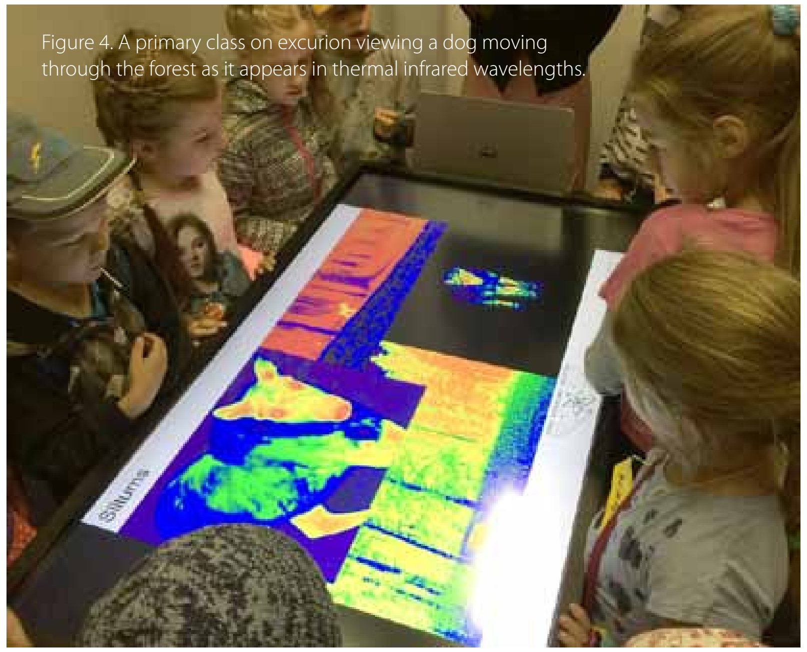


Figure 4. A primary class on excurion viewing a dog moving through the forest as it appears in thermal infrared wavelengths.

the Academy of Science of the Czech Republic, 'Pasaules Dabas Fonds' (Formerly – WWF Latvia), the European Herb Growers Association, the Baltic Environmental Forum, and others. IES developed its stateof-the-art technology ARSENAL in cooperation with Canadian manufacturers and innovators of remote sensing technologies.

Contributions

- Since its inception, IES has performed environmental research and business development activities to a value of approximately 5 million euros.
- IES has developed the state-of-the-art airborne remote sensing technology ARSENAL, which integrates eight mutually operable sensors that cover a wide range of the electromagnetic spectrum. The data captured by ARSENAL give us the opportunity to transcend the limitations of our human senses, to discover far wider ongoing processes in nature, and to develop a more sophisticated understanding of them (e.g. to uncover the past and present ecological changes of different ecosystems – freshwater, terrain and marine; detect ancient river patterns; model the future habitats for protected species, as well as human; reveal high value biodiversity in forests and grasslands).
- IES is implementing three R&D projects funded by the European Space Agency's PECS program:
  (1) *Simulation of Sentinel-2 images for Land Cover/Land Use Monitoring Using Hyperspectral Airborne Remote Sensing;*
  (2) *Simulating Performance of ESA Future Satellites for Water Quality Monitoring of the Baltic Sea;*
  (3) *Assessment of Grassland Quality and Quantity Parameters and Management Activities Using Sentinel-1&2 Data (SentiGrass)*.
- In 2014, IES received the Vidzeme Success Story award.
- In 2016, IES organised, for the first time in Latvia, and the first training on this topic: an ESA Training Course on Radar and Optical Remote Sensing.
- At the beginning of 2017, the European Commission (EC) awarded IES the status of "Copernicus Relay", one of 62, to act as local Copernicus ambassadors, exchange best practices and provide Copernicus feedback to the Commission.

ARSENAL's infrared image revealing diversity of tree species and poor vegetation areas (in light blue) within the Oslo area, Norway. Image: IES

INSTITUTE FOR ENVIRONMENTAL SOLUTIONS

Institute for Environmental Solutions Essentials

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Institute of Astronomy of the University of Latvia
Baldone Observatory / Riga Satellite Laser Ranging Station

The Institute of Astronomy at the University of Latvia performs scientific research in astronomy, astrophysics, and geodynamics.

It has two divisions:

- Baldone's Astrophysical Observatory (international code 069) and
- Satellite Observation Station 'Riga' (No. 1884, code RIGL). Formerly : The Astronomical Observatory of the University of Latvia.

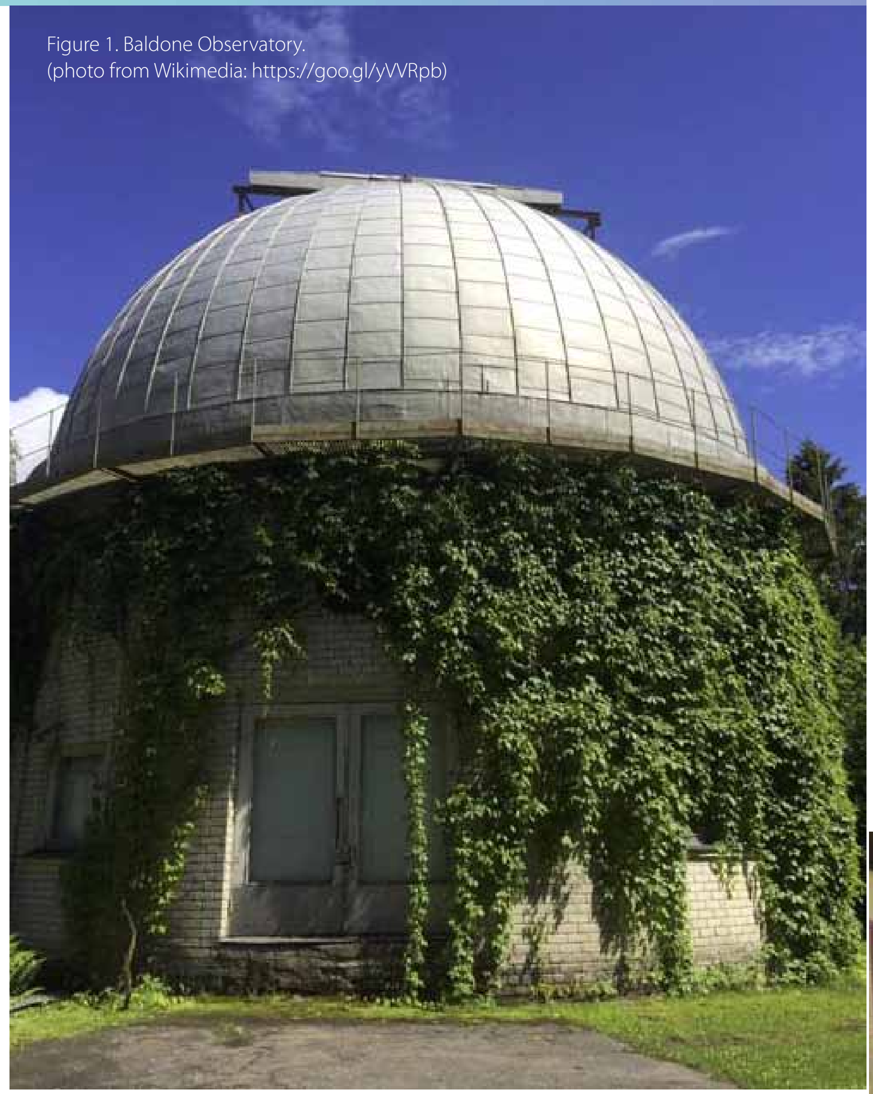
Figure 1. Baldone Observatory. (photo from Wikimedia: https://goo.gl/yVVRpb)

History

The Institute of Astronomy was founded in 1997 when the Astronomical Observatory for time determination and tracking satellites of the University of Latvia merged with the Baldone Astrophysical Observatory of the Latvian Academy of Sciences. However, these two observatories had been around for quite some time before they merged into a single institute.

Timeline

1922. The Astronomical Observatory of the University of Latvia is founded. A standard determination of time is established for Latvia.

1946. Astrophysics research begins at the Latvian Academy of Science.

1957. First visual satellite observations starting with Sputnik-1 take place in Riga at the Astronomical Observatory (Later renamed: Satellite Observation Station 'Riga'). This programme evolved into large-scale research in geodynamics.

1957. Observatory built near Baldone, which becomes the Astrophysical Observatory in the following year.

1966. Schmidt telescope, with a diameter of 1.2 meters, installed at Baldone Astrophysical Observatory; observations begin.

1971/1972. First satellite laser ranging measurements performed at the Satellite Observation Station.

1987. Regular satellite laser ranging measurements begin at the Satellite Observation Station.

1997. The Institute of Astronomy of the University of Latvia is founded by merging the University's Astronomical Observatory and the Academy of Sciences's Baldone Astrophysical Observatory.

Skillsets and Contributions of Note

The main directions of research at the Institute of Astronomy are:
1) investigations of carbon stars,
2) monitoring of small planetary bodies and
3) high-accuracy satellite laser ranging.

Carbon Star Research and the Photographic Plate Archive

The photometric investigations of carbon stars are recorded in the photometric (BVRI) system, using low- and high-resolution spectroscopy, employing the Baldone Schmidt telescope (diameter of correction plate 0.80 m, diameter of main mirror 1.20 m, focal length 2.40 m). More than 5% of all known carbon stars in the Milky Way Galaxy were discovered at the Baldone Observatory. They are listed in the General Catalog of Galactic Carbon Stars, published and maintained in the Strasbourg Astronomy Archives since 2001. Carbon star researchers at Baldone Observatory found a new type of variability of late-evolution-stage stars: DY Per with irregular dimming by 2–5 magnitudes.

The Observatory's historical archive (1967–2001) of wide-field photographic plates, obtained with the Baldone Schmidt telescope for the original purpose of carbon star observations, contains 24,300 plates.

Digital processing of the plates allows researchers to determine with high accuracy the coordinates and stellar magnitudes of all registered objects on these plates (the mean squared error of a fitted coordinate is ±0.08 arc sec and ±0.05 mag). The images are currently processed using an advanced set of LINUX / MIDAS / ROMAPHOT programs. The digitally processed photographic plates can be used for the rediscovery of asteroids and the correction of their orbits, investigations of variable stars, and the proper motions of stars.

Solar System Small Bodies Monitoring

The monitoring of small planetary bodies includes CCD observations of asteroids with the Baldone Schmidt telescope, which is equipped with two CCD STX-16803 cameras. The field of view of each camera is one square degree. During the last 10 years, 3511 astrometric positions of 826 asteroids have been published in the Minor Planet Circulars and the Minor Planet Electronic Circulars. Among them are 48 asteroids, which were discovered at Baldone, including one notable centaur (330836) Orius. Precise orbits were calculated for 36 of these asteroids. The mechanics and the optical system of the Baldone Schmidt telescope are continuously upgraded. The upgrades include Europe's only working prototype of the ESA FlyEye system, with optics designed by Māris Ābele. A near-future goal is to upgrade the Schmidt telescope for polarimetry measurements.


Figure 2. Baldone Observatory director Ilgmārs Eglītis showing part of the 25,000 Baldone Observatory Schmidt Plate Archive. (photo: A. Graps)

Institute of Astronomy of the University of Latvia
Baldone Observatory / Riga Satellite Laser Ranging Station

Satellite Tracking

The Riga Satellite Tracking Station has been tracking satellites since 1957 with USSR's Sputnik-1. Over the years, the Institute staff have designed a vast range of satellite tracking equipment including optical, photographic, and laser systems. Many of the world's satellite tracking systems from the Soviet period can trace their lineage back to the Institute of Astronomy in Riga. For example, the FU75 satellite tracking camera designed by Māris Ābele was in use for 30 years in 30 countries. Now the Satellite Tracking Station is running the satellite laser ranging (SLR) system LS-105 (diameter of main mirror 1.05 m). The picosecond timer used in half the world's SLR systems and marketed by Eventech was first built for, and tested at, the Riga Satellite Tracking Station. The SLR station is a member of the International Laser Ranging Service (ILRS) and Eurolas. The Station is also a permanent GPS station (RIGA_12302M002) for Latvia and is a member of the International GPS service (IGS) and the EUREF permanent GPS network EPN. The SLR station (ILRS code name '1884 Riga') is capable of day and night observations and measures distances to the satellites in the range from 400 to 28,000 km with single-shot accuracy of a few cm, depending on the range and satellite signature. High-accuracy SLR and GPS observations form the basis of the Latvian National geodetic coordinate system LKS-92 and ties it to the ITRF and EUREF international reference frames. The satellite and geodetic data produced are included and used in the yearly data sets by the global scientific community and the space agencies. The scientific research at the Station is concentrated on SLR-related activities: design and testing of new equipment, data analysis, algorithms, and software for tracking objects in the vicinity of Earth.


Figure 4. Classroom (Rīgas 6. vidusskola, Class 2D, October 2016) visit to Baldone Observatory. (photo: A. Graps)


Figure 3. Riga Satellite Laser Ranging Station in operation. Photo by the LU Institute of Astronomy

Public Outreach

The Institute of Astronomy is committed to Public Outreach. Four times a year the popular science magazine *Starry Sky* is published in Latvian and distributed in the local bookstores. The magazine was founded by Jānis Ikaunieks (1912–1969), who was instrumental in founding the Baldone Astrophysical Observatory. Once a month, the Institute of Astronomy offers its 20 cm Schmidt-Cassegrain telescope and tower for public viewing. See also the intersection with public outreach by the Friedrich Zander Museum of Space Exploration. The number of young visitors to the Baldone planetarium shows is also growing steadily: In 2015 there were 4000 classroom visitors; in 2016 there were 6000 classroom visitors.

Our institute seeks new collaboration in astronomical spectroscopy, astronomical photometry, asteroid observations, satellite laser ranging, and photonics.

Latvian Institute of Astronomy Essentials

Academic staff: 10, Leading researchers: 3
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Scientific secretary: Mag. phys. Kalvis Salmiņš
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Friedrich Zander Museum of Space Exploration

The Friedrich Zander Museum of Space Exploration is a part of the Museum of History of Sciences and Technology of University of Latvia.

History

Friedrich Zander (1887–1933) (German: Friedrich Zander, Russian: Фридрих Цандер, Latvian: Frīdrihs Canders) was a Baltic German pioneer of rocketry and spaceflight in the Russian Empire and the Soviet Union. He was born in Riga, now the capital of Latvia, and studied engineering at the Riga Polytechnic Institute. In the same period when Robert Goddard developed his rocketry, Friedrich Zander designed the first liquid-fueled rocket launched in the (new) Soviet Union, and made many important theoretical contributions to the exploration of space. For example, Friedrich Zander was the first person to calculate the possibilities of using a solar sail for the spacecraft propulsion.

Timeline—Friedrich Zander

1887. Pioneer of rocketry and spaceflight Friedrich Zander is born.

1933. The Soviet Union's first liquid-fueled rocket, designed by Friedrich Zander, is launched.

1987. The Museum of Friedrich Zander, pioneer of rocketry and spaceflight, is opened in Riga.


Figure 1. Friedrich Zander, a pioneer of rocketry and spaceflight. Painting by Alberts Goltjakovs


Figure 2. The house in Riga where Friedrich Zander's family lived. F. Candera Street 1, 1898–1913. Photo by *SeptembriS1, CC SA 4.0 license*

The Friedrich Zander Museum of Space Exploration was opened in 1987 in the house where he spent his childhood and teenage years (Candera 1, Rīga), celebrating the centenary of the birth of the famous space pioneer. In 2005, the Museum was moved to the main building of the University of Latvia (Raiņa bulvāris 19, Rīga), where Zander studied at the Riga Polytechnic Institute, Faculty of Mechanics (1907–1914). These were the years when he became acquainted with the work of Konstantin Tsiolkovsky, and space travel became his foremost scientific passion.

At the start of World War I, Zander moved to Moscow and spent the rest of his life there. In 1924, he was introduced to the work of Robert Goddard. In that year, Zander himself promoted Tsiolkovsky's rocketry work and then developed it further. Zander was a founding member of GIRD (Group for the Investigation of Reaction Propulsion) (Группа изучения реактивного движения (ГИРД)) in Moscow. As head of Brigade №1, Zander worked on the OR-2 (GIRD-02) rocket engine, to power the 216 winged cruise missile. He also worked on the engine and rocket GIRD-10, which flew successfully on 25 November 1933.

Together with his GIRD colleagues, Zander calculated the trajectories of spacecraft orbits, designed spacecraft and rocket engines, and build experimental rockets.

One of Zander's trajectory calculations was for a spacecraft flight to Mars. Mars held a special fascination for Zander, and "Forward to Mars!" (Вперед, на Марс!) became his famous motto.

The museum collection not only tells the story of Friedrich Zander's life and achievements, but also describes the global history of space exploration and provides a history of astronomical research in Latvia. Many old instruments from the Astronomical Observatory of the University of Latvia are displayed. A large collection of meteorites that contains common types of meteorites and some rare specimens is also a part of the museum exhibition. Here you can even touch the piece of the Moon!

Friedrich Zander Museum of Space Exploration

The Friedrich Zander Museum of Space Exploration is a part of the Museum of History of Sciences and Technology of University of Latvia.

Figure 3. Astronomical Tower of the University of Latvia.
Photo by *Toms Grinbergs, LU Preses centrs*

Figure 4. An exhibition at the Friedrich Zander Museum of Space Exploration.
Photo by *Toms Grinbergs, LU Preses centrs*

Astronomical Tower of the University of Latvia

During the daytime it is possible to look through the 20 cm Schmidt-Cassegrain telescope to observe the attractive sights of the Historic Centre of Riga—the Old Town.

On workday nights the Moon, planets, double stars, nebulae, star clusters, and galaxies can be seen through the telescope. www.lu.lv/astronomiskaistornis/

The Museum also operates a mini-planetarium where celestial objects are demonstrated on the big flat screen. Planetarium shows are available on Thursdays by request for groups of more than 10 people at Raiņa bulvāris 19. www.lu.lv/planetarijs/

Missing stars in your everyday life? Come visit us!

Friedrich Zander Museum of Space Exploration Essentials

Museum Head: Dr. paed. Ilgonis Vilks
Street address: Raiņa bulvāris 19, Rīga, LV-1050, LATVIA
Tel: +371 670 34 587,
Email: ilgonis.vilks@lu.lv.
Web: https://www.lu.lv/par/strukt/muzejs/kosmosa/
Twitter: @LUMuzejs, Facebook: https://www.facebook.com/lumuzejs/

Open on weekdays by request.

Ventspils International Radio Astronomy Centre (VIRAC)

Engineering Research Institute of Ventspils University College

History

The Ventspils International Radio Astronomy Centre (VIRAC) began operation on 10 June 1967 as a secret Soviet military and communication center that was used to spy on communications in the West. When the Russian military left the installation in 1994, it was rescued from demolition by the Latvian Academy of Sciences, who received strong support from the international community of radioastronomers, led by Swedish and Russian civil researchers and from the Ventspils City Council.

On 22 July 1994, VIRAC officially became a scientific research facility and part of the Latvian Academy of Sciences.

In 2004, the Republic of Latvia added the limited liability company VIRAC to Ventspils University College (VUC) under the Latvian Ministry of Education and Science. In 2005, VIRAC became a department of Ventspils University College and was listed in the Registry of Research Institutions operated by the Ministry of Education and Science of the Republic of Latvia. Furthermore, in 2010, VIRAC was added to the VUC Research Engineering Centre. Its official name is now the Engineering Research Institute: Ventspils International Radio Astronomy Center of Ventspils University College. We like VIRAC for short!

Facilities

VIRAC's core capital consists of two fully turnable, parabolic, radio telescope antennas with primary mirrors, RT-32 and RT-16 (having diameters of 32 and 16 meters respectively), as well as buildings, constructions, and the communications needed to ensure the work of these antennas. The main operating frequency bands are the C, M, X, and L bands, which are available for Very Long Baseline Interferometry (VLBI) and single dish observations. During the last years, VIRAC has greatly refurbished its infrastructure and modernized both radio telescopes, RT-32 and RT-16. Two new broadband (4.5-8,8 GHz) cryogenic receivers were installed at both radio telescopes and were successfully tested and calibrated to the European VLBI standard. Since 2016, VIRAC has participated in the European Very Long Baseline Interferometry Network (EVN) of more than 25 distributed instruments observing as one large-scale research infrastructure unit.

Both antennas are equipped with Digital Base Band Converters (DBBC) and Mark5C data recorders, which allows parallel (two polarizations) recordings of up to 1 GHz bandwidth with a data rate up to 4 Gbps. Simultaneously, this data flow is recorded at the correlation centre in JIV EERIC in the Netherlands in real time via a direct broadband network connection.

Figure 1. Completely renovated RT-16 with carbon composite parabolic surface. After modernization, the positioning speed was upgraded to 16 times what it was before.

Skillsets

Research at VIRAC can be classified into four fields:
1) Astronomy and Astrophysics,
2) High Performance Computing,
3) Remote Sensing, and
4) New Generation Antenna Development and Satellite Engineering and Electronics.

Astronomy and Astrophysics

The institute performs research in the field of solar active regions, astrophysics, observations of interstellar clouds and active galactic nuclei, molecular radio lines in space observations that trace the evolution of stars, and emissions from supermassive black holes in the centers of galaxies, using VLBI (Very Long Baseline Interferometry). The aforementioned work is supported by polarized radiation transfer theory research in several geometries and media.

In 2016, VIRAC became a full member of the EVN and Latvia became a member of the JIVE-ERIC organization (one of ten European Strategic Forum for Research Infrastructures (ESFRI) for mega-infrastructure coordination). The EVN is a collaboration of the major radio astronomical institutes in Europe, Asia, and South Africa, and performs high angular resolution frontier observations of cosmic radio sources. In addition, the International Celestial Reference Frame (ICRF), essential for global positioning systems and astrometry, is continuously improved using VLBI.

High Performance Computing

This division reflects emerging competence in space and earth geodesy, planetary small bodies (with new PhD students), space debris, ionosphere observations, big data processing support to other divisions, and calculations in areas of engineering physics—complicated mechanical models, aero- and hydro-dynamic flow modelling, as well as electromagnetic process modelling.

Remote sensing

VIRAC's remote sensing is Earth observational using free- and commercial- satellite hyperspectral images, LIDAR (Light Detection and Ranging) orthophoto data, developed with unique math algorithms, and using machine- learning techniques with the aim of performing research on:

- Forest resource monitoring and inventory through satellite imagery, aerial photography, and LIDAR data (tree canopy frame analysis through the detection and identification of individual tree crowns and their classification into species, estimating stand yield and biomass).
- Oil slick pollution of natural water basins (primarily offshore) using synthesis aperture radar (SAR) data, from Sentinel1, Radarsat2 and TerraSARX.
- Urban building mapping with the aim of detecting heat losses (In IR spectral diapason).
- Precision agriculture (PA) by analysing the spectral signatures of grain species and helping to obtain larger, and more high-quality, yields and providing automated solutions.

Since 2010, we've successfully implemented ~8 projects, including training for more than 15 students.

Figure 2. RT-32 after 2015-2016 refurbishment.

Ventspils International Radio Astronomy Centre (VIRAC)

Engineering Research Institute of Ventspils University College

Satellite engineering and electronics

We have a team of engineers who can build space-qualified nanosatellite electronics, perform nanosatellite systems engineering, and research nanosatellite subsystems, in particular with high-speed, on-board data -handling, processing, and transference for high-capacity nanosatellite missions. One of our successes is a prototype of CCSDS-based communication subsystem (HSCOM) for use in 3U CubeSats. The purpose of HSCOM is to mitigate nanosatellite frequency band overcrowding, ensuring adaptive downlink channel with high spectral efficiency according to the CCSDS 131.2-B-1 recommendation standard. Flight tests are planned during ESTCube-2 missions using radiotelescope RT-16 as the ground station.

Latvia's first satellite Venta-1, launched June 23, was developed as a VUC educational project, implemented by the Ventspils High Technology Park, VUC and the University of Applied Sciences Bremen in collaboration with specialists of the University of Latvia and the Riga Technical University. Since Venta-1's launch, VUC engineering students have the opportunity to study the maritime Automatic Identification System (AIS) receiver from the satellite in Low Earth Orbit via a dedicated S-band frequency link. A last-minute payload on Venta-1 is the remarkable 'Sprite' wafercraft by the Breakthrough Starshot program. The Sprite on Venta-1 and its sister-craft in LEO are the smallest spacecraft ever launched. They are the prototypes for the eventual wafercraft, which would require much less energy to accelerate them to relativistic speeds, that Starshot hopes to send to Alpha Centauri.

Current Projects

VIRAC is currently working on nine international and national level significant projects:

- *Building an Advanced LOw-Frequency ARray (LOFAR), (10–240MHz) station (2019) and Digital Aperture Radar Laboratory*
- VIRAC Radio Telescopes infrastructure modernization—stage three
- The European Comission H2020 Twinning: *Building on Advanced LOFAR Technology for Innovation, Collaboration, and Sustainability* (BALTICS)
- European Regional Structural Funds: *Asynchronous Logic Circuits: Methods and Tools for the Design in Reconfigurable Environment*
- The European Commission and Latvian Academy of Science funded The New European Wind Atlas
- European Regional Structural Funds: "Physical and chemical processes in the interstellar medium" (ASTRA)
- Latvian National Research Program: *Multlfunctional Materials and composItes, photonicS and nanotechnology*
- European Commission Advanced Research Network: *RADIONET-4*— research in radio astronomy in Europe
- Latvian National Research Program's Subprogram No. 4 "The new generation of large-scale data processing systems"

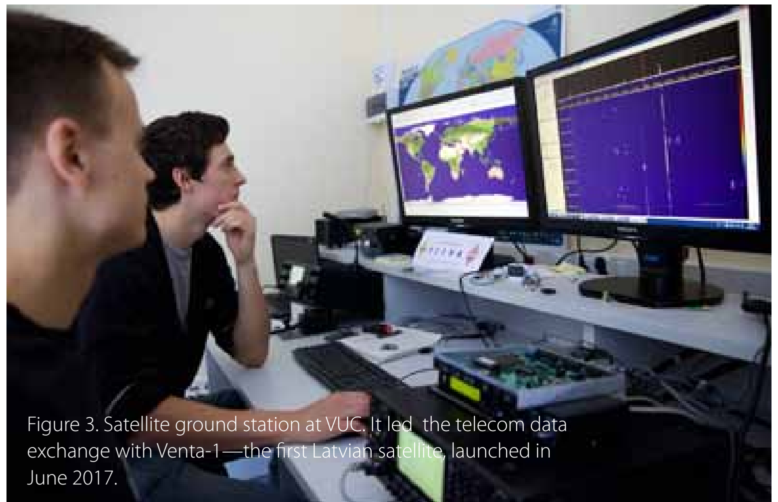

Figure 3. Satellite ground station at VUC. It led the telecom data exchange with Venta-1—the first Latvian satellite, launched in June 2017.

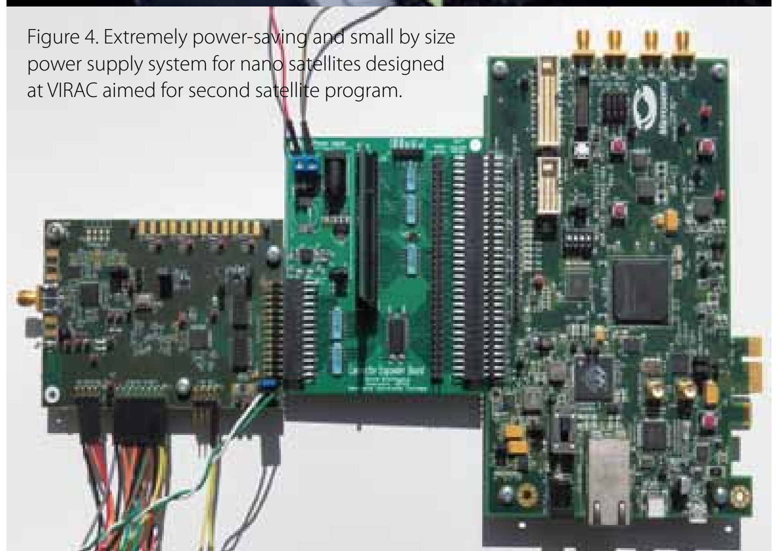

Figure 4. Extremely power-saving and small by size power supply system for nano satellites designed at VIRAC aimed for second satellite program.

Figure 5. The student satellite study lab plays a valuable role in training students involved in the space balloon and nanosatellite programs.

VIRAC serves as a centre of research training for young astronomers and space researchers from all over Europe—in particular the Nordic and Baltic countries. Since 2010, VIRAC has organised two international satellite-building summer schools, the young radioastronomers conference YERAC, four international Baltic Applied Astroinformatics and Space data Processing (BAASP) conferences funded by the European Commission's FP7 and Horizon 2020 programmes and other science funding organisations. VIRAC has participated in the European Researchers' Night events every year since these public outreach activities began and is visited by more than 6000 people every year. You are also welcome!

VIRAC Institute Essentials

Staff: 76 scientific employees (with full-time equivalent of 45 employees) of which 22 (or 11.32 full-time equivalents) are scientists with PhDs.
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Moletai Astronomical Observatory

Institute of Theoretical Physics and Astronomy, Vilnius University

History

The first observatory in Lithuania was established in 1753 by Vilnius University and is the 19th oldest 'true observatory' in the world. Due to interference from the city lights, two new domes were built on the outskirts of Vilnius in 1921; however, soon the city lights reached the astronomers there, as well. In 1969, a new observatory was founded in the Molėtai district, about 70 km north of Vilnius, by the Institute of Physics and Mathematics of the Lithuanian Academy of Sciences. It was built on Kaldiniai Hill near the small village of Kulionys, about 10 km from the town of Molėtai. Nowadays the Molėtai Astronomical Observatory is maintained by the Institute of Theoretical Physics and Astronomy, which has been a part of Vilnius Univerity since 2010.

Facilities

The Molėtai Observatory (MAO: international code: 152) operates three telescopes: a 1.65 m Richey-Chrétien (since 1991), a 63 cm Cassegrain (since 1974), and a 35/51 cm Maksutov-type telescope (since 1975). The facility also employs two CCD photometers, a coravel-type radial velocity spectrometer, and a high-resolution spectrograph (VUES). The 1.65 m telescope was renovated in 2016 when the VUES spectrograph was installed. Both the Richey-Chrétien and Maksutov telescopes are now usually operated remotely.

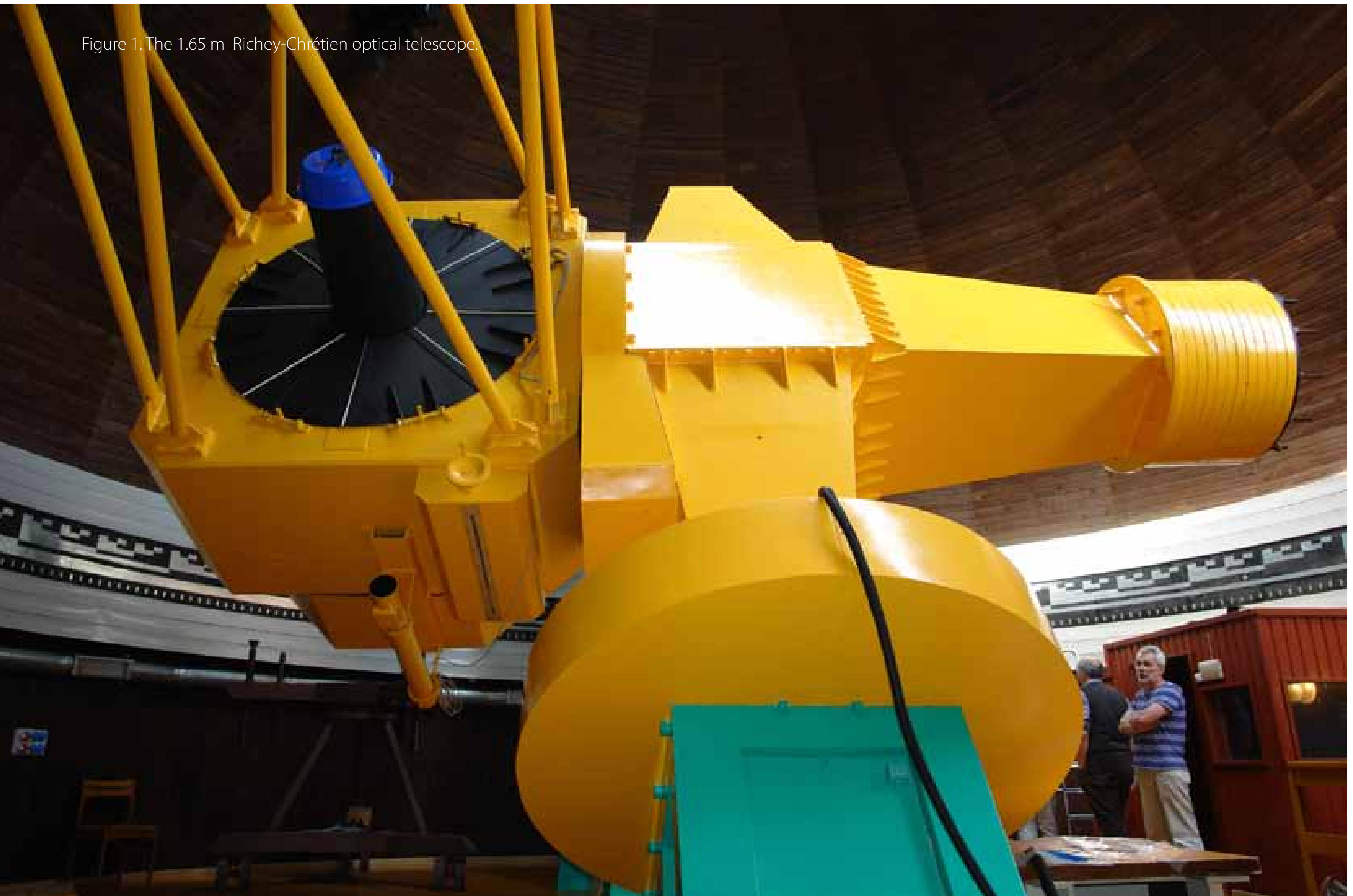
Figure 1. The 1.65 m Richey-Chrétien optical telescope.

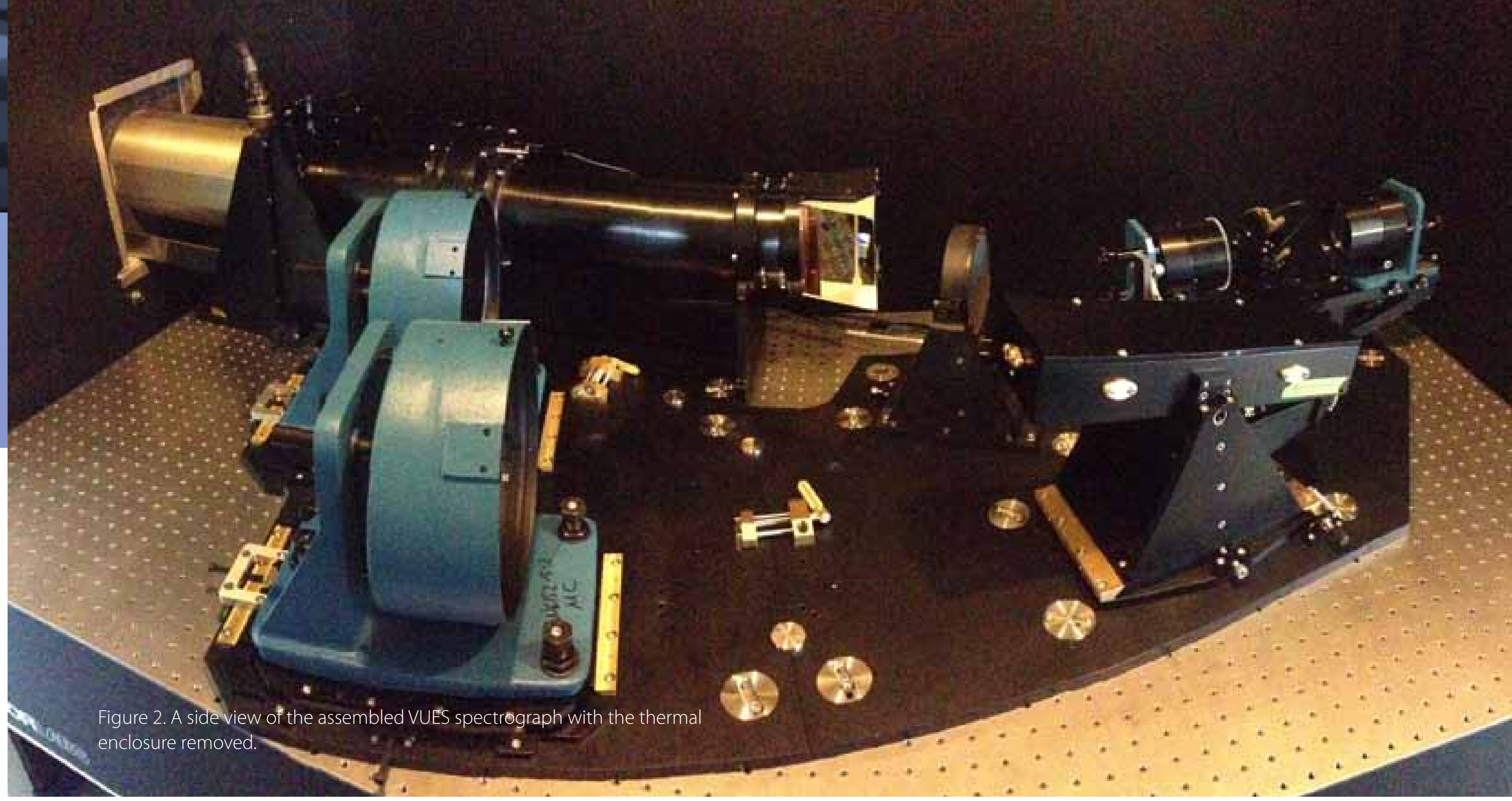
Figure 2. A side view of the assembled VUES spectrograph with the thermal enclosure removed.

Contributions of Note

During 1963–65 Lithuanian astronomers created and developed the Vilnius photometric system, a seven-colour intermediate band system, optimized for photometric stellar classification in the presence of interstellar reddening. This system was widely used to investigate galactic structures, interstellar extinction, the distances to dust clouds, and since 1986, MAO has been participating in the world-wide Whole Earth Telescope network of more than 25 astronomical observatories that cooperate to obtain uninterrupted time-series measurements of stellar asteroseismic activity.

Skillsets

Since 1998, when the coravel-type radial velocity spectrometer was produced, stellar radial velocity investigations have been among MAO's top priorities. Identification and analysis of small planetary bodies is another active field of research for the observatory. More than 400 asteroids, including four that are potentially hazardous for the Earth, were discovered and investigated.

The high-resolution spectrograph VUES, which was mounted on the 1.65 m telescope in 2016, has opened new research possibilities. The spectrograph has three resolution modes (R = 30000, 45000, and 60000) and a wavelength coverage of 400–880 nm. It is used for studying the galactic chemodynamic evolution and stellar chemical composition analysis, including planet-hosting stars.

Currently MAO is conducting the project *A Spectroscopic and Photometric Survey of the Northern Sky for the ESA PLATO Space Mission*. The astronomers are taking advantage of their northern geographic location to prepare a dataset of the brightest targets of the northern-most regions of the sky-sphere for the northern PLATO 2.0 fields employing the observatory's spectroscopic and photometric instruments. MAO is also participating in the NASA Kepler Follow-up Program, which was initiated to conduct follow-up observations of Kepler 'Objects of Interest'. MAO is among the more than 50 ground-based observatories involved in the Gaia Science Alerts Working Group, which is focussed on the real-time detection of variable sources. MAO is also involved in the BRITE (BRIght Target Explorer) Constellation network, which aims to investigate stellar structure and the evolution of the brightest stars in the sky and their interaction with their local environments. Observations of small planetary bodies are funded by the European Commission EUROPLANET 2020 Research Infrastructure project. MAO also plans to contribute to the NASA TESS and NASA/ESA/CSA James Webb Space Telescope missions by making ground-based determinations of the detailed chemical compositions of planet-hosting stars.

Moletai Astronomical Observatory
Institute of Theoretical Physics and Astronomy, Vilnius University

Figure 4. Participants of the Summer School programme **Formation and Evolution of Planetary Systems and Habitable Planets**, held at the Molėtai Astronomical

Figure 3. Dr. habil. Gražina Tautvaišienė, head of the Molėtai Astronomical Observatory since 2003, and prof. dr. habil. Vytautas Straižys, the former head.

The Molėtai Astronomical Observatory serves as a centre of research training for young astronomers from all over Europe; the Baltic and Nordic countries, in particular. Since 1999, MAO has organised 12 international summer schools programmes funded by the NorForsk, European Commission FP7, Horizon 2020, and Erasmus+ programmes, the European Union COST programme, and other science-funding organisations. MAO has participated in the European Researchers' Nights and National Science Festivals every year since the beginning of these public outreach activities, and is visited by more than 5000 people every year.

You are also welcome!

Molėtai Astronomical Observatory Essentials

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