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ESA to launch satellites investigating the evolution of the universe in May

Finnish technology will help scientists study the birth of the universe

The European Space Agency (ESA) is preparing to launch two scientific satellites, Planck and Herschel, in May. The satellites will help scientists to investigate the structure of the universe and the formation of stars and galaxies. Finnish enterprises and scientists have made a significant contribution to the development of the satellites.

Planck and Herschel will be launched in tandem from Europe's Spaceport in Kourou, French Guiana. Finland has delivered high-technology scientific instruments and satellite technology for both missions.

"Finland's involvement in the Planck project is one of the largest contributions we have made to space projects. It has required cutting-edge expertise from the companies and research teams involved," says Technology Director **Kimmo Kanto** from Tekes.

Planck listens to cosmic microwave background radiation from the very dawn of time

The Planck satellite will study the cosmic microwave background (CMB) radiation which holds clues to how the galaxies, stars and planets started to form 14 billion years ago. Planck will also be used to study other sources of radio-frequency radiation, such as galaxies and star-forming regions in the Milky Way.

Scientists at the Observatory and Department of Physics at the University of Helsinki, the Helsinki Institute of Physics, the Metsähovi Radio Observatory at the Helsinki University of Technology and the Tuorla observatory in Turku will be able to use the data obtained from Planck in their research. Their input has been vital in both the design of the Planck satellite and the implementation of its scientific programme.

The world's most sensitive radio technology delivered by the Finnish team

Planck carries some of the most sensitive radio technology ever developed. The 70 GHz radio receiver was developed and built in Finland. The project was coordinated by MilliLab, the joint laboratory of VTT Technical Research Centre of Finland and the Helsinki University of Technology (TKK), and the receiver was built by DA-Design Oy.

"The work was very demanding in nature, which gave us the opportunity to develop valuable expertise that we can also use for other applications", says **Jussi Tuovinen**, Research Director at VTT. Tuovinen was responsible for the component construction for the Finnish Planck project. The technology developed in the project is available for use in, for example, security checks or detecting vehicles through fog. It is also suitable for high-precision cloud radar and future telecommunications applications.

Herschel's principal mirror was polished in Piikkiö

A space observatory that operates in the long-wavelength infrared spectrum, Herschel will allow scientists to study the mechanisms of star formation. The primary mirror of the space observatory was polished by the Finnish company Opteon Oy. The mirror is the largest and technically most demanding silicon carbide mirror ever constructed for a space mission.

The Central Data Management Unit Application Software for the Herschel and Planck missions, which directs the satellites' functions such as fault repair and thermal control, was developed by Space Systems Finland. Herschel's Cryostat Control Unit, which maintains the temperature of the focal plane

of the scientific instruments at as close to absolute zero as possible, was designed and constructed by Patria.

The Finnish involvement in the development of the scientific instruments and technology deliveries totals some 14.5 million euro. Tekes coordinates and finances Finland's participation in ESA programmes. The Academy of Finland has provided funding worth over 2.5 million euro for research by Finnish scientists related to Herschel and Planck.

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Finnish instruments in the scientific payload of Planck and Herschel

MilliLab & DA-Design: Sensitive, low-frequency radio receiver

The scientific payload of ESA's Planck mission includes an extremely sensitive 70 GHz radio receiver developed and constructed in Finland. The receiver will be used to measure the CMB radiation originating from the early universe. The project was coordinated by MilliLab, the joint laboratory of VTT Technical Research Centre of Finland and the Helsinki University of Technology (TKK). Construction and testing was carried out by the Finnish company DA-Design Oy.

The technology developed in the project is available for use, for example, in security checks or detecting vehicles through fog. It is also suitable for high-precision cloud radar and future telecommunications applications. In addition to a 1.5-metre radio telescope, the Planck spacecraft will have two instruments on board: a Low Frequency Instrument and a High Frequency Instrument. The most demanding components of the Low Frequency Instrument were designed and built in Finland. The receiver required several new technical solutions.

”Essentially, the Planck receiver resembles a crystal radio,” says Technology Director **Jussi Tuovinen** from VTT. ”However, the frequency of the cosmic microwave background radiation is a million times that of normal radio transmissions. Thus instead of a wire antenna we use a parabolic antenna - a radio telescope - and instead of crystals, diodes and amplifiers to amplify the signal 500,000 times.”

http://virtual.vtt.fi/virtual/millilab/pages/Planck_MilliLab.htm
www.da-design.fi

Space Systems Finland Oy: Satellite guidance software

The Central Data Management Unit Application Software for the Herschel and Planck missions, which directs most of the satellites' functions including fault detection, isolation and recovery, thermal control and resource management, was developed by Space Systems Finland. The software is critical to the success of the Herschel and Planck missions.

The orbit of the satellite will be 1.5 million kilometres away from the Earth and the ground station will only have visibility per two hours per day. This extremely narrow satellite maintenance window is a high-risk factor in terms of software design. The stringent requirements concerning operational reliability and real-time functionality added to the challenges of the software development. Exhaustive testing ensured that the software meets the quality specifications. A specifically constructed automated testing environment enabled continuous testing at all times. As is typical of critical system development, testing was the most resource-intensive phase of the software development project.

Space Systems Finland's Herschel and Planck project was launched in 2003 and completed in summer 2008. Established in 1999, Space Systems Finland is a Finnish software engineering company that specialises in the production, testing and quality control of mission-critical solutions. The company has 34 employees.

www.ssf.fi

Opteon Oy: Polishing the Herschel mirror

The Herschel mirror is the world's largest silicon carbide mirror, and the largest mirror ever to be used in space. The mirror structure is ultra light: the thickness of the mirror surface is a mere 2.5 mm, and the entire mirror weighs only 250 kg. Silicon carbide is an extremely hard material that can only be worked using diamond tools. It took the Opteon team eight months to grind and polish the mirror surface. Completed in April 2005, measurements of the polished mirror satisfied all of the requirements. Specialists in the field characterise the mirror as "undoubtedly the most demanding mirror ever built for a space mission".

The Herschel space observatory was originally a joint ESA/NASA project, with NASA responsible for delivering the telescope primary mirror. When the demonstrator reflector fabricated using carbon fibre technology failed to meet the specifications, NASA withdrew from the project. At the same time silicon carbide (SiC) mirror technology was being developed in Europe. ESA's survey identified Opteon Oy as the only European company using the technology required for polishing SiC mirrors. The Herschel primary reflector demonstrator, which had a diameter of 1.35 metres and which was constructed of silicon carbide, was handed over to Opteon for polishing in 1998. The polished demonstrator satisfied the specifications, and the decision was made to fabricate Herschel's mirrors using silicon carbide technology.

Opteon also undertook the polishing of Herschel's 3.5-metre primary mirror, which required the construction of new polishing facilities and a new polishing machine. The parabolic mirror has an extremely short focal length and its asphericality (deviation from a sphere) is unprecedented, which meant that new methods and equipment had to be developed to measure the mirror profile.

www.opteon.fi

Patria: Cryostat Control Unit

The Cryostat Control Unit (CCU) of the Herschel space observatory was designed and built by Patria. The CCU maintains the temperature of the IR telescope at as close to absolute zero as possible. This enables extremely accurate observation without interference from the thermal radiation of the spacecraft itself. This project is a good example of the traditional value chain in satellite construction

where cross-industry cooperation promotes basic research and scientific advances and vice versa. Had the scientific community not participated in the construction of the Herschel spacecraft, it would not gain access to the research data Herschel will provide. On the other hand, if there were no benefits to the science, Herschel would not have been constructed in the first place.

www.patria.fi

Space research using the Planck and Herschel scientific satellites

The purpose of ESA's Planck satellite is to map cosmic microwave background radiation with greater sensitivity than any previous satellite. CMB radiation consists of microwaves coming from the furthest reaches of space - so far, in fact, that it has travelled undisturbed almost ever since the universe was formed 14 million years ago. As a result, CMB radiation gives us a snapshot of the universe when it was very young, only some 400,000 years old.

The distribution of matter was quite uniform in the early phases of the universe, and there were only tiny variations (approximately one part in ten thousand) in the density of matter. The goal of the Planck satellite is to measure the properties of these variations as accurately as possible and thus help scientists determine the physical process leading to their formation.

The structures of the current universe – galaxies, stars and planets formed of gravitating matter - evolved from these original variations in the density of the universe, the "seeds of galaxies", over billions of years. One of the fundamental questions in cosmology (the study of the origins and evolution of the universe) is what caused these variations.

Scientists at the **Department of Physics at the University of Helsinki** and the **Helsinki Institute of Physics (HIP)** hold key positions in the Planck project – for example, in the process of making sky maps from Planck data in different frequency bands. The maps will be created using the Madam mapmaking code, which was developed by the team for the Planck mission. As regards the properties of the original density variations, the team is particularly interested in discovering whether variation density were similar for all particle types or whether differences can be discovered between them.

Not all of the microware radiation coming from space originated in the early phases of the universe. Many foreground objects - objects in front of the CMB radiation – also emit radio-frequency radiation. In order to distinguish between CMB radiation and other objects, Planck will measure radiation at nine frequency ranges. This means it will detect a huge number of foreground radio sources, including galaxy groups and clusters, active galaxies and star-forming regions in our own Milky Way. Planck will extract a great deal of new information about these objects using high radio frequencies not covered before.

Planck will help scientists at **Tuorla Observatory** (Department of Physics and Astronomy at the University of Turku) and the **Observatory of the University of Helsinki** study galaxy clusters, huge groups consisting of hundreds of galaxies. Even large groups, superclusters, are among the largest structures in the cosmos. Only 5% of the universe is made of normal, visible matter. However, even half of this visible matter is 'missing', that is, it still remains undetected. Scientists have actually hypothesized that a significant portion may reside within superclusters in gaseous form. CMB radiation passing a galaxy cluster receives energy from the hot gas particles in the cluster. Planck detects distortions in the CMB radiation, which both hold clues to the composition and distribution of the gas and help scientists discover previously unknown clusters. The Tuorla Observatory team collaborates closely with the cosmology group at the University of Tartu observatory in their research related to Planck and superclusters.

The **Metsähovi Radio Observatory (TKK)** team hopes the Planck data will help unravel the mysteries of remote active galactic nuclei, or quasars. The centre of the quasar contains a supermassive black hole in the vicinity of which, in combination with plasma flows streaming at almost

the speed of light, violent emission bursts are produced. Thanks to its unique wavelength coverage in the higher radio frequencies, Planck's observations of how quasar emission bursts occur and evolve will hold clues to how a supermassive black hole produces the enormous amount of energy which makes quasars radiate strongly enough to be brightly visible billions of light-years away. The Metsähovi team has also developed an innovative Quick Detection System software package for the Planck mission, which will allow the scientists to be among the first to access the scientific observations obtained from Planck.

Scientists at the **Observatory of the Helsinki University** will use the observations of the Planck space observatory to study the mechanisms of star formation in our home galaxy, the Milky Way. Stars form from interstellar gas clouds when the cloud nuclei collapse due to gravity. However, studying the early stages of the process has proved extremely difficult as the cloud nuclei are initially very cold – their temperature is only some ten degrees above absolute zero. Planck will revolutionise research into the origins of star formation, since its measurements can be used to create the first ever comprehensive list of the cold cloud nuclei in the Milky Way. Furthermore, observations made by the Herschel satellite will allow scientists to determine the internal structure of cloud nuclei. Combined with computer models the measurements will help scientists understand how the cloud nuclei form and evolve and how stars are born.

Observatory, University of Helsinki
http://www.astro.helsinki.fi
http://wiki.helsinki.fi/display/PlanckHerschel

Department of Physics, University of Helsinki
http://www.physics.helsinki.fi/
http://www.helsinki.fi/~tfo_cosm/tfo_planck.html

Helsinki Institute of Physics (HIP)
http://www.hip.fi/index_fin.html

Metsähovi Radio Observatory's Planck website
http://www.metsahovi.fi/quasar/planck/index.htm

Tuorla Observatory (Department of Physics and Astronomy at the University of Turku)
http://www.astro.utu.fi/index.fin.shtml