

Development goals and measures (UMV) 2017-20 DTU Space

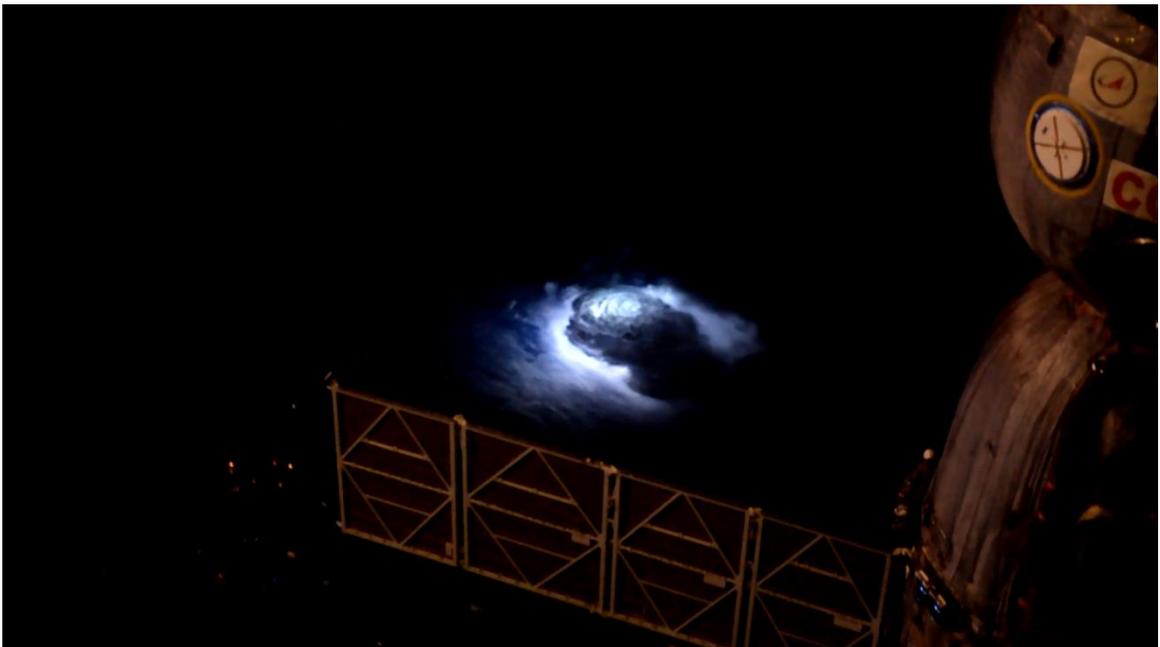


Image of thunderstorms captured by Danish astronaut Andreas Mogensen onboard the ISS as part of the DTU Space lead THOR experiment.

July 1, 2016

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1. Academic profile and expected performance goals of the department

DTU Space develops and creates lasting value by using the natural and technical sciences within the broad area of space to benefit society. The institute is characterized by a vivid interaction between the natural and technical sciences and engineering in order to foster and advance space activities at the highest international level. The goal of DTU Space is to be a *preferred international partner*, participating in, and profiting from, international projects and missions through innovative collaborations with the private and public sector. DTU Space strives to have a *strong educational profile* by recruiting bright students, educating them to the highest international level, and thereby enabling graduates to pursue attractive careers and meet the demands of employers.

The interaction and experiences gained from *being involved in the full life cycle* of space activities strengthens the institute's global position by creating satellite missions and by exploiting their applications. The full life cycle includes: Concept and design, construction and proto-typing, calibration and validation, implementation and operations, data analysis and dissemination, practical applications – leading to ideas for new space instruments and missions.



DTU Space is developing new space technologies, e.g. for extending the life time of satellites.

For the institute to reach the above-mentioned goals, it is imperative that the *institute features a handful of research "lighthouses"* at world leader level. Furthermore, the institute targets a sufficient science & technology span to enable high quality education, scientific advice to public authorities, and innovation, as well as the agility to pursue upcoming and promising new areas.

DTU Space appreciates, and strives to meet, Denmark's needs for a public space center with sufficient capacity, breadth and excellence to achieve and sustain pre-eminence in space technology and science, thus maintaining and developing leadership in space and its applications. A broad knowledge base in space, along with the proper facilities and skilled staff, are prerequisites for Denmark to benefit from the opportunities offered by space and to ensure independence in this strategic area. Space has a large and increasing importance in addressing societal challenges, adding value to Danish companies, and pushing the borders of knowledge about space technology, our planet, the Solar System and the cosmos, e.g. developing and utilizing satellite infrastructures to map and monitor the Earth to the benefit of authorities, companies and research. In many cases, going to space is the most efficient, and often the only, way to improve understanding of the Earth, further industrial development and improve our quality of life. Furthermore, the inspiration and pride aroused by the institute's successes encourages young people to undertake the scientific and technical careers that Denmark so clearly needs to foster its growth in key areas, essential to maintain the position on the global scene.

Most important strategic goals 2017-2020

Research. For decades, DTU Space has focused the research activities and placed the institute in a key position within several strategic fields in space science, geoscience and space technology, making the research technology attractive to even the most highly profiled space missions. The institute develops systems, methods and instruments for satellites and aircraft and exploits these to study the physical conditions and processes on Earth and in space. The scientific and application-related challenges require the development of new technology, and technological research opens new avenues for science and applications. Facilities/infrastructures in space, in the air, on the ground, and in the labs is the basis that provides an excellent knowledge base and development ground for current and new activities.

DTU Space will further develop the institute's research lighthouses and fill several professorships in order to strengthen strategically important research areas.

Education. DTU Space will fully implement the Earth and Space Physics and Engineering (ESPE) education. The education has been designed to include elements corresponding to society's increasing demand for skills in the use of global space-based systems for monitoring the environment, climate and security. The full roll-out of the ESPE program requires development of a portfolio of student projects preferably in collaboration with industry and other institutions. The institute will have a continued focus on the development of the pedagogic skills of all teachers as well. The institute will furthermore enhance recruitment efforts towards Danish as well as international students, especially in relation to the ESPE education.

DTU Space will fully implement the ESPE education and fill several new faculty positions.

Scientific advice. The institute will continue and develop its high international level of public sector consultancy to be the natural and preferred supplier of services in the fields of Earth observation, geodesy and mapping of interest to authorities in Denmark. There will be special focus on business development within research based public sector consultancy regarding the Arctic. By leading the cross disciplinary DTU center, Polar DTU, the goal is to make DTU a driver in establishing a sustainable development of the Arctic and meeting the increasing commercial and political interests in this area. The institute strongly supports the national authorities regarding the Danish membership of ESA and it is a key adviser to the Danish Defense, especially regarding scaleable space infra-structures in the Arctic.

DTU Space will develop and demonstrate the scaleable space infra-structure concept, especially regarding the Arctic.

Innovation. DTU Space will strengthen the Danish company yields from the Danish membership of the European Space Agency in cooperation with research institutions, authorities and industry. The institute will implement a number of research and development projects in cooperation with Danish and foreign companies, which will provide a significant transfer of knowledge and technology. DTU Space pays special attention to identifying proprietary technologies, research and knowledge resources with the potential to be transformed into entrepreneurship in the form of start-ups or new business activities within existing businesses.

DTU Space will focus on satellite-based applications from the Galileo and Copernicus programs and on commercial realizations of drone infra-structures through the DTU Space DroneCenter.

2. Education and teaching

Education and teaching (BEng, BSc and MSc programs). Educational activities are based on high international level research at the institute. DTU Space contributes significantly to the BSc and MSc programs in Earth and Space Physics and Engineering (ESPE) (Geofysik og Rumteknologi) including the two directors of studies. Furthermore, DTU Space contributes to the Electrical Engineering (EE) BEng, BSc and MSc programs, to the Mathematical Modelling and Computing (MMC) MSc program, to the Environmental Engineering MSc program, and to the BEng programs in Arctic Technology (AT) and Civil Engineering (CE).

Earth and Space Physics and Engineering. The ESPE programs will in the coming years undergo consolidation of courses and continued development with special focus on creating a portfolio of student projects, including bachelor and master thesis projects. The directors plan to visit relevant universities to be inspired, to form networks, and possibly to enter into collaboration agreements. The MSc director will appoint mentors for the Honors program. The DTU decision that the BSc students should be bilingual will be implemented by ensuring, that at least some of the ESPE BSc courses are taught in English, and that the students get to practice and have their abilities tested to present both orally and written in both Danish and English.

Other study programs. DTU Space is responsible for the study line Space Technology in the EE MSc program, a major part of the electronics courses in the EE BEng program, the focus area on Geomatics in the MMC MSc program, and the specialization on Geoinformatics in the CE BEng program. DTU Space contributes to the Arctic Semester, which will be part of the Cold Climate Engineering (CCE) Northic master program, with focus on remote sensing, geoinformatic and geodesy in the Arctic. DTU Space will continue to develop these contributions, and hence contribute to the fulfillment of Vision125.



Pedagogic development and didactic organization of study programs and teaching. DTU Space gives high priority to the pedagogic development of the courses. The Study Committee (SC) will streamline the processing of evaluations by introducing a preprocessing of the results for setting up priorities for which courses are evaluated. In addition to this processing, the SC performs a detailed evaluation of the course content and curriculum with an approximate 5 years cycle.

Together with the reference group and the DTU Learning Lab, the directors will evaluate the ESPE programs' diversity in the didactic organization and progression of the programs. Many courses at DTU Space involve assignments, project-based learning and learning through active experimentation. Especially, the project-based learning is key to many teaching activities, and the focus will be to use tools like e.g. peer review, video presentations for status reports, and Google Drive, both in order to improve the learning process for the students, but also to make more efficient use of the teachers time due to the increasing number of students. The SC will use a group of teachers interested in e-learning as a reference group for implementation of e-learning tools. The goal is that one new course each year will include e-learning tools.

Development of teacher's pedagogical competences. The teachers responsible for a course must have pedagogic skills corresponding to the UDTU course, or they must be enrolled in that course. The UDTU course will be offered to all newly employed researchers and assistant professors. Meetings will be arranged for the teachers to ensure a common understanding of pedagogic content and quality and act as a forum for exchange of good practices.

Student completion rates, readiness for the labor market, and student projects. The directors of studies for the ESPE programs will continue monitoring the student completion rates and launch appropriate activities to ensure a swift completion of their studies. DTU Space arranges each half year a project day where students can discuss student projects with supervisors, to streamline starting e.g. the master thesis project. The DTU Space network of possible employers will be utilized to define student projects carried out in collaboration with companies. DTU Space will seek to incorporate sustainability, climate technology and environmental aspects in courses and projects to enhance the contribution to DTU's Green Challenge initiative. DTU Space will re-define the continuation of the DTUsat activity with stronger ties to courses and student projects by using drones and hot air balloons.



Recruitment and internationalization. DTU Space contributes significantly to DTU's recruitment activities, e.g. "Åbent Hus", MSc information day, SRPs, visits by high schools, participation in DTU Explore, and web pages. DTU Space expects to increase the activities in high school students projects (SRPs) to recruit students especially for the ESPE BSc program. The directors of studies for the ESPE programs seek to increase the exchange of students with international universities by customized study plans and establishing networks. Special efforts will be made to attract international students to the ESPE MSc program by constantly improving the web pages, e.g. with testimonials from international students.

Study environment. An attractive, inspiring, and creative study environment for the students is a must. DTU Space has already allocated some workspace for student projects. When the ESPE programs are fully established more than 250 students are expected simultaneously. Hence, there is a need for generally improved student facilities and more workspace for projects.

Laboratory and research based teaching. The institute is operating a number of unique research facilities originating from the high activity level in design, implementation, launch, and operations of space flight instrumentation. At the widest possible level, these facilities are used in the education program, both in regular classes and in projects, to offer cutting edge education and foster innovative thinking. DTU Space will exploit these unique facilities in the promotion of both the educational programs but also natural sciences and technology in general.

2.1 PhD programme

The goal of the institute's PhD program is to graduate excellent candidates, who will increase the knowledge base and, hence, set their mark on the development of society. The candidates should thus be able to excel either in the public sector or in private companies. DTU Space aims at increasing the PhD population to ~30 PhD students due to the increasing number of graduates from the ESPE MSc program and in order to ensure a lively PhD environment of sufficient size. The PhD students meet monthly for an informal lunch, quarterly for formalized information and networking meetings, and annually for a PhD day, where the PhD students present their projects with ample time for informal discussions and feedback.

Innovation is stimulated by encouraging PhD students to stay 6 months abroad, focusing on establishing PhD projects with industry, and by involving PhD students in international space projects. The institute's large instrumentation and space mission portfolio enables students to work at the highest possible level of relevance to maximize innovation and collaboration with industry. First hand involvement in space missions and the derived data and services establishes PhD graduates in a strong position for a successful on-wards career.

The institute strives to offer 1-2 dedicated courses or research schools per year, and supplement with (joint) courses from other institutes or universities to offer a healthy mix of specialized and broad PhD courses. DTU Space will actively ensure education and skills development for new supervisors, e.g. by participating in the DTU supervisor courses.

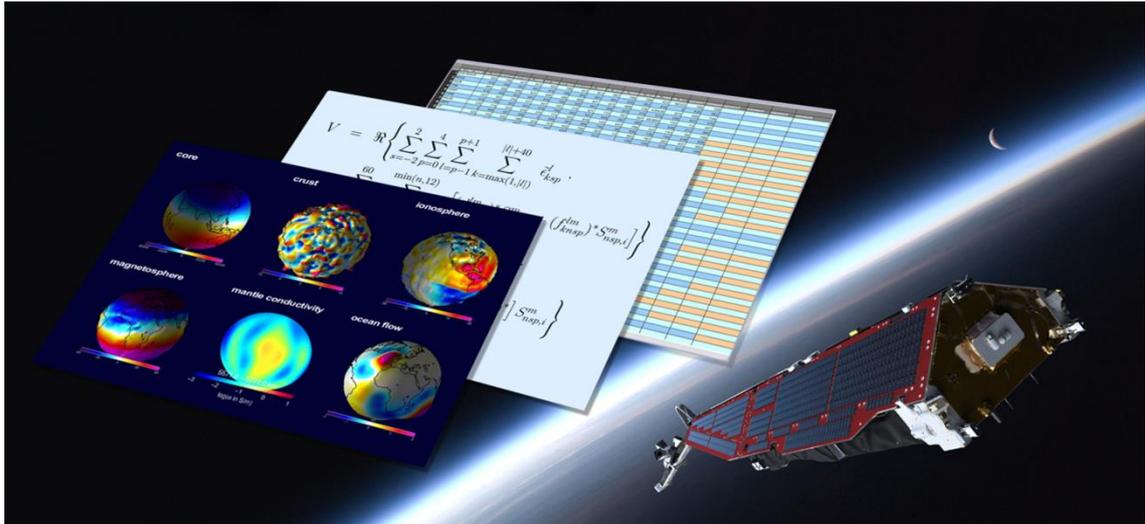
2.2 Continuing education

DTU Space collaborates with the Royal Danish Defense College in order to facilitate possible involvement in the new educational program for officers. Furthermore, activities on continued education for officers and other military personnel will be discussed with the Danish Defense.

3. Research

Research is the "engine" of the DTU Space activities, enabling high quality, and offering new challenges for, education, innovation, and research-based consultancy. The goals for research at DTU Space are that (1) DTU Space is world leading in a handful of space areas, (2) DTU Space's research base is broad enough to support our education, public sector consultancy and innovation, and (3) DTU Space research focuses on the combination of engineering, technology and science.

DTU Space research activities fall within three broad areas (with considerable overlap) defining the institute: Space instrumentation and technology systems, Earth Science, and Space Science. In order to have a prominent international profile DTU Space must be a world leader in at least a handful of areas, so-called "lighthouses", demonstrating the excellence of the institute. Research "lighthouses" are areas where DTU Space already has a unique position, i.e. amongst the few world leaders in the field of focus, or DTU Space has the potential to reach that level within a few years. The lighthouses are space driven and combine technology and natural science, and ideally they have strong ties to education, innovation and research-based consultancy and they encompass well the full lifecycle of space activities. Lighthouses are further characterized by a size making them self-sustaining. The institute's present 6 research lighthouses are listed in the table below. An organic growth within all main areas is foreseen, but continued adaptation will be effectuated when necessary.



The Swarm DISC consortium, managed by DTU Space, is responsible for processing of the Swarm satellite data. (Credit: ESA/ATG medialab).

Funding strategy. The key external sources of funding continue to be ESA, EU, NASA, space companies, international space agencies and national research councils and foundations. Motivated by the 2 % cuts in basis funding and the increasing competition for external funds, the focus will be on increasing the success rate of applications in close collaboration with DTU's strengthened project office. The instruments will be, e.g. early identifying the most promising projects, set up the best proposal teams and provide internal feedback on draft applications. After a proposal round, the results will be evaluated in order to implement actions, which could increase the success rate. In particular, EU Horizon2020 actions will be a natural target for the institute's funding efforts over the coming years, e.g. the COPERNICUS program, and it is an objective to attract a major ERC grant or a center of excellence.

| Research lighthouse | Activities 2017-2020 |
|---|--|
| Changes of the cryosphere | Develop improved methods for measuring changes in the cryosphere by a host of ESA and NASA satellites, such as GRACE, CryoSat, and the Sentinel satellites, supplemented by airborne instrumentation and campaigns. Particular focus on monitoring of changes, for Greenland and Antarctica, as well as Arctic sea ice, particularly as part of the ESA Climate Change Initiative and the upcoming EU Copernicus Climate Change Service. In situ research includes the use and development of the GPS station network in Greenland (GNET) for monitoring mass loss in the Greenland ice sheet. |
| Sea level and gravity | Develop methods of measurement, processing and interpretation of Earth observation data for gravity mapping, monitoring of ocean, river and lake levels to develop new space-based services. Gravity field data from satellites are used together with airborne and in-situ data for modeling the Earth's gravity field to fine details, both for use in geodesy (geoid determination) and geophysics (Earth structure). |
| Geomagnetism – exploring Earth's interior and its environment | Scientific exploitation of data from the 3-satellite constellation mission Swarm. Strengthen DTU Space's international role by establishing the ESA-funded "Swarm DISC" consortium (12+ organisations from Europe, Canada and the US coordinated by DTU Space) that is responsible for the data processing, scientific exploitation, as well as of the communication and public outreach of the Swarm mission. Continued development of world leading geomagnetic reference models, with greater integration of source physics. |
| Scientific instrumentation for high energy astrophysics satellite missions | Collaborations with institutions in both Europe and USA for preparation of focusing optics in hard X-rays for several planned missions and optics for the ESA mission ATHENA. Develop X-ray detectors with unprecedented position and energy resolution in the hard X-ray/Gamma-ray range. |
| High performance autonomous space instrumentation systems | Development and implementation of large-scale aperture systems – single as well as multiple spacecraft solutions. Sub-arcsecond technologies: Enabling the next generation satellite platforms, by improving the benefit to cost ratio by an order of magnitude. Data fusion methods: Autonomy and robustness of operations may benefit substantially from correctly fused data from multiple sensor systems. |
| Radar- and radiometer systems and measurements of the Earth's surface | Microwave Earth observation with focus on three equally important research topics: microwave radiometer systems, radar systems, and methods of processing and interpreting data from such systems from airplanes as well as from satellites for several applications. |

Besides the research lighthouses, there will also be focus on the following key research areas:

Large-scale Structure of the Universe based on observations from PLANCK and planned science with the James Webb Space Telescope and Euclid.

Research on compact objects in order to understand the detailed physics of neutron stars, based on INTEGRAL, SWIFT, NuSTAR, and NICER.

DTU Space contributes to several planetary science missions with enabling technology, instruments and scientific research, e.g. NASA's Juno, Clipper, and Mars 2020 and 2022 missions. DTU-Space is also involved in the development of the technology base for several "New Space" programmes.

The space weather activities at DTU Space will support ESA's Space Situational Awareness program (e.g. through provision of geophysical data from DTU Space's network of magnetometers and GPS stations in Greenland).



The Juno mission with DTU Space star trackers is arriving at Jupiter on July 4th 2016 (Credit: NASA).

Investigations of the underlying physical-chemical mechanism behind cosmic rays' influence on climate via cloud formation. The Atmosphere-Space Interactions Monitor experiment will be mounted on the ISS in 2017 in order to reveal high-energy processes associated with thunderstorms.

Development of applications of satellite-based navigation from new technologies and systems, such as the upcoming European GALILEO and its associated services. DTU Space performs cutting edge research in high-precision drone navigation aiming at using drone-swarms in fixed constellations and using of drones in polar environments.

Interdisciplinary collaborations with other DTU institutes. Polar DTU, being the cross disciplinary center for polar activities at DTU, is a center with a broad range of research-based services such as teaching, scientific advice and technology development with a focus on the Arctic and Antarctic and comprises more than a dozen DTU institutes and centers. In cooperation with CREO-DK and "Forum for Arktisk Forskning", special focus is on creating activities within DTU relevant Arctic areas of interest in the EU Horizon 2020 program.

DTU Space is a driver in establishing a strategic cooperation between DTU and the Danish Defense. The institute is a key partner in DTU Smart Avenue and DTU Space continues collaborations with the CERE center and is establishing collaborations with the new Danish Hydrocarbon Research and Technology Centre as well as the with the Water DTU initiative. The Climate-KIC co-location center at DTU offers opportunities for interdisciplinary collaborations and the DTU Space DroneCenter is driving inter-institute projects.

DTU Space will also intensify cooperation with other institutes, especially for polar and marine related activities (e.g., DTU Byg/ARTEK and DTU Aqua/new Polar section), but also on developing new sensor development (e.g. DTU Compute for inertial navigation system processing, e.g. for drones and aircraft). DTU Space collaborates with DTU Physics in various areas, in particular in X-ray optics simulation, where we make use of software developed at DTU Physics to calculate performance of the optics and to compare with our own simulations.

Additive machine processes is a relatively new technology, still in its infancy, that has proven to add value to a range of high value technologies and products. In space flight properties such as increased strength, fatigue resilience and higher isotropy are highly sought properties for the next generation spacecraft. From multiple contacts with other DTU departments, we have found that additive machining is becoming increasingly attractive across a broad range of technologies. DTU Space is therefore initiating the planning of a center of excellence in this field, which may service multiple DTU departments as well as high tech industries. The activity will be centered around a high end additive processing facility, and will encompass both prototype production as well as procedure and process expertise to the participating entities.

4. Scientific advice

Scientific advice is one of DTU Space's research-based core activities. Some focus areas are definition of global geodetic reference systems, advising on the Danish membership of European Space Agency (ESA), cooperation with the Danish Defense, and applications of satellite data in order to create extra value for society. DTU Space performs scientific advice for government ministries, agencies and other public sector administrative bodies such as municipal and regional authorities, and international institutions. DTU Space's goal is to be an internationally leading provider of services to public sector authorities in the fields of space science, geoscience and associated technical sciences.

Public sector consultancy tasks comprise advisory services, monitoring, mapping, project management, research and development. In a range of areas, DTU Space also handles Denmark's monitoring and data collection obligations in relation to international organizations. This applies, for example, in the fields of geodesy, geomagnetism and geodynamics. The Polar areas have a particularly strategic focus for DTU Space and The Arctic Strategy of the Kingdom of Denmark represents a framework for DTU Space Arctic strategic prioritization.

Agency for Data Supply og Efficiency (ADSE). DTU Space has a central role in advising ADSE on geodesy and mapping. DTU Space engages in a 4 year running agreement with ADSE, as a part of the general agreement between the Danish Ministry of Energy, Utilities and Climate and DTU, covering areas such as definition and maintenance of national and international reference systems, including operating observatories in Greenland as a part of the international network of defining stations for GPS, Galileo and Glonass. DTU Space seeks to develop the cooperation

with ADSE further, covering issues such as precise navigation and positioning, coastal zone management and Earth observation in general.



Copernicus Sentinel-1 satellite – has provided key new data on the changes of the Greenland ice sheet as well as sea ice, and is used intensively in the ESA Climate Change Initiative, where DTU-Space plays a major role (Credit: ESA).

The Ministry of Higher Education and Science is managing the Danish membership of the European Space Agency (ESA), which is a key international partner. Denmark's membership of ESA is strongly supported by the institute by advising the Ministry regarding ESA. DTU Space has an obligation to exploit research, innovation and instrumentation tasks within the ESA mandatory scientific program, covering fundamental physics, astrophysics and solar system physics.

Danish Transport Authority. DTU Space DroneCenter is the primary consultant entity to the Danish Transport Authority on technical advice regarding deployment of Unmanned Aerial Systems (UAS or drones) in the Kingdom of Denmark. In close cooperation with the Danish Transport Authority, other public authorities and industry, DTU Space seeks to develop the framework and market for a future use of drones as an integral part of transport infrastructures.

Ministry of Foreign Affairs. DTU Space is a key adviser to the Ministry of Foreign Affairs on law of the sea regarding delimitation issues such as the Continental Shelf Project where the Kingdom of Denmark is seeking expanded sovereignty rights beyond the 200 nautical miles zone in areas around of the Faroe Islands and around Greenland.

Greenland and the Faroe Islands. Leading the interdisciplinary center of polar activities, Polar DTU, the institute has a special focus on servicing public authorities with responsibilities and

activities in the Arctic region. DTU Space advises public authorities in Greenland and The Faroe Islands, especially covering geodesy, Earth observation as well as climate change and adaption due to the potential large impacts on geographical infrastructure, security, and environment.

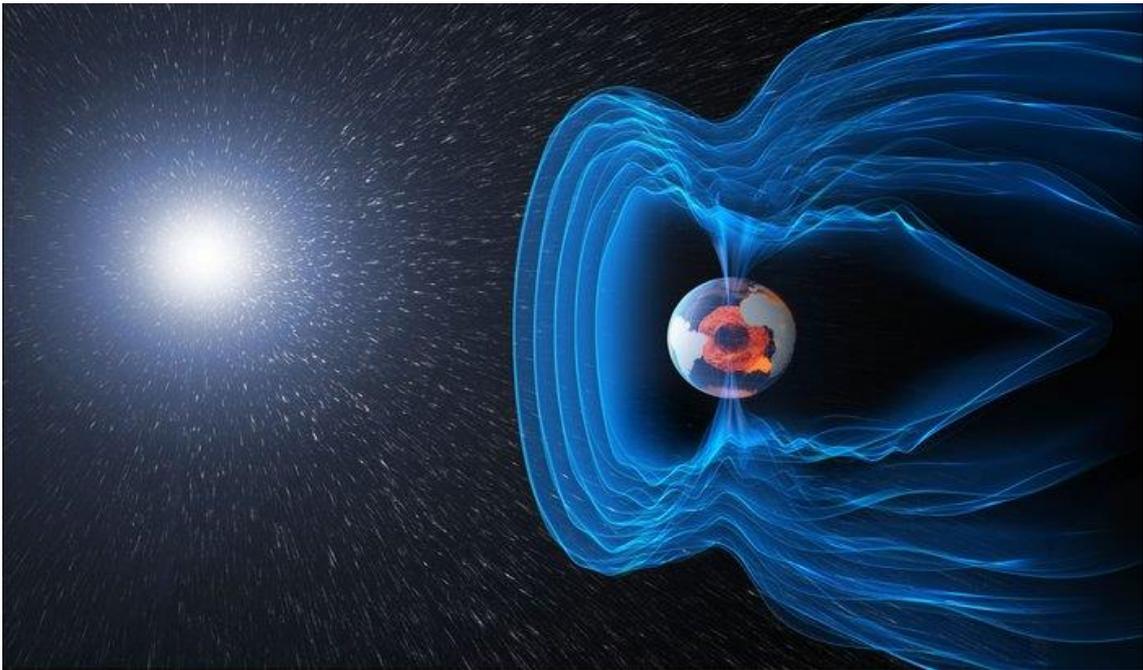
Danish and US Defense. During the last couple of years DTU Space has consolidated its role as a key adviser to the Danish Defense on satellite and UAV infrastructures, especially in the Arctic region, supporting the Danish Defense in defining a new Arctic strategy. It is the ambition of DTU Space to leverage the existing cooperation and strong relationships with Danish Defense units to develop other areas where DTU may provide primary and beneficial consultancy services. The Defense DTU initiative will coordinate and facilitate the development of scientific advice to the Danish defense based on the entire portfolio of technology, know-how and competences at DTU. Two major collaboration projects related to satellites and UAVs are already underway. DTU Space will continue the cooperation with the US defense on delivery of satellite instrumentation, mapping of the global gravity field and running a core GPS station at Thule Airbase.

Civil security. The public sector consultancy of DTU Space also covers elements of civil security like global ocean models and sea level, sea ice and Earth observation from satellites, including radar and lidar. The potential is considerable, covering issues such as geographical infrastructure and climate change monitoring and adaption with special focus on authorities in Greenland and the Faroe Islands as well as, e.g. the Danish Maritime Authority, Danish Coastal Authority and the Danish Defense (Search and Rescue).

International public authorities. DTU Space cooperates with foreign authorities and public organizations via projects on establishment and maintenance of national geodetic reference systems to develop and enhance the use of satellite position and navigations systems. DTU Space has a strategic cooperation with the National Geospatial-Intelligence Agency (NGA) in USA on these issues with special focus on Asian and African countries, and on Antarctica. The goal of the NGA is to map global gravity for orbits and navigation, but also for dual-use purposes such as national geoid determination for modernizing geodetic infrastructure and height determination. DTU Space cooperates with NGA through satellite and airborne measurements of gravity worldwide, with national survey agencies as active research partners in these activities.

5. Innovation

The overarching ambition for innovation activities at DTU Space is to be a driving force for economic value creation in the Danish society, in the form of growth, new knowledge-based enterprises and jobs. Innovation at DTU Space will be integrated into the institute's activities within education, research, and scientific consultancy and the institute is dedicated to an ongoing dialogue with the business community. Innovation activities at DTU Space naturally have a global scope - both providing access to a proprietary portfolio of in-house technology, knowledge and know-how, which can cater to industrial needs, and as a gateway for Danish industry to an international network of high-caliber public research organizations.



Earth's magnetic field can be thought of as a huge bubble, protecting us from cosmic radiation and charged particles that bombard Earth in solar winds. The Swarm satellite constellation mission will help to better understand the complex interaction of the various sources contributing to the geomagnetic field (Credit: ESA/ATG medialab).

Innovation and entrepreneurship. DTU Space will focus on integration of innovation and entrepreneurship in the educational programs. In collaboration with the Confederation of Danish Industry and other Danish universities, DTU Space seeks to establish student projects with companies through matchmaking arrangements, e.g. the Space Day event. DTU Space is one of the driving forces in the establishment of the Smart Avenue Living Lab for Smart City technology, allowing students to test and develop sensors and methods with a large innovation potential.

Commercial satellite-based applications. Leveraging the commercial opportunities within satellite-based applications through innovation and entrepreneurship is a primary area of focus for DTU Space. The establishment of two new EU operational space-based infrastructures within navigation (Galileo) and Earth observation (Copernicus) opens up commercial windows of opportunity both for existing companies in Denmark and for innovative start-ups. As operational satellite systems, Galileo and Copernicus will ensure a security of supply of reliable

navigational and monitoring services. This will enable companies to make existing products and services more efficient and to develop new, innovative products and services. Especially the integration of different satellite-based services - e.g. location-based monitoring services – has significant commercial potential.

Unmanned Aerial Systems. The utilization of Unmanned Aerial Systems (UAS) as platforms for commercial applications, e.g. surveying and mapping, high precision farming, management of water resources and monitoring for security and environment, will soon be a high-growth industry. DTU Space is well-positioned to contribute to the development of the Danish UAS industry within key technology areas due to the heritage from many years of space technology development: Like space instrumentation, payloads onboard smaller UAS are constrained by very limited mass and power budgets. Other relevant areas of UAS expertise at DTU Space are formation flight, high-precision navigation, and data and image processing. In order to create a focal point for the interaction with Danish industry within this area, the institute has launched the DTU Space DroneCenter, which collaborates with several other institutes at DTU.

Innovation for Arctic companies. Through Polar DTU, the institute will continue to work to leverage the collective portfolio of know-how, competences and technologies at DTU and its strategic partners - especially Nordic Five Tech - to create value for companies with commercial activities or commercial interests in the Arctic area, e.g. within the exploitation of on-shore and off-shore raw materials, maritime transportation and fisheries. In collaboration with Maritime DTU, Polar DTU has recently initiated the establishment of a Maritime Arctic Platform which will facilitate research-based innovation and competence development in the maritime industry in Denmark and Greenland with regards to Arctic operations.

Increased collaboration with companies within defense and security. As a key partner in the InnoPro innovation network led by CENSEC - Center for Defense, Space and Security - DTU Space will increase the collaboration with companies within the defense and security sectors. One of the areas of collaboration will be best practice dissemination with regards to quality and product assurance, where defense, security and space share the challenges of meeting superior standards.

6. Partnerships

DTU Space has a well-developed and dynamic, global network of partners. Partnerships are established with leading international parties who can contribute to realizing the institute's strategic goal as a preferred international partner. In total, the institute has +100 partners globally. The four partners at the end of the following list are probably the most valuable strategic partners also for other DTU institutes.

European Space Agency (ESA) is conducting most European scientific space missions, as well as Earth observation missions, and is as such DTU Space's "home market". DTU Space is collaborating with ESA at all levels from mission design and science studies over core technology and support instrumentation to mission operations and science products.

National Aeronautic and Space Administration (NASA). The largest space organization in the world, NASA, is a key partner. NASA's fast mission lifecycle makes it an indispensable

partner in order to maintain our international leading position. DTU Space works with most NASA centers on specific missions.

US universities. The leadership in space research is shared between several universities in USA. DTU Space has collaborations with all universities leading a research field of interest to DTU Space. The most important US universities are Caltech, MIT and U. of Texas.

Airbus ADS is Europe's largest system integrator with companies in most European countries. DTU Space collaborates with ADS entities in Germany, France, Spain and Portugal, on technology development and mission designs. This work will be intensified in the coming years.

National Geospatial-Intelligence Agency (USA) is DTU Space's largest foreign public authority partner, primarily regarding gravity surveys and gravity field modelling.

GeoForschungsZentrum, Potsdam (GFZ). DTU Space cooperates with GFZ on e.g. the Swarm and CHAMP satellite missions, via the Swarm DISC consortium, and through several space weather activities.

Technical University of Munich is a key European partner in gravity field modeling using the GRACE and GOCE satellite missions for determination of ocean currents.

Agency for Data Supply and Efficiency is in charge of the majority of DTU Space's contracted consultancy with the Danish authorities and constitutes the major partner in geoscience.

Danish Meteorological Institute (DMI). DTU Space has a close and long-term collaboration with DMI on, e.g. development of methods for sea ice and glacier monitoring.

Terma A/S (DK). DTU Space has a long-standing and evolving collaboration with Terma, the largest space company in Denmark; currently on the ASIM instrument and on radar applications.

University of Copenhagen (KU). DTU Space is collaborating with KU on research and education within geoscience, climate change, and astrophysics.

7. Human resources

7.1 Organisation

DTU Space has a flat organization, which is dynamically adapted to changing challenges and opportunities. Currently there are 6 academically focused divisions plus the division of Innovation and Research-based Consultancy. DTU Space is lead by institute director Kristian Pedersen, who in addition to the overall responsibility of the institute, is directly responsible for research, PhDs, HR, and communication. The Executive Board consists of Kristian Pedersen, Niels Andersen, who is in charge of innovation and research-based consultancy, and Henning Skriver, who is in charge of education and the institute economy.

Matters of interest to DTU Space are discussed in the institute's Management Team, chaired by the institute director, and consisting of the heads of the seven divisions. Within core areas, strategic committees have been established, which discuss activities and strategy within their respective topics and provide advice to the Management Team. The committees have at least one representative from each division and take up issues on their own initiative or deal with specific tasks commissioned by the Management Team. The institute's operations are carried

out by the Management Office (referring to the institute director) and Electrical and Mechanical Services (referring to Niels Andersen).

7.2 Leader and leadership development

Strategic leadership is a focal point of DTU Space. Division heads are thus actively participating in the strategic leadership of the institute through the Management Team, as well as leading their own division. DTU Space continually ensures that managers develop their leadership and management skills, typically via DTU's management training program. The institute aims at taking all managers through DTU's management training program and experienced managers are encouraged to participate in more specialized training. It is an important goal to continuously identify and train the next generation of division heads, and consequently, deputy division heads have been appointed. A key outset for the annual performance appraisal interview (LUS) is each manager's performance with regard to the development objectives of the institute's Action Plan. In the LUS it is thus discussed how the individual manager can be supported in order to achieve these objectives and where there might be an unrealized potential.

Top class research is often conceived and carried out by strongly driven individuals. DTU Space embraces this by making room for "stars", as well as by actively nurturing and recruiting upcoming "stars". The institute is accommodating and flexible in order to ensure that unconventional, but promising, ideas are tested and supported.

DTU Space continuously focuses on job satisfaction, in particular through the regular job satisfaction surveys, where critical points are identified and action plans for addressing these are laid out and followed up at institute level, as well as at division level. In particular, there will be greater focus on stress, on increasing recognition at all levels, and on improved communications at all levels.

7.3 Employee development

DTU Space strives to obtain a transparent, simple and effective management where the individual's duties and responsibilities are clear to the individual employee, the colleagues, and the manager. There is a high degree of delegation and employees are supported to be self-managing, for example through coaching and the annual performance appraisal interview (MUS) discussion. A key starting point for the annual MUS is the employee's performance in relation to the development objectives of the division and the institute. The manager should clarify how the employee contributes to the institute's development and, together with the employee, align expectations for the development of the employee. Thus during the MUS it is discussed how the employee can be encouraged to achieve these objectives and where there might be an unrealized potential. For any employee, the goal is that the mix of assigned tasks should be perceived as interesting, challenging, and rewarding.

7.4 Attracting and recruiting

Due to the institute's history of fusion and growth, there is a heritage of different cultures at the institute. Each employee's "basis group" has its own culture and values and the best values from these cultures are nurtured and fused into a common institute spirit.

DTU Space strives to foster and develop a stimulating work environment with skilled and helpful colleagues, where employee diversity and mutual respect are catalysts for creativity and team effectiveness, e.g. by sharing knowledge and best practices. Employees should be active in the development of a stimulating work environment, conducive to their best performance, and in accordance with the institute's values and goals. The most important values of DTU Space are:

- (1) *That "rocket science feeling"*: The drive to do the best, pushing the boundaries of knowledge
- (2) *Credibility*: When collaborating with colleagues and when dealing with external partners, it is of prime importance to be credible and capable, in order to build confidence and lasting relations
- (3) *Recognition*: Employees should be recognized for their achievements, be it individually, as a team or division, or as an entire institute.

7.5 Attracting and recruiting

Recruiting top class employees at all levels is crucial for maintaining the institute's international leadership. Hence, the institute continuously assesses the need to recruit new, excellent staff. This is achieved by nurturing internal talent as well as by attracting the best international candidates. In both cases, some diversity is desirable in order to have a dynamic and fruitful mix of staff at the institute. DTU Space's communications efforts are focused on sharpening the profile and visibility of the institute in order to highlight the institute as a leading international space institution, and thus an attractive workplace for all types of employees. In order to facilitate the inclusion of new staff at the institute (especially new international staff) DTU Space will in collaboration with DTU HR establish and implement an introduction program for new employees in order for them to quickly integrate into the institute - and the rest of DTU.

7.6 HR key figures

The general trend is an expected slight increase in activities within all main areas and hence an increasing number of staff. However, the completion of ASIM flight hardware, projected for the end of 2015, will result in a normalization of the number of technical staff to a lower level. On the other hand, new teaching positions for fully rolling out the ESPE education will be filled over the next year and several professorships will be filled in order to consolidate and develop strategic areas of the institute.

8. Material resources

DTU Space is presently in the process of acquisition and installation of a new high accuracy lathe, configured to achieve micrometer level global accuracies. The equipment is optimized to achieve the required accuracies for the novel milli-arcsecond attitude reference system presently under development at the institute.

8.1 IT

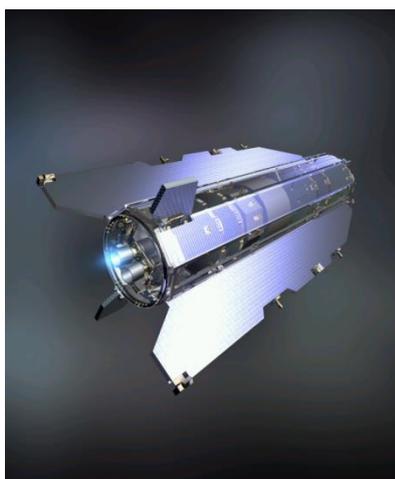
DTU Space continues to work with the IT security group based in AIT to ensure that the ISO system is correctly implemented. This will be completely rolled out and maintained in the UMV period.

DTU Space continues to operate and maintain a high performance mini computer cluster to allow the institute to comply with the requirements to do the scientific processing of data from the SWARM mission and from late 2017 also the ASIM mission. The two data centers will also store invaluable scientific data, where the focus regarding IT security will be to ensure the data's integrity and availability.

Space continues to operate an institute wide Unix server environment which, in close connection with our mini HPC, provides a homogeneous computing environment used for both research and teaching. DTU Space also plans to upgrade and update the current data- and disk servers and parts of the printer park.

8.2 Laboratory equipment/scientific infrastructure

Facilities in space and on the ground. Instruments and s/w operating in space and from aircraft are the strongest non-human assets of the institute. Through its engagement in technological research satellites, DTU Space also has privileged access to guaranteed observation time, controlling and managing mission profiling. This access provides in-situ "space laboratories" where the institute's researchers can conduct investigations and verification of new ideas, concepts or measurement principles. This significant investment forms a crucial basis for the institute's cutting-edge technology research.



ESA gravity mission GOCE (Credit: ESA). DTU space led airborne PolarGap team at South Pole.

DTU Space has a significant expertise and know-how in airborne/suborbital flight operations. Key elements include an expensive suite of own-developed or own-implemented sensors (radars, lidars, imagers, GPS, inertial navigation systems, power systems, etc.) and know-how for cold-region operations.

Qua Denmark's membership of international organizations, DTU Space employees furthermore have access to major international observatories on Earth and in space, accelerators and other research facilities. Continued access to these facilities is absolutely essential to perform state-of-the-art research and technology development and construction.

To meet the market demand, a substantial enhancement of the laboratory capability and capacity will continue in the following years: (1) Long baseline robotic rail system, (2) Large

focal length optical test stand, and (3) Ultra-stable optical attitude methodology lab. DTU Space will also upgrade its airborne remote sensing instrument suite (P-band radar, inertial navigation and gravity sensors), primarily for satellite validation and augmentation campaigns.

DTU operates permanent GPS and geomagnetic stations/laboratories in Greenland and in Denmark, as part of the global network for establishing international standards. Moreover, they form the basis for research-based consultancy for the authorities of Greenland and the Agency for Data Supply og Efficiency as well as specific deliveries to industry. DTU Space also operates tide gauges to support early warning services, e.g. for tsunamis. DTU Space furthermore sublet specially built non-magnetic pavilions in Brorfelde by Holbæk for geomagnetic observations and calibration of magnetic instruments.

8.3 Premises

DTU Space is located at DTU Lyngby Campus making DTU very visible as an international technical university with focus on space. Buildings 327, 328, and part of buildings 348 and 371, host the institute's offices, laboratories, machine shop, clean-room facilities, EMC tests as well as X-ray and radiation test facilities. DTU Space uses the facilities on Landmålervej with its test track and control points in Dyrehaven, for training in surveying and geoinformatics of civil engineering students at both diploma and master programs.

Developments. With the still increasing number of students in the ESPE program, a focus area over the next years are to improve the facilities to host this student population, i.e. project work space and student meeting rooms. The institute has already allocated rooms for project work, and these rooms needs to be upgraded and probably extended. Also, student meeting and work facilities must be secured for ESPE students in e.g. building 325. The lecture rooms and laboratories need to be upgraded with up-to-date e-learning technologies.

Building 348 needs general maintenance due to many years' usage; in particular, the corridors need glass doors at ends of corridors and selected north-side rooms.



Denmark seen from the International Space Station (Credit: ESA/Andreas Mogensen).

9. Communication

DTU Space activities are conducted with the support of, and in close interaction with, society, i.e. industry, authorities and other institutions, and thus the communication efforts support and promote these activities. DTU Space is implementing a communication strategy that will focus on strategic communication by identifying key target groups and stakeholders, and by prioritizing objectives, activities and channels for communication efforts. The communication is based on availability, reliability, professionalism, functionality, and independence.

DTU Space will in the coming period focus on recruitment of students from both home and abroad to the ESPE education's bachelor and masters program. In this respect the institute will contribute to DTU's communications efforts, e.g. "DTU Avisen", "Dynamo", dtu.dk, "DTU Open House", "Forskningens Døgn", and "Kulturmatten". The institute will also continue to receive school visits and to give lecturers at colleges as well as promote the institute's activities through the media via, e.g. interviews, articles and popular talks in various fora.

Alumni activities are gearing up due to the increasing number of ESPE graduates. Consequently, DTU Space will draw on DTU's other alumni networks with respect to the wider dissemination activities and with a focus on collaboration across DTU. Furthermore, staff, students, and graduates will be used as ambassadors for DTU and the institute when they participate in meetings, conferences and visits abroad.

10. Process and employee involvement

DTU Space's strategy and objectives (including this report) are outlined in close cooperation between the institute director, the institute Executive Board and the institute Management Team. Discussions about strategy and objectives are anchored in the divisions of the institute, both through the division heads and through the strategic committees. Strategy and objectives are addressed at the divisions' regular meetings so that all employees have the opportunity to express views and suggestions to be taken up by the strategic committees and by the Management Team.

In addition to the formal lines of communication the division heads and the institute director practices an "open door policy", meaning that all employees are encouraged to come by for discussions and expression of opinions.

The study committee, including both representatives for teachers and students, as well as the directors of studies for the B.Sc. and M.Sc. programs of Earth and Space Physics and Engineering and the secretary of studies, has either contributed directly to section 2.1 on Education and teaching or they have had the possibility to comment on the content. The institute's contribution to the other educational programs mentioned in Chapter 2 is coordinated through a continued dialog with the relevant directors of studies. In addition, the relevant directors of studies have been asked directly for input.