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Bavarian Ministry of Economic Affairs, Energy and Technology

Editorial

Aerospace – modern and future-oriented mobility

Questions about mobility, especially in the area of aviation, as well as the usability of suitable energy sources are huge challenges seeking appropriate answers.
The Bavarian aerospace industry is set up for this and offers interesting prospects to small and medium-sized companies as well as startups.

Radar eyes capture the earth and provide new insights for environmental protection and an outlook on future developments.

The Galileo program provides navigation services and influences the infrastructure for transport concepts of the future, such as autonomous driving or flying.

The contributions in this issue show the way towards a better quality of life and an understanding of the technologies of the future:

- What will aviation look like in 2050?
- What new technologies and business models enable more efficient and sustainable aviation?
- How can an objective, continuous and areal database be achieved in order to capture global changes?

The course has been set for a positive and successful development in the aerospace industry. Bavaria excels through its diversity and quality in research, development and application.

Walter Fürst
Managing Director

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Unmanned, Electrical and Urban – The best is yet to come

Florian Holzapfel

I can very well remember buying a modem as a freshman at university – a really fast one – it allowed me to transfer data to university at 14.400 baud from a command line interface. At that time, established industrial leaders and experts, just like renowned university professors have torn the naïve visions of IT prophets like Bill Gates apart. – Soon everybody will be online? – Music over the internet? – Online shopping? – Nonsense. Mobile phones – who needs that? Online with the mobile device – why? Why a smartphone, my Nokia is enough!

And then Elon Musk (whose cars still sell better than many want to admit) announces to build private space transportation systems – of course not to be taken serious. And so the predicted first three failures on Falcon 1 launches have confirmed the experts. The world was in order – aerospace is something for "professionals".

2018 launches speak another language – the Falcon 9 by SpaceX (the rocket landing on it's tail which based on expert judgement will never work) is leading by a large margin over the launcher ranking second in the list of "established" space nations (of course the number of successful Long March launches in China is far ahead – even ahead of SpaceX).

But still, in the heads of many (especially of aerospace "professionals"), the world is still as it has always been: Aerospace is expensive and complex, the leading innovation hub is the Silicon Valley so we need to pump our money there and something great will result and if we just had as much public money as the Americans, we could do everything much better.

If you dump all your own inventions in Western direction for low money, it's counted as a triumphant success. Cooperations in Eastern direction however are immediately seen in the light of know how theft where we have to protect ourselves – this is a very common view of the world.

By the way – concerning view of the world: looking at the actual numbers of the international monetary fund on ranking nations by purchase power parity (PPP) based gross domestic product, the view of the world of many gets some cracks. India, Russia, Indonesia, Brasil – they are all ahead of our "G7" partners UK and France… of course you may wonder if PPP makes sense at all for ranking – however, still I am pretty sure that most people are not aware of this ranking. When it comes to advances in technology, China has a working Global Navigation Satellite System, large internet corporations like Ali Baba, Tencent or Baidu and they are not only world market leaders when it comes to consumer drones, but also in other domains like mobile communication they made it to the top. And quite some European companies that are now in Chinese hand are doing better than others sold to corporations or investment trusts from other countries.

Do I want to talk everything bad back at home? – Not at all! Just over the last couple of years, small and medium sized companies and startups in Bavaria have attracted more than 250 Million US Dollars of private funding from abroad. While German corporations

pump money to the Silicon Valley, young Bavarian companies could acquire money from there – and especially in Asia, the technological potential, the excitement and the bright perspectives of many startups and small and medium sized jewels in Bavaria are highly appreciated and supported.

For many people here, unfortunately the potential only becomes visible after foreign investors have given our startups the opportunity to turn their ideas into prototypes and demonstrate them. Very often, here the potential is not appreciated at all – Who needs that? – Do we need that? – We have been living without that in the past! – Nobody wants that!

And immediately the experts are back on stage – studies, panels and discussions analyze if things can work, if they do make sense and if they are beneficial for us – everything is complex, multidimensional, full of facets…

No – things are quite simple. – There is many people on this planet who with all justification believe in the opportunities of new technologies – unmanned aviation, electric aviation, urban aerial mobility - and they are willing to invest billions – today. Of course we now could question those people – but most of them have earnt the money they are using to invest by themselves – so it seems that they might not be that dumb…

Bavaria and Southern Germany are at the spearhead of those who can excel in those areas – Lilium, Volocopter, AutoFlightX, Ascending Technologies (now Intel), Quantum Systems, EMT all as OEMs or Autel Robotics and Phoenix Wings as R&D sites of OEMs from abroad – all that could now be continued over pages on subsystem and component level. And also established aircraft manufacturers like Grob Aircraft are globally successful, if they are allowed to deliver. All of that goes far beyond manufacturers – operations, training, maintenance, documentation – these are all areas in which small and medium sized companies from Bavaria write success stories.

Many call the trilogy comprising of electric aviation, unmanned aviation and urban aerial mobility as the third revolution in aerospace, following the first powered flight and the jet age. Especially for unmanned aviation, unanticipated chances and economic potentials are existing – right now.

The great hope and perspective that in this new domain, start-ups and SMEs are back as players on the OEM level – as leaders in the first row as current examples prove.

This creates hundreds of new High-Tech jobs – exciting positions oriented towards the future – also in domains that have become vicitms of internationalization in the classical German aerospace system. After a long phase of overconsolidation this is a revitalization and enrichment of the aerospace landscape. It is good and justified to have a large diversity of companies in our area. And thanks to a global market, they do have a place – diversity and competition warrant agility and lead the way into the future.

What can we do, to really support the start-ups and other jewels form the SME landscape and help to give them the momentum to become the shining winners of this third revolution in aerospace?

There is one thing they don‘t need – unsolicited expert advice.

To be internationally competitive and sell on the global scale, it is important that they can test and demonstrate their products at home. Just outside the company building.

Compared to the remainder of Germany, both politics and people in Bavaria are rather innovation friendly and do appreciate SMEs. But especially in aerospace it is important, to acknowledge the role of start-ups and SMEs particularly in these new domains of aerospace and support them with specific measures:

- Immediate availability of clear, internationally competitive, reliable and binding rules for the operation of new aerial systems in our “home“ airspace.

- Immediate availability of suitable test areas with transparent rules of operation, common infrastructure and open access which is not controlled by economic interests – the area Oberpfaffenhofen – Landsberg – Mindelheim – Kaufbeuren would be an ideal solution for Bavaria.

- Active consideration of synergies with and developments in other domains (digitalization, battery and engine technology, automation) when defining regulations to enable competitiveness by scale effects. – To blindly stick with existing aerospace standards does not constitute a safety case – Regulation must not be abused to influence the market. If regional restrictions are used to locally protect established players from new competitors, the basis for success of new players on the international stage is destroyed.

- Fast modernization of export control regulations to current realities (especially for unmanned flying) and active support of start-ups and SMEs in fast, efficient and transparent handling of export issues. – you can order a 5kg drone from China on ther internet in Germany, but to deliver such a product the other way is a major challenge. – As an example the dual use lists would have to be updated to the state of the art and technology in a pragmatic manner. If certain products are openly available in a foreign country from local production, it makes sense that such products can also be exported there.

- Active participation of German Authorities in international bodies defining the regulations for the development, certification, production and operation of the new aerial systems. Also here, an active consideration of the needs and inputs of start-ups and SMEs is crucial – they know best what they need.

- Direct dialog of authorities and politics with start-ups and SMEs –new and smaller market participants must have an independent voice – third parties may not be allowed to claim to represent them without their consent and authorization.

- Active publicity to not only highlight the chances of the new technologies but also to allow people to avoid irrational fears and prejudice by active individual contact and experience with the new technologies.

- Active support for international market access

- Support to mitigate export and currency exchange risks

- Fair and immediate consideration of the new companies as stand-alone providers in public acquisition programs by governmental bodies (without intermediaries)

- Fair treatment of foreign investors for mergers and acquisitions – assessment based on specific perspectives and not just generalized by country of origin

The same holds fort he successful contribution of Bavarian Start-ups and SMEs to the exciting new aircraft programs currently taking shape around the world! – Also those pose a tremendous chance particularly for SMEs and the Bavarian competencies are highly appreciated and welcome! Many people would prefer the past times where one publicly funded development program chased the other one and they see us already over the peak of the development of aerospace in Germany –

However: the best is yet to come!

The global marketplace of today allows to freely present own ideas and chances are better than ever to find investors abroad which enables inventors and entrepreneurs to follow their dreams and visions and make them come true. If we can secure the right conditions in Bavaria the entrepreneurs and inventors of tomorrow can be successful from home and do not have to go somewhere else – and maybe we can even attract innovators from other places.

The bigger the crowd of potential customers and the more global the market, the higher the chance that the best ideas will prevail. Currently, we have many examples in our country proving that we profit from those developments –

The new stars in the sky are from Bavaria!

At home in Bavaria – successful in the world.

Prof. Dr.-Ing.
Florian Holzapfel

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bavAIRia e.V. – the Bavarian AEROSPACE Cluster links members to new trends

Ever since the Bavarian State Government commissioned bavAIRia e.V. with the management of the Bavarian AEROSPACE Cluster in 2006, bavAIRia actively pursues the promotion and support of regionally based companies. The networking/consulting of companies and research institutes, marketing services and continuing education are key pillars of the work of bavAIRia. The international commitment of bavAIRia stimulates and consolidates business relations far beyond the Bavarian borders.

Furthermore, bavAIRia is actively involved in the cooperation with EACP (European Aerospace Cluster Partnership). Interested members can now benefit from the extensive network created by the 43 current cluster members from 18 European countries. The innovative field of Unmanned Aircraft Systems (UAS) is also supported. bavAIRia plays a leading, active role within the largest European association for drones, the UAV DACH. Being a member of the National Drone Advisory Council ensures that the needs of our members are represented at the German federal level. The International Drone Association UVS International maintains contact with European and worldwide representatives of this rapidly growing market. Likewise, we are involved in the complex yet-to-be formulated regulatory systems. The Bavarian e-tonomous Air Mobility (BeAM) Forum, which emerged from the bavAIRia UAS Forum, is actively involved in the further development of its test centre in Oberpfaffenhofen near Munich for BVLOS flights and the establishment of innovative companies in this field.

F.-J. Pschierer (former Bavarian Minister of Economic Affairs) Sept. 2015, H. Steinberg (Member of the Board bavAIRia) E.V. Lauschner (bavAIRia), A. Kohle (CFO Grob Aircraft Systems), F. Seibel (CEO), A. Busse (CFO Quantum Systems) at the opening of the German Test facility for UAS in Mattsies, Bavaria ■

The development of innovative applications and services will also be successfully promoted in the future.

In the field of aviation, the focus of bavAIRia is on the following topics:

- Support the implementation of actions in the Bavarian Aviation Strategy 2030
- Promoting supply chain excellence, i.e. optimization of the process chains
- Supporting members in going international
- Further development of Unmanned Aircraft Systems (UAS).

In addition to aviation, space and space-based applications are also important drivers of growth and innovation for the Bavarian economy. The thematic diversity ranges from earth observation via satellite navigation and communication to space propulsion and technologies. This includes the development of space-based applications in the fields of transport, tourism, agriculture and environment. Furthermore, bavAIRia organizes subject-specific user forums and working groups and also contributes to the networking and linking of the individual fields of activity. bavAIRia has up-to-date and comprehensive knowledge of the current aerospace industry gained through the various tasks it performs. The extensive network of contacts to companies, research institutions, ministries and authorities in Germany and abroad is a key factor in supporting the more than 300 active members. ■

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bavAIRia e.V.

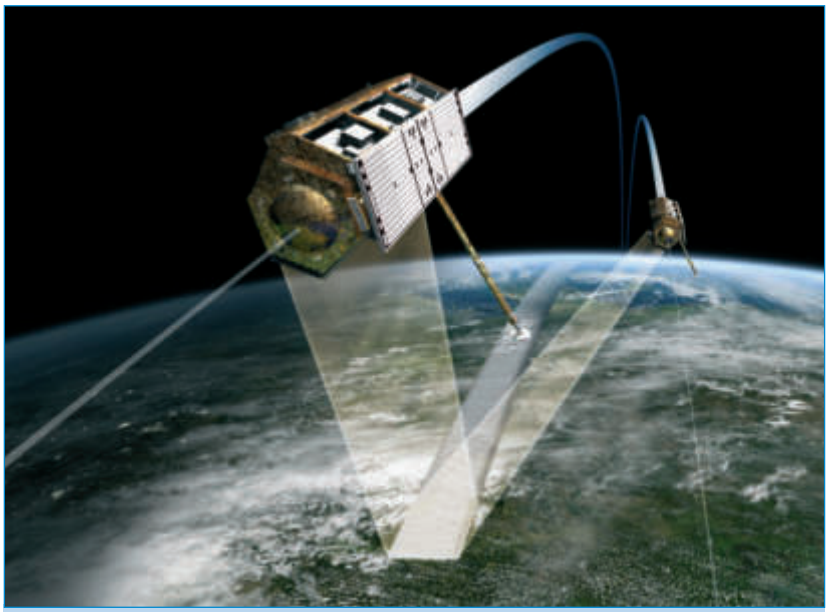
Radar eyes for the Earth and environmental monitoring

With its radar satellites TerraSAR-X and TanDEM-X, Germany has assumed a leadership position in radar technology. The DLR Microwaves and Radar Institute provides an insight into these flagship projects within Germany's space programme and takes a look at future developments.

Following the successful launch of TerraSAR-X from Russia's Baikonur Cosmodrome in Kazakhstan on 15 June 2007, mapping of the Earth in a new quality and resolution has begun. Since then, the German radar satellite has been orbiting the Earth in a polar orbit at an altitude of 514 kilometres, delivering images with a resolution of down to one metre, independent of weather conditions, cloud cover or daylight. Since then, it has acquired many thousands of images of the Earth, the quality of which far surpasses the initial requirements.

TerraSAR-X (hereinafter referred to as TSX) takes a close look at the Earth's landmasses. This includes mapping forest areas, creating and regularly updating land use maps, capturing crop varieties on arable land, and researching and monitoring geologically active areas such as volcanoes and seismic regions. It also regularly monitors glaciers, oceans and coastal areas.

On 21 June 2010, three years after the launch of TerraSAR-X, the almost identical TanDEM-X satellite (hereinafter referred to as TDX) was launched, also from the Russian Baikonur Cosmodrome. This marked the beginning of the TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) mission, with the objective of creating a high-precision, three-dimensional image of the Earth in the form of a Digital Elevation Model (DEM) with uniform quality and an unprecedented level of accuracy. ■



Artist's impression of the TanDEM-X and TerraSAR-X satellites flying in close formation. ■

The TerraSAR-X mission

Although the launch of the second satellite marked the start of a new chapter in radar remote sensing and radar interferometry, the initial objective of the TerraSAR-X mission – to capture conventional synthetic aperture radar (SAR) images – was nonetheless maintained, albeit now using two satellites. Both satellites are equipped with a modern SAR sensor that operates in the X-band at a carrier frequency of 9.65 GHz, which corresponds to a wavelength of approximately three centimetres. The active phased array antenna allows different operating modes, such as stripmap mode (resolution three metres, swath width 30 kilometres), spotlight mode (resolution 1 metre, scene size 5–10 kilometres x 10 kilometres) and a ScanSAR mode (resolution 16 metres, swath width 100 kilometres). In order to meet the growing demand for high-resolution imaging for detailed analysis

TerraSAR-X image of the Suez Canal, Egypt. ■

as well as large-scale coverage, the product portfolio was expanded in 2013 with two new operating modes – a novelty for an ongoing mission with satellites in orbit.

These new operating modes include a further development to the spotlight mode, to the so-called ‚Staring Spotlight' mode, which enables a geometric resolution down to 20 centimetres in the flight direction, with a scene size of approximately 2.5 kilometres by six kilometres. The longer steering of the radar beam during the flyby increases the illumination duration for the target area, so that reflections can be received over a longer period, leading to a significantly improved azimuthal resolution. The other development is the ‚Wide ScanSAR' mode, which allows scenes to be captured with a swath width of up to 270 kilometres with a resolution of 40 metres. The flexible design of the satellites and the ground segment make it possible to demonstrate new techniques and imaging modes. For instance, an improved mode for large-area acquisitions – Terrain Observation by Progressive Scan (TOPS) – was tested in an early phase of the mission. This mode suppresses the wave-like noise distribution, also referred to as the scalloping effect, which is visible in conventional ScanSAR images. The BiDirectional (BiDi) SAR was demonstrated as part of the development of new experimental modes. The term ‚bidirectional' refers to the simultaneous imaging of a scene in two different directions with a single antenna with only one receiving channel. The antenna is controlled in such a way that it generates a radiation pattern with two main lobes, one pointing forwards along the flight direction and one pointing backwards, against the direction of flight. As a result, the target area is imaged twice during the overflight, with a short time delay. During image processing, the signals can be separated and two images produced. In the process, changes in the scene that have occurred in the intervening period become visible and it is also possible to estimate the speed of moving objects, as they are detected in different positions. ■

The TanDEM-X mission

Previously, only coarse, inconsistent or incomplete elevation models based on a variety of different data sources and surveying methods existed for large parts of the Earth. The primary objective of the TanDEM-X mission was to close these gaps and to provide a homogeneous elevation model that will serve as an indispensable foundation for an array of commercial applications and scientific investigations. The primary goal of the TanDEM-X mission was thus to create a digital elevation model of the Earth's entire surface with a consistent level of quality and an unprecedented degree of accuracy. For this purpose, the TerraSAR-X and TanDEM-X satellites were flown in close formation, in order to create a configurable, bistatic SAR interferometer in space.

A digital elevation model represents the digital, numerical storage of the elevation information about the Earth's natural surface. In the case of the TanDEM-X mission, the elevation values were generated in raster format, which involves placing a uniform grid over the terrain, with a height value assigned to each grid point. The global DEM produced by DLR has a grid width of 0.4 arc seconds, or about 12 metres, and according to specifications should have an absolute height error of 10 metres and a relative height error margin of 2 metres (for a slope of less than 20 percent) or 4 metres (for a slope greater than 20 percent).

A large number of technological and technical challenges had to be addressed to meet these requirements. These included the following innovations:

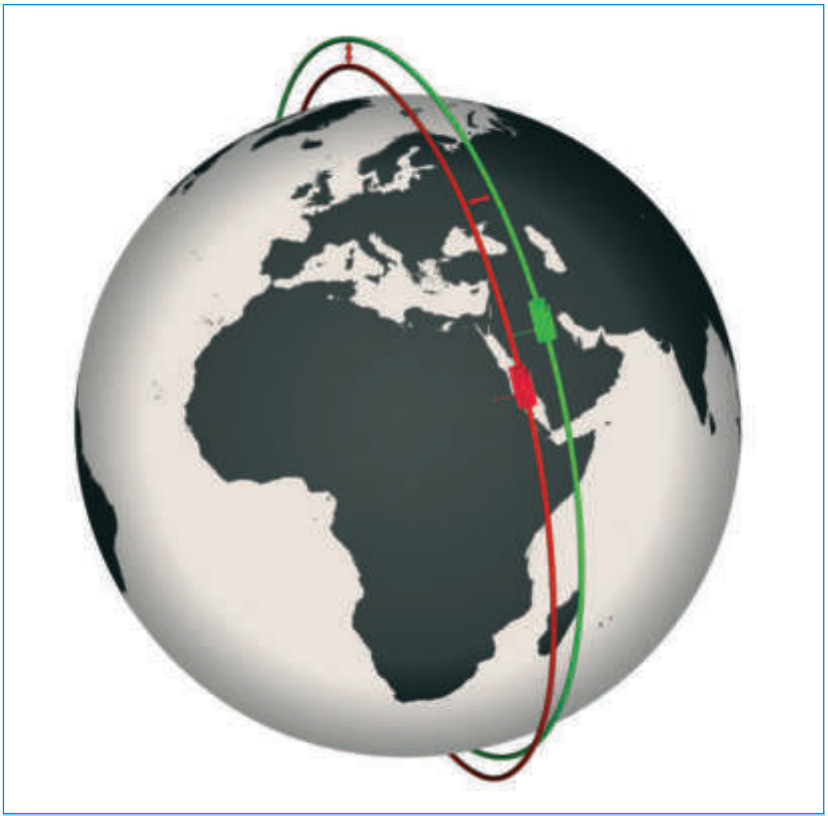


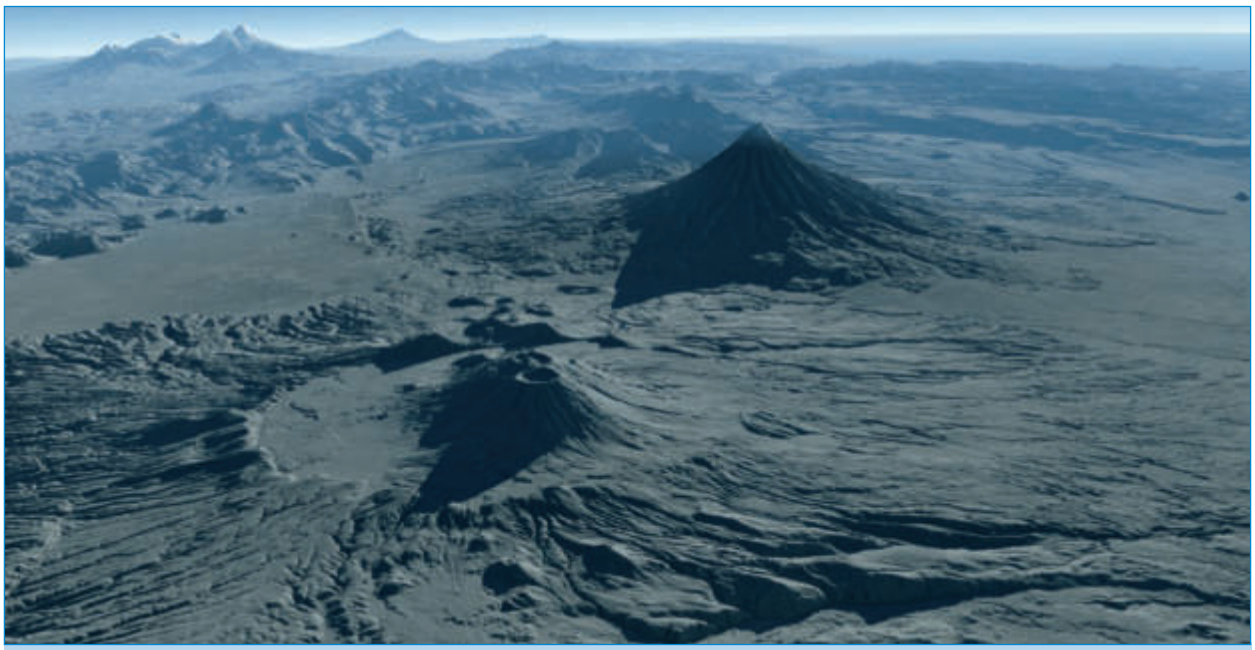
Illustration of the helix formation. TerraSAR-X moves on the orbit shown in red, TanDEM-X on the orbit shown in green; typical baselines vary between 120 metres and 500 metres; their orbits never cross. ■

- Flying in close formation in a helix orbit using a separation of the eccentricity-inclination vectors with adjustable baselines from 120 metres to several kilometres, with a minimised risk of collision
- Determining the interferometric baseline with millimetre precision from the data provided by dual-frequency GPS receivers
- High-precision phase synchronisation between the two radar systems through the analysis of synchronisation pulses, which are exchanged via special horn antennas
- Interferometric processing of 2500 terabytes of data to create a global elevation model

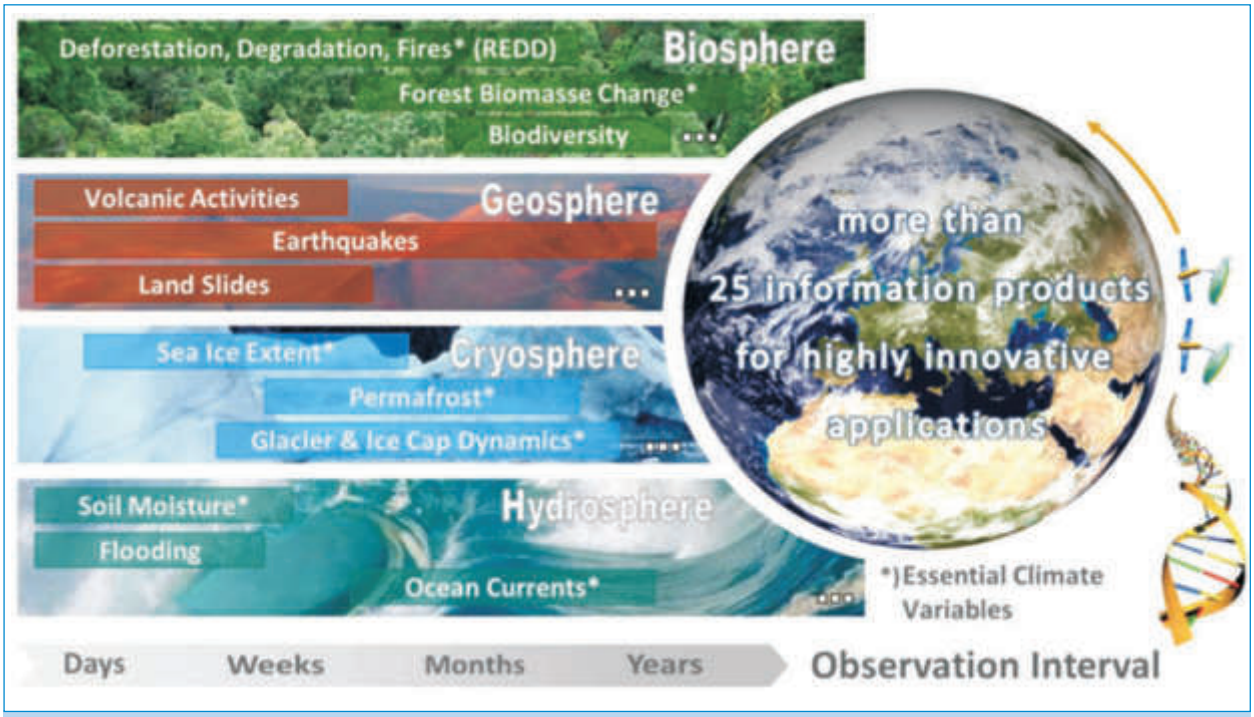
After the launch in June 2010, the monostatic commissioning phase for the TDX satellites focused on calibrating and verifying the system. This confirmed the accuracy of the calibration and the performance of the TDX-SAR system and its products at the TSX level.

After extensive tests of the various security mechanisms, close formation was achieved in October 2010 and the formation flight set with typical distances of 120 to 500 metres. Operations have been smooth and stable ever since.

The bistatic commissioning phase for the TanDEM-X mission focused on testing the complete bistatic chain all the way from acquisition planning through to the bistatic and interferometric processing and the creation of the RawDEMs (30 by 50 kilometre scene-based elevation models). The acquisition of the global DEM finally began in December



TanDEM-X DEM of the Kamchatka Peninsula in an oblique perspective view; in the foreground is the Krasheninnikov Caldera and the 3528-metre Kronotsky volcano – an almost perfect cone. The Klyuchevskaya Sopka volcano is visible on the horizon on the left-hand side; at 4835 metres tall, it is the highest peak in Kamchatka. ■



Examples of dynamic processes from different Earth spheres and the observation intervals required to observe them systematically. Tandem-L will be able to map the entire land surface up to twice a week using innovative techniques and technology ■

2010, while the first and second global coverages (with the exception of Antarctica) were completed in March 2012 and March 2013, respectively. After an acquisition phase aimed at filling in gaps in the DEM dataset Antarctica was also mapped under local winter conditions (due to the better signal-to-noise ratio). The helix formation was modified in August 2013 to allow more difficult, respectively mountainous terrain to be captured from the opposite direction. After the helix formation was reversed in April 2014, the subsequent second coverage of Antarctica and the further filling in of gaps, data collection for the global DEM was completed in 2015. DLR finished processing the final, global DEM product from the intermediate products (over 500,000 RawDEMs) in September 2016. The final global DEM consists of over 19,000 tiles, each covering an area of one degree by one degree (longitude by latitude). The overall cumulative absolute height error in the end product is 3.5 metres (for low-vegetation areas and for areas not covered by ice it is only 0.9 metres) and thus far surpasses the 10-metre specification. The number of gaps in the dataset, for instance due to acquisition-related shadowing, amount to only 0.107 percent, which is well under the permitted three percent. In other words, the degree of coverage is currently over 99.89%. The full-resolution data, with a measuring point distance of 12 metres, also allowed the creation of versions with reduced resolutions of 30 metres and 90 metres.

From 2014 to mid-2016 DLR also performed a number of data acquisitions for scientific purposes, in order to achieve even more precise DEMs on a local scale, along-track interferometry and new SAR techniques, focusing on multistatic SAR, polarimetric SAR interferometry, digital beamforming and super-resolution.

During DEM production, comparison between different measurement periods revealed changes in elevation. In particular, repeated acquisitions for scientific purposes clearly show that the Earth's surface is a highly dynamic system when analysed with this degree of accuracy. Along with elevation changes in glaciers, permafrost regions and forests, agricultural activities and changes to infrastructure also leave clear traces. Therefore, in 2017 the decision was made to acquire the Earth's total landmass once again and to create another independent and unique DEM dataset for the period from September 2017 to the end of 2019, thus enabling temporal changes to be assessed in comparison with the TanDEM-X DEM. The name of this product is ‚Change DEM'. In addition, data will continue to be collected to fill small gaps and to improve data quality for selected regions in the global DEM.

In the meantime, both satellites have significantly exceeded their nominal lifespan of 5.5 years – by six years in the case of TSX, and three years for TDX. Nevertheless, the radar systems of both satellites are in very good condition and the performance data are still completely stable even after 11 and 8 years of operation respectively. The radiometric stability measured over this period is

Tandem-L satellites flying in formation; the large, deployable reflectors measure 15 metres in diameter. ■

0.15 dB in both cases. The radar performance and calibration of each satellite are still well within the specified limits, and there are no signs of degradation – a fact that is notably reflected in the consistently outstanding quality of the SAR products. From today's perspective, the satellites and the ground segment are working without any restrictions, while the consumables – particularly the propellant and battery capacity – should allow the satellites to continue operating for another five years. Altogether, more than 2400 scientists from 70 different countries are currently working with the radar data from TanDEM-X and TerraSAR-X. Access to the 12-metre and 30-metre elevation models is subject to restrictions due to commercial use and requires a scientific proposal in a standard announcement of opportunity process. The 90-metre DEM is freely available for scientific purposes and requires only with a simplified user registration. ■

Tandem-L – an environment and climate mission

Tandem-L is a proposal for a highly innovative satellite mission for the global observation of dynamic processes on the Earth's surface with unprecedented quality and resolution. Due to its novel imaging techniques and enormous acquisition capacity, Tandem-L will provide vital information for solving pressing scientific questions in the biosphere, geosphere, cryosphere, and hydrosphere. For the first time ever, Tandem-L will simultaneously measure seven essential climate variables in one satellite mission. Tandem-L will thus make a significant contribution towards achieving a better understanding of the Earth system and its dynamics.

Important Tandem-L mission objectives include: the global measurement of forest biomass and its temporal variation for a better understanding of the carbon cycle; the systematic monitoring of deformations of the Earth's surface on a millimeter scale for the investigation of earthquakes and risk analysis; the quantification of glacier motion and melting processes in the polar regions; the fine scale measurement of variations in the near-surface soil moisture, as well as observations of the dynamics of ocean surfaces and ice drift.

In times of intensive scientific and public discussion about the scale and impact of climate change, Tandem-L delivers important, currently unavailable information for improved scientific forecasts and socio-political recommendations based upon these. Beyond the primary mission objectives, the dataset acquired by Tandem-L will have huge potential for the development of cutting-edge scientific, commercial and governmental applications. One example is the preparation and supervision of international climate and environmental agreements such as

REDD+ (Reducing Emissions from Deforestation and Forest Degradation). Radar tomography can be used to determine the necessary information, such as forest height, forest biomass and any changes to it (for example due to deforestation, forest fire or indeed reforestation), as well as the vertical forest profile.

The Tandem-L mission concept uses two radar satellites operating in L-band (23.6-centimetre wavelength). Use of the special synthetic aperture radar (SAR) technique allows high-resolution imaging of the Earth's surface, regardless of the weather or daylight, and thus offers optimal conditions for the ongoing observation of dynamic processes on the Earth's surface. One particular challenge for the Tandem-L mission is fulfilling user requirements for large swath width, short revisit times, high resolution and fully polarimetric operation. For this purpose, DLR researchers have developed innovative digital antenna technology in combination with a large deployable reflector. This technological revolution combines the advantages of digital beamforming with the high sensitivity offered by the very large aperture area of the deployed reflector. Tandem-L thus surpasses the performance of conventional radar satellites by more than a factor of 10. According to current plans, the Tandem-L satellites could be launched in 2024.

The revolutionary techniques and technologies used in Tandem-L form the basis for future generations of satellite SAR systems. The Tandem-L mission is thus paving the way for a global remote sensing system for the continuous observation of the Earth's surface, in the same way that weather forecasting using a network of geostationary satellites is the state-of-the-art today. Tandem-L will consolidate and expand Germany's leading role in the field of radar in a sustainable way. With its unique products, the mission is a turning point in remote sensing, and will form the basis for future generations of satellite SAR systems. ■

Tandem-L features

Technological and methodological innovation

- Tandem-L will provide an up-to-date, high-resolution image of the Earth's entire landmass every eight days using the latest digital beamforming technology.
- Its imaging performance will be over 10 times better than all existing SAR satellites and thus represents a development lead of at least seven years.
- For the first time, Tandem-L will be able to measure the vertical structure of vegetation and ice globally using polarimetric SAR interferometry and tomography developed in Germany.

Scientific excellence

- Eight Helmholtz Association centres and 18 partner and associated institutions are already involved in a Helmholtz alliance of organisations laying the groundwork for the comprehensive and systematic use of Tandem-L data.
- For the first time, Tandem-L will make it possible to simultaneously measure seven essential climate variables in a single satellite mission.
- Tandem-L is the world's first mission for the systematic and high-resolution observation of dynamic processes in the bio-, geo-, cryo and hydrosphere.
- Over 100 research institutions have already expressed a keen interest in using Tandem-L data and are members of the Tandem-L science team.

Programmatic approach

- Tandem-L offers unique potential for environmental monitoring, which is becoming increasingly important. One example is the REDD+ programme for forest protection.
- Tandem-L is laying the foundation for a unique observatory for the ongoing observation of the Earth and the environment, which is comparable with the network of weather satellites.
- Tandem-L will consolidate and expand Germany's leading role in the field of synthetic aperture radar (SAR) in a sustainable way. ■

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The asto Park Oberpfaffenhofen – Campus of Technology

Oberpfaffenhofen is the cradle of German aerospace and - for over a decade - has been known for its asto Park technology hub and its research centre.

More than 80 technology companies in the fields of satellite navigation, IT, robotics, mechanical engineering and the automotive industry, from start-ups such as audEERING, Lilium, Quantum Systems and AutoflightX through to large established companies such as Diehl Aviation, Valeo and OHB, are represented here at asto Park. asto Group's goal, which they announced 10 years ago, of colonising sustainable companies from the aerospace industry which fit the profile in order to concentrate resources through collaborative project work was able to be achieved. Performance was able to be increased due to sinking costs and, therefore, a competitive edge over the otherwise medium-sized structure in the region and its companies was secured.
The employees in the 8,000 workplaces which have developed in the meantime come from many different countries. The internationality and different cultures provide dynamism and innovation. Grouping interests and activities, especially those of smaller start-ups, makes the site so special.

The high-tech campus has featured a hotel, Courtyard by Marriott, which is available to visitors and project specialists from internationally active companies since May 2018.

Courtyard by Marriott is customised for the needs of modern, discriminating business travellers. The hotel will profit from the site's increasing demands and complements these optimally with its top future prospects.

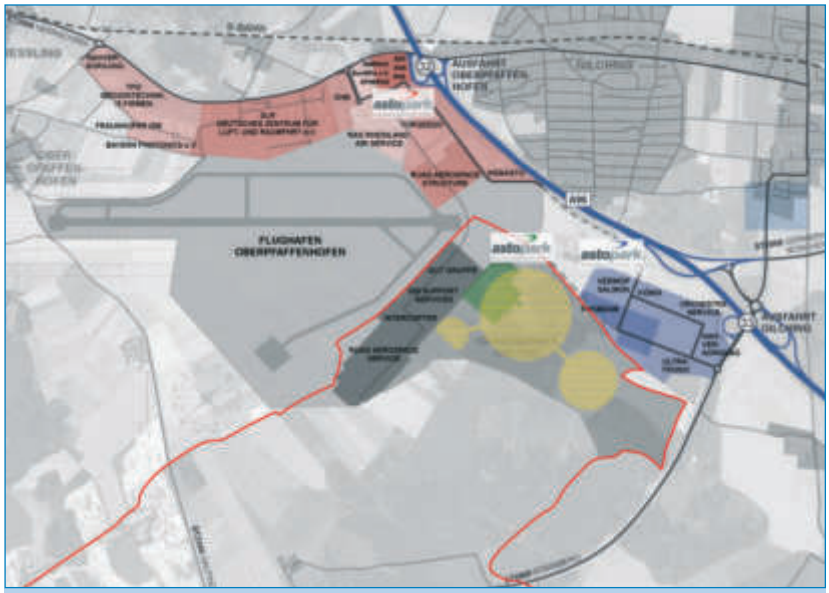
asto Workspace Park Gilching Süd is located directly adjacent to the asto Park and houses companies in the sectors of electron beams and medical technology, such as the companies pro-beam and Pari GmbH. Expansions are individually designed according to the tenant's wishes. The sometimes complex production, of medical items for example, requires very particular equipment attributes. But mechanical engineering and laser technology equipment are also represented here.

asto Park Oberpfaffenhofen

asto ECO PARK GAUTING, the "green" industrial facility bridges a gap in the research aerodrome. It organically connects to the already established asto Park industrial area and the asto WORKSPACE and will fulfil high environmental requirements. Conceptual workshops are currently running with specialists from the fields of energy, transport, logistics and mobility. This modern facility's development requires a high degree of innovative, forward-looking planning to live up to its sustainability and high environmental demands.

Courtyard by Marriott at the end of the street beside the asto Group headquarters. ■

In conjunction with Starnberg county's energy revolution, which aims to use only renewable energy which is regionally available by 2035, heat and electricity are taken from geothermal energy and photovoltaic units. But sociological aspects of the changing working day are also taken into consideration here, such as concepts for day care facilities for parents of employees from within the campus, recreational facilities like a gym and health facilities such as physiotherapy practices and pharmacies. Emphasis will be on migrating highly technological production facilities here. Synergistic effects can only be achieved through the creation of co-working areas. The town of Starnberg is also planning a technology campus in **Schorn** near Starnberg. The asto Group is also investing in the future here, partially following the already quite advanced Gautinger project's conceptual design. Similarly, a modern site with good connections to Munich and the surrounding area should be created primarily for technology-based companies.



The asto Park with its already existing and its planned (yellow) quarters in Oberpfaffenhofen and Gilching Süd. ■

Young, innovative user companies as well as established technology companies which want to use the site's dynamics and focus their activities will be approached first of all.

Energy for the companies will be provided by an additionally constructed CHP-driven small district heating and cooling network and also using (deep) geothermal energy. ■

astopark
BUSINESS INNOVATION CENTER

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Earth Observation for Global Change Research

Earth Observation Center (EOC) des DLR

Over the last decades mankind has changed the earth's surface to an unprecedented extent and speed. The population has more than doubled within the last 50 years. By 2050, more than 10 billion people are expected to live on the planet. The impact of human activities is visible everywhere: settlements and agricultural areas are growing and the consumption of natural resources is increasing. Climate and environmental changes affect the densely populated world. In order to assess, analyze and eventually deal with global change, objective, continuous and comprehensive data are needed. Remote sensing is the ideal technology to provide such data. Satellites continuously monitor the earth's surface and take measurements on the state of land, water and air. ■

The Earth Observation Center (EOC)

The Earth Observation Center (EOC) of the German Aerospace Center (DLR) is located in Oberpfaffenhofen near Munich. Here, remote sensing data are received, processed and analyzed in order to gain insights into natural and man-made processes on Earth. The EOC consists of the German Remote Sensing Data Center (DFD) and the Remote Sensing Technology Institute (IMF). While the IMF is primarily focusing on algorithms and processor developments for remote sensing data, DFD focuses on data analysis and research concerning global change and civil security issues. In addition to Oberpfaffenhofen, DFD is also located in Neustrelitz, one hundred kilometers north of Berlin. This is where DFD's national ground segment and the Maritime Safety and Security Lab are located. The IMF has branch offices in Berlin and a Maritime Safety and Security Lab in Bremerhaven. The EOC is closely linked to the Bavarian universities, in particular the University of Würzburg and the Technical University of Munich, but also to the universities of Augsburg, the LMU Munich and the Catholic University of Eichstätt-Ingolstadt. ■

Fig. 1: *The Earth Observation Center of DLR in Oberpfaffenhofen, close to Munich.* ■

Management of Remote Sensing Data

Remote sensing satellites have been operating for four decades, but it is only in recent years that Earth observation data have become available in large quantities and free of charge. Especially the Copernicus program of the European Union contributes to the increasing amount of data with this unique Earth observation program. It comprises an extensive satellite fleet consisting of six satellite types, called Sentinel focusing on different applications. At the same time, the program includes the development of data infrastructures, in-situ measurement networks, accompanying research programs and derives information products for the society. With these an unprecedented amount of data is currently available. New concepts are also explored within the private sector. Instead of large, complex satellite missions, constellations of small satellites with low-cost hardware are launched, supplementing

Fig. 2: *The receiving stations near the North and South Pole allow frequent contact with remote sensing satellites, enabling thus the download of large data amounts.* ■

scientific missions with daily acquisitions and a high spatial resolution. In parallel, processing platforms are being developed that give users access to a vast pool of data offering unprecedented opportunities for environmental analysis on a global scale.
This flood of data holds completely new opportunities and a challenging task for the EOC: The EOC's German Satellite Data Archive (D-SDA) stores the data of national and international missions for future analyses and makes them available to current and future generations of researchers.
With its archiving and processing capabilities and it's receiving stations in the Arctic, Antarctic and Germany, the EOC is an integral part of the European Earth observation landscape.
On behalf of ESA, it works, among other things, as a Processing and Archiving Centre (PAC) for several Sentinel satellites (Sentinel 1, Sentinel 3 and Sentinel 5p).

Earth Observation for a better understanding of the environment

Only long-term time series allow an analysis of the past and identification of trends. The analysis over several decades reveals environmental changes and makes it possible to distinguish between natural fluctuations and real changes. How does the environment develop, how does snow cover change, how do the earth's large water reservoirs behave, how much forest is cleared, how clean is the air, how are settlements developing worldwide? Questions like these become important in a rapidly changing environment. The EOC tries to provide answers to these questions on the basis of satellite data.
For example, the EOC developed the Global Urban Footprint (GUF) and its successor, the World Settlement Footprint (WFS). Both data show built-up areas, whereby the WFS contains various layers of information, such as the development of settlement areas since 1985. The maps show the earth's settlements and their dynamics in detail and serve among others as a basis for analy-

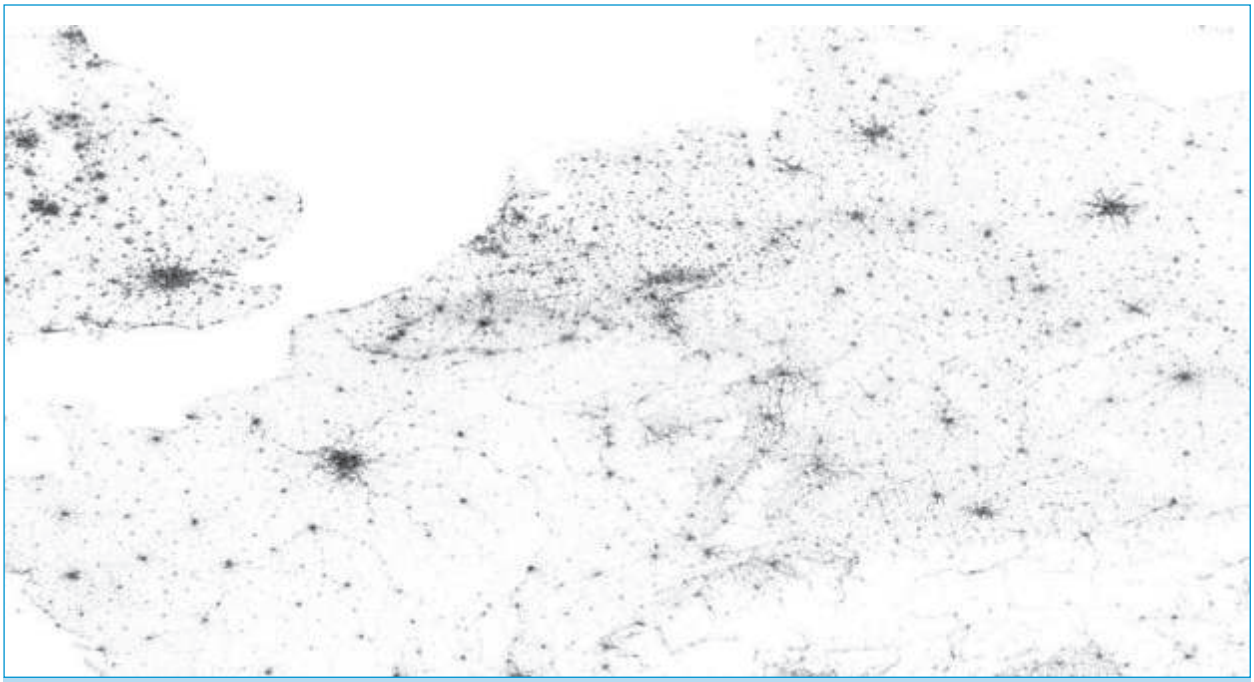

Fig. 3: *The ‚Global Urban Footprint' (GUF) for central Europe. This global settlement map is based on data from the TerraSAR-X and TanDEM-X mission.* ■

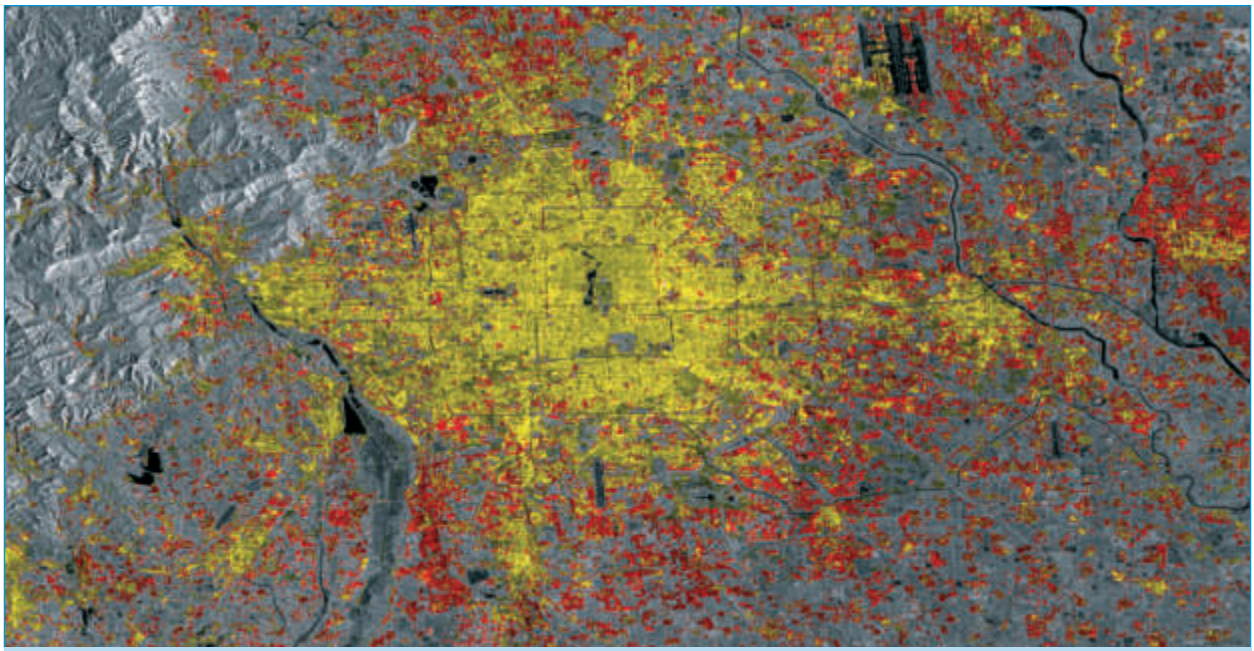

Fig. 4: *Beijing's rapid growth in twelve years: in yellow the city in 2002-2003, in red the expansion of Beijing in 2014-2015.* ■

Fig. 5: *The comparison of the vegetation (NDVI) in June 2018 and the mean over 18 years shows the extent of the unusually dry and hot summer in Germany in 2018 (database: MODIS).* ■

sis for the World Bank. The Global Urban Footprint was created as a by-product of the TanDEM-X mission. The primary objective of this German radar mission was to create a homogeneous global terrain model with a ground resolution of twelve meters. This, too, is a globally unique data set.

With the help of artificial intelligence, these settlement masks at DFD were blended with socio-economic data and social media data, e.g. from Twitter, in order to characterize districts, identify informal settlements or estimate population distributions more accurately.

These are important information, e.g. for rescue forces in case of major natural disasters such as floods, tsunamis, earthquakes or volcanic eruptions. Risk maps are produced at the Centre for Satellite Based Crisis Information (ZKI) at the EOC and provided to decision-makers.

In addition to urbanization, food safety is another research topic at EOC: the expansion of agricultural land in Africa, changes in cropping patterns and the extent of droughts, such as in Germany in the summer of 2018, is mapped. Also aquaculture is becoming

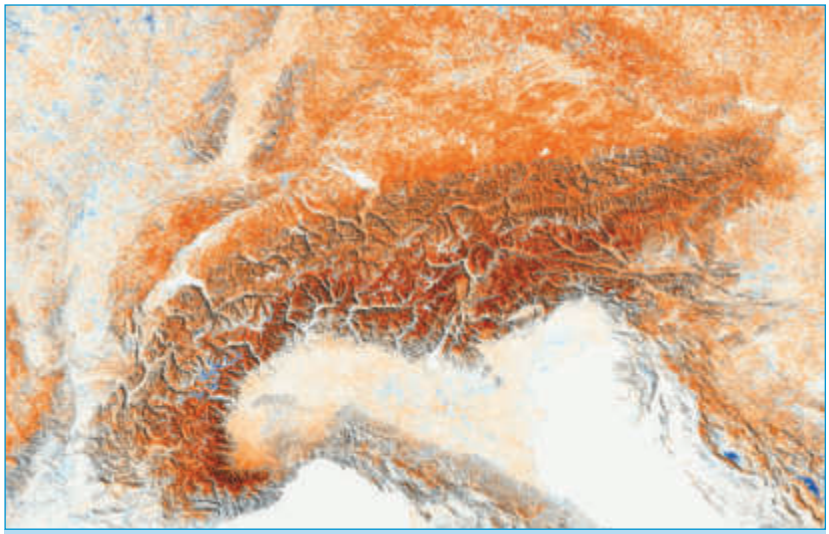

Fig. 6: *Large parts of the Alps remained snow-free in winter 2015/16 more than 40 days (in orange) longer than the long-term average. With the ‚Global Snow Pack' data set DLR scientists can globally determine when snow fell and how long the snow cover duration is. These long-term data allow statistical evaluations of snow cover conditions.* ■

increasingly relevant. It is the fastest growing sector in the world regarding food production. Using a method developed at the EOC, the aquaculture basins can be mapped and their average yield estimated. The collected data provide information on the extent and potential yield and document as well the loss of valuable coastal habitats.

The effects of climate change, one of the most important socio-political issues of our time, can only be determined through long-term observations. The EOC therefore derives e.g. daily snow cover. For more than a decade and a half, the data show, how snow cover is changing. The early recognition of trends helps to prepare agriculture, energy industry, water supply and tourism for such changes. Together with the global overview of the current water level of lakes, which is also generated at the EOC, these are indications of the water supply of regions and possibly threatening droughts.

Furthermore, the EOC is working on the development of information systems that also address non-specialist users, so that authorities and the public can benefit directly from the wealth of data. It develops Earth observation applications in regional, national and international projects. The actual satellite data are increasingly incorporated into complex computer models of our environment in order to inform the user about air pollutant concentrations or health risks in general.

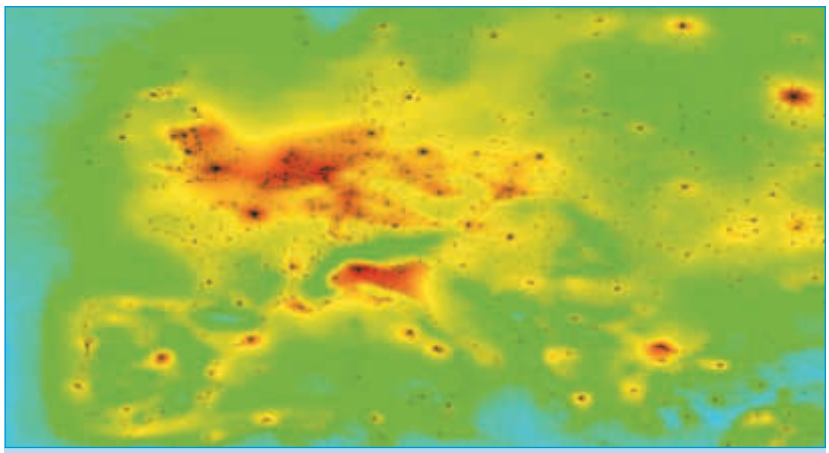

Fig. 7: *Nitrogen dioxide concentrations (NO_2) over Europe in combination with settlement areas. NO_2 is a result of combustion processes and occurs in high concentrations (red) in densely populated areas and low (green) in rural areas.* ■

The examples given above are a selection of the research topics at EOC. The data and information products of the EOC can be accessed through the internet portal (EOWEB), the web service (EOC-Geoservice) or the atmospheric data portal WDC-RSAT. Also archived data can be accessed through the portals. ■

Contact persons:

Stefan Dech

Stefan Dech is Director of the German Remote Sensing Data Center (DFD) and current Speaker of the Earth Observation Center (EOC) at the German Aerospace Center (DLR). Since 2001 he holds the Chair of Remote Sensing at the Institute of Geography and Geology at the University of Würzburg. His research focuses on satellite remote sensing applications for terrestrial ecosystem research in the context of global change and sustainable land use.

Doris Klein

Doris Klein is a scientific advisor at DLR's German Remote Sensing Data Center (DFD) since 2011. Her PhD and later research activities focused on the combination of different satellite systems for the assessment of ecosystem change processes.

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Augsburg Innovation Park with the Technology Centre Augsburg

Location factor innovation competence

The new challenge in the aerospace industry is faster and more economical production, automation, greater flexibility and above all increased resource efficiency in the use of energy and materials throughout the entire production and use cycle of the aircraft.

To meet these challenges, Augsburg has founded one of the largest economic development projects.
The Augsburg Innovation Park with the Technology Centre Augsburg is an economic development measure of the city of Augsburg and the Region of Augsburg, supported by the Free State of Bavaria, the Economic Chambers as well as further institutions.

Technical Centre Hall in the Technology Centre Augsburg, Photo: © Wolfgang Hehl ■

The goal is to support innovation and technology transfer for businesses in the field of aerospace, lightweight construction, fibre composites, mechatronics and automation, digitization, industry Technology companies can settle in the 70-hectare Innovation Park or work closely together with research institutions as a project group in the 12,000-m² Technology Centre Augsburg in order to improve production processes and products. 40 users such as start-ups, regional businesses and global players are already on site.
In the modern event area, over 15,000 specialists have exchanged information and experience on technological topics in the past 2 years. 13 technology-oriented research institutions from the above-mentioned technology fields are active in the Park and provide important contributions to moving the aerospace industry forward – such as the DLR German Aerospace Centre, the AMU Application Centre for Material and Environmental Research, the Fraunhofer Research Institute for Casting, Composite and Processing Technology IGCV and the ITA Institute of Textile Technology Augsburg as well as the central offices of the Bavarian and federal cluster institutions in the fields of carbon fibre, the environment, mechatronics, digitization and aerospace.
The innovation competence is also supported by excellent specialists provided by the university, technical colleges and further educational institutions.

Simulated aerial image, Innovation Park, Photo: © KCAP Architects & Planners ■

Welcome to the Augsburg Aerospace Area! ■

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Augsburg Innovation Park

Stadt Augsburg

Augsburg – a leading production centre

Factors that favour Augsburg

Augsburg Inner City
Photo: © Ruth Plössel ■

LOCATION FACTOR PRODUCTION COMPETENCE

The economic region of Augsburg is a leading production centre of the European aerospace industry with our 20,000 people employed within one hour from Augsburg. Pioneering companies like Messerschmitt and Piccard are writing aerospace history here.

We offer a unique concentration of small specialists and world market leaders with competences in aircraft construction throughout the entire value creation chain. Here the essential components of renowned products are produced, such as parts of ARIANE rockets or AIRBUS and BOEING airplanes or complete aircraft such as AIRBUS HELICOPTERS.

This is all made possible by production factories, large system integrators and global players of the industry. Particular competence is available in the field of carbon fibre materials. Here companies like the SGL Group, Coriolis and Premium Aerotec, research institutions like the ITA Institute of Textile Technology Augsburg, the MRM Institute for Materials Resource Management and the Fraunhofer Research Institute for Casting, Composite and Processing Technology IGCV as well as network structures like Carbon Composites e.V. and MAI Carbon are world-leaders in many activities.

Air Park / Airport Augsburg
Photo: © Siegfried Kerpf ■

LOCATION FACTOR AEROSPACE-RELATED SPACE AVAILABILITIES IN THE AIR PARK

Besides the Augsburg Innovation Park, aerospace-related business can also find an ideal location for production, research and office space in the Augsburg Air Park – and at attractive conditions. This commercial area has construction-ready properties and is connected to public transportation and fiberoptics. Companies can position themselves as airport service providers here right next to the international City Airport Augsburg or find a generous space for their aerospace-related production companies. The Airport of Augsburg is appealing due to its maximal flexibility (no slots), suitability for all weather conditions (ILS) and short distances for international business travel or maintenance or training flight traffic. ■

Augsburg inner city
Photo: © Ruth Plössel ■

LOCATION FACTOR QUALITY OF LIFE

Augsburg offers not just good working conditions but also the best quality of life and excellent prospects for the future at an attractive cost of living. High security, intact nature, a state theatre, a university clinic, an international school, diverse cultural offerings, multicultural population and 2000 years of history can satisfy the most various needs. ■

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The reality in maps

3D surveying and digitization of landscapes, cities and historic buildings with drones and planes

3D RealityMaps GmbH is Europe's leading provider of 3D digitization and 3D real-time visualization. The Bavarian computer specialists have succeeded in developing a unique software that allows users to display 3D datasets, unlimited in size, interactively on the internet and across platforms ranging from laptops, tablets, smartphones and virtual reality devices. Landscapes are digitized in 3D using high resolution aerial and satellite imagery. Unlike topographic maps, these photorealistic 3D maps are an innovative way of presenting maps on the internet. Because the 3D maps are accurately georeferenced, relevant geographical information about the region can be displayed exactly at the geographically correct location. These interactive 3D maps open up a new dimension to search for information on the internet. For example, tourism destinations can attractively present their landscape and activity portfolio on the web as never before. Guests receive all necessary information for travel planning and orientation at the destination.

The 3D maps not only work in the web browser, but also on smartphones and tablets. All information is always available en route and the 3D maps are fully navigable. With the app and its custom tour portal, 3D Outdoor Guides (www.outdoor-guides.de), 3D RealityMaps also sets new standards in outdoor navigation and orientation with smartphones. The app 3D Outdoor Guides, with the unique 3D map of the Alps and an individual route plus GPS tracking function, turns any smartphone into a fully-fledged GPS device.

A key advantage is that the app user can recognize their own position in a photorealistic map of the real landscape. Using the GPS tracking function, their position while en route is displayed continuously within the 3D map. Areas in danger of natural hazards, such as falling rocks and avalanches, can only be detected using photorealistic 3D maps. Even with bad visibility, at night, in snow-

Fig. 1: *3D Outdoor Guides – simple and safe navigation for hikers and bikers.* ■

3D RealityMaps GmbH

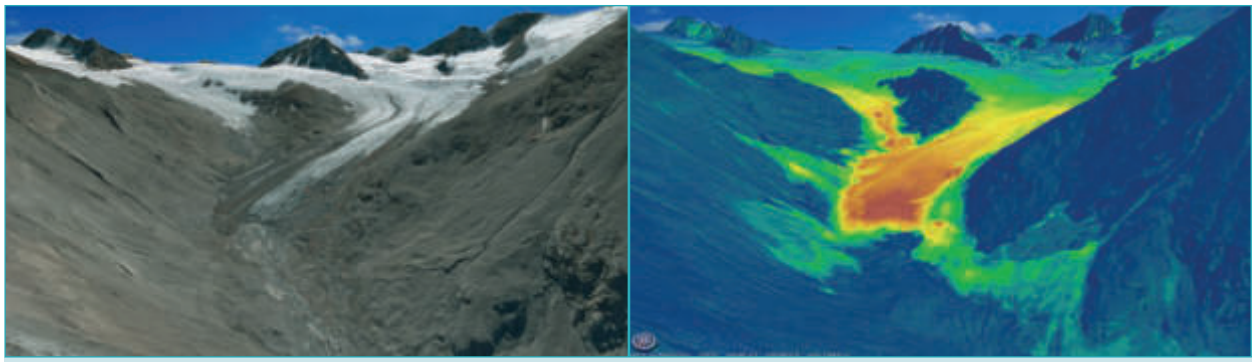

Fig. 2: *Left: 3D model of the Schalfferner, Ötztaler Alpen; right: Loss of glacier ice over a period of four years* ■

storms and/or fog, the combination of a photorealistic map and GPS functionality offers hikers, bikers and winter athletes the best possible orientation option.

3D RealityMaps works closely with research institutions and universities to develop further innovative products based on the 3D technology. As part of the 'AlpSense' research project, 3D RealityMaps is coordinating with the Technical University and the Ludwig Maximilian University in Munich and the Bavarian Academy of Sciences to develop remote sensing techniques for the early detection of climate-related natural hazards in the Alpine region. One current project aims to develop an early recognition system of potential danger spots due to mass movements and glacier retreat, accomplished through continuous monitoring and change analyses. Through repeated aerial and drone surveys together with high-precision GPS georeferencing and photogrammetric 3D mapping, as well as multi-temporal comparison of surface models, the Hochvernagtferner in the Ötztal Alps and the Hochvogel in the Allgäuer Alps are currently being explored.

Another area of application lies in high-precision 3D measurements with drones. Projects have covered mapping of historic buildings, churches, outstanding new buildings or even sports stadiums, which are first photographed with drones from thousands of different perspectives. A very detailed 3D model is calculated from the aerial photographs and visualized using software developed by 3D RealityMaps. On behalf of the Bavarian State Ministry of Finance, State Development and Home Affairs, 3D RealityMaps has digitized selected historical castles such as Neuschwanstein and Linderhof. The spatial accuracy is in the range of a few centimeters. Historic buildings, for which there are usually no blueprints, can thus be efficiently surveyed and digitally archived. ■

3D model of Neuschwanstein castle

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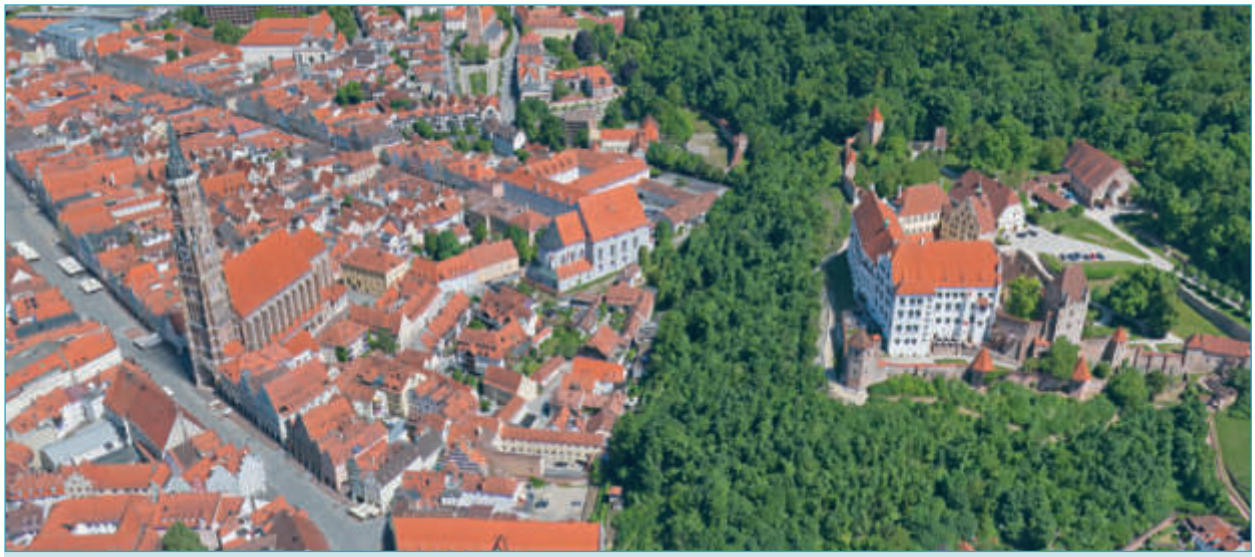

Fig. 3: *3D model of the historic Landshut city center* ■

How Copernicus supports the energy transition

RSS - Remote Sensing Solutions GmbH provides insights into the research project COP4EE, in which Earth Observation (EO) data are used to determine the renewable energy potential of areas. The resulting scenarios aim to support policy makers in finding the optimal solution for Bavaria.

RSS – Remote Sensing Solutions GmbH

Although the energy transition is governed at both European and national scales through laws and regulations, it is implemented at a regional level. Regional administrations define their own targets for the production of renewable energy and adapt them to local demands and potentials. However, the decision makers are often not fully aware of the their spatial units' potentials and limitations. This can result in negative land-use related side-effects of the energy transition such as agricultural intensification, land use competition (e.g. food crops), or an irreversible transformation of permanent grassland to arable land. In order to plan the energy transition in an efficient and environmentally friendly manner, large-scale and precise information on the area-specific potential for renewable energies, the conflicting land use and the sustainability criteria are required.

COP4EE uses high-resolution, open-access Sentinel data from the European Copernicus Programme to determine the potential of areas for wind power plants, photovoltaic plants, district heating or the production of biomass. Copernicus data also allow researchers to continuously monitor land use, crop type cultivation and the use of permanent grasslands. By combining these data with digital elevation models, climate data and other existing spatial information (e.g. soil data, Natura 2000 sites, other conservation areas, locations of power plants), the most suitable renewable energy source for an area can be determined. In addition, scenarios specially adapted to a given region can be computed to address regionally defined energy transition targets. The unique advantage of such an EO-based decision support is that it considers the economic and ecological aspects associated with the expansion of renewable energies equally.

Fig. 1: *Wind and biomass as renewable energy sources in Germany* ■

RSS conducts the project in collaboration with DELPHI IMM GmbH, the Research Center for Energy Economics (FFE e.V.) and M.O.S.S. Computer Graphics Systems GmbH. The project is funded by the Federal Ministry for Economic Affairs and Energy (BMWi) via the Space Administration of the DLR. RSS – Remote Sensing Solutions GmbH is one of the leading

Fig. 2: *Forest- and peat fires lead to vast amounts of carbon dioxide emissions* ■

earth observation companies in Germany. RSS specializes in the processing and analysis of satellite data in the field of nature conservation, climate change and natural hazards. The services range from spatial data processing (satellite, aircraft, drones) to image and spatial data analyses and cloud-based monitoring systems. RSS has completed more than 100 projects invested in a diversity of topics. These include analyzing the effects of global warming, deforestation processes, natural hazards like forest fires or desertification, agriculture, food security and nature conservation.

RSS develops new methods and technologies in cooperation with universities and internationally renowned research institutions, which enables RSS to offer cutting-edge and innovative products. These products are used worldwide in developing and emerging countries in the context of development cooperation projects. RSS GmbH also provides technical support for the implementation of climate and nature conservation measures in more than 25 countries. For example, a method that detects and quantifies forest fires is being developed and used to enhance existing fire prevention strategies used in Indonesian governmental agencies.

In February 2018, RSS was rewarded for its innovative ability, when it developed a new peat mapping methodology and won an innovation prize of $1 million dollars. The two-year competition involved 44 international research teams and aimed to find a method capable of quickly, accurately and cost-effectively mapping Indonesia's carbon-rich peatlands. Indonesia's peat forests contain vast amounts of carbon which is released into the atmosphere as carbon dioxide (CO_2) during deforestation fires and peat drainage activities. These activities are common when establishing new plantations and the resulting emissions have been shown to contribute significantly to global warming. The „International Peat Mapping Team" led by RSS won the prize for its unrivaled, accurate and fast mapping of peat. ■

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Technologies for Aviation 2050

How will mobility and air traffic in particular change by 2050? Will we fly in completely different aircraft, and what energy sources will we use? These are questions that a think tank on the long-term development of aviation needs to address. At Bauhaus Luftfahrt, 37 researchers are currently working with students from a wide variety of disciplines on a variety of topics that could influence the future of aviation.

New technologies as well as new business models lead to innovations in all areas of our daily lives. One of the central tasks of Bauhaus Luftfahrt is to observe research as well as other business areas and to identify new, radical approaches and evaluate their potential. Particularly promising approaches will be transferred into the context of aviation applications in order to assess the extent to which these technologies and business models can enable more efficient and sustainable air traffic.

Over the years, concrete topics have emerged that can have a significant influence on new aircraft, but also on their operation in the air traffic system. In addition to new, more efficient propulsion systems, these include alternative forms of energy as well as new operating concepts that bring aviation closer to the cities and thus the traveller. ■

The concept of the „Composite Cycle Engine“ ■

New propulsion concepts

With the introduction of the "Geared Turbofan" technology in recent years, the efficiency of the aircraft in operation has been further increased by approximately 15%. Further developments of this technology promise further improvements in the coming decade, but today we are asymptotically approaching certain physical limits. With the aim of shifting these limits, the research focus on energy technologies and propulsion systems is dealing with new, more radical propulsion systems and their integration in aircraft.

A major focus of the work is the investigation of new propulsion systems that could significantly increase efficiency even further by combining different thermodynamic cycles. Together with industry partner MTU Aero Engines and in close cooperation with many international research institutes, the „Composite Cycle Engine“ concept was subjected to rigorous analysis and further development. This essentially involves replacing the high-pressure compressor of a conventional turbo engine with one or more piston engines capable of operating at higher pressures and temperatures. Although this increases the complexity and weight of the propulsion system, it also significantly reduces fuel consumption. Based on initial feasibility studies, concrete steps are now being taken to implement such a propulsion system.

The combination of classic combustion engines and electric propulsion systems could also be a possible solution for aviation. We already see a similar situation in ground mobility, but the effects and potential cannot be transferred one-to-one to aviation. The special operating conditions and flight emissions, for example, do not permit energy recovery. In a large number of studies on how both forms of energy can best be combined, it quickly became clear that we had to make further improvements possible at the aircraft level via the electrical propulsion systems. Electric propulsion systems are much better suited here for improving the aerodynamics of the aircraft locally, for example. A particularly promising approach seems to be to use the effects of the flow around the fuselage to improve the overall efficiency of the aircraft. The actually negative fuselage drag can thus be partly converted into more efficient thrust generation. Within the framework of the EU projects „DisPURSAL“ and „CENTRELINE“ under the leadership of Bauhaus Luftfahrt, the feasibility and potential of the „Propulsive Fuselage“ concept is being investigated. ■

New operating models

On the one hand, radical propulsion concepts help to further increase the efficiency of aircraft, but at the same time may also make entirely new operational concepts possible. The new engines and their integration in the aircraft can contribute to a drastic reduction in noise and pollutant emissions during operation. One of the great potentials of hybrid electric aircraft concepts could be fully electric flight during take-off and landing. This could create the basis for the operation of aircraft in more densely populated areas, including air traffic in urban areas. In close cooperation with Bavarian industry and research, Bauhaus Luftfahrt is working intensively on the concept of „Urban Air Mobility“, i.e. the use of smaller aircraft in urban areas, as well as on the more efficient city-city connection (City2City). While in the concept of „Urban Air Mobility“ so-called „air taxis“ complement the ground-based traffic systems and enable a partial transfer of traffic into the air, a new City2City system with smaller regional aircraft and dedicated „city airports“ would be used to set up a new air traffic system. The concept study "CentAirStation" showed the basic feasibility and the advantages for the passenger as well as the benefits for the existing air traffic system. While inner-city airports, for example above railway stations, would drastically improve intermodal mobility, at the same time the capacity-limited airports would be relieved as air traffic hubs. Together with technological innovations, this will result in completely new models for operators and airlines. ■

Alternative fuels

Despite all the technological progress made in further improving the efficiency of engines, aircraft and operations, aviation will not succeed in achieving the targets set for reducing CO_2 emissions solely through these measures. We will need new, sustainable energy options for aviation in order to reduce CO_2 emissions to 50% in 2005, while at the same time tripling transport performance. Alternative fuels offer an

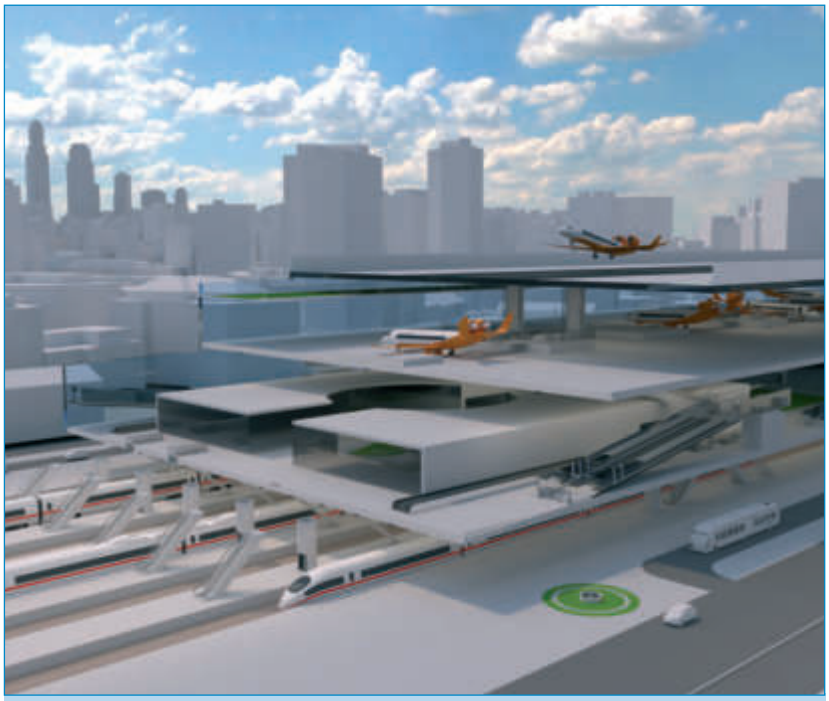
EU-Project „CENTRELINE“ - Synergistic integration of a hybrid electric engine in an aircraft ■

EU Project „SUN-to-LIQUID"- pilot plant in Móstoles, Spain ■

interesting option here if they can be used without fundamental technical changes in existing and future aircraft, through the so-called „drop-in" capability.

While biofuels show only limited long-term potential for the sustainable supply of aviation, research is currently focusing on other, in some cases more direct processes for the production of sustainable fuels. In close cooperation with ETH Zurich and other partners, the direct conversion of water and CO_2 using solar energy in a solar thermal process is being investigated. After the demonstration of the basic feasibility in the laboratory within the framework of the EU project „SOLAR-JET", the EU project „SUN-to-LIQUID" is now about a demonstration under real conditions. The latest research results assume that the system is highly efficient, but also clearly show that the CO_2 cycle must be closed for sustainable production. It is therefore necessary to find technological approaches for extracting CO_2 from the atmosphere that are both efficient and economical.

In addition to these highly relevant topics for the future of aviation, Bauhaus Luftfahrt is dedicated to a multitude of other technological and innovative issues. Together with the strong industrial and scientific network, the researchers identify the essential drivers and impulses for the further development of aviation. ■



„CentAirStation" – Concept of an inner-city airport ■

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For over fifty years, ESG has been one of Germany's leading companies in the development, integration and operation of complex, security-relevant electronic and IT systems. Some 2,000 ESG group employees working within the three brands ESG DEFENCE + PUBLIC SECURITY, CYOSS (Cyber Security and Data Analytics) and ESG MOBILITY deliver products and services in logistics, systems development, training and consultancy to a range of customers that includes governmental authorities as well as defence and industry organisations in Germany and internationally. Our company has its roots in the aircraft sector. By participating in all important national programmes in fixed and rotary wing aircraft over the past fifty years, we have a unique domain knowledge and comprehensive system expertise at our disposal. ■

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We develop, integrate and support customisable avionics and IT systems for aircraft, helicopters and special systems for our range of customers, including military agencies, governmental authorities and industry. Through our logistic services and our range of simulation and training, we ensure

Simulation & Training ■

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ESG DEFENCE + PUBLIC SECURITY is a special systems company for mission avionics, simulations and training, as well as special deployment systems. As a company specialising in aviation technology development, we take on the responsibility for developing and integrating customer-specific systems. Our customers benefit from our profound domain knowledge, technological know-how, strength in implementation and our consulting experience. As a result, our cooperation as partners on equal terms guarantees the project's success. ■

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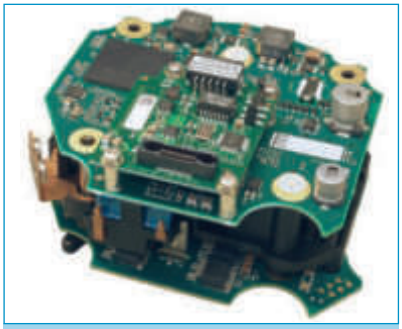
Silver Atena – System Supplier for Air Taxis

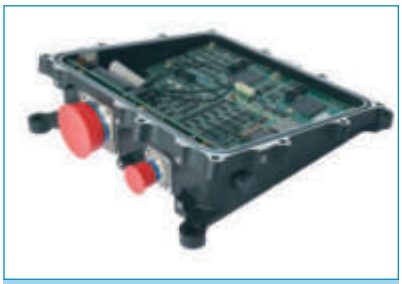
Both established companies in the aircraft industry, as well as numerous start-ups are working on mobility concepts which rely on autonomous electrical air taxis. The topics of autonomy and electric propulsion not only break new ground in technical implementation, but also especially in certification in civil aviation. Here Silver Atena can contribute its many years of experience in the development and manufacture of systems in accordance with international aerospace standards and in compliance with aviation safety regulations to development partnerships. ■

Extensive portfolio

Silver Atena, supplier of safety-relevant electronics systems and performance electronics, is increasingly positioning itself in aerospace in the areas of electric and autonomous flying. The company has been a sought-after system supplier for the aerospace industry for decades and is intensively engaged in the new technical challenges for vertical take-off electric light aircraft. The current portfolio offers customers of the future aerospace industry technical solutions in key areas of electric and autonomous flying: electric drives and actuators, power supply and distribution including battery management, avionics, computer platforms for flight control and route planning. With its range of engine governors and starters/generators the company also offer solutions for hybrid drive systems. ■



Example for a space-optimised 5 kW drivetrain inverter. © Silver Atena ■



A flight control computer can be implemented on this powerful computing platform for the highly-automated control of manned or unmanned small aircraft and rotorcraft. © Silver Atena ■

Contributing to electrical drives

Silver Atena develops and delivers inverters for highly-dynamic electrical drives, as are also used in modern aerospace. With voltages of up to 900 volts and outputs of up to 500 kW the inverter portfolio covers a multitude of applications in the field of electrical drives. Thanks to a modular approach, Silver Atena can offers solutions with low technical risks with tried and tested modules, which correspond to the high safety requirements of the aerospace sector right from the start. The inverters can be flexibly adapted to the available space, as well as to cooling with air or water, and thereby achieve a specific output of up to 15 kW/kg.

„Safety systems developed and tested according to aerospace standards that combine high performance with low weight and compact design – that is what we contribute to the development of these innovative aircraft“, says Josef Mitterhuber, Managing Director of Silver Atena. „Not only do we supply concepts, but also develop prototypes and series-produce electronic system components that can quickly and safely overcome the technical hurdles in the development of new air taxi mobility concepts.“ ■

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Competence Center Optics (CCO)

IABG breaks ground for a competence centre unique in Europe for measuring and qualifying optical systems.

With a symbolic breaking of ground, IABG started construction work on a centre for qualifying electro-optical space systems and components. This centre will establish a unique facility in Europe that will boost the technology site and in particular drive the development of new technologies. The centre will be attached to the existing national space test centre and will ensure all customers from industry, technology and research non-discriminatory access to a comprehensive range of testing facilities. This centre for electro-optical systems and components will close a national capabilities gap.

The chosen configuration also takes into account the sustainability of the new testing capabilities. It has a modular design that can be extended and adapted at any time for test objects of all sizes. In particular it will be able to examine innovative systems of the future like spatial and spectral high-resolution passive imaging systems or active optical systems for optical communication, for example.

The installation will feature a thermal vacuum chamber that is 14 metres long with a working diameter of 5 metres; two vibration-free optical benches with a total length of 14 metres are implemented in the chamber. The core element of the facility will be an optical test bench with collimators, different sources of radiation, plane mirrors, high-precision angle measuring instruments and the associated precision positioning devices.

The new testing facility, just as the existing space test centre, is a national research infrastructure and thus also an integral element of the national space strategy. After its completion in 2021, the Competence Center Optics (CCO) will be used by IABG to actively support the development and qualification of the GEORG satellite system pertinent to national security. The establishment of this test facility for electro-optical systems and components delivers an essential requirement for the success of future missions in the fields of space exploration, terrestrial observation and climate protection.

IABG mbH is proprietor of the Competence Center Optics. The new construction was designed by WSSA Architekten GmbH, Munich, in collaboration with specialized engineering offices and internal and external IABG plant specialists. Completion is planned for mid-2021. ■

About IABG

IABG offers integrated, ground-breaking solutions in the sectors Automotive • InfoCom • Mobility, Energy & Environment • Aeronautics • Space • Defence & Security. We provide independent and competent consulting. We implement with future viability and target orientation. We operate reliably and sustainably. Our success is based on an understanding of market trends and requirements, on our staff's technological excellence and a fair relationship with our customers and business partners.

The photo above shows from left to right:
Engelbert Kupka, Chairman of Supervisory Board IABG,
Dr.-Ing. Walter Pelzer, DLR,
Prof. Dr. Rudolf F. Schwarz, Managing Director IABG,
Franz-Josef Pschierer, Bavarian State Minister of Economic Affairs, Energy and Technology,
Christoph Göbel, Administrator District of Munich,
Florian Hahn, Member of the German Bundestag.

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The Galileo programme DLR GfR mbH

DLR Gesellschaft für Raumfahrtanwendungen mbH, or DLR GfR mbH for short, is a wholly owned subsidiary of the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt (DLR e. V.)) based at the DLR premises in Oberpfaffenhofen, near Munich. DLR GfR mbH spun off in 2008 from the Space Operations and Astronaut Training department of the German Aerospace Center in Oberpfaffenhofen and has grown from a small team of 20 to currently 166 employees within its ranks. The company's core activity is provision of navigation services on behalf of the European Commission. DLR GfR works in the machinery room of the Galileo system, enabling the availability of time and navigation services made in Europe.

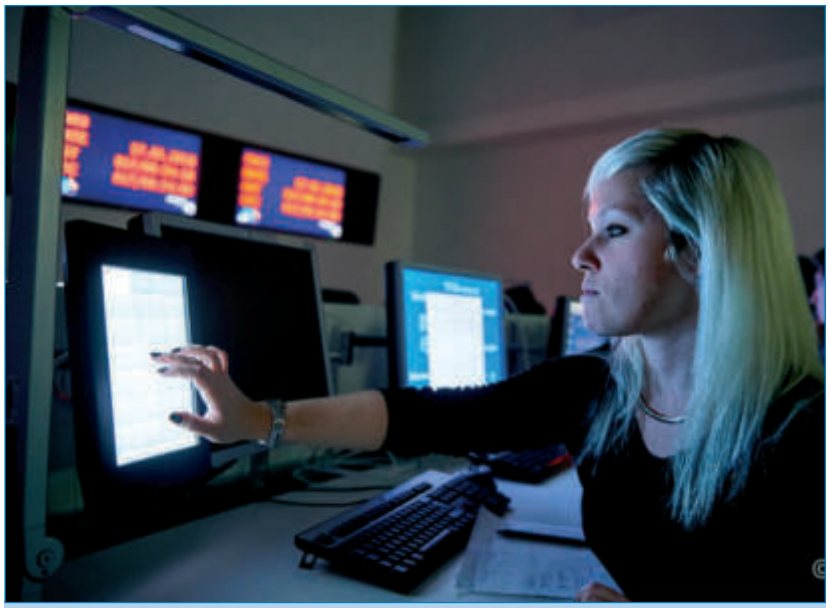
DLR GfR monitors and controls the whole satellite fleet as well as the associated ground control segment for Spaceopal GmbH. Alongside a responsible role in systems maintenance, we also provide reliable support of the control centre in Oberpfaffenhofen.

Operation of the globally distributed infrastructure both on the ground and in the Earth's orbit is organised from this site, commenced by satellite start preparations across the entire life cycle of individual mission phases. This covers mission planning and flight dynamics services, efficient team management including training measures, reliable configuration monitoring and ensuring worldwide service levels. Furthermore, the DLR GfR mbH portfolio covers provision and management of operating services in line with relevant client wishes whilst taking the applicable certified safety standards into consideration.

Main control room of the Galileo control centre Oberpfaffenhofen
Copyright GSA ■

In addition, DLG GfR also provides services within the navigation sector.

Based on years of experience as a Galileo Constellation Operator, DLR GfR can bring tailored and market-oriented service portfolios to mark as an independent air navigation service provider (ANSP) that is independent of manufacturers, whilst these services range from selection and implementation of threat detection technologies for critical infrastructures (e.g. airports) to setting up a secure CNS infrastructure for future traffic concepts such as autonomous driving or flying.



Operations in the main control room of the Galileo control centre Oberpfaffenhofen Copyright GSA ■

Galileo is a civil European satellite navigation and timing system under civil control (European GNSS). It delivers worldwide data regarding accurate positioning and is compatible with other worldwide satellite navigation systems (e.g. the American NAVSTAR-GPS, the Russian GLONASS, and the Chinese BEIDOU).

The Galileo programme is financed by the European Union and is their property. The European Commission is responsible for the programme, as well as managing and monitoring implementation of all activities for the EU.

Provision of Galileo, its design, and the development of new generations of systems as well as the technical infrastructure is safeguarded by the European Space Agency (ESA).

The European Commission delegated operational management of the programme to the European Global Navigation Satellite Systems Agency (GSA), which monitors provision of Galileo infrastructure and Galileo services without interruptions to service in the stated schedule.

The Galileo space segment will consist of 30 Galileo navigation satellites in the future. The ground segment consists of two control centres in Europe (GCC-D and GCC-I) in Oberpfaffenhofen and Fucino, the Galileo Service Centre (GSC) in Madrid, as well as the Galileo Security Monitoring Centre (GSMC) in Paris and Madrid, supplemented by an In Orbit Test (IOT) Station in Redu, Belgium.

There are also antenna stations with a worldwide communications network managed by Telespazio S. p. A.. Both the Search and Rescue (SAR) Centre and the Medium Orbit Local User Terminal (MEOLUT) are available for rescue missions with stricken persons.

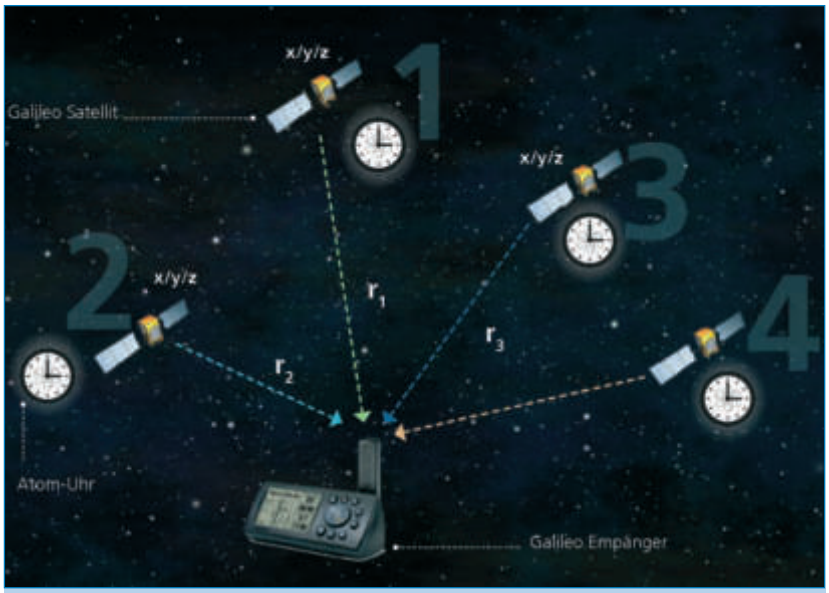
Spaceopal GmbH, headquartered in Munich and founded for acquisition and settlement of Galileo orders, had been responsible for the ESA operating contract since 2010.

On 15 December 2016, Spaceopal GmbH obtained the award to carry out the Galileo Service Operator (GSOp) follow-up project, which started on 1 July 2017. In the case of the GSOp contract, this is a 10-year contract divided into various individual contracts which can be called up separately. DLR GfR mbH has a 50% shareholding in Spaceopal GmbH. The Italian company Telespazio has the other 50% shareholding.

The European Commission announced provision of the initial services on 15 December 2016. This means that navigation services in the application are already accurate, just not globally available. Accessing GPS services compensates for the as yet not full availability during this period. The full operational capability phase, in other words continuous availability of the Galileo signal, is expected to start from the middle of 2019.

Current smartphones such as the iPhone (from version 7 onwards) and Samsung devices (Galaxy S8, S9) already have receivers for Galileo Signals installed in them for navigation purposes.

Galileo Ground Segment - Global Galileo satellite network (Copyright ESA) ■



Principle of satellite-aided navigation (Copyright DLR GfR mbH) ■

DLR GfR mbH takes over monitoring tasks in its control centre in Oberpfaffenhofen as well as monitoring the ground control segment of the whole Galileo constellation (including maintenance). The worldwide antenna stations enable such communication with Galileo satellites via signals in the microwave sector. In addition, DLR GfR mbH is responsible for stocking and procuring replacement parts for operations.

If the sister control centre in Fucino, Italy, which is responsible for the ground mission segment, were to fail then the infrastructure here is capable of continuing the associated mission operations for a duration of up to 4 weeks.

If the opposite situation occurred, namely if the ground control centre in Oberpfaffenhofen failed, then the control centre in Fucino is also able to handle the ground segment activities carried out by GCC-D for a period of 4 weeks.

With the period of Galileo activities over the previous years, the main focus has developed from pure provision of infrastructure to reliable service provision at a global level. Now the primary focus lies on strengthening and improving the system's strong reputation regarding its precision in all matters relating to location and time. DLR GfR focuses on safeguarding operational readiness and availability of the system.

The final launch of four additional satellites on 25 July 2018 from the European space port in Kourou with an Ariane 5 carrier rocket is an excellent example of the maturity of the Galileo project and its process flows. The schedule for the starting campaign was observed, as was the case with the previous launch in December 2017. This is also due to the excellent cooperation between everyone involved.

DLR GfR is confident that the new satellites will be implemented into the existing fleet on time, representing a further milestone on the path to an independent European navigation system.

DLR GfR will see another première in 2020, namely after the 11th satellite start which is planned for the period between 1 September and 31 December 2020, DLR GfR mbH will relieve the French Centre National d'Etudes Spaciales (CNES) in their task of supporting the launch und early orbit phase. This is known as an LEOP phase, covering a very short timeframe and describes the activities which have to take place after the release of the satellite into orbit. These include the functional testing of all relevant system components (In Orbit Test, IOT) and manoeuvring the satellites into their final relative position and orbit.

With this new challenge, DLR GfR mbH sets a new foundation in demonstrating their competence as a commercial satellite operator and to underline their claims of being a reliable partner for the European Union in Germany for the operation of Galileo.

We are proud to play a key part in the Galileo project and to have the opportunity to support the European Commission as well as the GSA and ESA agencies with our technical expertise and the enthusiasm of our whole team.

DLR GfR mbH
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