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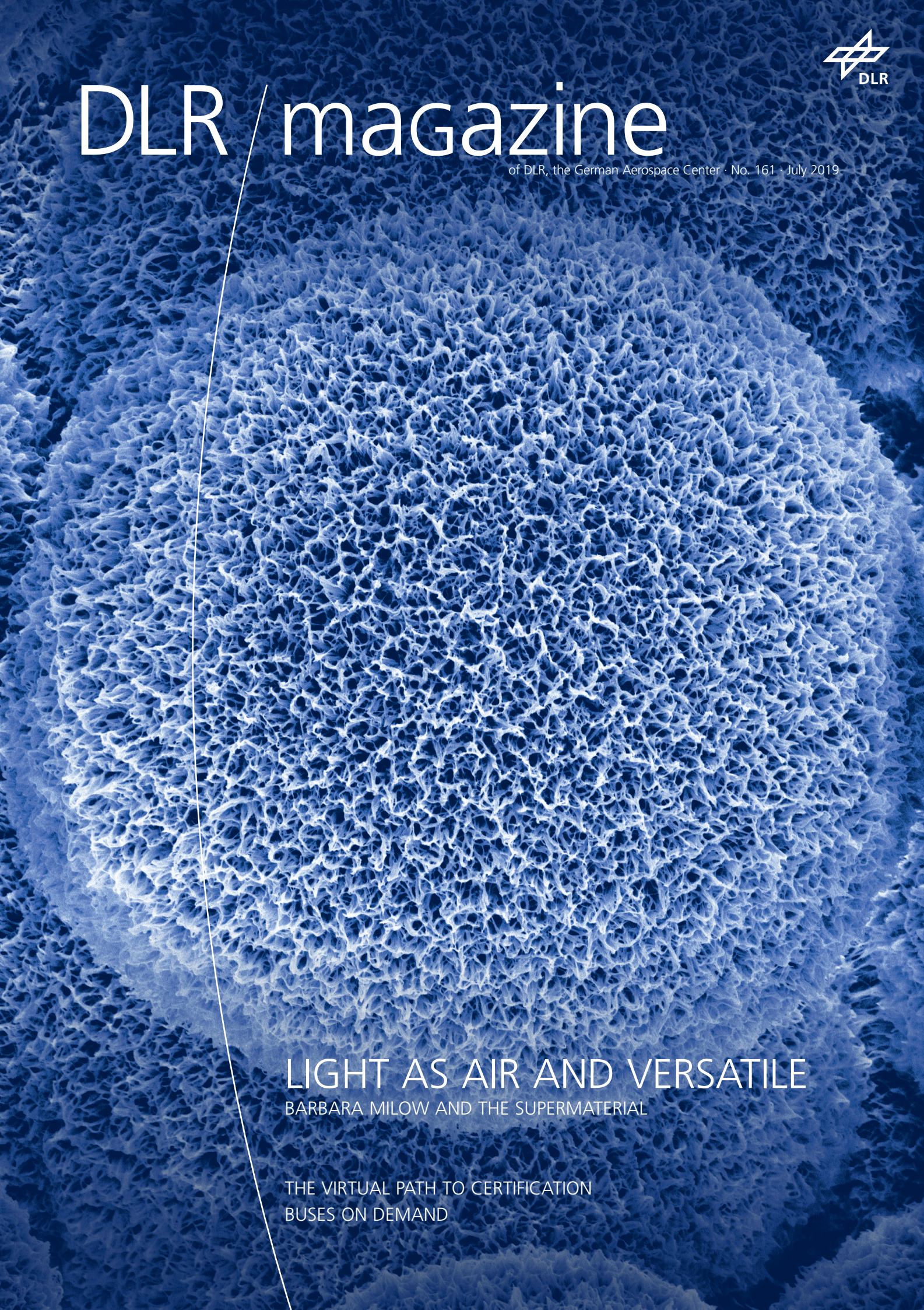


LIGHT AS AIR AND VERSATILE

BARBARA MILOW AND THE SUPERMATERIAL

THE VIRTUAL PATH TO CERTIFICATION

BUSES ON DEMAND

DIGITAL – FROM TOWER TO FLIGHT DECK

27 March 2019, 10:11 – the DLR Falcon research aircraft takes off from Oberpfaffenhofen Airport; its flight is a world first. On board is a demonstration version of the new L-band Digital Aeronautical Communications System (LDACS). In future, it should enable cryptographically secured, efficient data exchange between air-traffic control and the flight deck. In addition, the researchers are testing an alternative navigation system that will guide aircraft safely to their destination – even in the event that their satellite navigation systems fail. By the time the Falcon completed its approximately 90-minute journey, the team had taken a major step towards LDACS standardisation.

LDACS digital aeronautical communications – secure data and voice transmission.

An article from the DLR Institute of Communications and Navigation

The technology underlying the rather cryptic LDACS acronym can be compared to a terrestrial mobile radio network specifically adapted for aviation. The ground station is analogous to the mobile network base station, and the radio equipment in the aircraft corresponds to a smartphone. The new system will allow a better exchange of instructions and information between air-traffic controllers and pilots, as data and voice can be transmitted simultaneously. A team of DLR researchers has been working on LDACS with external partners since 2007. Alongside Frequentis AG and the University of Salzburg, the European Organisation for the Safety of Air Navigation (EUROCONTROL) and Deutsche Flugsicherung GmbH, the German air-traffic control organisation, have also been involved in developing the technology from the beginning. German industry partners Rohde & Schwarz GmbH & Co. KG, BPS GmbH and iAd GmbH became partners approximately six years ago and have been playing an important role since then.

New air-traffic management requires a modern aeronautical radio communications system

The new development is driven by the need to modernise the current air-traffic management system. Advanced, efficient communications are an important prerequisite for ensuring the safe and effective management of steadily growing traffic volumes. "Analogue technology from the 1930s is still being used for aeronautical radio communications today. This is seen as highly inefficient and cumbersome in the modern age. It needs to be upgraded urgently," says Michael Schnell, Project Manager at the DLR Institute of Communications and Navigation. An example of one such unwieldy process is the method of changing flight sector. At present, pilots must verbally register and deregister with the air-traffic controllers and manually enter the new radio frequency when changing flight sectors. The air-traffic controller then communicates route changes to the pilot verbally, using voice radio, which the pilot reads back to rule out possible misunderstandings. The pilot then manually enters the changes into the flight management system on board the aircraft. In future, such data will be transmitted automatically and activated upon confirmation by the pilot.

In addition, the existing analogue voice radio makes very inefficient use of the frequency spectrum. "Only a limited number of frequencies are available for aeronautical radio communications, yet the number of flights is growing year on year," notes Schnell, adding: "It is high time for us to enter the digital age!" LDACS will not only make the communication between pilots and air-traffic controllers more efficient, but it will also enable the exchange of complex information that cannot be transmitted using the current analogue voice radio. For example, the transmission of routes will include time information. When combined, the flight path and time data create a 4D flight trajectory. This indicates

The DLR Falcon research aircraft takes off for its first flight with LDACS

THE WORLD'S FIRST CRYPTOGRAPHICALLY SECURED TRANSMISSION OF PRECISION LANDING DATA

During the flight tests, Michael Schnell's team managed to carry out another special demonstration, this time of the world's first cryptographically secured data transmission to an aircraft for the Ground-Based Augmentation System (GBAS) precision landing system. GBAS provides correction data for satellite navigation, enabling new, quieter and more fuel-efficient approach procedures, which also allow reduced separation between aircraft.

At present, correction data for GPS are sent via VHF Data Broadcast (VDB) when landing with GBAS. Due to the limited bandwidth of this service, other satellite navigation systems such as Galileo, GLONASS and Beidou have not been catered for. The new digital aeronautical radio standard LDACS is able to send GBAS correction data for several satellite navigation systems simultaneously, thus enabling higher system availability. The GBAS correction data are also transmitted in a cryptographically secured manner by LDACS. This means that the exchange of information is protected against possible cyber-attacks and an automated landing approach cannot be manipulated.

both the route the aircraft will fly, as well as additional information on when the aircraft will arrive at specific points on that route. Situations in which two aircraft could come close together can thus be identified and avoided before the aircraft take off.

Cryptographically secured flight and communications

Thanks to its high capacity, LDACS digital aeronautical radio can support all current and foreseeable communications services necessary for modern air-traffic control. The structure of the system also allows the integration of new applications, including sectorless air transport. This would allow air-traffic controllers to consider the airspace as a whole and contrasts with current methods that divide the airspace into distinct areas, each the responsibility of a different controller. LDACS also provides communication services for airlines, enabling them to manage their fleet more effectively. One key advantage of LDACS over conventional systems is that data is exchanged over a cryptographically secured connection. "In view of the increasing automation of air-traffic management, cyber-security is absolutely indispensable, as the human is increasingly being taken out of the loop," explains Schnell.

Christoph Günther, Director of the DLR Institute of Communications and Navigation, explains the main challenge encountered during the development of LDACS: "No new frequencies could be made available for this digital service. The new system thus had to allow its service to be operated in parallel with other services in the same frequency band." This meant that the researchers were not able to use commercially available technology. Using specially developed technologies, they positioned LDACS in the frequency spectrum between existing aeronautical navigation systems.

One system – plenty of functionality

Although LDACS was primarily developed as a communications system, it can also be used to reliably and accurately determine the position of an aircraft. To do this, the researchers used LDACS signals from different ground stations, supported by inertial and barometric altimeter measurements. LDACS can therefore also be used as a back-up for satellite navigation, allowing the existing and costly ground-based navigation infrastructure to be dismantled.

The team has been working on another innovation since early 2019. LDACS will also be able to connect aircraft with one another. This would allow the exchange of real-time flight data on the position, destination and speed, as well as about air currents and the local weather situation.

From theory to practice

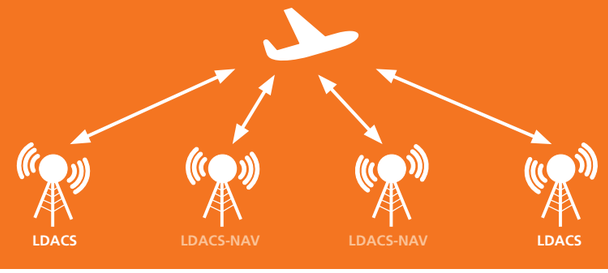
"Theory is fine," says Schnell, "but you have to show the world that your idea really works. This is particularly important in aeronautics, where safety is of the utmost importance." As part of the Integrated Communications and Navigation (ICONAV) project, the team addressed the navigational functionality of LDACS while including a first laboratory demonstration. In the Migration towards Integrated COM/NAV Avionics (MICONAV) project, a fully functional and airworthy demonstration model was built and trialled in the laboratory and during flight tests.

In addition, the team set up four ground stations in the southwest of Munich. Two of these stations are fully operational LDACS ground stations, while the other two are navigation stations. The latter only transmit LDACS signals, which are needed by aircraft to determine their position. Communications take place with the two LDACS ground stations that can transmit and receive. The researchers carried out six measurement flights with the LDACS demonstration system fitted in the DLR Falcon research aircraft. "Our measurement campaign was a complete success," concludes Schnell. "We were able to test and validate all of the essential communications and navigation functionalities in flight." Registering and deregistering with the LDACS ground station was quick and free of errors, as was the hand-over from one ground station to another. During the flight, the aircraft and LDACS ground stations communicated reliably with one another in different situations including high-altitude overflights and take-off, landing and taxiing at the airport. The researchers used typical aeronautical applications such as Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance – Contract (ADS-C) for data exchange. To ensure secure communication the researchers also implemented a 'post-quantum' cryptography algorithm that will enable LDACS communications to withstand future cyber-attacks of the most modern kind.

What now?

Fully implementing the technology into flight guidance systems worldwide will likely take a few years. A DLR-led working group at the International Civil Aviation Organization (ICAO) has been working on standardisation since 2016. "Once the standard is finalised, manufacturers and airlines will be called upon to adopt it," says Schnell. In his opinion, this could happen by 2022.

During the first test, the Falcon flew over four ground stations. Two of them are navigation stations (LDACS-NAV), which send LDACS signals to the aircraft for the purpose of position determination. Two are LDACS stations, which send and receive digital aeronautical radio data.



HOW DOES THE CRYPTOGRAPHIC PROTECTION OF GBAS DATA WORK?

LDACS uses the Timed Efficient Stream Loss-tolerant Authentication (TESLA) broadcast authentication protocol to secure the GBAS data transmission. With TESLA, time is divided into intervals of equal length, with each interval assigned a key with which the message is cryptographically secured. Post-quantum cryptographic methods can be used to generate these keys. After a predefined number of time intervals, the sender releases the keys to all of the recipients. The keys then make it possible for the recipients to verify the authenticity and origin of the message. This ensures that GBAS messages are not falsified and that data from unauthorised persons or systems does not enter the system.

The first test of a cryptographically secured GBAS transmission is in progress and the aircraft is receiving GBAS correction data completely digitally for the first time

The experimental setup installed in the research aircraft

POST-QUANTUM CRYPTOGRAPHY

Post-quantum cryptography refers to encryption techniques that – unlike current methods – cannot be cracked by quantum computers. Quantum computers are the subject of ongoing research and allow multiple hypotheses to be tested in parallel. This makes quantum computers particularly fast and efficient.

THE MICONAV AND ICONAV PROJECTS

DLR implemented the Integrated Communications and Navigation (ICONAV) and Migration towards Integrated COM/NAV Avionics (MICONAV) projects together with partners Rohde & Schwarz GmbH & Co. KG, BPS GmbH and iAd GmbH. Both projects were part of the Federal Aviation Research Programme (LuFo), funded by the German Federal Ministry for Economic Affairs and Energy (BMWi).

About DLR

The German Aerospace Center (DLR) is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, security and digitalisation is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8200 employees at 26 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Cochstedt, Cottbus, Dresden, Göttingen, Hamburg, Hannover, Jena, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Rhein-Sieg-Kreis, Stade, Stuttgart, Trauen, Ulm, Weilheim and Zittau. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

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Editorial staff: Nils Birschmann (Legally responsible for editorial content), Cordula Tegen, Julia Heil, Elke Heinemann (Editorial management), Karin Ranero Celius, Peter Clissold (English-language editors, EJR-Quartz BV). In this edition, contributions from: Merel Groentjes, Florian Kammermeier, Lakshmi Magon, Denise Nüssle, Doris Pfaff and Michel Winand.

DLR Department of Public Affairs and Communications
Linder Höhe, D 51147 Köln
Phone +49 2203 601-2116
E-mail kommunikation@dlr.de
Web DLR.de
Twitter @DLR_en

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Cover image
Shown here is the spherical structure of a novel biopolymer aerogel developed by DLR researchers in a laboratory experiment. It is produced by combining chitosan with a thermoset. You can read more about the versatile aerogels and about Barbara Milow who, together with her team, is 'cooking up' new recipes, on page 30.

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