The agility to succeed in the digital future

Digitalisation and demographic change pose real challenges for business. TU Darmstadt is researching how companies can prepare for the future.

Photo: Jakob Kaliszewski

Professor Ruth Stock-Homburg

New approaches in research
As part of the 2016 Darmstadt Study of Company Futurability, employees, executives and HR-managers from approximately 1,000 German companies 300 trainees, interns and students, and 2000 employees from eight countries were surveyed using the "Future Work Navigator". Leap-in-Time GmbH, a spin-off company from TU Darmstadt, has been conducting research into the future of work and advising companies since 2014. It is running the Future Innovation Lab in Darmstadt since March 2016.

By Jutta Witte

"Businesses striving for success in the future need to be agile and respond quickly within their markets, whilst simultaneously accommodating the requirements of different working generations," explains Professor Ruth Stock-Homburg, an economist and head of the department of Marketing and Human Resource Management at TU Darmstadt. If companies do not adapt to new environments and are not receptive to new business models they are, in Stock-Homburg's view, at risk of losing high-performing employees and falling victim to the "dodo effect" (succumbing to new competitors, despite having good resources, and ultimately "becoming extinct").

The economist's most recent study shows that German and Japanese companies are presently trailing behind in terms of futurability. India comes first, followed by the USA. South Korea, Brazil, China and Russia occupy the middle ground. "In general, companies should do their homework in their areas of core business and operate efficiently. At the same time, however, they need to summon up the courage to explore new concepts of work and new business models," recommends the expert. Eventually, the aim is to combine both worlds.

"Companies high in futurability successfully manage four dimensions. Exploitation, exploration, integration and future orientation." Stock-Homburg and her team have designed an instrument – the Future Work Navigator – in order to systematically assess how fit companies are for the future, as well as to provide a road map for further development.

The Future Work Navigator takes the form of a questionnaire that participants can complete on their mobile phone and checks the status quo of organizations based on the four dimensions mentioned above. "It turns out that all dimensions influence a company's reputation, ability to innovate and its economic success," says Stock-Homburg. In the face of dynamic change, however, it is insufficient to solely focus on the development of one dimension alone.

Moreover, the instrument also analyses the individual adjustments a business is making to core modules that influence its future direction. "It's definitely a cross-sectional challenge for companies to leverage the new opportunities that digitalization presents in order to support their staff in terms of being efficient, creative and flexible," adds Stock-Homburg. Out of a total of eight defined action areas, she considers leadership, people management and workspace design to be priorities.

In future, leadership, for example, will revolve much more around trusting and coaching increasingly autonomous employees. The workforce is also set to become more and more diversified, forcing HR departments to adjust their programs to increasingly heterogenous employees with a multitude of individual needs. Similarly, workspaces for knowledge work will become more varied, according to the professor's estimation. Three of these working worlds of the future are exhibited and explored in the Future Innovation Lab in Darmstadt

If companies know where they stand, they are benchmarked with other organizations and industries. In a final step, new concepts and strategies are tested and implemented. According to Stock-Homburg, businesses in Germany are only just in the starting blocks: "But they have recognized the explosive nature of the issue."

The author is a science journalist and has a PhD in history.

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Electromagnetic sensors meet biomedicine

They can already open doors, park cars and monitor fill levels. Is there any reason why electromagnetic sensors couldn‘t also detect molecules, examine cells or treat tumours? ESSENCE, a nationwide German priority programme, is exploring this issue through a series of ten sub-projects.

By Hildegard Kaulen

The past three years have been particularly challenging for Professors Rolf Jakoby, Christian Damm and Ulrich Göringer. As the three coordinators of the ESSENCE priority programme, they have succeeded in attracting dozens of project partners and convincing the German Research Foundation (DFG) to invest up to ten million euros over the next six years into researching electromagnetic sensors for biomedical applications. These researchers are breaking new ground. The scientists involved will be examining the effect of electromagnetic waves in the micro-, millimetre and terahertz wave bands on individual molecules, cells or clusters of cells, as well as possible applications within the life sciences. Ideas range from fast, contactless diagnostic tools at patients‘ bedsides to treatments for cancer and vascular diseases. Jakoby heads the Institute of Microwave Engineering and Photonics at TU Darmstadt, Damm is leading the group terahertz sensors, both are part of the Department of Electrical Engineering and Information Technology, whilst Göringer is a biologist, head of the research area „Molecular Genetics“.

“Can an electromagnetic sensor also detect cancer cells or resistant bacteria reliably? The potential would be enormous.“

The idea firstly emerged three years ago. At that time, Professor Damm, Dr. Martin Schüßler and Dr.Margarita Puentes were investigating how electromagnetic waves of specific sensor structures interact with artificial tissue. They recorded measurable differences between the various tissues. „Of course, we immediately asked ourselves whether an electromagnetic sensor could also detect cancer cells, resistant bacteria or biomolecules reliably,“ says Jakoby. „The potential would be enormous.“ It was clear from the beginning that the electrical engineers can only face this potential by working closely together with physicians and biologists. That is the reason for the priority program to support only interdisciplinary teams.

What makes electromagnetic sensors so interesting to the life sciences? They are wireless, contactless and perform measurements in real time. Biological markers are no longer necessary either. The measurement process is based on the interaction between the sensor‘s electromagnetic field and the substances, tissues or cells under examination. The water content of diseased tissue, for example, differs from that of healthy tissue. An electromagnetic sensor is able to detect those changes of dielectric properties. Jakoby and his team are focusing on microwaves with a frequency range between 300 megahertz and 300 gigahertz. „We are interested in this frequency range because water, proteins and biomolecules have distinct electromagnetic properties within this microwave range,“ explains Jakoby. „Water, for example, has an absorption line at 22 gigahertz. Because of that, this frequency range seems predestined for sensors.“

The priority programme is supporting ten sub-projects across Germany. TU Darmstadt is playing a key role in shaping three of them. In conjunction with Professor Thomas Vogl from the university hospital in Frankfurt am Main, Jakoby is developing a dual microwave applicator intended to detect and treat tumours in the liver. Vogl is a radiologist and director of the Institute for Diagnostic and Interventional Radiology. The special feature of such a device is that the applicator can work in two operation modes, a diagnosis and a therapeutic mode. What is special about this applicator is the two modes of operation. Featuring both a diagnostic and a therapeutic function, it will be possible to switch between the two modes. For this purpose, a tiny new microwave probe would be inserted into the liver. The procedure is designed to be minimally invasive. Initially tumours are to be detected at a low power. Turning up the power is intended to heat and destruct the cells – without changing the position of the microwave applicator. For Vogl, it is also important that the system is compatible with MRI scanners so that the success of treatment can be monitored in real time.

For this form of therapy, there is already a precursor known as RF ablation. It uses radio waves, however, rather than microwaves. Much more power is needed to heat the tumours and detection is not possible. The microwave system that Vogl and Jakoby are working on would offer patients significant added value due to the two operating modes and compatibility with MRI scanners. Over the next three years, comprehensive testing will be performed on phantoms, healthy and diseased tissue using various microwave probes and the optimum frequency ranges for differentiating cells will be identified. Carolin Reimann will be carrying out these tests. „First we will set up a reference database so that we are certain that we are actually able to measure even subtle differences,“ explains Reimann. „We hope to have a functioning and reliable prototype by the end of funding. Right now we are just getting started.“

Dr. Martin Schüßler is in charge of another subproject involving Professor Thomas Schwartz and Dr. Bastian Rapp from the Karlsruhe Institute of Technology. The partners on this project aim to use high-frequency measurement equipment that is yet to be developed and microfluidics to analyse pathogens in biofilms. These can develop on implants and catheters, for instance. First, the project partners will perform an inventory of biofilms and identify the bacteria by their genome. The next step is to check whether the genome data and high-frequency data correlate. „We hope to scan biofilms using high-frequency measurement equipment and thus be able to determine their composition,“ says Schüßler. „It may then be possible to render germs harmless using the high-frequency technique because any object containing water can be heated by microwaves.“

On another sub-project, Damm and Göringer are teaming with Professor Heinrich Kurz from AMO mbH, a company from Aachen, to develop a new sensor for detecting African trypanosomiasis. This parasitic disease causes sleeping sickness and results in death if untreated. Early detection of the parasite in the blood is therefore essential. Up to now there is no method that works in difficult on-site conditions and without laboratory diagnostics. The scientists aim to plug this gap using an electromagnetic sensor that operates in the terahertz frequency range. Expectations of this priority programme are high.

The author is a science journalist and has a PhD in biology.

Photo: Katrin Binner

Series of measurements to develop minimally invasive microwave test probes which in future could be suitable for diagnostic and treatment purposes: Carolin Reimann M.Sc., Prof. Rolf Jakoby, Dr. Martin Schüßler, Dr. Margarita Puentes (from left to right)

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More efficiency, less pollutant emission

Clear objectives: 90% less nitrogen oxide and 75% less CO² in the air. Aircraft engines must become more efficient and eco-friendly. This will only happen with new combustion technologies and a vastly improved, advanced turbine design. TU Darmstadt and Rolls-Royce are investigating how the combustion chamber and turbine can be optimised jointly in the "Combustor and Turbine Aerothermal Interaction" research centre.

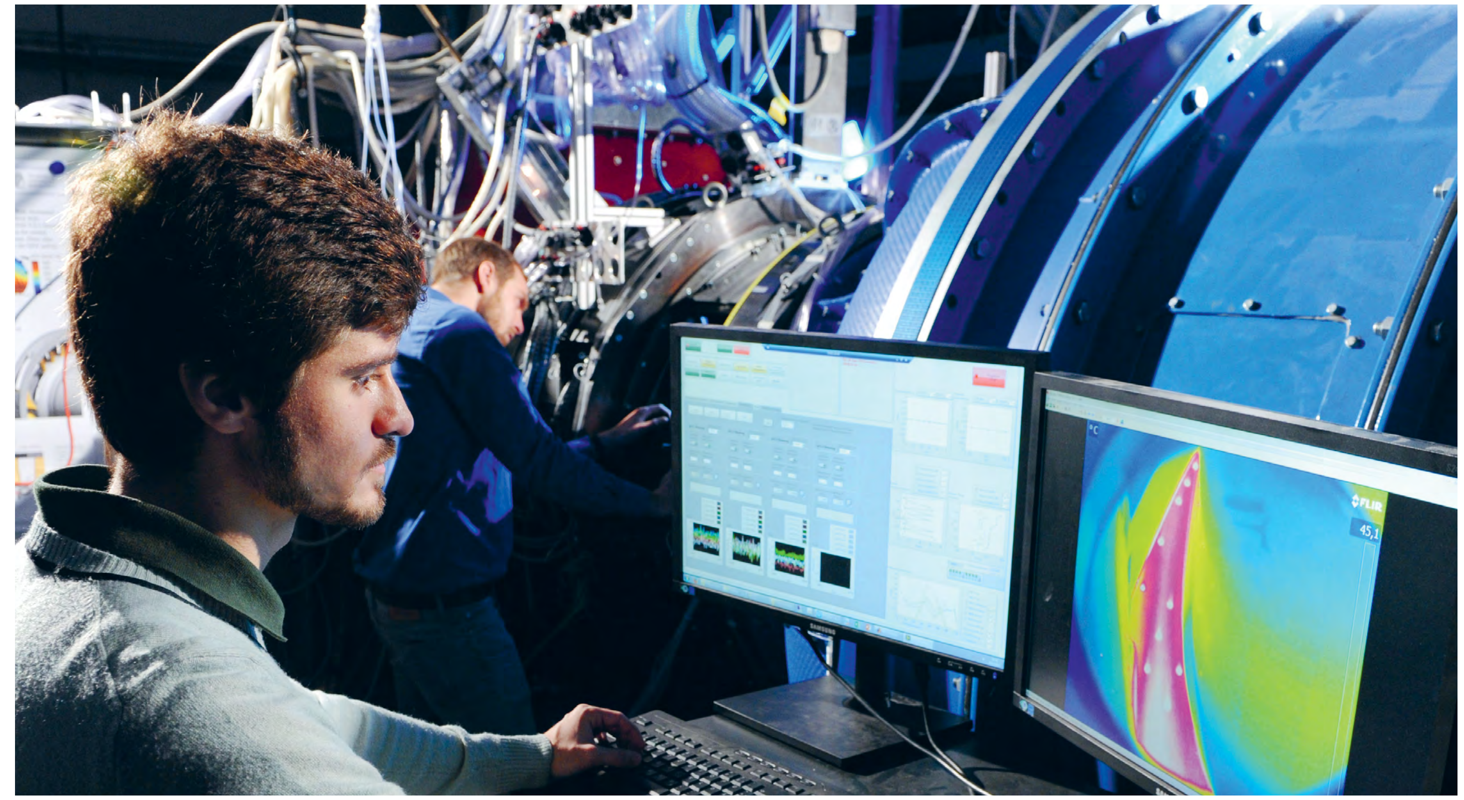
Photo: Rolls-Royce Deutschland

Test analysis on the "Large Scale Turbine Rig"

By Jutta Witte

The superlative turbine test rig: Scientists from the Institute of Gas Turbines and Aerospace Propulsion are adapting engine turbines to the combustion technologies of the future on the „Large Scale Turbine Rig" (LSTR). You can stand upright in this test facility – the LSTR turbine in the machine hall at the university is almost twice the size of a real engine turbine. This turbine test rig is the only one of its kind in the world so far, and occupies three rooms in total. The turbine at the centre looks like a huge cigar, surrounded by hoses and cables. These make up a network totalling 800 pressure measuring points and 200 temperature measuring points. The primary air for the turbine is supplied through piping from an adjoining room, the air for the cooling system is taken from the exhaust air duct and diverted to a third room. There it is compressed to a higher pressure and finally made available to the turbine as secondary air. The whole thing works as a closed loop system that is as efficient as it is flexible.

"We need this scaling for optimum access to the areas of measurement", explains Professor Heinz-Peter Schiffer, Head of the Institute for Gas Turbines and Aerospace Propulsion, or GLR for short. The research centre's "Combustor and Turbine Aerothermal Interaction" (CTI) experiments on the LSTR currently address interface boundary conditions between the combustion chamber and the turbine that arecrucial to the development of modern engines. The focus here is on the aerodynamic and thermal interaction between the two components. Because although new concepts, such as so-called lean combustion, where the proportion of air mixed with fuel at the entrance to the combustion chamber is far higher than in conventional combustion chambers, can greatly reduce the production of pollutant emissions, they also change the flow field, as well as the temperature distribution at the transition to the turbine.

Even conventional combustion processes expose the turbine components to tremendous thermal and mechanical stresses. The airflow can be as hot as 400 Kelvin at the entry to the high pressure compressor which keeps compressing the air until it reaches the combustion chamber. After combustion, it encounters the first row of turbine stators at around 1800 Kelvin. This is way above the melting temperature of the materials used, and a complex cooling system is required to make flying safe. "The rotor hub and tip sections are the most crucial areas", explains Schiffer. But if you reduce the temperatures, you also lose engine efficiency and increase fuel consumption. Engineers must also take into account the centrifugal force acting on the rotating components of the turbine. It is a delicate balancing act to keep everything in equilibrium.

Lean combustion, where 70% of the compressed air is injected through nozzles, together with the fuel, at the entrance to the combustion chamber, poses new challenges to the scientists. In the so-called entrance traverse, the transition from the combustion chamber to the turbine, it causes the combustion gas to swirl powerfully as it hits the turbine, and leads to an uneven distribution of variable quantities such as pressure, temperature and velocity. "We have now realised just how high the losses can be, if this inhomogeneity is not taken into account when designing the turbine", says Schiffer. As much as 1.5% of the turbine efficiency was lost in this situation. Although this may not sound like much at first, it gets put into perspective once you consider that it takes a manufacturer up to ten years to increase turbine efficiency by just 1%.

"We are fighting here for every tenth of a percentage point that we can end up winning, or at least not losing", says Schiffer. "So it is crucial to know exactly what the conditions are at the entrance traverse". The expert sees two main determining factors with regard to the new combustion technology: improving turbine efficiency by minimising losses here, adapting the cooling system to the changed conditions there.

As a CTI research centre partner the GLR scientists start their tests on the "Large Scale Turbine Rig" where the research work of the numerical modelling and simulation experts from the department of "Energy and Power Technology" (EKT) on the reactions in the combustion chamber, ends. In addition to basic measurements, for determining the efficiency of the turbine, for instance, the researchers also get to the bottom of the details, including checking how well the blade cooling system is working. The blading is extensively equipped with instruments for this purpose. Photos taken by an infra-red camera through small inspection windows record the temperature distribution of the heated end wall. Using its temperature, the temperature of the air and the heat introduced to the end wall, it is possible to determine the heat transfer and the effectiveness of the cooling film in this area.

The test facility is also extremely flexible. The tips of the turbine blades, with their different geometries, can be changed in accordance with the modular concept – "a highly ingenious system", in Schiffer's opinion. Three generations of students were involved in its development during their bachelor and master theses. Six research associates have already carried out their tests for their doctorates. It takes a day to configure the facility for each investigative cycle. This also includes setting up the 16 swirl generators that are positioned around the circumference of a fixation ring upstream of the turbine. They are necessary because the experiments run without real combustion. The scientists use the swirl generators to simulate the velocity and pressure distributions occurring at the exit from realcombustion chamber or at the entrance to the turbine.

> *"We are fighting for every tenth of a percentage point that we can end up winning, or at least not losing."*

It was three years in total before the GLR experts were ready to start using the rig for combustion chamber turbine interaction tests under aerodynamic turbine inlet conditions similar to those generated by lean combustion. "We can now measure the distribution of pressure and velocity between each row of blades, as well as follow how the entire process develops, from where the air enters, to where it leaves the turbine.", reports Schiffer. "We want to work forward gradually, from the entrance to the turbine to the last row of blades."

With experiments on the rig, his scientists can examine how reliable the design tools developed by their industry partners actually are. They can explain why certain conditions worsen or improve and when they do so, and ultimately, they can make concrete recommendations to the manufacturer about development, and designing products for future engines. "We provide the impetus for change", stresses the Head of GLR. So far, lean combustion chambers have only been tested in a core engine being operated in a test facility. The next step is to fly with such a combustion chamber in one of the four engines of a Boeing 747 test aircraft. Experts estimate that it will be at least five more years before the new technology can be used in passenger aircraft.

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More efficiency, less pollutant emission

The development of aircraft engines will not work without new methods of simulation. The Department of Energy and Power Plant Technology at TU Darmstadt shows how numerical modelling can help.

University Technology Centre (UTC)
The "Combustor and Turbine Aerothermal Interaction" (CTI) research centre is one of 31 University Technology Centres (UTC) run by Rolls-Royce throughout the world in collaboration with famous universities. Since its foundation in 2006, a total of 28 doctoral projects have been supported, as well as around 50 bachelor and master theses written. The CTI wants to keep trying to achieve one of the key objectives of the aviation industry – the clear reduction of fuel consumption and pollutant emissions. Working on behalf of TU Darmstadt are the Institute of Gas Turbines and Aerospace Propulsion (GLR) and the Department of Energy and Power Plant Technology (EKT), partners in the basic agreement with Rolls-Royce. Also involved in the research collaboration in individual projects are the Institute for Reactive Flows and Diagnostics (RSM) and the Institute for Mechatronic Systems in Mechanical Engineering (IMS). The research centre works together with small and medium-sized local companies to produce the components for the "Large Scale Turbine Rig". In 2013, TurboScience GmbH was founded as an engineering services provider for turbomachines, as a UTC spin off. 600 people are working worldwide in the UTC network, around 400 publications are produced from UTC research work every year, 10% of the annual Rolls-Royce patents stem from this research group.
www.glr.tu-darmstadt.de/glr_forschung/utc/index.de.jsp

Increasing environmental and efficiency requirements are further advancing the optimisation of aircraft engines. Without complex numerical simulations to describe in advance how a technical system behaves and thus provide useful guidance data for its development, manufacturers such as Rolls-Royce cannot identify and exploit this potential. At the Department of Energy and Power Plant Technology (EKT), it is all about figures, equations and algorithms. The scientists develop new methods, so that they can be calculated by high performance computers. They must provide as much accurate information as possible in advance, so that developers and technicians feel safe putting it into practice at a later date. As part of the "Combustor and Turbine Aerothermal Interaction" (CTI) research centre, Professor Johannes Janicka and his team are currently concentrating on the careful examination of the processes in the combustion chamber and at their transition to the turbine. "It will be a major step forward when we succeed in describing the interactions at this transition", explains Janicka, head of EKT..

"We need a whole set of differential equations that sometimes even a computer can only resolve approximately."

The objective is a simulation model that firstly simulates the interaction between flame, turbulence and fuel in the combustion chamber, but which secondly also simulates the behaviour and properties of the flame at the transition to the turbine – and ideally, by using a single numerical system. A whole conglomeration of processes, all inter-related, is included in the calculations: chemical reactions that affect temperature, emissions and particle concentration, physical processes such as flow, and last but not least, the behaviour of the kerosene injected into the combustion chamber. "To cover all that in a simulation, we need a whole set of differential equations that sometimes even a computer can only resolve approximately", explains Janicka.

What this means can be shown by taking a look at the injection of fuel into the combustion chamber. This leads to reactions between the droplets of kerosene and the air from the compressor, between the drops themselves and in the transition from the liquid to the gaseous state. To be able to make predictions that are as realistic as possible, even though the processes are so complex, the scientists simplify the processes and only take the most important variables into account in their models. Ten to twenty are usually left over at the end. This reduces the amount of effort required to calculate the problem. This three-dimensional flow field is divided into tens of millions of points. The computer then calculates the correlations between these points.

"We simulate reality in a reduced system", says Janicka. A simulation can last for a few days or even weeks. But it is worth the effort. Numerical modelling and simulation are so important because they also save the industry from having to carry out complicated, lengthy and expensive experiments. "The trend is towards finding out as much as possible in advance, on the computer", explains the expert. Six of the approximately 30 people in his team are currently involved in Rolls-Royce projects. "We are effectively creating the toolbox the company needs for its development work". The codes that are being developed here will first be verified by comparisons with the experimental work of the Institute for Reactive Flows and Diagnostics (RSM) at TU Darmstadt and will then be used in the Rolls-Royce Technology Centre.

Without research, such as that currently in progress at EKT, the next generation of combustion processes currently being developed by the company would not be conceivable. Combustion in aircraft turbines runs according to the so-called rich/lean combustion principle. An RQR (Rich Quench Lean) combustion chamber consists of three zones: in the first, the air compressed in the compressor arrives at a pressure of around 50 bar; the kerosene is injected in droplets through a nozzle. Because the proportion of the droplets in the mixture is high, it is called a "rich mix". In the second zone, additional air is supplied from the holes in the wall of the combustion chamber, until in the third zone, a lean flame is burning with a lower ratio of kerosene. The process is good for the flame, because its burning is controlled through all the flight phases, thus ensuring a safe flight. Although it does produce a considerable amount of soot and CO in the primary zone and a lot of nitrogen oxide at the transition to the lean mix.

This effect is reduced if the so-called stoichiometric points at which the highest temperatures occur are passed as quickly as possible. However, the problem can only basically be solved by a totally new combustion system – lean combustion. If the mixing process takes place immediately after the compressor, there can be no local occurrence of peak temperatures. As a result, the temperature in the combustion chamber drops and less nitrogen oxide is produced.

But how do you stabilise a flame under these conditions? This is the challenge that the numerical modelling experts and their colleagues from the Institute of Gas Turbines and Aerospace Propulsion (GLR) exploring the issue experimentally, work together to deal with the challenge. Because lean combustion requires a new design of combustion chamber,the EKT scientists must develop new models for this problem and bring together in a simulation the currently still separate calculations for the combustion chamber and the turbine.

This is difficult, because the unstable flames that occur during this process are far thinner than in rich/lean combustion. Different temperatures and velocities prevail here. Turbulence takes on a new form and intensity. What is needed are finer numerical grid structures and new modelling concepts to cover the problem. In addition to this, the calculations for the compressor and the turbine on the one side and the combustion chamber on the other, currently use different software, because different pressure prevails at the two locations.

With this problem, the experts have resolved the first step by developing the existing design code "PRECISE-UNS" to the extent that both components can now be calculated uniformly with compressible methods. "Admittedly it is still only a combustion code", says Janicka, "but now we can include the turbine in our calculations". But the objective is to be able to simulate an aircraft engine as a complete system.

The author is a science journalist with a doctorate in history.

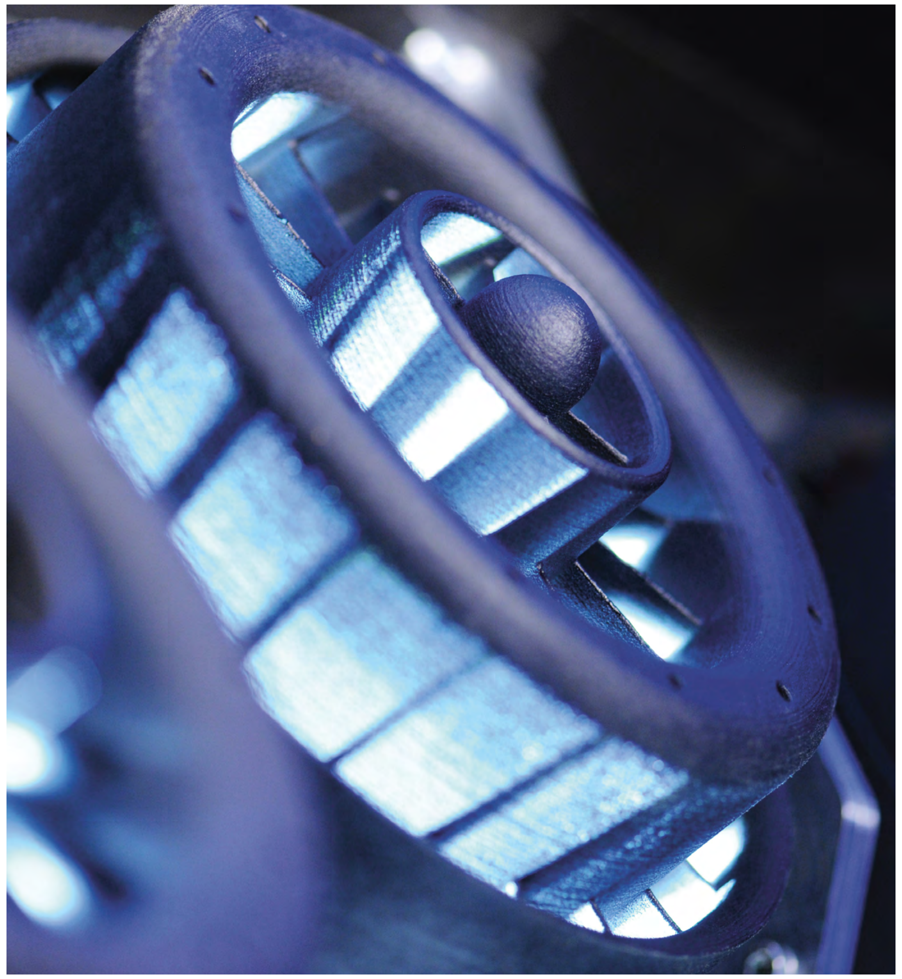

Photo: Rolls-Royce Deutschland

Flow swirl burner at the entrance to the turbine on the „Large Scale Turbine Rig".