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RESEARCH NEWS

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1 Space probes: sterile launch into outer space

Components used on a space mission must be cleaned meticulously. Fraunhofer researchers designed a cleanroom for the ESA (European Space Agency) in which the most infinitesimal contaminants can be removed. These experts, together with partners, are sterilizing ESA's "ExoMars" Mars rover, scheduled for launch in 2018.

2 Smart driver seat that responds to gestures

A multitude of professional drivers suffer from back problems. One cause: driver seats that are inadequately adjusted to each driver's ergonomic needs. Fraunhofer's researchers, in joint collaboration with Isringhausen GmbH & Co. KG, engineered a driver's seat whose shape and position can be adjusted by using simple hand gestures.

3 Proving nanoparticles in sunscreen products

Loads of cosmetics like sunscreen lotions contain titanium dioxide. These nanoparticles are contentious. Experts suspect they may have harmful effects on people and the environment. But it is difficult to prove that the particles are in the lotions. Using a method developed by Fraunhofer researchers, the particles can now be calculated.

4 A flexible solution for secure IT in cars

Today, almost everything in your car is managed by an electronic control unit (ECU). The problem is that these minicomputers are increasingly coming under attack. Fraunhofer researchers have now developed a platform that makes it possible to flexibly install secure devices in a way that is based on open and vendor-neutral hardware and software standards.

5 Heating with the sun

Solar-Active-Houses heat themselves using heat collectors and water tanks. However, no one had conducted an objective assessment of how efficiently they do so. Fraunhofer researchers put some of these solar houses to the test, identified where there was room for improvement and laid the scientific groundwork for this housing concept.

6 Cutting costs in aircraft turbine production

Compressor disks for aircraft turbines are milled from a single piece of material. During processing, the blades begin to vibrate. Now, a novel clamping system boosts vibration absorption for the blades by more than 400 times, and cuts manufacturing costs by as much as 5000 euros.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 66 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 24,000, who work with an annual research budget totaling 2 billion euros. About 70 percent of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the Americas and Asia serve to promote international cooperation.

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Space probes: sterile launch into outer space

Space missions are inextricably linked to tremendous costs and great risks. The numerous aborted projects lend proof to this fact. Since an unmanned space probe, once started, can no longer be repaired, it is imperative that no part or assembly fail. All the effort would otherwise be for naught, and scientists would have to wait several years for a replacement mission. Contaminants play an important role. Because dirt can block mechanisms, cause a short or disrupt the electronics. Things start getting especially tricky when a probe is supposed to look for traces of life on a distant planet – which is precisely the agenda for the "ExoMars" European Mars Mission, scheduled to launch in 2018. A Mars lander will set down on our neighbor planet and then launch a rover about the size of a car by automaker smart. To ensure its sensors operate reliably as they search for signs of life, the mission must avoid introducing any organic material from earth.

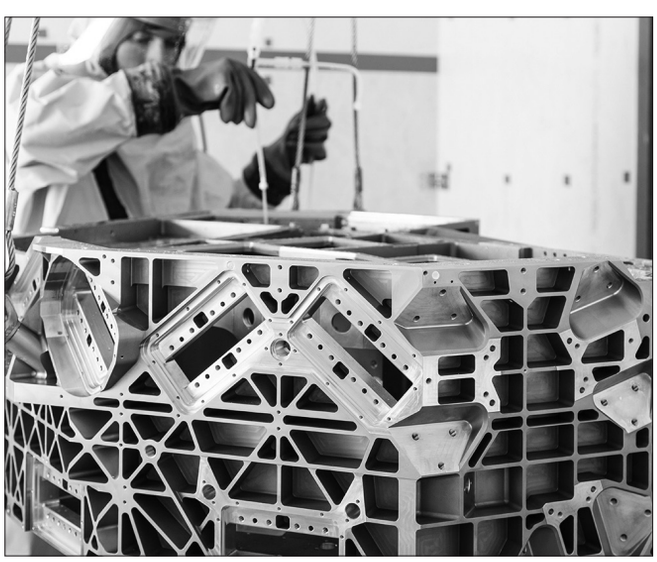
Cleanroom designed for the ESA

On behalf of the European Space Agency, ESA, the research team at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA is working assiduously to ensure all components are utterly and perfectly sterile, removing even nano-sized contaminants. For its design, the scientists could fall back on the collective expertise at Fraunhofer; indeed, one of the best-equipped cleanrooms in the world is located at Fraunhofer IPA in Stuttgart. To ensure they can sterilize the Mars rover reliably, the experts at ESA drafted the plans for a cleanroom and installed it in the Dutch town of Noordwijk, at the headquarters for the European Space Research and Technology Center (ESTEC). The roughly 70 square meter, sterile-controlled area is sufficient to meet the toughest purity standards, including ISO Class 1. This means that a cubic meter of air may not contain more than ten particles of 0.1 micrometers in size. The ultrasterile section is about one billion times cleaner than the air in the surrounding environment.

The design by the IPA researchers encompasses both the planning as well as the layout, quality assurance, realization, certification testing, and operational launch. "We tied together an all-round, no-hassle package, measured the space, decided on the selection of sterilization and cleaning technology, the systems and ventilation equipment, the floor coatings, the filtration systems, and the sterilization equipment, and submitted recommendations to industrial partners who built the space," Dr. Udo Gommel, Manager of the "Electronics and Microsystem Technology" business unit at IPA explains. "For instance, it is important that the floor fits with the walls with respect to its exhaust gas performance. Synthetics isolate destructive exhaust products that might collect on optical lenses, for instance. These contaminants would trigger imaging errors," the engineer and physicist further explains.

One process that has proven to be especially effective for sterilizing the Mars rover was developed at IPA and has patents pending. The method originates from the USA, and is used to remove paint from aircraft fuselage. A powerful jet of frozen carbon dioxide (CO_2) crystals, about the size of a rice kernel, blasts the paint right off the metal. The researchers made this crude instrument substantially more refined. Instead of CO_2 pellets, they use carbon dioxide snow to work on each individual component – from the highly sophisticated aluminum workbench to the ring washers. Here's the rub: the beam that the jet emits is additionally accelerated with a blast of CDA (clean dry air) that encases it. This is how it penetrates into every nook and cranny, removing even the minuscule pollutant. As soon as the tiny snowflakes hit the relatively hot surface, they become gaseous, causing their volume to explosively expand 800-fold. The detonation pressure completely sweeps away every single bit of dust, even fingerprints which the cold gas had just turned brittle. "This approach involves a dry process that does not warp surfaces. When cleaning, these can be gently treated with CO_2. That makes it unnecessary to apply heat or chemicals," Gommel says when explaining the advantages of this method.

The cleanroom is already operating; the research team is equipping it on an ongoing basis with sterilizer and cleaning technology, and optimizing the flow of material. In addition to the ESA, other national institutions – Thales Alenia Space Italy, an Italian aerospace corporation, for example – are using the facility for their space missions. And still other space agencies like NASA engage Gommel and his team on a consulting basis.



Scientists are regularly preparing instruments for space missions at their cleanroom laboratories. Here, "star attraction" on center stage is the preliminary cleaning of a satellite component. (© Fraunhofer IPA) | Picture in color and printing quality: www.fraunhofer.de/press

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Smart driver seat that responds to gestures

Sitting for hours on end with little movement: it's part of everyday working life for the professional driver. On average, they spend nine hours a day in the vehicle cabin. As a result, at some point a number of drivers develop problems with their back. In study after study, statutory health insurance was able to demonstrate that a driver's seat that is adjusted to the person at the wheel in terms of shape and position, can be an effective countermeasure to back pain. Certainly the majority of truck seats possess a wide selection of seat position options – yet the majority of drivers use them only sporadically, since operation is complicated and there often is not enough time for a correct setting.

A new, intuitive operating design should change all this. Researchers at the Fraunhofer Institute for Silicate Research ISC, in collaboration with Isringhausen GmbH & Co. KG., have engineered a driver's seat that can be calibrated intuitively through gestures. „To accomplish this, we use a sensor-based gesture control system in the driver's seat," explains Johannes Ehrlich of the Center for Smart Materials (CeSMa) at Fraunhofer ISC. „With the aid of simple hand gestures, the driver can move the seat forward and back, as well as up and down. In addition, he or she can also custom-set the incline of the thigh support and back rest in the same manner."

Sensors that react to a brush of the hand

The scientists integrated various sensors into the synthetic side cover so that the seat reacts to the driver's hand motions. Piezosensors are sensors that respond to pressure. They ensure that the motion-controlled system is activated. To do so, the user has to briefly press a certain point on the side cover. „This way we prevent the motion control from being accidentally triggered," Ehrlich explains. In addition, seat positions can be stored through this point by pressing several times. A useful option if multiple drivers are using the same truck. Proximity sensors that are likewise built into the side cover are used to detect gestures. They can track the smallest changes in electrical fields in the environment, such as when they are triggered through hand motions. Another software program likewise engineered at ISC reads these sensors and determines the hand's direction of motion from this. The arrangement of the sensors in the side panel is therefore of decisive importance. „We have attached electrodes to the relatively limited space, so that the necessary control gestures are easy and ergonomically favorable," explains Ehrlich. Moreover, an intelligent algorithm in the software guarantees that multiple electrodes can be evaluated simultaneously, thereby reducing incorrect operation.

In order to set the seat position, the driver performs brief hand motions along the entire side cover – you can more or less imagine this to be similar procedure to the „brushing" motion on a touchscreen. That means that the driver only has to lightly

touch the cover. Depending on the directional motion of the gesture (up/down, forward/back, diagonal), the individual seat elements are adjusted accordingly. Once the operator has performed the settings, the gesture control automatically shuts off as soon as the hand is moved away from the sensor area. The driver then receives confirmation that the gestures were stored successfully through an LED-instrument.

Isringhausen GmbH, together with the ISC scientists, has already realized a fully functional prototype of the sensor seat. It will be unveiled at the IAA in Frankfurt this year. Currently, the project partners are concentrating on the automotive market. Over the long term, the gesture-controlled seat may also be of interest to the middle and upper-class automotive market, in order to enhance driver comfort.

Ease into the correct seat position: with the new seat model, a few hand gestures at the side panel are all you need. (© Isringhausen GmbH) | Picture in color and printing quality: www.fraunhofer.de/press

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Fraunhofer

Proving nanoparticles in sunscreen products

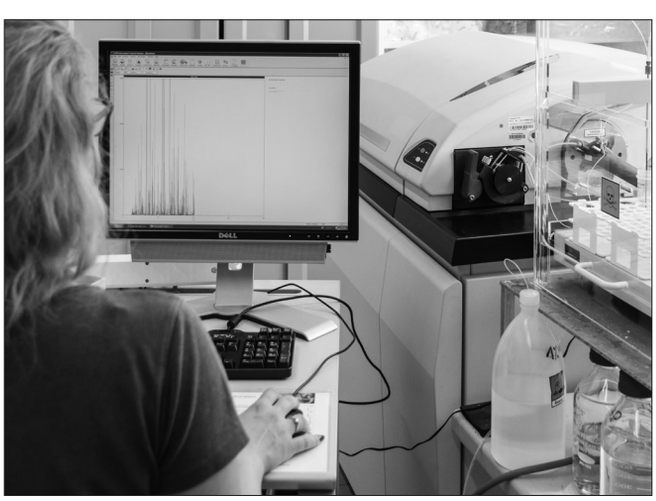
Cosmetics increasingly contain nanoparticles. One especially sensitive issue is the use of the miniscule particles in cosmetics, since the consumer comes into direct contact with the products. Sunscreen lotions for example have nanoparticles of titanium oxide. They provide UV protection: like a film made of infinite tiny mirrors, they are applied to the skin and reflect UV rays. But these tiny particles are controversial. They can penetrate the skin if there is an injury, and trigger an inflammatory reaction. Its use in spray-on sunscreens is also problematic. Scientists fear that the particles could have a detrimental effect on the lungs when inhaled. Even the effect on the environment has not yet been adequately researched. Studies indicate that the titanium oxide which has seeped into public beaches through sunscreens can endanger environmental balance. Therefore, a labeling requirement has been in force since July 2013, based on an EU Directive on cosmetics and body care products. If nano-sized ingredients are used in a product, the manufacturer must make this fact clear by adding "nano-" to the listed ingredient name. Due to requirements imposed by the legislature, the need for analysis methods is huge.

Determining particle sizes down to the tiniest scale

Today's electron microscope imaging processes, such as transmission-electron microscopy or scanning electron microscopy, are based on the properties of light dispersion. They are used to detect all particles present. They do not differentiate between a cell, a nanoparticle – or a piece of lint. These methods are ideally suited for the study of surface properties and shapes. "The light diffusion process and microscopy are not selective enough for a lot of studies, including toxicological examinations," says Gabriele Beck-Schwadorf, scientist at the Fraunhofer Institute for Interfacial Engineering and Thin Films IGB in Stuttgart. The group manager and her team have advanced and refined an existing measurement method in a way that allows them to determine titanium nanoparticles within complex media consisting of several different components that are highly sensitive and delicate. Researchers measure individual particles by single particle, inductively coupled plasma mass spectroscopy (or SP-ICP-MS). "With this method, I determine mass. Titanium has an atomic mass of 48 AMUs (atomic mass units). If I set the spectrometer to that, then I can target the measurement of titanium," explains Katrin Sommer, food chemist at IGB. With particle measurement, a suspension is sprayed into the plasma that contains both large and small particles in non-homogeneous distribution. The suspension has to be thinned out sharply so that one titanium dioxide particle after another can be detected and analyzed. Ions are formed out of these particles in hot plasma of about 7,000 Kelvins. They get to the spectrometer's detector as an ion cloud, and are counted within the briefest measurement time of about three milliseconds. Signal intensity correlates to particle size. "We convert the intensity into nanometers. At the same time, we count particle signals, from which we calculate particle concentration with up to ten percent accuracy. We can establish

exactly how many particles are of a specific size," says Sommers, explaining the procedure. It was IGB scientists who originally developed the methods for measuring titanium oxide nanoparticles in wastewater. "But the process is generally suitable for complex media, and can also be applied to sunscreen lotions," the researcher indicates. A unique feature of this approach: the IGB team performs the data analysis and data processing without specialized software. "We have statistically evaluated the raw data using a standard computer program, and thus can work irrespective of the producer. Compared to existing methods, SP-ICP-MS involves a rapid process that uses detection limits that extend down to the ultra-trace amount scale below ppm." For example, one sample of just a few milliliters can be examined in about six minutes.

Cosmetics makers, nanotechnology businesses, and consumers can benefit from the particle analysis for quality assurance of sun protection and body care products, but also use them for analyzing water, drinking water, and food. The researchers are planning to measure other nanoparticles in the future as well, such as silica dioxide. One can only determine whether a product contains silica dioxide through complex measurements. In order to establish the presence of nanoparticles, one must first determine their size or size distribution. Based on the EU's definition, declaration requirements apply to a nanomaterial if at least 50 percent of the contained particles are of a size measuring between 1 and 100 nanometers (nm). Previous analysis methods are hitting their limits here. These make it possible to establish particle sizes only in pure solutions. They are not suited for analysis of complex media that one finds in modern cosmetics. In addition, nanoparticles with various chemical properties cannot be differentiated from each other this way.



When a nanoparticle enters into plasma, a discontinuous signal occurs. Signal intensity correlates to particle size. (© Fraunhofer IGB) | Picture in color and printing quality: www.fraunhofer.de/press

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A flexible solution for secure IT in cars

Cars are as much a part of the digital revolution as anything else – ECUs are used in controlling the engine, steering and braking. They can improve road safety, automatically call for help in emergencies and guide drivers to their next destination quickly and safely. Today's cars contain over 100 of these minicomputers. "IT has become one of the greatest drivers of automotive innovation," says Dr. Christoph Krauß of the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt, Germany. His focus is on IT security in vehicles. "Cars used to be closed systems, but today's IT interfaces are making them increasingly vulnerable to attacks," Krauß adds. There is no shortage of current examples either – hackers mine personal information, used-car dealers tamper with odometers, car thieves open doors and cheat immobilizers, and car tuning enthusiasts enable functions they haven't paid for. As technology continues to advance, it's becoming increasingly important to improve IT security in vehicles. "There are of course cryptographic solutions out there, but these tend to lack the required flexibility," Krauß says.

Development platform based on new security standards

Krauß and his colleagues have built a solution that uses hardware security modules (HSMs) for device protection. It's based on the latest version of the Trusted Platform Module – TPM 2.0 – an international open standard developed by the Trusted Computing Group. Almost all major IT companies are members of this consortium and they have been working together for over ten years to establish standards. For its part, Fraunhofer SIT shares its expertise in hardware-based security solutions. "Our solution is a software platform for developing secure ECUs based on TPM 2.0. It allows you to first simulate all essential vehicle ECU elements – hardware and software – for virtually any application before implementation," says project manager Andreas Fuchs. "This provides manufacturers with important information during development, which means they can reconstruct a range of application scenarios and iron out any kinks. They need to do this because they can't have a peek into real, completed HSMs for security reasons."

Depending on exactly what needs to be protected, TPM-based solutions developed using the new platform can either be installed directly into a given ECU or preset for it. The solution's hardware acts as a "trust anchor": A secure place for storing cryptographic keys and an execution environment for all security-relevant operations. It detects attacks and releases the key only when it is sure the device is working reliably. "Say someone has interfered with a car's parking assistance feature. In that case, the engine's ECU will prevent the car from starting. That means the parking assistant can't affect steering behavior in a way that may cause injury," Krauß says. The job of HSM software is to communicate with the hardware and to ensure that the security functions provided are embedded in the ECU's core tasks. Using this framework, the

Fraunhofer SIT research team developed an HSM demonstrator for a head unit, which is used to control a car's infotainment features. This head unit protects both manufacturer data as well as vehicle users' private data by preventing unauthorized extraction.

"TPM security modules can now be found in almost every desktop and laptop computer; for example, they safeguard the BitLocker drive encryption program for Microsoft Windows," Fuchs says. "Our development environment is helping the TPM standard to become more widely used in automotive applications. It's now easier for manufacturers to implement security standards as well as the applications based on them. What's more, the platform could also be used in other sectors – for instance, as a secure means of controlling industrial plants or for application in the Internet of Things." The technology is already in line to be licensed for two industrial applications and the researchers are very close to a finished automotive product. Krauß concludes, "It's clear that we're heading towards a world of automated driving, which only underlines the importance of automotive IT security."

The head unit demonstrator protects manufacturer data as well as vehicle users' private data by preventing unauthorized extraction. (© Fraunhofer SIT) | Picture in color and printing quality: www.fraunhofer.de/press

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Heating with the sun

Most of us know how irritating it is to pay for domestic hot water and space heating and then find out at the end of the year that you still owe. This wouldn't happen to you if you lived in one of the 1700 solar houses dotted around Germany, Switzerland and Austria. These houses are heated primarily using solar energy: Solar thermal collectors on the roof are used to heat water, which is stored in a large tank and used later for heating the house and providing hot water. Since these houses have excellent insulation, that takes care of some 60 percent of their heat demand.

Solar-Active-Houses are ideal for achieving the European Union's Energy Performance of Buildings Directive, which stipulates that all buildings built from 2021 onwards have to be nearly zero-energy buildings – in other words, buildings that consume minimum amounts of fuel. Solar houses are a viable alternative to passive houses, which rely chiefly on very strong insulation and a ventilation system that recovers and redistributes heat. Solar-Active-Houses have, however, been struggling to overcome one flaw – they hadn't undergone any systematic scientific testing or objective assessments of their efficiency.

Nine solar houses scientifically monitored

It is this scientific groundwork that has now been completed as part of the "Heizsolar" project, conducted by researchers from the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, together with colleagues at Solar- und Wärmetechnik Stuttgart, the Technische Universität Ilmenau and the Sonnenhaus-Institut. "For Heizsolar, we monitored nine Solar-Active-Houses over multiple heating periods," says Gerhard Stryi-Hipp, group manager at Fraunhofer ISE. "This gave us a foundation from which to optimize the houses and lower costs. We expect this will significantly enhance their importance in the future." The project was supported by the Forschungszentrum Jülich and received 1.5 million euros in funding from the German Federal Ministries for the Environment, Nature Conservation, Building and Nuclear Safety, and for Economic Affairs and Energy.

So what options do Solar-Active-Houses offer? In theory, it's possible to tap enough solar energy to cover a building's entire heating needs. But 100-percent solar houses are still something of a rarity – they are expensive and require that a significant amount of space be given over to the necessary long-term heat storage unit, which can sometimes be large enough to hold up to 50,000 liters. "Solar-Active-Houses which generate around 60 percent of the heat required using solar thermal collectors are a good and affordable compromise," Stryi-Hipp explains. "During spring and fall, 40 square meters of solar thermal collectors and a 5000-liter tank are fully sufficient for a single-family home. From November through January, the additional 40 percent must come from a gas or wood-fired boiler."

Up to now, the design of solar houses has relied mainly on the practical experience of individual experts. The researchers therefore decided to explore how to further optimize the Solar-Active-House and came up with a suitable simulation model to examine various aspects. For example, to what extent can the size of the tank be reduced in order to increase these houses' popularity? "It's possible to vary the ratio of tank size to collector surface area: In our 60-percent Solar-Active-House, we found we could reduce the tank volume from 6000 to 3000 liters as long as we also increased the area of solar heat collectors from 40 to 60 square meters."

Solar houses still have their share of challenges to overcome. The researchers have concluded that several of these challenges can be easily solved with thorough planning. Take the heat emitted by the storage tank, for example. While this is welcome in winter, in summer no one wants to further heat up an already warm house. "If you install the tank in the stairwell, for instance, the waste heat isn't wasted during heating season. And if you also install a window through which waste heat can be released, it won't bother you in the summer," says Stryi-Hipp. Other challenges call for further research, including how Solar-Active-Houses stack up against zero-energy or plus-energy houses. These are equipped with photovoltaic elements to generate electricity that is used in part to power heat pumps. The researchers plan to address this topic as part of a follow-up project so they can provide users with reliable assessment criteria.

Solar-Active-Houses get most of their heat from the sun. Researchers carried out scientific tests to explore how this energy concept can be optimized further. (© Klaus Lambrecht, solaroffice.de) | Picture in color and printing quality: www.fraunhofer.de/press

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Cutting costs in aircraft turbine production

Flying somewhere for vacation or jetting off to Rome, Paris or Madrid for a long weekend? Air traffic is on the rise, and passenger traffic in particular doubles every fifteen years. That's why manufacturers of aircraft turbines are trying to match their production capacity to this increased demand. It's not easy: Turbine blades are mounted on compressor disks, and to make these disks as light as possible, they are now milled from a single piece of material rather than constructed blade by blade, as they were in the past. Compressor disks made this way are known as "blade-integrated disks" or "blisks", and their job is to compress air in the turbine. But because turbine blades are by nature long and thin, manufacturing them all at once causes problems. They begin to vibrate like a tuning fork during production, which complicates any further work. To avoid this, manufacturers don't mill each blade completely, but instead precede step by step – manufacturers process the outer edge of the blade to its finished state before moving on. However, this manufacturing process has its own problems; the tension on the turbine blades causes their geometry to become slightly warped.

Clamping system eliminates vibration problems

A new clamping system from the Fraunhofer Institute for Production Technology IPT in Aachen promises a remedy for eliminating blade vibration. "With the clamping system, absorption in titanium blisks is 12.5 percent. Without it, absorption falls to just 0.027 percent," says Roman Kalocsay, an engineer at IPT. Using the clamping system, manufacturers can roughly mill the blades first, and then perform the precise finishing work because the blades no longer vibrate.

Eliminating vibration with the clamping system slashes manufacturing costs, too – as much as 5000 euros per blisk. The components can cost between 30,000 and 80,000 euros because vibrating blades also put a strain on the tools' cutting edge, forming fissures that quickly increase in size with mechanical and thermal stress. Tools often have to be replaced after cutting only four meters' worth of material. Initial experiments with the clamping system, however, suggest that tools could be used about two to three times longer than before.

So how does the clamping system work? "Spring-loaded clamps automatically grasp the blade with equal amounts of tension on both sides," Kalocsay explains. "As soon as the elements are in position, they are hydraulically clamped in place and hold the workpiece as if it had grown there." The clamping system prototype was created by the Fraunhofer Innovation Cluster Adaptive Production for Resource Efficiency in Energy Generation and Mobility AdaM.

During repair, the blades cannot be milled piece by piece out of the material – after all, all of the blades are already in place. Instead, if their edges appear to be "frayed", for

example, the manufacturer reapplies the material using laser metal deposition and then mills it to the desired form. Workers attempt to hold the blade in place as best they can using clamps or rubber, but it is nearly impossible to align them perfectly. Consequently, the workpieces must be re-measured afterwards in a time-consuming process because it is not clear how much they have drifted to the left or right. The clamping system helps here, too. "It doesn't change the blisk's geometry by even a micrometer. The blade is fixed in place in just a few seconds and can be worked on immediately," says Kalocsay. The process is slightly different than with a new blisk, however: The clamping elements are arranged in a circle and hold, not one, but all blades at the same time.

The three-part clamping system holds the blisk blades (just below the middle of the picture in white). Cooling lubricant is being injected from above. (© Fraunhofer IPT) | Picture in color and printing quality: www.fraunhofer.de/press

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