Fully equipped for space

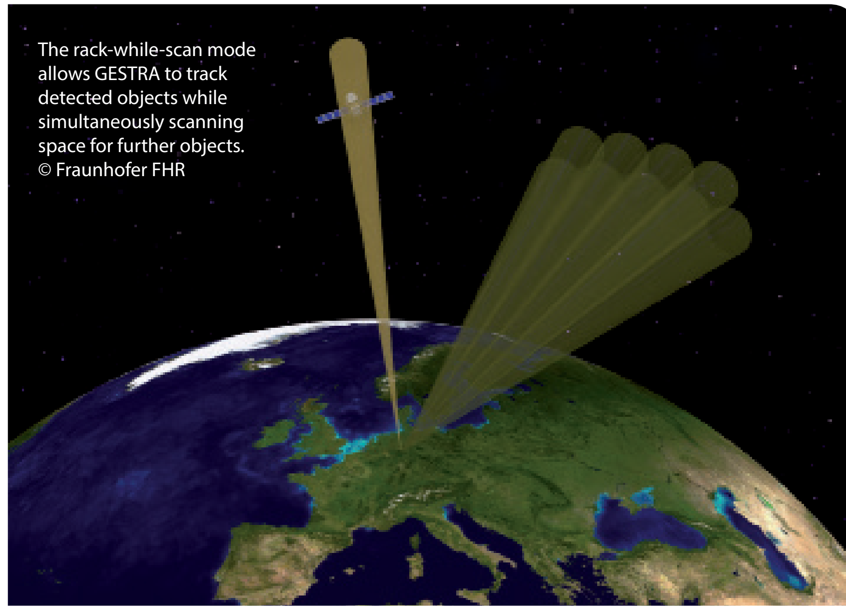
Space travel should be safe, cost-effective and environmentally friendly. A new radar system for the detection of space debris, special software for the vulnerability analysis of satellites, the versatile small satellite ERNST and a high-performance eco-fuel all combine to make this possible.

Text: Sonja Endres

ERNST is about the size of a shoe box, making it one of the larger small satellites.

In the blockbuster movie Gravity, the characters Dr. Ryan Stone and Matt Kowalski — played by Sandra Bullock and George Clooney — learned to their distress how devastating pieces of debris in orbit can be. And in real life, too, debris hurtling around in space damages satellites and space stations.

Back in 1978, American astronomer Donald Kessler warned about the common practice of leaving large objects such as burned-out rocket stages, payload fairings and disused satellites to orbit the Earth uncontrolled. He pointed out that every collision generated a large number of pieces of debris, which – in a chain reaction – would lead to countless more collisions in turn. Ultimately, this would render near-Earth orbits unusable, argued Kessler. Even launch vehicles would be unable to traverse this zone collision-free on their way to higher orbits – space travel would be at an end.
Although the amount of debris in space has increased considerably since the 1970s, happily this scenario has yet to transpire. Nevertheless, orbiting debris poses a serious threat to everything that moves in space. To avoid this debris, it is important to know where it is.



The rack-while-scan mode allows GESTRA to track detected objects while simultaneously scanning space for further objects. © Fraunhofer FHR

Safe travels thanks to GESTRA and TIRA

"Using the GESTRA surveillance radar, which was developed at Fraunhofer FHR, objects and pieces of debris can be reliably detected in low Earth orbit up to an orbital altitude of 3,000 kilometers," says Helmut Wilden, Team Leader for Multifunctional RF Sensor Technology at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg near Bonn.

While GESTRA is able to scan large regions of space around the clock, the TIRA radar system — also from Fraunhofer FHR – observes individual objects more closely (see January 2018 edition of Fraunhofer Magazine). "GESTRA can detect unknown objects, determine their number and calculate their orbits. More precise information about their size, shape or possible damage is supplied by TIRA." In this way, the two complementary radar systems supplement U.S. orbit catalogs, which have been the main sources of information to date. "NASA does not disclose all its data. Therefore, it is important to be able to access our own measurement data. We're proud that DLR Space Administration entrusted us with this official task on behalf of the German government," says Dr. Nadya Ben Bekhti, Co-Project Manager for GESTRA at FHR.

GESTRA consists of a transmission system and a receiver system, each of which are enclosed by protective casing known as a shelter. "The antenna technology is based on the phased array principle, which involves the pooling of radiation energy from numerous individual antennas. Using the beams – or "lobes" as we call them – you can not only scan large areas very quickly and flexibly for objects but also set aside one lobe for object tracking, while the remainder continue searching independently of the tracking lobe. This track-while-scan mode is optimized for use in space surveillance," explains Ben Bekhti.

GESTRA is unique in being extremely powerful and yet mobile. It can be transported anywhere using a heavy goods vehicle. "In this way, we can respond to changed environmental conditions," says Ben Bekhti. As soon as integration of the individual components into the shelters has been completed and everything has been successfully tested, GESTRA will be brought to its installation site in the summer of 2019. "It is expected that GESTRA will be installed on the Schmidtenhöhe site in the German city of Koblenz. The radar system will be connected to the German Armed Forces' Space Situational Awareness Center in Uedem in the far west of Germany, from where it can be operated by remote control," says Wilden.

Vulnerability analyses and intelligent design

When collisions with pieces of debris are unavoidable, robust materials and clever designs help protect satellites against serious damage. The new PIRAT software developed by the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI in Freiburg calculates whether the satellite design or individual components are able to withstand impacts from space junk. To do this, PIRAT takes into account the flight path of the planned mission and the

Conventional rocket fuel causes acid rain .
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particle collisions to be expected on that course. Combining this with the experimental simulation of collisions, the researchers at EMI create vulnerability analyses and protection concepts. Dr. Martin Schimmerohn, Group Manager for Spacecraft Technology at EMI, explains: "PIRAT allows us to determine the failure probability of individual components – including inside the satellite – if a piece of space debris pierces the external wall upon collision and spreads out as a cloud of fragments. Through the clever placement of components and the adding of thin protective layers, you can find a safe design with minimum impact on the overall system."

ERNST: the quick and cost-effective way of traveling to space

So that yet more space debris is not created in the future, today's engineers ensure that new satellites are able to re-enter the Earth's atmosphere under their own power to burn up there when their mission is over. The small satellite ERNST will also be equipped with technology to allow re-entry. In developing ERNST, EMI scientists have created a small satellite that is lightweight, reliable and versatile – reducing the development time and costs. "Generally, several small satellites ride piggyback with large launch vehicles – this allows even small groups of researchers with limited financial resources to carry out tests in space. In research, this is an important step forward for us,"

www: Fraunhofer-Allianz Space
www.space.fraunhofer.de/

says Thomas Loosen, Head of the Fraunhofer Space Alliance Administrative

Fraunhofer Space Alliance website: www.space.fraunhofer.de/

Small satellites – sometimes called cube sats on account of their shape – have a standard size of one unit (roughly 10 x 10 x 10 centimeters). Consequently, they fit perfectly into special containers which are stacked on top of each other in the launch vehicles. The disadvantage of cube sats is their limited performance. For example, they cannot be fitted with a large solar panel surface for generating power. In addition, the payload weight is also limited. As a result, there has been a trend toward building larger cube sats.

"ERNST consists of twelve units, making it about the size of a shoe box. The format is ideal, because it facilitates the carrying of more complex payloads and offers higher performance, while also ensuring compatibility with commercially available cube sat components," says Schimmerohn. Despite its larger size, ERNST still fits in the standard transport containers used in launch vehicles, filling their space to the maximum.

"The small satellite is designed as a sort of basic assembly kit, which is reproducible and can be individually adapted to meet the needs of particular missions," adds Schimmerohn. "We've procured flight-proven technology, such as the on-board computer, and combined it with our own technological developments, such as a filter wheel and a data processing unit."

Expanding possibilities in space

For its mission, which begins at the start of 2021, ERNST will be equipped with an infrared camera for Earth observation. Interestingly, the camera is mounted on a special bracket known as an optical bank, which was manufactured using metallic 3D printing technology. 3D printing methods afford new, almost unlimited design freedom as well as shorter production times. They have previously been used only to a very limited extent in the space sector on account of the stringent safety and quality standards.

"It's not the 3D components that are problematic, but conventional testing techniques. Many tests are based on optical methods, which do not work with the comparatively rough surfaces of additively manufactured parts," explains Schimmerohn. "The strain on the components is greatest during the launch of the rocket. In comprehensive tests, we established that the optical bank withstands this strain."

Schimmerohn and his team used the advantages that additive manufacturing techniques offer. Using intelligent algorithms, they developed a light, organically appealing structure that adapts optimally to the environmental conditions. “On the outside of the optical bank, we created a three-dimensional surface made up of many small pyramids. This gave us a larger radiating surface, via which the heat generated during operation of the satellite can escape into space. In this way, we could combine various functions in a unique component.”

Schimmerohn is convinced that additive manufacturing methods will be used increasingly in space technology in the future – not instead of, but as a useful complement to conventional techniques. “Equally, small satellites will not replace large ones, but will substantially expand our possibilities in space.” Schimmerohn sees great potential especially in the collecting and connecting of additional data. In addition, many small satellites can be connected to each other to form larger constellations, enabling them to provide services such as blanket Earth observation in higher quality.

Environmentally friendly launches

So that Earth does not suffer from the increasing activity in space, researchers at the Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe have now developed a rocket fuel that does not use ammonium perchlorate (AP), which is harmful to the environment and to human health. AP is used in conventional fuels as an oxidizer, which ensures that enough oxygen is available for combustion. The problem is that it produces tons of hydrochloric acid as a waste product – during the launch of the European Ariane or Vega rockets, around 70 tons; during the launch of the American Space Shuttle rocket, more than 80 tons. This acid gets into the environment and causes acid rain in the area around the rocket launch pads.

AP itself is also dangerous: it disrupts the human hormonal balance and leads to various serious effects in organisms. For this reason, the European Commission is considering whether to ban the production and use of AP. “With our fuel, which was developed in the joint European project GRAIL, we offer an AP-free alternative that is just as powerful,” says project manager Dr. Volker Gettwert. He and his team replaced AP with ammonium dinitramide (ADN) – an oxidizer that was developed in Soviet laboratories in the 1970s. “ADN is commercially available in large quantities. That is a big advantage compared to products we develop ourselves, because there are often problems in upscaling the volumes, in other words the step up from small quantities in the laboratory to large quantities in the factory. That costs time and money.”

However, it is not simply a matter of replacing AP either, because the new oxidizer also changes the characteristics of conventional fuel. “ADN burns off much faster than AP. We have to adjust the fuel mixture accordingly. After all, the rate of combustion determines the amount of gas that is produced – and more gas generates more thrust for the rocket. The new fuel must also withstand the compressive load generated during ignition. If it crumbles or cracks form, a huge surface is suddenly created. Then, much more is burned than intended, the pressure in the combustion chamber rises, and the whole thing can explode.”

The ICT team has managed to optimize the new fuel so that its characteristics match those of conventional fuel. “That’s a big advantage, as it means that the rocket propulsion systems do not have to be technically adapted to be able to use the new fuel. Accordingly, the chances are good that the fuel will be used in space travel in the near future.”

For transport, GESTRA’s radar dome can be removed and the antenna retracted.
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