# TO THE POINT.

## FROM EARTH OBSERVATION TO AUTONOMOUS DRIVING

Capturing the road environment accurately in an image: The radar satellite TerraSAR-X records distinctive points on the roadside (DriveMarks), such as traffic signs and guardrail posts (here at the Hittistetten motorway junction near Ulm). The information about lane markings was acquired from aerial images provided by a DLR research aircraft equipped with the Institute's own 3K camera system.

**Bright and piercingly sharp – a constellation of tiny white points appeared before Hartmut Runge's eyes every time he looked at the radar images acquired by TerraSAR-X. Focusing his gaze on these bright clues, the scientist from the DLR Remote Sensing Technology Institute made a surprising discovery – these were none other than lamp posts, traffic lights, street signs and similar objects along roads. At first, they were not useful for creating typical Earth-observation products, such as land use maps or digital elevation models. But the curiosity of the experienced researcher in the area of transport was sparked – because some of his colleagues had recently developed a high-precision position measurement technique.**

The DLR-developed DriveMark® technology now makes the creation of high-resolution digital road maps from space possible

By Bernadette Jung

GPS, Galileo and other global navigation satellite systems (GNSS) have become our loyal companions on unfamiliar and even well-known routes, always on hand to point us in the right direction. Such systems pinpoint our position with ever greater accuracy, depending primarily on the satellite signal. Every centimetre matters, especially when autonomous vehicles are increasingly part of road transport. Today's new cars are equipped with plenty of assistance systems and semi-autonomous functions that relieve the pressure on the driver. To achieve full autonomy, cars must be equipped with both satellite navigation and a system that indicates the correct route without using GNSS – should the signal be interrupted.

When Hartmut Runge identified the points of light in the radar image as traffic-related objects, the idea for DriveMark® was born: navigation using landmarks. Using vehicle sensors and a network of landmarks creates a globally available, highly accurate and reliable navigation system, independent of GNSS. "With the TerraSAR-X radar satellite and a special geodetic processing chain, we can pinpoint the x-, y- and z-coordinates of landmarks to a few centimetres without being in that exact spot. This makes it possible to record large or difficult-to-access areas very efficiently. With DriveMark®, we use satellite remote sensing technology and methods for navigation applications. We create reference points and road maps that are particularly useful for driver assistance systems and automated vehicles," says the DLR scientist in a calm and thoughtful manner. In recent years, he has had to present his application idea to key industry representatives in a host of presentations and pitches – and they showed a great deal of interest.

In 2013, his proposal won over the expert jurors in the international ‘Copernicus Masters’ idea competition, which is held annually by the AZO Anwendungszentrum GmbH Oberpfaffenhofen. The DLR scientist did not only win the individual ‘BMW Connected Drive Challenge’ invitation to tender, but was the overall winner of the competition.

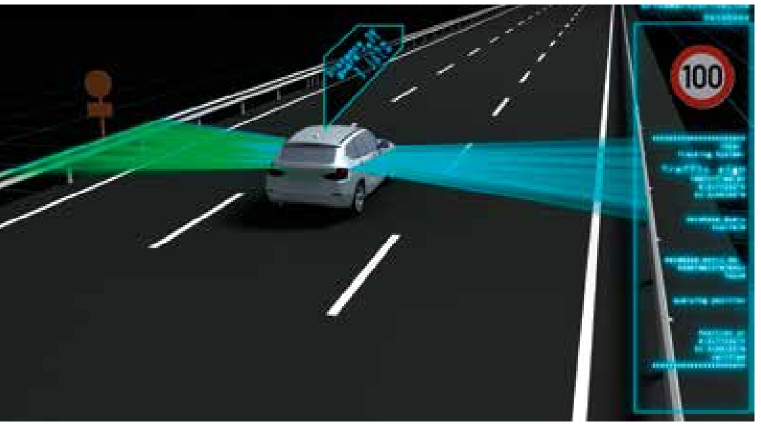
Runge’s award included consultation sessions with the Munich-based car manufacturer, allowing him to define the requirements for modern maps for autonomous driving and to further develop his idea in a targeted way. The patented DriveMark® system thus emerged as the theme of an innovation project with DLR Technology Marketing and support from the Helmholtz Validation Fund.

**Classic measuring principle and state-of-the-art technology**

The basic principle of finding one’s way using landmarks comes from traditional surveying. For centuries, people have used church towers, mountaintops and other fixed points of reference to triangulate the coordinates of other objects in the area. In the past, these landmarks always had to be plotted by a local survey team – any other method would have proven inaccurate. This was a cumbersome process that, unlike the satellite-based method, does not allow comprehensive mapping. Nevertheless, remote sensing satellites do not provide the required level of accuracy for navigation applications. DriveMark® now serves as a bridge between age-old measuring techniques and the very latest cutting-edge technology, opening up new horizons for future applications. To achieve this, Runge’s team has developed a three-part automated processing chain that converts remote sensing data into digital road maps with an absolute accuracy of 10 centimetres. As such, DriveMark® also meets the requirements for use within the autonomous mobility sector.

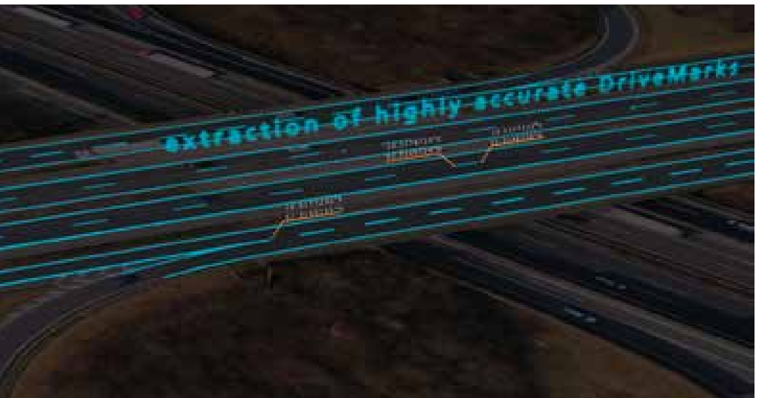
For this purpose, it is necessary to first identify traffic-relevant landmarks within the radar image and determine their exact coordinates. Traffic signs and guardrail posts are ideal for this purpose, as they stand on flat ground immediately adjacent to the road, thus forming a right angle. As such, they act as retroreflectors and return the radar signal in a highly focused form. In the radar image, they have a distinctive signature – sharp, bright dots against a dark background. “This is the same effect as the flash of cateye reflectors on a bicycle when the headlights of a passing car shine upon them – you simply cannot miss it,” the radar expert explains. Runge uses the base of the masts and poles as measuring points, known as ‘ground control points’ (GCPs), for the landmarks. In an automated process, the geodetic SAR processor – developed by the DLR Remote Sensing Technology Institute – determines the most suitable GCPs in the radar image and calculates the coordinates. It also takes account of, and compensates for, contributing factors that distort the measured results, such as ionospheric and tropospheric disturbances, as well as geodynamic effects due to tidal forces.

The ‘optical co-registration processor’ is used to transfer the coordinates of the landmarks from the radar image to optical images from satellites or aircraft. This is essential if the end product is to be used as a road map, and has the additional benefit that aerial images offer particularly high resolution. The processor ensures that a precise georeferenced view of the GCPs is generated, with an absolute accuracy of 10 centimetres. In the final processing step, topographical features are also extracted and digitalised from the optical image. The special ‘road feature extractor’ recognises, for example, road markings and supplements the landmark overview with lanes, side lanes and exits, creating a digital road map. “We have developed the technology in close collaboration with car manufacturers in order to offer a user-oriented product. The automated digitalisation of the control points and the map as a whole are essential features of and prerequisites for the marketability of DriveMark®.”

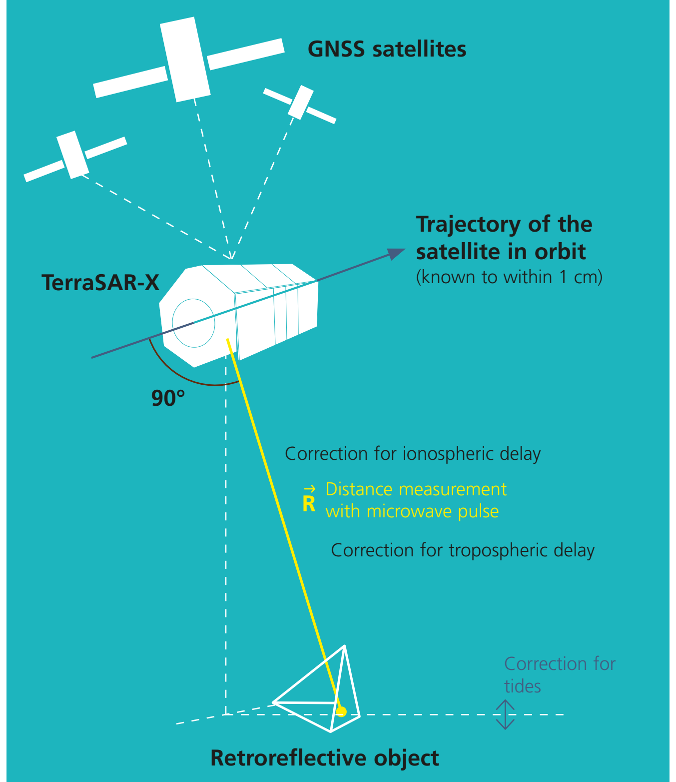



Positioning of an autonomous vehicle within the lane of traffic. The ‘DriveLines’ (crash barriers as well as the lines with the lane markings) are incorporated in the map with their exact coordinates. The traffic sign serves as a ‘landmark’ in order to safeguard the vehicle’s position once again.

Lane markings with their
exact coordinates are extracted from the aerial or satellite image




## REMOTE SENSING OF GROUND COORDINATES WITH TERRASAR-X




**Autonomous mobility and other applications**

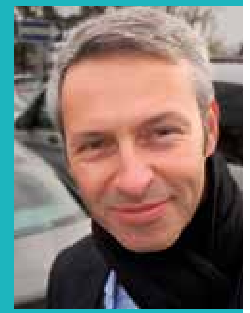
The ground control points obtained can be used individually as reference points as well as in the overall view of the navigation map. As such, they can be used as anchoring points for ‘mobile mapping’ and the ego-localisation of autonomous vehicles. Since the GCPs are digitalised, they can be fed into existing assistance systems, so that a vehicle equipped with an on-board camera, for instance, can aim for these control points and thus determine its own position. Drivers know exactly where they are at any given time or place regardless of GPS and other such systems. This makes automated driving with clear lane guidance and complex driving manoeuvres, such as changing lanes and making a turn, possible.

Hartmut Runge and his team have already developed the next process and applied for a patent. With DriveLine®, crash barriers and noise barriers on the edge of the road can be used to position the vehicle accurately within the lane. With the help of remote sensing, it is therefore possible to not only map the street itself, but also buildings in the surrounding area. Distance sensors in the vehicles continuously determine the distance to the ‘DriveLines’ and constantly compare these measurements with the map. This lane-keeping method serves as redundancy, for example, when back light causes glare in conventional camera-based systems. An accurate map can – if thought through consistently – also be used to prevent collisions and help to precisely locate sudden changes in surroundings due to accident sites and temporary roadwork.

This new method can also be used within the transport sector to map the test areas for autonomous driving in a targeted way, as this requires fast and precise data. In addition, map service providers can check their products for spatial accuracy, allowing efficient and independent quality control. Using ground control points is also a very attractive method in the construction industry, as there is no need for labour-intensive GNSS measurements on-site, especially in difficult-to-access areas. DriveMark® provides aerial and satellite images with exact coordinates, making them suitable for classic surveying and mapping tasks.

In the future, this unusual combination of remote sensing and navigation may also give rise to an array of new technologies and potential applications. Could Runge have predicted this turn of events when he first saw those bright pinpricks of light in the TerraSAR-X images? “No, of course not,” the experienced scientist says with a laugh. “I had no idea how big the project would become. In fact, when you take into account the preliminary studies, developing the technology and preparing it for industry, it was actually three projects in one. At the outset, I simply wanted to know whether these points could be used for traffic applications at all.” Well, this point has been made clear.

## INTERVIEW WITH ROBERT KLARNER, DLR TECHNOLOGY MARKETING



**Robert Klarner**

**How is the technology transfer process progressing for DriveMark®?**
The innovation project has been successfully completed and the results have been validated. The requirements have been met in full; indeed, in some areas the level of precision is even better than expected. As such, we have started marketing it to potential users of the technology. The initial orders for sample data show that there is real interest out there. The aim is to transfer the DriveMark® solution in such a way that commercial licensees can independently enhance or validate their highly accurate mapping products.

**Car manufacturers are already testing autonomous vehicles. How can advanced concepts like DriveMark® be used within this context?**
Experts agree that the new generation of navigation maps in the best possible resolution – meaning HD – are indispensable for safe and highly automated driving. DriveMark® can play its part by providing exact reference points that allow lanes and ‘road furniture’ to be pinpointed with precision. One particularly advantageous aspect of the system is that it can be applied comprehensively and automatically everywhere – in the United States or Asia, as well as in Germany. All of these are crucial success factors for the practical application of the technology.

**DriveMark® and DriveLine® are registered DLR trademarks – how does this drive a project?**
We are aware of the fact that our new process requires careful explanation and needs to become established. That is why we have opted for the registered trademark – it raises the profile of the technology with a focus on its key application. Ultimately, it is about developing the technology to create a new product for our clients and their customers. In the meantime, DriveMark® has become an international brand with recognition value within DLR and beyond. After all, innovation is what matters to the outside world for market execution.

**Hartmut Runge** is a communications engineer and has been involved in SAR technology development at DLR from the very beginning. He has been working in the field of transport applications for about 10 years.

## TerraSAR-X AND TanDEM-X

DriveMark® uses data from the German radar satellites TerraSAR-X and TanDEM-X to determine the position of objects on the ground. The orbits of the twin satellites are calculated with centimetre precision by the German Space Operations Center in Oberpfaffenhofen. Similar accuracies are achieved thanks to modern radar geodesy for the distance measurement between the satellite antenna and the object on the ground. Several shots from different angles are necessary for position determination in geodetic x-, y- and z-coordinates. The high precision of the DriveMark® process is further enhanced by the high geometric resolution of the radar images in the so-called ‘spotlight mode’. The radar satellites have been in orbit since 2008 and 2010, respectively, and are in excellent condition both in terms of battery performance and the radar instruments on board, so that operation can be expected to continue beyond 2020.