

PRESS RELEASE

PRESS RELEASE

June 2, 2025 || Page 1 | 4

Expert interview: satellite-based early warning

Improved Protection Against Missile Attacks

Satellite-based electro-optical sensors are intended to detect missile launches early on, gaining valuable time for initiating countermeasures in case of an attack. The Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB is developing design concepts for sensors like these on behalf of the German Ministry of Defense. In this interview, Caroline Schweitzer, a research scientist at Fraunhofer IOSB, explains what electro-optical sensors can do and how they work.

Why is research on electro-optical sensors becoming increasingly important in the security segment?

There has been a fundamental change in the security policy environment for Germany and the rest of NATO in recent years. It's gotten more complex, with more volatility. Numerous countries that are close enough to Europe to attack it are also able to develop and launch their own ballistic missiles. Some high-risk countries either already have or are developing missile systems with long combat ranges that allow them to reach targets in Europe. The use of satellite-based early warning systems is growing more and more important in light of the changing security architecture in Europe. Electro-optical (EO) sensors play a crucial role in this.

What can EO sensors do?

Electro-optical sensors built into satellites will be a smart addition to ground-based air defense. They can detect missile launches from the infrared signal of the missile's exhaust plume. This means fire-control radars can be pre-instructed precisely and countermeasures initiated faster. The use of a satellite-based early warning system with EO sensors would extend the advance warning time ahead of a missile attack, gaining valuable time to initiate countermeasures. Even just a few seconds can make all the difference.

How do electro-optical sensors work?

Electro-optical sensors are electronic detectors that convert light or a change in light into an electronic signal. Our technology demonstrators combine infrared camera technology with smart image processing algorithms to supply accurate target information.

Contact

Monika Landgraf | Fraunhofer-Gesellschaft, Munich, Germany | Communications | Phone +49 89 1205-1333 | presse@zv.fraunhofer.de
Ulrich Pontes | Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB | Phone +49 721 6091-300 | ulrich.pontes@iosb.fraunhofer.de
Fraunhoferstrasse 1 | 76131 Karlsruhe, Germany | www.iosb.fraunhofer.de

Developing sensors like those is complex. What do developers need to keep in mind?**PRESS RELEASE**June 2, 2025 || Page 2 | 4

We optimize the sensor design on an individual basis, geared toward the planned satellite missions. In addition to the satellite's orbital observation geometry, we also take all of the environmental conditions into account, as they have a crucial effect on an EO system's detection range. Different kinds of clouds, climate zones, seasons and earth backgrounds are all examples of these influencing factors.

What other factors are important when designing the sensors?

The sensors detect signals in the infrared wavelength range. Depending on the satellite's orbit altitude, the ideal wavelength range needs to be defined with an eye to terrestrial and atmospheric conditions in order to be able to detect medium- and long-range missiles as soon as possible. To achieve this, we specify the infrared filter, which is only permeable in certain wavelength bands. We put that filter in front of the sensor so only the infrared wavelengths that are relevant for missile early warning purposes get through. There are also other parameters, like the sensor's integration time and satellite vibration, that we have to take into account.

What requirements need to be met for the sensors to work?

Reliable early warning is only possible if the ratio between the missile signal and the background — including aspects like different terrestrial surfaces and types of cloud cover — exceeds a certain threshold. Choosing the right spectral band is crucial to achieving a value that is high enough for this. If you select the right spectral bands, it is significantly easier to detect a missile launch against a terrestrial background in bright sunshine, for example.

How do you test a sensor concept's performance for use in space?

Ensuring that early warning of missiles is successful requires an advance simulation that models how the satellite-based EO sensor would observe the Earth. We use a software program called MATISSE by Onera for modeling purposes, and we work with the developer to refine and further extend it. We use MATISSE to generate image sequences for a hypothetical threat scenario, from the missile launch to when the last boost stage burns out. During these sequences, we model not only the entire observational geometry and missile signature along its flight path but also how the atmosphere affects the sensing range of this kind of terrestrial observation system. We use image processing algorithms to analyze the realistic image sequences so we can iterate on them and optimize them for the threat scenario. The whole goal is to be able to sound and pass on the alarm as soon as possible when a missile is detected.

How does the algorithm prevent false alarms?

The algorithms are programmed for the missiles' heat signatures. So if there is a hotspot visible across multiple image sequences in succession, that is an indication of a missile in flight. But if that spot disappears after a short time, that's a false alarm caused by sunlight reflecting off an object, for example. The algorithm uses a database to continuously compare an expected flight profile against the one that has just been detected.

Are EO sensors that you designed already in use?

Yes, indeed. For example, we developed the design concept for the EO sensor in the ERNST research satellite that was launched into space in August 2024. Plans for the small satellite from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI include demonstrating the feasibility of missile detection from orbit. Aside from that, we also work as part of other consortia led by industry partners. At the national level, for example, we are working with Airbus Defence and Space on a geostationary terrestrial observation system.

PRESS RELEASE

June 2, 2025 || Page 3 | 4



Fig. 1 Electro-optical sensors integrated into satellites can detect missile launches from the exhaust trail's infrared signal.

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Fig. 2 Dipl.-Ing. Caroline Schweitzer, scientist at Fraunhofer IOSB

PRESS RELEASE

June 2, 2025 || Page 4 | 4

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