



# **Satcom IoT for Education**

## **Final Report**

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## **Abstract**

The objective of this ARTES activity covers the development of a bespoke satcom IoT solution for educational purposes, providing students with hands-on learning experience in collecting, processing, and transmitting Internet of Things (IoT) data via satellite networks. Internet of Things data plays a larger role in our daily life than just a few years ago and supports the growth of the economy worldwide. At the same time, satellite-based connectivity is transforming society. Therefore, it is paramount that we have a skilled workforce able to implement, use, and further develop the underlying technology. To ensure Europe can supply the skilled workforce needed to meet this demand, we must ignite a passion for digital innovation within our schools. The product developed during this activity engages students with hands-on activities about sensors, IoT, and satellite communications.

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# 1 Objective of the Activity

The increasing significance of data for our planet's wellbeing calls for inspiring and innovative educational approaches. This ESA project offers a fantastic opportunity for educators and students to engage with cutting-edge technologies and make a meaningful impact.

Internet of Things (IoT) data plays a larger role in our daily life than just a few years ago and supports the growth of the economy worldwide. At the same time, satellite-based connectivity is transforming society. Therefore, it is paramount that we have a skilled workforce able to implement, use, and further develop the underlying technology. The future of our security, renewable energy, sustainable supply chains, smart farming or climate protection, heavily depends on our capabilities with all things data.

Students in today's classrooms will be the ones embracing this 4th industrial revolution. To ensure Europe can supply the skilled workforce needed to meet this demand, we must ignite a passion for digital innovation within our schools.

The objective of this ARTES activity covers the development of a bespoke satcom IoT solution for educational purposes, providing students with hands-on learning experience in collecting, processing, and transmitting IoT data via satellite networks. This initiative aims to inspire the IoT and satcom experts of the future. In addition to being an intuitive and easy to use framework on its own, the developed components can also be used together with existing educational kits such as LEGO, Arduino, Micro:bit, and others.



Figure 1: LEGO rover with a satcom modem sending sensor data from Greenland.

The presented activity is a follow-up of a pilot study, which took place during 2020-2021 as an initiative by ESA (PO 5201022280 and 5001031502). The overall objective of the pilot study was to investigate space, satcom and IoT education in schools using LEGO and an IoT satcom modem as the teaching platform.

The pilot study was executed with children aged 10-16 and included both theoretical and hands-on lessons. After getting acquainted with the platform, the children built a LEGO rover, which was equipped with an IoT satcom modem prototype and sent to Greenland, where it collected data and sent it back to the school via the Lacuna Space satellite network.

The pilot activities were carried out in collaboration with LEGO Education, Future Classroom Lab, Lekolar, and SAGA Space Architects. SAGA Space Architects were at the time carrying out their 3-months analogue Lunar mission called Lunark<sup>1</sup> in Greenland and facilitated the operation of the rover in Greenland.

The pilot study was a great success and received a lot of interest both from stakeholders from the educational sector and the media and inspired the development of the educational products described in this report.



Figure 2: ESA astronaut Andreas Mogensen with a LEGO rover built by students.

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<sup>1</sup> <https://www.saga.dk/projects/lunark>

## 2 Key Issues and Challenges

School curriculums are evolving to keep pace with the rapid advancements in technology, including IoT and satellite communications. Many countries are enthusiastically embracing the challenge of integrating new technology into classrooms. While teachers may initially feel apprehensive about teaching subjects outside their expertise, this also presents a wonderful opportunity for professional growth and collaboration. With the right support and resources, educators can confidently deliver valuable and engaging lessons in these cutting-edge fields.

The key challenge of this project is to make teachers feel confident in introducing this new technology to the classrooms by providing a solution with curriculum relevant lesson material, teacher guides, easy-to-use interfaces, technical support and has a clear educational value.

The educational sector is an inherently price sensitive market with many schools operating on a very tight budget. In order to make the developed product inclusive and attractive for all schools, and at the same time keep a European supply chain, a rather challenging cost optimization was required already during the design phase.

Given the price sensitive nature of the market, using well established legacy satcom infrastructure for the developed product is not a financially viable option. Instead, one of the emerging satcom networks dedicated to IoT applications must be used and these networks are still in a very early stage with uncertain future. Although this poses a significant risk to the developed product, using a standard-based satellite network eliminates vendor lock-in and reduces the risk of commercial failure in the longer term.

## 3 Products and Services Developed

The developed solution includes a satcom-enabled IoT device, called SatGO, accompanying software infrastructure, and educational material.

The SatGO device can function as a standalone IoT device collecting and sending data from built-in or external sensors, or as a sensor device sensing real-time sensor data to a computer. The SatGO device has built-in GNSS receiver for accurate time and location determination, environmental sensors for measuring air temperature, humidity and barometric pressure, as well as inertial sensors for measuring linear acceleration, rotation and magnetic fields along 3 axes. The device can be powered using its built-in rechargeable battery or an external power source via a USB-C connector.



Figure 3: The developed satcom IoT device, SatGO.

Thanks to the built-in radio module and antenna, the collected sensor data is transmitted wirelessly over either a terrestrial LoRaWAN network or the Lacuna Space satellite network. In both cases the data is forwarded to the Data Collection and Visualisation Software, which shows current and historical data on graphs.



Figure 4: Historical data from SatGO devices shown on graphs to the end user.

In addition to the above-mentioned data visualization software, an interactive host software showing real-time sensor data from the device has also been developed. Using this software the students can get acquainted with the sensors work and react

to external stimuli. This turned out to be a rather popular and engaging feature during field trials, as it allowed the students to explore their surroundings using sensors and see the world around them in a different way.

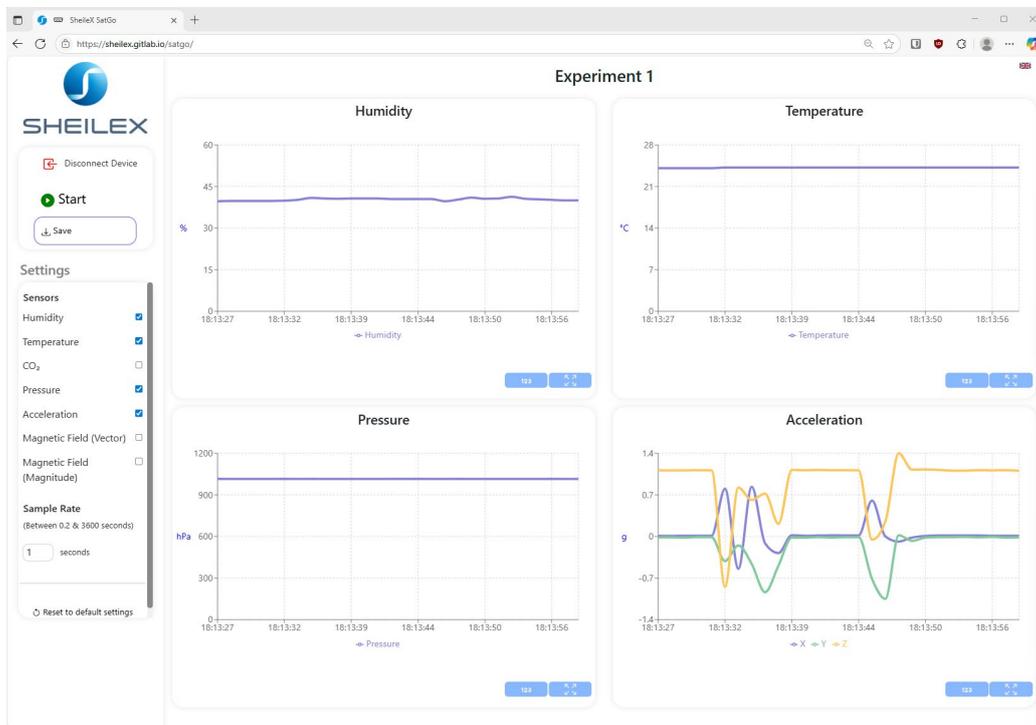


Figure 5: SheileX SatGO interactive host software.

Both software applications are accessed using web browser, making the products usable with PCs, Macs or even low-cost Chromebooks. This was an important factor for the software architecture, since Chromebooks tend to be a popular choice in European schools.

The developed hardware and software products are accompanied by educational material consisting of lesson plans and background material, targeting students in 5<sup>th</sup> grade and above.

The lesson plans cover engineering topics like sensor technology, data analysis, satellite-based navigation and satellite communications. They also explore how these technologies can be applied in real-life scenarios, providing students with practical and engaging learning experiences. Each lesson comprises a student guide and a teacher guide based on the 5E Model: Engage, Explore, Explain, Elaborate, and Evaluate. This avoids front-loading the students with too much theory and instead focus on hands-on exercises.

## 4 Field Tests with End Users

An important aspect of the development activities was to carry out early field tests with end users and collect feedback before the product enters the commercial phase. To that end, 8 field test sessions were executed over a period of 5 months:

- Three sessions with high-school graduates participating in the ESA Discovery Week at ECSAT, Harwell Campus.
- Four sessions with 5<sup>th</sup> grade students in two different Danish schools.
- Two sessions with 7<sup>th</sup> grade students in a Danish school.

This provided a surprisingly good sample distribution of the test subjects with highly valuable feedback and lessons learned.

In general, the test sessions confirmed that the SatGO hardware, software, and 5E-based lesson structure offer a highly effective foundation for exploratory, technology-supported science learning. Across all contexts and age groups, students engaged quickly and intuitively with the technology, often beginning to experiment before formal instructions were given. This indicates that the solution is close to achieving the intended “plug-and-play” usability.

The tests sessions confirmed that hands-on, exploration driven activities not only increase student motivation but also improve their ability to explain the underlying theory of the subjects. This was especially evident when students were encouraged to investigate freely, design their own experiments, and interpret real sensor data.

At the same time, the sessions revealed several important considerations for the finalization of both the teaching material and the product. The 5E framework worked as intended when students were introduced to technology early, but learning outcomes were reduced in cases where extensive theory front-loading came before practical exercises.

The tests also highlighted the importance of clear and easy to understand background material for teachers, since STEM teachers for the younger grades in Danish schools do not necessarily have a STEM background.

Overall, the field tests confirmed that the developed product has the potential to become a highly engaging and popular educational product and provided valuable feedback on what needs to be addressed before the product is launched on the market.

## 5 Main Benefits

Education in natural sciences subjects (math, physics, science, etc.) expect students to practice prediction, collection, analysis and comparison of data, learning to inform long-term decisions. Today, students must be able to work with data and understand the relevance of big data used in industry, academic and vocational careers.

The developed solution enables teachers and students, be they children, teenagers or young adults, to explore the wonderful world of IoT, sensors, and satellite communications, enabling them to collect data from remote locations. The integration with well-established educational platforms like LEGO, Arduino, Micro:bit, etc., makes the product flexible, expanding the possibilities and educational value of the solution beyond what was initially envisioned.

Our vision is to create teaching opportunities that give students hands-on experience with satellite communications, real-time sensors, and various other technology domains. This approach enhances their understanding of science and technology through practical application, making learning both engaging and impactful.

## 6 Future Perspectives

The developed hardware and software provide a solid minimal viable product that can be used for addressing the urgent need in education and for proving the market opportunity. However, for a long-time viable product, further evolution will be needed as the product matures on the market. This includes cost optimization of the hardware, continuous improvements of the software and keeping the technologies utilized up to date as they evolve.

On the commercial side, initial product launch is planned to take place in Denmark, closely followed by other European countries before taking on the global market.

Looking beyond the educational sector, the products and services developed under this contract provide a good foundation for developing future satcom-enabled IoT products for other markets targeting both commercial and governmental end users.