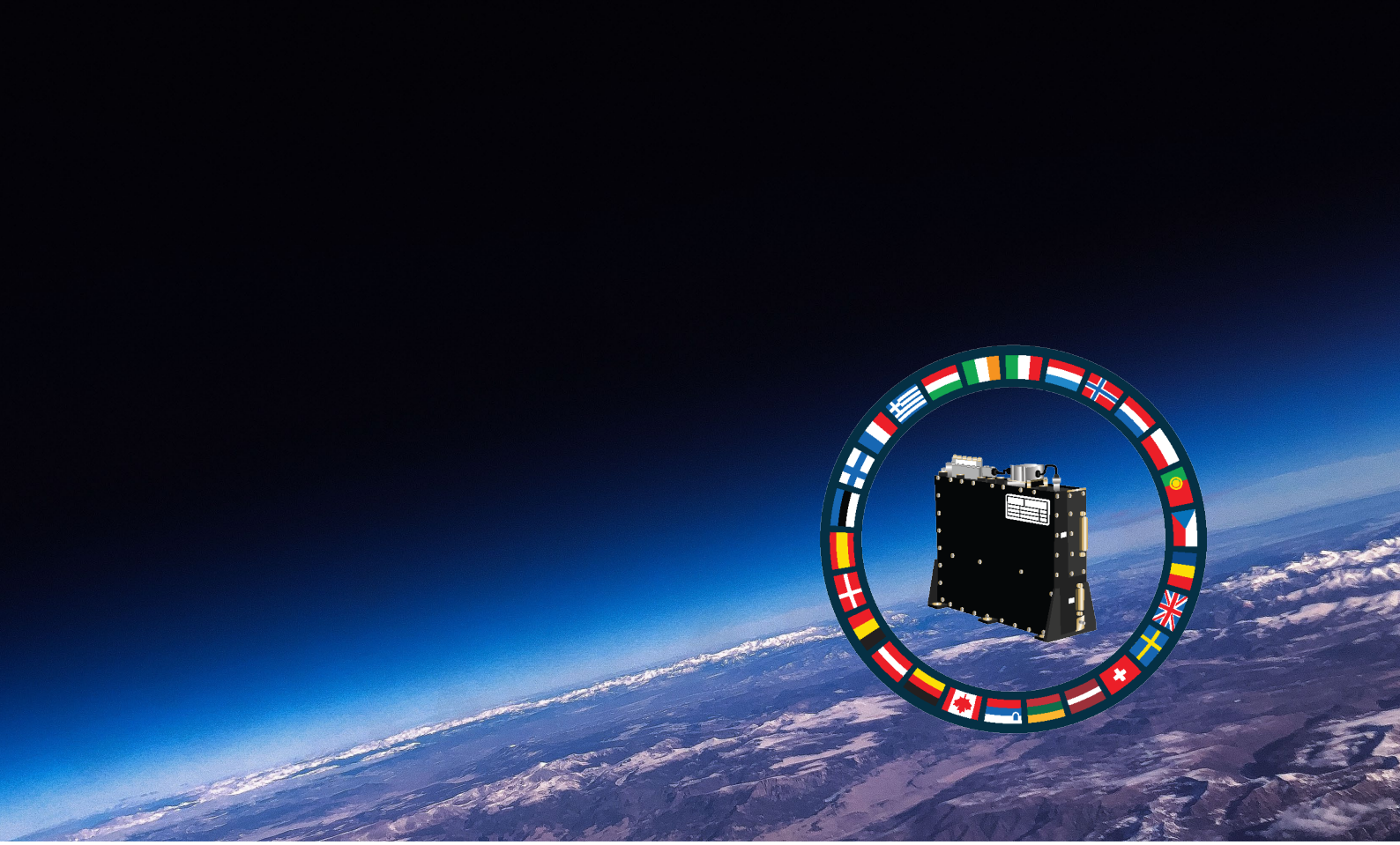


Socio-economic benefits from ESA's Science Core Technology Programme

A report for esa

CASE STUDY: Telemetry, Tracking & Command Subsystem

know.space

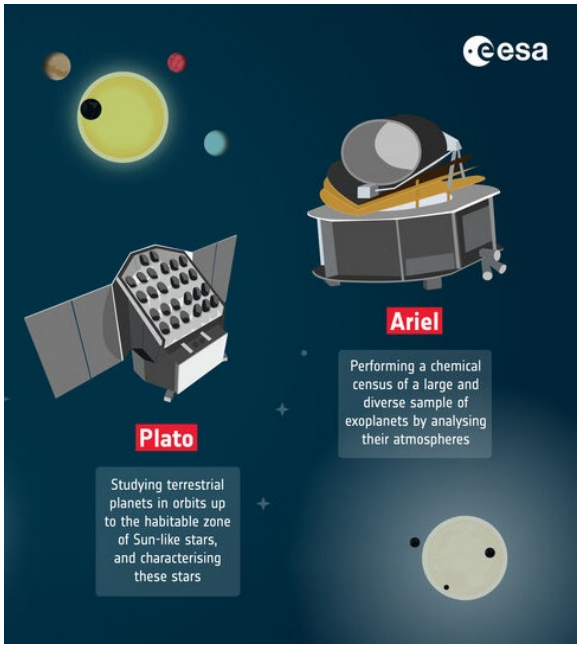
June 2022

The need for a high-performance TT&C subsystem …

The telemetry, tracking, and command (TT&C) subsystem of a satellite provides a connection between an orbiting spacecraft and ground infrastructure. TT&Cs are vital to the successful operations of satellites. The subsystem performs four different key tasks:

1. It monitors the health and status of the satellite by collecting, processing and transmitting data from the various spacecraft subsystems;
2. It determines the satellite's exact location by receiving, processing and transmitting ranging signals;
3. It controls the satellite by receiving, processing and implementing commands transmitted from the ground; and
4. It sends the data collected by the satellite to the ground.

ESA identified the need to develop more performant TT&C subsystems for science missions, notably to increase the data rate to keep up with the ever more advanced satellite instruments and to diversify its suppliers. This led ESA to fund technology development projects for a TT&C K-band transmitter for PLATO and an X-band transponder for ARIEL under the Science Core Technology Programme (CTP).



ESA

This was also seen as a **good opportunity to develop Norway's space-based competencies**. Building on its existing industrial TT&C product capabilities for the satcom market to supply TT&C for science missions represented a big jump. Indeed, flying further away from the Earth and equipped with powerful instruments, science satellites require TT&C systems that are much more sensitive and capable of transmitting data at higher rates than the TT&C on telecommunication satellites.

Ultimately, this capability building would help achieve wider and more stable Norwegian participation in ESA Science missions.

… fulfilled by Kongsberg Space Electronics' innovative technology …

KONGSBERG

KSE

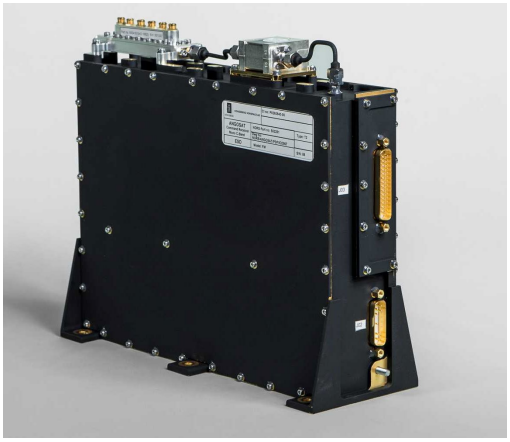
CTP funding was thus awarded to Norway's Kongsberg Space Electronics (KSE). The company possessed extensive existing expertise in the development of TT&C products for the commercial satellite telecommunication industry, which was particularly attractive to ESA, as it provided a base on which to build.

Under CTP, KSE developed TT&C subsystems, which integrates and assembles electronic units that are either purchased on the market or developed in-house. The company required a larger and more advanced processing platform, and thus chose one that had recently been developed in the semiconductor industry. It ensured that the TT&C subsystem would meet the demanding requirements for science missions and be at the forefront technologically, thus

remaining competitive for longer. The designs implemented on this new digital platform represents a major step forward in the company's Digital Signal Processing (DSP) capability.

The subsystem-level focus of the CTP activity has introduced co-engineering activities with the major European satellite manufacturers, deepening the understanding of the technical and operational requirements for the equipment under development.

KSE's work on the project was flagged as particularly challenging, as the company started from a low TRL and rapidly advanced the maturity of its new subsystem, which required considerable learning. Overall, **using CTP funding, KSE developed a TT&C subsystem that meets the demanding performance requirements for science missions**, and which was described as cost efficient and competitive in comparison to existing alternatives.



KSE

… with a potential for significant socio-economic benefits

While KSE's TT&C subsystem components are currently shifting from development to flight stage (for example, with the transmitter) or are early phase (e.g. the transponder for ARIEL), some initial socio-economic benefits have begun to emerge. Many larger, benefits are also anticipated to come through its successful commercialisation – for the company, their customers, Norway's space ecosystem, and for the broader European industrial landscape.

Bringing new knowledge, expertise and competitiveness for TT&C subsystems

New knowledge and expertise

The system engineering knowledge, expertise and processes spill-over from the CTP programme has helped increase KSE's competitiveness within the company's main expertise market, i.e. the commercial satcom sector

Before its work with ESA CTP, KSE's TT&C activities were primarily for telecommunication TT&C as a unit supplier.

However, transposing that capability onto a complex, state-of-the-art mission for space science comes with challenges, especially from a technological perspective. Indeed, a science mission has to go much further into space than satellites which remain in orbit around the Earth, making the signal much weaker and requiring a system that is more sensitive. It also needs to transmit science data, which needs heavier processing capabilities than that of telecoms satellites. **Data rate is a key component for science missions**.

Therefore, Kongsberg Space Electronics had to move up the supply chain in terms of knowledge and expertise, learning about what the system wants and what it needs, building their capabilities, and further developing their skillsets such as in digital processing.

Thanks to the system engineering knowledge, expertise and processes spill-over from the CTP projects, KSE has seen this benefit other activities within the company, providing an improvement loop back to their telecommunication work. Indeed, they can apply their new knowledge of innovative programming in digital design to their own products, lowering the price and being more competitive on the market.

Working with ESA CTP has enabled KSE to evolve their TT&C product line further.

Increased competitiveness on the export market

Between the increase in knowledge and expertise, the new market opportunities, and the new product itself, **KSE has enjoyed an ongoing increase in global competitiveness**.

With its K-band transmitter, KSE has developed a product on the market that is comparable, if not better, than many of its competitors, and its performance and power requirements make the product well-suited for compatibility with the demanding requirements of missions such as PLATO and ARIEL. KSE is also competitive on pricing, and there has been interest from overseas from countries such as Japan.

New market opportunities

With its new TT&C knowledge and expertise, KSE can now enter the Data Downlink market segment, as well as Earth Observation, with future potential for missions, including to the Moon

CTP funding has enabled KSE to place themselves into new market segments, expanding from its traditional telecommunication focus.

For example, thanks to the CTP contracts, they have now developed capabilities in the data downlink domain, which is the communication link between the satellite and the ground station, and so can offer a high-rate Data Downlink Modulator solution. This is a huge market potential when considering the large number of small satellites due to be launched across the next few years.

The company is also looking to enter into the Earth Observation (EO) market, where there is great commercial potential, since future EO missions require the same type of equipment. Therefore, KSE can broaden their range to EO TT&C.

In the future, there will also be a need for lunar missions to have a complex, robust TT&C system, and with experience from PLATO and ARIEL, KSE could be well-placed to address the needs of a mission of this type. Indeed, its CTP work has opened the door to the institutional TT&C market.

Increased potential revenues

There are great potential future revenues for KSE through the development of its TT&C subsystem, especially within the new market opportunities mentioned above.

Over 1,100 satellites for commercial EO alone have been announced to launch by 2028[1] on top of ESA's planned EO missions, while EO data revenues are expected to post a sustained growth in the next decade (CAGR of 3.5%)[2]. This highlights the importance of having a robust system for transmitting the data. **In the future, major satellite constellations (excluding communications) will be for Earth Observation, with a potential need to order a high number of transmitters**.

For example, the institutional TT&C market for Europe has the potential to reach an estimated €100m across science, EO and lunar activities within the next decade, which highlights there being strong opportunity for selling this niche type of unit by the company.

Job creation

KSE has been hiring new full-time employees and anticipate to continue to do so, justified by both the direct activities from their CTP projects and their development activities, spreading also

[1] NSR, 2020. *The future of satellite-based Earth Observation*. Available from: https://www.nsr.com/the-future-of-satellite-based-earth-observation/
[2] EUSPA, 2022. *Earth Observation Market*. Available from: https://www.euspa.europa.eu/european-space/euspace-market/earth-observation-market

through other work within the company. KSE is acting as an important source of employment within the Norwegian ecosystem.

They have also had to gather new skillsets through the hiring process, and **CTP has especially helped them to build up their employee base on digital processing products** – which will be increasingly useful in upcoming years.

Wider partnerships and collaborations

KSE's work with ESA CTP on large science mission technology development has **brought new attention and expanded the company's network**.

For example, they have gained popularity with the big primes in Europe through their higher-profile work. This is important for future commercial opportunities, since the larger companies often have a preferred 'go-to' list of suppliers for their activities, so building a relationship with these companies is important.

With the TT&C subsystem for a mission such as PLATO, it was vitally important to have discussions with the actors in charge of operating the satellite, since their component is the single contact point between the ground operator and the satellite. This represented a learning experience and network expansion opportunity for KSE, which will be useful for future work.

Introducing niche expertise for TT&C components to the Norwegian industrial ecosystem

Increased involvement of Norway in the Science programme

KSE's shift into providing science-mission level TT&C subsystems provides opportunities to increase the involvement of the Norwegian industry in ongoing future space missions, such as PLATO and ARIEL.

While the framework conditions for growth of Norwegian space businesses are set by Norway's national space strategy and with national budget allocations, implementation is predominantly carried out through Norway's participation in ESA and the European Union's space programme. Furthermore, one of the key responsibilities of the Norwegian Space Agency is to support local businesses to win contracts through ESA's development programmes, and so **Norway's membership in ESA is perceived as its most important route to influence**.

However, historically Norway has been under-represented within ESA's Science Programme compared to its investment in the programme. Through its CTP funding opportunities and the development of its TT&C product line, KSE has helped to address aspects of this challenge. Since KSE's technology is a core element of science missions, and considering it is European-developed and globally competitive in its processing approach to data, **KSE is positioned strategically for providing more regular usage of Norwegian technology on board ESA missions in the long-term** (with the assumption that many future science and other missions will require the TT&C technology).

Therefore, developing the TT&C subsystem has built expertise within the country that is niche, yet covers a critical component of any spacecraft, but especially for those not restrained to Earth's orbit.

Expanding space-based competencies

As previously mentioned, the technical requirements for TT&C systems within science missions are far more complex and difficult to achieve than for telecommunication satellite systems.

The satellite communication industry generates around two-thirds of all space-related revenues in Norway, for which KSE is a major actor[3]. Therefore, while there was already niche knowledge for TT&C systems within the country, it was in relation to telecommunication satellites specifically, which from a technological perspective are less demanding than the complex transponders required for science.

Therefore, ESA CTP's support of KSE's shift up of its product line to be able to address science missions also means that **the level of expertise and knowledge for TT&C systems increased within the space ecosystem in Norway**.

National space policy support

The '*Government's strategy for Norwegian space activities*' paper sets out some key objectives for the Norwegian space sector, outlining four goals it wants to achieve in its aim to maximise the benefits the country receives from its participation in space activities. These goals include "promoting profitable companies, growth and employment", recognising that the government has oriented itself towards encouraging practical benefits, with emphasis on business development and addressing opportunities in a cost-effective manner.[4]

Its space policy also acknowledges the value creation stemming from space activities, and the fact that through supporting the space sector, it is also supporting profitable jobs, value creation and sustainable growth.

By winning contracts with ESA CTP, KSE has been able to expand its business, enter into new market segments, establish new company expertise and become increasingly competitive. These business activities have therefore **directly contributed towards addressing some of the priorities outlined in the Government's strategy for Norway**.

Supporting an increased data rate for scientific missions

Expanding European non-dependence

With its TT&C subsystem developed with CTP support, KSE has helped broaden the industrial base for TT&C in Europe and further expand European non-dependence with its advanced capabilities

While there is already another European competitor providing a solution available on the market, it uses older technology. Meanwhile thanks to its inclusion of an innovative new FPGA (Field-programmable gate array) for its processing capabilities, **KSE offers the most advanced solution on the European market**, meaning KSE's product is a preferable option for the demanding requirements of ESA missions.

It is also important to note that a reliance on one single-source supplier does not create a secure supply chain for such a vital component, and so by developing their product, **KSE has helped broaden the industrial base of satellite TT&C in Europe**.

[3] Norsk Romsenter, 2020. *The Government's strategy for Norwegian space activities.* Available from: https://www.romsenter.no/Aktuelt/Publikasjoner/The-Government-s-strategy-for-Norwegian-space-activities

[4] Norsk Romsenter, 2020. *The Government's strategy for Norwegian space activities.* Available from: https://www.romsenter.no/Aktuelt/Publikasjoner/The-Government-s-strategy-for-Norwegian-space-activities

KSE has already been pre-selected for two significant upcoming ESA missions for its TT&C subsystem: PLAnetary Transits and Oscillations of stars (PLATO) and the Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL).

PLATO is a M-class (medium class) mission sitting within ESA's Cosmic Vision programme. Its goal is to find and study extrasolar planetary systems, especially exploring the properties of terrestrial planets in the habitable zone around solar-like stars, under the Cosmic Vision thematic question of "what are the conditions for planet formation and the emergence of life?". It has a target launch date of 2026. For PLATO, KSE has developed the K-band transmitter, and is now developing the flight unit so it can be integrated into the spacecraft. **This K-band transmitter has completed qualification development**, and ESA has awarded a contract for flight on PLATO.

ARIEL is also an M-class mission within the Cosmic Vision programme, which aims to address the key scientific questions around how exoplanets are formed and how they evolve over time. It is the first mission dedicated to measuring chemical composition and thermal structures of hundreds of transiting exoplanets, contributing far-reaching planetary science towards the Cosmic Vision theme and requiring highly technological components to achieve its goals. It has a foreseen launch date in 2029. **For ARIEL, the X-band transponder is in an early development phase**, with a contract awarded from ESA to continue further development.

Beyond these two missions however, **KSE will also be well-placed to provide TT&C subsystems/developments to future space science missions**. Outlined in the table below are future planned and proposed missions (launching after 2023), that could potentially utilise a TT&C subsystem component such as the one KSE will offer:

ESA-led Science & Exploration missions	Other Science & Exploration Missions

• Large (L-) class missions
  ○ L2, ATHENA: Advanced Telescope for High Energy Astrophysics, planned launch in 2035
  ○ L3, LISA: Laser Interferometer Space Antenna, planned launch in 2034
• Medium (M-) class missions
  ○ M3, **PLATO**: search for exoplanets and stellar oscillations measurements, planned launch for 2026
  ○ M4, **ARIEL**: Atmospheric Remote-sensing Infrared Exoplanet Large-survey, planned launch in 2029
  ○ M5, EnVision: Venus orbiter for radar mapping, planned launch in 2031
• Small (S-) class missions
  ○ S2, SMILE: study of interactions between Earth's magnetosphere and the solar wind, planned launch in 2024 (joint ESA-Chinese Academy of Sciences mission)
• Fast (F-) class missions (launched alongside M-class missions as an 'add-on')
  ○ F1, Comet Interceptor: encounter and explore a pristine comet, planned launch in 2029
  ○ F2 (to be selected, to be launched with M5)
• Missions of Opportunity (M*): PROBA-3 (planned launch in 2023)
	• MMX: Martian Moons eXploration (JAXA-led with ESA, NASA and CNES participation, planned launch in 2024)
	• MOM2 (ISRO-led, planned launch in 2024)
	• DESTINY+ (JAXA-led, planned launch in 2024)
	• LiteBIRD (JAXA-led, planned launched in 2028)

Increase in scientific data

One of the key parameters scientists are often seeking in science missions is a higher data rate.

The instrumentation built for the spacecraft is extraordinarily complex and with high capabilities, pushing to the forefront of technology, meaning that it has the ability to produce an enormous amount of data. In astronomy for example, there will be extremely high-resolution pictures that need to be transmitted back to Earth, and these are "heavy" for data processing. If the transmitter is poor or not able to process enough data, then it creates a large constraint on the mission and the underlying scientific data that the scientists will receive. Additionally, there are other constraints for the data, such as the frequency spectrum, which is a finite resource and hence as much data needs to be transmitted as possible using, in the example of KSE's transmitter for PLATO, the K-band.

With its innovative approach to this transmitter, using a state-of-the-art FPGA, KSE has enabled a higher data rate for future missions, **ensuring that valuable data can be transferred back to Earth for scientists to analyse and produce exciting discoveries**.

Would these benefits have been realised without ESA?

The benefits outlined in the previous sections would not have occurred without CTP funding, as the considerable level of risk associated with such technology developments would have precluded KSE's involvement, had it been required to fund these projects internally.

ESA

KSE is also gaining access to networking and learning opportunities that are specific to ESA-funded projects. Indeed, the Norwegian company accessed ESA's expertise, was introduced and formed collaborative relationships with end-users (i.e. satellite operators), and is now better linked to large European prime contractors.

"This level of risk would have never been undertaken without ESA support on the financing side. The expertise, knowledge and people at ESA have supported us throughout the projects"

Eystein Sedberg, Grunde Joheim (KSE)

… plus further development and benefits to come

KSE indicated that it has gained considerable knowledge through its CTP-funded work, notably in system engineering, **which it anticipates to water down to improve its satcom TT&C products**. The new procedures and firmware developments established are also anticipated to **spill-over to other areas of the company's activities**. This could be important to enhance the company's competitiveness, particularly relevant in the context of New Space. KSE also developed its network, notably building relationships with large European prime contractors, which is strategically valuable to secure future contracts. KSE has already been awarded a contract to assess an extension of the transmitter for EO missions.