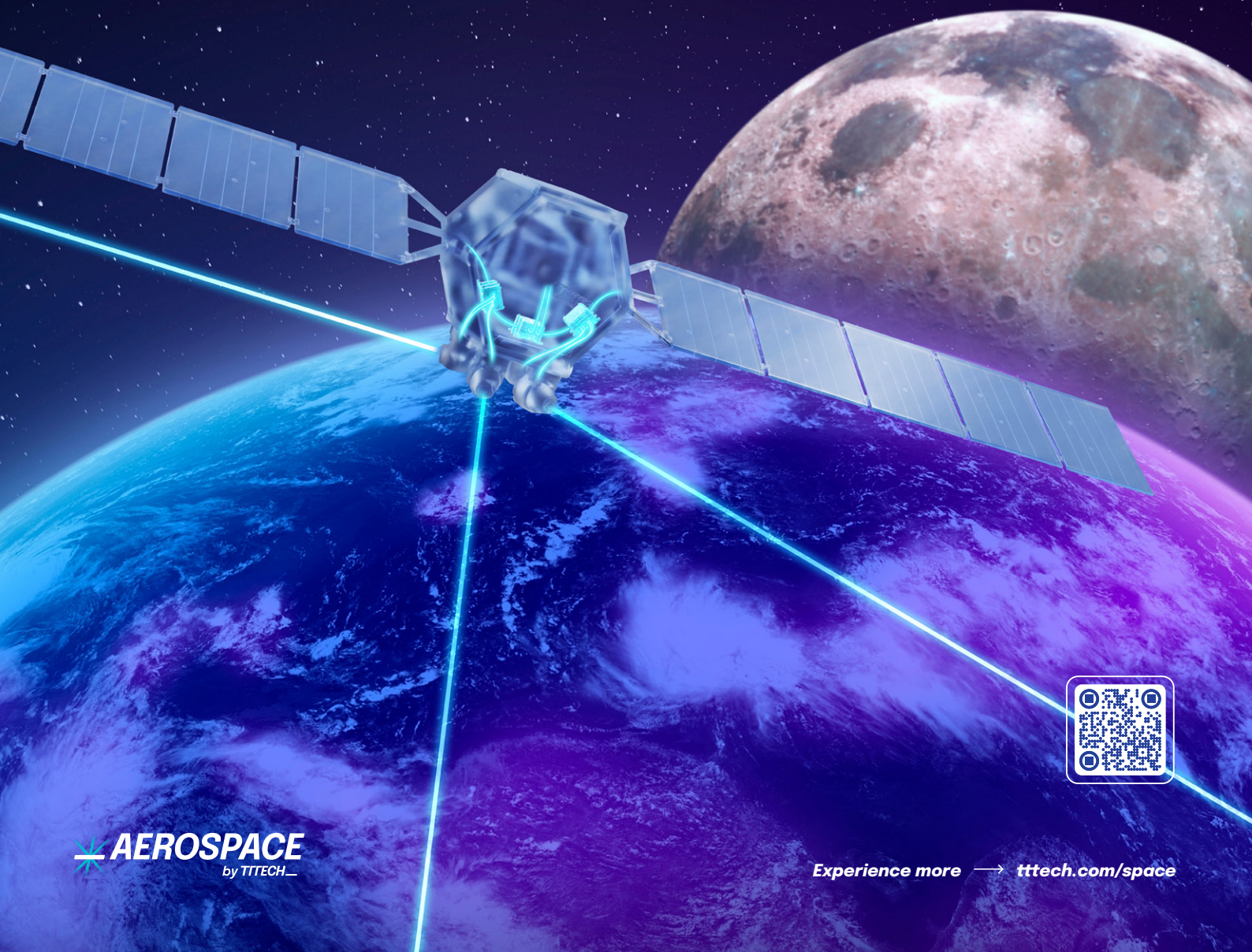
TTTECH

SCALABLE SOLUTIONS FOR SPACECRAFT SOFTWARE AND SYSTEM ARCHITECTURES

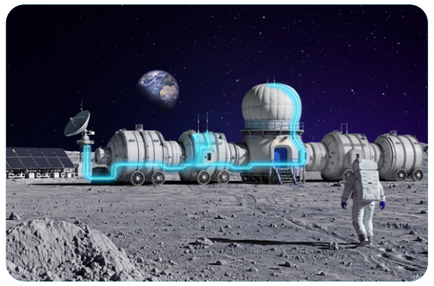


AEROSPACE
by TTTECH

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ADVANCED INTEGRATED SYSTEMS AND DETERMINISTIC NETWORKS





TTTECH Aerospace provides deterministic embedded network and platform solutions for safety- or mission-critical applications in aviation, space, defense and adjacent industries. In the space sector it focusses on reliable radiation-hardened components and integrated modules for Ethernet networking and high-speed routing. As fab-less product developer it benefits greatly from cross-industry synergies and the choice between several electronic manufacturing partners: Class A where needed, cost-efficient automotive/industrial grade where feasible.

TTTECH's avionic backbone network systems act as the "central nervous system" of various spacecraft (including NASA Orion and its European Service Module, and the European flagship launch vehicle Ariane 6). Qualified avionics platforms are available to support satellite applications in various orbits, space transportation, deep space, lunar, and human-rated missions.

LEVERAGING DECADES OF TECHNOLOGY LEADERSHIP

+25 YEARS

TTTECH Aerospace has become part of TTTech Systems SE, which develops and delivers safe, secure, and highly dependable computing, networking, and platform solutions in aerospace, defense, critical infrastructure, and industrial machinery. Headquartered in Vienna, Austria, it combines its Austrian innovation and R&D hub with engineering teams across Europe and in the USA. This fast growing business entity supports customers worldwide with a clear focus on market expansion in Europe and the Americas.

As an integral part of TTTECH Group, a global group of high-tech companies with more than 1,200 employees worldwide, TTTech Systems SE builds on more than 25 years of cross-industry technological expertise in mission- and safety-critical systems.



VALUE

SCALABLE PLATFORMS FOR COMMUNICATION, COMMAND & CONTROL

- Modular and scalable system architectures enable cost savings
- Simplify: A single Ethernet network for command and control as well as payload data
- Scale: Up to 100 Gbit/s bandwidth per link for advanced high-speed communication
- Save: Significant lifecycle savings through simplified integration, testing and re-qualification
- The network transparently manages redundancy across paths and devices for highest dependability
- Real-time performance: Guaranteed transmission latencies and predictable jitter
- Fault tolerance and fault containment to increase both safety and availability
- Expert support through the whole development and product maintenance lifecycle
- Future-proof: Interoperability through use of open global standards such as IEEE 802.1DP (TSN), A664 p.7, ECSS-E-ST-50-16C
- Customers can focus on their applications and services, our mission is to take care of the underlying platform



PRODUCTS FOR SPACE EXPLORATION

TTEthernet

TTETHERNET® LAB-GRADE EQUIPMENT



TTESwitch Space 3U cPCI (EDU)

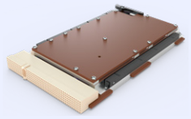


TTEEnd System Space 3U cPCI (EDU)

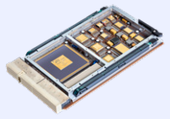


TTESwitching Unit (EDU)/ TTEAvionics Core Unit (EDU)

TTETHERNET® FLIGHT-GRADE EQUIPMENT



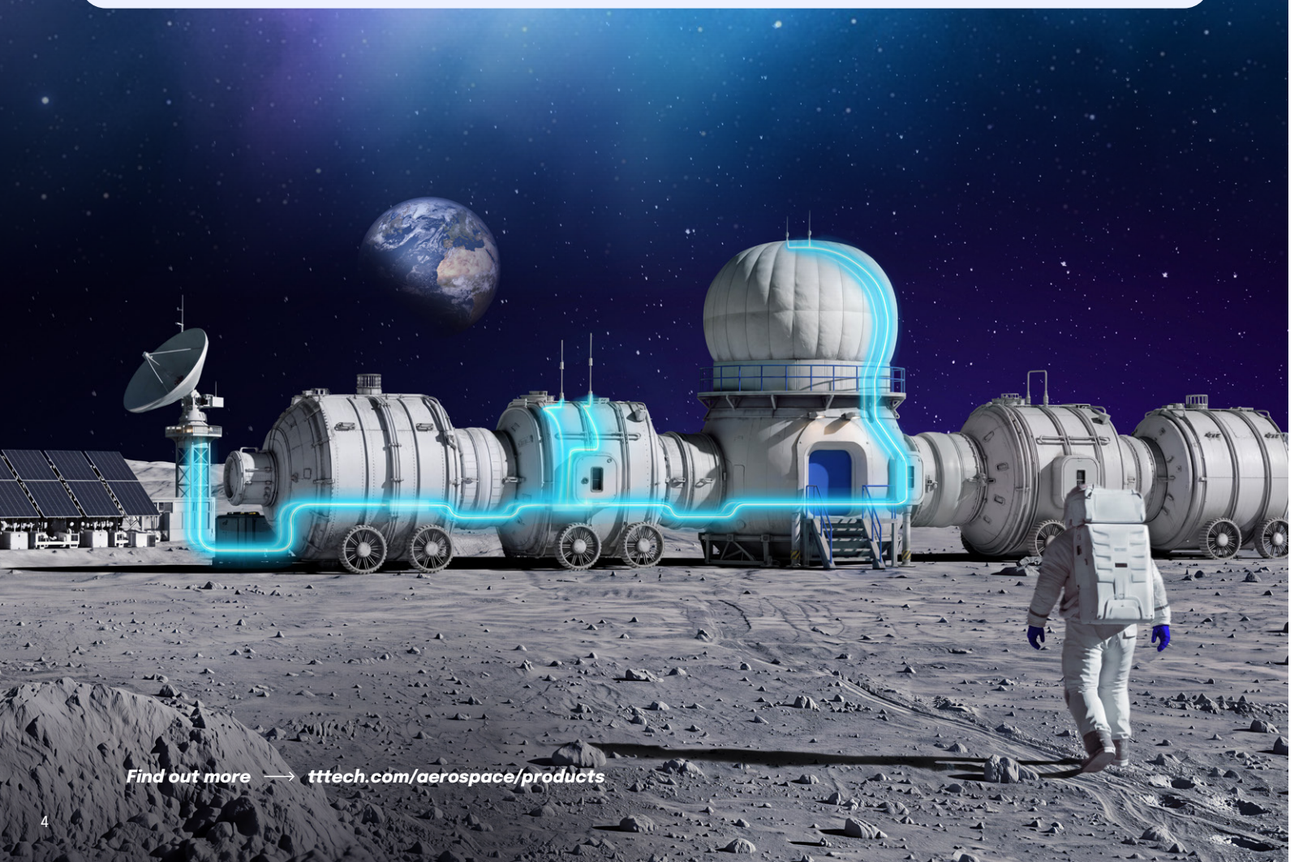
TTESwitch Space 3U cPCI (FLIGHT)



TTEEnd System Space 3U cPCI (FLIGHT)



TTESwitching Unit (FLIGHT)/ TTEAvionics Core Unit (FLIGHT)



Find out more ⟶ tttech.com/aerospace/products

MODULAR, ETHERNET-BASED SPACE PRODUCT PLATFORM

Our Ethernet-based deep space avionics platform was fully qualified in 2026 for missions lasting up to 15 years in lunar orbit, flight models have already been delivered. It was jointly developed with Beyond Gravity Austria. The platform's main benefit is risk reduction - in particular for orbital infrastructure and spacecraft that needs to be qualified for long mission durations or be human-rated. This is due to the use of building blocks which have already been qualified together with ESA and NASA.

The platform supports different types of Ethernet traffic (from regular to rate-constrained/TSN-like to fully synchronous). In coming years it will be expanded to support 10 Gb/s channels and the full TSN Aerospace profile. Also support for the VPX standard is foreseen.

This fully qualified avionics platform offers the functionality needed to implement a robust space-grade compute and control architecture. It allows the implementation of highly reliable systems sharing safety-critical and non-critical data on the same Ethernet backbone. This reduces network complexity and cabling, so also weight. Strict time and space partitioning of the traffic across the network enables the fault-tolerance and fail-operational behavior.

The solution is designed to provide a platform for modular avionics where integrators can focus on application development while data networking and computing power is abstracted through middleware layers like NASA cFS/cFE. Either building blocks (e.g. TTEEnd System or TTESwitch) or integrated units (including power supply and also an onboard computer) can be provided. The pre-qualified elements can be adapted to different real-time operating systems and hypervisors for example by Wind River Systems. Lead-customers for the platform are Northrop Grumman and Thales Alenia Space.

Our boards and integrated units are available in different quality levels to support a cost-efficient development flow during spacecraft design and integration:

- EDU (engineering model for development and functional verification)
- PROTO (typically used as engineering qualification model)
- FLIGHT (qualified model for use in deep space)

EDU's come largely off-the-shelf, while PROTO/FLIGHT are built-to-order which leads to delivery times of more than one year.

EQUIPMENT

KEY ELEMENTS

TTESWITCH SPACE 3U cPCI

- 6 x 1000BASE-T and 6 x 100BASE-TX Ethernet ports

TTEEND SYSTEM SPACE 3U cPCI

- 3 x 1000BASE-T/100BASE-TX Ethernet ports
- PCI or SpaceWire host interface

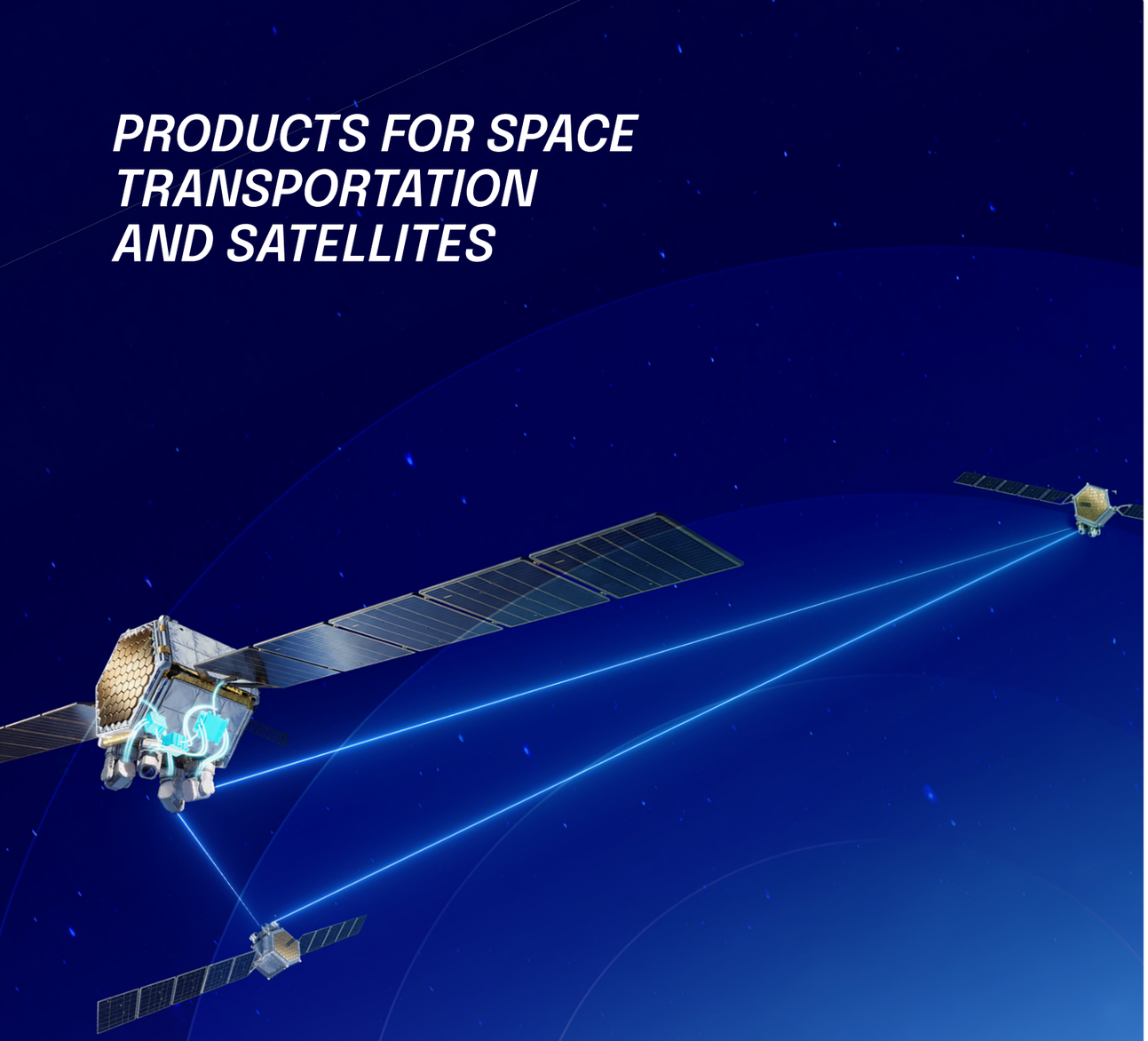
TTESWITCHING UNIT

- Two, three or four TTESwitch Space 3U cPCI integrated in a hosting unit (depending on the application)

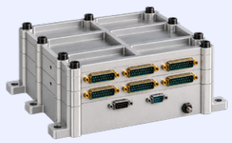
TTEAVIONICS CORE UNIT

- Processor Board
- TTEEnd System Space 3U cPCI
- Two TTESwitch Space 3U cPCI
- Hardware/software integration in a hosting unit

PRODUCTS FOR SPACE TRANSPORTATION AND SATELLITES



ETHERNET-BASED EQUIPMENT FOR DEVELOPMENT, GROUND SUPPORT AND FLIGHT



MYTHOS Switch
(several variants)



25-port Switch
(development/EGSE)



Terabit Router
for satellite communication

Find out more ⟶ tttech.com/aerospace/products

PAYLOAD AND PLATFORM SOLUTIONS

In 2015 TTTECH won the single data network for the Ariane 6 launch vehicle. This was the starting point for the development of a variety of solutions for the space transportation market where hard real-time behavior and high dependability under harsh conditions (shock and vibration) are key for the performance of the platform. Very low latencies and minimal jitter are essential for the reliable delivery of data. Before the launch, vehicles are controlled by the ground segment (or a test environment) in which then also deterministic Ethernet solutions by TTTECH can be deployed.

The MYTHOS product family was later developed to be used in both space transportation (including landers and tugs) and satellites as it can be deployed as a standalone unit or as a modular board solution (PC104 form factor). The MYTHOS network switches are qualified to different environmental standards, and all benefit from the re-use of a highly reliable, qualified software platform which was developed for the NASA Artemis program. Our promise from the beginning of our aerospace activities was a single on-board data network that is so robust that it can handle both platform (control) and payload traffic at the same time. This requires strict partitioning, buffer memory and enough cross-sectional bandwidth. Synchronization (in hardware) and fault-tolerance are other typical needs.

Most recently we see the adoption of Ethernet for satellite platforms and the wider use of optical communication which requires high-performance data routing. Having worked with ESA on several ARTES R&D projects, we are able to address the satellite communication market with a payload switch/MPLS router with an industry leading Tbps throughput in addition to the MYTHOS products. Now we are able to cover both highest safety as well as fastest routing.

Augmenting our portfolio for satellites is a security-certified edge computing platform which can be adapted for use in satellites managing software updates and new service features. It was initially developed for industrial machinery and is an integral part of the TTTech Systems SE solutions portfolio.

KEY CHARACTERISTICS AND BENEFITS

- → Develop and operate with configurable Ethernet networks from the beginning
- → Seamless use of state-of-the-art Ethernet, including full support for various TSN profiles
- → Based on own chip IP which translates to supply-chain integrity
- → Modular, future-proof platform solutions:
  - Support for standard Ethernet (IEEE 802.3)
  - Rate-constrained/TSN traffic where needed
  - Time-triggered traffic (SAE AS6802) for highest criticality
  - Addition of new features and traffic classes
- → Port speeds ranging from 100 Mb/s to 100 Gb/s
- → Latency and jitter in µs range enable real time applications
- → Network switches with up to 25 ports
- → Mature flight products optimized for size and weight
- → Cost-efficient functionally equivalent development equipment

* This component supports asynchronous Deterministic Ethernet traffic similar to and 100% compliant to the aeronautics standard ARINC 664 part 7.

HIREL & SPACE COMPONENTS



RAD-HARD COMPONENTS SUPPORTING VARIOUS ETHERNET TRAFFIC CLASSES

TTE Switch Controller HiRel
TTE End System Controller HiRel

TTE Switch Controller Space
TTE End System Controller Space

Find out more ⟶ *tttech.com/aerospace/products*

ETHERNET COMPONENTS AND SOFTWARE SOLUTIONS

TTTECH has re-shaped the way Ethernet is being used in various domains since more than two decades. It helped to establish open standards for Time Sensitive Networking (TSN) and Time-Triggered Ethernet, and it actively works on an update of the ARINC 664 part 7 standard for aviation networks (also known as AFDX®). For both TSN and Time-Triggered Ethernet/AFDX® network configuration and qualification tooling is available (see next page).

With our space components and software solutions we address three main use cases:

- Adding Ethernet connectivity where it is missing (for example in an inertial measuring unit)
- Improving Ethernet connectivity by
  - adding extra channels
  - adding determinism or a higher quality of service
- Building a space-grade Ethernet switch or router

These are the basic building blocks for on-board data networks, for integrating synchronized and non-synchronized functions into distributed systems using an Ethernet network.

TTTech Systems SE employs one of the largest chip development teams in the European space industry and therefore offers three types of connectivity solutions:

- Chip IP for common FPGA components (e.g. for a TSN End Point)
- Software-based end point solutions for specific microprocessors and RTOS
- Flight-proven, qualified controller ASICs with own management software, where almost the entire IP has been developed independently

Our application-specific integrated circuits support standard Ethernet, rate-constrained traffic*, and time-triggered traffic according to the SAE AS6802 Time-Triggered Ethernet Standard for high flexibility in communication. These components are based on a radiation-hardened design that provides the necessary radiation tolerance for use in harsh space environments.

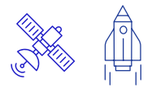
FOUR TTE-CONTROLLER PRODUCTS ARE AVAILABLE:

TTE End System Controller HiRel	TTE Switch Controller HiRel	TTE End System Controller Space	TTE Switch Controller Space

All HiRel products are qualified per a tailored automotive AEC-Q100 process including burn-in, while all Space products are offered with QML-V qualification when needed.

KEY CHARACTERISTICS AND BENEFITS

- Up to three (TTE End System) or 22 (TTE Switch) Ethernet ports with 100/1000 Mbit/s
- Supports three Ethernet traffic classes:
  - Standard Ethernet traffic (IEEE 802.3)
  - Rate-constrained traffic*
  - Time-triggered traffic (SAE AS6802)
- Three different host interfaces (SPI/Quad-SPI, PCI and SpaceWire) to connect TTE End System to different CPUs or FPGAs
- Integrated LEON2 CPU operating at 125 Mhz
- 1 MByte of internal memory
- Junction temperature range -40 °C to +125 °C
- Radiation tolerance for total dose up to 300 krad
- Latch-up immunity up to 60 MeV/cm²/mg
- Packaging: PBGA400 (HiRel, MOQ applies) or hermetic CQFP-352 (Space)
- Enables robust and ultra-reliable Ethernet networks in space
- High design flexibility thanks to available interfaces, integrated CPU, on-chip memory and configurable functional modules
- Same rad-hard die implemented in plastic or ceramic package for any type of space application and environment – from launchers to human space flight, from low earth orbit (LEO) to Mars.

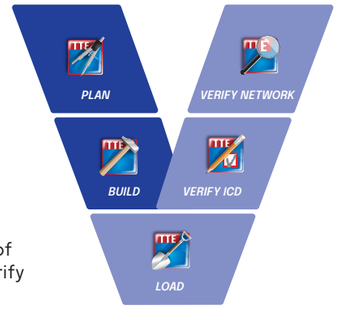


* This component supports asynchronous Deterministic Ethernet traffic similar to and 100% compliant to the aeronautics standard ARINC 664 part 7.

SOFTWARE TOOLS & EMBEDDED SOFTWARE

TOOLS FOR NETWORK DEVELOPMENT AND TESTING

TTTECH's PC-based software tools offer a powerful development environment for building and configuring fault-tolerant real-time systems based on deterministic Ethernet: The XML-based TTE-Tools Suite for TTEthernet® and A664 p.7, Slate XNS for Time Sensitive Networking (TSN). They enable seamless design, configuration, re-configuration, data loading, and validation of data networks during all phases of the product lifecycle.

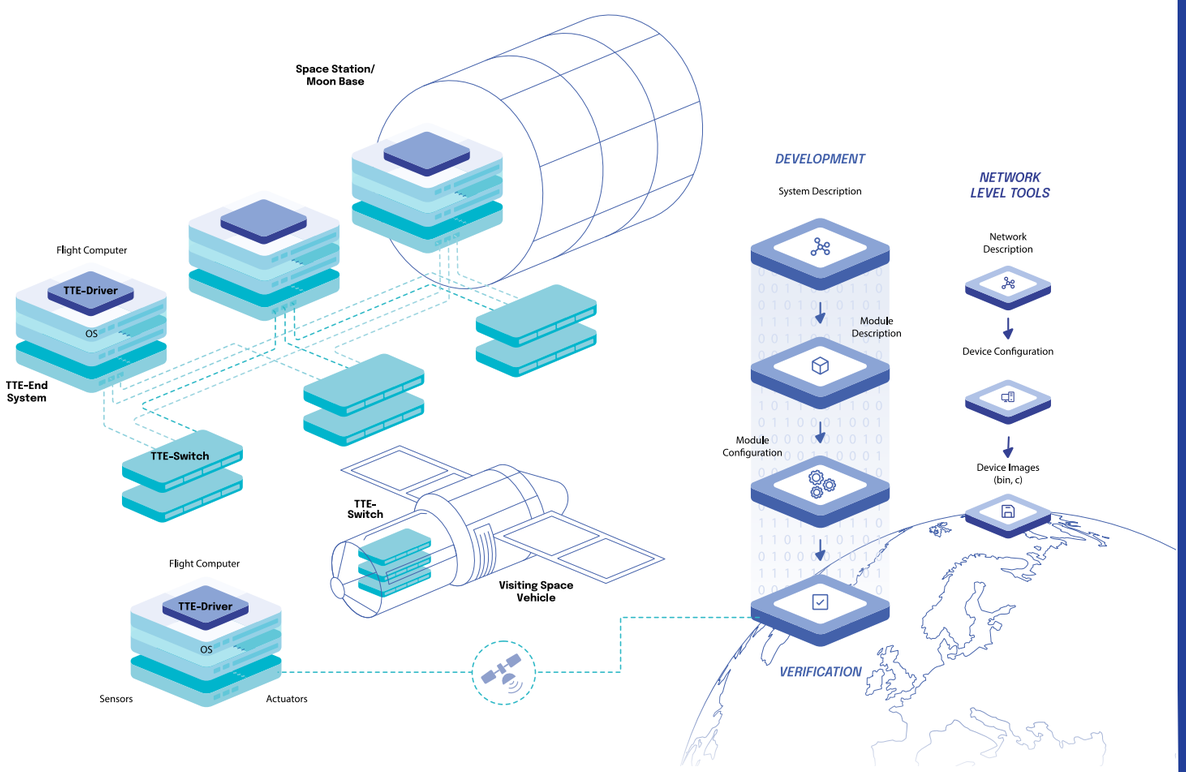


VERIFICATION AND FORMAL QUALIFICATION

TTTECH's easy-to-use verification tools for the aerospace market support one of our core technologies, TTEthernet. RTCA DO-330 qualifiable verification tools verify the configurations of TTEthernet networks.

EMBEDDED SOFTWARE

TTTECH's efficient embedded software components (TTE-Driver) have been developed according to DO-178C Level A and qualified to the highest space standards (human spaceflight). They can be seamlessly integrated with different hardware and software platforms including time- and space-partitioned operating systems. The latest innovation is an embedded software module which can take over functionalities



Find out more ⟶ tttech.com/aerospace/products

REFERENCES & CASE STUDIES

ARIANE 6

ArianeGroup has chosen TTEthernet as single avionics network for the Ariane 6 launch vehicle. TTTECH's TTESwitch Controller HiRel and TTEEnd System Controller HiRel are the key components to achieve fully deterministic high-speed connectivity.



NASA



Starting with the Orion capsule and its European Service Module, TTTECH has been deeply involved in the NASA Artemis program for more than two decades. This exploration program aims to put humans on the surface of Moon and Mars. Deterministic Ethernet has been selected as the digital backbone for human-rated spacecraft and habitation modules. TTTECH contributes built-in fault tolerance and redundant paths for ultra-reliable data communication enabling truly modular, safe system architectures - in orbit or on the lunar surface.

ARTEMIS

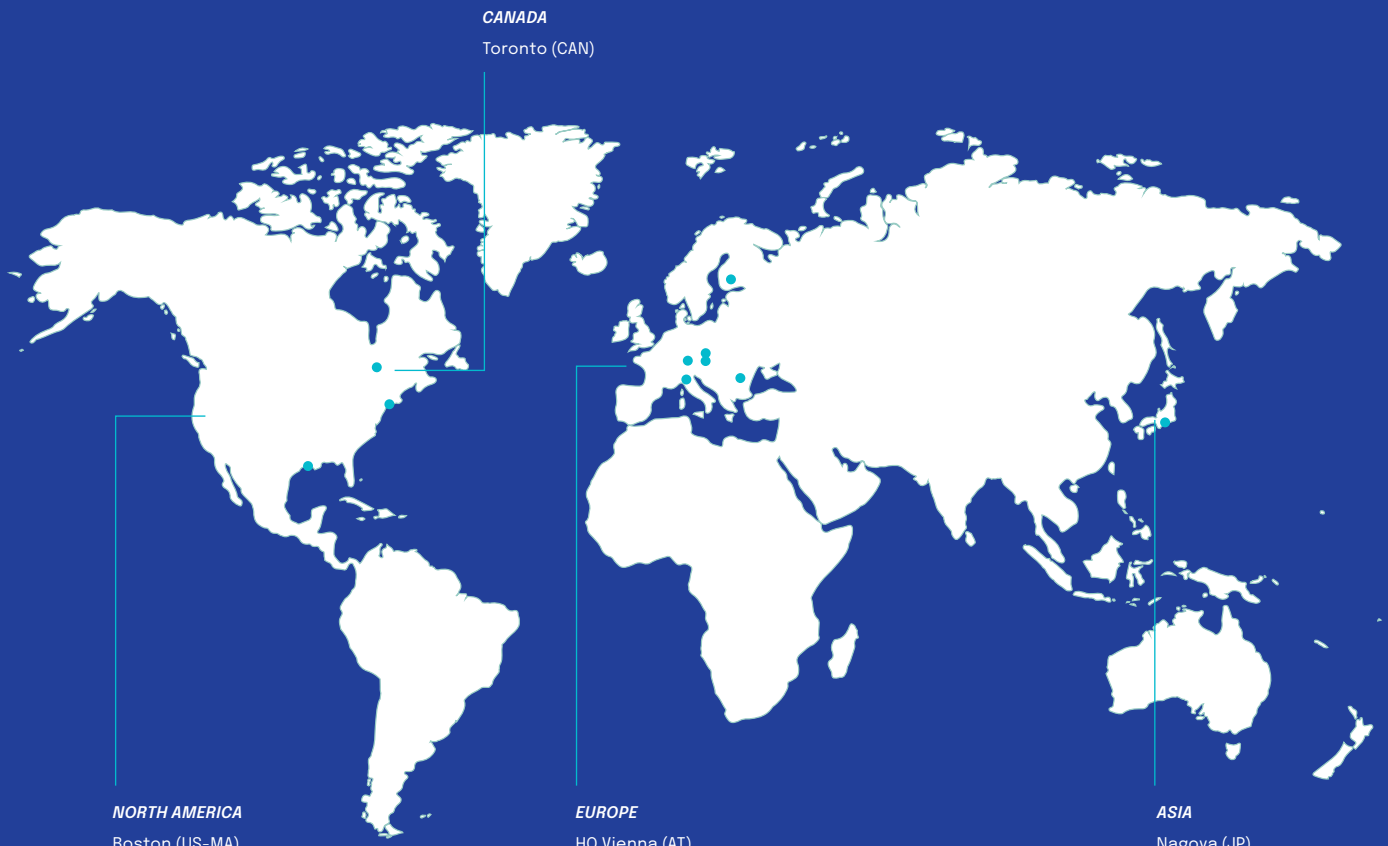
ESA

Shifting from space transportation and exploration to satellites in recent years, TTTECH has been working on several projects within the ESA ARTES program which focusses on innovation in telecommunication systems. As optical communication allows for ever higher data rates, one key development is the "Terabit Switch" which achieves Tb/s cross-sectional throughput in various space orbits. The other key project is the multi-processor system-on-chip (SoC) "GR765" to which TTTECH contributes core IP for deterministic Gb/s Ethernet connectivity.



ARTES

TTTECH



YOUR PARTNER FOR DEPENDABLE DIGITAL BACKBONES AND COMPUTE PLATFORMS FOR SATELLITES, SPACE TRANSPORTATION AND EXPLORATION

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