WHITE PAPER

Tactical Edge Computing Advances Defense System Developments.

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TELEDYNE e2V | Semiconductors
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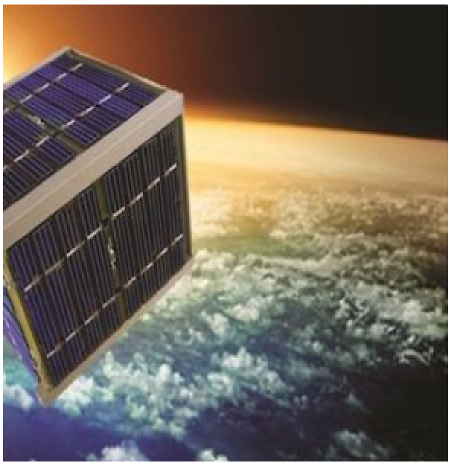
HUGE AMOUNTS OF DATA TO BE TRANSMITTED? SOLVING THIS ISSUE FOR DEFENSE SYSTEM DEVELOPMENTS...

While making **instantaneous decisions** that are **highly reliable and correct,** space and avionic defense system developers must address the issue **of overwhelming amounts of data transmissions,** and computations. Defense system developments often utilize commercial technology. However, there are crucial differences between military and commercial systems, especially at the tactical edge. Military systems (unlike commercial systems) use multi-hop networks while connecting across heterogeneous networks with computations, data transmissions, and decision-making; all within a dynamic environment contested by adversarial actions such as jamming and electronic warfare.

Therefore, as defense system networks expand, **the need to reduce raw data transmissions,** through localized and real time computational analysis and decision-making, **utilizing high reliability tactical edge computing, becomes necessary.**

This fundamentally requires **devices with the computing speed, size, weight, power dissipation, and cost** that will **meet the challenges and adaptability necessary for electromagnetic and radiation tolerant space and avionic defense system environments.**

WHAT IS EDGE COMPUTING?



Edge computing is an expandable distributed information technology architecture in which data is processed at the periphery of the overall network, as close to the originating sources as possible.

Highly reliable edge computing is the deployment of computing and storage devices at the location where data is produced, **within a hostile environment.** This ideally puts compute and storage at the same point as the data source; at the tactical edge.

Edge computing simply moves heavy computing and storage resources away from central data centers and closer to the source of the data itself. Instead of transmitting raw data to a central data center for processing and analysis, heavy computations are performed on the localized raw data. The results are then utilized locally, throughout the network, as well as then transmitted to the central data center for further review and assessments.

Edge computing is therefore a matter of location. Space and avionic defense system developers are continually required to shift the focus away from the overall systems central data center to the tactical edge of the systems periphery, and only the results of the analysis are sent back to the principal data center.

The principle of edge computing is ultra-basic: If one cannot get **the data closer to the data center**, get the data center closer to the data. Edge computing therefore puts the heavy computing and storage where the data is collected. The edge computing module is deployed in shielded and hardened enclosures to protect the circuitry from extremes of temperature, moisture, and other environmental conditions; therefore, it must be hi-rel. qualified.

It addresses three principal network limitations: Bandwidth, Latency, and Congestion/Reliability.

- **Bandwidth** is the amount of data which a network can carry over time, usually expressed in bits per second. All networks have a limited bandwidth. This means that there is a finite limit to the amount of data (or number of devices) that can communicate data across the network.

- **Latency** is the time needed to send data between two points on a network. Latency causes delays in analytic computations and decision-making; therefore reducing the ability for a system to respond in real time.

- **Congestion/Reliability** limitations force time-consuming data re-transmissions and network outages that can shut down defense systems completely.

While edge computing can eliminate many principal network limitations, **it also has some inherent localized benefits: autonomy, data sovereignty, and data security.**

- **Autonomy:** Edge computing is useful where connectivity is unreliable and/or bandwidth is restricted due to environmental/situational conditions. Edge computing does the heavy computational work on site. By processing data locally, the amount of data to be sent is significantly reduced, requiring less bandwidth and connectivity time.

- **Data sovereignty:** Transmitting data across national and regional boundaries creates significant problems for data security, privacy, and legal issues. By definition, edge computing localizes data near its source and within the bounds of prevailing data sovereignty laws. This allows raw data to be processed locally, obscuring or securing any sensitive data before transmission to a primary data center.

- **Data Security:** Edge computing also defines that any data transmitted back to the data center will be secured through encryption to guard against counter attacks.

HEAVY COMPUTING REQUIREMENTS FOR EDGE DEFENSE SYSTEMS

On-board processing capabilities have been the limiting factor for advanced space and avionics defense development systems. Most space satellites and atmospheric vehicles operate simply as relays which essentially convert, amplify, and process data with an on-board microprocessor which requires high speed DMIPS processing capabilities. **The on-board microprocessor and corresponding technologies have to be fast, ultra-reliable, and radiation-tolerant during mission engagement;** as well as, have the ability to repair or replace itself after the satellite is put into orbit. Also, recent advances in the efficiency of power generation, and digital processing, have allowed for enhanced on-board processing which enables heavy edge computing calculations for decision-making and providing communication capabilities such as flexible routing/channelization, beamforming, free-space optics and even signal regeneration.

Teledyne e2v's Space Quad Core ARM® Cortex A-72 Radiation Tolerant Space microprocessor (LS1046-Space) provides a solution for the computing requirements mentioned above. It utilizes a 3-way decode out-of-order, speculative issue, superscalar pipeline technology. Together with space-hardened ARM software modules available, the LS1046-Space is fully capable to enable on-board telecommunication-specific processing which can also be upgraded during the satellite lifetime.

Military tactical edge systems utilize high levels of complex and precise calculations for fast results and decision-making. Such applications devote most of their execution time to heavy computational analysis, as opposed to I/O data transmissions, and therefore typically involve smaller volumes of data. In "compute-intensive" edge applications, multiple operations are performed simultaneously, with each operation addressing a particular part of the problem. The fundamental challenges for "data-intensive" computing are managing and processing exponentially growing data volumes, significantly reducing associated data analysis cycles to support practical, timely applications, and developing new algorithms which can scale to search and process massive amounts of data.

Also, as military defense system developments migrate towards tactical edge computing, often times by necessity, it is simply due to overwhelming increases in data transmission traffic. The need to migrate away from data transmission and towards locally processing the data, for immediate results, becomes clear as data traffic exponentially increases year-on-year.

The global data center traffic forecast, a major component of the Cisco GCI report, covers network data centers worldwide operated by service providers as well as enterprises. The Cisco GCI reports that:

1. Annual global data center IP traffic will reach 20.6 Zettabytes (ZB) (1.7 ZB per month) by the end of 2021, up from 6.8 ZB per year (568 exabytes [EB] per month) in 2016,
2. Global data center IP traffic will grow 3-fold over the next 5 years.

Overall, data center IP traffic will grow at a Compound Annual Growth Rate (CAGR) of 25 percent from 2016 to 2021. Data center traffic will continue to dominate internet traffic for the foreseeable future, but the nature of data center traffic is undergoing a fundamental transformation brought about by cloud applications, services, and infrastructure.

DEFENSE SYSTEM APPLICATIONS IN SPACE & AVIONICS

The creation of the US Space Force (USSF) as the space service branch of the US Armed Forces (sixth armed service branch) is a historic milestone and the world's first independent space force and reflects the growing importance of the space enterprise to national security (established Dec. 20, 2019). The USSF consists of thousands of personnel and operates 77 spacecraft. Major spacecraft systems include the Global Positioning System constellation, military satellite communications, Boeing X-37B spaceplane, US missile warning system, US Space Surveillance Network, and the Satellite Control Network (SCN).

On August 10, 2020, the Space Force released its capstone doctrine: **Spacepower: Doctrine for Space Forces** in which it articulates five core competencies: space security, combat power projection, space mobility and logistics, information mobility, and space domain awareness. Spacepower also lists seven disciplines required for the core competencies as orbital warfare, space electromagnetic warfare, space battle management, space access and sustainment, military intelligence, cyber operations, and engineering/acquisitions.

In addition to the USSF, the **Space Development Agency (SDA)** which is a **directorate of the US Department of Defense,** will transfer to the USSF around October, 2022.

SDA projects:

1. Include optical communications between satellites, and
2. From satellites to a military drone aircraft,
3. Provide a resilient, persistent response to ballistic missile detection,
4. Build the JADC2 (Joint All-Domain Command and Control2) satellite backbone, using the National Defense Space Architecture (NDSA) rapid response launch proliferation.

Other countries are also rapidly developing their own space force capabilities such as the French Space Command (Commandement de l'Espace, CdE) which is a formation of the French Air and Space Force; it supersedes the Joint Space Command, which was created in 2010. The French military is currently carrying out drills to test the capabilities of its Space Command in tackling threats to its satellites. The exercises are part of France's strategy to become the world's third-largest space power.

Confronting the evolving threat to critical in-orbit and avionic assets will require innovative approaches and continued leadership to build more resilient and agile space and avionic defense system architectures.

While the passage of the 2020 National Defense Authorization Act lays out many high-level priorities and leadership structures, the details of how the newest branch of the military takes shape and ultimately advances US interests in space will be born out over the coming months and years. Decision makers will have to navigate a rapidly changing landscape, as potential adversaries develop anti-satellite weapons, and the growing commercial market unlocks new possibilities for space.
For example, tactical edge servers in space will greatly improve:

- The Internet of military things,
- The Internet of battlefield things, and
- The JADC2 tactical edge network.

Tactical edge servers are able to quickly and effectively acquire and transmit geographical data, identify and track targets using object recognition technologies, and engage the enemy during missions that would ordinarily be too difficult, time-consuming, or dangerous for direct human involvement. Edge computing mitigates any delays in transmitting and processing sensor-acquired data from the battlefield and instantaneously increases situational awareness.

Tactical edge servers offer low latency and high reliability which are the most important benefits for military grade heavy edge computing in order to: monitor, collect, relay, and engage in the battlefield – faster. Normally, significant delays in data transfer occurs if the sensor-acquired data must travel long distances for computations and decision-making. Edge computing results in a smoother, more efficient data analytics process for locally collected intelligence. **With local data analysis improved, and network latency and traffic reduced, military leaders can take advantage of an enhanced common operational picture (COP).** As foreign adversaries continue to advance artificial intelligence (AI) and machine learning (ML) capabilities within the battlefield, **edge computing allows for split second decision-making and is a core technology for battlefield competitiveness.**

In other applications, the **US Air Force is in development of Next Gen OPIR**: a system of satellites to provide **early warning of intercontinental and theater ballistic missile launches.** It will ultimately replace SBIRS (Space-Based Infrared System) by providing more survivable and resilient missile warning from geostationary satellite orbits.

The Next Gen OPIR program consists of three **GEO and two polar satellites** (the first geostationary orbiting satellite is scheduled to launch in 2025 and all other satellites are expected to be in orbit by 2029). In addition, DARPA is in development of the Blackjack program which will provide another layer of continual global coverage. Designed to operate in low Earth orbit (LEO), Blackjack will network multiple sensors together. Blackjack's mission (ultimately for missile warning systems) is to also demonstrate sensors, including OPIR sensors, that are low in size, weight, power, and that can be mass-produced to fit on many different buses from different providers, for less than $2M USD per payload. With edge computing, Blackjack will be able to task itself and be aware of its health which means that it will be able to automatically adjust to deliver information to the end user, without intervention from the operator.

Another example of a military defense system against ballistic missiles are **Exoatmospheric Kill Vehicles (EKV)** which can destroy long-range ballistic missiles in space. Launched atop missiles, EKVs use sensors, lenses, and rocket thrusters in order to pick out warheads and steer into their paths. The EKV acquires its target using multi-color sensors, utilizing an on-board edge computer and a rocket motor that steers it towards the target in order to destroy it by collision (no traditional warhead is necessary).

Lastly, the 18th Space Control Squadron (18 SPCS) predicts when and where man-made objects will reenter the Earth's atmosphere. 18 SPCS is a tactical unit and is responsible for maintaining and providing foundational **space situational awareness (SSA)** for the US Department of Defense, as well as interagency, commercial, and international partners around the globe.

The core functions of 18 SPCS includes:

- maintaining a space catalog through space surveillance and tracking data received from the US Space Surveillance Network (SSN),
- generating spaceflight safety data, and
- processing high-interest events such as launches, reentries, and breakups.

18 SPCS analysts perform daily screening of all objects in the space catalog for decay status and then determine which objects are most likely to decay and add them to a list for entry into the reentry assessment process. 18 SPCS utilizes the Ground-based Electo-Optical Deep Space Surveillance (GEODSS) system in order to fulfill their mission.

TELEDYNE E2V EDGE COMPUTING DEVICES FOR SPACE AND AVIONICS' SYSTEMS

Teledyne e2v develops and manufactures Radiation Tolerant Digital Compute Intensive components for Space payloads and platforms. They deliver both Ceramic Non-Hermetic Flip Chip Solutions in **QML-Y** (robust ceramic packaging handled by Teledyne e2v from a bare die to stacking options) and Organic Package **Solutions following ECSS / NASA Space Qualification.**

It's Space Multi Core PowerArchitecture® Microprocessors are continuously being shipped to customers (see Figure 1) providing **successfully launched onboard space systems**; since their Space quality, reliability, and radiation features make them the candidates of preference for Space demanding applications.

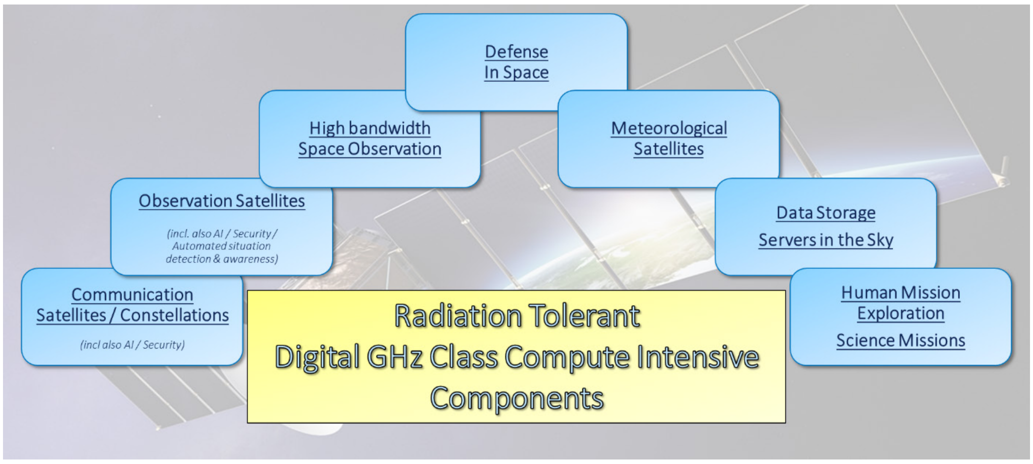


Figure 1: Examples of Space applications served by Teledyne e2v

More recently, Teledyne e2v has introduced the most powerful CPU for the Space market, a Quad ARM® Cortex®-A72 (30,000 DMIPS), as well as high-speed high density DDR4 memory (4GB - gigabytes).

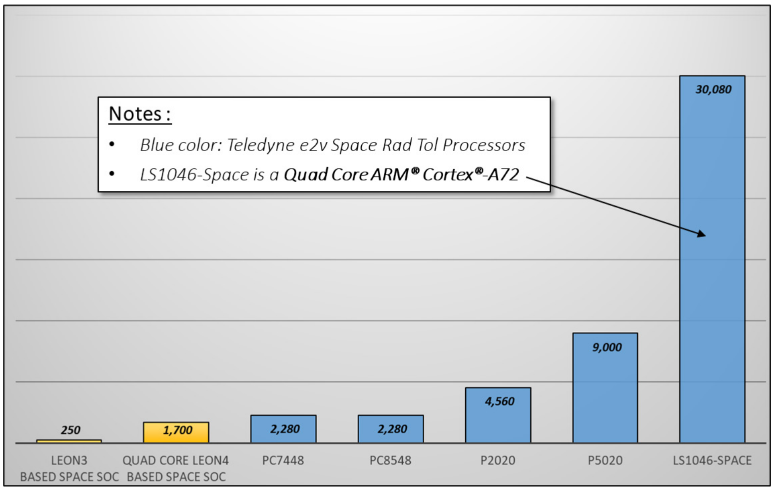
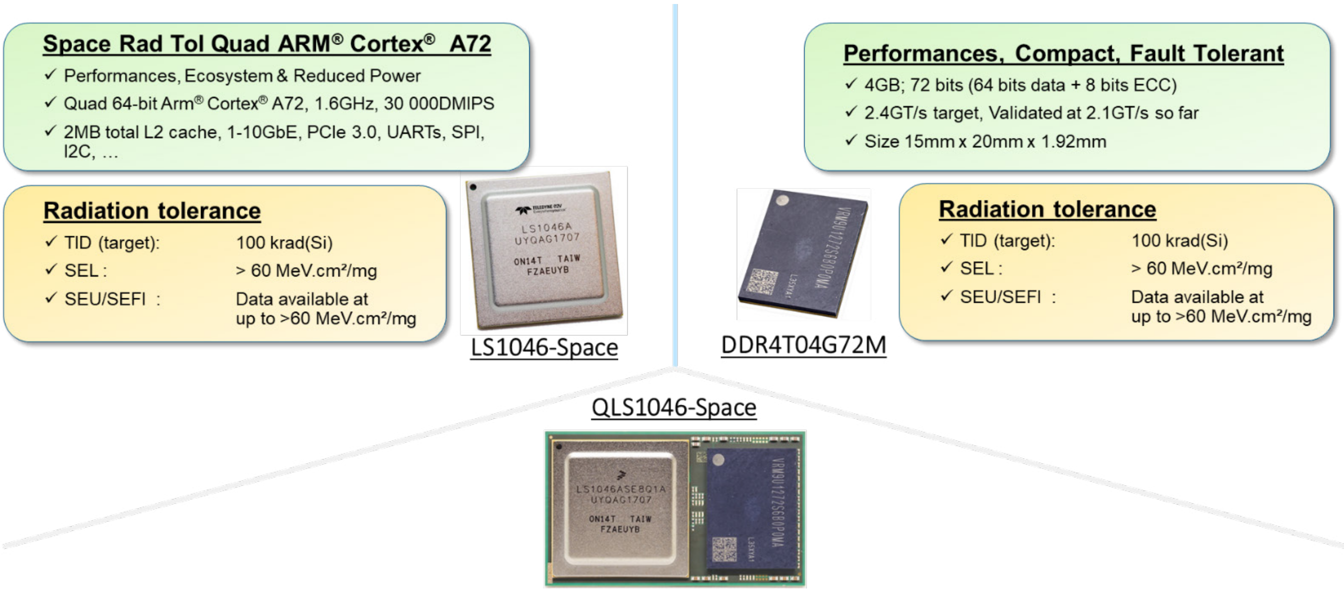


Figure 2: Space processors DMIPS capabilities



Teledyne e2v is proposing both components for Space applications, as well as an integrated optimized version to ease hardware integration, reduce PCB area and lower Time-to-Market.

Figure 3: Teledyne e2v Next generation Space Rad Tol Compute Intensive Offering

DDR4T04G72 is also perfectly compatible to work with usual Space FPGAs, such as KU060, Zync UltraScale+, and RT PolareFire.

The LS1046A-Space offers more than 45,000 CoreMarks® of compute performance, combined with dual 10Gb Ethernet, PCIe Gen3, and SATA Gen3 interfaces. Together with high levels of reliability, high speed computing, available peripherals, and radiation tolerancy, these components are perfectly suited for a range of high reliability space level edge applications.

CONCLUSION

Currently, space and avionic defense system designers are entering a crucial development phase due to the requirement for tactical heavy edge computing microprocessors and storage modules. At the core of each design is the need for stand-alone, reliable, hi-rel., radiation tolerant microprocessors and memory components with the heavy computing processing, storage, speed, reliability, size, weight, power, and cost that will meet the challenges and adaptability for these developments.

Teledyne e2v's next generation of space radiation tolerant compute intensive components enable intelligent heavy edge computing space and avionic defense system developments for real-time reconfiguring while deployed in battle. With local data analysis improved, and network latency and traffic reduced, military leaders can take advantage of an enhanced common operational picture (COP).

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