



Autonomous Systems Safety and Efficiency

Resilience in Extreme Environments

Executive Summary

This white paper explores the impact of edge computing on improving the safety and efficiency of autonomous systems in complex and harsh environments. The integration of rugged edge computing servers, anticipated to reach \$111.3 billion by 2028, is crucial for overcoming these concerns in extreme settings where autonomous vehicles and systems operate.

In industries prioritizing efficiency and safety such as heavy equipment, agriculture, defense, energy, maritime, government services and others, the integration of customizable compute platforms allows seamless adaptation to existing infrastructure for long-term deployment. Advances in sensor capabilities and artificial intelligence (AI) enhance safety by minimizing human exposure, reducing accidents and risks, while robust communication features improve coordination among autonomous systems and vehicles, ensuring streamlined traffic management and safer work conditions.

The core strength of autonomous machines resides in versatile and open, high-performance edge systems, seamlessly harmonizing computational power with unyielding ruggedness – an attribute not universally delivered by most platforms. Highlighting real-world applications, the paper underscores the advantages of private AI at the edge, a subset of edge computing where state-of-the-art AI processes, analyzes and responds to data locally on devices, rather than relying on centralized cloud servers. Illustrating the benefits of high reliability in defense applications, low-latency performance for increased productivity in agriculture, and data security in mining, these scenarios demand systems equipped with sophisticated computational capabilities and rugged characteristics to effectively process data at the source.



Leading the industry, Kontron's S1901 platform consolidates what would typically consist of many different systems wired together into a single unit. The power efficient, conduction-cooled system integrates a server grade Intel Xeon processor with high-capacity memory, seamlessly unified with an NVIDIA GPU and lightning fast NVMe storage. The fully optimized network operating system incorporates a managed Ethernet switch with 1/2.5/10GbE external connections and PTP support for critical timing, which is essential for synchronizing with external timing sensitive devices. This platform can further scale with power efficient next-generation accelerator modules or application specific safety modules, while its generous offering of a wide range of high speed I/O provides the versatility system integrators need.

Leveraging years of expertise and collaborations with other embedded ecosystem technology leaders, Kontron guarantees a state-of-the-art solution specifically designed for mission-critical applications. Designed for long-term deployment with exceptional reliability, the S1901 was built from the ground up to fulfill diverse standards such as MIL-STD, avionics, and heavy equipment specifications, ensuring resilience in extreme environments. It boasts resistance to electromagnetic interference, harsh power inputs, lightning strikes, fluids, ice, immersion, wide temperature fluctuations, as well as shock and vibration.

The open platform's comprehensive hardware integration is complimented with low-level drivers, APIs, and software integration packages compatible with various embedded and real-time operating systems. This enables system integrators to develop applications effortlessly and deploy them across an array of open and proprietary software tools and solutions. The platform's flexibility and open foundation support an infinite range of industry applications and use cases, driving innovation, safety, and faster time-to-market for system integrators.



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In the ever-evolving realm of intelligent autonomous embedded systems being used in vehicles, machines, and devices, technology continues to fundamentally reshape the way industries approach work. The integration of high-performance edge servers emerges as a crucial factor, propelling organizations to achieve elevated productivity, reduced operational costs and substantial advancements in workplace safety. Intelligent edge servers resilient enough to withstand these challenging environments, where equipment and workers are at risk due to extreme weather, temperature, fluids, terrain, and other hazards, are a necessity.

Amidst the surge of autonomous AI systems, Internet of Things (IoT) devices, and smart sensors, there is a growing demand for localized real-time data processing coupled with intelligent decision making. Edge platforms play a pivotal role in analyzing and acting on data at the source, minimizing the necessity for extensive data transmission to central or cloud-based servers. The incorporation of rugged edge platforms is paramount in not only ensuring the resilience of critical systems but also contributing to enhance worker safety in often challenging, hazardous conditions.

In situations where not every server can withstand these environmental rigors, Kontron's S1901 platform offers reliability by processing data closer to where the information is being generated, consolidating the capabilities of multiple servers into a single unit. Contrary to commercial grade systems with standard or industrial boards and components, the S1901 leverages Kontron's proven product line in defense, avionics and heavy equipment by using ruggedized hardware that is carefully designed and tested to ensure continued operation in unpredictable settings. This capability is pivotal in industries where traditional systems may struggle to operate reliably, often necessitating the use of multiple servers working together to accomplish the same tasks.

Dependency on "rugged" modular edge servers

As industries strive to enhance efficiency, precision, and workplace safety through the adoption of autonomous systems and vehicles, the reliance on rugged edge computing servers is expected to witness significant growth. Projections indicate an anticipated surge, poised to reach \$111.3 billion by 2028, according to insights from [*research firm Markets and Markets*](#)^(c). This upward trajectory is attributed to advancements in accelerator models and inference, AI and large language models (LLM), next gen sensors and IoT devices, 5G technology, and the demand for low-latency processing.

As an example, the operational landscape of autonomous vehicles demands robust computing power to effectively manage complex, data-intensive applications. With reliance on AI and machine learning, autonomous systems navigate, perceive their surroundings, and make real-time decisions. Processing vast amounts of data, including inputs from sensors like cameras, LIDAR, and radar, vehicles interpret and understand their environment.

In this technological milieu, prioritizing worker safety is crucial. Leveraging inference on specialized accelerator hardware and machine learning algorithms executed on powerful GPUs, vehicles gain the capability to discern and recognize objects within their surroundings. This allows them to identify elements such as people, other vehicles, and various obstacles. Furthermore, continuous machine learning allows autonomous vehicles to enhance their performance based on real-world experiences. This real-time processing demands sophisticated compute power that not every platform can deliver.

Enter the S1901, a solution equipped with powerful computing capabilities and an IP67 rating, making it an ideal choice for installations on moving vehicles in rugged outdoor environments resulting in more accurate data capture. This unique combination of advanced computing and rugged design positions the S1901 as a reliable solution capable of navigating the intricacies of dynamic environments.

Due to its customization abilities, the S1901 offers a scalable, modular architecture for seamless integration with diverse applications and equipment. With its wide range of industry standard interfaces, integrators can connect sensors, cameras, communication devices, and other hardware components based on specific requirements, ensuring compatibility with existing infrastructure for long-term deployments. In mining for example, a customer may require connectors and interfaces tailored to match those on their mining vehicles and the types of sensors deployed. Military professionals may need more flexibility to modify their systems as technology evolves, guaranteeing that they remain at the forefront of innovation. This adaptability proves especially beneficial in responding to the global challenges faced by many countries today.



Creating a safer workplace for all

Mining, heavy equipment, and agriculture industries are no stranger to work-related injuries, given the inherently hazardous nature of their operations. Heavy equipment handling, exposure to chemicals, repetitive tasks and difficult terrain increase the likelihood of accidents, long-term injuries, and even fatalities. According to the 2021 Workplace Safety Index by Liberty Mutual, *employers were estimated to have paid over \$1 billion per week* ^(**) in direct workers' compensation costs for non-fatal workplace injuries causing disability in 2018. This highlights the necessity of implementing remote systems capable of either semi-autonomously or fully autonomously operating equipment, thereby keeping workers out of hazardous environments.

Simultaneously, it's crucial to establish stringent safety protocols for autonomous systems, integrating advanced, safety-certified technologies to mitigate errors, AI hallucinations and unintended risks to workers and other unintended consequences. The S1901 platform addresses the ongoing concern of workplace safety by providing more options to system integrators, reaffirming its role as a dependable solution in autonomous technology.

When compared to other systems in the marketplace, these features significantly bolster safety on the S1901 platform. Leveraging state-of-the-art software that takes advantage of the onboard Xeon server grade processor, advanced GPU, and/or specialized accelerator, optimized inference models and machine learning algorithms run seamlessly on the system and enable vehicles to accurately identify and respond to moving elements. When combined with an independent functional safety mechanism, the vehicle can attain specific levels of function safety. This guaranteed performance for real-time awareness minimizes the risk of collisions and ensures a proactive approach to safety in the field.

In addition, the S1901 incorporates robust communication and connectivity features, facilitating seamless coordination and information exchange among autonomous and semi-autonomous vehicles. This ensures a synchronized and harmonized operation, reducing the likelihood of accidents caused by conflicting actions among vehicles. The platform can be connected over wired Ethernet to the vehicles' communication systems and synchronize via onboard PTP and GNSS functionality. Furthermore, it can integrate with its own onboard Wi-Fi and/or 4G/5G cellular modem to act as the vehicle's cyber-secure wireless communication hub. This allows it to connect to a remote network operating center (NOC) or other vehicles and control systems within the secured network. The ability to create a cohesive network of autonomous vehicles enhances overall workplace safety by promoting efficient traffic management and avoiding potential hazards.

The platform's comprehensive monitoring and control interface ensures operators have a centralized view of the entire autonomous vehicle fleet. This control enhances situational awareness, permitting swift responses to any emerging safety concern. The system can provide real-time analytics and reports on vehicle performance, potential risks, and overall safety metrics, empowering organizations to proactively address issues and implement preventive measures.



Enhancing efficiency and cyber security with private AI at the edge

In the context of autonomous vehicles and industrial applications, private AI at the edge, a subset of edge computing brings significant advantages to diverse markets. By integrating the benefits of edge computing with the privacy and security of locally processing sensitive information, private AI at the edge becomes especially relevant for applications where data privacy and rapid, autonomous decision-making are critical.



Real-world use cases leveraging S1901

► Safety and Security in mining

Safety and cyber security are paramount in remote mining operations. Long term injuries of operators driving these vehicles in harsh environments is well documented and the industry is leveraging AI technology to solve these problems. Consider a scenario in the mining industry where Kontron's S1901 is deployed in semi-autonomous or fully autonomous mining vehicles. These vehicles are equipped with various sensors and AI capabilities to optimize mining operations by allowing them to operate continuously and enabling the human operator to monitor or control the equipment remotely. In such an environment, the operator requires a safety mechanism to perform a remote stop. The machine should also be able to execute an emergency stop when it detects a hazard.

By processing AI computations directly on the S1901 platform within the mining vehicles, the need to transmit this sensitive data to external servers is minimized. This means that critical operational insights stay within the confines of the mining vehicle, reducing the risk of exposure to external threats. The robust construction of the S1901 ensures the physical integrity of the server, guarding against potential tampering or damage caused by the harsh conditions of mining operations.

Moreover, its onboard security utilizing secure boot, advanced encryption, TPM 2.0, and stringent access controls add many layers of security. In this mining scenario, encrypted communication protocols and the ability to en-

sure no malicious firmware or software is installed on the system is crucial, as the autonomous vehicles need to exchange information with each other and potentially with a central control system. The advanced security features and encryption minimizes the risk of unauthorized access or interception of data during these communication processes, protecting critical information.

► Enhanced autonomy in oil and gas

In an oil and gas extraction facility, the reliable operation of pumping stations is critical for maintaining the continuous flow of crude oil. Unplanned downtime in these stations can lead to significant production losses. In this scenario, the facility deploys Kontron's S1901 open platform with Edge AI capabilities in a harsh environment. This allows the human operator to manage the equipment and implement an advanced predictive maintenance solution in a dangerous setting, remotely.

The embedded AI algorithms analyze various sensor data connected to the platform to detect patterns indicative of potential issues such as pump wear, visual data, weather conditions, imbalances, or variations in fluid pressure. The S1901 has sufficient local processing power to monitor, control and continuously refine predictive models based on historical data and real-time inputs, thus predicting when maintenance is required. Its remote connectivity and secure interfaces allows the operators to also provide software updates or additional virtual machines to run improved applications and algorithms to continuously improve operational efficiency without the need for human intervention.

The S1901 open platform, coupled with the required sensor array and software applications, enables real-time monitoring and task automation along with proactive maintenance, which reduces the need for emergency repairs and human intervention, lowering overall maintenance costs and extending the lifespan of pumping equipment. In addition, the oil and gas facility can maintain a consistent and reliable flow of crude oil, optimizing production efficiency while keeping workers safe.

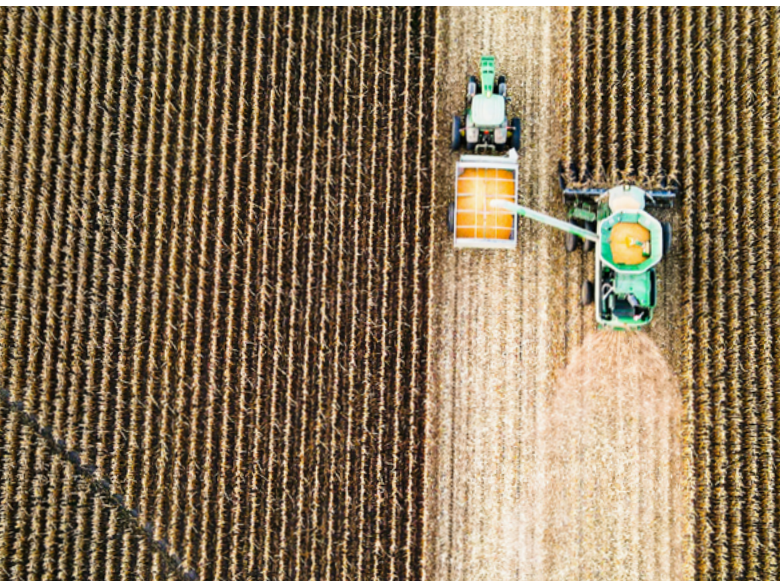


► Low-latency in agriculture

In precision agriculture where Kontron's S1901 is integrated into autonomous farming equipment, vehicles are equipped with advanced sensors and edge AI capabilities to make real-time decisions for tasks like planting, irrigation, weed control, and harvesting. Timely and accurate decision-making is critical for optimizing crop yield and resource utilization.

The ability to perform AI computations and process data locally on the farming equipment becomes invaluable in this context. The S1901 device runs AI algorithms locally, enabling the autonomous farming vehicle to analyze sensor data, like crop image recognition, soil moisture levels and other crop health indicators in real time, without sending large amounts of data to central servers.

In this scenario, reducing latency is crucial for timely decision-making. On-device processing ensures that equipment can make instantaneous decisions without the delays associated with transmitting information to a remote server and waiting for a response. This capability is especially beneficial during time-sensitive operations, such as adjusting irrigation levels or applying fertilizers, contributing to improved operational efficiency and overall safety in precision agriculture.



► Safety and increased productivity in agriculture

On a farm for example, the S1901 is ideal for preventing accidents in areas where people and machines work in close proximity. If a hazard is detected, collision avoidance enables the machine to come to an emergency stop until the environment is safe again. With GPU-performing video analytics plus AI, the system can detect obstacles and temporarily divert the machine's path, allowing it to avoid the obstacle at that moment. The machine then returns to its original route once the obstacle has been cleared from the area. As a result, farmers can run a more productive business. Rather than having to stop production altogether when hazards occur, autonomous systems will continue to work and revisit the original path at a more convenient time.

Additionally, in a leader follower scenario, a machine operated by a human operator can lead the way while autonomous machines with no operators follow. In this model, follower vehicles will automatically follow the leader vehicle, making agriculture operations much more efficient. With systems interconnecting in this way, the farm performs tasks more rapidly while keeping workers safe from hazards. The integration of leader-follower systems not only enhances efficiency on farms but also prioritizes worker safety, heralding a promising future for agricultural technology.

► High reliability in defense

In a defense scenario, consider the deployment of autonomous or semi-autonomous reconnaissance ground vehicles, maritime craft or airborne drones equipped with Kontron's S1901 platform. These unmanned vehicles are designed to operate in challenging environments, and harsh weather conditions, where maintaining a reliable SATCOM or GPS connection may be challenging.

The ability to operate and make decisions locally in real-time, even in the absence of a remote connection becomes crucial in this defense application. For instance, a vehicle equipped with S1901 may be tasked with surveying a remote and hostile area where SATCOM or GPS connectivity is disrupted or jammed.

In such a scenario, the specialized onboard processing power utilizes the vehicle sensor array to maintain continuous operational functionality of the autonomous vehicle, allowing it to navigate, collect data, and make decisions autonomously without relying on a stable connection or direct operator control. This capability contributes to the reliability and effectiveness of defense operations in remote and harsh conditions, where maintaining continuous functionality is paramount for mission success and the safety of military personnel.



The Kontron expertise

Kontron's extensive expertise in constructing rugged edge servers for mission-critical applications is rooted in over 25 years of experience and an understanding of the unique challenges posed by harsh and demanding environments. Tailored for sectors such as defense, aerospace, maritime, railway, heavy equipment/agricultural, energy, emergency/government services, and industrial automation, Kontron's rugged edge servers are designed to endure extreme conditions, including temperature variations, water exposure, shock and vibration, protection from lightning or harsh voltage and power fluctuations and electromagnetic interference (EMI). This system ensures uninterrupted performance in mission-critical scenarios where reliability and availability may be of concern.



By collaborating with other technology leaders, Kontron integrates leading-edge components into its products, granting customers access to the latest technological advancements. Partnerships are significant in enhancing the interoperability of Kontron's products with a broader ecosystem of technologies, facilitating integration into existing infrastructures. Through the pooling of expertise and resources, customers benefit from a more robust and reliable product offering, along with the assurance of ongoing support and updates.

Kontron's unwavering commitment to continuous innovation and a customer-centric approach is evident in the development of its rugged edge servers that adhere to stringent industry standards. Servers incorporate cutting-edge technologies, such as optimized thermal management for conduction cooling, modular components, and optimized power consumption, ensuring longevity in rigorous operational settings. These features enhance overall workplace safety by providing employees with reliable equipment.

These servers go beyond standardized solutions, providing a flexible framework that empowers integrators to optimize their systems for the most demanding applications. The S1901 serves as a foundational open platform extending further than its inherent durability. Designed with modularity in mind, it offers customizable options to meet specific industry or application requirements. This adaptability allows users to tailor the system to address evolving needs, establishing a scalable, safe, future-proof solution.

Kontron's S1901 platform, a beacon of reliability, processes data closer to the source, consolidating the capabilities of multiple systems into a single, rugged unit. In challenging environments, where traditional systems will falter, the S1901 stands as a resilient and versatile solution, reflecting Kontron's commitment to shaping the future of autonomous systems and vehicle technology for a safer and more efficient working environment for all.



- References:
1. **Edge computing market** ^(*)
 2. **Business case** ^(**)



About Kontron

Kontron is a global leader in IoT/Embedded Computing Technology (ECT) and offers individual solutions in the areas of Internet of Things (IoT) and Industry 4.0 through a combined portfolio of hardware, software and services. With its standard and customized products based on highly reliable state-of-the-art technologies, Kontron provides secure and innovative applications for a wide variety of industries. As a result, customers benefit from accelerated time-to-market, lower total cost of ownership, extended product lifecycles and the best fully integrated applications.

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