WHITE PAPER

Engineering One Computing Platform for All Classes of Train

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Executive Summary

This white paper examines what key technological and material requirements should be required for effective on-board train computers. With the rapid advances in train automation of these last ten years, a spectrum of graded on-board train systems has opened up, broadening the potential uses that computers may be put to aboard trains. This has made every aspect of rail operations safer, speedier, more convenient, and more reliable, while increasing not only the design complexity, but also the design potential of all on-board systems. To make the most of these advancements, on-board computers must meet a range of hardware requirements.

Defining Classes of Train Automation

These days no train is entirely without automation, but the precise extent varies widely from system to system. That means there is a bewildering variety of on-board systems. In this context, two standards are useful: CENELEC's EN 50155 / IEC 60571 may be taken as the essential prerequisite for any electronic equipment that is part of a train system, while the grades of automation (GoA) defined by IEC 62290-1 are helpful classes for discussions. GoA1 is defined as minimally automated vehicles, systems equipped only for warding off catastrophic driver errors with mechanisms like dead-man's-switches, called "automated train protection systems" (ATPs). The contrasting highest grade is GoA4, which describes fully automated, unattended train operations (UTO) where all train signaling and control is handled by a computer system. In between these two extremes (minimal ATP and full UTO), UITP further defines two more grades: piloted trains with both ATP and automated train operation systems (ATO), and driverless-but-attended systems, which are fully automated but still require a human presence.[i]

Though originally framed in terms of mass transit systems, these categories equally apply to freight and mainline systems, as well; they also exemplify how recent developments in operator automation have primarily focused upon increasing safety by reducing human involvement in signaling and navigation. In many places, that shift is already complete: fully unattended trains now run in many places, as far afield as Dubai, Taipei, Copenhagen, and Sao Paulo, and more are opening up every year. Yet industry discussions of these advancements often gloss over ancillary support platforms to focus solely on the strictly regulated and more technically demanding core signaling and control systems.

Whereas train crews traditionally required several people working in support of the engineer (brakeman, conductor, fireman, etc.), so too complementary systems are needed for a fully

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functioning train system. These onboard applications will vary depending on the specific class of train being served; however, just as GPS has become a truism for any mobile platform, so too certain features will be required by every train, regardless of its class. While core control and signalling systems will always need to be carefully reviewed for compliance with the strict, safety and reliability specifications governments demand, a large part of train automation—in many cases, the larger part—is embodied by equally indispensable support systems. In this whitepaper, we review what sort of hardware is needed for auxiliary on-board automation systems.

Freight, Mainline, and Mass Transit Train Systems

With the roles for onboard train systems still mutating and shifting, the first requirement for auxiliary computing platforms is scalable modularity: there is little benefit to installing a computer that will withstand inferno and earthquake for seven years if it is made obsolete in only two. The rapid pace of changes in today’s on-board automation systems makes versatility a key requirement, which translates into on-board systems that may be precisely tailored to each train’s needs. In the next few sections, we take a look at what those needs precisely are for each class of train.

Durability and Reliability in Freight Systems

Auxiliary Computing Applications	**Freight Trains**
Telemetry & monitoring	Various predictive maintenance and events monitoring
WAN Communications	Wi-Fi, cellular, (no trunking), likely radio and sat-phone extensions
Networked Video Recorder	External train monitoring for collisions, security, and vandalism
Operator Logistics	Arrival estimates, crew scheduling and information, manifest management, maintenance alarms, etc.
Durability Requirements	Highest durability: Industrial-grade, 24/7 operations; harshest environment with respect to vibration and temperature; data preservation and system security most important

Of the three classes of trains, freights present the most demanding mechanical requirements with the least demanding functionality. Freight engines effectively run 24/7, for years on end, with only sparsely scheduled stops for maintenance along the way; they are engineered for power and durability, not comfort. With consists that average two to three kilometers in length and automation systems that have reduced crews to only two or three people, on-board computing platforms are a key engine component, with rugged dependability the paramount concern. For freight trains, the key computing roles outside signaling and train control will be crew communications (both local and remote), crew-related scheduling and management, payload tracking and management, and safety/security monitoring. All of these may be served by a single computing station located in the train engine.

Auxiliary Freight Train Computing Systems: An Overview

Crew communications to the ground will be served over Wi-Fi and cellular uplinks to wayside stations, and these could further serve either as a communications gateway for the signalling and control systems, or a wireless LAN. For some systems, serial and Ethernet interfaces may also be needed to link satellite phones, or regional radio services like SMR; and as the local gateway to wider area networks, the server will require a firewall and intrusion detection system to secure the entire system (but especially control and signalling) against unauthorized access.

Lighter applications for crew scheduling, cargo manifests, and other management functions may be also be installed; these would likely take the form of several distinct databases served by an integrated user interface. Finally, the most processor-intense service this central platform could offer would be an NVR with multiple CCTVs. The NVR’s first role would, in most instances, be as a collision monitoring and recording system; for that purpose, cameras could potentially be installed in many spots along the first engines. However, depending on security needs, operators might also decide to outfit cameras along the entire consist

Thus, compared to mainline and mass transit systems, freight trains require a rather compact bundle of service features. As mentioned before, the primary requirement for freight trains is durability, so of much greater concern is the elimination of as many points of failure as possible. Currently, the two most common points of computer failure are fans, and data storage.

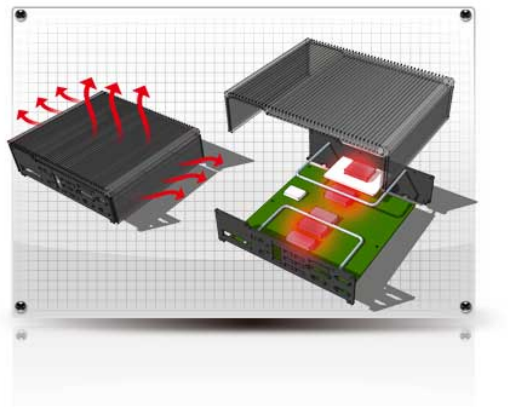
Data Storage

Today, the most cost-effective data storage mechanisms are hard disk drives. While solid state drives do offer tempting features, there are several reasons why, in most cases, hard disks are still a superior choice for storage medium. First, there is cost: the cost-per-bit for solid state drives is still somewhere close to three times what it is for hard disk drives. This means that building high capacity network storage can quickly become prohibitively expensive.

Secondly, however—and more importantly—solid state drives are still troubled by limited life cycles and sudden, unpredictable failures. This is because all flash media devices are still restricted to a (relatively low) hard limit on the number of write operations they can sustain, and it is very difficult to predict when that limit will be reached. More importantly, once an SSD fails all of the data it once stored is irretrievably lost. This means that, when used for high access computing applications like NVRs, the lifetime of solid state drives is considerably shorter than that of hard disks and, as it approaches its end of life failure, much less reliable. Pair that with the cost-per-bit relative to a hard disk drive, and it is readily apparent why disks are often preferable to solid state devices.

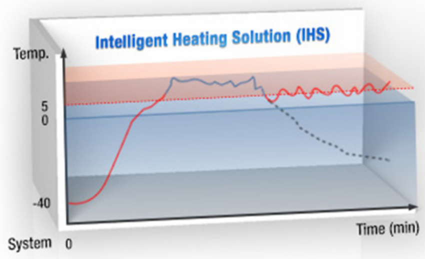
Taking these caveats into consideration, SSDs can already be said to be a preferable solution for root system storage, even if, as of today (April 2013), hard disk drives remain superior for tasks that involve a lot of disk writes. Industrial-grade hard disks engineered for high-vibration mobile environments—the sort that have been engineered for automotive systems—are thus the best high capacity storage alternative for the high vibration environment of freight trains.

System Fans



Internal fans are among the least predictable and quickest-to-go of computing components; consequently, in the last few years many industrial customers have come to view fanless computers as a base requirement. Creating a fanless hardware platform means maximizing thermal efficiency by carefully arranging computer internals, and allow the computer case to be sealed once the fans have been eliminated, protecting it from moisture, dust, and other corrosive contaminants. Together, these two enhancements do more to increase the average mean-time-before-failure (MTBF) than perhaps any other single design change. These benefits may be boosted when the internal components are also conformally coated.

Temperature Tolerance

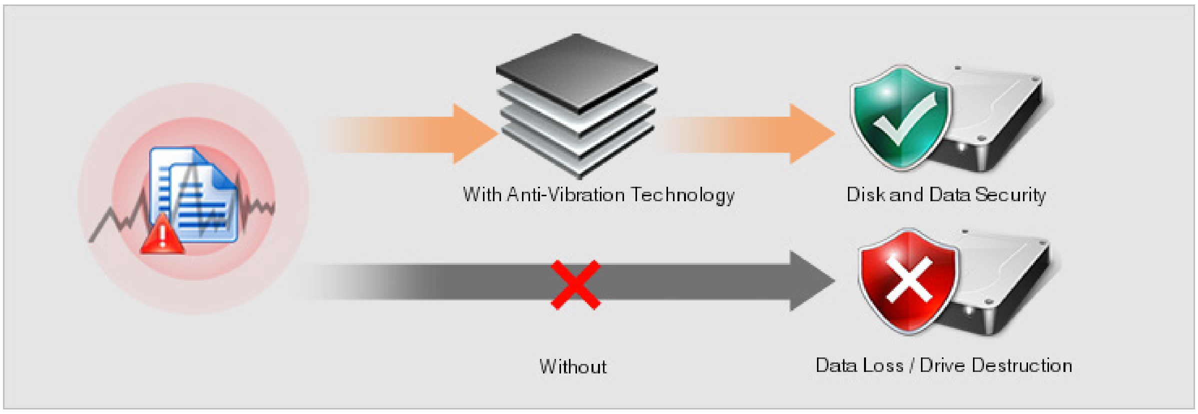


Freight trains are likely to experience wider temperature fluctuations than other classes of trains, so the system's temperature engineering shouldn't end with eliminating the fans. Frigid cold is as likely a problem as sweltering heat. Beyond the possibility of damaging internal components, either of these extremes will also rapidly debilitate a storage drive. Thus, after eliminating the fans a train system should next be provided with on-board heaters and an integrated, independent temperature sensor (T-sensor). These enhancements allow the system to protect itself by shutting down hard drives when things get too hot (thereby eliminating a key heat contributor and protecting data), or by heating up storage devices when the device's ambient temperature drops to well below zero. Further, an independent T-sensor may also serve as a powerful supplementary tool for predictive maintenance (PdM) analysis of the local system.

A related mechanical problem takes us back to considering memory storage mechanisms, again. Obviously, whenever the system shuts drives down a backup device should be available to store data for later writes. For these purposes, an integrated, non-volatile flash memory device should be employed for temporary storage when the drives power down. Once conditions are appropriate to bring the drives back up, the data may be transferred from the temporary medium back to the main drives.

Vibration

Vibration is a huge problem for train computing platforms. Measures must be taken to control and account for the unrelenting shocks and shimmies that constantly shake a freight engine. Such measures may be passive shock absorbers mounted internally, at the drive mount, or externally, at the computer's mounting bracket within the computer cabinet. However, because vibration is such a critical effect, ideally the computer will be equipped with an independent vibration sensor (G-sensor), in addition to any that might be included with the memory drives. An independent G-sensor will, like the T-sensor, also facilitate PdM diagnostics, and will also provide valuable data for configuration analysis. For those willing to make the most of it, the G-sensor may even be customized for further control automation. With these enhancements in place, temperature and vibration conditions and responses may be automatically monitored, analyzed, and addressed.



EMC: Electro-Magnetic Compatibility

The last and perhaps most important safeguard is protection against electric surges. Trains in general—but particularly freight trains—suffer constant power surges. In addition, they also suffer intermittent, unpredictable power failures; these failures may only be milliseconds in length, but they are enough to cripple a system with constant restarts or data corruptions. To ensure proper functioning under these conditions, capacitors are used to provide repositories that will carry the system through these failures, and electric isolation protection is designed in as well, to protect against common surges.

In comparison to other train environments, complementary computing roles for freight trains are more restricted, but the durability demands are much higher. Outside of the core control and signalling systems, the roles for computing platforms will be largely limited to communications, NVR support, and the miscellany of crew and cargo management.

Flexibility for Passenger Line Systems

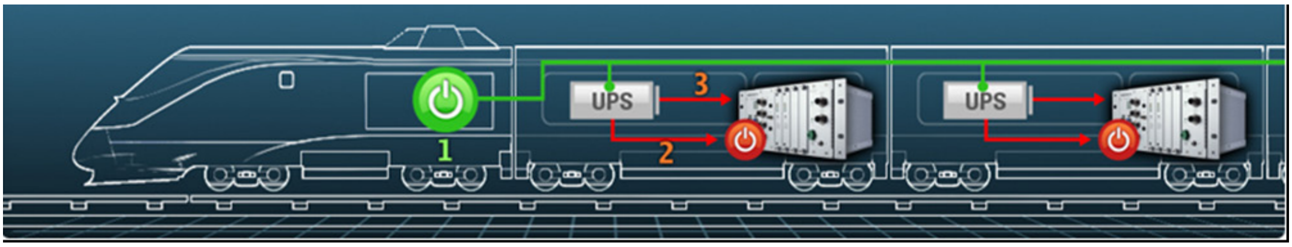
Auxiliary Computing Applications	Mainline Trains
Passenger Wi-Fi	High Priority
Telemetry & monitoring	Predictive maintenance monitoring, Door operations (interior), HVAC, etc
WAN Communications	Wi-Fi, cellular roaming; channel trunking likely
Networked Video Recorder	Internal train monitoring for passenger safety, logistical planning, and train security
Passenger Logistics	Passenger analysis, ticketing systems, logistical analysis,
Operator Logistics	Supply stock (food, water, newspapers, and other vended items); ticketing systems; crew scheduling and information systems; lighting, seating, etc.
Passenger Infotainment Systems	Extensive: High-availability, feature-length presentations, highly interactive with a wide selection
Durability Requirements	Low to moderate durability: Harsh, high-vibration environment; likely wide temperature fluctuations; distributed multi-node systems; high security

On-board computing environments on mainline trains are much different than those found on freight trains. In comparison to freight environments, mainline trains will have more effective climate control, better HVAC systems, and will be engineered to serve passenger comfort, rather than just the hauling of cargo. Thus, mainline trains pose a distinct set of design challenges atop the same conditions found on any train: EMC, vibration, heat, and cold will all still cause problems, so the same qualifications regarding storage media, vibration protection, temperature tolerance, enclosures, heat dissipation, and so forth will also still apply.

With mainline systems, on board computing assets will support more automated services and applications than on any other type of train. The on-board roles for mainline computers are significantly expanded, while the computing infrastructure will be more widely distributed throughout the train, extending much farther than a freight system. As with freight trains, mainline computers will handle communications with wayside stations and control centers; what is most different is that WLAN is no longer optional. Mainline passenger trains require public WLAN availability, and will additionally coordinate an internal network that manages passenger comfort, passenger services, and a large range of logistical issues.

Power Centralization

While mainline trains need the same sort of EMI and power protections as freight trains, they also require one more feature: crews will need consolidated power controls and redundant power supplies. As just mentioned, mainline computing systems will be distributed across the entire consist, with perhaps every car along the train served by a local computer station. These stations could include gateways, wireless routers, computer servers, networked storage devices, sensors, controllers, or even RTUs, as well as other devices. Consequently, without a consolidated power control, shutting down a full mainline train system would be a burdensome and time consuming process of going into every car, opening the cabinets, and powering down the stations one by one. Such an approach could take hours. To get around this, digital I/O switches connected to a central power control may linked to serial or Ethernet interfaces on the computer so that the computer can be configured to initiate an automated shutdown once power is cut.



Yet there is also a more complete solution: power redundancy and centralized control may be simultaneously served by universal power supplies (UPS). These can be wired into a control system so that the local UPS handles the shutdown procedure; this would be initiated whenever central power is lost, regardless if it is a scheduled procedure, power failure, or an emergency operator shutdown. Indeed, using SNMP or a control logic, it would even be easy to set up graded responses, to deliver intelligent handling for a variety of power events. To build these management options, just as above the computer only needs to support serial or LAN connectivity and communicate in standard, established protocols.

Complementary Systems

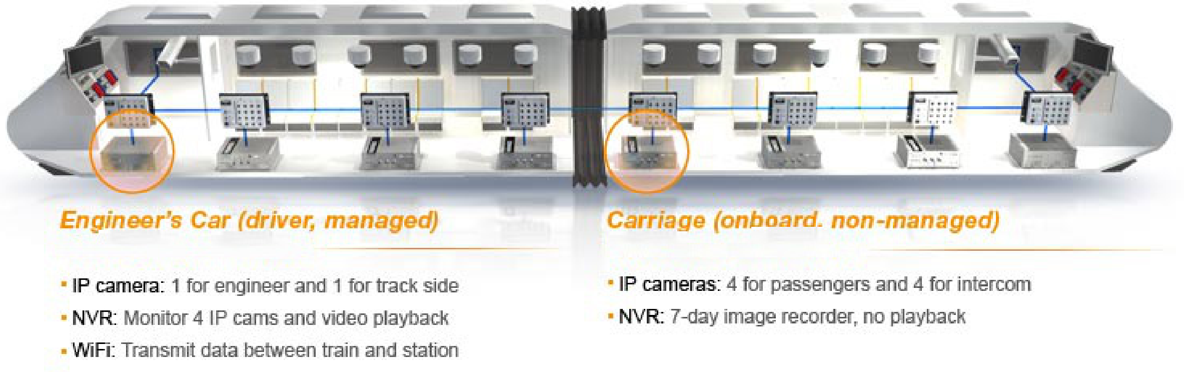
As with freight systems, the first responsibility for computers on mainline trains will be to maintain communications links with the primary control center and wayside stations. Both cellular and Wi-Fi modules will be imperative, here, but with the additional caveat that the computing hub will be serving a Wi-Fi access point (AP) for passengers. In that event, cellular trunking of several modules may be required, and—depending on the bandwidth of the connection and the services offered—so also more than one Wi-Fi module, as well. For these reasons, the communications features for a mainline computing system will, in most cases, be far more demanding than for a freight train and may include a series of distributed servers.

Passenger Logistics

Because mainline trains serve passengers across long hauls, there will be several passenger subsystems peculiar only to them. Foremost among these will be passenger ticketing and logistics systems. Passenger logistics encompasses a potentially huge class of subsystems that may involve CCTV, card readers, both WAN and LAN Wi-Fi links, localized automation, passenger analysis software, and passenger safety systems. Some of these subsystems will involve intricate software suites that integrate video, audio, RFID, Wi-Fi, 3G cellular, with serial IA interfaces. Passenger ticketing systems, for instance, can potentially range from the extremely simple—involving little more than a database and a human intermediary—to the very complex, involving fully automated wireless systems based around RFID cards, perhaps also serving personal mobile devices which connect over Wi-Fi, and that may be integrated with serial I/O systems. Consequently, a powerful, modularized base computing system that can be quickly and easily adapted to platform demands will always be a core requirement.

Video Systems: CCTV and NVR

On-board video surveillance systems complement both passenger and operator logistics, but they serve such an important role that they must be considered an independent system in their own right. An NVR system for a long-haul train of any sort will need to be capable of managing scores of CCTV stations, and must integrate these systems with security systems, sensor data, and automated alarms and controls. The network bandwidth and data capacity will require a strong, fast CPU capable of managing the high throughput of generated data, while highly reliable and suitably large data storage systems must be available for recording the images. To protect these storage devices, strong anti-vibration measures will be required to protect against the vibrations that pervade any train environment. Thus, long haul mainline train systems will require much the same sort of vibration protections as freight systems, but with much greater data storage demands.



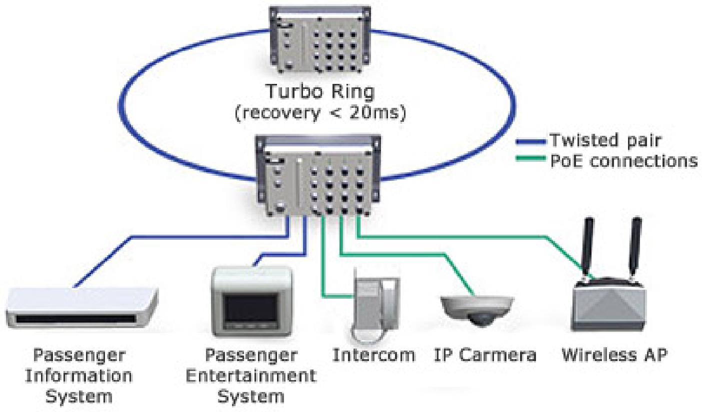
Operator Logistics

As train automation shrinks train crews to fewer and fewer members, the need for centralized operator control and awareness of logistical issues grows. Operator logistics will be a wholly distinct subsystem from the information gathering and analysis involved in passenger logistics.

Auxiliary computing operations will employ both independent and integrated hardware and software, possibly monitoring things like plumbing and HVAC systems; intrusion detection and network tools for IA and IT systems; the stock taking of vended supplies like food, reading materials, souvenirs, and other knick-knacks; potable and non-potable water supplies; crew schedules and information services; the ticketing system backend; plumbing, lighting and electrical monitoring; and so forth. With such a wide variety of sensors and actuators potentially scattered throughout the train, the necessity of network distribution is once again starkly contrasted against the crew's awareness and response capabilities.

Passenger Infotainment

One of the key systems that has become a requirement on the latest long-haul, mainline passenger trains is a passenger information and entertainment system. These systems vary widely, and can incorporate public screens, private in-the-seat screens, and digital signage like scrolling LED/LCD carriage marquees that inform passengers of arrival/departure times, delays, weather conditions, and other points of interest. These systems may also serve passengers with links to the train crew, internet connections, or entertainment like movies, music, and games. For long-haul trains, these systems will need to be built to serve highly available, high-bandwidth connectivity with security measures strong enough to support monetary transactions.



Generally speaking, while in some ways mainline train systems will require durability comparable to that required for freight systems, because of their distributed architecture and relatively mild operating environments hardware requirements are less strict. The biggest challenge these computers will need to address are the extensive software and automation subsystems they must manage, and the consolidation of controls that crews will require. Modules for additional Ethernet or serial interfaces will be important, as will Wi-Fi and cellular additions, so that operators may conveniently extend their systems to meet their passengers' ever-increasing demand for high bandwidth internet access.

The Happy Medium of Mass Transit Systems

Auxiliary Computing Applications	Mass Transit Trains
Passenger Wi-Fi	Low priority
Telemetry & monitoring	Door operations / obstructions, HVAC, etc.
WAN Communications	Most limited: limited Wi-Fi, likely not trunked.
Networked Video Recorder	Carriage monitoring for passenger safety, maintenance, and logistical planning
Passenger Logistics	Lighter: basic information, passenger comfort, safety)
Operator Logistics	Light
Passenger Infotainment Systems	Minimal: short presentations, rapid delivery, limited passenger interaction
Durability Requirements	High durability: Moderately harsh environment w/r/t temperature and vibration; distributed data storage, high security

Mass transit systems include tramways, metros, and when the devices are NMEA approved, even buses; they are distinct from both mainline and freight systems, and represent a median between the two extremes. These onboard systems might, like mainline systems, provide Wi-Fi access to its passengers, but they also might not; they will provide reliable Wi-Fi communications for the operators, but cellular will may be entirely unnecessary. Similarly, where mainline systems require large passenger information and entertainment systems, passenger infotainment for mass transit is minimal, typically restricted to marquees displaying arrival times, location, operator notifications, and perhaps larger screens providing services like weather reports, tourism information, or advertisements. In contrast, though, because of their unrelenting work schedules the durability requirements for mass transit trains may skew more towards freight standards than the milder mainline passenger environments. In short, provided the computing platform is extensible, adaptable, and durable, any computer that can serve both main- and freight lines will be ideal for mass transit systems.

One Computing Platform for Any Computing Need

For trains, it is clear that many on-board computing roles outside the vital control and signaling systems already exist. To satisfy the demand for a durable, versatile computing solution that fills this need, Moxa has developed the EN 50155 compliant TC-6110 train computer. With two Gigabit Ethernet LAN ports, 2 USB hosts, an RS-232 serial interface, and two slots for expansion modules, the TC-6110 can be easily configured with Wi-Fi modules, cellular clients, additional networking interfaces, and additional storage capacity. GPS, independent vibration and temperature sensors, and conformal coating all come built-in with standard models. Housed in a durable, fanless, compact 3U rack-mount shell, the TC-6110 further features Moxa's SafeGuard™ technology suite, a collection of software and hardware optimizations to give maximal data security and computer reliability under the harsh conditions peculiar to train environments. When combined with Moxa's line of railway-optimized switches, serial-to-Ethernet gateways, modular RTUs, remote I/O, IP cameras, and all-purpose 802.11 wireless stations, the TC-6110 and V-series mobile computing platforms deliver an on-board technology solution that will provide you with a reliable, durable, and versatile solution. Contact Moxa about our broad line of train components today.

Find out more about the TC-6110 here.
Read up on the SafeGuard™ technology suite here.

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[i] http://www.uitp.org/Metro%20Automation-promotion/What%20is%20UTO/what%20is%20UTO.htm#Grade_of_automation