Cica Group
White Paper

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Australian Tolling System Specifications

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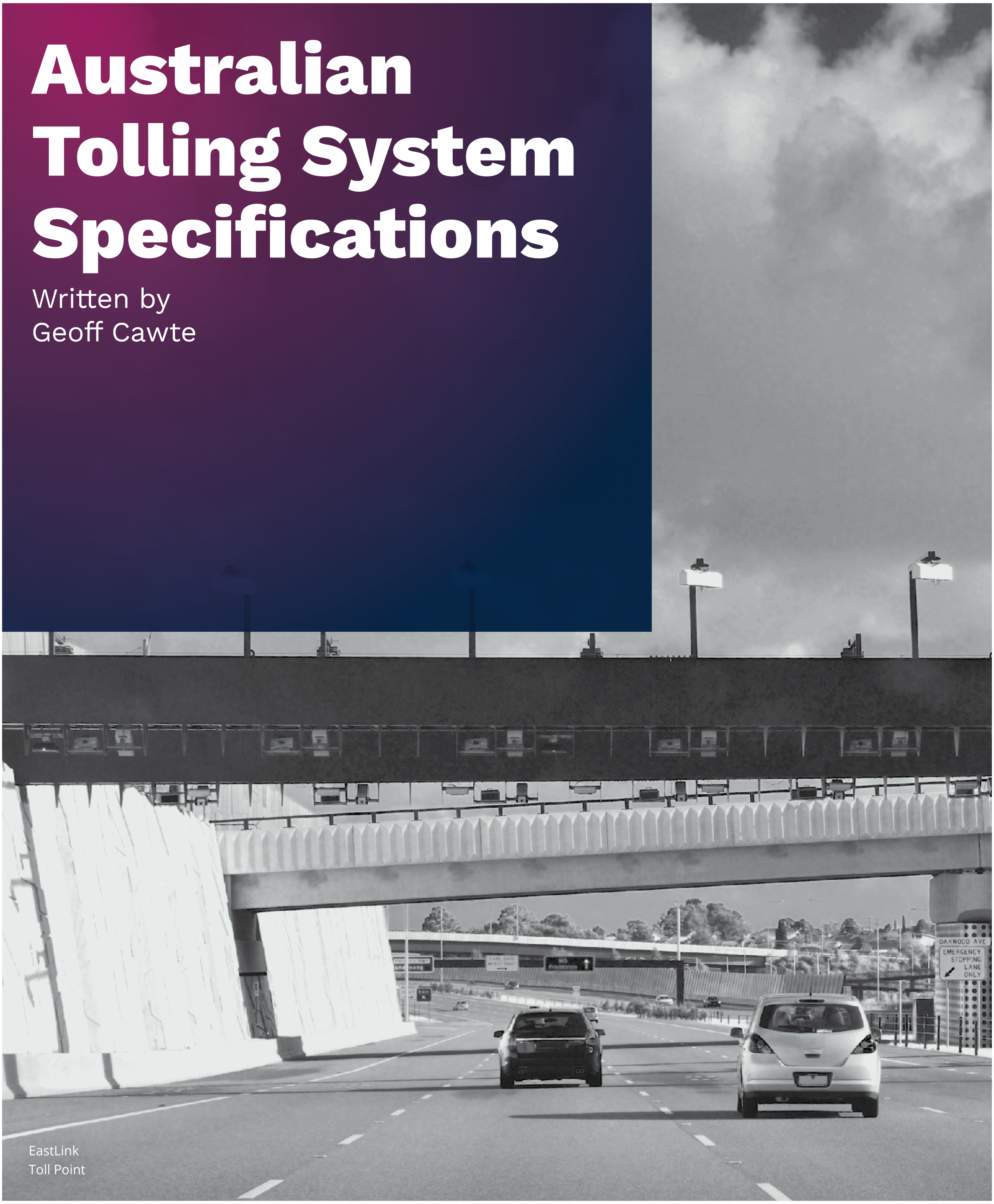

EastLink
Toll Point

There are a common set of design specifications used across toll collection systems implemented in Australia. This white paper describes the common styles of gantry systems, vehicle classification requirements and how they differ between states, preferred technologies and performance specifications, as well as security systems, warranty and testing programs and expectations for implementation of future tolling projects.

Gantry Systems

The majority of modern tolling systems in Australia employ dual or single gantries at the roadside for the detection and classification of vehicles, interaction with an on-board unit (OBU or Tags) and capture of images for vehicle recognition.

Gantries for Multi-Lane Free Flow (MLFF) tolling situations generally are freestanding walk-on structures which allow maintenance and equipment replacement to be carried out without traffic lane closures.

Construction standards require gantries to have a design life of 50 years minimum. The gantries are constructed of galvanized steel or anti-corrosion coated steel and may be clad to blend more effectively with their surroundings.

Equipment mounting height varies between 5.5m and 10.4m depending on the sensor type and system design requirements. Gantry transverse beams have a minimum height above the roadway, which varies from 5.5m to 7.0m depending on the type of equipment mounting system being employed.

It is normal to have some form of safety mesh surround to prevent loose objects falling onto the roadway. The sensors themselves may be mounted below, within or above the transverse beams.

All ladders used to access gantries must be equipped with fall-arrest systems as must the walkways on the gantries to service the roadside tolling equipment.

Equipment mounts are normally of quick-connect type to minimise loose items (e.g. attaching bolts and nuts) and all equipment have safety lanyards attached to prevent removed equipment being dropped onto the road. Floor hatches, where they are used, must be designed to prevent personnel being able to fall through.

The sensors used on the roadside gantries are:

Tag Readers/Transceivers

These read and write to the tag and locate the tag in time and space either continuously through the tag communication zone or at specific points to enable correlation to the vehicle.

Vehicle Detection systems

These utilise either lasers or optical systems; treadles or loops may also be used, but these are not normally the primary detection sensor in MLFF systems. However, these are used where axle counting is required for tolling purposes. Lasers can be up to four per lane in one direction (two entry per lane, two exit per lane with overlap between sensors). Optical sensors are normally one per lane per direction, with overlap between sensors. These sensor overlaps are to ensure that vehicles are detected anywhere within the tollpoint boundaries.

Vehicle Tracking systems

These can be optical or laser, are either continuous or at discrete points throughout the detection zone. Optical tracking systems require some form of enhanced illumination to optimize performance; this has typically been white or blue-end light, but infrared (IR) systems are now being deployed in which the illumination is invisible to the human eye. These systems are required to correlate both tags and images to a vehicle passage and are a necessary piece of the Roadside Equipment (RSE).

Vehicle Classification systems

These are either laser or stereoscopic optical systems.

In some systems the functions of vehicle detection, vehicle tracking and vehicle classification can be performed by the one gantry sensor sub-system.

Vehicle Recognition (VR) systems

Images of vehicles including the licence plate are captured, retained and processed. Modern VR systems employ high resolution streaming video cameras, from which the VR Controllers select the images to be used for vehicle recognition.

VR cameras are generally deployed as a single set per lane, with fields of view providing overlap between lanes to enable image capture of lane-splitting vehicles.

All VR systems capture both front and rear images of vehicles, using IR monochrome for front and rear and, in some States colour for the rear scene image. Note that the use of colour imaging requires high-intensity white light to be effective in low light/night conditions, so the colour imaging is being phased out where it is no longer required for evidentiary purposes.

With the elimination of white light for VR imaging and use of IR for Vehicle Detection and Classification (VDC) sensors, it is now possible for MLFF toll points to operate without the use of any visible lighting.

Off-gantry roadside equipment

This may include sensor sub-system controllers and tollpoint controllers. They are normally housed within equipment shelters or cabinets located near the gantries; these installations are normally specified to be able to operate independently of connection to the back office for up to seven days. In some installations, the off-gantry equipment can be located at a considerable distance from the toll point via fibre-optic cable to a central equipment room, other than for those sub-systems with critical timing requirements. The downside of such centralisation is that it creates a single point of failure, whereby an outage at the central equipment room would take down the whole roadside tolling system.

Vehicle Classification Requirements

Vehicle classification in Australia allows for up to five separate classes for tolling purposes, as follows:

Class 1: Motorcycle, generally specified by maximum length and width.

Class 2: Car, generally specified by maximum height and length.

Class 3: Light Commercial Vehicle (LCV), generally specified by two axles, cab-chassis construction and Gross Vehicle Mass (GVM) between 1.5 to 4.5 tonne. This category can overlap with Car, in which case Vehicle Model or Purpose of Use must be applied (which is not able to be assessed at the roadside). This class is used in Victoria, where Vehicle Model is the criterion; in Queensland the criterion is Purpose of Use; NSW does not currently use this class.

Class 4: Heavy Commercial Vehicle (HCV), generally specified by GVM and number of axles, although length and height is used in NSW.

Class 5: Other. This is normally expected to be Bus, but may also be applied to over-length or overweight vehicles, such as B-Doubles or B-Triples. Note that this class is not currently in use in any Australian State, but Bus would be impossible to be detected by physical dimensions alone as most buses overlap with Class 4.

It should be noted that detection of vehicle weight is not currently used as a tolling criterion on Australian toll roads. Use of this criterion would require integration of Weight In Motion Sensors (WIMS) at each tollpoint; this requirement would appear to be overly complex and too prone to error to be worth incorporating into the tolling strategy.

Vehicle classifications differ between states

Victorian Classifications:

Car - Cars are motor vehicles other than those that comply with the motorcycle, light commercial vehicle, heavy commercial vehicle or taxi classifications (below). Cars include those Cars towing trailers and caravans.

LCV - Light Commercial Vehicles have two axles, cab-chassis construction, and a gross vehicle mass greater than 1.5 tonnes but not exceeding 4.5 tonne.

HCV - Heavy Commercial Vehicles include all of the following vehicles:

a. Vehicles with three or more axles, cab-chassis construction, and a gross vehicle mass greater than 1.5 tonnes;

b. Articulated Vehicles with cab-chassis construction, and a gross vehicle mass greater than 1.5 tonnes;

c. Buses with more than 12 seating positions (including the driver);

d. Vehicles with two axles, cab-chassis construction, and a gross vehicle mass greater than 4.5 tonnes; and

e. All other vehicles with a gross vehicle mass greater than 30 tonnes.

Motorcycles - (no tag required) are two wheeled motor vehicles (including those with side cars).

Taxis - are motor vehicles licensed for operation as a taxi-cab under the Transport Act 1983 (Vic). Taxis are tolled at different rates from Car or LCV in Victoria, but this is a back-office process as the roadside systems cannot distinguish Taxi dimensions from those of the corresponding Car or LCV classes.

Queensland Classifications

Motorcycles - Two wheeled motor vehicles (including vehicles with a trailer, fore car or side car attached).

Cars - Four-wheeled motor vehicles, including taxis which are not commercial vehicles (including vehicles towing a trailer or caravan).

Light Commercial Vehicles - Motor vehicles that are registered for commercial use and:

a. are two-axle rigid trucks or load carrying vans or utilities, having a gross vehicle mass greater than 1.5 tonnes but not exceeding 4.5 tonnes or

b. have spatial dimensions which are substantially consistent with the criteria in paragraph (a) above.

Heavy commercial vehicles: Motor vehicles that:

a. are rigid trucks with three or more axles;

b. are articulated trucks;

c. are buses;

d. are two axle rigid trucks having a gross vehicle mass greater than 4.5 tonnes

e. are motor vehicles having a gross vehicle mass greater than 30 tonnes, or

f. have spatial dimensions which are substantially consistent with the criteria in any of paragraphs (a) to (e) above.

NSW Classifications

NSW tolling classifications are based on vehicle dimensions, as follows:

Class 1 Motorcycle: A vehicle 1.2 m or less wide AND 3.0 m or less long.

Class 2 Car: A vehicle 2.8 m or less high AND 12.5 m or less long.

Class 4 HCV: A vehicle higher than 2.8 m OR longer than 12.5 m.

Configuration and preferred technology for Road Side Equipment (RSE)

The classic means of identification of vehicles without tag is through the extraction of the license plate number (LPN) and State of Registration from the VR images taken at the roadside. Modern VR cameras have on-board optical character recognition (OCR) engines that can determine LPN and State in near real-time, and which operate deterministically so that degree of accuracy can be determined from confidence levels. It is also possible for the VR controller to integrate the individual camera outputs to provide highly reliable vehicle identification in cases where the vehicle licence plates are legible.

Further OCR is often carried out in the tolling back office to further improve the accuracy of vehicle identification and reduce false positive identifications.

The most highly automated and accurate Vehicle Identification systems utilise vehicle characteristics in addition to licence plate characteristics. Often called “fingerprinting”, these systems build up a repository of confirmed unique vehicle identities, which is used to improve accuracy of identification and minimise false positive identifications.

Electronic Toll Collection Using On Board Units (OBU)

The OBU are also called Tags in Australia (not to be confused with the US use of “Tags” for licence plates).

Tag Readers use a CEN 278 5.8GHz Dedicated Short Range Communication (DSRC) microwave link to communicate and transact with Tags. All Tag Readers must conform to the protocol mandated by AS4962:2005 standard “Electronic toll collection – Transaction specification for Australian interoperability on the DSRC link”.

The standard is available for purchase from Standards Australia if required, see *www.asnzs.org/as-49622005-electronic-toll-collection-transaction-specificat-p-5276.html*

AS4962:2005 mandates two different EFC transaction types:

- Type A transaction, which uses single-DES encryption, as used by Q-Free tags, and
- Type B transaction, which uses triple-DES encryption, as used by Kapsch tags.

All tags in current use in Australia are hard-cased and windscreen-mounted internally in the vehicles. The tags are transponders, which modulate the received carrier downlink frequency to provide the uplink communications.

Tag Reader systems in use are of two types:

- Separate beacon transmitters combined with distributed receiver arrays. These systems use the individual received signal strengths to estimate vehicle lateral position on the road. The normal equipment allocation per carriageway is one or two transmitter units and an equally-spaced array of receivers of at least one per lane.
- Combined transceivers, which provide both downlink beacon and uplink reception from tags. Vehicle location can be achieved either by relative received signal strengths, or by use of phased array antennae to determine the signal vectors to the tags. This latter system provides accurate Tag location through multiple transceiver triangulation. The equipment allocation per carriageway is at least one transceiver per lane.

System Redundancy

Redundancy in on-gantry equipment is normally achieved by means of sensor footprint overlap, which can vary from minimal to cover lane-splitting vehicles up to 100 percent overlap. In some cases redundancy is achieved through use of complementary sensor systems, where different sub-systems are used to measure the same parameters, for example optical sensors and separate laser sensors to perform the VDC function. Use of dedicated redundant switches for low-latency gantry sensors, with sensors divided between these switches, ensures that the low-latency requirements are met and that the sensor system has no single point of failure. Where common switches carry both high and low latency traffic, separate VLANs are generally used. In the case of sensor arrays, it is common to designate one of these sensors as the master and another as the stand-by master; the stand-by master monitors the master and is programmed to take over in the event of failure or anomalous behaviour of the master.

Generally, one picture is selected from each camera covering the vehicle passage; for the VR Camera configuration [IR (Front) + IR (Rear) + Colour (Rear)] there will normally be a set of three images, but in the case of a lane-splitting vehicle, there may be six (6) images in the image-set.

Redundancy in off-gantry equipment varies widely within different systems. Use of redundant power supplies in controllers and switches is common, as is the use of redundant digital switches. Most systems do not employ multiple synchronized controllers, mainly due to the inherent reliability of the controllers, which makes the added complexity unnecessary and uneconomic. However, one supplier of roadside tolling systems does provide a standard fully redundant suite of off-gantry equipment.

Communications links are usually designed to provide both physical and logical redundancy. Single-mode fibre-optic cable is the standard communications medium used between toll points and the tolling back office.

Where practicable, separate physical fibre runs are employed, with switches programmed to re-route data in the event of a failure. The redundancy is usually achieved through establishment of single or multiple physical or logical ring topologies. With the increasing amount of data being generated at the roadside by new generation sensor sub-systems, fibre-optic cable is replacing copper in most on-gantry sensor sub-systems.

Performance Specifications

Typical Roadside performance requirements are detailed in the table below:

Table 01 RSE Performance Specifications

REQUIREMENT	PERFORMANCE LEVEL
System Availability	>99.99%
Traffic Volumes	2,400 vehicles per lane per hour, peaking at 3,000 vehicles per lane per hour for short periods.
Traffic speeds	0 (stop-start) to 160kph
Stand Alone Toll point Operation	Around seven (7) days
Percentage of correctly mounted toll tags detected at toll point	99.5% to 99.9%
Percentage of vehicles detected at toll point	99.95%
Vehicle classification accuracy	98 to 99%
Image set capture	99.95%
OCR Accuracy (in camera)	Around 90%
Correlation rate Tag to vehicle	99.9%

Service level agreements are typically based on maintenance of the specified and tested performance levels, with the associated KPI regime including penalties for failure which are normally set to reflect the revenue loss or additional overhead incurred as a result of the KPI breach.

Monitoring and auditing systems

All new roadside systems are specified to include comprehensive monitoring and auditing systems. These systems include near real-time monitoring, alarms and reporting, as well as comprehensive historical reporting capabilities. Near real time dashboard displays of roadside events and parameters are available, as well as individual roadside sub-system performance, including live feeds from Vehicle Recognition (VR) and surveillance cameras.

All roadside data is generally held on a dedicated monitoring/audit database separate from the tolling back office database, which enables both formal and ad-hoc reporting in support of roadside system monitoring and auditing requirements.

Configuration and communications technology

All toll roads in Australia employ dedicated fibre-optic communications systems. 3G/4G communications are not currently used for tolling purposes, although with the inevitable advent of inter-urban toll roads at some point in the future, these terrestrial communications systems may be used in conjunction with GPS tolling applications.

Security Equipment

All toll points are provided with physical security such as fencing, lighting and surveillance systems together with remote alarms on gantries and technical cabinet/shelter access points. Fire suppression systems can be provided in technical shelters or cabinets where these are deemed to be operationally critical. Dual redundant air conditioning of Equipment Shelters or Equipment Cabinets is standard in Australia. Within Equipment Shelters and Cabinets, all racks are required to have cooling air circulation to all equipment housed within the rack.

Where practicable, major toll points are fed from two separate mains power supply systems. However the normal arrangement for power to toll points is a single mains supply backed up by a standby dedicated generator, together with an Uninterruptible Power Supply (UPS) that is capable of holding the essential toll point equipment during the cutover in the event of mains power failure and for a period of time beyond in the event of failure of the standby generator to come on line. Standard practice is for the controlled shutdown of all roadside equipment to be effected prior to the end of the UPS holding period.

Warranty and testing

The standard warranty period for new roadside tolling systems is two years. This can be varied either way depending on the degree of risk agreed between Principal and Supplier.

The standard formal testing regime includes the following:

a. Factory Acceptance Testing (FAT), where the Supplier formally tests the functionality of the roadside system to confirm that it complies with the functional requirements of the contract.

b. Site Acceptance Testing (SAT), where the Supplier confirms that individual tolling sites (usually a toll point) are complete and fully functional.

c. System Integration Test (SIT), where the Supplier confirms that the roadside tolling system as a whole is fully functional and can interface to and interoperate with the back office tolling system over the range of communications media required.

d. System Performance Test (SPT) where the Supplier confirms that the roadside tolling system meets the individual and overall performance requirements of the tolling system contract.

e. System Acceptance Tests (SyAT). This acceptance testing involves formal testing by the Supplier and is witnessed by the Principal. It is usual for this testing phase to involve both formal scripted testing prior to opening to traffic and free-play testing once traffic has commenced. The actual sequencing will differ between greenfield and non-greenfield situations.

Work program expectations

The generally accepted minimum timeframe for implementation of a roadside tolling project is around 15 to 18 months. This timeframe could be reduced where the Principal is prepared to share risk or where the roadside system is well proven and is already a good fit to the Principal's requirements.

Greenfield sites are generally lower risk, from a schedule perspective, than existing motorways where lane and road closures will be strictly regulated and may be limited in number and duration.

Conclusion

Cica Group has prepared this white paper to provide an overview of the design standards for tolling roadside systems in Australia.

The report has been based on Cica Group's understanding of the Australian market and reflects general practice and averages across the Australian toll roads.

Cica Group consultants have had direct experience in every operational toll road in Australia and has gained a wealth of information in respect to toll road operations.

For more information visit our website cicagroup.com.au

About the Cica Group

Cica Group is a collective of highly experienced project advisors with a proven record in guiding enterprises to successfully deliver complex technology projects. Formed in 2012, Cica Group combines client-focused strategists, advisors, technologists and commercial contractual managers. Each has a proven record in guiding enterprises through analysis, planning, management, realisation and the ongoing support of complex technology projects.

About Geoff Cawte

Geoff is a self-motivated entrepreneur with extensive experience working across a wide range of demanding industries including tolling, logistics, automotive systems, air traffic control, avionics and Formula 1 vehicle monitoring systems .

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