Trustworthy Positioning: Why We Need To Take It Seriously

Never Stand Still

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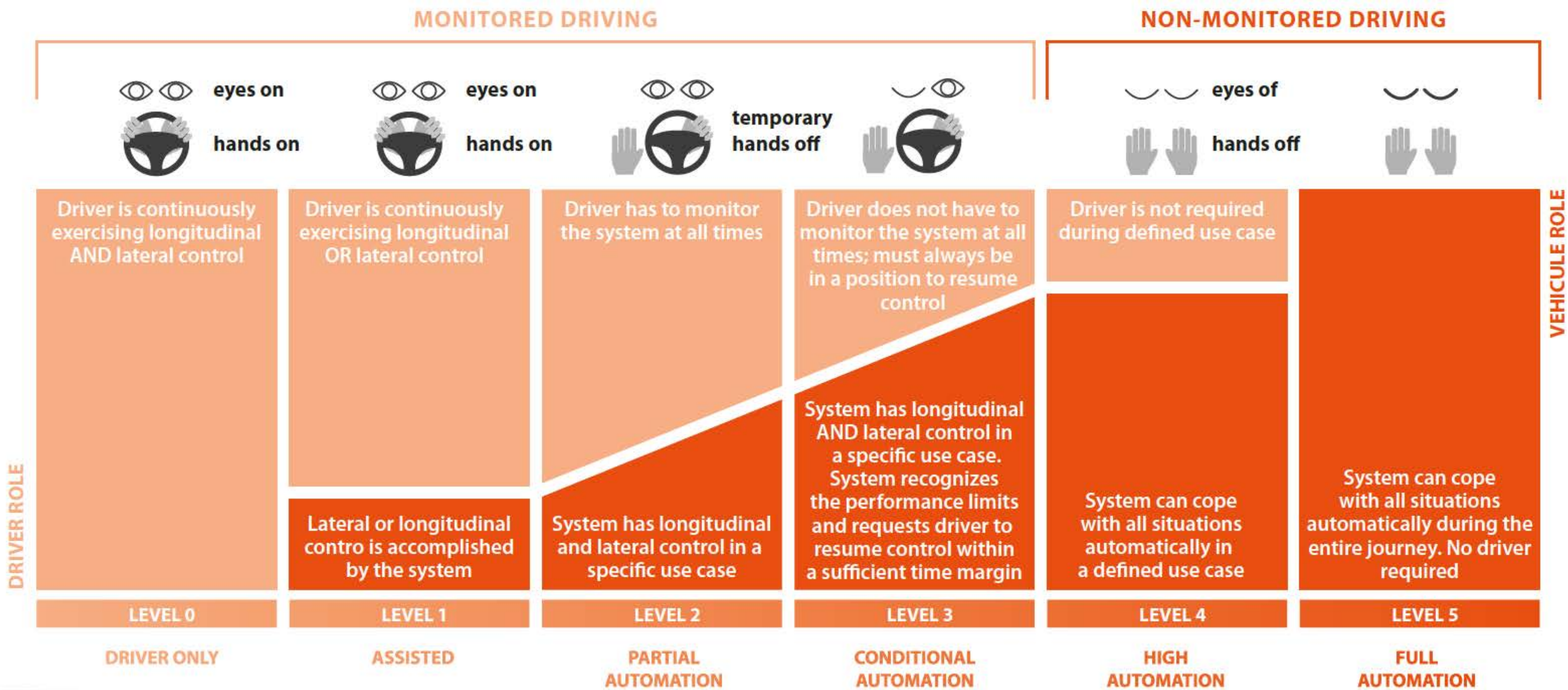
Positioning and Mapping needs to address the advanced ITS challenges...

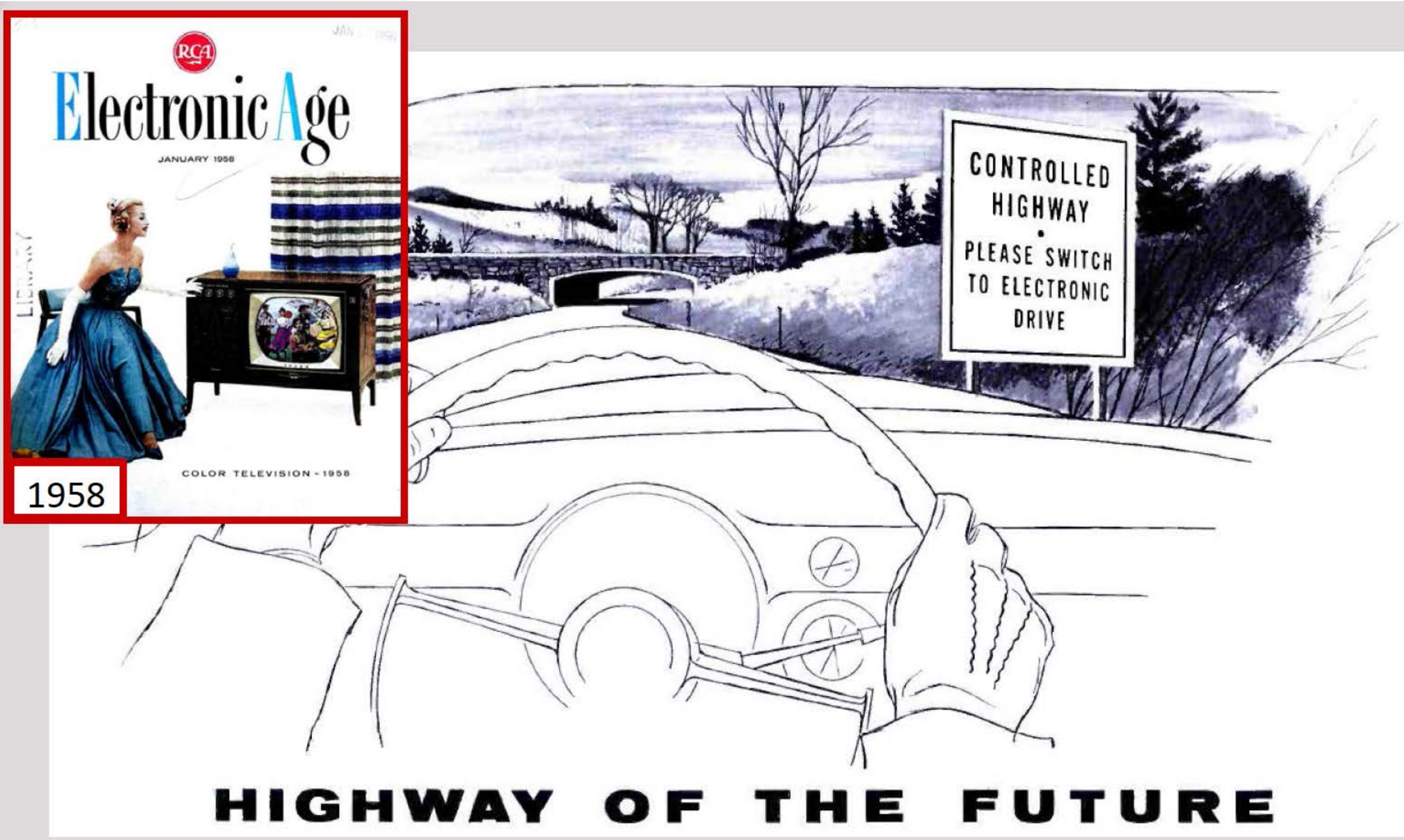
- Performance specifications are very *tight*
- Highly Automated Driving (HAD) is going to become a reality very *soon*
- GNSS (or other sensor technologies) is *not reliable* enough
- *Mass market* in Precise Positioning has different drivers to *professional market*
- ***If we don't, who will?***

What are we talking about?



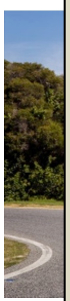
Positioning in vehicles is going from ***Passive*** *to* ***Active****…*
From simple navigation to information about traffic,
to warnings about hazards, to actively avoiding hazards,
to supporting ***HAD modes***

HAD... *Utopia 1958*

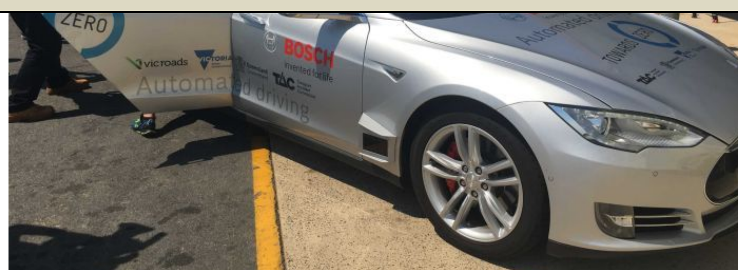


HAD... *now, everyone wants in*

UBER



There are non-technical concerns:
What are the design & performance specs? Who certifies these? Who is responsible for insurance cover? What about other road users?...



Australian govts agree on provisional driverless car rules

By Paris Cowan
Nov 11 2016
12:06PM

2 Comments

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Fully autonomous vehicles not expected until after 2020.

Australia's federal, state and territory transport ministers have agreed to a suite of national policies that will guide Australian road rules through the journey to the widespread adoption of fully driverless cars.

The National Transport Commission is not expecting driverless cars to hit the mainstream until after 2020.

Australian governments have been waiting on the opinion of the NTC – which has been conducting a comprehensive review of road rules and stakeholder concerns over the past year – before they start amending their driving regulations, so as to avoid patchwork approach to traffic legislation.

The commission has now received the green light from federal, state and territory ministers to go ahead with 24 new policies that iron out some of the legal shortcomings with driverless cars.

For the time being, Australian governments have jointly committed to an existing policy consensus that a human driver has full legal liability for a vehicle, even if it is "partially or conditionally" automated.

Human drivers must also not undertake in-car activities currently banned under Australian road rules, like speaking on a mobile phone, even when a car is effectively driving itself.

Under the NTC's rationale, this buys road authorities a few more years to nut out a new regime before fully automated vehicles become commonplace.

It has identified a raft of legal grey areas that will need to be tackled before this time, including:

Tesla

Tesla driver dies in first fatal crash while using autopilot mode

The autopilot sensors on the Model S failed to distinguish a white tractor-trailer crossing the highway against a bright sky

Danny Yadron and Dan Tynan in San Francisco

Friday 1 July 2016 09.14 AEST

Joshua Brown, the first person to die in a self-driving car accident. Photograph: Facebook

The first known death caused by a self-driving car was disclosed by Tesla Motors on Thursday, a development that is sure to cause consumers to second-guess the trust they put in the booming autonomous vehicle industry.

The 7 May accident occurred in Williston, Florida, after the driver, Joshua Brown, 40, of Ohio put his Model S into Tesla's autopilot mode, which is able to control the car during highway driving.

Trustworthy Positioning... lots of technology

GNSS?

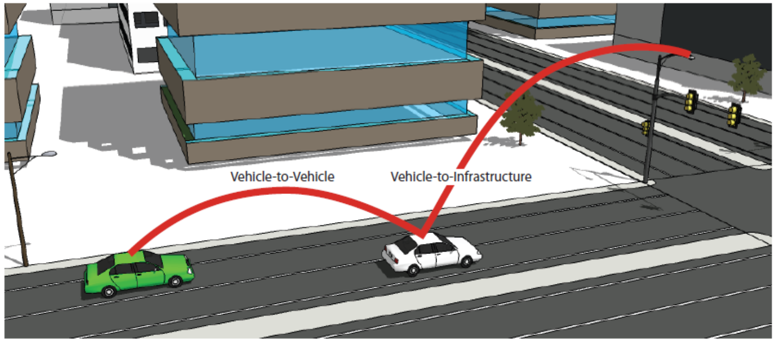
Need Precise & Reliable positioning, as well as Robust positioning...

But how to define performance specifications, SARPs, etc?

Levels of positioning accuracy required...

- **road-level** - which road is the vehicle on?
- **lane-level** - which lane is the vehicle in?
- **where-in-lane-level** – where within the lane is the vehicle?

Positioning includes V2V (relative) and V2I (absolute)



“Vehicle Positioning for C-ITS in Australia”, AustRoads Research Report, April 2013

https://www.onlinepublications.austroads.com.au/items/AP-R431-13

ITS positioning requirements…

Type	Level	Accuracy Requirement		Research prototype	Communication Latency (second)
		95 % confidence level (m)	Root means square (order)	Root means square (order)	
V2I: absolute *(V2I = Vehicle to Infrastructure)*	Road-level	5.0	Metre	Metre	1-5
	Lane-level	1.1	Sub metre	Sub metre	1.0
	Where-in-lane-level	0.7	Decimetre	Decimetre	0.1
V2V: relative *(V2I = Vehicle to Vehicle)*	Road-level	5.0	Meter	Sub metre	0.1
	Lane-level	1.5	Sub metre	Decimetre	0.1
	Where-in-lane-level	1.0	Decimetre	Centimetre	0.01-0.1

"Vehicle Positioning for C-ITS in Australia",
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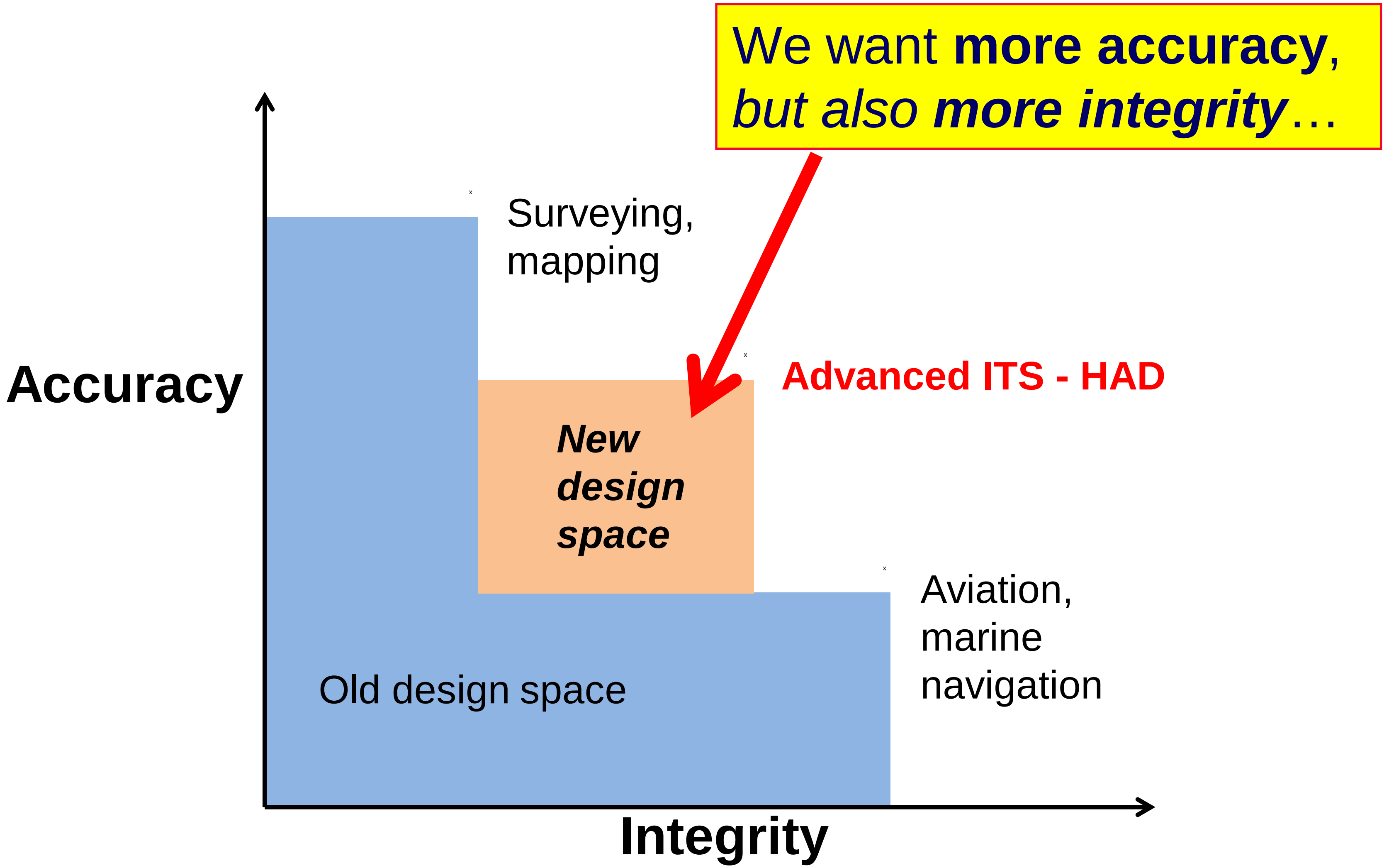
Trustworthy Positioning... new design paradigm



Required Navigation Performance Parameters (1)

No uniform performance standards for advanced ITS with respect to positioning have been established. ***The preferred technological solution should not be specified.***

The following RNP parameters need to be considered:

•**Accuracy** – the degree of conformance of an estimated or measured position at a given time wrt a defined reference value:

- *Absolute* vs *Relative* is important
- Confidence level is important, e.g. RMS at 68% vs 95% as in ISO GUM vs 99.9% vs 99.999999%

•**Integrity** – the ability of the positioning system to identify when a pre-defined alert limit has been exceeded, and to then provide timely and valid warnings to driver systems

(Source: Feng, Higgins and Millner for ARRB, April, 2013)

Required Navigation Performance Parameters (2)

- **Continuity** – the ability of the system to provide a navigation output with the specified level of accuracy and integrity throughout the intended period of operation
- **Availability** – percentage of time during which the service is available and satisfying all of the accuracy, integrity and continuity requirements
- **Interoperability** – the ability of different vehicle positioning systems with different absolute positioning capabilities to be used on the road network, and still meet the RNP specs
- **Timeliness** – the ability of the system to update position solutions at the required rates or on an event basis

(Source: Feng, Higgins and Millner for ARRB, April, 2013)

ICAO aviation performance specifications

REQUIREMENTS	MEASURES OF MINIMUM PERFORMANCE CRITERIA TO MEET REQUIREMENTS						
	ACCURACY (95%)		AVAILABILITY	CONTINUITY	INTEGRITY	TIME TO ALERT	COVERAGE **
	Horizontal	Vertical					
Oceanic	10 or 4 nmi***	N/A	0.99 – 0.99999		1-1x10^{-7}//hr	N/A	N/A
Enroute	2 nmi					5 min	N/A
Terminal	1 nmi					15 s	N/A
Non Precision Approach	220 m	N/A	0.99 – 0.99999	1-1x10^{-4}/hr to 1-1x10^{-8}/hr	1-1x10^{-7}/hr	10 s	N/A
APV-I	16 m	20 m	0.99 – 0.99999	1-8x10^{-6}/15 s	1-2x10^{-7} in any approach	10 s	N/A
APV-II	16 m	8 m	0.99 – 0.99999	1-8x10^{-6}/15 s	1-2x10^{-7} in any approach	6 s	N/A
CAT I	16 m	6 – 4 m	0.99 – 0.99999	1-8x10^{-6}/15 s	1-2x10^{-7} in any approach	6 s	N/A

Behind these are a HUGE volume of SARPs...

* From ICAO Annex 10 Vol 1 Table 3.7.2.4-1. ICAO is in the process of changing approach definitions of the APV classification and including LPV-200 as a precision approach.

** Not Specified by ICAO, Annex 10, Vol. 1, Table 3.7.2.4-1, Signal-in-Space Performance Requirements.

*** Depends on the navigation specification (RNP 10 or RNP 4) employed in the oceanic area.

http://www.navcen.uscg.gov/pdf/FederalRadionavigationPlan2014.pdf

Highway Performance Specs (US FRP2014)

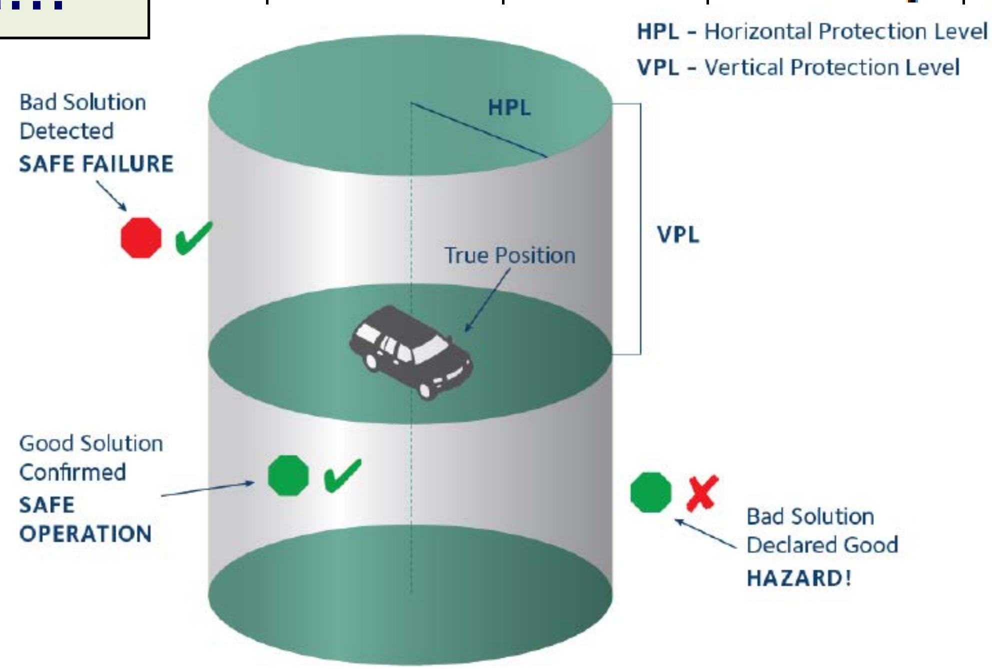
REQUIREMENTS	ACCURACY (meters, 2 drms)	AVAILABILITY	CONTINUITY	INTEGRITY (Alert Limit)	TIME TO ALERT	COVERAGE
Navigation and route guidance	1 – 20	>95%	*	2 – 20 m	5 sec	Nationwide / Surface Coverage
Automated vehicle monitoring	0.1 – 30	>95%	*	0.2 – 30 m	5 s – 5 min	Nationwide / Surface Coverage
Automated vehicle identification	1	99.7%	*	3 m	5 sec	Nationwide / Surface Coverage
				0.2 – 30 m	2 – 15 sec	Nationwide / Surface Coverage
				0.2 – 1 m	2 – 15 sec	Nationwide / Surface Coverage
Collision avoidance	0.1	99.9%				
Geophysical survey	1	**				
Geodetic control	0.01	**				
Accident Survey	0.1 – 4	99.7%				
Emergency Response	0.1 – 4	99.7%				
Intelligent Vehicle Initiative	0.1	99.9%				

* Continuity applies to phases of operations. For highway applicati

** In these instances, availability of a real-time solution is not neede

*** This is typically done using post-processing techniques. While int can be provided after data is collected

Note: the technological solution is not specified...



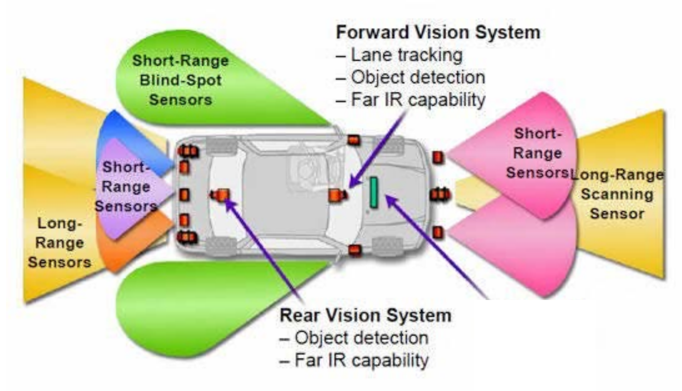
http://www.navcen.uscg.gov/pdf/FederalRadionavigationPlan2014.pdf

Moving forwards...

- **GNSS** is the primary navigation technology for “absolute positioning”
- **Other sensing/imaging technologies** used for “relative positioning”... *essentially collision avoidance systems*
- **Mapping data** used for ancillary purposes... *“global situation awareness”, “around-corners” capability, POIs, etc*
- **Biggest challenge** is ensuring **100% availability** and **very high integrity**... *correctly identified degraded performance is not critical, but HMI is*
- **Complexity of multi-sensor systems**, coupled with **AI**, operating in a **highly dynamic environment**, is a huge challenge... *compared with Aviation systems*
- Many players, many solutions, many standards... *what could Australia do (in a meaningful way)?*

Positioning... more than meets the eye

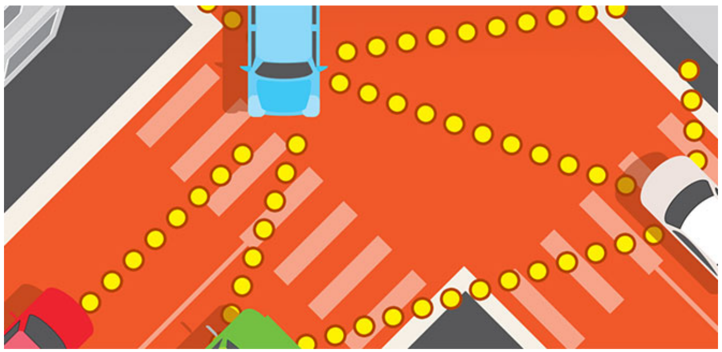
1: “I can see clearly now...” *sensing the world*



2: “I know where I am...” *everything in its place*

Each technology/approach has its strengths & weaknesses...

3: “With a little h *cooperative approaches*



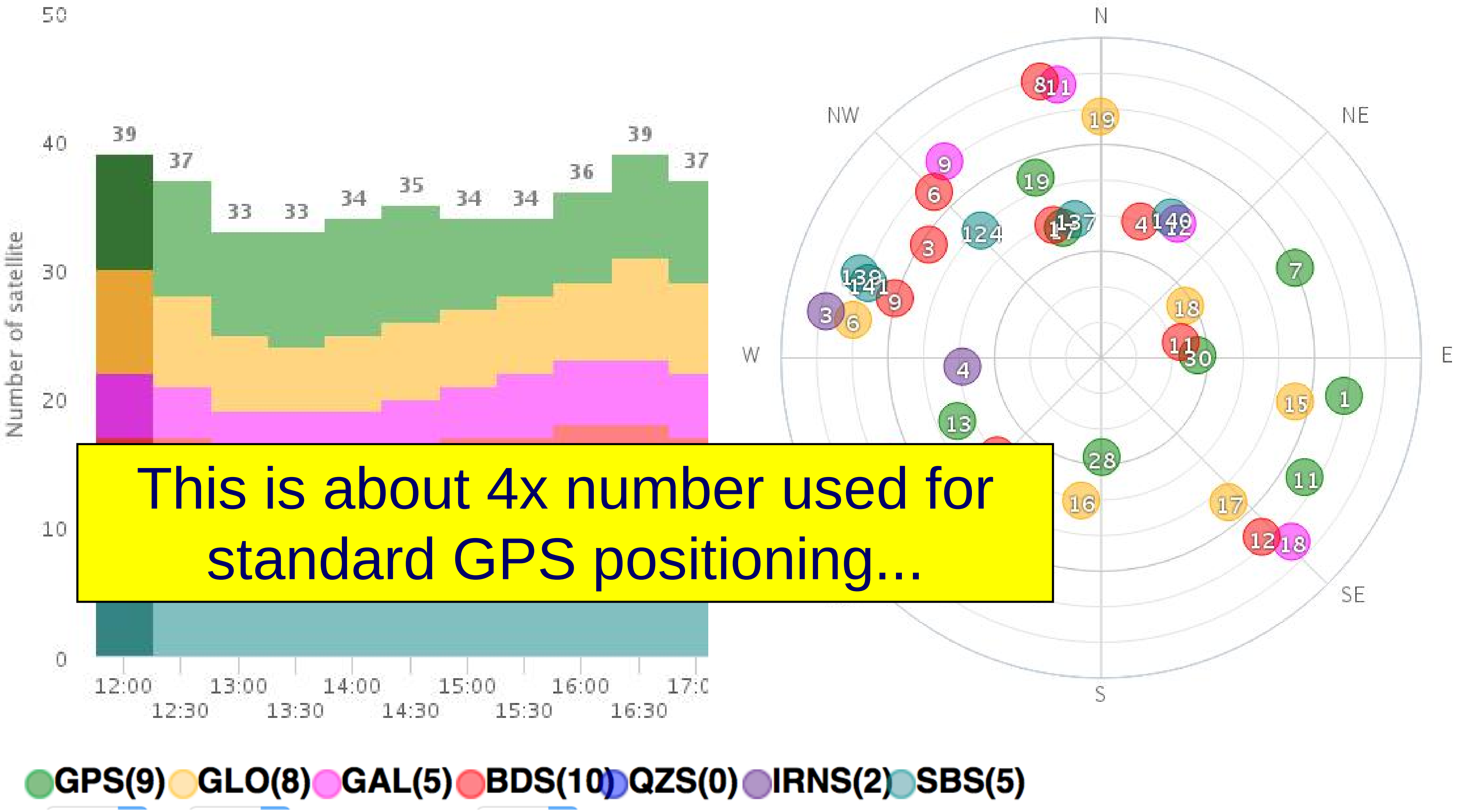
Five-tier GNSS-based techniques

Tier	Technique Option	Status		Accuracy range	Cost	ITS applications
		Current	Future			
1	A	Standalone GPS (SPS)	Standalone multiple GNSS	10-20m	Low	Vehicle navigation, personal route guidance and location based services (LBS)
2	A	Standalone GNSS (DF), Code DGPS	Standalone multi-GNSS positioning	1-10m	Low	Vehicle navigation, LBS, road traffic management
3	B	Current WAAS Commercial WADGPS	Future SBAS design for multi-GNSS	0.1-1m	Low	ITS safety applications: lane-level positioning, lane-level traffic management and where-in-lane-level applications
	C	Smoothed DGPS	Smoothed DGNSS	0.1-1m	Medium	
4	D	RTK	Combined PPP and RTK (seamless)	0.01-0.1m	Medium to High	Research prototype ITS safety systems, offering bench mark solutions for testing low-cost units
	E	PPP				
5	Advanced D and E	Static positioning	Sub-cm RTK with multi-GNSS signals	0.001-0.01m	High	Geosciences and geodynamic studies. Not recommended for ITS applications

(Source: Feng, Higgins and Millner for ARRB, April, 2013)

M-GNSS visibility: Sydney

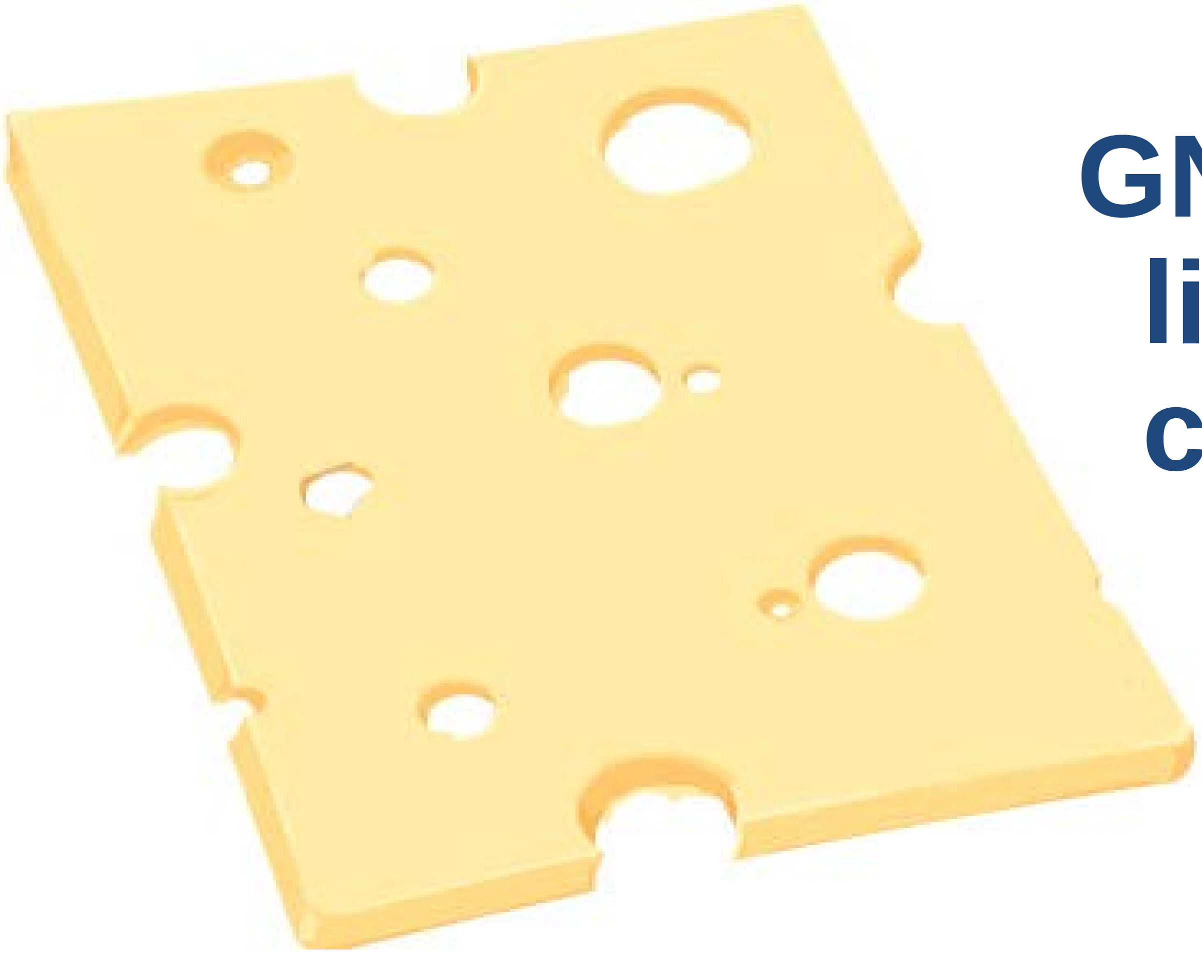
10deg elev, 7 December 2016



This is about 4x number used for standard GPS positioning...

http://www.taroz.net/GNSS-Radar.html

<u>But</u> GNSS was never designed to be a Ubiquitous Positioning technology*... Signals are too weak & vulnerable*



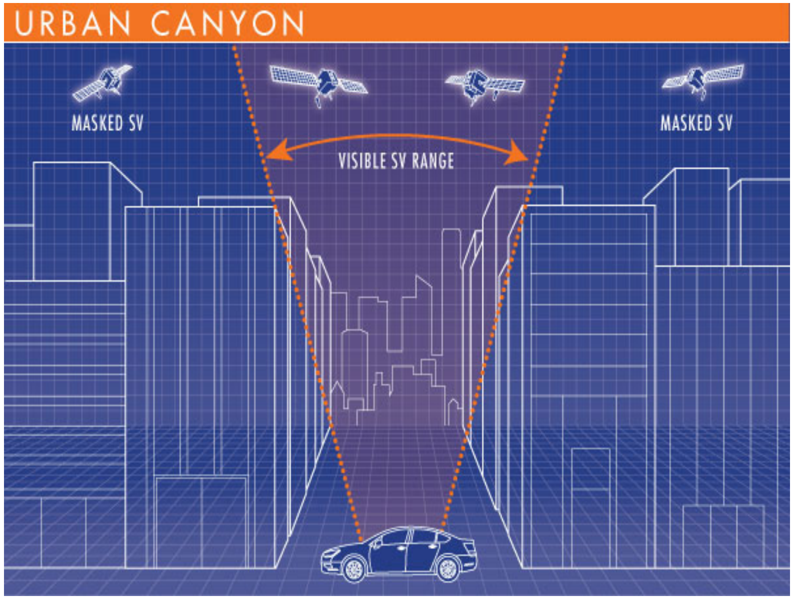
GNSS is like Swiss cheese…

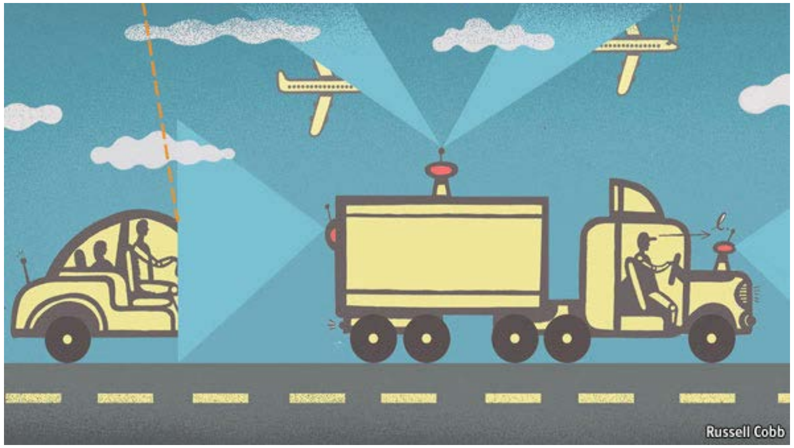
… it's full of holes"

Nunzio Gambale
Locata Corp

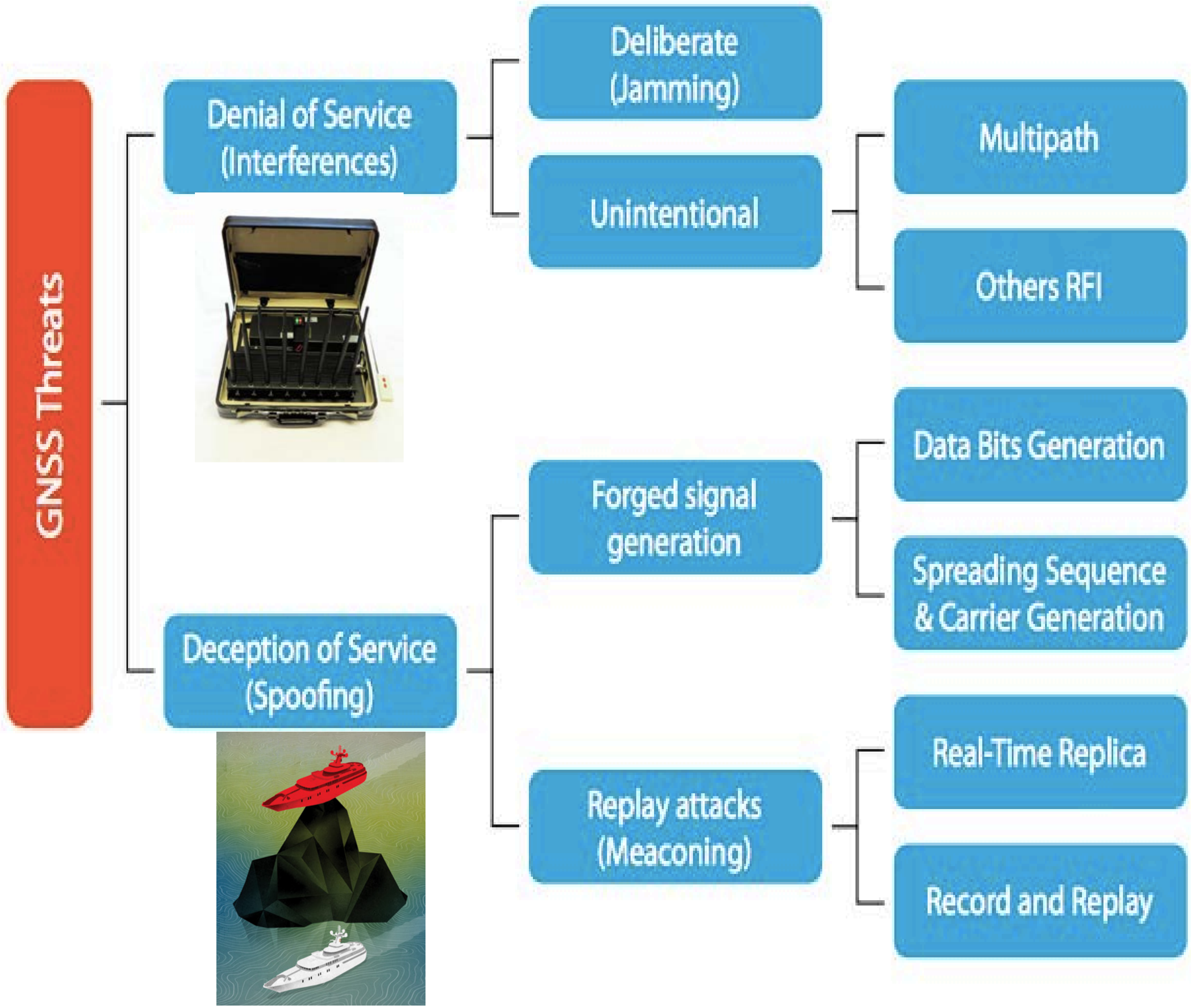
GNSS positioning: the reality

- In some environments (such as tunnels, built up urban areas, or in the presence of signal interference or spoofing) *GNSS performance deteriorates rapidly*
- GNSS *on its own* cannot satisfy the “high performance positioning” needs of applications that are liability-critical or life-critical
- Positioning for advanced ITS apps is *not* an “off-the-shelf” solution... *state-of-the art fusion of sensor outputs blended with machine-based reasoning*
- Multiple approaches likely to be used... *variety of R&D, commercialisation and implementation challenges to be addressed*





A simplified taxonomy of man-made RF threats to GNSS



Known Unknowns...

1. What level of HAD do we focus on?
2. Which “school” of HAD will prevail?
3. What can we learn from Aviation?
4. Who will provide the positioning/navigation solutions?
5. How to make GNSS-based positioning more trustworthy?
6. What could we do with SBAS in Australia?
7. What is the optimal mix of positioning technologies?
8. What test or certification processes will Australia insist on?
9. Who will drive the introduction of HAD systems in Australia?
10. How will we cope with mix of HAD and traditional driver behaviour?

ARC project “Trustworthy Positioning for Next Generation ITS” (2017-2019)...

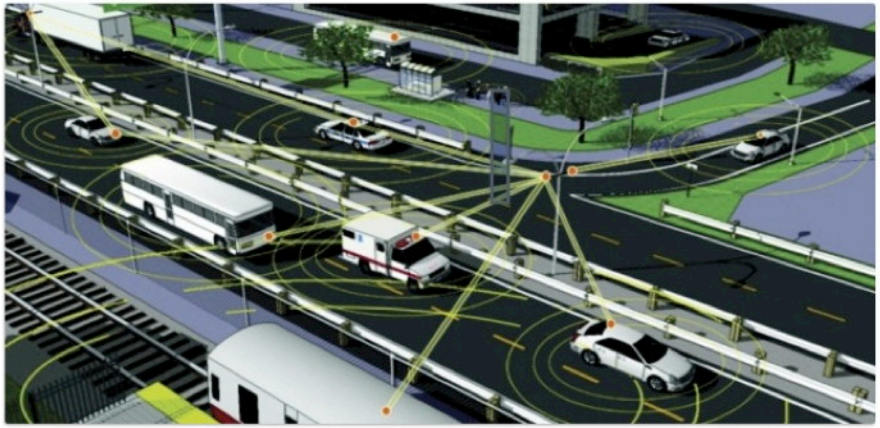
Where do we start?

Task 1: Foundation for Integrity Monitoring for C-ITS

Task 2: Dealing with Critical Issues Causing Significant Interruption to Positioning Services

Task 3: Building a Robust Integrity Monitoring Scheme for Reliable Positioning in C-ITS

What sort of Integrity Monitoring is appropriate for positioning to support HAD?...



Concluding Remarks...

- GNSS (both augmented & unaugmented) will have to be monitored... *at system provider, service provider & user level*
- HAD proponents are sceptical of PNT technology... *Navigation community must start promoting Trustworthy Positioning*
- HAD is much more than GNSS or PNT technology... *but we have to start defining RNPs*
- We need holistic solutions, need awareness raising, need test beds, need alternative technologies...