A Framework for Understanding and Specifying GNSS Positioning Requirements for Cooperative Intelligent Transport Systems

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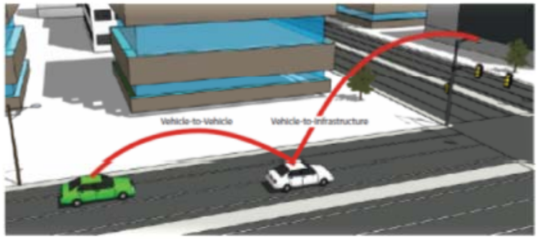
Presentation Outline

1. Motivations for Cooperative-ITS



2. What is Cooperative-ITS?


AP-R413-12
AUSTROADS RESEARCH REPORT
Cooperative ITS Strategic Plan

3. Cooperative-ITS in Australia

4. Positioning Requirements

5. Comments on Relevance to ICG

International Committee on Global Navigation Satellite Systems

Road Safety: A serious problem everywhere in the world

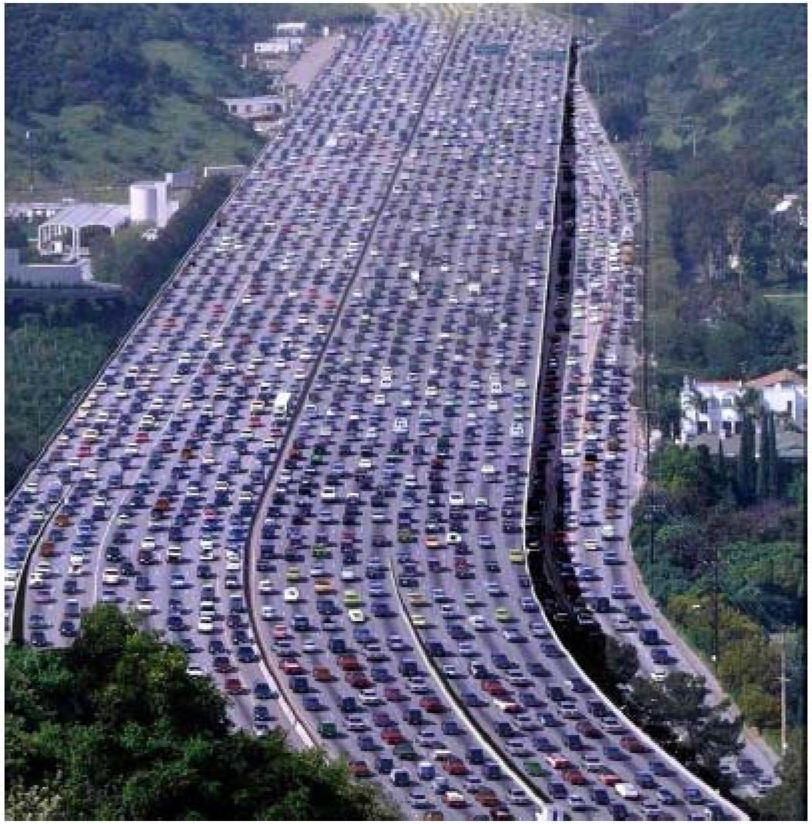
- Road accidents are a leading cause of deaths worldwide. It is estimated each year that
  - 1.2 Million people killed
    - 70,000~80,000 in China
    - 43500 in USA
    - 40000 in Europe
    - 1500 in Australia
  - 50 Million injured worldwide
  - **Worldwide, loss of 1%~ 2% of GDP**
    - **RMB 420-840 Billion in China**

(Courtesy of Chris Nicol)

(Source: Feng, 2011)

Congestion and Emissions

- Avoidable traffic congestion in Australia is estimated to cost over **$10 Billion** per annum (about 1% of GDP)
- Furthermore, this figure is predicted to **double** by 2020 if no action is taken.
- Congestion amplifies energy consumption and resulting emissions: fuel consumption under congested conditions is approximately **twice** that of free-flow conditions.
- Congestion is responsible for **17%** of all transport-related greenhouse gas emissions
- Road transport is responsible for 68.9 million tonnes of CO_2-e. This is **12%** of Australia's total emissions



(Courtesy of Chris Nicol)

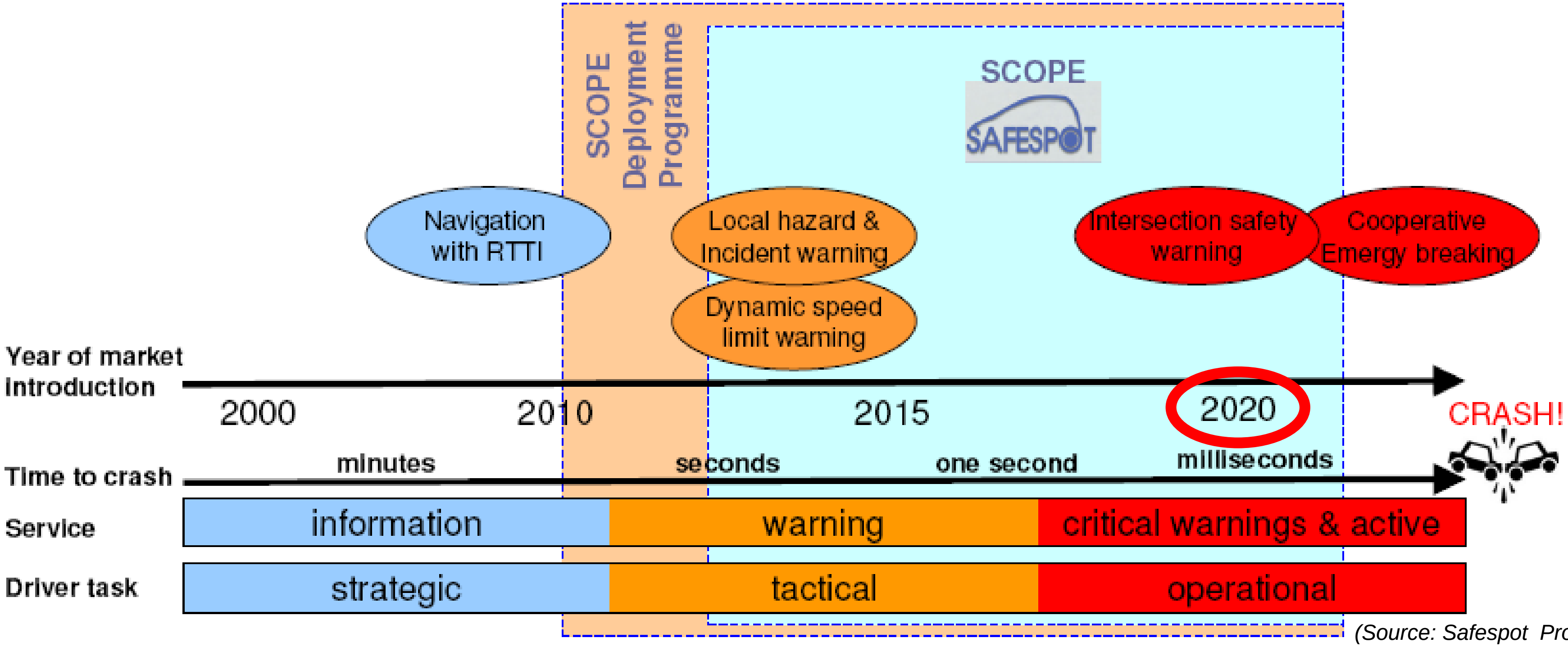
(Source: Feng, 2011)

Visions for the Future

Organisation	Visions
ERTICO -ITS Europe	"Intelligent Mobility" • Towards zero accidents • Towards zero delays • With reduced impact on the environment • Towards fully informed people
Sweden	"Sweden's Vision Zero": • No one will be killed • No one is seriously injured in road traffic
ITS America	"Zero Fatalities Vision" •Zero fatalities •Zero delay
ITS Australia	"Vision Zero for 2030": • Zero fatalities • Zero avoidable congestions • Reduction of 50% transport GHG

(Source: Feng, 2011)

Cooperative Intelligent Transport Systems (C-ITS)



(Source: Safespot Project via Qld DTMR)

Use of Positioning in Vehicles is going from Passive to Active... from simple navigation to information about traffic to warnings about hazards to actively avoiding hazards.

Time frame for development of Road Safety Applications is quite parallel to time frame for deployment of Multi-GNSS ~ 2020

Cooperative – ITS

- **Definition of Intelligent Transportation Systems (ITS):**
  - ITS is defined as the application of advanced information and communications technology to surface transportation in order to achieve enhanced safety and mobility while reducing the environmental impact of transportation
- **Definition of Cooperative-ITS:**
  - employs vehicle to vehicle to infrastructure (V2I) and vehicle to vehicle (V2V) communications to connect transport infrastructures, vehicles and travellers to achieve ITS purposes.
  - V2I and V2V provides a powerful and transformative opportunity

(Source: Feng, 2011)

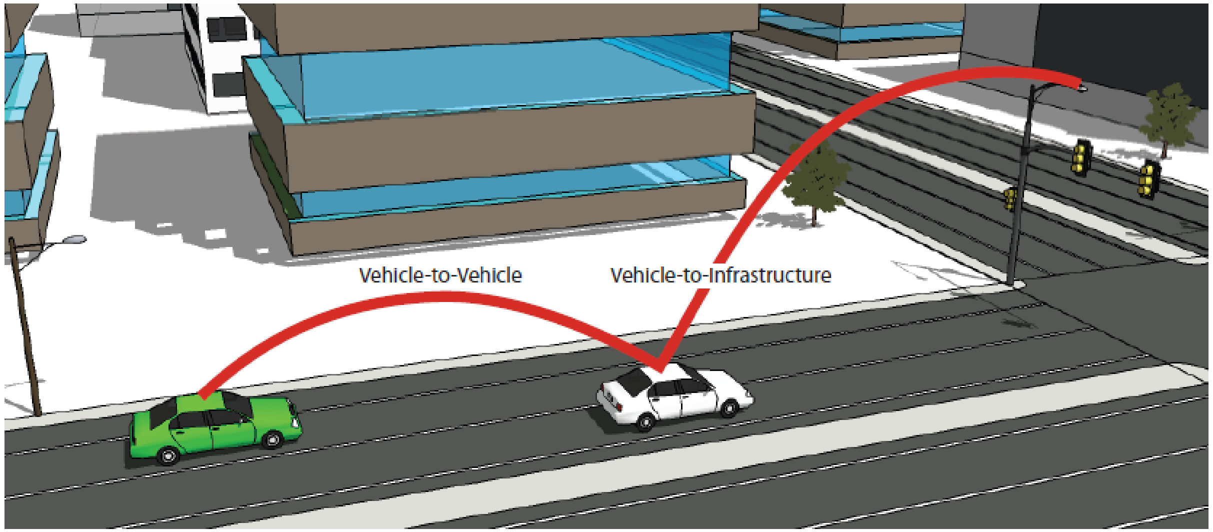
Three key technologies in Cooperative-ITS:

- **V2I and V2V wireless communications**
  - **WWAN:** 3G cellular technologies, WiMAX and satellite communications etc
  - **WLAN:** Dedicated Short-Range communications (DSRC)-
    - Low-latency, high-reliability, high availability wireless communications, based on IEEE 802.11p, 75 MHz at 5.9 GHz
- **Enhanced digital road maps:**
    - **Active safety:** Advanced Driver Assist System – ADAS
    - **Cooperative safety**: Lane-level applications
- **Cooperative vehicle positioning**
    - V2I: Lane-level and in-lane positioning
    - V2V: Precise relative vehicle positioning

(Source: Feng, 2011)

DSRC for V2V and V2I communication

- Dedicated short range communications combines **wireless connectivity, accurate positioning and an on-board computer** to allow vehicles to communicate directly to each other (vehicle-to-vehicle, or V2V links), and to road-side units (vehicle-to-infrastructure or V2I).



Source: www.cohdawireless.com

(Source: Feng, 2011)

V2I-enabled safety

- Blind Merge Warning
- Curve Speed Warning
- Emergency Vehicle Signal Preemption
- Highway/Rail Collision Warning
- Intersection Collision Warning
- Intersection Crossing Assistance
- In-Vehicle Signage
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Pedestrian Crossing Information at Intersection
- Road Condition Warning
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning

V2V-enabled safety

- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- Emergency Electronic Brake Lights
- Highway Merge Assistant
- Lane Change Warning
- Post-Crash Warning
- Pre-Crash Sensing
- Vehicle-Based Road Condition Warning

NOTE: Highest ranking applications based on safety benefit estimates are highlighted in red: Source: Task 3 CAMP VSC1 Project

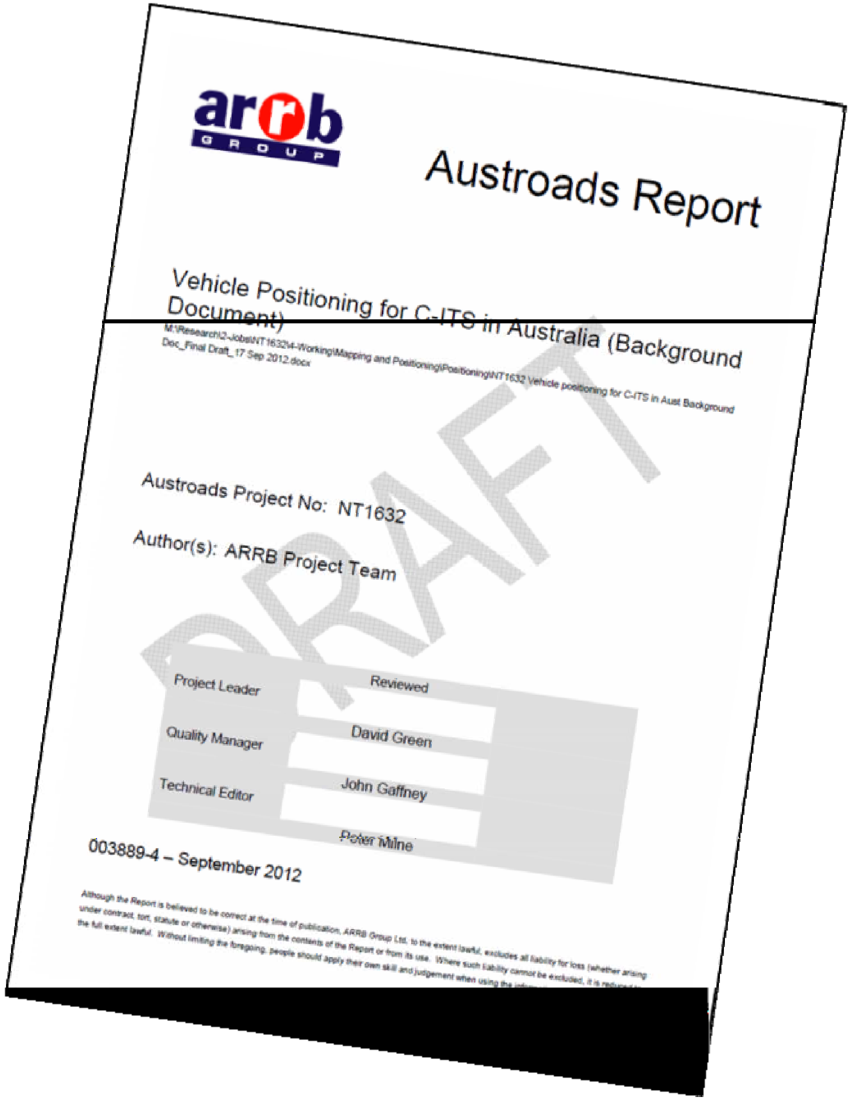
(Source: Feng, 2011)

Cooperative ITS in Australia

- Austroads bring together the Australian state and territory road transport and traffic authorities, the Commonwealth Department of Infrastructure and Transport, the Australian Local Government Association and the New Zealand Transport Agency;
- Austroads has developed a Cooperative ITS Strategic Plan that has identified a number of key policy areas of challenge to the introduction and roll-out of C-ITS in Australia:
  - Dynamic and uncertain environment;
  - Interoperability;
  - Functions, responsibilities, liabilities and governance;
  - Privacy and security;
  - Human-machine interface (HMI);
  - Digital mapping and positioning;
  - Telecommunications;
  - Aftermarket devices and applications;
  - Potential for conflict between public and private objectives;
  - Roadworthiness;
  - Consumer confidence and market penetration.

Vehicle Positioning for C-ITS

- The following slides are drawn from a Draft Report by the Australian Roads Research Board (ARRB), which draws on background work by Feng, Higgins and Milner;
- The Report is not yet released so the following slides concentrate on the technical framework for evaluating positioning options rather than any specific findings for Australia and New Zealand.



C-ITS - Required Navigation Performance Parameters (1)

Given that C-ITS safety applications are at various phases of development around the world, no uniform performance standards with respect to positioning have been established. However the following parameters are proposed as essential:

•**Accuracy** - defined as the degree of conformance of an estimated or measured position at a given time to 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%;

•**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 drivers;

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

C-ITS - Required Navigation Performance Parameters (2)

- **Continuity** - the capability of the navigation system to provide a navigation output with the specified level of accuracy and integrity throughout the intended period of operation;
- **Availability** - the 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 capacities to be used on the road network and still meet the required relative positioning performance requirements;
- **Timeliness** - the ability of the on-board systems to update absolute and relative position solutions at the required rates periodically or on an event basis.

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

C-ITS - Levels of Positioning Accuracy Required for Safety Applications

- The accuracy requirement for the general suite of C-ITS safety applications is classified into three levels:
- **road-level** - which road is the vehicle on?
- **lane-level** - which lane is the vehicle in?
- **where-in-lane-level** - where the vehicle is in the lane?

Protection Envelope in Aviation vs C-ITS

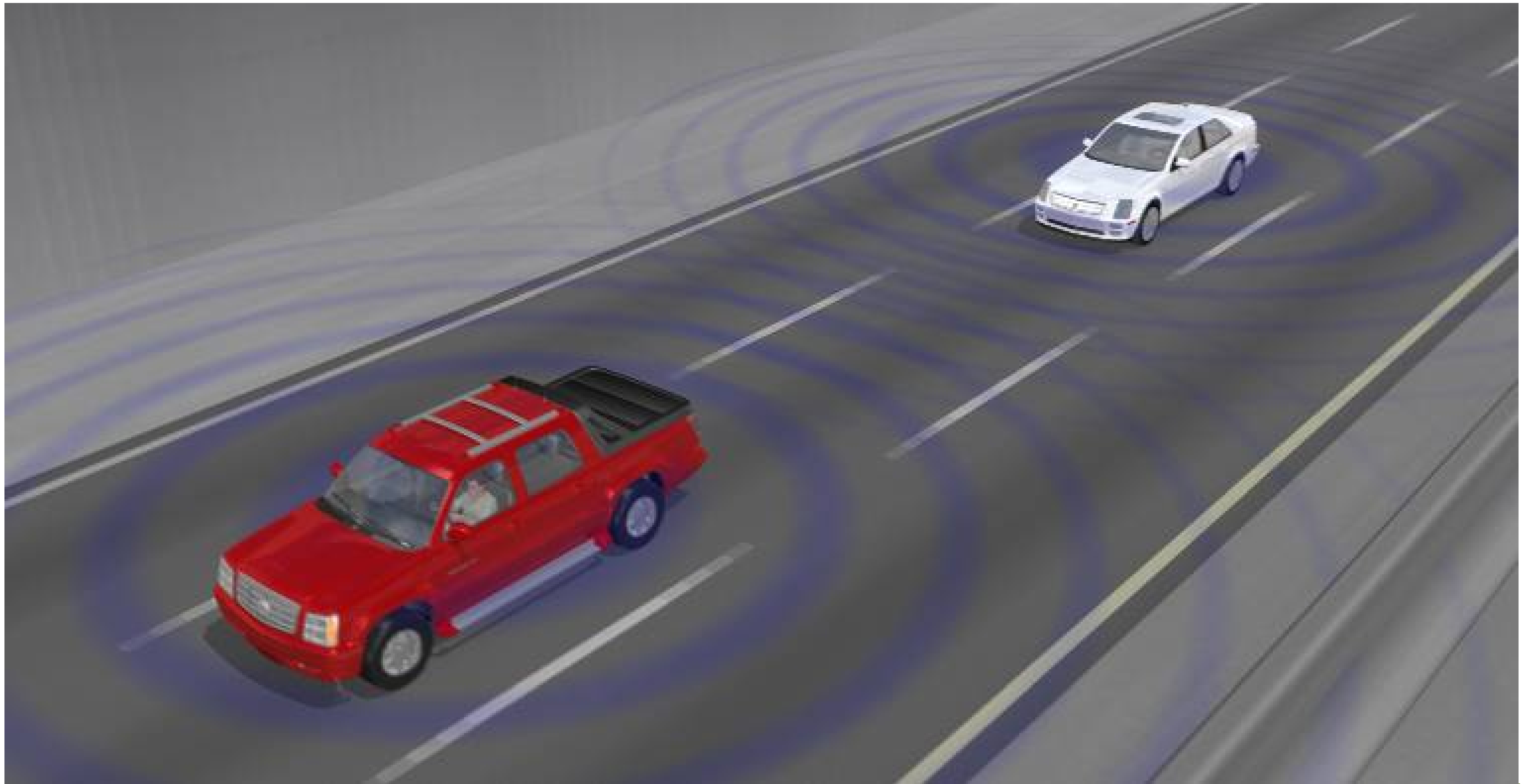
(Source: Feng, Higgins and Milner for ARRB, September, 2012)

Requirements for Positioning Accuracy and Timeliness

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

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

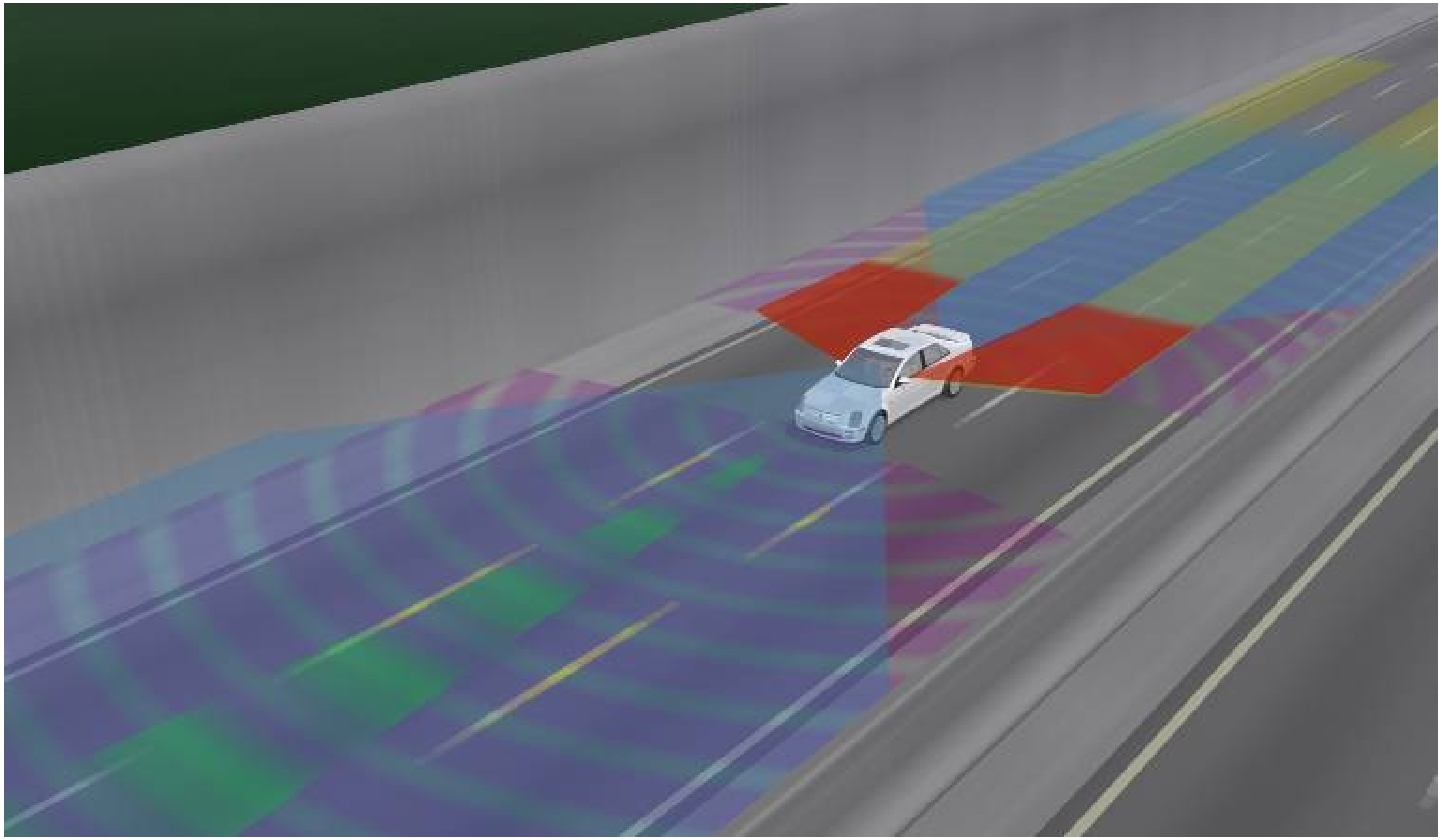
Simple Positioning + Wireless Communications



- V2V with GPS is a new type of all-around object detection sensor
- Reduced cost and complexity
- Extended range up to 300 meters
- Immune to false alarms and extreme weather conditions
- Enables new types of driver assistance features

(Source: Grimm, GM, 2008)

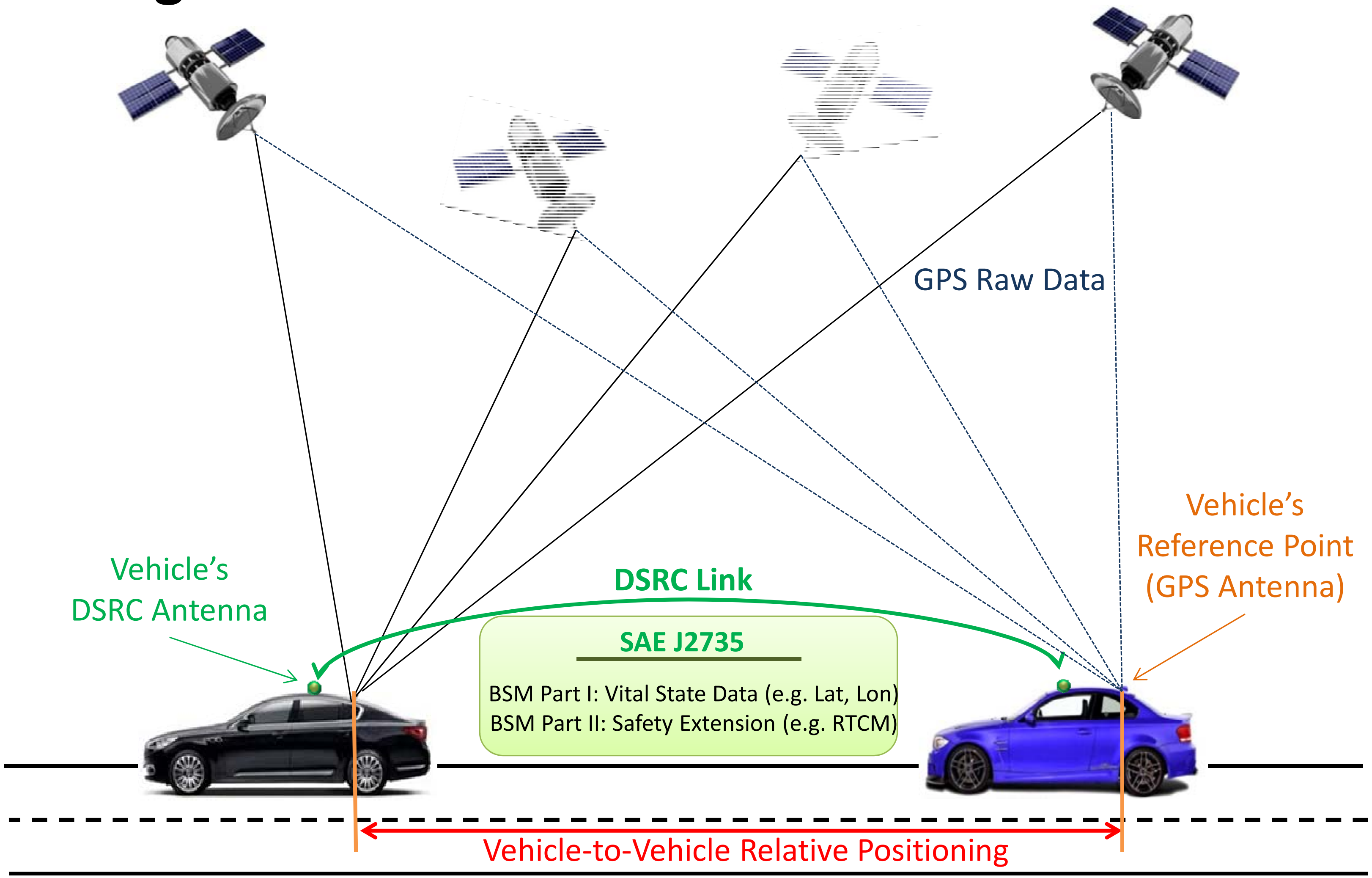
Vehicle Safety – Autonomous Sensors



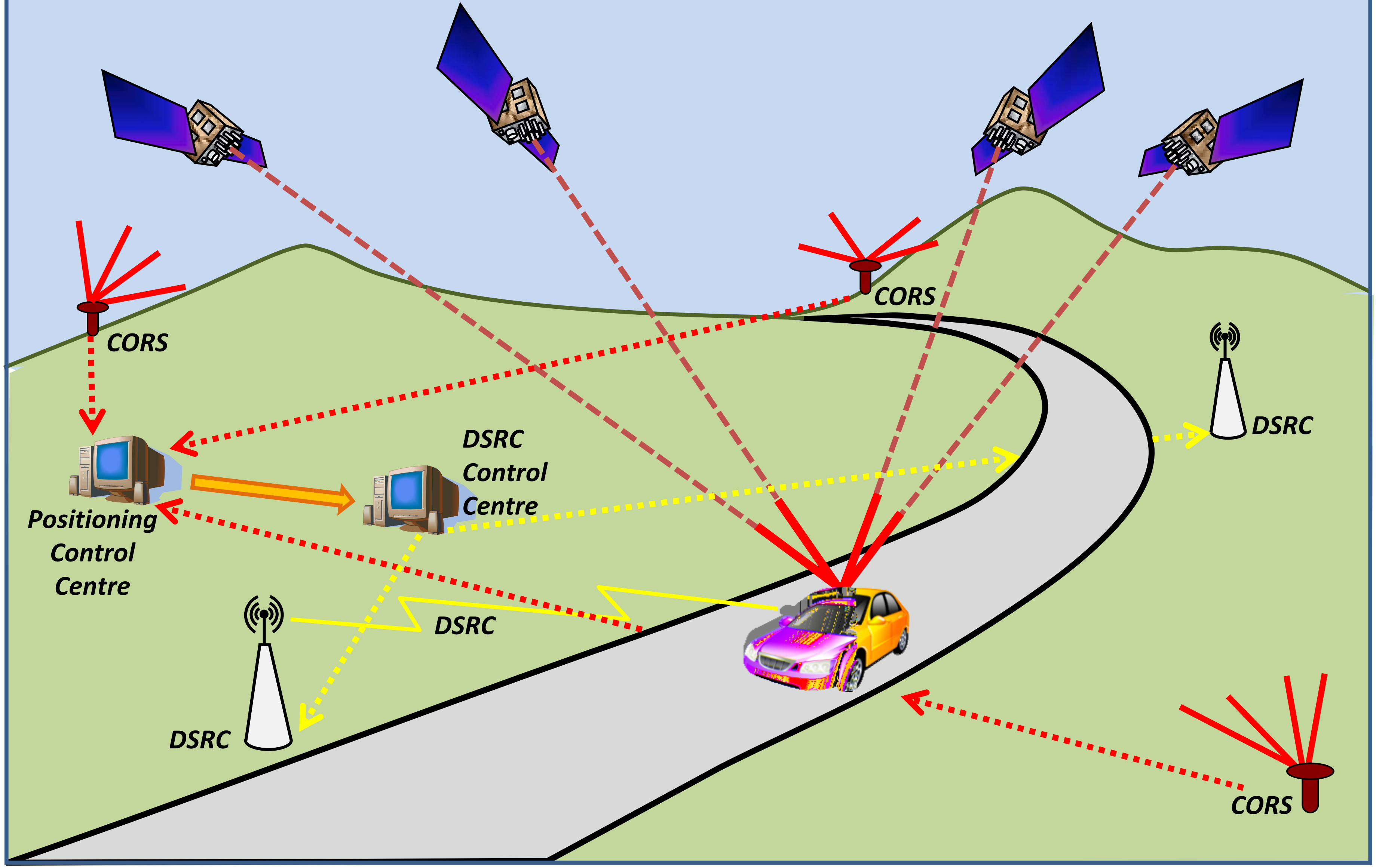
Long range radar/lidar
Front/Rear vision
Front/Rear short range radar/lidar
Side short-range radar/vision
Side mid-range radar/vision

(Source: Grimm, GM, 2008)

Concept of relative positioning with GPS raw data exchanged between vehicles



C-ITS with CORS and DSRC



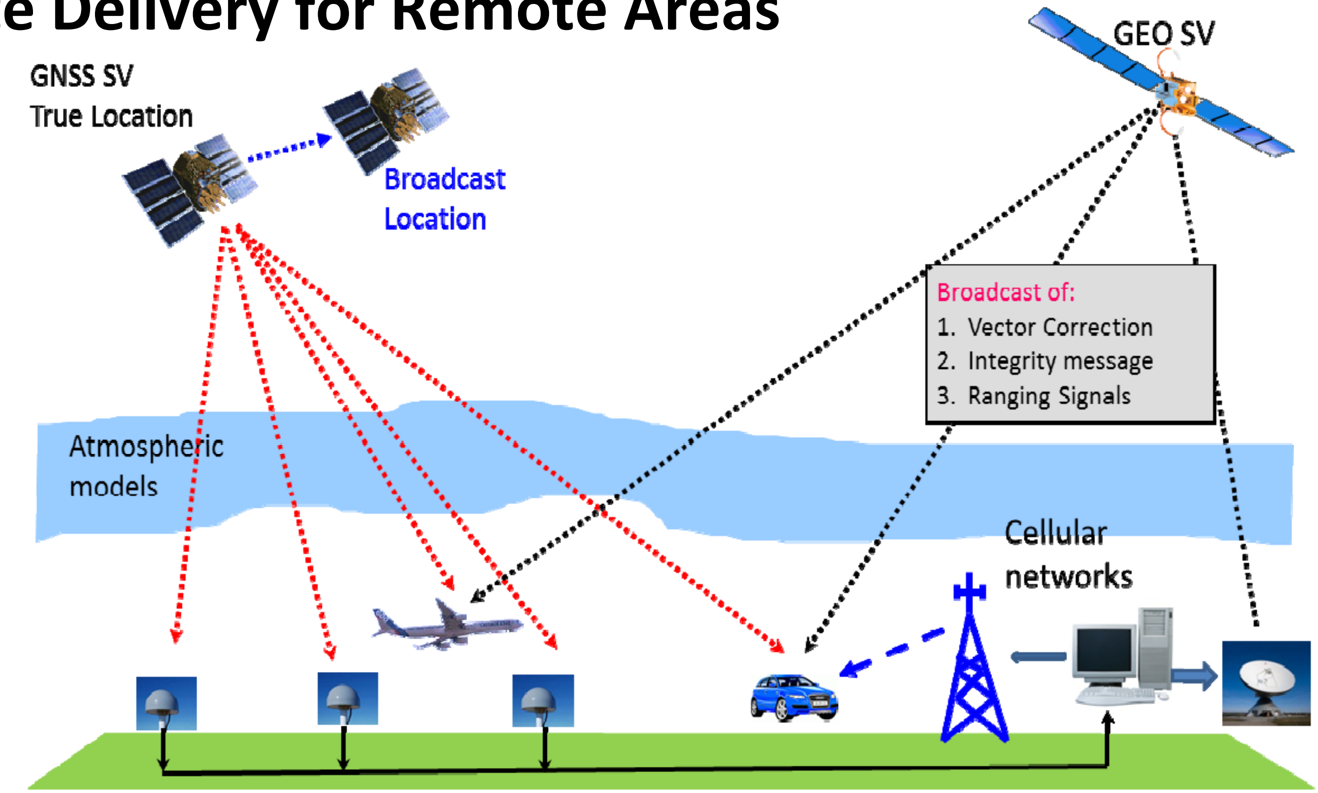
(Source: Feng, Higgins and Milner for ARRB, September, 2012)

C-ITS Vehicle Positioning Research Projects

Project	COOPERS	CVIS	SAFESPOT	EDMAP
General Approach	Hybrid / multi sensor	Hybrid / multi sensor	Hybrid / multi sensor	Hybrid / multi sensor
Satellite Navigation	GPS (L1) / EGNOS / Galileo	GPS (L1+L2) / EGNOS	GPS (L1) / EGNOS	GPS (L1+L2) /WAAS/NDGPS
On Board sensors	Odometer, gyroscope, differential odometer (all sensor information from CAN-Bus)	Accelerometer, gyroscope (as sensor in the OBU) 3-axis-IMU, compass, speed-sensor & laser scanner (as external sensors)	Camera, laser scanner, IMU (as external sensors) C2C communication (for relative GNSS)	Gyroscope, odometer & wheel pulse input (all sensor from internal CAN-Bus)
Infrastructure	IR-transmitter	Wireless Sensor Network (Loops, Cameras, Beacons), WLAN-Network, DGPS networks, Map-Matching	UWB communication	None
Database	Location table for the IR-transmitter	Location table for WSN, I2V-transmitters cameras complete road database. Extended map attributes land mark database.	Object database (for camera sensor) landmark database location table for UWB-transmitter complete road database.	Digital map
Estimated cost	100 – 300 €	> 1000 € (> 10 000 € for IMU)	> 1000 € (> 10 000 € for IMU)	> 1000 € (> 10 000 € for IMU)

(Source: ARRB Report quoting EDMap consortium (2004), Bebsky (2008), Coopers (2010) and Schokker (2010)

DSRC and Cellular where available + Satellite Delivery for Remote Areas



Ground Continuously Operating Reference Stations

Control and uplink station
Compute and distribute GNSS corrections and serve various users

- *C-ITS solutions being developed in EU, USA and Japan tend to assume an SBAS is available;*
- *Will SBAS be available in all countries; in terms of both comms and reference station coverage;*

- *Dual Frequency Multi-GNSS SBAS desirable for Road Safety;*
- *QZSS LEX an attractive option for where-in-lane applications;*
- *... but will these become standards?*

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

Candidate GNSS based techniques for C-ITS safety applications

- **Technique A**: Standalone (Global Navigation Satellite System) GNSS absolute positioning and V2V relative positioning with low cost GNSS receivers
- **Technique B**: Space Based Augmentation System (SBAS) absolute positioning and/or V2V relative positioning with low cost GNSS receivers
- **Technique C**: Smoothed Differential GNSS (DGNSS) absolute positioning and/or V2V relative positioning with low cost GNSS receivers
- **Technique D**: Real Time Kinematic (RTK) positioning with dual-frequency receivers
- **Technique E**: Precise Point Positioning (PPP) and V2V relative positioning with high-end GNSS receivers.

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

Five-tier GNSS-based techniques for CITS-applications

Tier	Technique Option	Status: Current	Status: Future	Accuracy range	Cost	C-ITS applications
1	A	Standalone GPS (SPS)	Standalone multiple GNSS	10-20 m	Low	Vehicle navigation, personal route guidance and location based services
2	A	Standalone GNSS (PPS), Code DGPS	Standalone multiple GNSS positioning	1-10 m	Low	Vehicle navigation, location-based services, road traffic management
3	B	Current WAAS Commercial WADGPS	Future SBAS design for multiple-GNSS	0.1-1m (utilising SBAS and V2V relative positioning)	Low	C-ITS safety applications: lane-level positioning, lane-level traffic management and where-in-lane-level applications
	C	Smoothed DGPS	Smoothed DGNSS	0.1-1 m	Medium	
4	D	RTK	Combined PPP and RTK (seamless)	0.01-0.1m	Medium to High	Research prototype C-ITS safety systems, offering bench mark solutions for testing low-cost units.
	E	PPP				
5	Advanced D and E	Static positioning	Sub-centimetre RTK with multi-GNSS signals	0.001-0.01m	High	*Geosciences and geodynamic studies. Not recommended for C-ITS applications*

(Source: Feng, Higgins and Milner for ARRB, September, 2012)

Summary and Comments on Relevance of C-ITS for the ICG (1)

International Committee on Global Navigation Satellite Systems

- **Precise Positioning is continuing to evolve** from specialist applications like Surveying through industrial applications like Precision Agriculture to mass market applications like Cooperative ITS;
- Some applications have higher accuracy requirements than C-ITS but at a lower reliability requirement and vice versa... but C-ITS is a very demanding GNSS application in terms of the **combination of accuracy and reliability**;
- Experience from Australia shows that many decision makers in road transport **assume the best of GNSS** ~ a level of complacency about achievable accuracy without augmentation, signal obstructions, multipath, reference frame issues, jamming etc;
- Growing gap between **Developed and Developing Countries** in terms of ability to support C-ITS ~ ICG link to UN is important;

Summary and Comments on Relevance of C-ITS for the ICG (1)

International Committee on Global Navigation Satellite Systems

- Despite these concerns, the **time frame for the evolution** of safety-of-life C-ITS applications **is synergistic** with the evolution of Multi-GNSS ~2020;
- In terms of user groups with demanding requirement for GNSS, Aviation Users and Surveying and Geodesy users seem to now be well engaged in the ICG ~ it is suggested that the ICG should continue to **develop engagement with the Road Transport sector**.

IGNSS 2013

Gold Coast, Queensland, Australia
16th to 18th July 2013
www.ignss.org

Thanks for your attention - matt.higgins@qld.gov.au