Precise GNSS Positioning – *Not just a niche technology*

UNSW AUSTRALIA

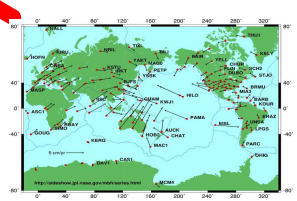
Never Stand Still | Faculty of Engineering | School of Civil and Environmental Engineering

Chris Rizos

Precise Positioning... *what does it mean?*

Precise Positioning... a spectrum of users...

Few mm | 1cm | 2cm | < dm | 1dm | few dm | sub-m



Science

Machine automation

Surveying

CTF agriculture

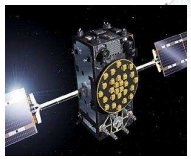
Datum

Deformation surveys

Engineering & construction

Map sensor georeferencing

Geodetic POD



LEO POD

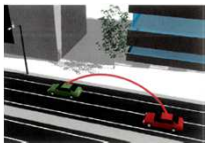
Mapping

Offshore engineering

ITS

Hydrography

Precision agriculture



GIS

Disaster response

Precise Positioning...

Few … 2cm < dm 1dm few dm sub-m

Precise Positioning is an "augmented accuracy" form of positioning with performance over-and-above that provided by the "standard" GNSS service

Precise Positioning is a civilian innovation that addresses the needs of certain market segments

Science

Dat…

Deformati… surveys

…recision

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LEO POD

GIS

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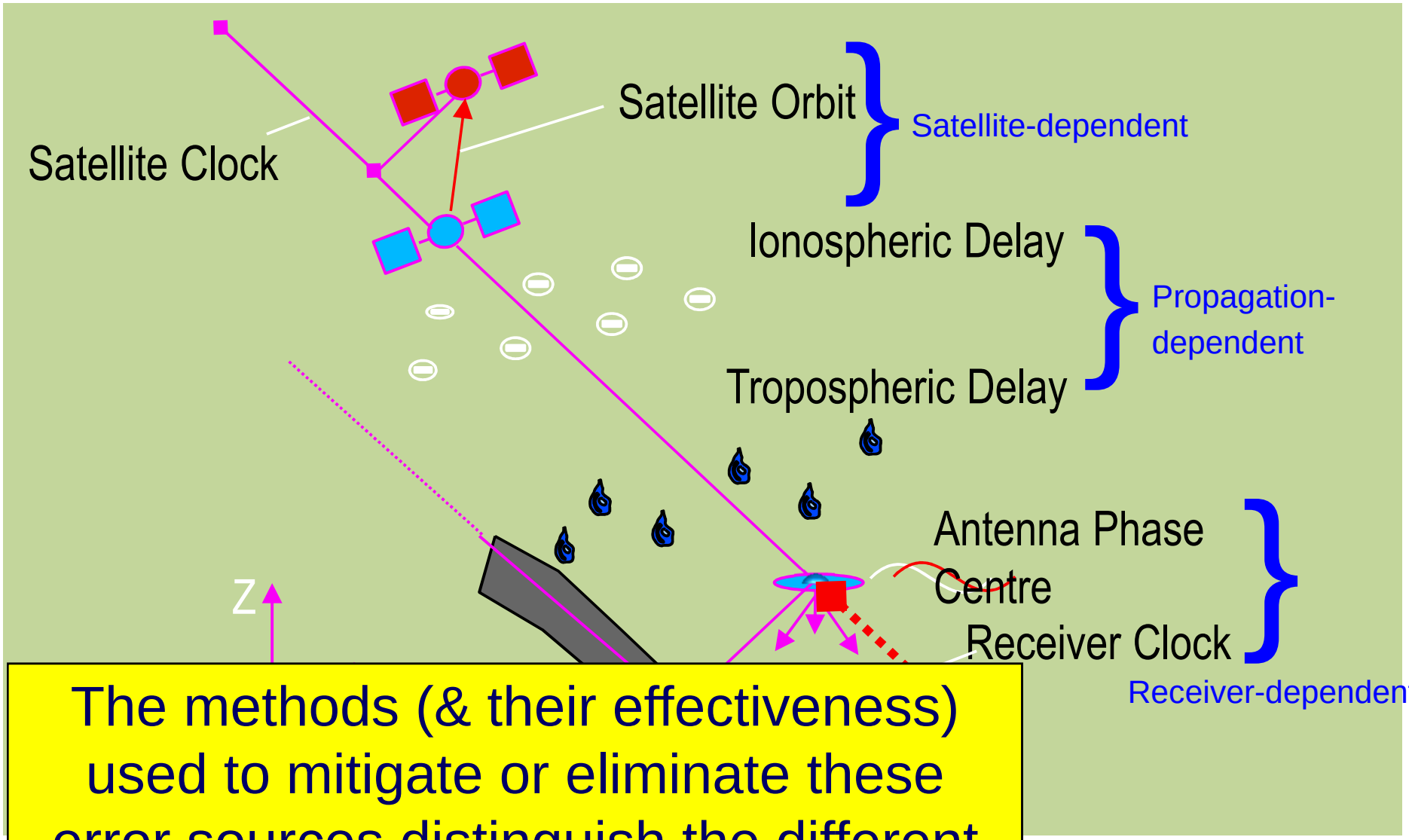
…ng

Geodetic POD

Disaster response

GNSS Error Sources



The methods (& their effectiveness) used to mitigate or eliminate these error sources distinguish the different classes of Precise Positioning

GNSS Market Segments…

SoL, Mission/Liability Critical

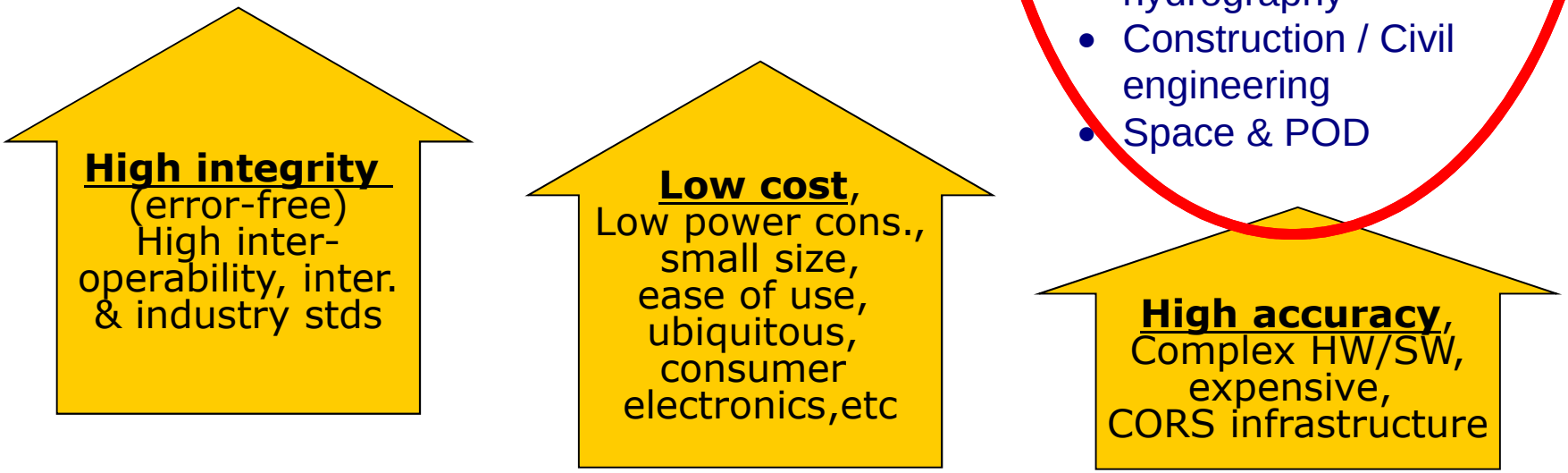
- Aviation
- Rail
- Maritime & inland waterways
- Ambulance / Police / Fire
- Search & Rescue
- Personal protection
- Dangerous goods transport
- ERP, tolls

Mass Market

- Personal mobility
- Cars, trucks & buses
- Geosearch, telematics & LBS
- Tracking
- Personal outdoor recreation, sport
- IoT, others…

Professional

- Mining, port operations & machine guidance
- Timing
- Advanced ITS
- Geodesy & science
- Meteorological
- Mapping
- GIS
- Surveying
- Precision agriculture
- Offshore engineering / hydrography
- Construction / Civil engineering
- Space & POD

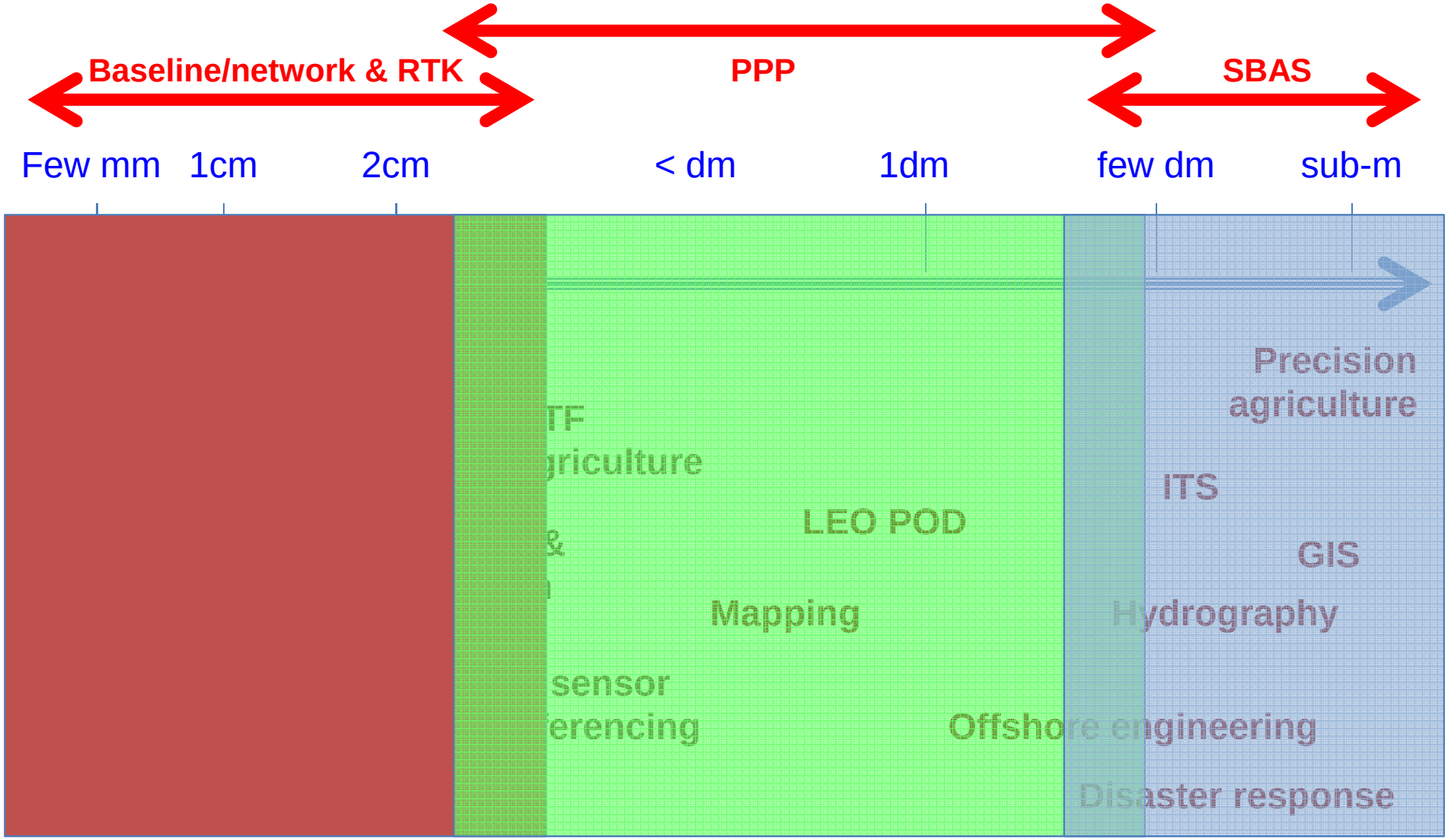


Precise GNSS Positioning Modes...

- **Augmented** GNSS, using PR measurements in “quasi-Single Point Positioning” mode, e.g. SBAS
- **High accuracy *differential* positioning**, using CPH measurements, e.g. RTK
- **High accuracy *absolute* positioning**, or Precise Point Positioning (PPP), using CPH measurements

All require contributions from terrestrial “base stations” (or CORS)...
Albeit with a variety of network configurations, HW, measurement algorithms, & service provision options

Precise Positioning... variety of modes...



Space-Based Augmentation System (SBAS)

GNSS
Const

Low-cost (HW & free SBAS signal access), single-frequency (i.e. L1), universal PR-based SPP (i.e. all chipsets SBAS-capable), seamless GEO satcoms (i.e. via Rx frontend), regional/national CORS (i.e. not global), designed for aviation (but non-aviation apps hamstrung by ICAO/RTCA approval processes)

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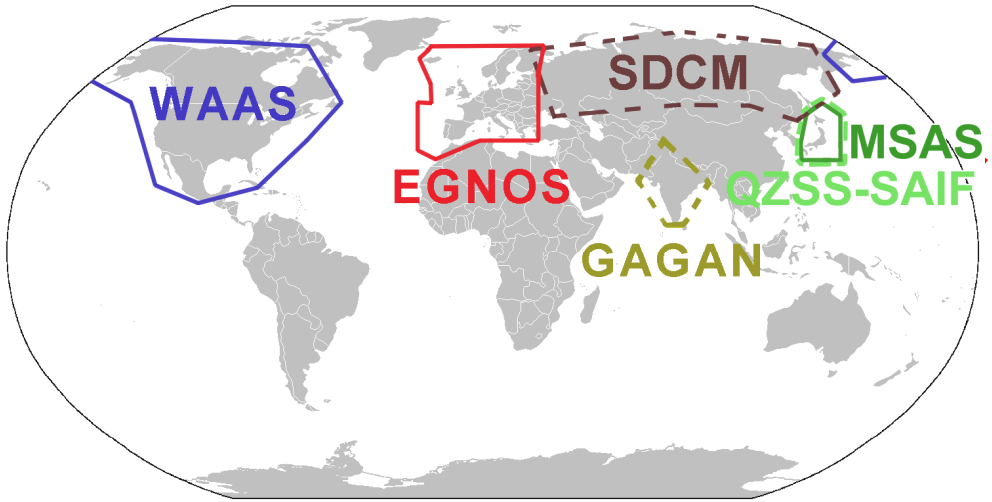
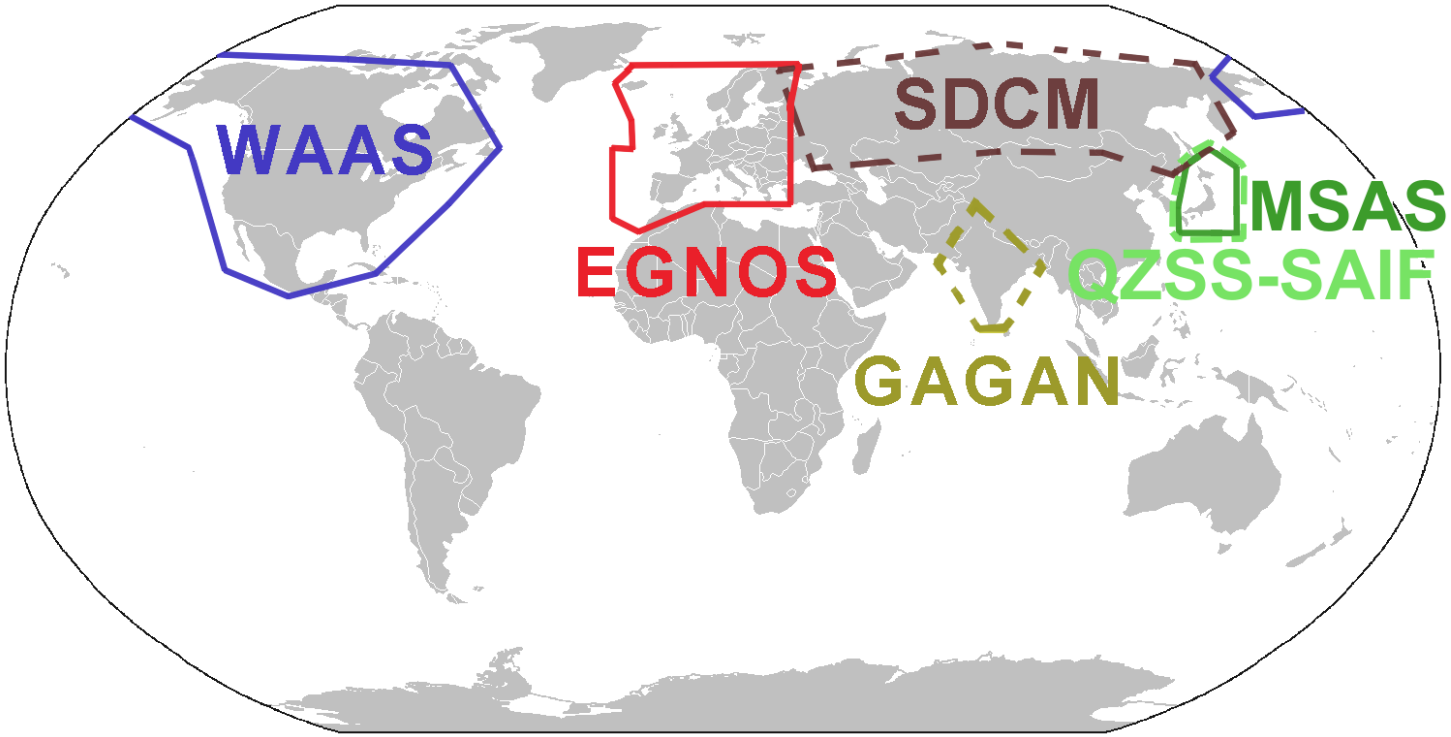


Correction messages for atmospheric, orbit & sat clock errors (via GEO "GNSS-like" satcom link)

- Wide Area Augmentation System (WAAS) – U.S.
- Multi-functional Satellite Augmentation System (MSAS) – Japan
- Quasi-Zenith Satellite System (QZSS-L1Sa) – Japan
- European Geostationary Navigation Overlay System (EGNOS) – E.U.
- GPS-Aided Geo-Augmented Navigation (GAGAN) – India
- System for Differential Corrections & Monitoring (SDCM) – Russian Federation
- *BDSBAS, and others*

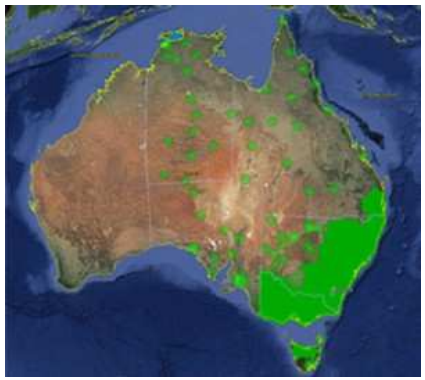


Differential CPH-based Positioning

GNSS Constellation(s)

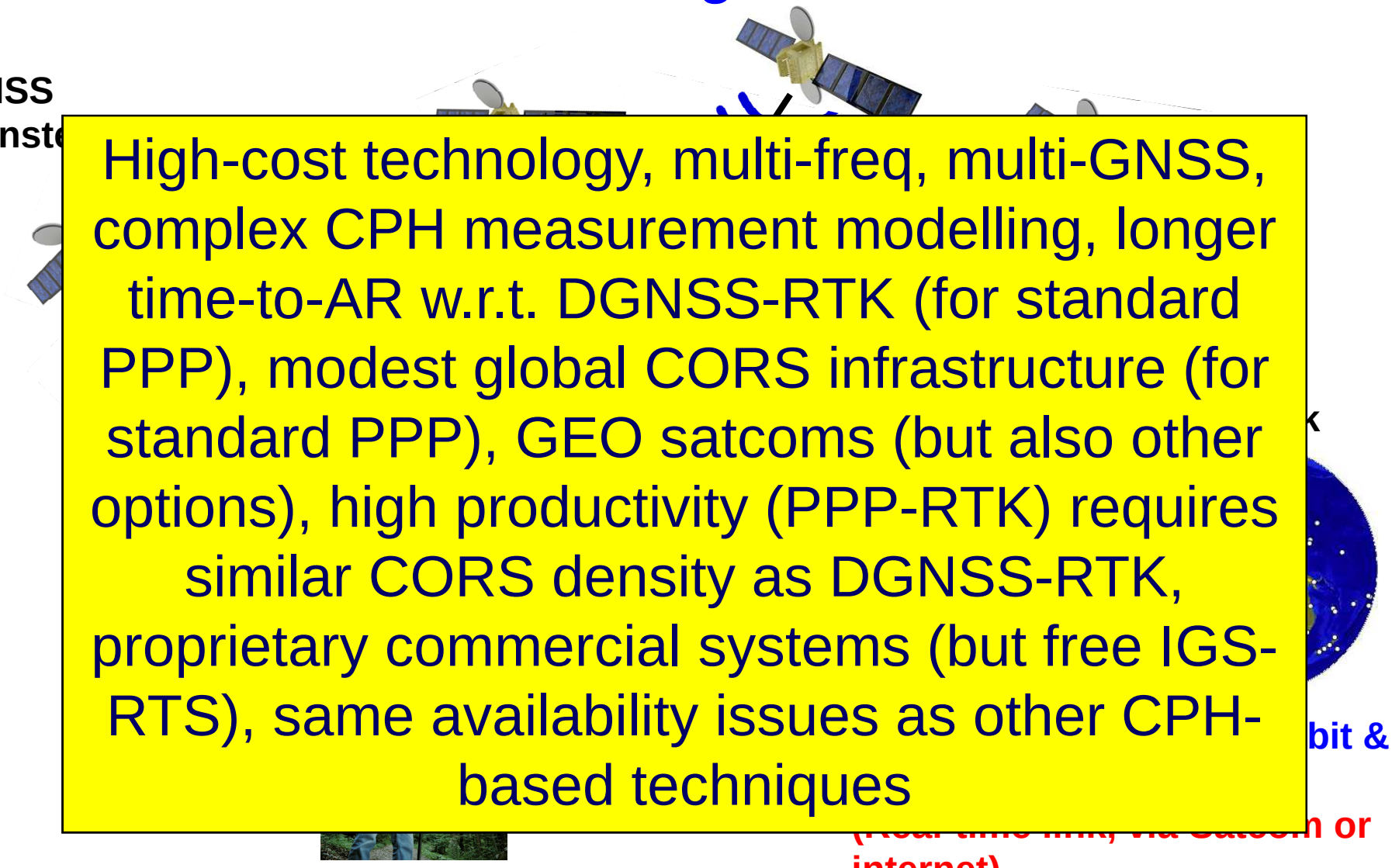
High-cost technology, multi-freq, multi-GNSS, high-accuracy (i.e. CPH measurement modelling), considerable local CORS infrastructure (i.e. rapid AR), terrestrial comms, typically commercial services, address high productivity apps (i.e. DGNSS-RTK), availability issues (i.e. loss-of-lock & AR)

Local



DGNSS w.r.t. CORS...
Real-time (RTK) or post-processing (baselines or network)

Precise Point Positioning

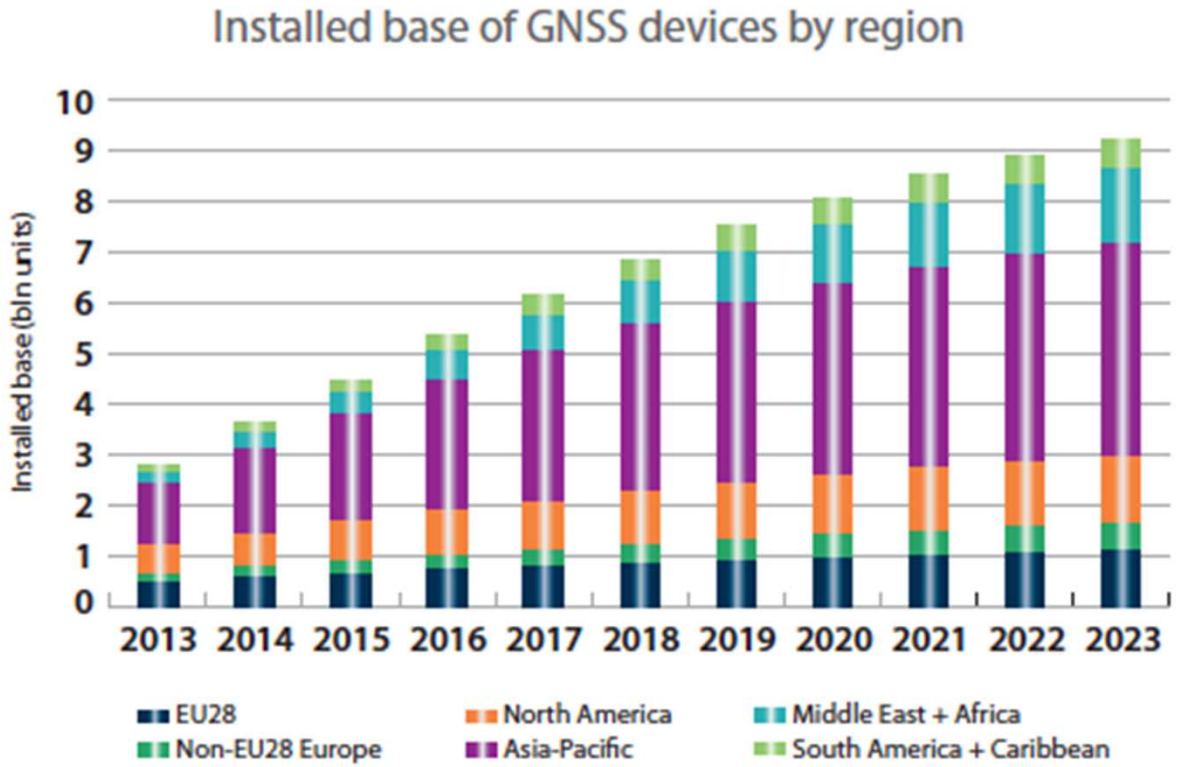


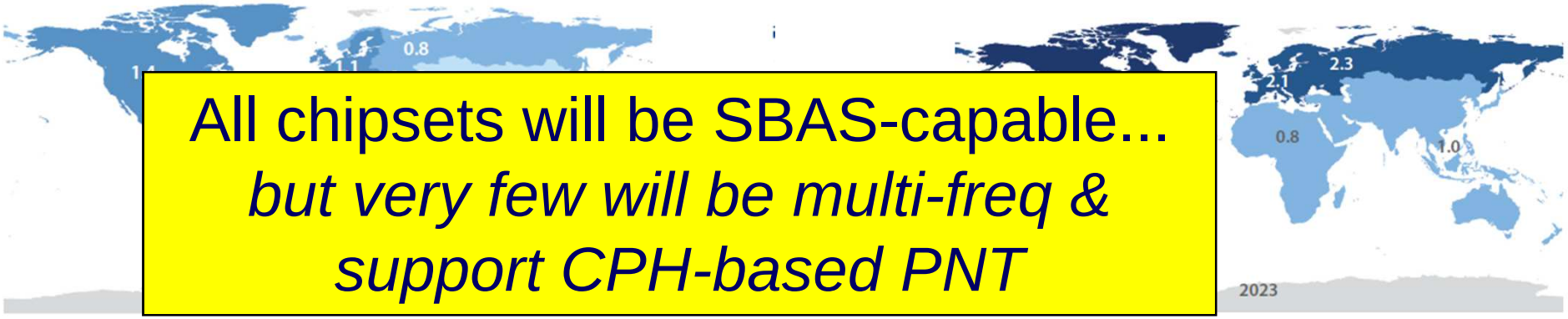
High-cost technology, multi-freq, multi-GNSS, complex CPH measurement modelling, longer time-to-AR w.r.t. DGNSS-RTK (for standard PPP), modest global CORS infrastructure (for standard PPP), GEO satcoms (but also other options), high productivity (PPP-RTK) requires similar CORS density as DGNSS-RTK, proprietary commercial systems (but free IGS-RTS), same availability issues as other CPH-based techniques

Precise Positioning... *who uses it?*

GNSS Market Studies... what do they say?

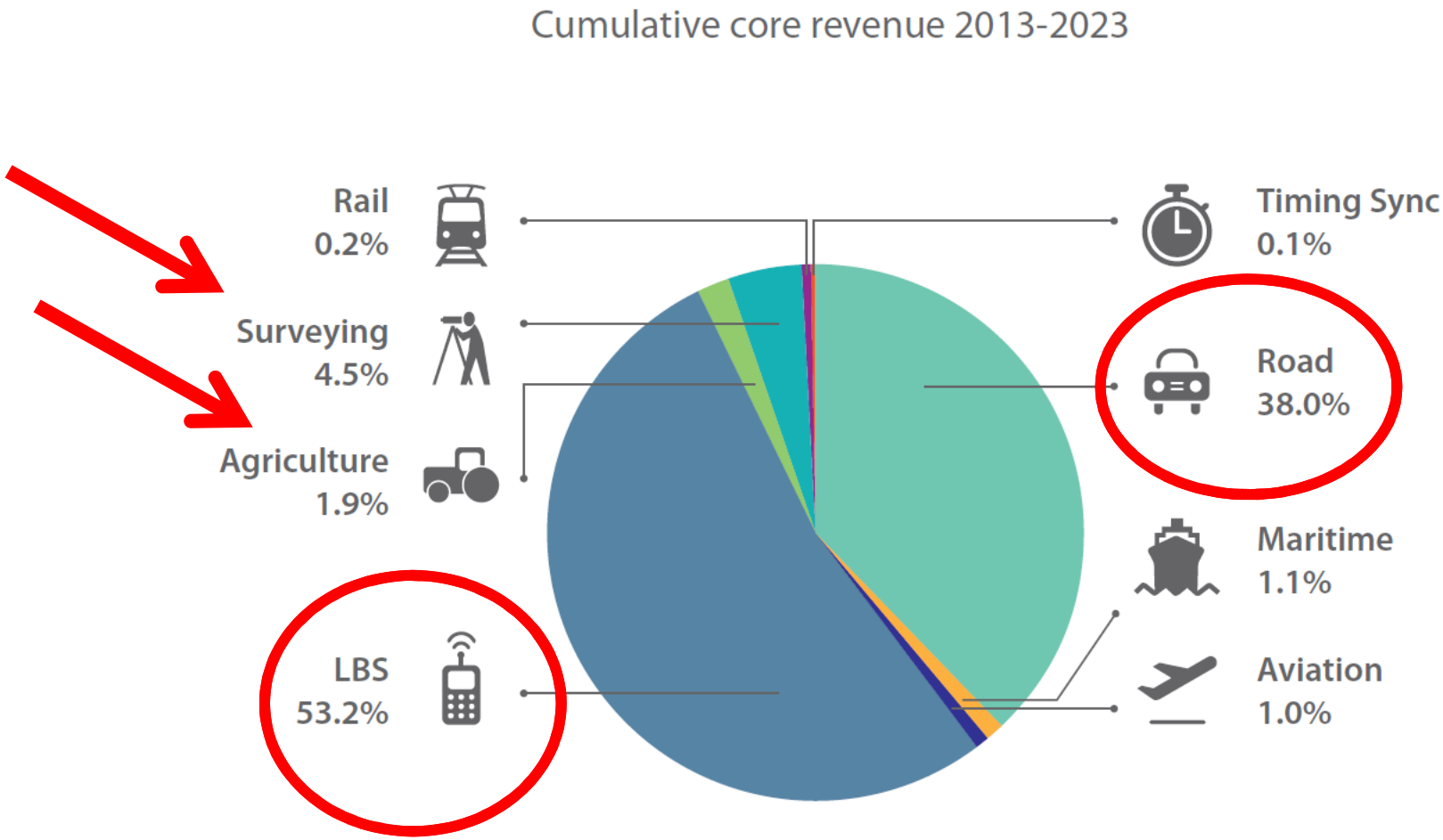
http://www.gsa.europa.eu/system/files/reports/GNSS-Market-Report-2015-issue4_0.pdf





All chipsets will be SBAS-capable…
but very few will be multi-freq & support CPH-based PNT

GNSS Revenue Predictions...



LBS Trends

Almost 3 bln mobile applications currently in use rely on positioning information

Key market trends

- The LBS market continues to grow, with high end devices now commonly making use of multi-constellation and hybrid positioning.
- The development of successful apps continues to drive the global growth of the smartphone market.
- Context-aware applications leveraging on location information make up almost half of this total, with games and entertainment representing the largest categories.

Apps

Navigation, social networking, travel, games, entertainment, fitness and sports, healthcare

On average, more than **70 apps** per device are downloaded by users, although 50% of users have never paid more than $1 for an app.
Downloads of apps that rely on positioning data will hit 7.5 bln by 2019, up from 2.8 bln in 2014.

App stores

Google and Apple dominate the app stores market with more than 50 billion downloads combined from the two stores in 2013.
Google Play surpassed the Apple App Store in terms of downloads and apps in store. However, Apple generated higher revenues by a factor of five.

Total unique apps in store – December 2014

- Google Play 1.43 mln apps
- Apple App Store 1.21 mln apps
- Windows Phone Store 300 k apps
- Amazon Appstore 293 k apps
- Blackberry World 130 k apps

Technology

- GNSS, Wi-Fi and NFC are now integrated into a single integrated Circuit (IC) platform
- Multi-constellation GNSS chipsets are implemented into high end devices
- Technological advancements in indoor positioning will enable new applications

Users

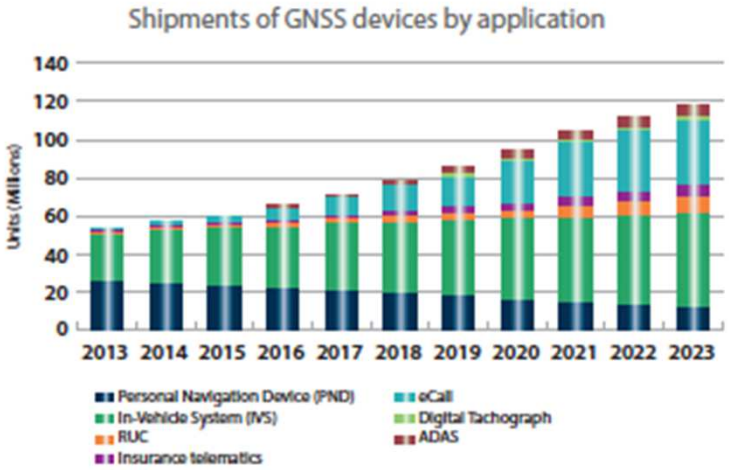
- Smartphone and tablet owners, people with illnesses or disabilities, workforce, outdoor activity enthusiasts.
- Global installed base of GNSS enabled handsets: 3.1 bln in 2014, up to 5.2 bln in 2017 (many users have more than one device).

Market trends... *but do they identify new markets (as opposed to new "apps")?*

Photo credit: © Thinkstock

Road transport market trends

New applications will double the size of the market in the next ten years



The **road navigation PNDs market** has reached full maturity. In the coming years, In-Vehicle Systems (IVS) and smartphone apps with pre-installed and self-updating maps will progressively replace PNDs. In the future, automotive manufacturers will take advantage of IVS to provide value added services, such as connected and autonomous vehicles and other safety-critical applications.

PND manufacturers are reacting with the launch of **HUD (head-up display) devices**, including the Garmin HUD, which deliver navigation cues, along with such information as speed and time to destination while allowing the driver to keep their eyes on the road. HUD innovation is creating market opportunity for new players focused on usability and user experience, such as Navdy.

Regulated applications will drive further growth in the Road market for GNSS. In particular, eCall-like systems worldwide (such as ERA GLONASS in Russia) are foreseen to account for 30 mln shipments in 2020.

Among commercial applications, insurance telematics solutions are foreseen to progressively penetrate the market, with annual shipments hitting 5 mln units in 2020.

A look into the near future: GNSS supporting autonomous driving

Autonomous vehicles can take over activities traditionally performed by the driver, thanks to their ability to sense the environment, navigate and, if combined with connected vehicle solutions, communicate with other vehicles and road infrastructure. Widespread adoption of autonomous driving can reduce traffic accidents and improve traffic flow, as well as improve driver comfort.

Autonomous vehicles are enabled by the combination of different technologies and sensors, allowing the IVS to identify the optimal path of action. GNSS plays a key role by providing relevant inputs for integrated navigation, such as vehicle location and speed. Multiple constellation, horizontal protection levels and advanced detection techniques provided by computer vision or LiDAR will be combined to ens

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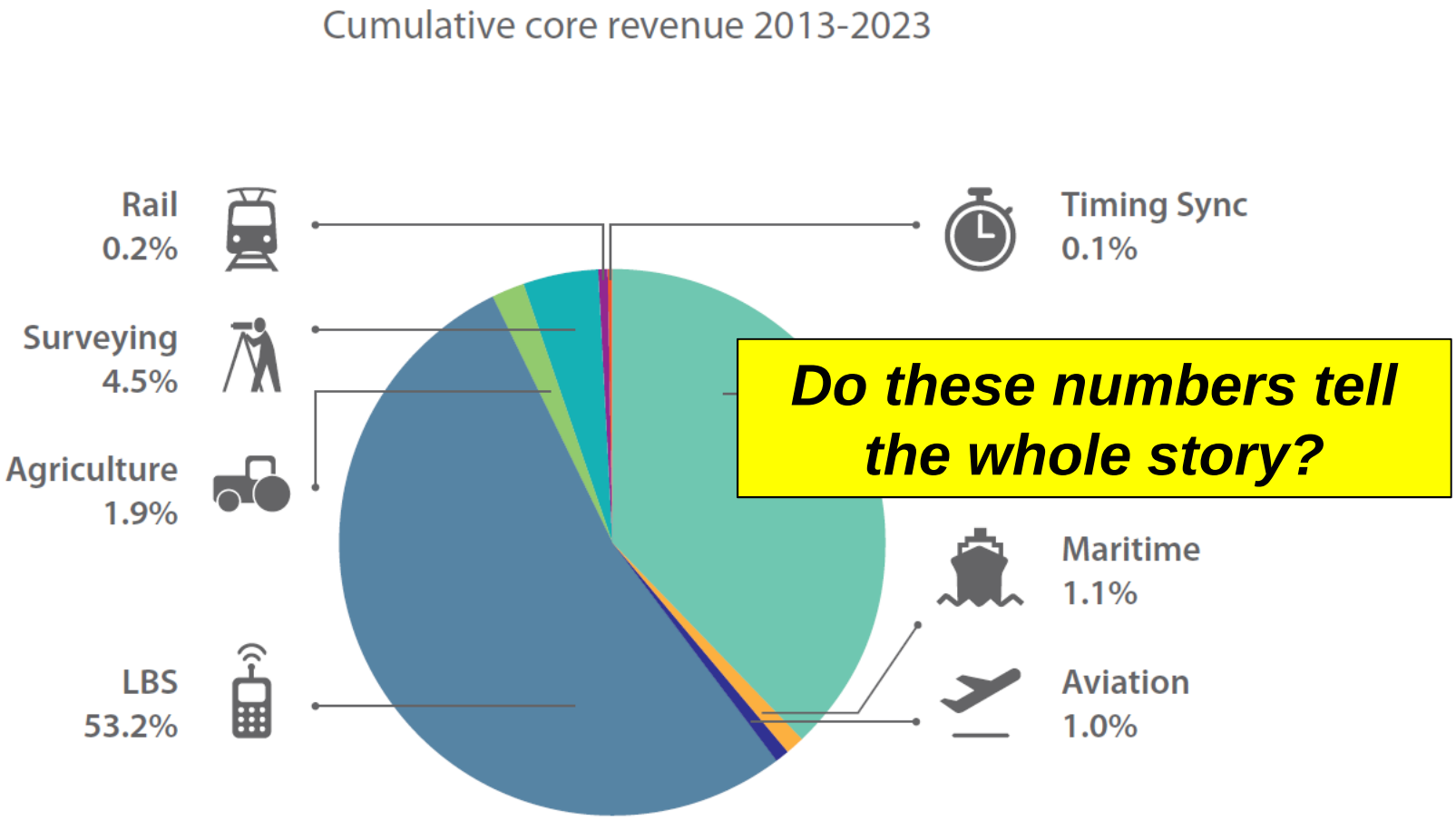
Market trends... *but is the past a good predictor of future markets?*

GNSS Market Size Predictions...



Do these numbers even make sense?

Progress in Quantifying GNSS Benefits: Economic Study under US PNTAB Now being Refined

Implies Precise Positioning benefits >50% of total GNSS economic benefits!

	Annual GPS Equipment Spending ($ billion)	Estimated Annual Benefits ($ billion)
Precision agriculture (crop farming)	$0.5	$19.9 - $33.2
Engineering Construction (heavy & civil and surveying/mapping)	$1.1	$9.2 - $23.0
Transportation (commercial surface transportation)	$3.2	$10.3 - $15.1
Sub-total (3 industries examined)	$4.8	$39.4 - $71.3
Other commercial GPS users	$3.5	[illegible]
Total commercial GPS users in the U.S.	**$8.3**	**$67.6 - $122.4**

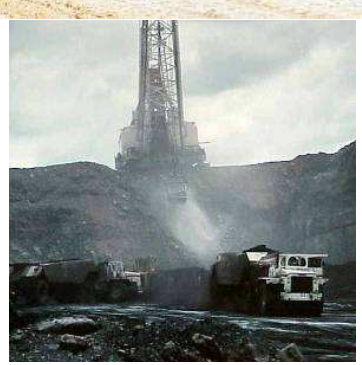
- Over $65B In Annual Benefits in identified Commercial Areas

Sou

Brad Parkinson, ICG-9 presentation, November 2014

GNSS PP Benefits - Australia

- Largest user group for DGNSS-RTK techniques
- High-cost, high CORS infrastructure requirements
- Recent study[1] found productivity gains with potential *cumulative* benefit AUD$73B to $134B over next 20 years - ***in agriculture, construction and mining alone***
- Also, significant ***environmental benefits***, through greatly improved fuel efficiency, as well as improved safety through increased automation



[1] "Economic benefits of high resolution positioning services", Allens Consulting Group, for CRC-SI & Vic. DSE, Nov 2008

Economic Benefits – Agriculture

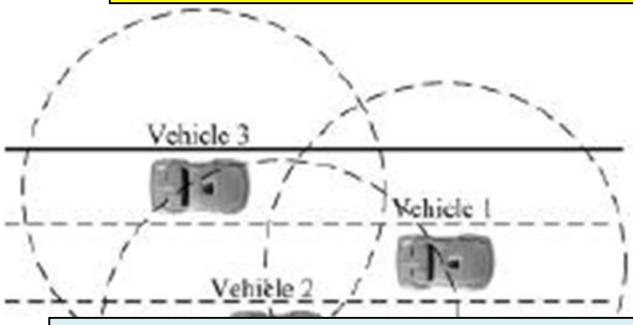
- GNSS machine guidance (RTK) applied widely in the grain, cotton, sugar and other broad-acre agricultural sectors
- Use of “control traffic farming” (CTF) can significantly reduce input costs (fuel, labour, etc.), study findings:
  - Annual yields up 10%
  - Fuel and oil costs reduced 52%
  - Labour costs reduced 67%
- (Similar findings in other countries)
- Sub-metre “precision agriculture” via SBAS (or similar)
- Benefits also for specialised small-scale agriculture using “farm-robots”, e.g. vinticulture, orchards, etc.
- Increasing use also for livestock management

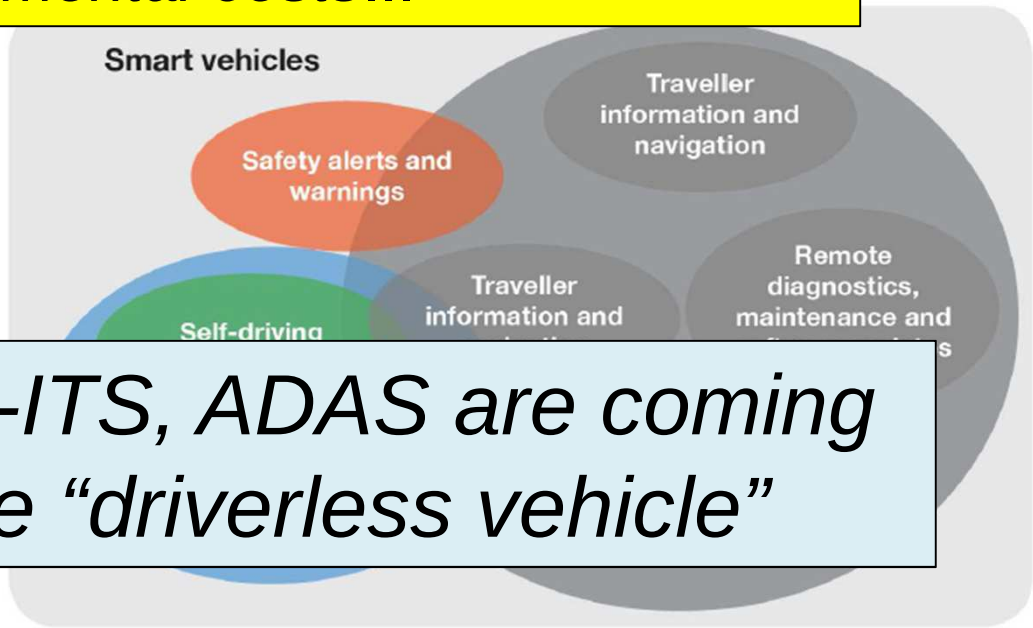
Economic Benefits – Construction, Surveying...

- In civil engineering, machine guidance via DGNSS-RTK can deliver significant increases in automation, accuracy, and improved on-site safety
- Productivity improved by as much as 30%
- No alternative technology for cm-level accuracy surveying, mapping & geodesy... *e.g. techniques based on terrestrial line-of-sight (lasers, microwave) or ultrahigh-cost space techniques (SLR, VLBI, etc)*

Precise Positioning... *what about the future?*

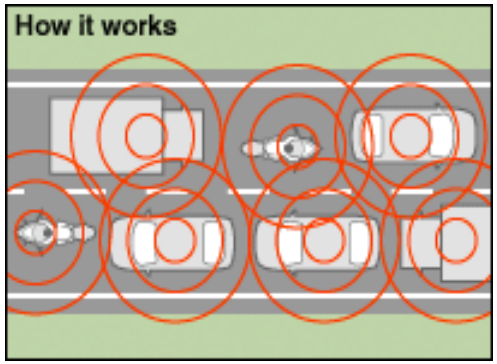
ITS is more a vision than a coherent program...
Comprising many elements... *harnessing ICT to improve future transport efficiency, safety & lower environmental costs*...





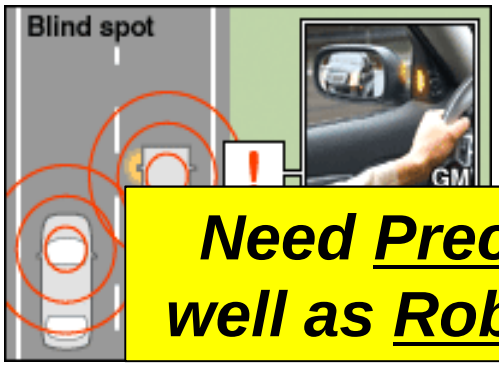
Advanced ITS, C-ITS, ADAS are coming very soon... the "driverless vehicle"

Advanced ITS applications...



Google

UBER



Need <u>Precise</u> & <u>Reliable</u> positioning, as well as <u>Robust</u> multi-sensor positioning...

Positioning in vehicles is going from Passive to Active... From supporting simple navigation to information about traffic to warnings about hazards to actively avoiding hazards to supporting self-drive modes

Positioning requirements…

Type	Level	Accuracy Requirement		Research prototype	Commun-ication 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-	1.0	Decimetre	Centimetre	0.01-0.1

All need some form of Precise Positioning...
*in both the "**absolute**" and "**relative**" sense*

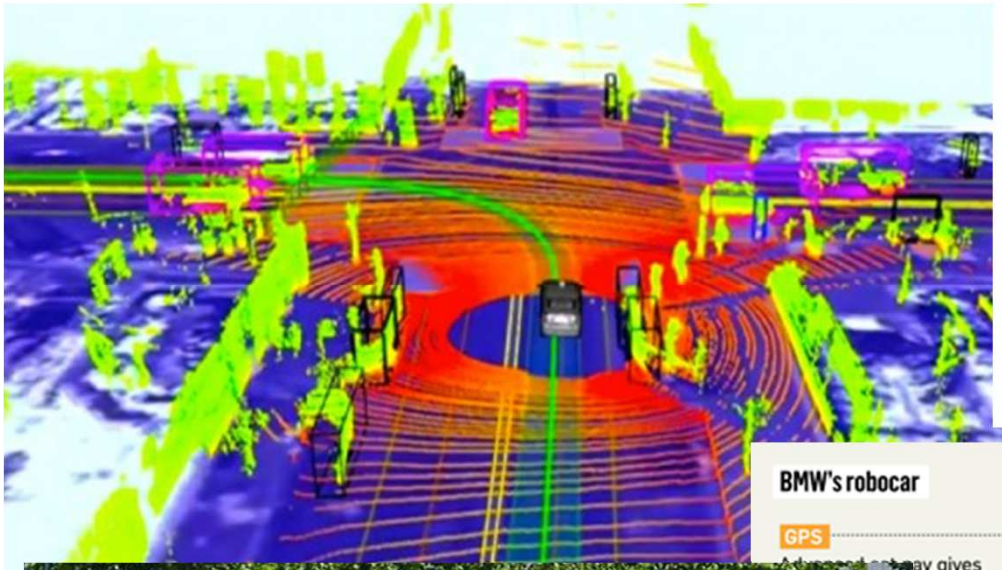
https://www.onlinepublications.austroads.com.au/items/AP-R431-13

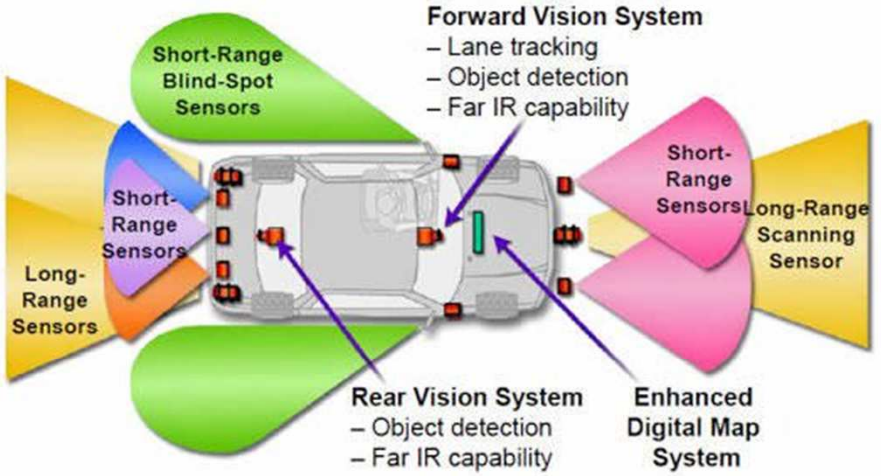
GNSS techniques for Advanced ITS applications

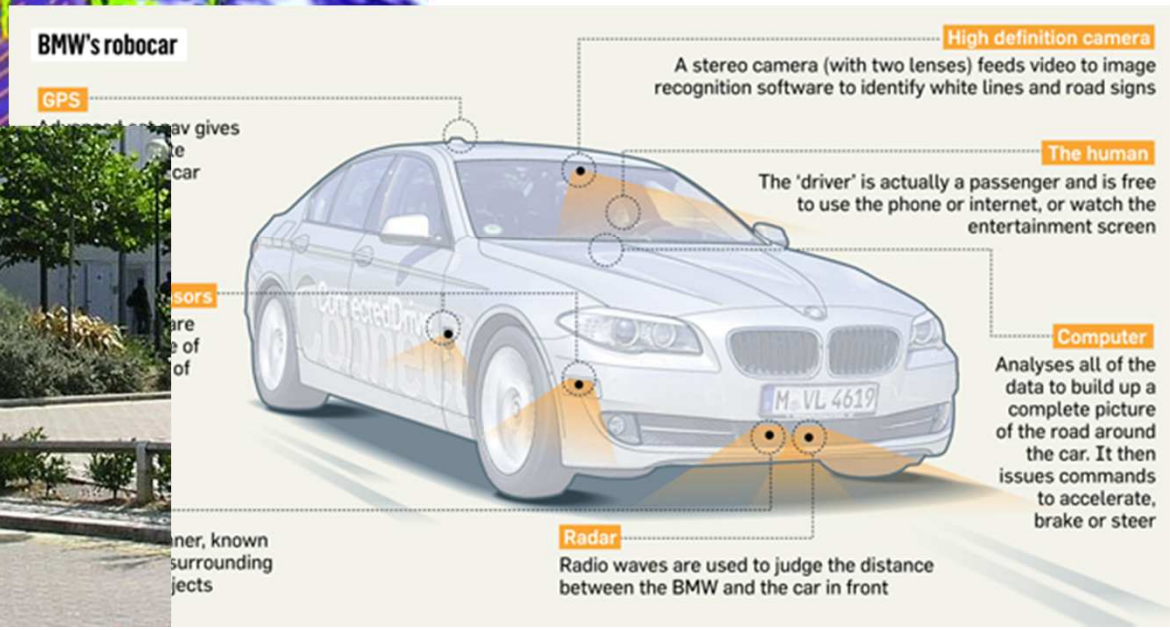
Technique Option	Status		Accuracy range	Cost	C-ITS applications
	Current	Future			
A	Standalone GNSS (SPP)	Multi-GNSS SPP	1-10 m	Low	Vehicle navigation, location-based services, road traffic management
B	Current SBAS Commercial WADGNSS	Future SBAS design for multiple-GNSS	0.1-1m (utilising SBAS and V2V relative positioning)	Low	Safety applications: lane-level positioning, lane-level traffic management and where-in-lane-level applications
C	Smoothed terrestrial DGPS	Smoothed DGNSS	0.1-1 m	Medium	
D	RTK	Combined PPP and RTK (seamless)	0.01-0.1m	Medium to High	Research prototype safety systems, offering bench mark solutions for testing low-cost units
E	PPP				

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

Its more than GNSS...







But GNSS is still essential for providing “absolute coordinates”, and to reference mapping data

PP is more than a niche GNSS technique...

- *Significant PP applications*
- *Expect increase use of GNSS PP in ITS (& other) applications*
- *Variety of PP modes provides considerable flexibility for current & new GNSS applications*