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LBS and ITS: Some Challenges & Opportunities for the Fields of Precise Positioning & Geodesy

Never Stand Still

School of Civil & Environmental Engineering, UNSW, Sydney, Australia

Chris Rizos

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In other words…

Where to next focus Geodetic Capabilities?...

<u>One option</u>:
addressing new societal needs for precise & consistent positioning...

Modern Geodesy's Capabilities

Geodesy now defined in terms of the following *capabilities*:

1. Determination of precise global, regional & local 3-D (static or kinematic) *positions on or above the Earth's (solid or aqueous) surface*
2. Mapping of *land, sea and ice surface geometry*
3. Determination of the Earth's (time & spatially) *variable gravity field*
4. Measurement of *dynamical (4-D) phenomena*:

Capabilities very dependent on Precise GPS Positioning...

- *Solid Earth (incl. cryosphere)*: surface deformation, crustal motion, GIA, polar motion, earth rotation, tides, water cycle, mass transport, etc.
- *Atmosphere*: refractive index, T/P/H profiles, TEC, circulation, etc.
- *Ocean*: sea level, sea state, circulation, etc.

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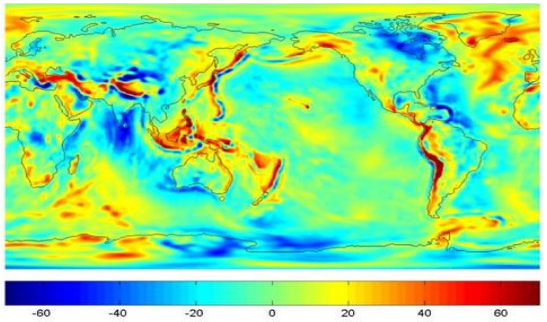
Over the past few decades Geodesy has benefitted enormously from the success of GPS (or GNSS)…

Current capabilities have largely satisfied Geodesy's traditional "mission":

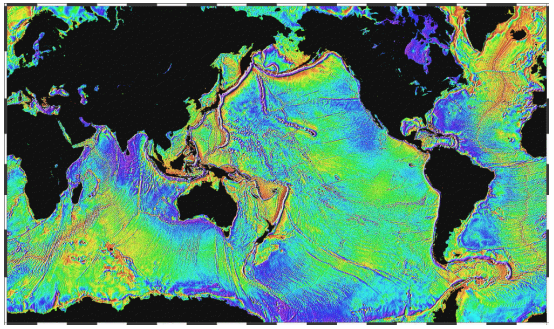
- Earth Observation Science
- Geospatial Reference Framework
- Precise Positioning

Geodesy as an Earth Observing Science

Answer questions, such as

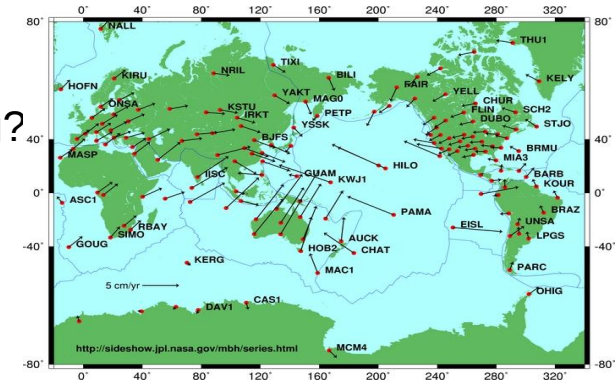


- Climate Change:
  - How much is sea level changing here?
  - How is the atmospheric circulation changing?
  - How is the Water Cycle changing?
  - How do the Earth, Atmosphere and Oceans exchange energy?



- Geohazards:
  - Is stress building on this fault?
  - Has a tsunami wave been detected?
  - Is there an impending volcanic explosion?
  - What is the ground & structural deformation?

- Environmental:
  - What is the mesoscale ocean circulation?
  - What is the pattern of the atmospheric water vapour?
  - How is the pattern of ground water & soil moisture changing?
  - What is the volume of ice being lost in the Arctic/Antarctic?



A Global Geodetic Reference Frame (GGRF) for *Sustainable Development*

- The UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) decided in July 2013 to formulate and facilitate a resolution for the global geodetic reference frame
- UN-GGIM recognises the growing demand for more precise positioning services, the economic importance of the global geodetic reference frame and the need to improve the global cooperation within geodesy

http://ggim.un.org

GPS/GNSS: *an extraordinarily versatile tool*

"GPS has revolutionised Geodesy, Surveying and Navigation"...

There is now a "trickle down" to non-traditional Precise Positioning applications...

more profound impacts are coming...

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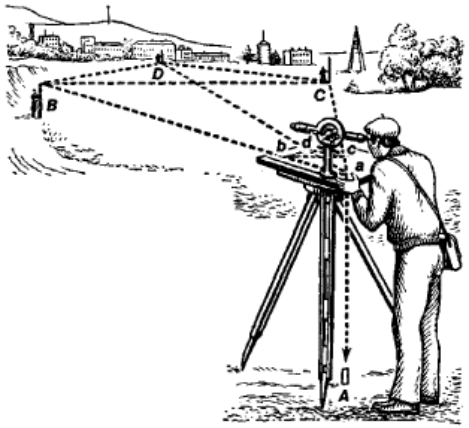
Positioning… some observations & trends

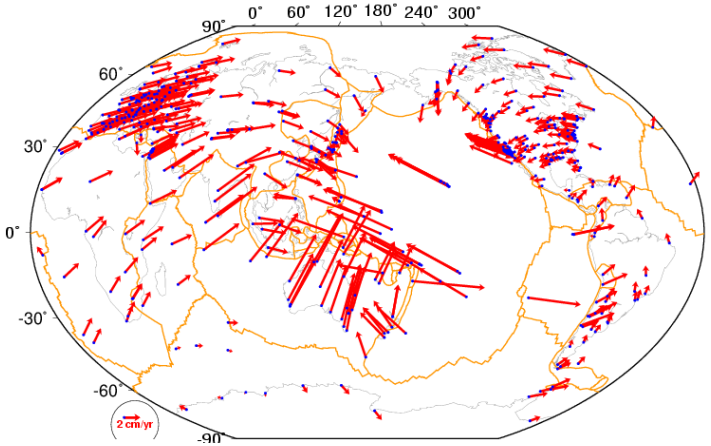
- ITRF-based datums for geodesy & geospatial
- Precise Positioning (PP) are practised *now*
- Dawn of a *multi-GNSS* world
- Evolution in PP *techniques*
- Evolution in PP *hardware*
- Evolution in PP *applications*

1. From National to Global Datums

"GNSS has radically changed how datums are defined and accessed"...

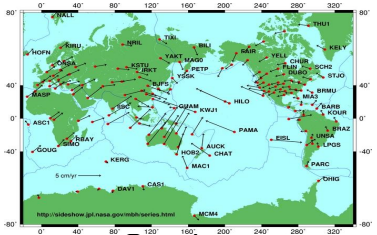
Best-practice is now to adopt an ITRF-based datum because the ITRF is accurate, globally relevant, regularly updated & is a core IAG product...





2. Current PP GNSS Applications

Building Construction



Geodesy

Monitoring

Rapid Mobile Mapping

Port Operations

Land Surveying

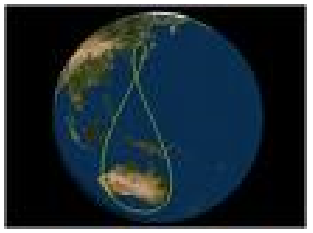
Machine Guidance

Precision Agriculture

- Surveying, precise navigation, & mapping
- Precise kinematic applications, e.g. machine guidance/control
- Define/monitor datum, geodesy applications, etc.
- Precise georeferencing of airborne or terrestrial scanning/imaging sensors
- *But what of the future?*

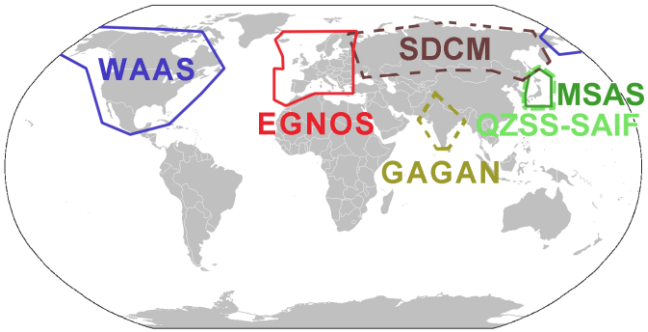
3. From GPS to Multi-Constellation GNSS

+



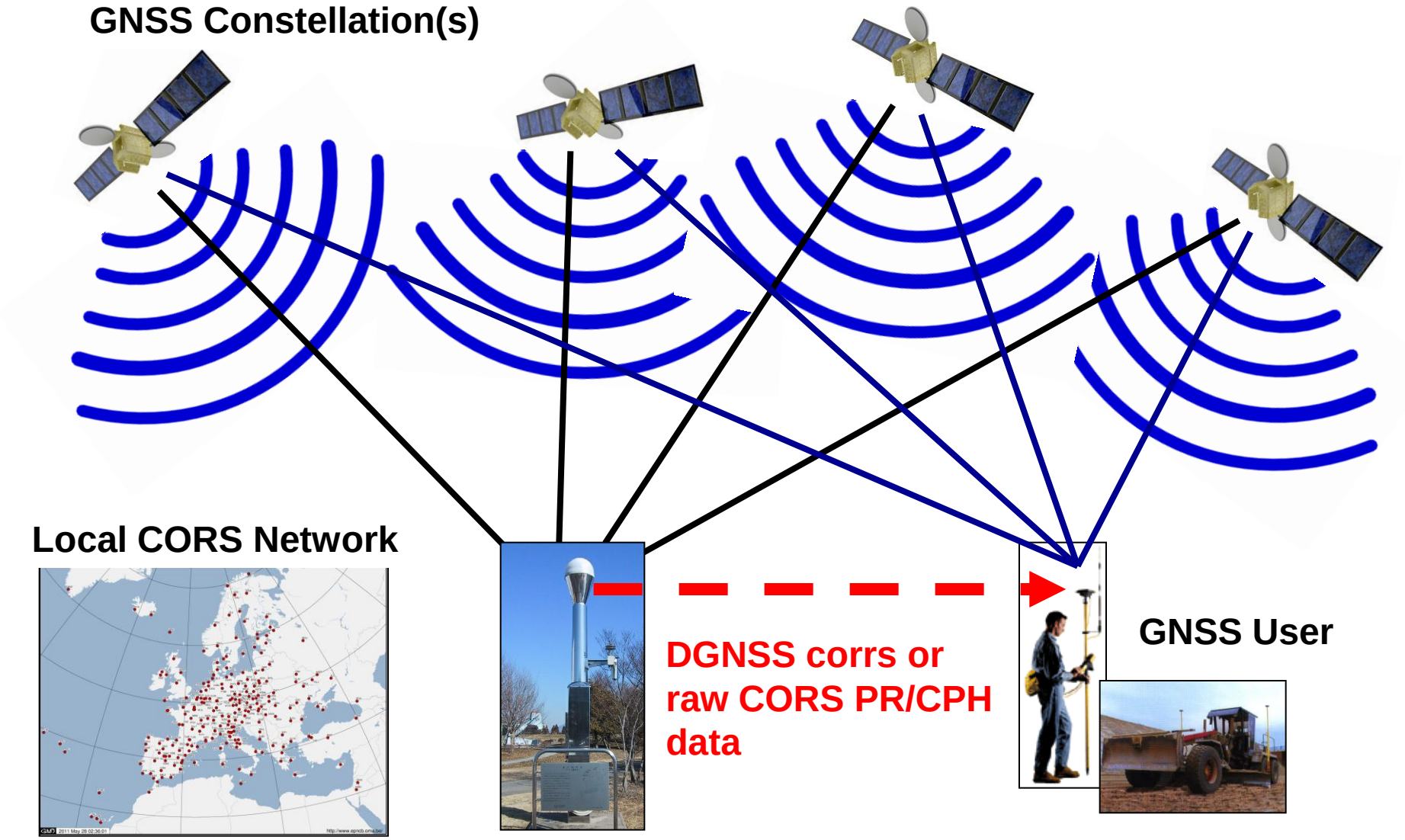
- GNSS:
  - GPS (32) *(32)*
  - GLONASS (24) *(30)*
  - Galileo (3-4) *(30)*
  - BeiDou (14) *(35)*
- RNSS:
  - QZSS (1) *(5-7)*
  - IRNSS (3) *(7)*

- SBAS:
  - WAAS
  - MSAS
  - EGNOS
  - GAGAN
  - SDCM

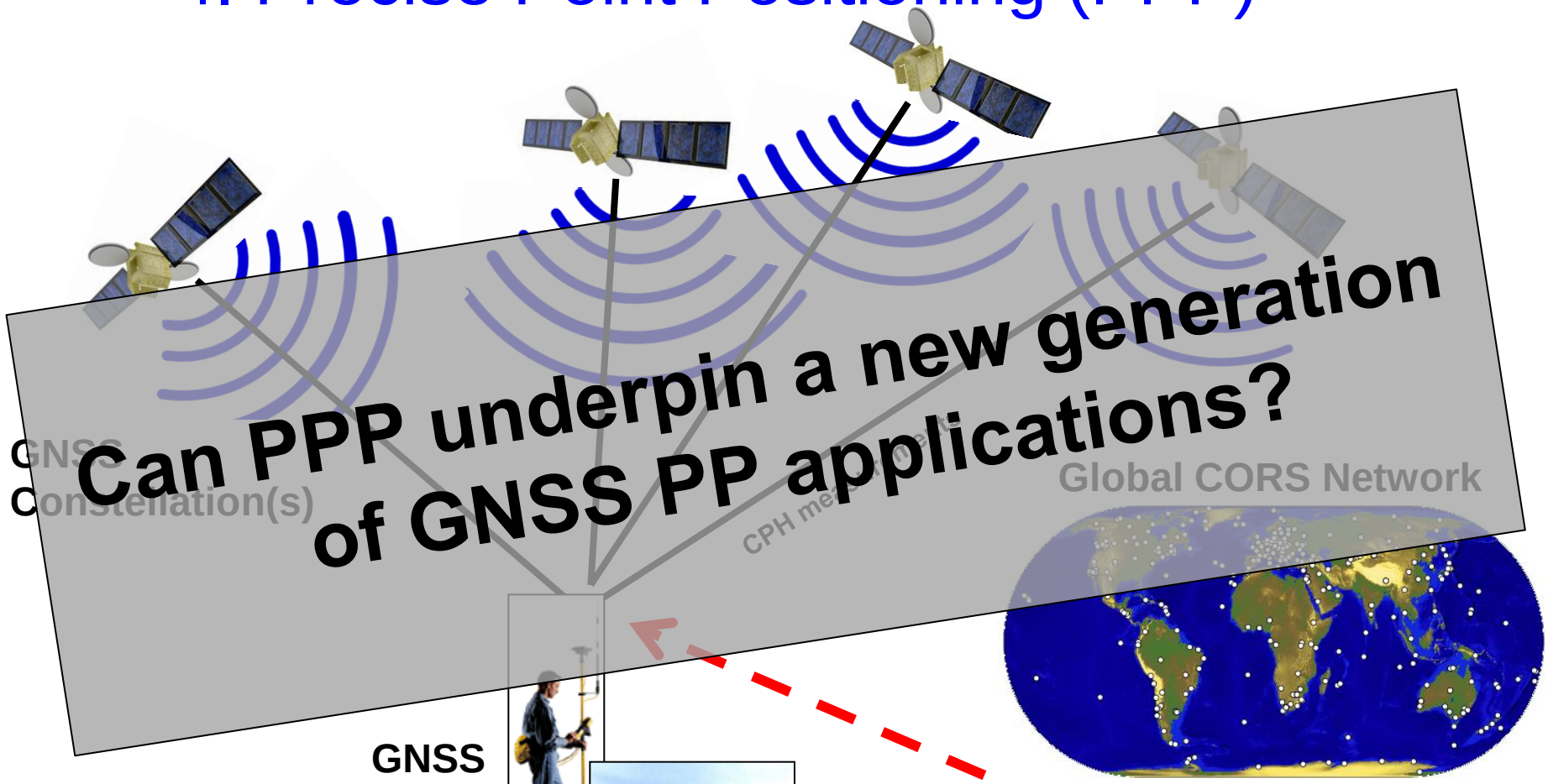


Number of satellites: (Current) *(Planned)*

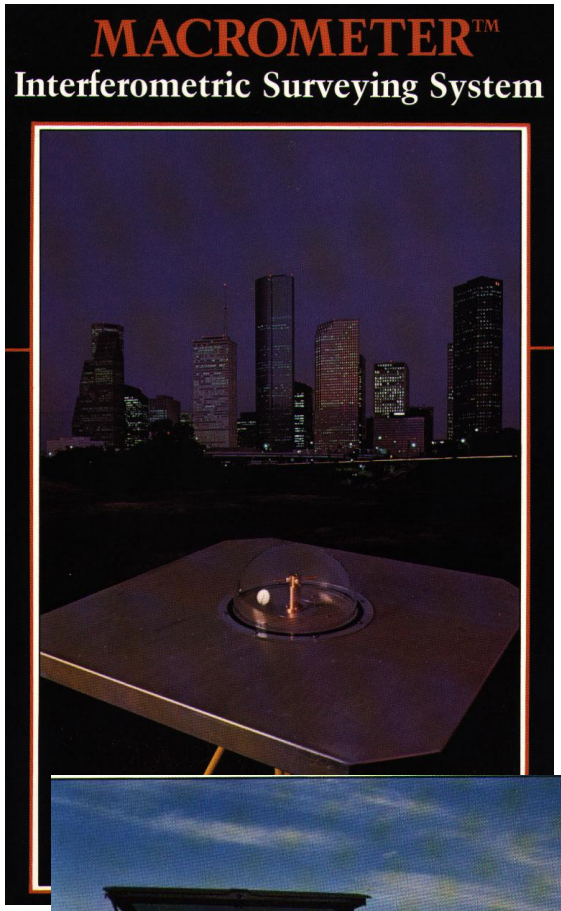
4. PP Differential Positioning (DGNSS)

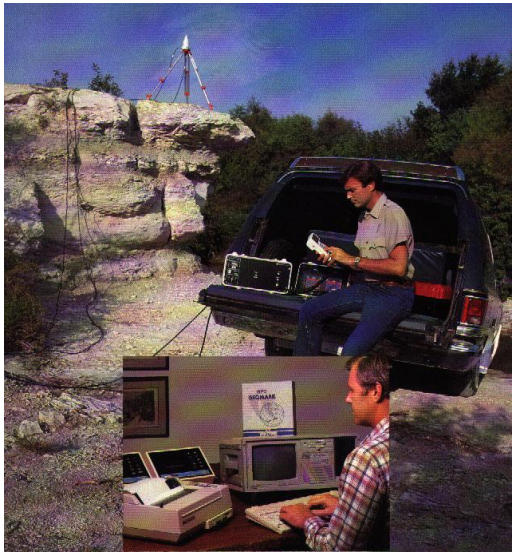


4. Precise Point Positioning (PPP)

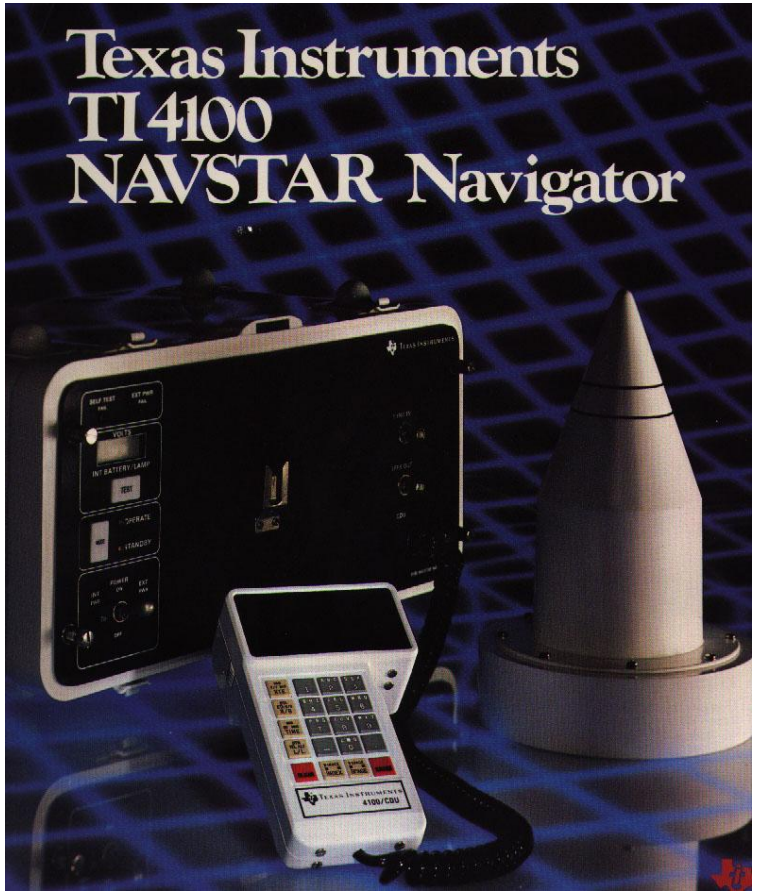


5. GPS receivers *then*...





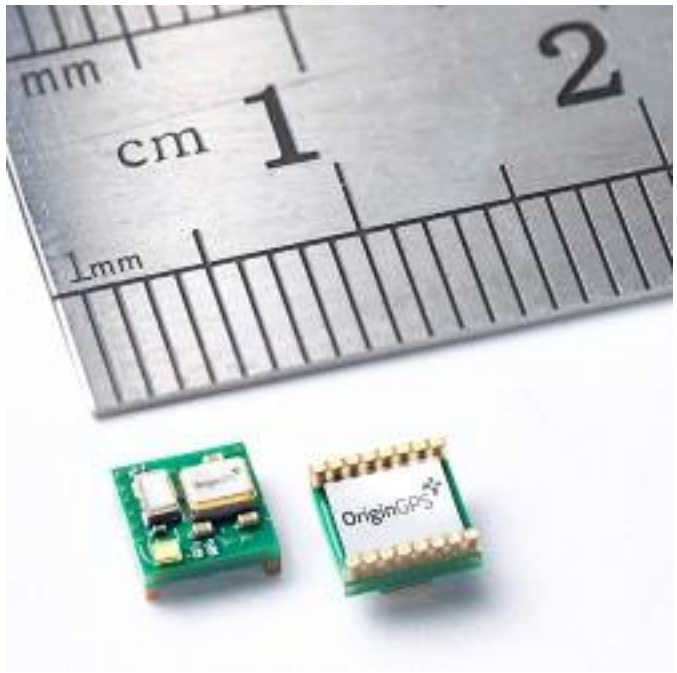
>$100K per unit!



First civilian Rxs were developed for geodetic surveying

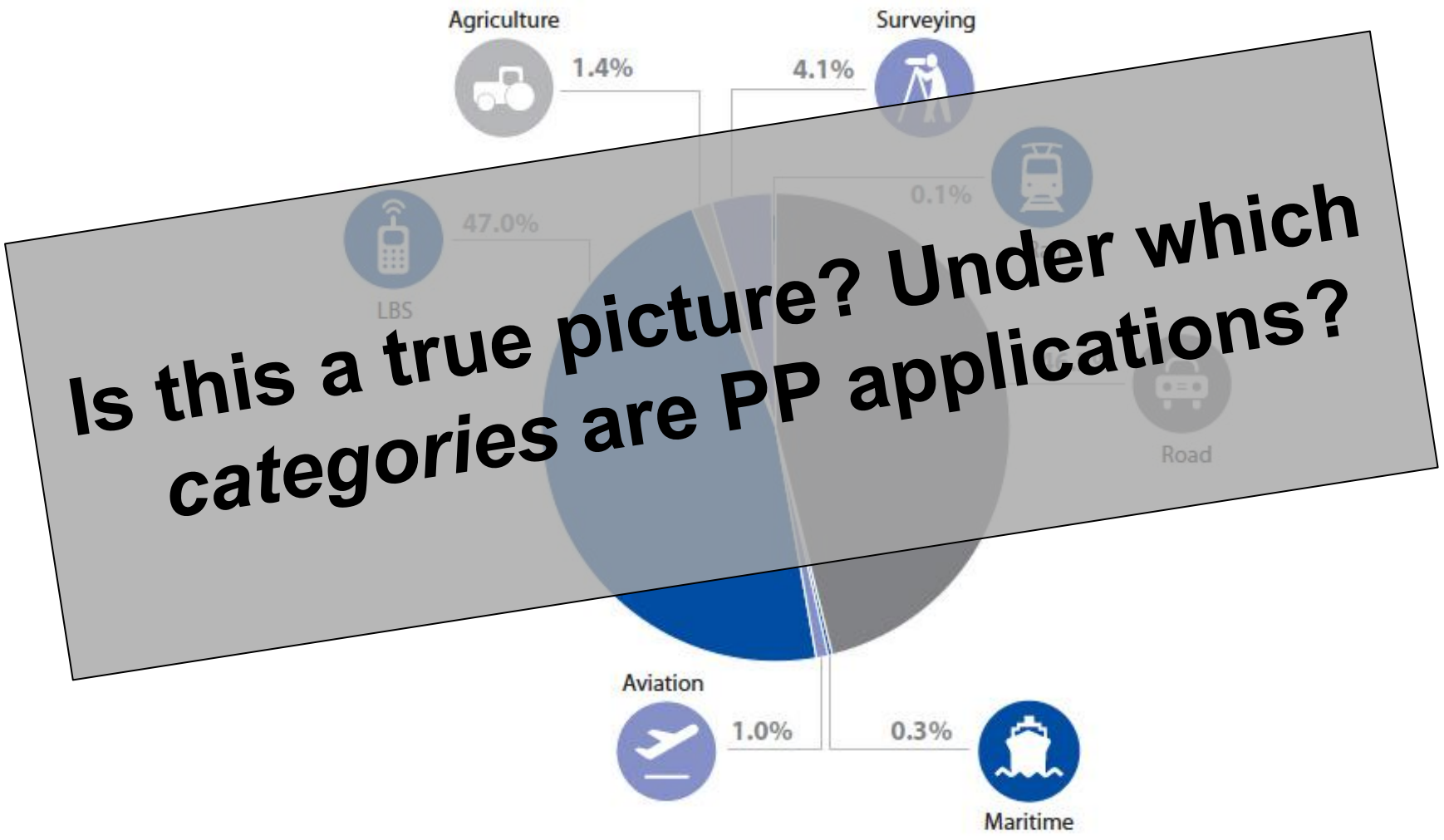
5. GNSS chipsets *now*...

≈$1 per chip *(in bulk)*



But PP-capable hardware still at high premium: >$1K

6. GNSS Applications... *Recent Market Study*



Is this a true picture? Under which *categories* are PP applications?

Traditional PP market segments small

http://www.gsa.europa.eu/sites/default/files/MarketReportMEP72012WEB.PDF, mid-2012

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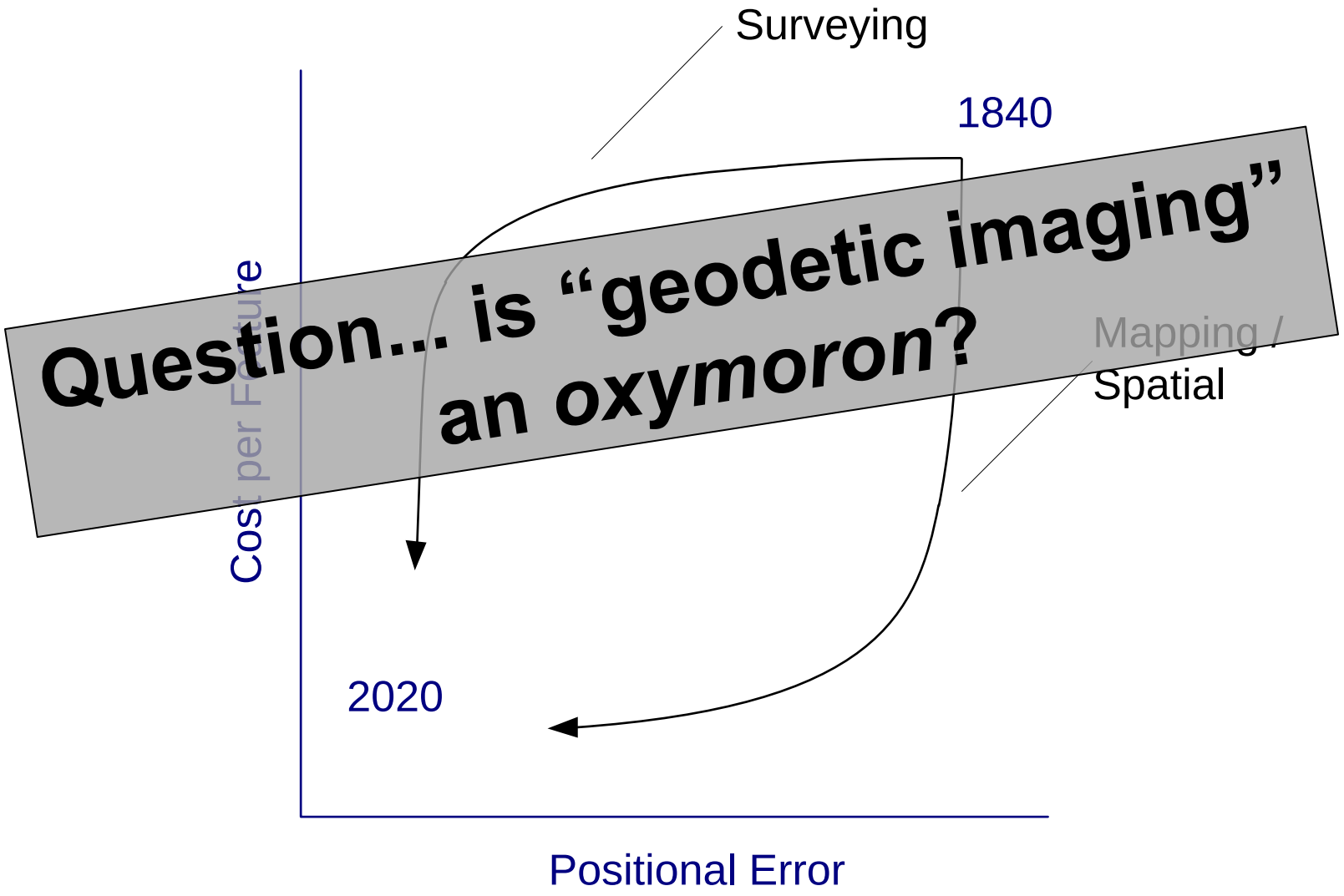
Some crystal ball gazing...

1. There's a revolution in geospatial technology...

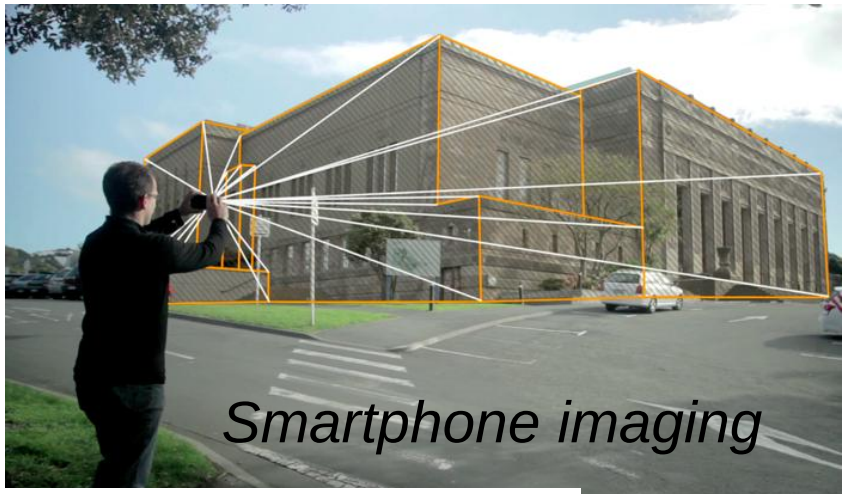
- *(Precise) Positioning is now a "commodity"!*
- *Both PP & Mapping are becoming easier!*
- *Mapping is a form of Precise Positioning!?*

1. Survey <–> Mapping/Spatial Convergence



Low-cost Mobile Mappers...

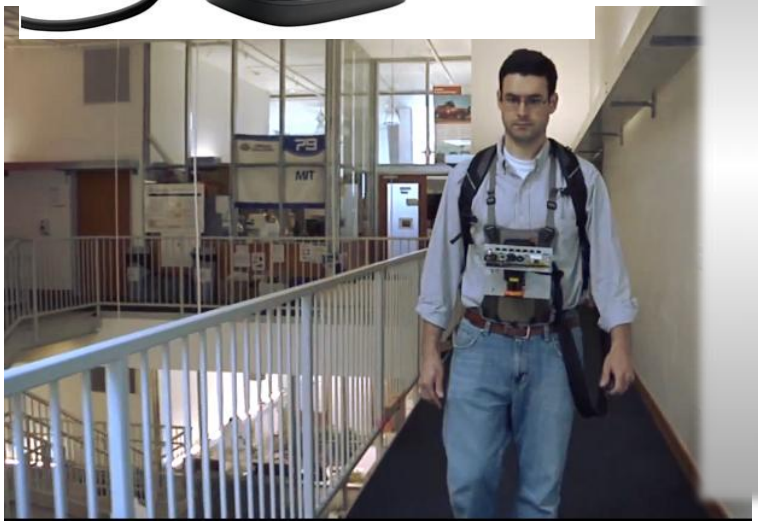
Robotics & SLAM



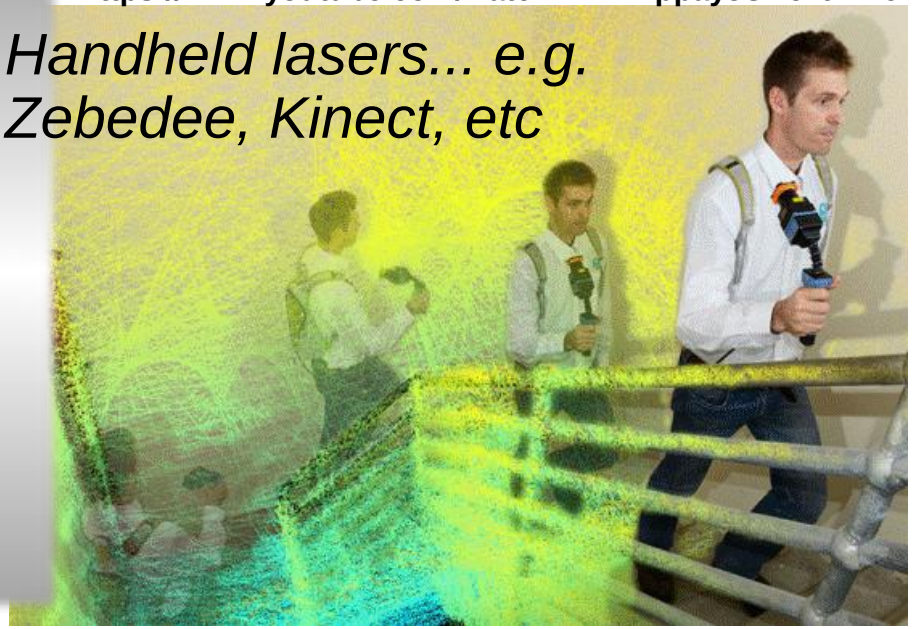
Smartphone imaging

Google Tango

https://www.youtube.com/watch?v=44vppay5UDc#t=179



Handheld lasers... e.g. Zebedee, Kinect, etc



Airborne & Satellite Imagery...

WorldView-3 artist rendering

UAVs are an extremely disruptive technology...

Satellite imagery is becoming more useful... Higher resolution, lower cost, ***and hence geospatial apps will grow***

Difficult to predict how UAVs will evolve, ***but geospatial apps will be very important***

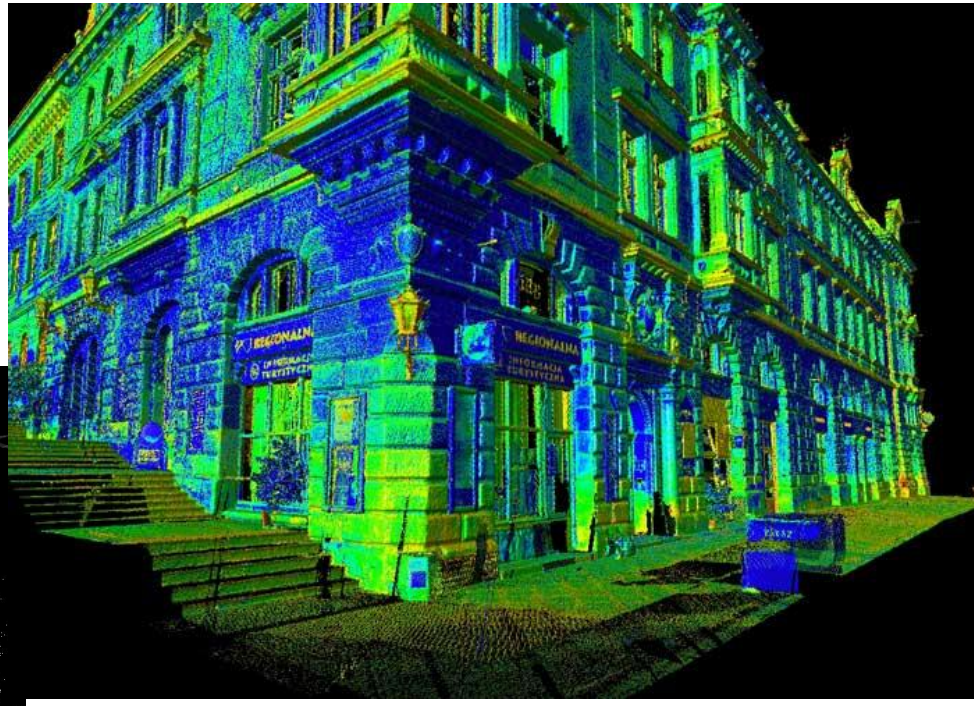
Skybox Imaging

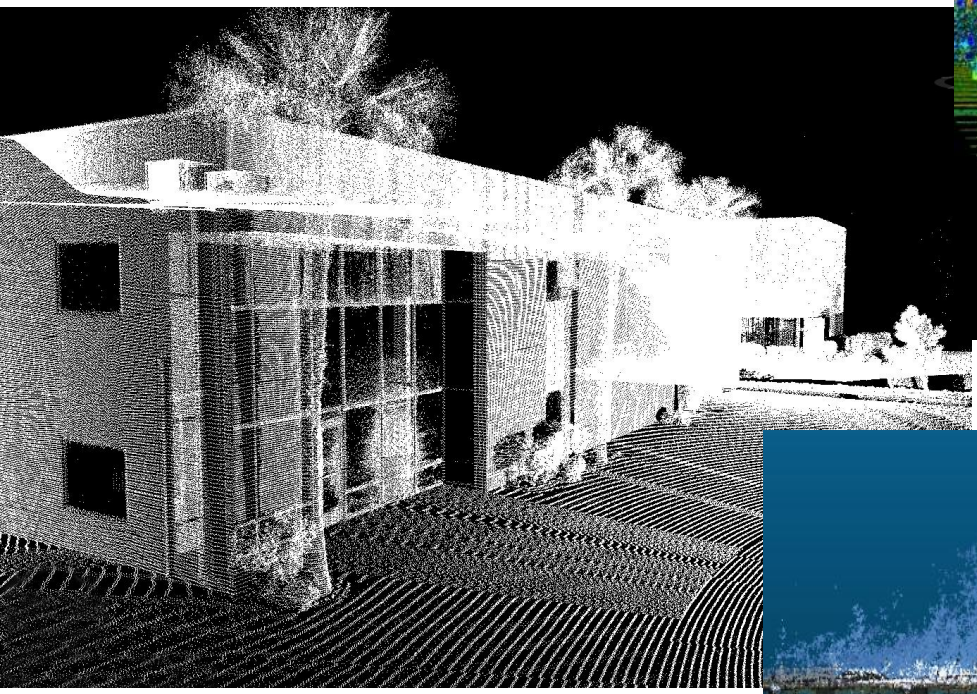
Google buys sat image company for $500M

http://spectrum.ieee.org/aerospace/satellites/9-earthimaging-startups-to-watch

Point Clouds & 3D Models...

coordinates & attributes





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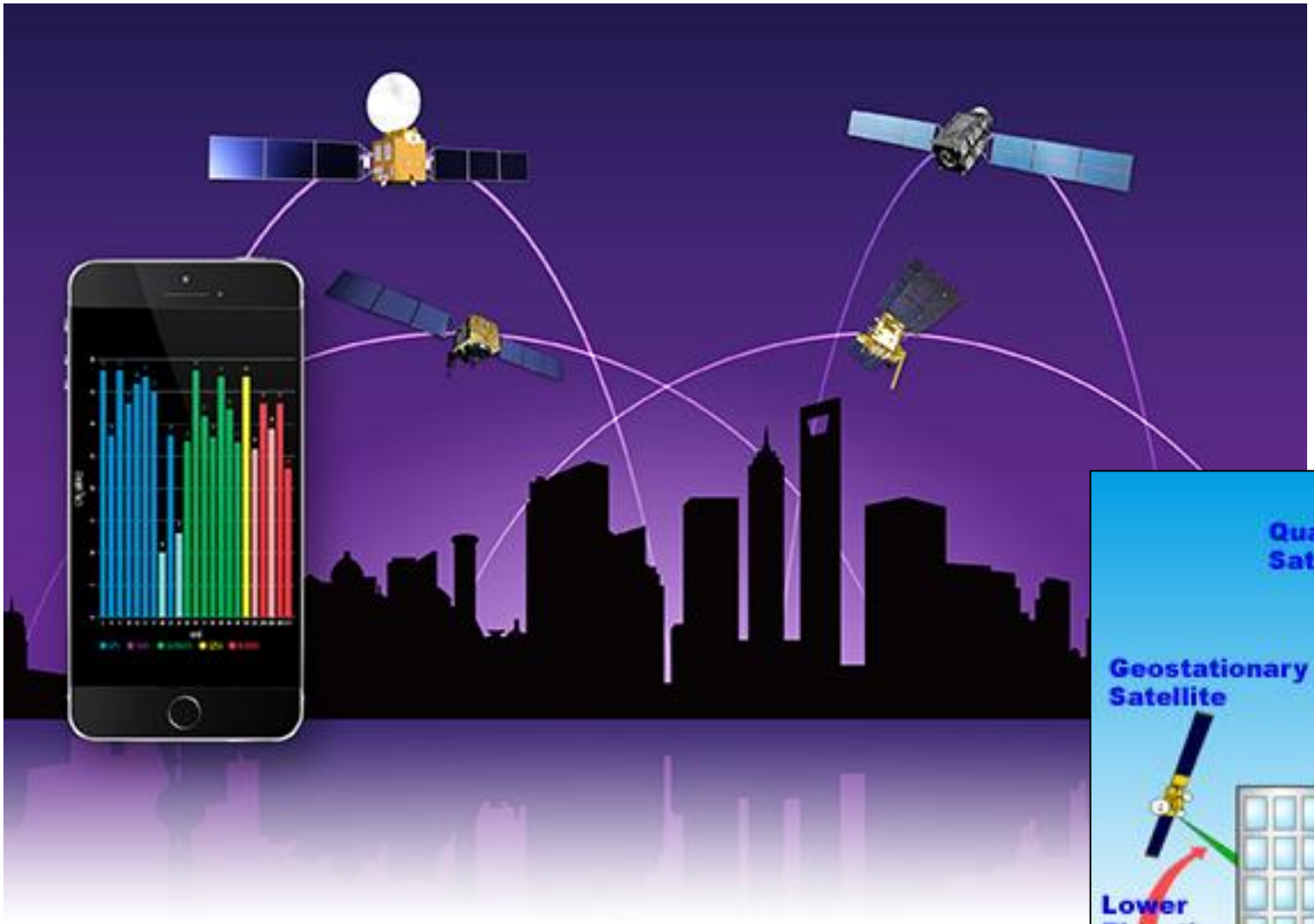
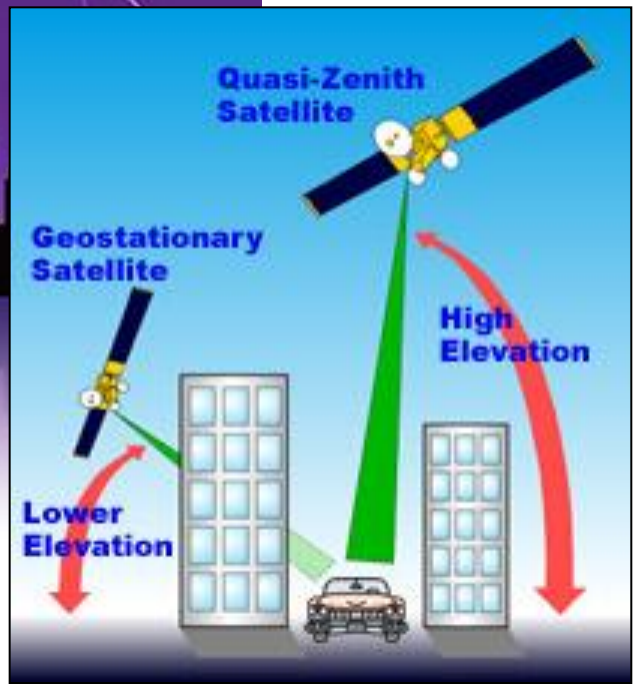
Some crystal ball gazing...

2. GNSS positioning capability becomes more available (to everyone)...

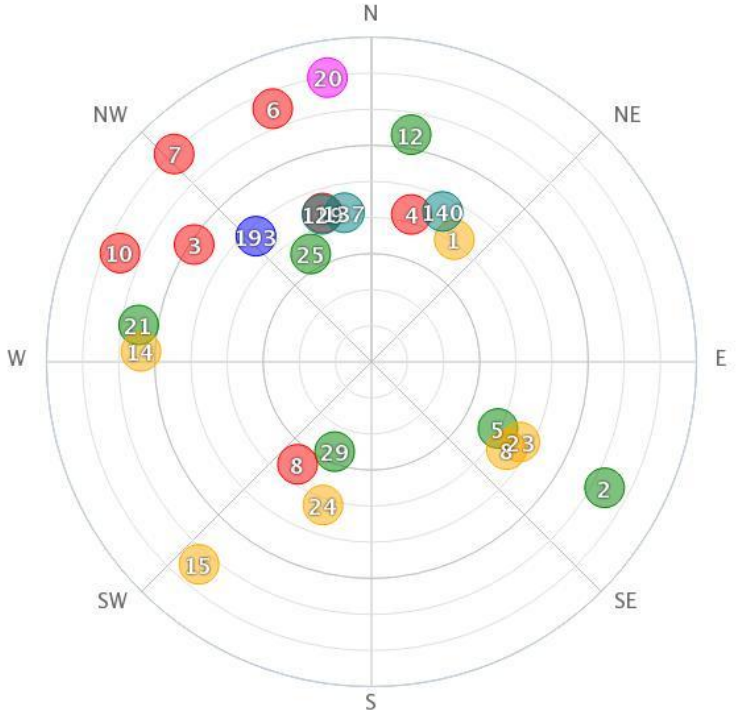
More devices, new configurations, many new signals

2. Multi-GNSS signals help LBS (urban) apps...

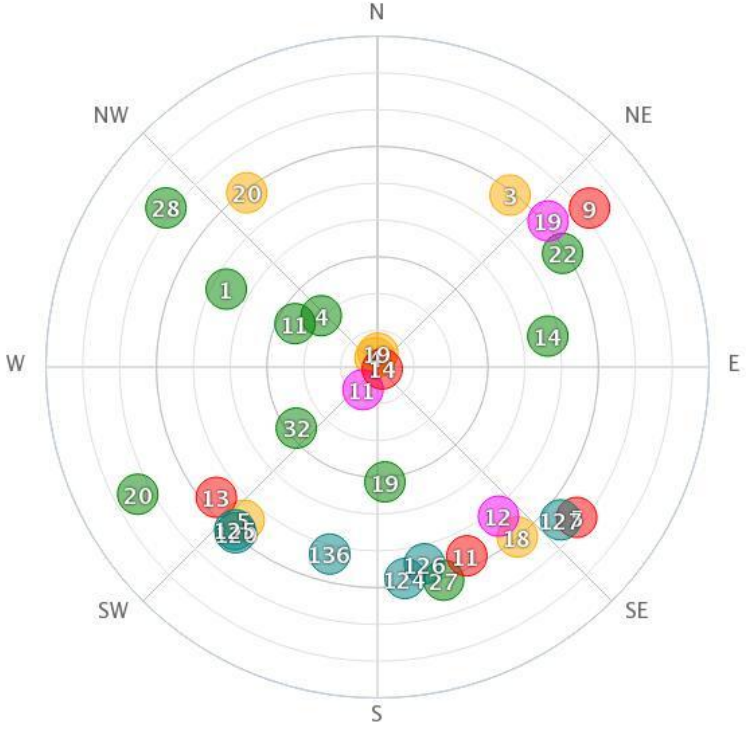


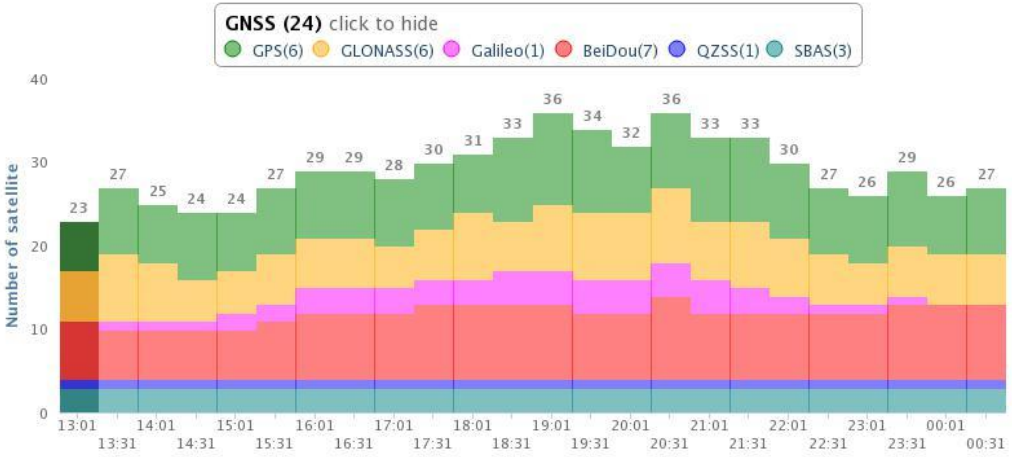


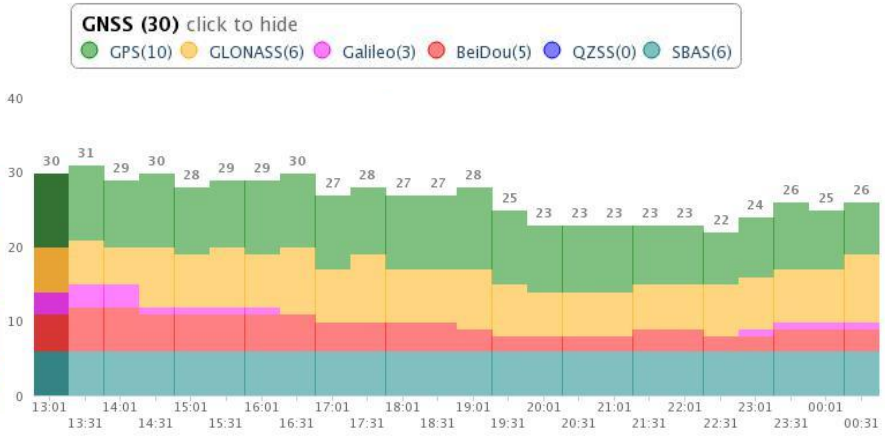
Sydney



Vienna

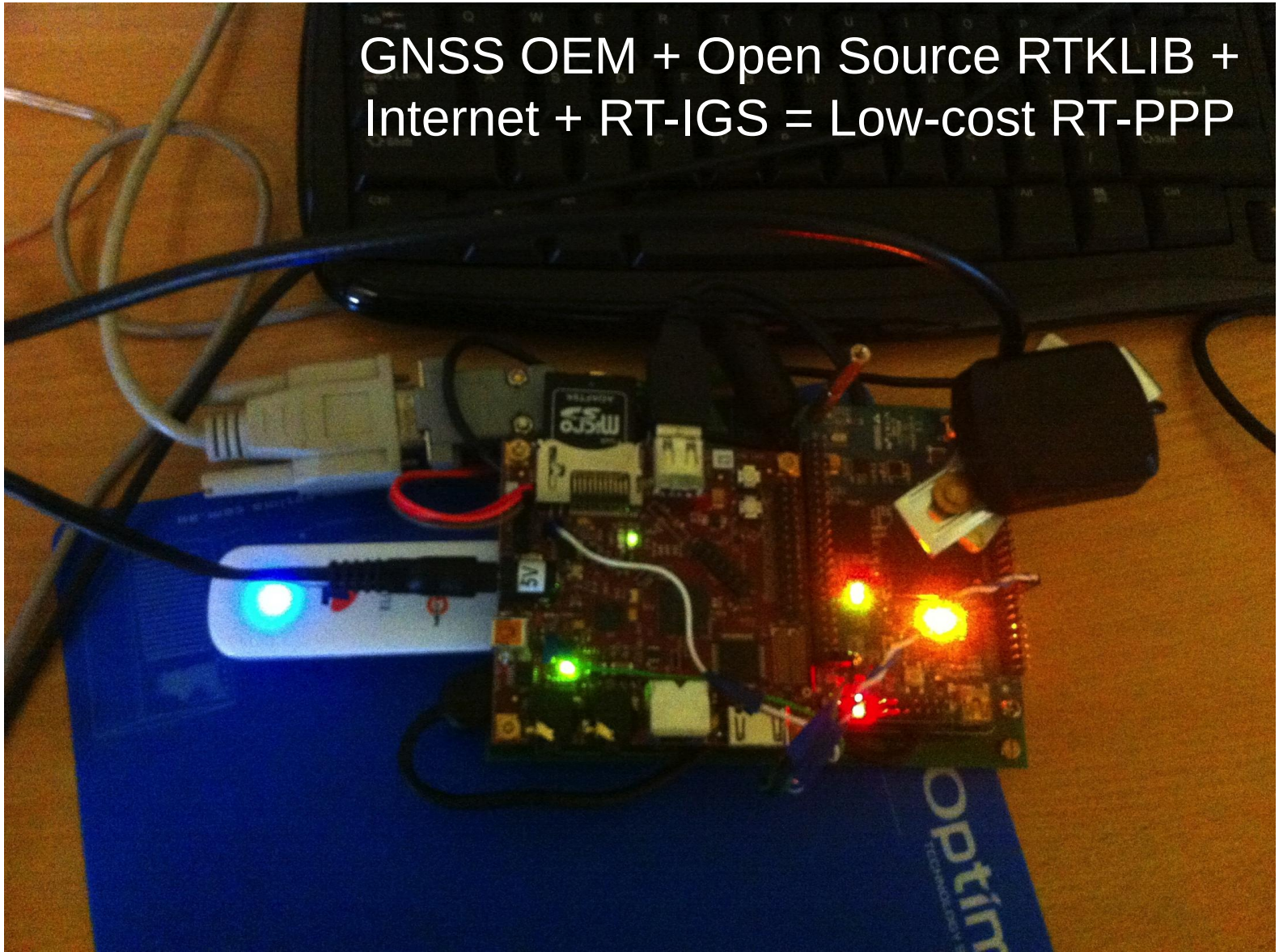






A sign of things to come...

RT-PP enabled by geodetic services & OEM components



Innovations in smartphone positioning...

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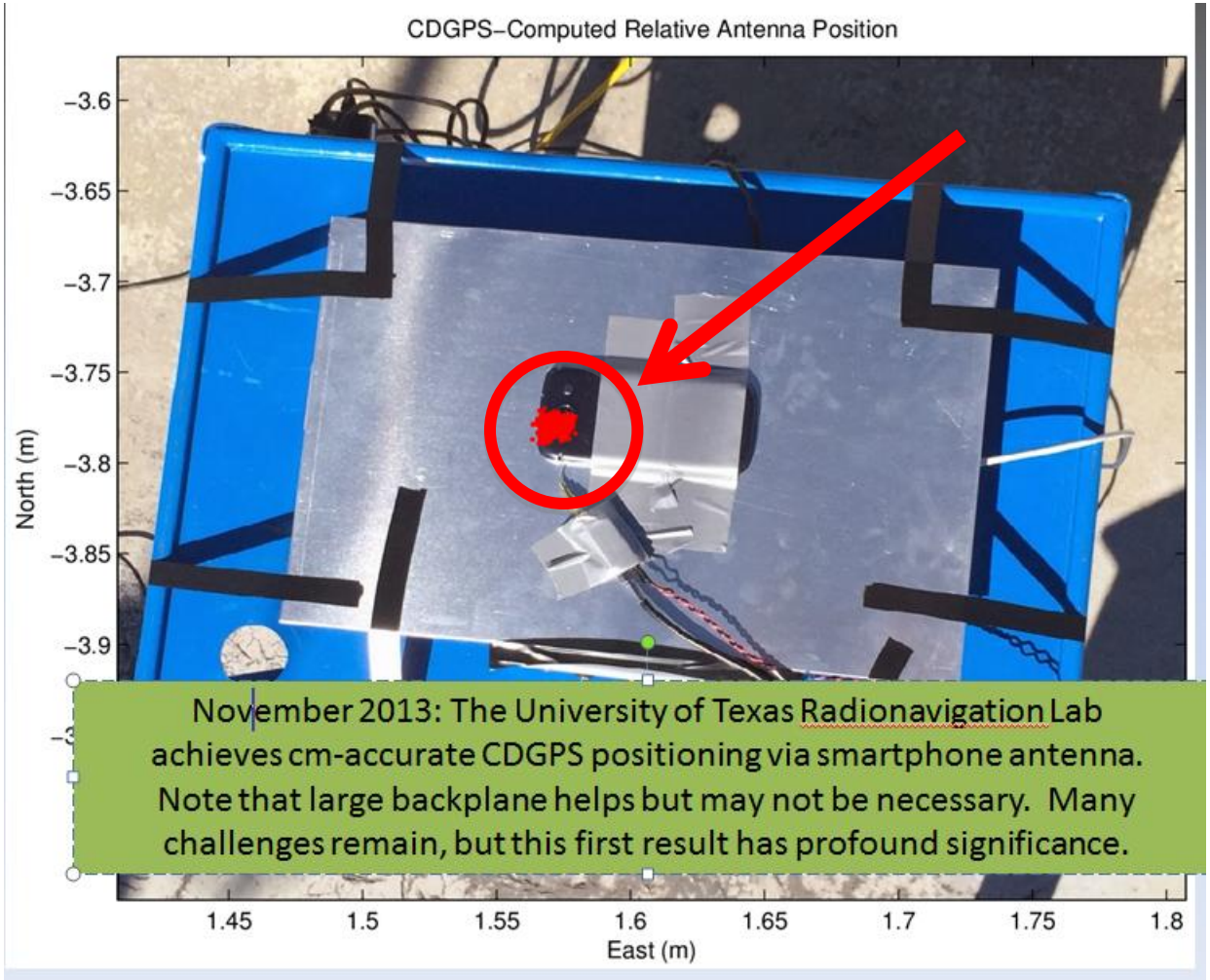
A sign of things to come...
mass market smartphone-type PP?



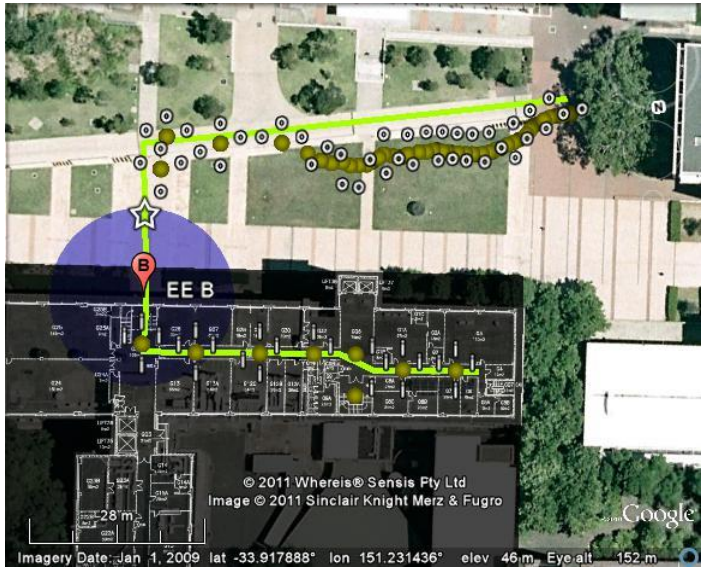
Can just as easily implement RT-PPP...

Some crystal ball gazing...

3. Indoor positioning (slowly) comes of age...

- *Many technology options!*
- *WiFi-based solutions nearest to GNSS's ubiquity*
- *PP for indoor applications is far more challenging!*

3. GNSS is not an indoor positioning technology…



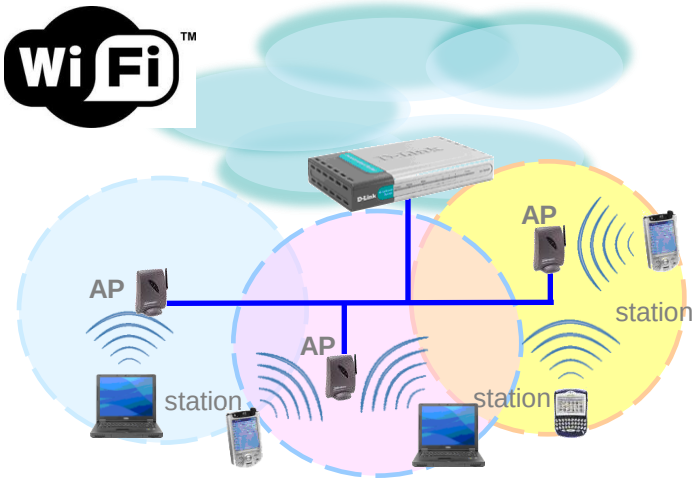
GNSS signals are attenuated indoors & other difficult environments, *hence cannot give performance similar to that provided outdoors*…

- There is no shortage of non-GNSS engineering options...
- However none simultaneously satisfies critical requirements… such as *low cost*, *low complexity*, *minimal infrastructure needs*, *wide coverage*, *good accuracy*, *high reliability*, *versatility*...
- **Some technological choices: (1) use "signals-of-opportunity", (2) dedicated ranging systems, (3) non-signal options** (inertial, magnetic, etc)**...**

Ad hoc solutions based on wireless comms…

plugging the holes...

...using "signals-of-opportunity"...*trading consistency for availability*



WiFi ubiquity...

- "Signals-of-opportunity" option... *hence benefits from ubiquitous infrastructure*
- Proximity/cellID or RSS "finger-printing" techniques... *several commercial solutions addressing smartphone location market*
- Accuracies from few metres to >50m (depending on AP spacing)
- Mobile computing & comms platforms are all WiFi-capable... *hence huge installed UE base*

WiFi is globally available in urban environments, reliable, *with no barriers to deployment for ubiquitous positioning*…

WiFi: Some comments

- Current best urban/indoor positioning technology for LBS markets
- No infrastructure cost
- Common user devices
- Improved availability via massive increase in hotspot AP deployment
- Modified versions using Bluetooth, Zigbee, RFID
- “Internet of Things” option
- Unpredictable accuracy
- ***No technological solution for improving accuracy***

GNSS-like performance, using dedicated user equipment, *but only where signal transmission infrastructure has been deployed*…

Specialist Ranging Systems

- Dedicated terrestrial signal systems... *GNSS-like accuracy*
- Total control over transmit freqs, signal power, signal structure...
- Transmitters can be established where required... *i.e. "hotspot" coverage*
- Many systems have been developed in labs... *but commercialisation is difficult*
- Need pioneering apps... *e.g. logistics, emergency services, indoor mapping, robotics*, *etc.*

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Some crystal ball gazing...

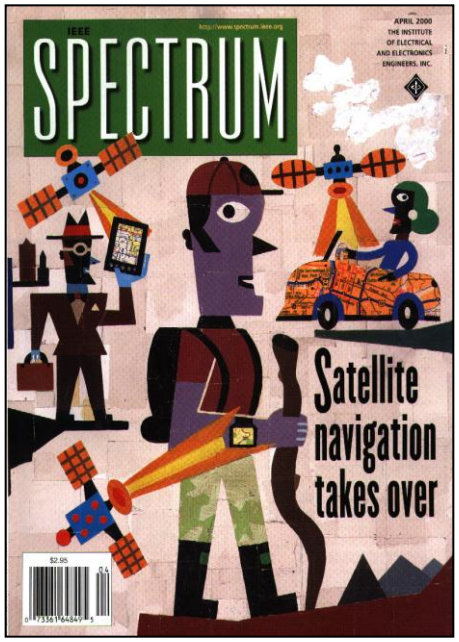
4. Precise Positioning will become mainstream...

- *Especially promising for emerging ITS applications!*
- *Also need reliable mapping!*
- *Supported by V2V & V2I comms technology*

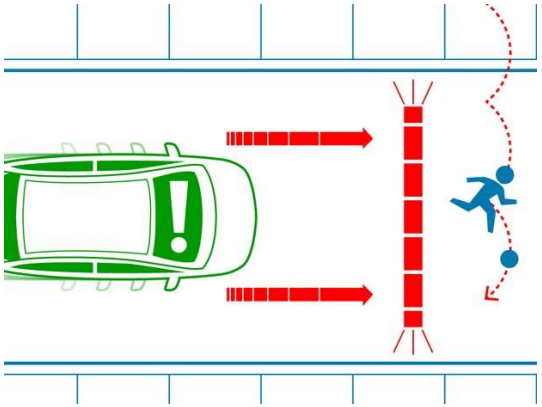
4. Precise Positioning:
from niche to mass market...

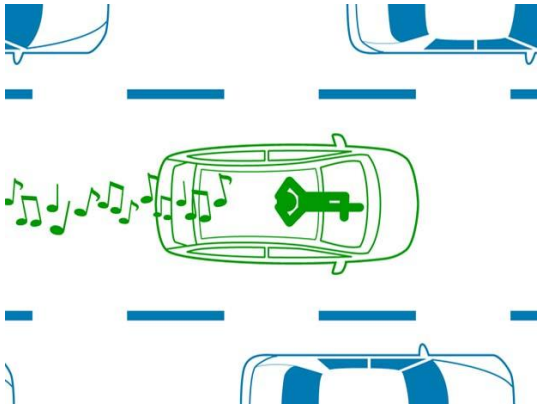
"PP expertise has been the preserve of professional elite for niche apps"...

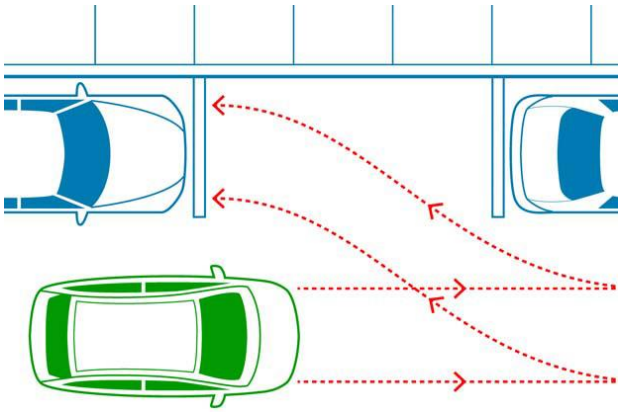
There is expected to be an explosion in PP applications, based on a wide variety of GNSS techniques & HW...
But the biggest mass market is ITS

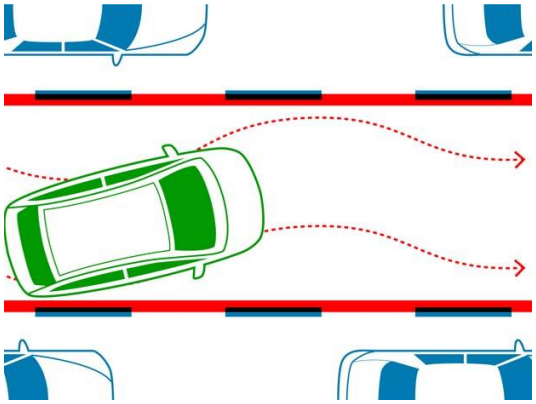


New PP applications in vehicles...









*Positioning in vehicles is going from **Passive** to **Active**...*
*from simple navigation **to** information about traffic **to** warnings about hazards **to** actively avoiding hazards by taking control of some driving tasks*

Positioning in ITS: Some comments

- Several “grades” of positioning: *road-level, lane-level, where-in-lane-level*
- Augmented GNSS needed to satisfy positioning requirements... *e.g. vision/radar & inertial sensors*
- Stringent requirements not just for accuracy, *but also for integrity & availability*
- Map data helps with “round-the-corner” apps
- GNSS-RTK is not necessarily preferred option
- RT-PPP is more robust, & uses less CORS infrastructure
- Low-cost multi-GNSS receivers are the key... *$20 chip?*
- ***Low-cost, reliable PP will be an enabler for many other applications***

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Concluding remarks...

- *GNSS is impacting all the geospatial disciplines in profound ways*
- *Precise Positioning will go "main stream", into LBS and ITS mass markets*
- *Artificial separation of PP and modern mapping activities is unnecessary (& unhelpful)*
- *Geodesy should no longer be considered a niche ("exotic") discipline*

Thank You!