GNSS is a positioning technology that has revolutionised navigation, surveying & geodesy...

Enhanced performance (accuracy, integrity, productivity, etc) when appropriate ground infrastructure is available to user...
Signal Providers’ Infrastructure...

Service Providers’ Infrastructure for DGNSS...

XXV FIG Congress, Kuala Lumpur, Malaysia, 16-21 June 2014
Service Providers’ Infrastructure for DGNSS...

CORS spacing is a function of GNSS positioning technique... though PPP is almost “infrastructureless”...

Less Infrastructure for Precise Point Positioning

GNSS Constellation(s)  CORS Network

CORS Network

GNSS Satellite Orbit and Clock Corrections

XXV FIG Congress, Kuala Lumpur, Malaysia, 16-21 June 2014
GNSS is an incredibly versatile positioning technology... able to address a very broad range of PNT applications... but it has some limitations.

It cannot be relied upon in environments where signals are blocked, weak, degraded, jammed or spoofed.

“GNSS is like Swiss cheese... ... it's full of holes”

Nunzio Gambale
• There is no shortage of non-GNSS engineering options...
• Some technological choices: (1) use “signals-of-opportunity”, (2) dedicated ranging systems, or (3) non-signal options (inertial, geomagnetics)...
• Possible accuracy, coverage area, nature & cost of infrastructure and user equipment, *varies greatly*...
However, signal-based options have similar issues because they all are *terrestrial systems*

*Ideally want local solutions…that fill the “holes”*

“LOCAL” can be any size:
- A room or warehouse (100’s m²)
- A campus or open-cut mine (<10’s km²)
- Airport area coverage (100’s km²)
- Wide-area, range or city-wide (1,000’s km²)
Terrestrial solutions = Local solutions

Pros
- Local control... governance, sovereignty, etc.
- Customisable technical characteristics... frequencies, power, signals, etc.
- Identifiable user community... receiver devices
- Quality of Service is “tunable”
- Scalable transmitter deployment... how “local”?
- Secure... encryption, closed systems, robust, etc.

Cons
- Expensive options... vis-a-vis GNSS
- Need user, operator, & manufacturer “ecosystem”... many technical options
- Variable conditions... geometry, signal strengths, etc.
- Poor vertical positioning
- Infrastructure deployment may be too expensive... hence geographically constrained solutions

Routers, APs, Reader, etc, Infrastructure...

This infrastructure is ad hoc, with highly variable spacing... but these should be mapped...
**WiFi ubiquity**

- “Signals-of-opportunity” option... ubiquitous AP/cell infrastructure
- Proximity/cellID or RSS “fingerprinting” techniques...
  commercial solutions address smartphone location market
- Accuracies from few metres to >50m... depending on wireless communications “granularity” & (RF) environmental factors
- Mobile comp/comm devices are all WiFi-capable
- Current “best efforts” solution...

WiFi is globally available in urban environments, it is reliable (though inconsistent), with no barriers to deployment...

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**Ad hoc solutions based on wireless comms**

...using “signals-of-opportunity”...trading consistency for availability
Terrestrial Ranging Systems

- Dedicated terrestrial signal systems... GNSS-like performance
- Total control over transmit freqs, signal power, signal structure...
- Transmitters established where required... "hotspot" coverage
- Initially not for mass market... eLoran is promoted as GNSS “back-up”
- Pioneering applications, *e.g.* logistics, emergency services, indoor mapping, mines, robotics...
- Many systems have been developed... *some being commercialised*

Consider high accuracy & availability positioning...

* i.e. *high performance positioning for non-mass market applications, for which “patchwork” solutions are unsuitable*

Example *Locata* technology... (there are others that we need to monitor)
**GNSS+Locata...open-cut mining application**

- First commercial Leica GNSS+Locata equipment & infrastructure installation for mining
- Located 140kms south of Perth (Western Australia)
- Consists of two Pits, North and South Pit -- South Pit is now about 300m deep, going to over 850m

**Drill Performance – Typical availability over 1 week**

<table>
<thead>
<tr>
<th>North Pit – GPS only</th>
<th>North Pit – With Locata</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="North Pit – GPS only" /></td>
<td><img src="image2" alt="North Pit – With Locata" /></td>
</tr>
</tbody>
</table>

Red = GPS Position Failure

Locata = 99.5% Good
During Recent GLONASS Failure...

- GLONASS failure made all GPS-RTK fail
- All GPS receivers have "no position" (red)
- Locata (JPS) still delivers “fixed RTK” cm-accurate positioning (green)
- Machine position: Excellent

Going Indoors... addressing multipath

- Takes advantage of Locata’s signal structure and time synchronisation
- Dynamically tracks only direct line-of-sight ranging signals
- New ORB-80 3D design
- Tests being conducted mid-2014
Data collection: At different indoor points

Non-GNSS positioning technologies cannot simultaneously satisfy user requirements *that GNSS can*... such as *low cost, low complexity, minimal infrastructure, wide coverage, good accuracy, low latency, high reliability, high versatility*...

But they may still be of value... GNSS vulnerability is a new driver for non-GNSS backups