New Global Navigation Satellite System Developments and the Impact on the Spatial Sciences

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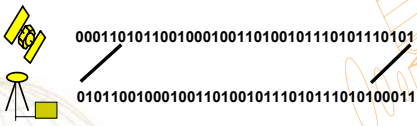
Outline of the Presentation

- Overview of the current State-of-the-Art with Global Navigation Satellite Systems (GNSS);
- Planned Developments in GNSS;
  - GPS Modernisation;
  - Revitalised GLONASS;
  - Europe's Galileo
- Trends for the future.

The "Pseudo-range"

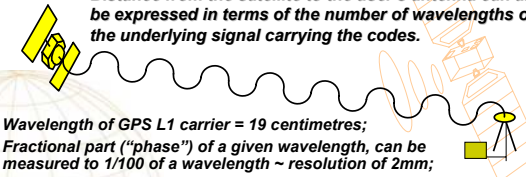
- ***Satellite sends binary code***



- ***Receiver generates same binary code that it should be hearing from the satellite at a particular time***
  - *Difference between what it should hear and what it does hear is the time delay (5 units in diagram)*
  - *Range Distance = Time Delay * Speed of Light*
  - *Not the true range; part of the time delay is due to Receiver Clock Offset ~ hence "pseudo-range"*

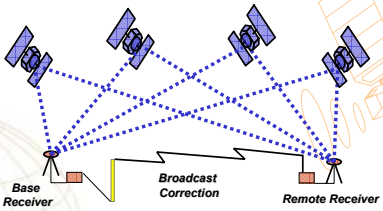
"Carrier Phase" Measurement

- ***Distance from the satellite to the user's antenna can also be expressed in terms of the number of wavelengths of the underlying signal carrying the codes.***



- *Wavelength of GPS L1 carrier = 19 centimetres;*
- *Fractional part ("phase") of a given wavelength, can be measured to 1/100 of a wavelength ~ resolution of 2mm;*
- *Enables position relative to a known point with centimetre accuracy;*
- *Dual frequency measurements most reliable but accessing L2 carrier signal has required expensive receivers – The new C Code on L2 should enable less expensive dual frequency receivers.*

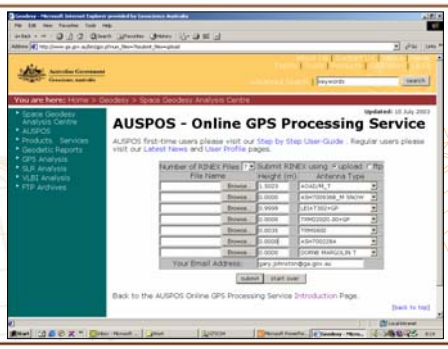
Current Techniques for Centimetre Positioning with GPS



- *Process 2 datasets in PC for Centimetre accuracy*
- *If Surveyor sets up their own GPS Base Receiver and their own radio for each Survey, "Real Time GPS Surveying" – on a Survey by Survey basis.*

Continuously Operating Reference Stations (CORS) - Next Logical Step

- Australian Regional GNSS Network
  - Geoscience Australia (National and International obligations);
  - Supporting Post-Processed Carrier Phase based positioning;
  - AUSPOS – Online Processing Service.
- CORS Networks in Australian States and Territories
  - Government owned networks in Victoria, Queensland, New South Wales and Northern Territory
  - Private Sector Network in West Australia
  - Supporting Post-Processed Carrier Phase based positioning;
  - Delivering Real-Time corrections for Carrier Phase based positioning;
  - Not full national coverage for centimetre accuracy.
- Nationwide Commercial Services from Omnistar and Starfire - Decimetre



NRMW's SunPOZ Service

- Centimetre accuracy in real-time using survey quality GPS receiver and mobile phone communications;
- Pilot Network since 2001;
- Operational Network during 2006;
- Trimble's GPSNet Software for production;
- Trialling Leica's Spider software;
- Coverage for cm accuracy includes 15km buffer around outside of network;
- Coverage much larger for sub-meter corrections;
- Supports post-processing;
- Gives substance to NRMW's role as Lead Agency in Queensland for GNSS.

What about the future?…

More Satellites

GPS (1973)

GLONASS (1976)

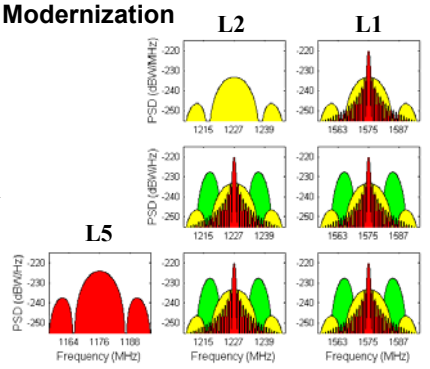
GALILEO (1999)

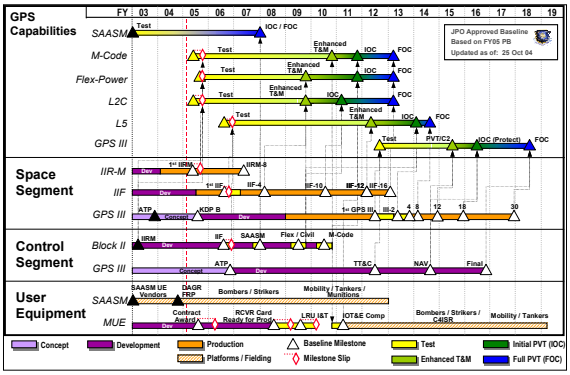
Global Navigation Satellite Systems (GNSS) are seeing many new developments in the next decade and Australia and Queensland can be involved in all…

- USA's GPS Modernisation and ultimately GPS-III (+ WAAS);
- Russia's GLONASS Re-vitalisation; (+ its own Global SBAS?);
- EU's Galileo (+ EGNOS);
- Japan's QZSS (+ MSAS);
- India's IRNSS (+ GAGAN);
- China's Beidou and/or Compass;
- Australian Augmentations: GRAS, CORS etc…

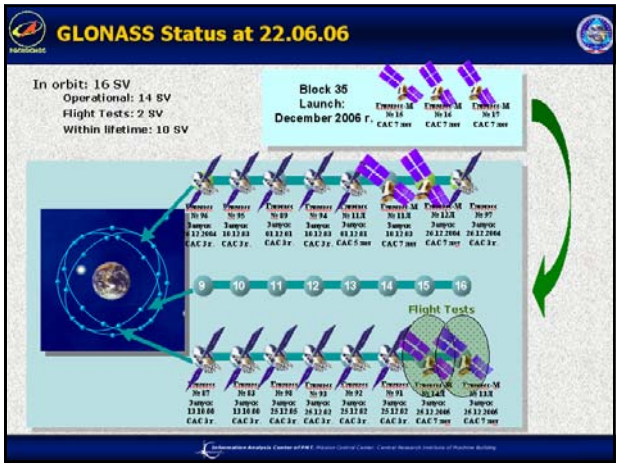
GPS Modernisation and GPS-III

GPS Signal Modernization

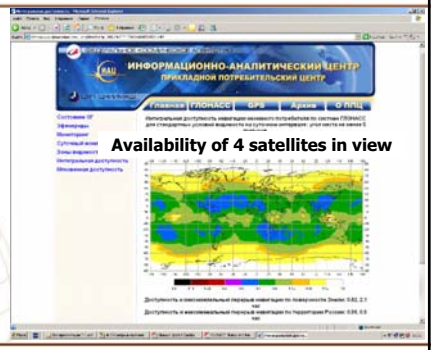




GLONASS Revitalisation



GLONASS Global availability 85%, the gap in navigation is 2.1 hours

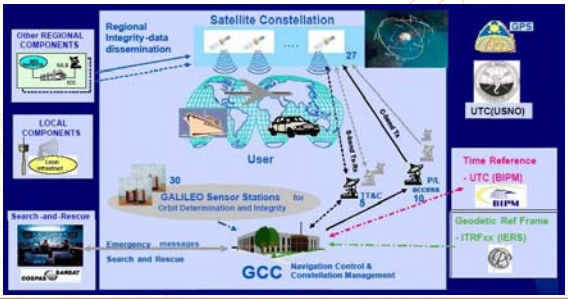


GLONASS - New Presidential Initiatives

- Directive issued at January 18, 2006
  - To ensure GLONASS minimum operational capability (constellation of 18 NSV) by the end of 2007
  - To ensure GLONASS full operational capability (constellation of 24 NSV) by the end of 2009
  - To ensure GLONASS performance comparable with that of GPS and GALILEO by 2010
- Directive issued at April 19, 2006
  - To ensure the navigation equipment mass production: encourage the industry in the manufacture renovation
  - Mass market development

Galileo

Galileo System Architecture



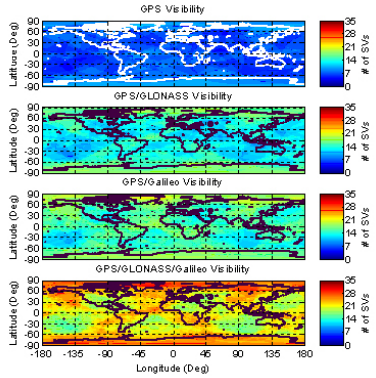
Galileo Management Structure – A PPP

Galileo Concessionaire is Consortium of:

- EADS - *setup to be Europe's Boeing* - owns Airbus, Ariane, Eurofighter and Eurocopter. In 2004 had revenues of €31.8 billion & employed more than 110,000 people!
- Alcatel – 2004 sales of €12.3 billion, in more than 130 countries;
- Thales – 2004 revenue of €10.3 billion, employs 60,000 people worldwide;
- Finmeccanica – 2003 turnover €8.6 billion, €1.2 billion on R&D, 51,000 staff;
- Inmarsat - 2004 revenue was $US480.7 million;
- Also involves Spain's AENA and Hispasat;

- So parent companies of the Concessionaire had 2004 revenues of more than €60 billion!
- Equivalent of (Telstra + Qantas + NAB + BHP Billiton) * 1.4

Multi-GNSS Availability



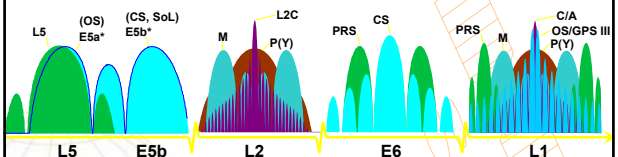
Benefits of Next Generation GNSS

- GPS and GLONASS combined have already demonstrated the benefits of extra satellites;
- Galileo brings all that and more;
- The benefits of the extra satellites and their signals:
  - Continuity (3 sub-systems are better than 1);
  - Accuracy (eg Galileo Commercial Service 0.1m in handset);
  - Efficiency (centimetre accuracy with shorter initialisation times);
  - Availability (60+ Satellites by 2010, 10 available will be common place, working in Urban Canyons, under Tree Canopies, in Open Cut Mines) and;
  - Reliability (more reliable signal tracking, also designed for Safety-of-Life).
- Coded signals brings cheaper receivers for centimetre applications.

What about the future?…

More Signals

GPS and Galileo Signals (let alone GLONASS!)



L5 (1176.45 MHz) | E5b (1217.14 MHz) | L2 (1227.6 MHz) | E6 (1278.75 MHz) | L1 (1575.42 MHz)

- Coded signals should make carrier phase tracking simpler and cheaper but which signals will be most useful and what receivers will be for sale?
- With state-of-the-art technology for generating and processing multiple signals, will differential carrier smoothed ranging deliver centimetre accuracy?

GALILEO[1]/GPS[2] Receivers for Centimetre Accuracy…

Decreasing cost

L1[1,2]	E6[1]	L2C[2]	E5[1]/L5[2]	# sats 2010; *# sats 2015*	Comments
30/28 *30/36*	30 *30*	18 *36*	30/10 *30/28*	**60-DF[1],28-DF[2]; 30-TF[1],10-TF[2]** ***60-DF[1],64-DF[2]; 30-TF[1],28-TF[2]***	A GPS+GALILEO
30/28 *30/36*	- -	18 *36*	30/10 *30/28*	**30-DF[1],28-DF[2]; 10-TF[2]** ***30-DF[1],64-DF[2]; 30-TF[1]***	B GPS+GALILEO
30 *30*	30 *30*	- -	30 *30*	**60-DF[1]; 30-TF[1]** ***60-DF[1]; 30-TF[1]***	C GALILEO
30 *30*	- -	- -	30 *30*	**30-DF[1]** ***30-DF[1]***	D GALILEO

A: Top-of-line GNSS Rx tracks all sats, *highest* availability, *highest cost*, *highest* in DF-only & TF-only performance, *best hybrid*.

B: *Moderate cost* GNSS Rx tracks all sats, but does not track E6, GPS TF-only positioning available 2015, *good price/performance compromise.*

C: *Moderate cost* GALILEO-only surveying Rx, TF-only positioning available 2010, *unclear if tracking of E6 requires user charges for CS.*

D: *Lowest cost* GALILEO-only surveying Rx, DF-only performance (*similar* to current GPS-only performance in 2010), *uses OS signals only.*

From Rizos, Higgins and Hewitson

What about the future?…

More Applications

Expanding User Base for Centimetre Accuracy

- Traditional Surveying users embracing online processing and real-time surveying – but the user base is moving beyond surveyors;
- New applications for centimetre accuracy, especially in "*Machine Guidance*" for Agriculture, Construction and Mining;
- High value and high cost industries where marginal improvements to efficiency bring large $ savings;
- Also a growing number of users who only need 10cm but with very high reliability (eg they require 5*sigma so 1*sigma must be 2cm)
- Reliance on high accuracy GNSS services by these new users is leading to a new category of *"liability critical"* applications where suppliers need to deliver 2cm @ 24/7!

Machine Guidance with Centimetre Accuracy

Port of Brisbane: New Port Road and Seawall built using GPS Machine Guidance

Mining – A Major Industry for Queensland

Mine Safety

Dragline Automation

Precision Agriculture

Improved Shipping Guidance

What about the future?…

More Organisation

International Committee on GNSS

- In 2004 UN General Assembly Resolution 59/2 (paragraph 11) invited GNSS and augmentation providers to consider establishing an international committee on GNSS in order to maximize the benefits of the use and applications of GNSS to support sustainable development.
- In December 2005 at a meeting convened by the UN Office for Outer Space Affairs in Vienna, interested Governments, intergovernmental and nongovernmental organizations present at the meeting agreed to establish the ICG.

International Committee on GNSS

- ***UN Office for Outer Space Affairs in Vienna will continue to act as the focal point for the ICG.***
- ***I will represent FIG on ICG.***

What about the future?…

More Infrastructure

A Major National Initiative for CORS

- National Collaborative Research Infrastructure Strategy
- $540m over 7 years
- Bids between 5m and 60m
- Infrastructure to encourage research in Australia targeting the National Research Priorities

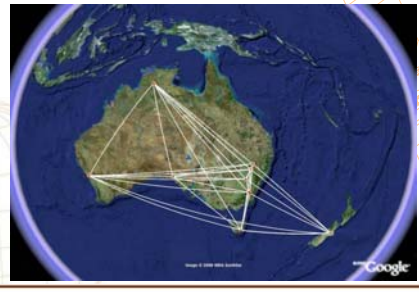
From Geoscience Australia

A Major National Initiative for CORS

- Capability Area on "*Structure and Evolution of the Australian Continent*";
- Geospatial Reference Frame enhancement
  - Expanded VLBI, SLR, Gravimetry, GNSS;
- Improve the Realisation of ITRF in Australia
  - GNSS network covering majority of applications;
  - State and Territory Cooperation.

From Geoscience Australia

Proposed VLBI Network



From Geoscience Australia

Proposed GNSS Network

- Cross continental GNSS transects for measuring intra-plate deformation
- Station spacing of few hundred kilometres
- Circum-continental coverage for measuring plate dynamics, and sea level change
- Major road and rail routes covered
- Major agricultural areas covered
- Major population zones covered
- Major areas of environmental research covered
- Some of the existing mining industry areas covered, although it is envisaged that this number would be increase by mine operators adding their sites collaboratively to the network.
- Major tourism areas covered

From Geoscience Australia

AuScope GNSS Reference Station Network

Queensland GNSS Infrastructure

- SunPOZ Expansion (for Dams and Statewide)
- Galileo Sensor Station in FNQ for ESA
- Investigating a GLONASS Station
- Possible role in NCRIS Network

So what are some trends for the future?…

Trends in GNSS

- More Multi-Dimensional:
  - Move from separate approach to horizontal vs height, (i.e. from *2D+1D* to *true 3D*);
  - Better handling of geodynamics… *to 4D*.
- More Accurate:
  - Existing and New Users needing centimetre accuracy;
  - Users requiring 0.1m but with high reliability (eg 2cm at 1 * sigma = 10cm at 5 * sigma);
- More Digitally Enabled:
  - eGeodesy project for Geodetic Adjustment Data;
  - SunPOZ for Real-time GNSS Surveying;
  - Auspos - Web based post-processing of GNSS Data.

Trends in GNSS

- More Widely Usable:
  - New users like "Machine Guidance" delivering improved efficiency in industries with high marginal costs (Mining, Agriculture, Construction);
  - Requiring 24/7 real-time access;
  - Accessibility on reasonable terms;
- More Collaborative:
  - National and International links;
  - Work with Industry and Local Authorities;
- More Innovative:
  - Based on latest Research and Development;

Broadening these Trends to the Wider SDI

- More Demanding Users;
- More Widely Usable;
- More Digitally Enabled;
- More Real-Time and *"Live";*
- More Mobile;
- More Pervasive;
- More Invasive;
- More Collaborative;

- ***Is the SDI Ready for these developments?***