Trends in Geopositioning

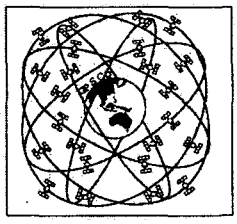
or "Where is GPS taking us?"

Chris Rizos

Joint KSGPC-UNSW Seminar
15-16 February 2005

THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY · 2052 · AUSTRALIA

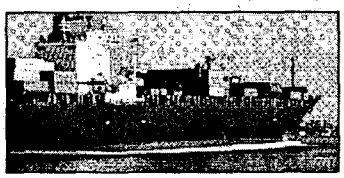
Proposition ...

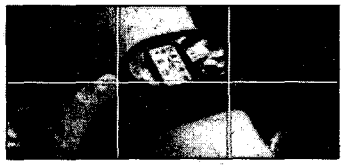


- 'Geopositioning' has been primarily a **professional** task ...
- Heirarchy of accuracy & sophistication ... *geodesy, surveying, mapping, navigation ...*
- GPS is the first positioning technology satisfying **all** requirements ... *including casual users*
- GPS will have a **fundamental** impact on society ... *technologies and applications*
- Understanding GPS trends is the **key** ...

GPS: Positioning System of Extraordinary Versatility…

- **Geodetic tool** --> accurate, low-cost, portable, addressing critical geoscientific problems.
- **Surveying tool** --> essential part of the survey/mapping toolkit.
- **Navigation technology** --> revolutionising marine-air-space-land navigation.
- **Consumer electronics** --> new location-based services provided through wireless technologies & embedded devices.





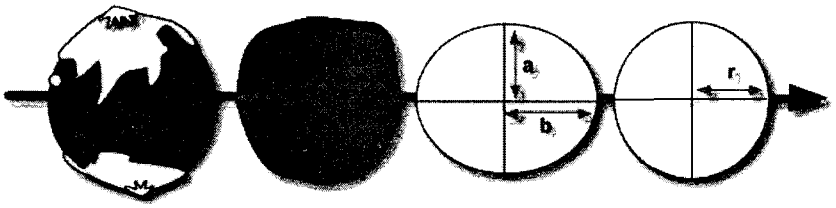
GPS is the 'first choice' technology for almost all applications

GPS & its impact …

- Scientific impact
- Surveyor's toolkit
- Revolution in navigation
- Ushering in the 'Location Aware Society'
- Geopositioning: now & in the future

GPS & Geodesy

- The first civilian application of GPS.
- *Still an extremely important tool of Geoscience.*



THE TERRESTRIAL SURFACE | THE GEOID | AN ELLIPSE | A SPHERE

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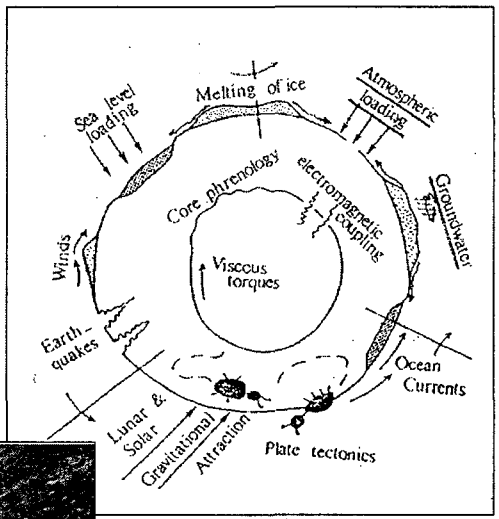
GPS & Geodesy:

Some achievements

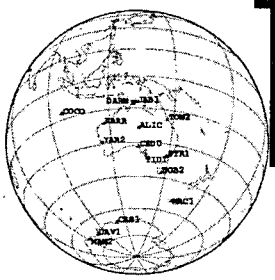
- Monitoring the 'Dynamic Earth':
  - kinematics
  - deformation of the surface

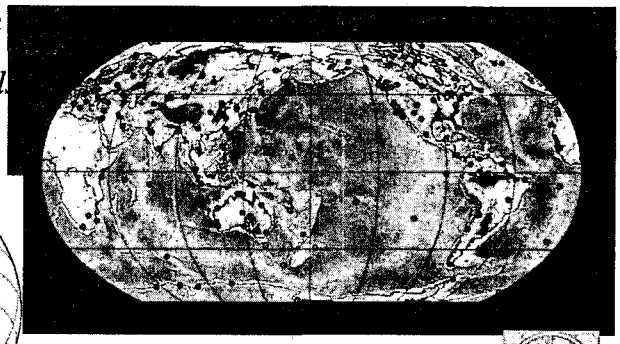


GPS & Geodesy:
Some achievements

http://igscb.jpl.nasa.gov

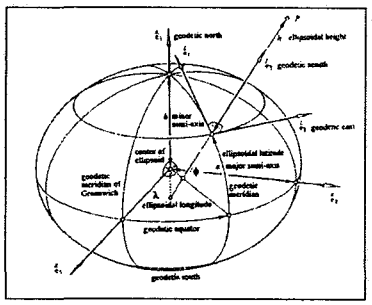
- Monitoring the 'Dynamic Earth'
- International collaboration …
  the IGS
  - *global tracking stn*
  - *orbits & ERPs*
  - *atmospheric model*
  - *sat clock results*
  - …



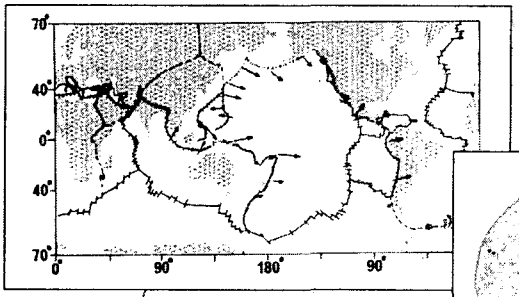


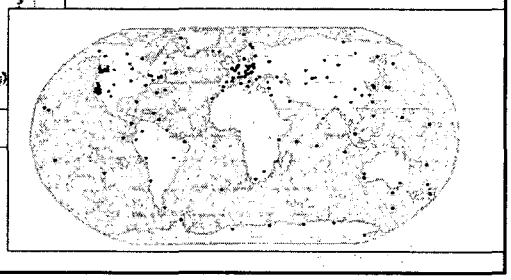
GPS & Geodesy:
Some achievements

- Monitoring the 'Dynamic Earth'
- The International GPS Service
- Fundamental datum … *ITRS*



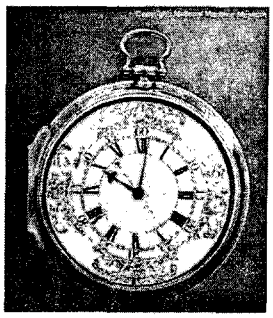
http://itrf.ensg.ign.fr

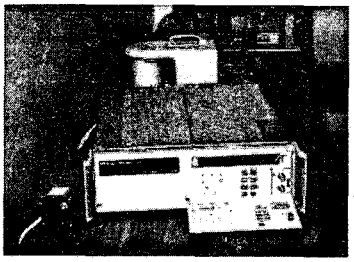


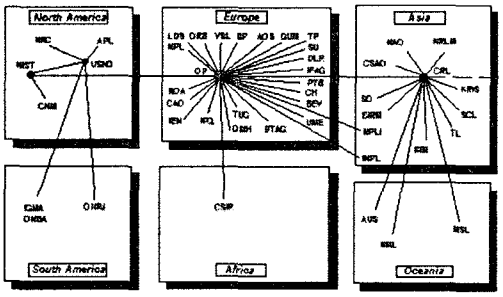


GPS & Geodesy:
Some achievements

- Monitoring the 'Dynamic Earth'
- The International GPS Service
- Fundamental datum ITRF2004
- Global time/transfer





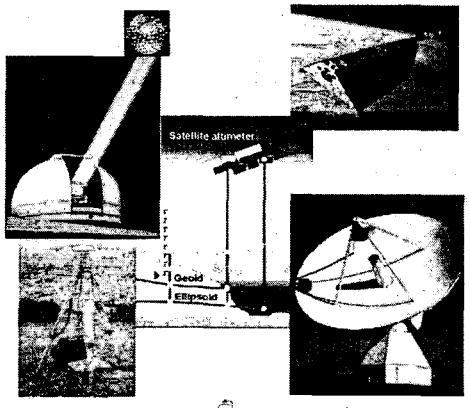


BIPM

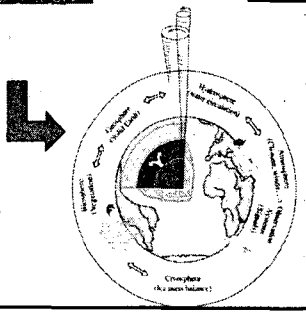
http://www.bipm.fr/en/scientific/tai/time_server.html

GPS & Geodesy:
Some achievements

- The 'Dynamic Earth'
- International GPS Service
- Fundamental datum ITRF2004
- Global time/transfer
- Global Geodetic Observing System (GGOS)



IAG Project, 2007+



GGOS

GPS & Surveying/Mapping

- From a technique for geodetic control … to coordinate determination tool for surveying & mapping.
- *Important part of the Spatial Information professional's toolkit.*

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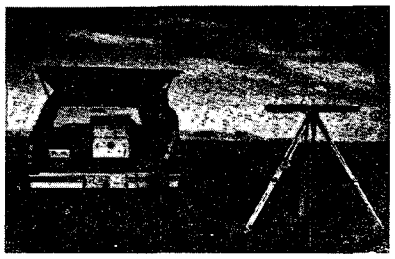
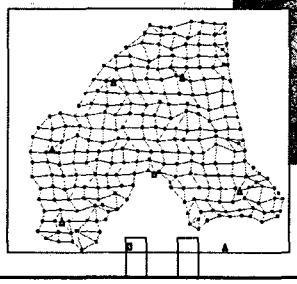
Satellite Surveying:

Some milestones



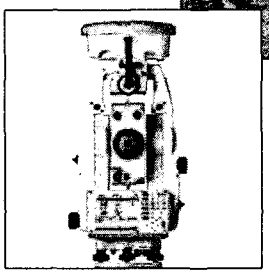
- Geodetic control surveys:
  - no inter-visibility necessary
  - long distances
  - high accuracy… *sub-ppm*

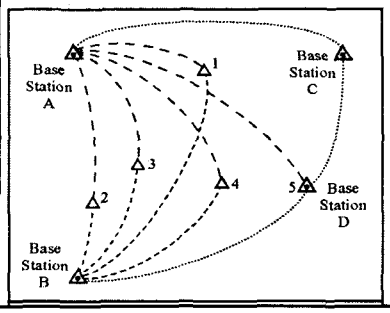
- Trends:
  - hardware lighter, smaller, cheaper
  - geocentric datum
  - use IGS products
  - CORS infrastructure
  - commercial software for ppm surveys only



Satellite Surveying:
Some milestones

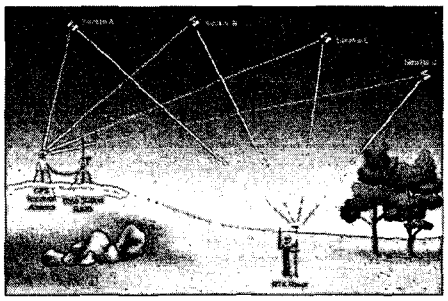
- Geodetic control surveys
- Surveying instrument:
  - cm-accuracy
  - GIS mapping
  - integrated systems

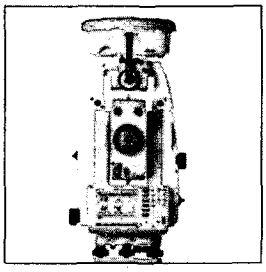




Satellite Surveying:
Some milestones

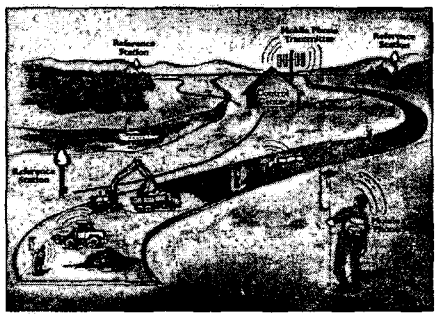
- Geodetic control surveys
- Surveying instrument
- RTK operations:
  - in-the-field results
  - UHF comms
  - Internet 'appliances' … *NTRIP*
  - competitive with 'Total Stations'… *integrated with them*

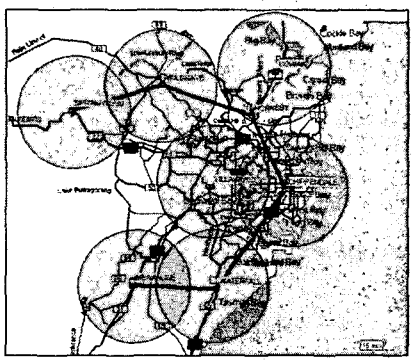




Satellite Surveying:
Some milestones

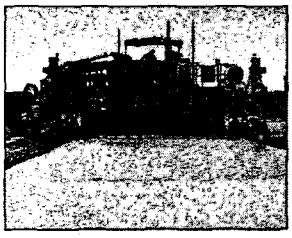
- Geodetic control surveys
- Surveying instrument
- RTK operations
- CORS networks:
  - basic infrastructure
  - network-RTK
  - legal traceability
  - single receiver user
  - Internet communications





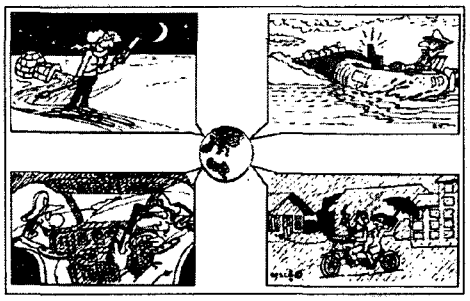
Satellite Surveying:
Some milestones

- Geodetic control surveys
- Surveying instrument
- RTK operations
- CORS networks
- Specialist tools:
  - machine guidance
  - deformation monitoring
  - GIS mappers



GPS as the Navigator's Aid

- Revolutionising air, sea, space and land navigation.
- *First choice technology for all outdoor navigation applications ... replacing or augmenting other navaids.*



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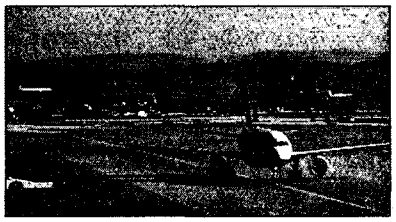
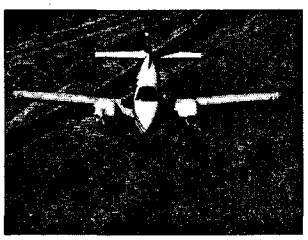
Satellite Navigation:

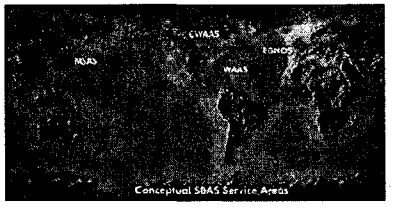
Air Navigation



- Airborne nav applications:
  - en-route & airport approaches
  - photogrammetry & airborne surveys
  - air traffic management

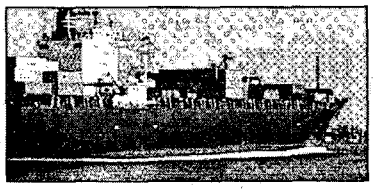


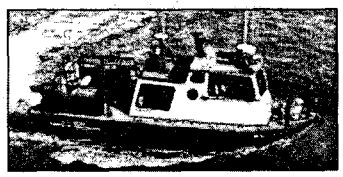
- ICAO defining standards for civil aviation.
- GPS-only does not have sufficient integrity for Cat I, II & III aproaches ... *WAAS, EGNOS, GRAS, etc.*



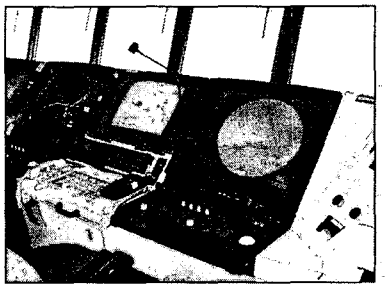
- Future GNSSs will be better.

Satellite Navigation:
Marine Navigation

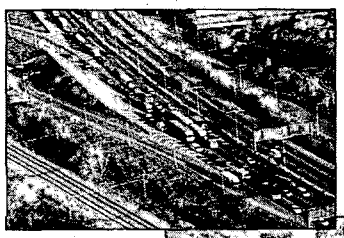




- Marine nav applications:
  - en-route & harbour approaches
  - hydro & oceanographic surveys
  - VTS & cargo tracking
  - search & rescue
- IMO/IALA defining standards for marine aviation.
- Critical component of ECDIS.



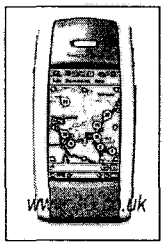
Satellite Navigation:
Land transport/navigation

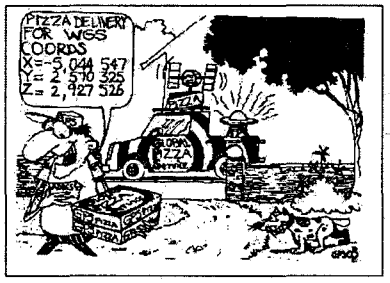


- Land applications:
  - telematics & car navigation
  - tracking & emergency services
  - road tolling & ITS
- First of the "consumer" applications.
- GPS integrated with other sensors ... *gyro, odometer, map-matching.*
- Significant social benefits of GNSS, e.g. "Galileo".

The 'Location Aware Society'

- Convergence of mobility, wireless telecoms, IT, spatial data & location determination technology … new *telematics* or *telegeoinformatics* products & services.
- *GPS is but one (vital) component …*





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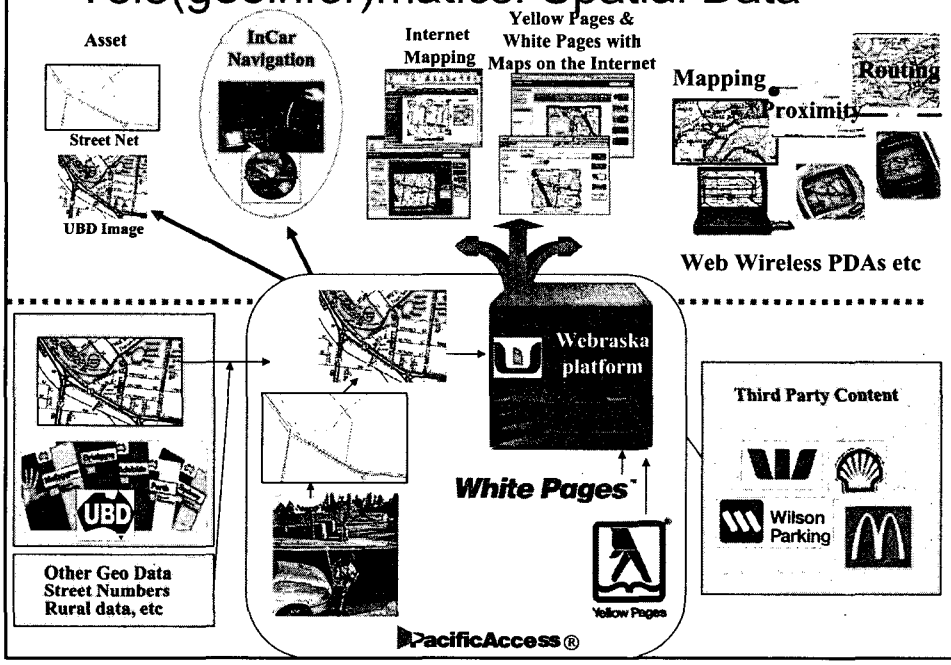
Tele(geoinfor)matics: Spatial Data



"What's in a Name?"

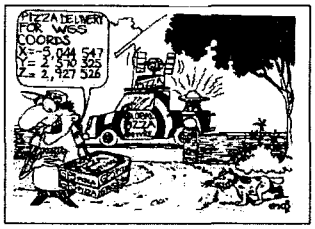
- L-commerce
- Location-Based Computing
- Tracking/monitoring
- Location-based advertising or marketing
- Location-based leisure activities
- Transport Telematics
- Mobile Internet
- "Augmented Reality"
- Location-Based Services (LBS)

Telegeoinformatics: position determination + SI + mobile computing + wireless comms

Location-Based Services

Service	Description
Local information	*What's nearby, news & reviews, phone numbers, bookings*
Navigation assistance	*Route direction, live traffic news, public transport, ETA*
Community, Gaming	*Share my position with colleagues or friends, interact, play games*
Commerce	*Permission based SMS, redeemable coupons, special offers*
Security	*My position, my childrens position, the whereabouts of my car*
Resource management	*Field staff management, logistics, assigning resources,*
Emergency services obligations	*E911 positioning obligations, similar legislation following in EU*
Local call routing/billing	*Mobile phone billing dependent upon location: home, work, on the move*

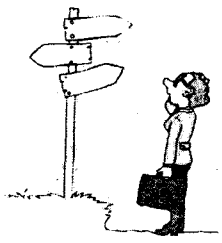
Varying levels of accuracy required, all lower than what GPS can provide! ...
so what's the problem & are there competitive/complementary technologies?



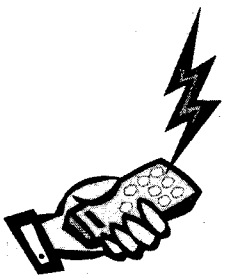
E911 Technology Driver

- FCC's E911 mandate for mobilephone positioning is driving innovation in **all** positioning technologies (not just GPS).
- Innovative GPS receiver designs (& augmentation schemes) promise positioning in almost all circumstances, including indoors, *albeit at a lower accuracy.*

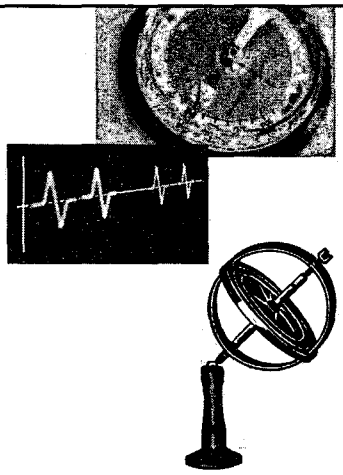
Position Determination Technologies



- Beacons/Proximity
- Dead Reckoning/INS
- Mobile Telephony
- Terrestrial Ranging Systems
- GNSS



PDT Issues



- Installed infrastructure
- Accuracy
- Availability
- Integrity
- User costs & constraints

Despite its shortcomings, GPS is the 'first choice' technology for almost all applications

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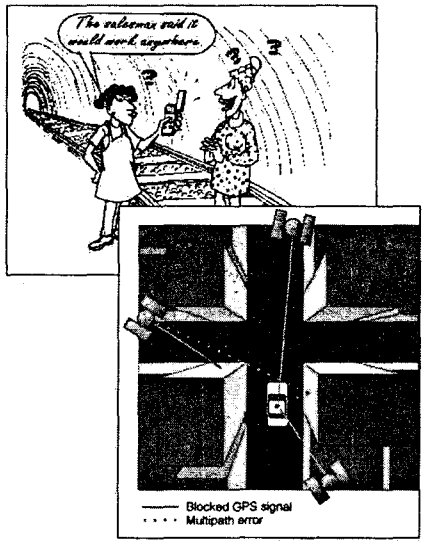
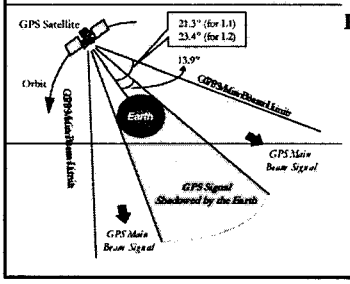
GPS: Technological Weaknesses

Although GPS is extremely popular, *there are concerns:*

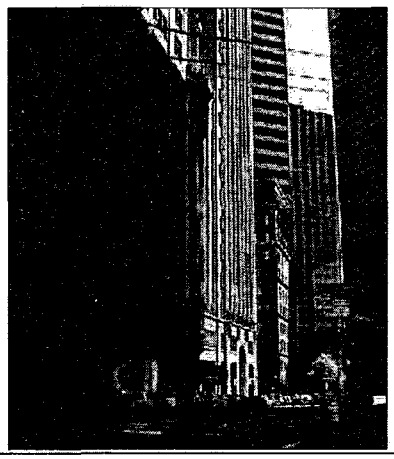
- Weak signal power (standard receivers easily blocked, even by leaves!), making indoor positioning very problematic.
- Easily jammed (intentional or unintentional), as currently only L1 frequency used for most civilian applications.
- Augmentations necessary to improve accuracy, availability, integrity.





PRN 11

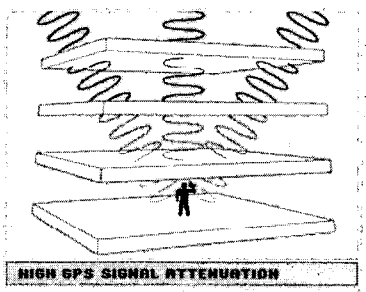
GPS Satellite Visibility/Availability

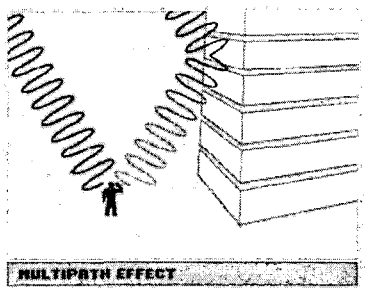


Could add more satellites & signals …
but currently work with what we've got

Weak-Signal GPS: Key Problems

- Acquisition & tracking
- Inability to extract the GPS data
- Cross-correlation issues
- Multipath


HIGH GPS SIGNAL ATTENUATION


MULTIPATH EFFECT

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Some Geopositioning Trends

- Modernization of GPS
- Other Global Navigation Satellite Systems
- Improvements to GNSS to track weak signals
- Augmentations to GNSS
- Advances in alternative positioning technologies
- Integrated systems

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GPS Signal Modernization

Present Signals

Block IIR-M

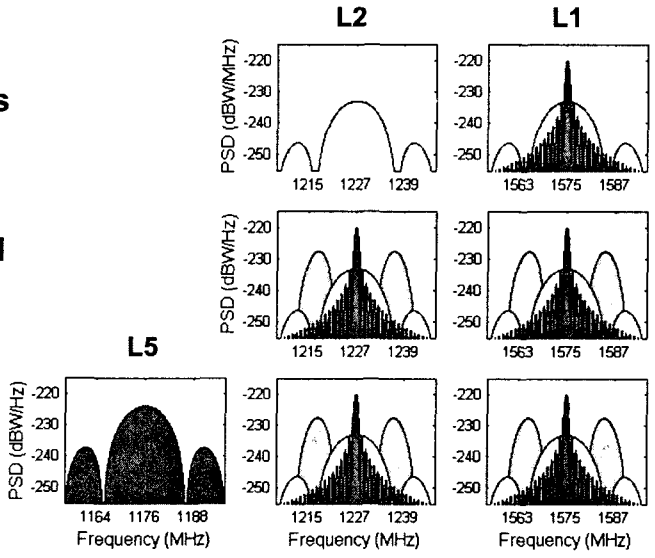
2nd Civil Signal and M Code

Block IIF

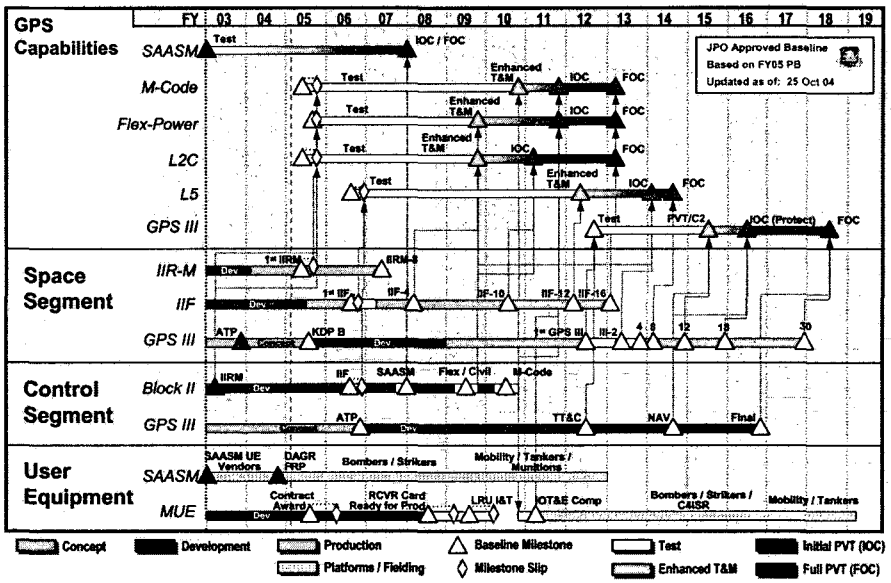
3rd Civil Signal

BPSK(10)

New Nav Message



GPS Modernization Schedule



GLONASS

- 24 satellite system similar to GPS, originally developed by the USSR (now Russian Federation). *Also military controlled.*
- GPS is CDMA-based, GLONASS is FDMA
- No direct user charges, as in the case of GPS.
- GPS+GLONASS receivers have been developed.
- Fully operational in 1996, but now only 10-12 functioning satellites.
- Several new (multiple satellite) launches in the last few years, *18 by 2007, 24 by 2010.*
- Russian president has made commitment to have FOC by 2010. *Think of the military applications!*
- Open, dual-use system, with civil L2 signal and new L5 signal (2007+), *compatible with GPS.*
- India has signed a MoU with Russia in January 2004.
- India's SBAS ('GAGAN') is based on both GPS and GLONASS.

http://www.glonass-center.ru/

GLONASS:
Should we be excited?

- There are already GPS+GLONASS navigation (PR-based) and surveying (CPH-based) receivers. *They work!*
- In some difficult signal environments having extra GLONASS signals is a significant advantage. *Useful marketing advantage for opencut mining apps.*
- GLONASS signals are free for use. *Just like GPS.*
- Currently dual-frequency, but plans for triple-frequency system by end of decade.
- India has indicated it will invest in GLONASS. *Will anyone else?*
- *If GLONASS is revived, the GPS/Galileo 'politics' will be interesting!*

Same issues as GPS,
GLONASS is a military-controlled '1G' system ...

GALILEO

- Initiative of the EU, supported by ESA, *to build a GNSS that challenges GPS.*
- Tension between EU & USA over issues of "interoperability" & "compatibility".
- Have commenced 'Development & Validation' phase (Joint Undertaking, Concessionaire).
- First (test) launch contracts issued, *for 2 test satellite launches in late 2005.*
- 30 MEO satellite constellation, *operational by 2008-2010(?).*
- Four levels of service: 2 fee-based to 'guarantee' certain level of performance (e.g. integrity for aviation users, accuracy for others), plus free (open) service to match GPS's SPS, & restricted service.
- 'Private-public partnership', *in contrast to USA military control/management of GPS.*
- Galileo is a '2G' system, *compared with GPS's '1G' system.*

http://www.galileo-pgm.org/index.htm
http://www.genesis-office.org/
http://www.galileoju.com/
http://www.esa.int/navigation/

Planned GALILEO Frequencies

There is no "overlay" with GPS L2!

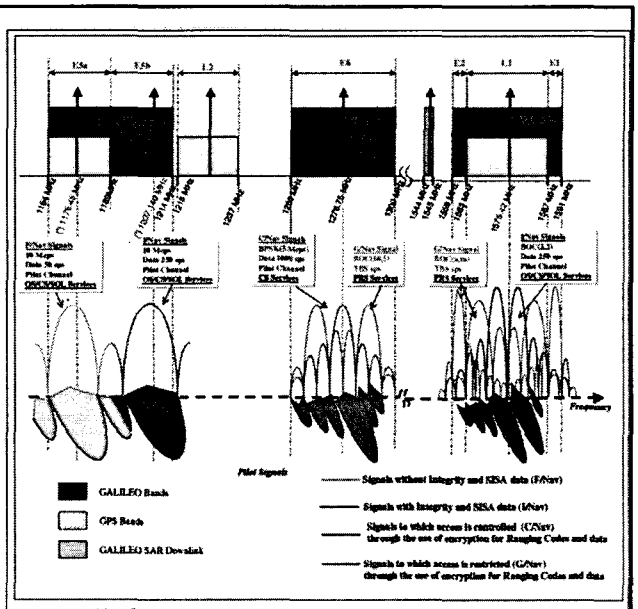


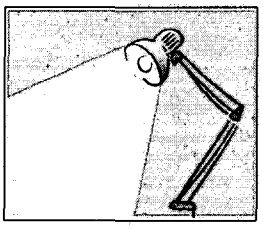
FIGURE 1 Galileo frequency spectrum

'Interoperable' with GPS

Independent of GPS in case of jamming, etc.

Weak-Signal GNSS: Some Solutions

- Receiver design improvements
- Aided/Assisted GPS/GNSS ("A-GNSS")
- System enhancements



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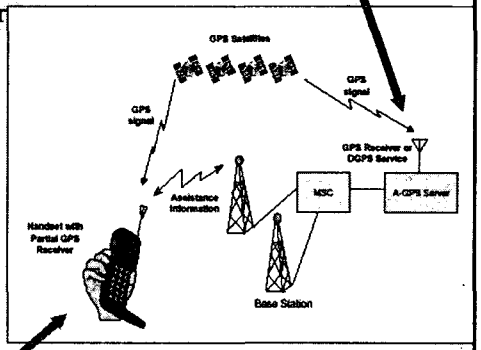
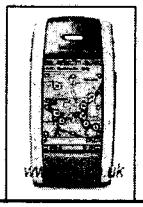
Assisted-GPS (A-GPS)

Need GPS CORS network

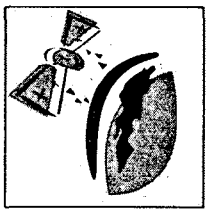
- A-GPS messages from reference station receiver delivered to mobilephone receiver
- A-GPS messages contain ephemeris, timing, Doppler-aiding & other information -- *helps speed up acquisition (e.g. it takes 18 secs to read clock/ephemeris data from Nav Message) and helps acquire signals with very low strength.*
- A-GPS can also support network(server)-based GPS computations.
- Extend to A-GNSS.





A-GPS is not the same as DGPS ...

System/Signal Improvements



- New GPS L5:
  - -154dBw, *6dB stronger than L1.*
  - "Dataless" Q5 quadrature signal, *hence can use (long) coherent integration.*
  - 10.23 Mchip/sec code (c.f. 1.023 Mchip/sec for C/A code), *allows narrower, taller correlations.*

System/Signal Improvements

- Galileo provides for all users:
  - 10.23 Mchip/sec codes
  - -152dBw signal strength
  - One of:
    - Dataless channels, or
    - Binary offset carrier (BOC) modulation – *superior multipath performance*

30 sats. deployed by 2008-2010 ...

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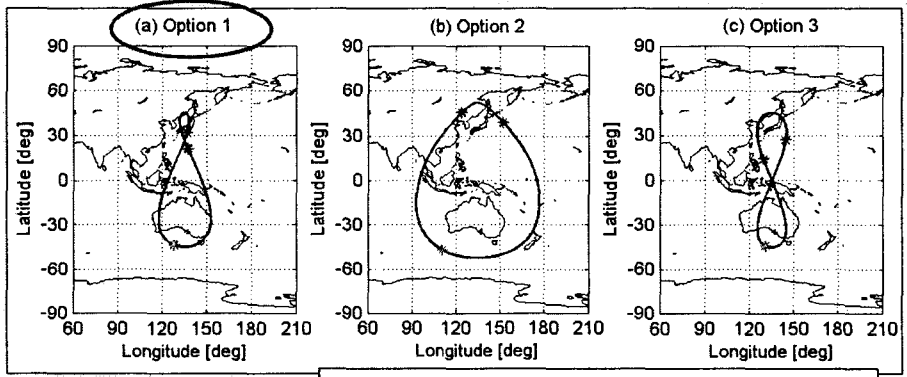
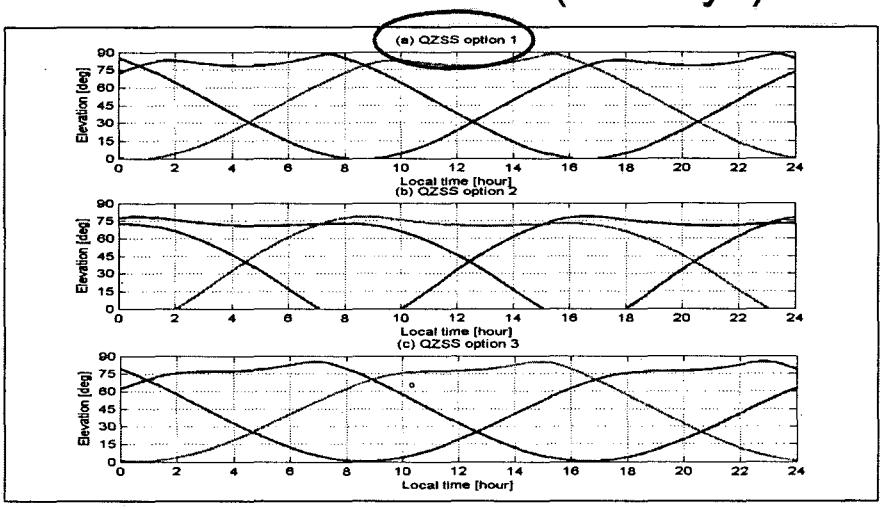
QZSS Satellite Constellations

QZSS option	Number of sat.	Semi-major axis	Eccentricity	Inclination	Ground track
1	3+1	42,164 km	0.099	45.0°	Asymmetrical 8-shape
2	3+1	42,164 km	0.360	52.6°	Egg-shape
3	3+1	42,164 km	0.000	45.0°	Symmetrical 8-shape



Regional SB augmentation of GPS ...

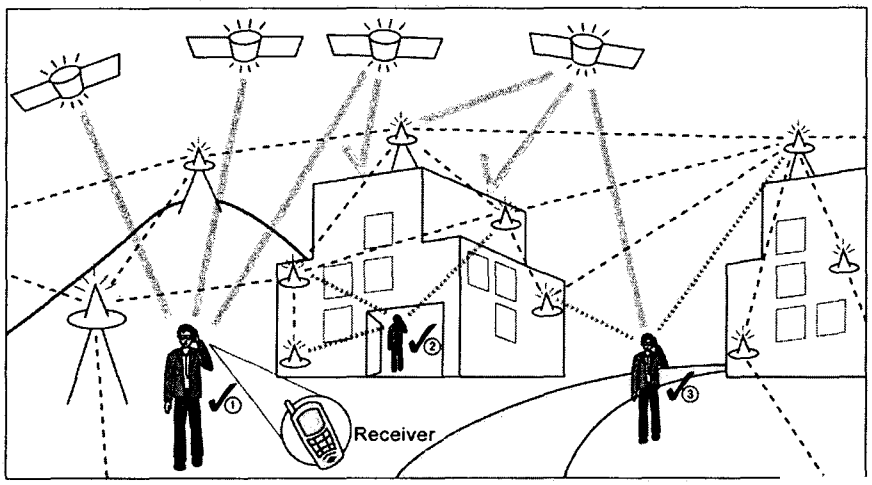
Elevation Variations (at Tokyo)



Mask angle 70°: one satellite, mask angle 30°: two satellites

Extra high sat. for urban areas in Japan (& S.E.Asian region),
plus other SBAS possibilities from China, India, etc.

Ground-Based Augmentation, e.g. PLs, UWB &/or INS



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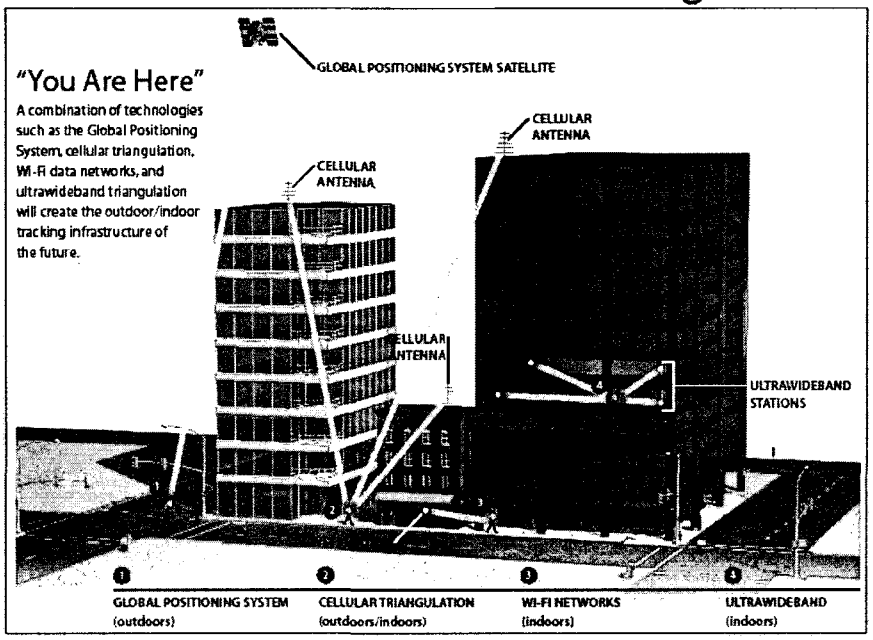
'Hot Zone' & Seamless Positioning Scenario



Welcome to the Future!

"In the same way that no one nowadays can ignore the time of day, in future no one will be able to do without knowledge of their precise location."

Geopositioning Technology:

Professional skill/tool to consumer service/device

SNAP Activity

SNAP Group
Satellite Navigation and Positioning

- R&D in weak-signal techniques.
- Next generation GNSS.
- SDKs & SDR-based research platforms.
- Pseudolite, WLAN & mobile telephony R&D.
- Multi-sensor systems.
- GPS-based deformation monitoring systems.

http://www.gmat.unsw.edu.au/snap/work/our_work.htm

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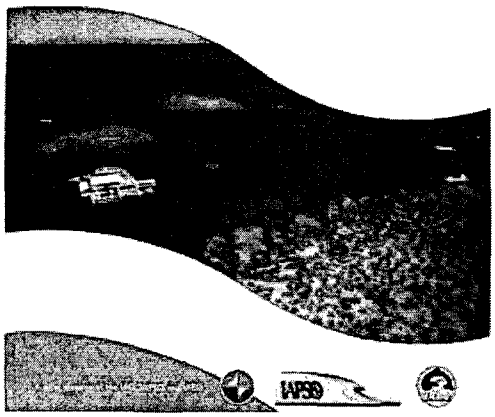
Concluding Remarks

- RF-based positioning technology will dominate, with more MEMS-IMU augmentations.
- GNSS technology will continue to advance rapidly, *incl. Rx weak signal capability.*
- Local, 'hot zone' augmentation with terrestrial signals will be increasingly likely.
- ***Tele(geoinfor)matics is a mega-market, with fierce competition for technologies & LBS apps.***
- ***But niche markets will also be very important, e.g. robotics, industrial, surveying/mapping, etc.***

Dynamic Planet 2005
Cairns Australia August 22-26 2005

Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools



Joint Scientific Assemblies of IAG, IAPSO & IABO

http://www.dynamicplanet2005.com