New GNSS Developments
& the Impact on Providers & Users
of Spatial Data Infrastructure

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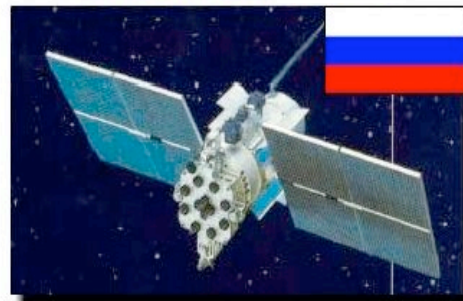The University of New South Wales, Australia

- Modernization of GPS
- Revival of GLONASS
- Deployment of GALILEO
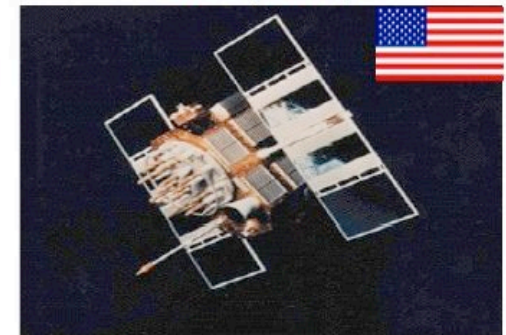- Regional SBAS

GALILEO

Global Navigation Satellite Systems (GNSS)

GLONASS

GPS

GPS ... *the old & the new*

> For the next decade there will be several generations of GPS signals …
> - *GPS-IIR: L1 C/A code, L2 codeless*
> - *GPS-IIRM (8): L1 C/A code, L2C code*
> - *GPS-IIF (16): L1 C/A code, L2C code, L5 code*
> - *GPS-III (30): L1C code, L2C code, L5 code*

L2C FOC 2012
L5 FOC 2014
GPS-III FOC 2017

> Receiver costs *should* drop for some signal combinations, but complexity will rise (in antennas, HW, SW).

> ***What will NOT change is tight U.S. military control over GPS space & ground segments.***

> ***No plans for introduction of user charges***.

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GLONASS … *here again!*

➢ 18 satellite constellation by 2008 (earlier?)…
- *GLONASS: dual-frequency (L1 & L2 'bands')*
- *GLONASS-M: dual-frequency*
- *GLONASS-K: triple-frequency (L1, L2 & L5 'bands')*

➢ Combined GPS+GLONASS receivers for highend users already have 'market advantage'.

➢ **Similar operational model to GPS, ie military control & no user charges.**

GALILEO … *here it comes!*

➢ 30 satellite constellation by 2011(?)

➢ Single generation of signals/satellites.

➢ Three frequency bands, & up to 10 trackable signals… *but not all are 'open'*.

➢ **Four levels of service:** (a) fee-based to guarantee certain level of performance (e.g. *integrity* for **SoL** users, *accuracy* for **CS**), (b) free **OS** to match GPS/GLONASS, & (c) restricted **PRS**.

➢ **'Private-Public Partnership'**, *implying new business model for GNSS services & possible implications for DGNSS, etc*.

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SBAS ... *"alphabet soup"*

➤ Regional augmentations: (a) aviation & (b) non-aviation

➤ Augmentations for increased availability, integrity & accuracy.

➤ **Aviation:** WAAS, EGNOS, MSAS, GAGAN ---> L1 & L5 (eventually).

➤ **Other:** QZSS - L1, L2, L5, ???
  More?

➤ *Unclear what these can contribute to highend (CPH) users.*

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➢ **GPS is currently unchallenged where signal availability & quality is good.**

➢ Increasing use of GPS+GLONASS for high accuracy applications.

➢ Trend for highend (high accuracy) users to no longer be just surveyors, *but they need reliable levels of performance*…

➢ Next generation GNSSs & augmentation systems will improve **performance**.

➢ *Ideal* scenario for highend users is *combination* of **ALL** available signals, *from all GNSSs*.

➢ Challenges of transitioning from current GPS to multiple GNSSs.

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From GPS to GNSS …

➢ **Assumption: survey/highend users seek best value *… balance cost with performance***

➢ Use multi-GNSS receivers, *to improve availability.*

➢ Use multiple-frequency receivers, *to improve accuracy & Time-to-AR for CPH-based techniques.*

➢ Will still need reference networks for DGNSS.

➢ Variety of Service Providers, *different scales/coverage/markets & business models.*

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Multi-Frequency Performance…

- **High accuracy*** --> with longer baselines or PPP.
- **Less CORS infrastructure*** --> longer baselines.
- **Improved efficiency (via faster TTFF/TAR)*** --> CPH-based cm/dm accuracy solutions with a few epochs of data.
- **Less vulnerability#** --> different signal options if there is interference/jamming.
- **Improved reliability #** --> redundant (a) measurements, (b) signals, & (c) frequencies.
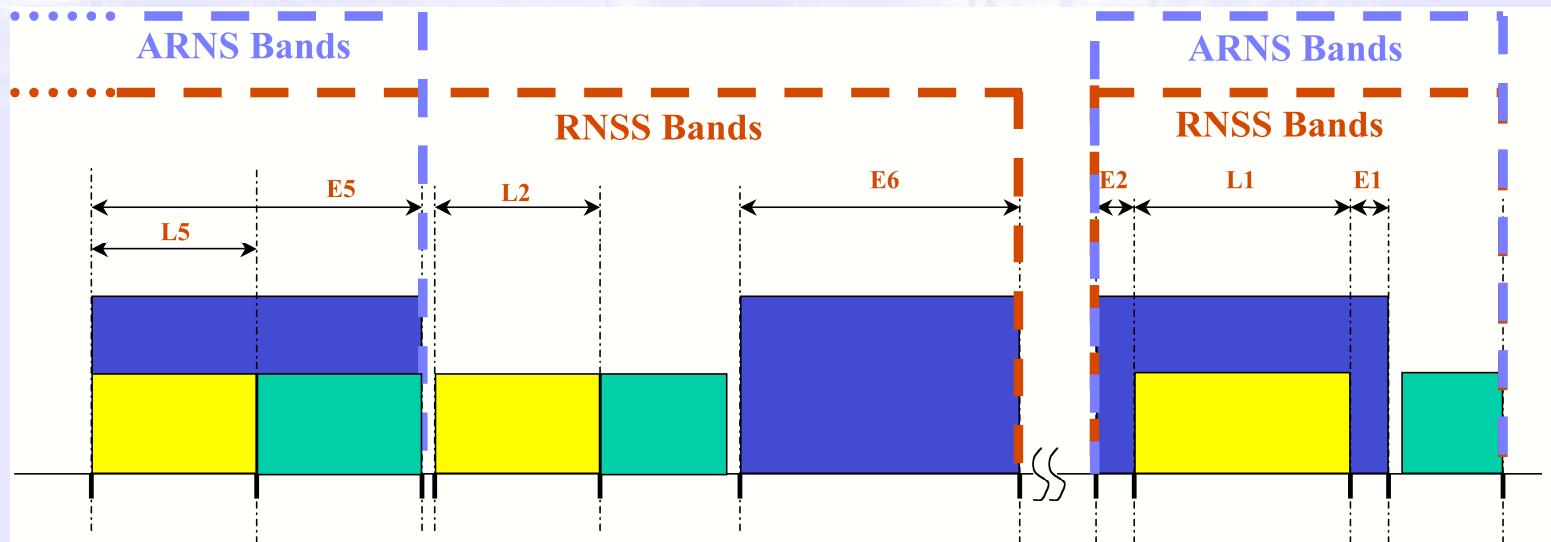
*TF combinations are used…*not single measurements*
#Independent measurements…*not linear combinations*

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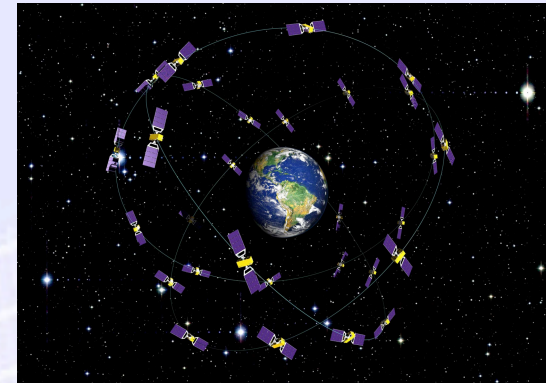SYDNEY · 2052 · AUSTRALIA

Frequencies…GPS, GALILEO & GLONASS

4 frequency 'bands'

Many trackable GNSS signals!

GALILEO Bands (Navigation)

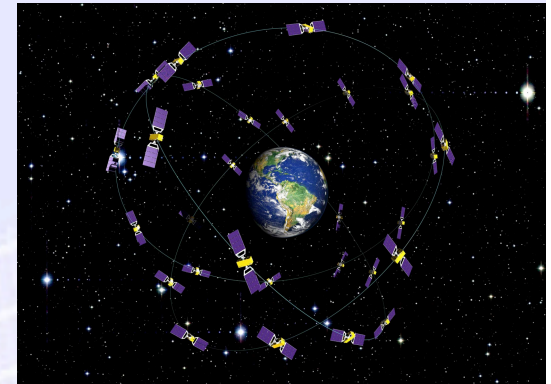GLONASS Bands (Current & modernized)

GPS Bands (Current & modernized)

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By 2010…

- ➢ GPS Modernization – *3 civilian signals for 10 sats (Block IIF), all 8 Block IIR-M sats.*
- ➢ Mixed generations of GPS & GLONASS, *can old Rxs track new L2C signal in codeless mode? When will new Rxs stop tracking "old" L2 signals?*
- ➢ Europe's GALILEO FOC?
- ➢ Some SBAS sats, *e.g. Japan's QZSS*
- ➢ No full triple-frequency overlap amongst all GNSSs, *have to use combined processing (as in GPS/GLONASS now)*
- ➢ Unclear situation re GALILEO <u>tracking</u> of all frequencies
- ➢ Getting "inside" GALILEO - *Regional Element*
- ➢ CORS networks, *from "Ad-Hoc" to "Infrastructure"*
- ➢ 2010 GNSS will have 50-60 satellites giving:
  - – *Surveying initialisation for cm accuracy in 1 sec*
  - – *Urban canyon availability 80% (up from 15%)*
  - – *Premium GALILEO CS 0.1m from handheld Rx*

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By 2015...

➢ GPS Modernization – *FOC 3 civilian signals for >24 sats.*

➢ *Triple-freq GPS FOC 3-5 yrs(?) <u>after</u> GALILEO*

➢ No more Block IIA/IIR sats operating.

➢ Half GPS-III sats launched?

➢ New generation GLONASS sats launched

➢ GALILEO upgrade sats launched?

➢ More SBAS sats., *e.g. Japan's QZSS, India's GAGAN, China's...?*

➢ *No full triple-frequency overlap amongst all GNSSs, but combined processing possible (as in GPS/GLONASS now)*

➢ *Less* CORS infrastructure?

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GPS Surveying Receivers…cm accuracy RT or PP

Decreasing cost →

L1	L2 codeless	L2C	L5	# sats 2010 *# sats 2015*	Comments
28 *36*	10 *0*	18 *36*	10 *28*	**28/10-DF, 10-TF** ***36-DF, 28-TF***	A Can old Rx track L2C in codeless mode?
28 *36*	- *-*	18 *36*	10 *28*	**18/10-DF, 10-TF** ***36-DF, 28-TF***	B
18 *36*	- *-*	18 *36*	- *-*	**18-DF** ***36-DF***	C

A: Rx tracks all sats, *highest* availability, *highest cost*, *improvement* in DF-only performance over current system, *no TF-only positioning until 2015, best hybrid*.

B: *Moderate cost* Rx, DF-only performance *improved* in 2015, *no TF-only positioning until 2015, good hybrid positioning*.

C: *Lowest cost* Rx, DF-only performance (*decreased* performance in 2010, but *improved* in 2015), *no TF positioning possible*.

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GALILEO[1]/GPS[2] Surveying Receivers…

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

Decreasing cost

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*.

NextGen GNSS: Some User Issues…

➢ Towards more **availability**, **efficiency** and **reliability**:
  – L1+L2 Rxs & processing less complicated - *cheaper Rx?*
  – L1+L2+L5 will give better accuracy, efficiency & reliability.
  – GLONASS has demonstrated advantage of extra sats/signals.
  – GALILEO will add all of this again, *and more.*

➢ **Concerns**:
  – Cost of upgrade to take advantage of new developments.
  – Mixed generations of GPS/GLONASS for many years.
  – There are many DF & TF combinations possible, *but quality & reliability will be variable unless "pure" TF positioning possible*.
  – What choice of Rxs will there be? *How will to select?*
  – Can standard RTK-DGNSS operate with multi-GNSS Rxs w/o paying for GALILEO's CS?

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NextGen GNSS: Some RefNet/SP Issues...

➢ **Concerns**:

– Cost to upgrade ref. networks to handle all GNSS signals.

– Mixed generations of GPS/GLONASS for many years, *how to support legacy systems?*

– Ref. networks are geodetic infrastructure, *but could also support GALILEO "local/regional element".*

– Can Ref. networks supporting RTK-DGNSS operate w/o paying for GALILEO's CS?

– How will current SPs compete with the Concessionaire & CS?

– What is the appropriate mix of free & fee-based services?

– The belief that there will be less need for RefNet infrastructure for surveyors may be illusionary, *unless all users are forced to TF-only positioning, but then all are vulnerable to loss of tracking of one signal!*

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Concluding Remarks

- **GPS is already a great tool**, when signal availability & measurement quality is good.
- **NextGen GNSS**, will have more satellites, more frequencies & more signals.
- Positioning with **NextGen GNSS** will be *more accurate, more efficient and more reliable*, but only if conditions are right (incl. CORS stn. spacing).
- Many unresolved issues with mixed GNSS Rxs & RefNet services, *especially wrt GALILEO*.
- GALILEO's ***revolutionary*** commercial focus may have a greater impact than the *evolution* of **NextGen GNSS**.