MODERNISING AUSTRALIA’S DATUM

Matt Higgins
Manager Geodesy and Positioning, Department of Natural Resources and Mines
President of the IGNSS Society of Australia
Member US Position, Navigation and Timing Advisory Board
Member Australian NPI Advisory Board
Outline

• What is a geospatial reference frame?
  Geocentric Datum of Australia (GDA) ~ GDA94 and GDA2020

• What are the drivers for change?

• How will it be implemented?

• What factors influence implementation? (examples).
What is a Geodetic Datum?
(a.k.a. Geospatial Reference Frame)
Geospatial Reference Frame

A frame of reference for all Geospatial Data
What is a Geospatial Reference Frame?

Coordinate Consistency

**Geodetic Datum**
Imagery + DCDB + Addresses + Transport

All Spatial Data on the same Geodetic Datum
Why do we need to update?
Tectonic movements – 1

Tectonic plates are constantly moving and the Global Datum used by GNSS needs to reflect that. GDA94 moved to a global reference frame but chose to ignore tectonic movement (fixed @1994.0).
Australian Plate moves at ~ 70 mm/year so difference between GDA94 and ITRF will exceed 1.8 metres by 2020.

**Issue:** Satellite positioning services will have a positional uncertainty of 6 cm (PU 95%, open sky)
Tectonic movements – 3

Viewed over a short period, tectonic movement seems linear but plates actually rotate around a so-called Euler Pole.
How tectonics affect Satellite Positioning is at the heart of why we need to move to GDA 2020.
Point Position Measurement in 3 Dimensions

\[(Pseudorange + \text{receiver clock offset} \times c)^2 = (X_S - X_R)^2 + (Y_S - Y_R)^2 + (Z_S - Z_R)^2\]
Computing a Position from Pseudoranges

\[(Pseudorange + \text{receiver clock offset} \cdot c)^2 = (X_S - X_R)^2 + (Y_S - Y_R)^2 + (Z_S - Z_R)^2\]

Coordinates of Satellite are known

Pseudorange is measured by receiver

Unknowns are the Coordinates of Receiver and the Receiver Clock Offset

So need 4 Equations to solve for 4 Unknowns. That is why receiver needs to measure Pseudoranges to 4 Satellites
Some more detail on Pseudoranges

\[(Pseudorange + \text{receiver clock offset} \times c)^2 = (X_S - X_R)^2 + (Y_S - Y_R)^2 + (Z_S - Z_R)^2\]

Coordinates of Satellite are known

“known” but with an uncertainty e.g. Broadcast vs Precise Orbits

So let’s stop and consider where the Broadcast Orbits come from?
Effect of Plate Tectonics on GPS Orbits

Precise receiver positions require precise satellite orbits. So system providers cannot afford to ignore tectonic motion.

The Control Segment for GPS includes a series of Monitor Stations spaced around the globe.

The measurements to the satellites from each Monitor Station are sent to the Master Control Station in Colorado Springs where orbits for all the satellites are computed. Where the satellites will be are then predicted and uploaded into each satellite, which broadcasts its position so a user’s receiver can compute its own position.
Effect of Plate Tectonics on GPS Orbits

Precise receiver positions require precise satellite orbits. So system providers cannot afford to ignore tectonic motion.

The Control Segment for GPS includes a series of Monitor Stations spaced around the globe.

GPS Monitor Station
Diego Garcia

GPS Monitor Station
South Australia

GPS Monitor Station
Kwajalein

If the 7cm per year between South Australia and Kwajalein was ignored then the accuracy of each Satellite’s orbit would be affected. So, with GPS for example, the WGS84 coordinates of the Monitor Stations are updated annually to remove this effect.
Ongoing Evolution of WGS84

So by 2020 there will be over 1.8m difference between GDA94 and WGS84@2020.5 (7cm/year for 26.5 years)

How will the other GNSS handle this?

For all of 2017 WGS84 for GPS Monitor Station in South Australia will really be @2017.5
ITRF Based Precise Orbits are @epoch of Data

ITRF is already a Dynamic Datum; So IGS Orbits are also Dynamic
The pretence that we are static is over...

GDA2020 +/- 0.1m

GDA94 +/- 5m
A second driver is continuous development of Satellite Positioning Technology and Applications
Precise Positioning Applications
Precise Positioning Applications

Almost 3 bln mobile applications currently in use rely on positioning information

Key market trends
- The LBS market continues to grow, with high-end devices now commonly making use of multi-constellation and hybrid positioning.
- The development of successful apps continues to drive the global growth of the smartphone market.
- Context-aware applications leveraging on location information make up almost half of this total, with games and entertainment representing the largest categories.

Apps
Navigation, social networking, travel, games, entertainment, fitness and sports, healthcare

On average, more than 70 apps per device are downloaded by users, although 50% of users have never paid more than $1 for an app. Downloads of apps that rely on positioning data will hit 7.5 bln by 2019, up from 2.8 bln in 2014.

App stores
Google and Apple dominate the app stores market with more than 50 billion downloads combined from the two stores in 2013. Google Play surpassed the Apple App Store in terms of downloads and apps in store. However, Apple generated higher revenues by a factor of five.

Total unique apps in store – December 2014

- Google Play 1.43 mln apps
- Apple App Store 1.21 mln apps
- Windows Phone Store 300 k apps
- Amazon Appstore 293 k apps
- Blackberry World 130 k apps

Source: Juniper Research, Statistic Brain, Statista 2014, appFigures 2015.
Positioning capacity improvement

Significantly improved precise positioning capability and opportunities

Datum Modernisation - IGNSS2016 - Higgins - December 2016
Better Signals on More Frequencies from More Satellites

State of the art survey grade receivers have more than 500 Channels!
How will the New Datum be implemented?
Spatial policy and statutory context

Australian spatial policy, governance and implementation

- **ANZLIC – the Spatial Information Council ~ Jacoby – Qld Rep**
  - Positioning: Australia’s authoritative spatial referencing system. Includes GNSS CORS, Survey control networks, geodetic processing, analysis and modelling, geoid and bathymetric surfaces.

- **Intergovernmental Committee on Surveying and Mapping (ICSM) ~ Priebbenow – Qld Rep**
  - Permanent Committee on Geodesy (PCG) ~ Higgins – Qld Rep
    - Technical and Policy Development
    - Coordination of national geodetic programs
  - GDA Modernisation Implementation Working Group ~ Karki – Qld Rep
    - Practical Implementation of Datum Modernisation
## Two frame datum concept

**Geocentric Datum of Australia 2020 (GDA2020)**
- Conventional static datum with rigorous uncertainty
- Based on ITRF, fixed 1 January 2020, available January 1, 2017
- ATRF available simultaneously
- Plate motion model + distortion model

**Australian Terrestrial Reference Frame (ATRF)**
- Time-dependent reference frame
- Continuously realised (or aligned with ITRF)
- Full deformation modelling capability
- Static datum maintained until no longer needed
Implementation Roadmap

ICSM developed a Datum modernisation roadmap and formed the GDA2020 Modernisation Working Group with representatives from each jurisdiction.

Stage 1 (GDA2020)

• Nationally coordinated implementation
• New standards, products and tools
• Implementation guidelines

Stage 2 (ATRF)

• Similar strategy to Stage 1 but realised continuously
• New technology, new techniques
Transition Activities

- Received ANZLIC endorsement
- Technical development underway
- Stakeholder engagement
- Ongoing Communication
- National and State level activities increase
Timing

“...an incremental, two stage implementation of a two-frame concept in which both a conventional datum and a reference frame will be simultaneously supported.”

Proposal endorsed by ICSM May 2015
Nationwide Survey

Respondents
Queensland 216 (20%)
Surveyors, GIS Experts, Technical Experts

Awareness
Why are we doing this?

Knowledge
Datum, Projection etc.

Knowledge
Datum, Projection etc.

Awareness
Why are we doing this?

Very Low
Very High

Very Low
Very High

Very Low
Very High

141 181 267 352 126
50 157 334 368 158
Technical Readiness

• Coordinates will change in 2020 by 1.8 metres
• Difference between real-time GNSS positioning and GDA2020 will be small
• Static datum can be implemented with current technology and techniques
  o 7 Parameter Transformation sufficient in Qld
  o Distortion grid for national datasets
• Not all data needs ‘shifting’ - 1.8m matters more for some datasets than others
• Beneficial side effect is that measuring heights using GNSS will be significantly improved
Stakeholder Readiness

• Develop an awareness of the difference between GNSS positioning and GDA94

• Develop a communications and education plan for transitioning stakeholders
  - Presentations to a wide variety of audiences
  - Online Discussion/Technical Forum
  - Simple Animations/Explanations via You-Tube
  - Educational content published on ICSM website
  - Webinars and moderated forums

• Facilitate and assist other organisations to make the necessary changes
Some insights that influence thinking about the New Datum
GDA94 is already affecting our ability to use it!
Baseline Processing Example:

- Data was from 25 AuScope and SunPOZ CORS;
- Trimble TBC processing used the same 7 days of data submitted to GA for “Reg13 Week” during 2013;
- Processing all 25 CORS resulted in 287 baselines with ambiguity fixed solutions;
- Longest fixed solution baseline was 1,880km;
- The seeding coordinates used in TBC were from GA’s Reg13 Week solution in 2 SINEX files with different reference frames; one in GDA94 and the other in ITRF2008@2013.486 (mean epoch of data);
- All processing used IGS Final orbits;
- The observation duration and ephemeris quality meant measurement noise was minimized, allowing the effect of seeding on effective reference frame to be seen more clearly.
Seeding TBC with GDA94 Reg13 Values - Residuals against GDA94 Reg13 Values

- TBC datum set to GDA94 (no datum transformation, only sets projection to MGA);
- Seeded with GDA94 Values from GA’s 2013 Reg13 week solution;
- Baseline dX,dY,dZ added to GDA94 Reg13 Values for the “From” Station;
- Residuals against GDA 94 Reg13 Values for the “To” Station.

![Graph showing residuals against baseline distance](image)

**Residuals**

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<th>dHt</th>
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Orbits are @epoch so GDA94 Seeding is skewing the solution
Seeding TBC with ITRF2008 Reg13 Values - Residuals against ITRF2008 Reg13 Values

- TBC datum set to GDA94 (no datum transformation, seems to only set projection to MGA);
- Seeded with ITRF2008@2013.486 Values from GA’s 2013 Reg13 week solution;
- Baseline dX,dY,dZ added to ITRF2008@2013.486 Reg13 Values for the “From” Station;
- Residuals against ITRF2008@2013.486 Reg13 Values for the “To” Station.

Residuals

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<td>Range</td>
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Seed ITRF2008@2013.486 vs ITRF2008@2013.486 Reg13 Values

Height Residuals reached 2cm at 1,838km. 2D Horizontal Residuals never reached 1cm.
Differential Processing has enabled Static Datum (plate fixed) to be hidden from the user by forcing GDA94 at Reference Station... but...
Absolute Point Positioning

There is a growing use of Precise Point Positioning (PPP) plus Single Point Positioning (SPP) will only improve. Both use a Dynamic Datum (earth fixed) like ITRF or WGS84.
QUT Tests - Low-Cost Precise Positioning Unit

- Hardware - computing board, GNSS receiver, GNSS antenna, (uBlox receiver as used in ITS Stations) + battery and mobile comms

4 sets of single frequency positioning solutions are generated and evaluated:
- Standard Point Positioning (RTKLib SPP mode ~ emulates receiver’s NMEA string);
- Enhanced SPP (eSPP adding precise orbit, precise clock, iono grid map);
- Single-Frequency Precise Point Positioning (SF-PPP as above but using PPP algorithm and L1 phase data);
- Real-time Kinematic (Single station RTK using L1 Phase).

Source: Wang, Miska and Feng, QUT, 2016
QUT Tests - Stationary Test

Source: Wang, Miska and Feng, QUT, 2016

3 to 6 years of tectonics

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QUT Tests - Future Development

Additional sensor integration
- IMU
- Vision
- Lidar

Correction services
- multi-GNSS support
- Regional correction

Positioning algorithm
- Accuracy
- Robustness
- Efficiency

Source: Wang, Miska and Feng, QUT, 2016
Work is also carried out using carrier phase measurements offering even better positional performance.

MatLab codes
To support this Google has released the MatLab code demonstrating both the data collection (GNSS data logger application) as well as calculation details for obtaining observations and calculating position.

With AGD66/84 to GDA94 adoption was a fairly straightforward proposition...

What about with the new Datum?
Positioning in Point Clouds

• Point Cloud data is only going to get more dense and more precise;
• If you want to fly an RPAS to inspect an asset, should you use a fixed or dynamic datum?
• Do you take the Point Cloud to the RPAS position?... or ...
• Do you take the RPAS position to the Point Cloud?
• What if it is a swarm of RPAS?
• Or a fleet of autonomous vehicles, e.g. road maintenance?

(Source: QTMR)
HD Mapping for Automated Vehicles

Toyota has announced its plans to launch a high-precision map generation system for autonomous vehicles that will rely on sensors installed in production vehicles. Using consumer vehicles equipped with multiple cameras and GNSS receivers, location information will be sent in real-time to data centres where it is automatically pieced together, corrected and updated to generate high precision road maps. This is a fundamentally different system to that currently used by other mapping companies, which rely on a dedicated fleet of customised mapping vehicles equipped with 3D laser scanners. Instead, Toyota plans to use data collected en-masse to generate near real-time high precision road image data from designated user vehicles, and quoted an expected margin of error of 5cm on straight roads.

Toyota plans to include this system as a core element in its vehicles by around 2020.
The ABC says it is happening, so it must be...
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www.icsm.gov.au

Thanks for your attention
Matt.Higgins@qld.gov.au