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## **The AUSLIG Online GPS Processing System (AUSPOS)**

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### **BIOGRAPHIES**

John Dawson is a Project Manager in the Space Geodesy Analysis Centre, Geodesy Program of the Australian Surveying and Land Information Group (AUSLIG) in Canberra. He graduated from The University of Melbourne with a Bachelor of Science (Computer Science) and Bachelor of Surveying (Hons) in 1994, and a Masters in Geomatic Science in 1996. His areas of interest include precision GPS/GLONASS/SLR/DORIS, global geodesy, satellite orbit determination and multi-technique space geodesy combination analysis.

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John Manning is the Geodesy Program Manager of the Australian Surveying and Land Information Group (AUSLIG) in Canberra. He is a Registered Surveyor and holds Masters Degrees in Environmental Science and Business Administration from Monash University. He is member of the International GPS Service (IGS) Governing Board and chairs the Geodesy Technical Sub Committee of the Intergovernmental Committee on Surveying and Mapping (ICSM).

### **ABSTRACT**

The Australian Surveying and Land Information Group's Online GPS Processing Service (AUSPOS) provides users with the facility to submit via the Internet, dual frequency geodetic quality GPS RINEX data observed in a 'static' mode and receive rapid turn-around precise coordinates. The service is free and provides both ITRF and GDA94 coordinates. This Internet service takes advantage of both the International GPS Service (IGS) product range and the IGS GPS network and works with GPS data collected anywhere on Earth. Aspects of the design, implementation, usage and future plans of this system are reviewed.

The AUSPOS system can be found at <http://www.auslig.gov.au/geodesy/sgc/wwwgps.htm>

### **INTRODUCTION**

Increasingly the spatial information sector is turning to the Internet as a tool to aid their activities. Both public and private sector organisations are developing, promoting and

delivering their services and products using the Internet as a medium. Organisations that use the Global Positioning System (GPS) are no exception and an Internet search using the keyword 'GPS' currently reveals thousands of GPS related web sites. These sites provide information on GPS related applications, GPS hardware and software and GPS related services. The field of high precision geodetic GPS is also well represented with many scientific, private sector and national geodetic agencies maintaining useful and informative geodetic GPS related web pages. The Australian Surveying and Land Information Group (AUSLIG) is one such agency, (AUSLIG, 2001), see <http://www.auslig.gov.au>.

AUSLIG is Australia's national mapping agency, providing fundamental geographic information to support the mining, agricultural, transport, tourism, and communications industries; and defence, education, surveillance and emergency services activities. AUSLIG operates within the Commonwealth Department of Industry, Science and Resources (DISR), (AUSLIG, 2001). AUSLIG as the national body for Geodesy in Australia is responsible for the national level geodetic infrastructure throughout Australia and its territories. As part of this role AUSLIG maintains a network of permanent GPS receivers throughout both Australia and the Australian Antarctic Territory (AAT). This GPS network shown in Figure 1, makes an important contribution to the national GPS infrastructure and further contributes to the international GPS community through the International GPS Service (IGS). AUSLIG is a Regional Network Associate Analysis Centre (RNAAC) of the IGS routinely submitting analysis products for further analysis and combination with other IGS contributors.

As high precision global geodetic GPS technology has evolved, processing and analysis software has become more sophisticated and in general more automated. This development has now seen the implementation of Internet based geodetic GPS processing services, the first being NASA Jet Propulsion Laboratory's Auto-Gipsy Service (JPL, 2001) and later the Scripps Orbit and Permanent Array Centre (SOPAC) coordinate generator (SOPAC, 2001).



Figure 1. The Australian Regional GPS Network (ARGN). Consisting of 15 dual frequency geodetic quality GPS receivers tracking continuously.

In Australia these International GPS Processing Services were being widely used by the geodetic GPS community. It was at this time that the potential for user confusion between the International Terrestrial Reference Frame (ITRF), as provided by these International GPS processing services and the Australian national datum, GDA94 was recognised.

Since GDA94 was based on the ITRF92 at a fixed epoch of 1994 (ICSM, 2001) the latest ITRF coordinates produced were becoming substantially offset. This difference is due largely to the tectonic motion of the Australian plate as shown in Figure 2. Coordinate differences between GDA94 and the ITRF are at this time approximately 0.5 metres in magnitude.

AUSLIG traditionally has offered a GPS processing service to its clients in the national interest such as aviation, defence and other commonwealth and state government agencies. For this processing GPS data was generally received on various digital media, including CDROM, floppy disks and email attachments. Customer service then relied on a hand-on-process and as such was not necessarily meeting the needs of the AUSLIG clients. Defence clients for example were increasingly requiring a 24 hour x 7 day a week access to a precise GPS processing service.

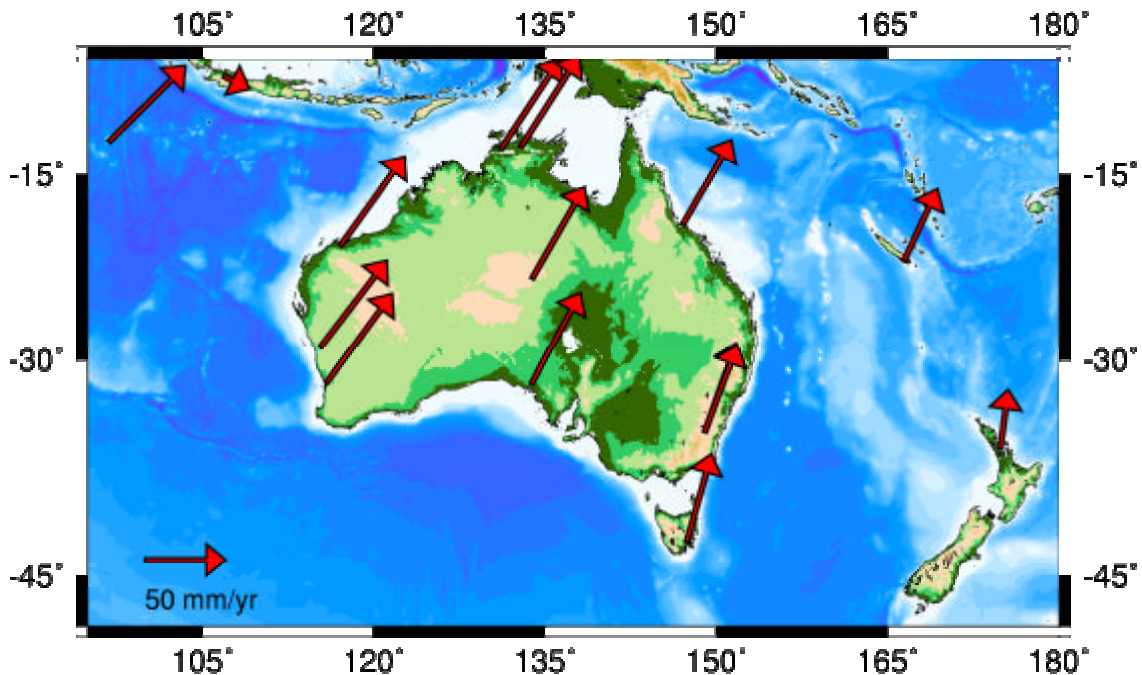


Figure 2. Tectonic motion of the Australian land-mass. Tectonic velocity associated with the Australian land mass tends to the North East at approximately 70 mm/yr. Source: IGS cumulative solution, IGS-1P20.SNX (IGS, 2001).

In this context in early 2000 a decision at AUSLIG was then made to develop a 24 hour a day online web based GPS processing service that would provide users with access to GDA94 based coordinates for Australian users, and ITRF for International users. After several months of development a Beta-Testing program was commenced and several months later version one of the processing software was complete. Software improvements continued and the service was officially released on the 11<sup>th</sup> November 2000 by the Parliamentary Secretary to the Minister of Industry, Science and Resources, Warren Entsch, MP. This service known as the AUSLIG Online GPS Processing Service or AUSPOS and has now been in continuous operation for over 12 months and is accessible via the AUSLIG web site at [www.auslig.gov.au](http://www.auslig.gov.au).

## THE AUSPOS SYSTEM DESIGN

AUSPOS was designed and implemented with the following features and design goals;

- an easy to use web page interface;
- dual frequency geodetic GPS data processing capability;
- standard web-browser direct upload or ftp;

- highest quality global GPS processing standards;
- 24 hour x 7 days a week service;
- rapid processing turnaround, < 15 minutes/file;
- results returned by email and ftp server;
- applicable anywhere on Earth; and
- GDA94 compliant for Australian users, ITRF elsewhere.

To meet this design goals the AUSPOS system was implemented with three major software components in its system including a web interface, a GPS job processing controller and geodetic parameter estimator. Table 1 shows a breakdown of each of these software components or modules.

Table 1. The AUSPOS software components.

Software Component	Description and Purpose
gps.cgi → PERL CGI script → located at www.auslig.gov.au	web interface → uploads data → collects GPS antenna height and type → reports GPS processing status
Cosmgps_server → C language software → located inside the AUSLIG firewall	GPS job processing controller → interfaces to web application → interfaces to MicroCosm suite → processing job queue → user data quality checking → user data preparation → IGS data collection → report GPS processing status → PDF report generation → email distribution
MicroCosm → Fortran software → located inside the AUSLIG firewall	orbit and geodetic parameter estimation → GPS data processing → receiver clock estimation → least squares parameter estimation

The AUSPOS design facilitates its use for a variety of applications, including;

- DGPS reference station positioning
- remote GPS station positioning;
- ultra-long baseline positioning;
- GPS connections to IGS stations;
- high accuracy positioning; and
- GPS network quality control.



Figure 3. GPS Surveyor at work in a remote Australian location.

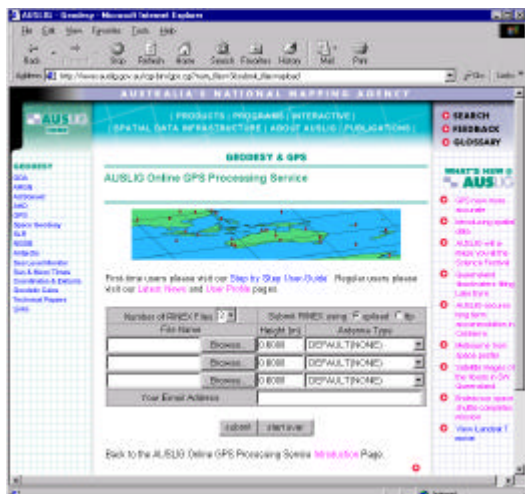


Figure 4 shows the AUSPOS web page interface. Users can directly submit or upload GPS RINEX data to AUSLIG where it is processed and results returned by email and anonymous ftp. The AUSPOS web site includes a step by step user guide, frequently asked questions, new feature and bug reports, and regularly updated user analysis and user location maps.

Figure 4. The AUSPOS web interface.

## THE INTERNATIONAL GPS SERVICE (IGS)

The IGS is a multinational membership of organisations and agencies and provides GPS data and products. IGS products include GPS orbits, Earth Orientation Parameters, atmospheric and other high-quality GPS data products. The IGS products are designed to meet the objectives of a wide range of scientific and engineering applications and studies (IGS, 2001). As shown in Figure 4 the IGS tracking network consists of over 200 permanent GPS receivers.

AUSLIG contributes data and analysis products from the 15 AUSLIG GPS receivers, as shown in Figure 1, that are located across Australia territories to the IGS network. The AUSPOS system was designed to exploit both the IGS product range and the IGS global GPS network. AUSPOS positioning is by differential GPS to several IGS stations using IGS precise orbit, Earth Orientation and station coordinate and velocity parameters.

## REFERENCE FRAMES

### The International Terrestrial Reference Frame

The International Terrestrial Reference Frame (ITRF) produced by the International Earth Rotation Service (IERS) is a realisation of an ideal reference system. The frames produced by IERS as realizations of International Terrestrial Reference System (ITRS) are named International Terrestrial Reference Frames (ITRF) (IERS, 2001). The IGS undertake their own realisation of the ITRF using analysis results from the IGS community. The IGS cumulative solution (IGS-SSC) is one such solution and is currently aligned to the ITRF97 reference frame. AUSPOS undertakes all computations using the IGS cumulative solution as its reference frame.

## The Geocentric Datum of Australia, 1994 (GDA94)

In 1992 GPS observations were completed on eight geologically stable marks at sites across Australia, these marks form the Australian Fiducial Network (AFN). Additional GPS observations were also carried out at a number of existing geodetic survey stations across Australia. In 1993 and 1994 these were supplemented by further observations and results in a network of about 70 GPS sites with a nominal 500 km spacing across Australia and is known as the Australian National Network (ANN). GPS observations at both the AFN and ANN sites were combined in a single regional GPS solution in terms of the International Terrestrial Reference Frame 1992 (ITRF92) and the resulting coordinates were mapped to a common epoch of 1994. The positions of the AFN sites were used to define the Geocentric Datum of Australia (GDA). The positions of both the AFN and ANN sites were used to constrain a re-adjustment of the Australian geodetic networks (ICSM, 2001). GDA94 is officially regarded as the Australian national datum.

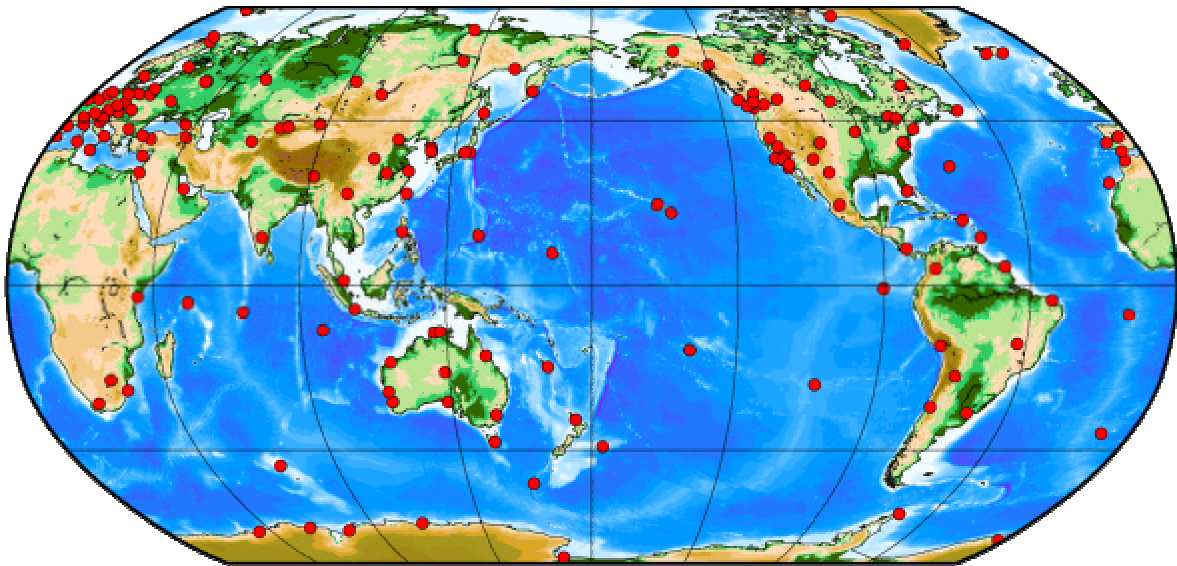


Figure 4. The International GPS Service (IGS) network of permanent GPS stations (IGS, 2001).

## Transformation between the ITRF and GDA94

As one of the main purposes of the AUSPOS system is to provide GDA94 coordinates to Australian users a transformation must be performed between the ITRF in which all computation are undertaken and GDA94. A simple approach is applied where a seven parameter transformation is applied from the latest IGS-SSC mapped to the epoch of interest to the GDA94 coordinates at the AFN, the resultant transformation can then be applied to the estimated ITRF station coordinates. Tables 2 and 3 show coordinate difference before and after transformation at the AFN. The transformation parameters are recomputed every week when the IGS-SSC is updated.

Table 2. Raw differences between ITRF(IGS-SSC) at 1<sup>st</sup> June 2001 and GDA94 at the AFN stations.

<b>Station Name</b>	<b>DOMES</b>	<b>DEast (m)</b>	<b>DNorth (m)</b>	<b>DUp (m)</b>
Tidbinbilla	50103M108	-0.1688	-0.3786	0.0595
Yaragadee	50107M004	-0.2917	-0.3767	-0.0215
Hobart	50116M004	-0.1328	-0.3720	0.0218
Alice Springs	50137M001	-0.2595	-0.3922	0.0560
Karratha	50139M001	-0.3044	-0.3874	0.0596
Townsville	50140M001	-0.2364	-0.3698	0.0778
Ceduna	50138M001	-0.2382	-0.3980	0.0087
Perth	50133M001	-0.3050	-0.3854	0.0715
Darwin	50134M001	-0.2599	-0.3947	0.0465
	<b>RMS</b>	<b>0.2504</b>	<b>0.3840</b>	<b>0.0523</b>

Table 3. Difference between ITRF(IGS-SSC) at 1<sup>st</sup> June 2001 and GDA94 at the AFN stations after seven parameter transformation, (estimated scale 4.19 ppb, rotations X, Y, Z -10.59, -10.46, -10.96 mas, translations X, Y, Z, -7.23, -0.88, 4.89 cm).

<b>Station Name</b>	<b>DOMES</b>	<b>DEast (m)</b>	<b>DNorth (m)</b>	<b>DUp (m)</b>
Tidbinbilla	50103M108	-0.0026	-0.0064	0.0129
Yaragadee	50107M004	0.0091	0.0033	-0.0458
Hobart	50116M004	0.0010	0.0019	-0.0143
Alice Springs	50137M001	-0.0046	0.0053	0.0076
Karratha	50139M001	-0.0126	-0.0035	0.0260
Townsville	50140M001	0.0095	0.0148	0.0135
Ceduna	50138M001	-0.0048	-0.0029	-0.0307
Perth	50133M001	-0.0080	-0.0042	0.0492
Darwin	50134M001	0.0166	0.0077	-0.0100
	<b>RMS</b>	<b>0.0078</b>	<b>0.0067</b>	<b>0.0276</b>

## AUSPOS FEATURES

The AUSPOS features and functions are summarised in Table 4.

Table 4. AUSPOS feature and function summary.

<b>Feature/function</b>	<b>Description</b>
Observations	RINEX dual frequency GPS code and carrier phase. User GPS navigation data is not required.
Data quantity	Minimum of 1 hour, recommended minimum of 6 hours
Multiple files submission	Maximum of 7 user files per submission
Compression	UNIX, ZIP, Hatanaka formats only
Orbit and Earth Orientation	IGS precise, ultra-rapid, rapid, final
Observations used	Double difference carrier phase
Reference frame	IGS-SSC (nominally ITRF97 at present), GDA94 for Australia
Geoid	Heights above the geoid are supplied within Australia using AUSGeoid98 (Johnston and Featherstone, 1998).

# IGS stations used	3
Results quality	<10mm horizontal <20mm vertical with 6 hours of data
Antenna phase centre	IGS or NGS models
Report delivery	Email and anonymous ftp
Report format	ADOBE PDF

## AUSPOS SYSTEM MODELLING AND ANALYSIS

AUSPOS GPS processing is undertaken in accordance with the International Earth Rotation Service computation standards and is summarised in tables 5, 6 and 7. Within the computation module AUSPOS uses the MicroCosm software suite (Martin, 2000) which is a full implementation of the IERS96 computations standards (McCarthy, 1996). MicroCosm has been used at AUSLIG for geodetic orbit determinations and parameter estimation for not only GPS but Satellite Laser Ranging (SLR) and Doppler Orbitography and Radio Positioning Integrated by Satellite (DORIS) (Govind *et al*, 1999).

Table 5. AUSPOS observation Modelling.

Component	Description
Observable	Carrier phase. Pseudo-range for receiver clocks only. 20° Elevation cut-off. 30 second sampling rate
Ionosphere	Ionosphere corrected L1 double difference
Troposphere	Modified Hopfield (Goad, 1974)

Table 6. AUSPOS Orbit Modelling.

Component	Description
Earth's Gravitational (Static) Potential	EGM96 – degree and order 12
Solid Earth Tides (Dynamic) Potential	Love Model
Ocean Tide (Dynamic) Potential	Christodoulidis
Third Body Perturbations	Sun, Moon and Planets. Values for physical constants AU, Moon/Earth mass ratio, GM from JPL DE403 Planetary Ephemeris.
Direct Solar Radiation Pressure	ROCK
Centre of Mass Correction / Attitude	Observation Correction applied

Table 7. AUSPOS station position modelling and reference frame modelling.

Component	Description
Precession	IAU76/IERS96 (McCarthy 1996).
Nutation	IAU80/IERS96 (including epsilon and psi corrections) (IERS, 1996). Sine terms added to accumulated precession and nutation in right ascension as in IERS TN 21, p. 21 (McCarthy, 1996).
Geodesic Nutation	As in IERS TN 21, p.37 (McCarthy, 1996)
Polar Motion	C04 – apriori (IERS, 2001)
Earth Rotation (UT1)	C04 – apriori (IERS, 2001)

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Daily/sub-daily tidal corrections to X,Y and UT1	Applied
Plate Motion	IGS cumulative solution (IGS, 2001)
Planetary and Lunar Ephemeris	JPL DE403
Station Displacement	
Solid earth Tide Loading	Williamson and Diamante (1972) + Wahr (1980) for the frequency dependent elastic response of the Earth's fluid interior.
Ocean Tide Loading	Not applied
Pole Tide	Applied
Atmospheric Loading	Not applied
Reference Frame	IGS-SSC cumulative solution (IGS, 2001)

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## CONCLUSION AND FUTURE PLANS

The AUSPOS service is clearly helping the Australian private sector in the growing International spatial information sector by providing access to a sophisticated GPS analysis system free of charge. Feedback shows positive support for the service and Australian companies are competing internationally for contracts using the AUSLIG service as an important 'selling' point for own services. Effectively every small survey/GPS organisation now has access to a sophisticated GPS analysis system.

Further development of the AUSPOS system is continuing. Already the users are suggesting that a metre level accuracy service (possible using less than with a few minutes of data) would be useful for a variety of applications, including mapping and GIS control. A service based single frequency data may also have a niche. AUSLIG and the authors continue to seek the advice of GPS users so that development of our GPS/Internet services can best meet user requirements.

The AUSPOS system can be found at <http://www.auslig.gov.au/geodesy/sgc/wwwgps.htm>.

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