SCIMS3: The Next Generation Survey Control Information Management System

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ABSTRACT

The Survey Control Information Management System (SCIMS) contains coordinates, heights and related information for about 250,000 survey marks in New South Wales (NSW). It is maintained for the purposes of cadastral boundary definition, engineering surveys, mapping and a variety of other spatial applications. The current system (SCIMS2K) was developed in 1999 to accommodate the introduction of the Geocentric Datum of Australia 1994 (GDA94) and its Map Grid of Australia 1994 (MGA94) coordinate system, and to improve the efficiency in the delivery of data across the internet. Incremental improvements have been incorporated into SCIMS2K since then and the system is currently based on an Oracle 10 platform of about 50 tables utilising a similar number of in-house developed stored procedures to provide conversions of positions and heights in various coordinate systems and formats. SCIMS3 is currently under development with the objective of incorporating and integrating other closely related systems and datasets such as CORSnet-NSW station metadata, the survey mark issue register, geodetic measurement data and mark images. This paper describes some of the major improvements being undertaken and discusses typical productivity improvement envisaged for SCIMS3.

KEYWORDS: *SCIMS, next generation, survey control, infrastructure*.

1 INTRODUCTION

The demand for spatial data with associated high levels of positional accuracy and integrity is increasing. All endeavours striving to meet this demand have one thing in common: the inherent dependency on positions and heights of known accuracy with a stable control reference framework. The Surveyor General and Land and Property Information (LPI) hold responsibility for establishing, improving and maintaining the State's survey control network. Both private and public sector surveyors contribute to the currency of the network by placing and surveying new permanent marks that extend the network on the ground. The network is presently represented physically by over 240,000 permanent ground marks, 6,300 beaconed trigonometrical stations and over 100 Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS). Digitally, the network comprises the Survey Control Information Management System (SCIMS), the records and archive of adjustments and survey measurements as well as the applications to deliver the information to users.

In 2008, LPI Survey embarked on a major capital investment program of Survey Infrastructure Improvement. A significant portion of this investment has been in building CORSnet-NSW (Janssen et al., 2011; LPI, 2013a), but the other components include:

- Infrastructure Preservation, involving replacing and establishing new EDM baselines (Ellis et al., 2013) as well as reviewing and rationalising the maintenance requirements of monuments and beacons at 6,500 trigonometrical stations.
- Survey Systems Improvement, such as the development and deployment of the new SCIMS-SIX online application.

Most users will be familiar with the SCIMS web interface (Figure1), available via the Spatial Information Exchange (SIX) portal. However, the primary investment for Systems Improvement in the project is planned for the development of SCIMS3 and related systems, which is the subject of this paper.

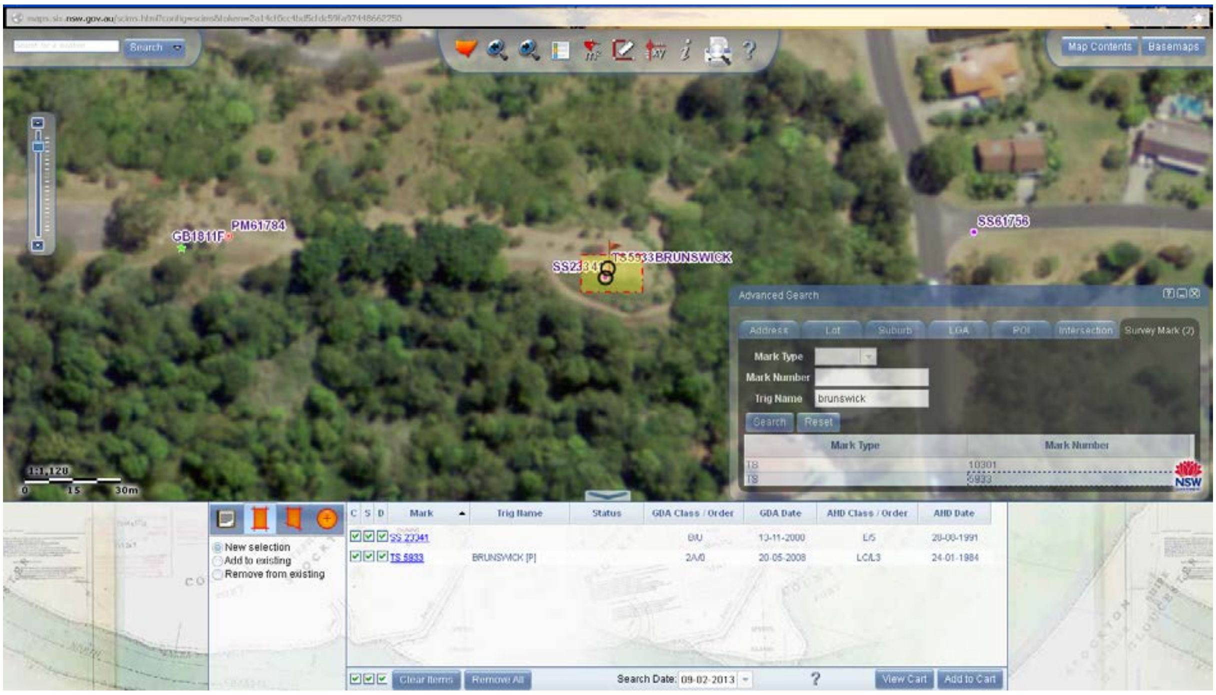


Figure 1: Example of a SCIMS-SIX Online enquiry.

2 SCIMS 2000 AND RELATED SYSTEMS

2.1 SCIMS2000

The current SCIMS2000 (SCIMS2K) was developed in 1999 and launched in July 2000. The development was necessary to accommodate the introduction of the new Geocentric Datum of Australia 1994 (GDA94) and its Map Grid of Australia 1994 (MGA94) coordinate system as well as improve the efficiency in the delivery of data across the internet. SCIMS2K was built on a combination of database technology and products available at the time of development, including the merger of the Geodetic Station Register (maintained by the Central Mapping Authority) and the Survey Control Database (maintained by Integrate Surveys Branch).

Improvements and additions of options were incorporated into SCIMS2K. However, at the time of development, only the existing in-house developed spatial searching tools were available. SCIMS is currently based on Oracle 10g RDBMS of about 50 tables incorporating some 50 in-house developed stored procedures to provide conversions of positions and heights in various coordinate systems and formats.

The datum used for the horizontal position of survey marks is GDA94. Coordinates are provided as Easting and Northing values on the MGA94 projection or as geographic latitude and longitude. Heights of survey marks relate to the Australian Height Datum 1971 (AHD71). Traditionally, the horizontal and vertical (orthometric) datum have been treated independently and this was carried forward into the implementation of SCIMS2K.

Accuracy codes (class and order) are assigned to each position and height. SCIMS2K was designed to store Positional Uncertainty (PU) and Local Uncertainty (LU) values. PU was determined for the 2,500 points adjusted in the GDA94 national adjustment and populated in SCIMS2K. However, LPI currently does not have the necessary business processes required to manage PU in breakdown adjustments. Other related information held in SCIMS2K includes details of mark types, eccentric/witness marks and trigonometrical stations.

There are well established business procedures to update and maintain the integrity of the data elements in SCIMS (LPI, 2006). The majority of coordinates and heights are updated using the SCIMS2K bulk update application in Oracle Forms, which reads and loads a series of MGA Easting, Northing and height (if applicable) values from a Comma Separated Variable (CSV) file. Figure 2 shows the update interface for the SCIMS2K Oracle application. The CSV output is obtained from a least squares adjustment. The process creates a transaction on SCIMS, which is stored and traceable. A number of in-house software tools have been developed over the last decade to increase the efficiency of the preparation for an update. For example, the Transaction Check utility (Dickson, 2009) reads GeoLab and HAVOC output files and reformats the data to display it in a similar way as the Oracle forms in the SCIMS bulk update application. An overview of the existing SCIMS2K and its relationship with update and output to users is shown in Figure 3.

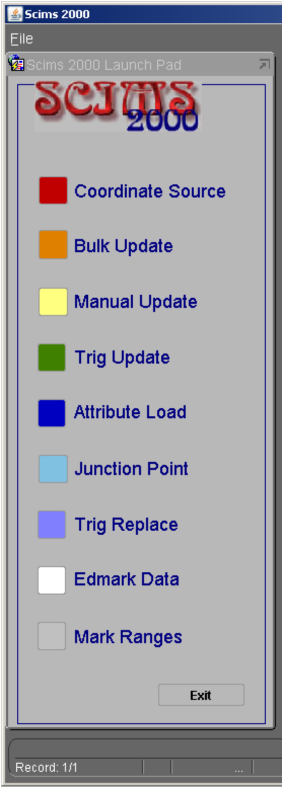


Figure 2: SCIMS update application.

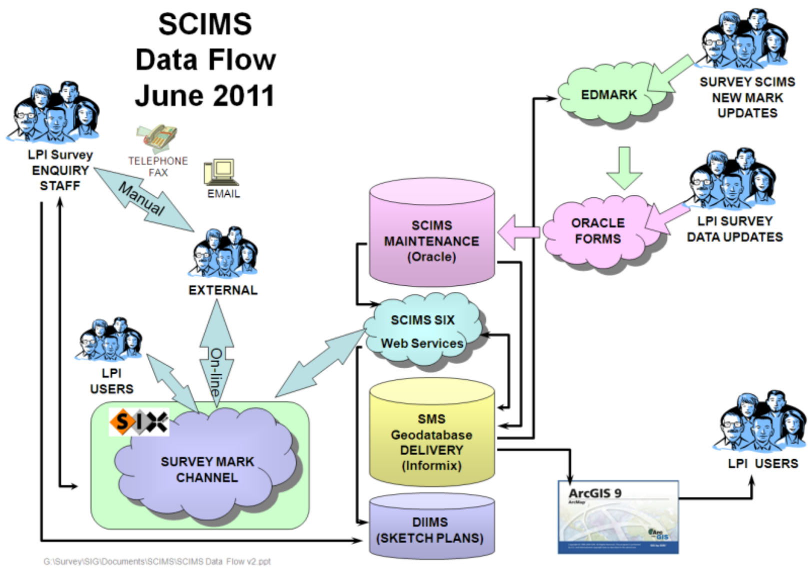


Figure 3: SCIMS2K dataflow.

2.2 Survey Mark Register

LPI is the sole supplier to the State's spatial information industry of survey control mark unique identifiers as well as the wholesale supplier of most of the associated survey mark hardware such as Permanent Mark (PM) cover boxes, numbered brass plates and numbered State Survey Marks (SSMs). Under the Survey Coordination Act (1949), a Register of Permanent Marks was started in the early 1950s. The Register records the name of the surveyor or organisation the mark was issued to, the date of issue and the survey project for which the mark would be used. If a bulk order for marks was supplied to an authorised distributer, this was recorded in the Register, and updated with details of the end user with information supplied by the distributor.

When the Locality Sketch Plan (LSP) is received at LPI, the date of receipt was also recorded in the Register. Generally, confirmation that a permanent mark has been placed occurs when the LSP is received at LPI. Then the permanent mark is initialised in SCIMS with the approximate coordinate shown on the LSP. Previous to the Surveying and Spatial Information Regulation 2006, if an approximate coordinate was not shown on the plan, LPI survey staff used maps or a Geographic Information System (GIS) to plot the mark using the features and measurements shown on the plan. A GIS-based application called Edmark was developed to assist in plotting the correct location of the permanent mark. Sometimes LPI only becomes aware that a permanent mark has been placed when it is shown on a Deposited Plan lodged for registration.

Maintaining the manual series of registers (Figure 4) continued until 2002 when a local PC database was developed. This MS Access database has since been redesigned and commenced operation in 2012. The database, called the Survey Services Data Base (SSDB), has been populated with mark numbers from SCIMS and the 5 separate document collections of LSPs for PMs, SSMs, Trigonometrical Stations (TSs), Miscellaneous Marks (MMs) and Geodetic Bench Marks (GBMs) held in LPI's Document and Integrated Imaging Management System (DIIMS). As at January 2013, the SSDB holds 277,334 records. The information in the manual registers is gradually being transferred to the SSDB on a time permits basis. The system has around 70 data elements, several of which also appear in SCIMS, such as MarkType and MarkNumber and involved party data (Name, Organisation, Address, etc.).

Figure 4: Examples of the Permanent Mark Register in book form.

2.3 CORSnet-NSW Database

All GNSS CORS administered by LPI are categorised as trigonometrical stations and assigned a TS number, which is generated and obtained from SCIMS. When a CORS is first established, the GDA94 latitude, longitude and height entered into SCIMS are derived from an AUSPOS solution (GA, 2012a) using 24 hours of data. In order to manage this information within LPI, it was necessary to establish a separate local database as SCIMS2K was not physically designed to hold 3-dimensional Cartesian coordinates (X, Y, Z) or metadata associated with a CORS.

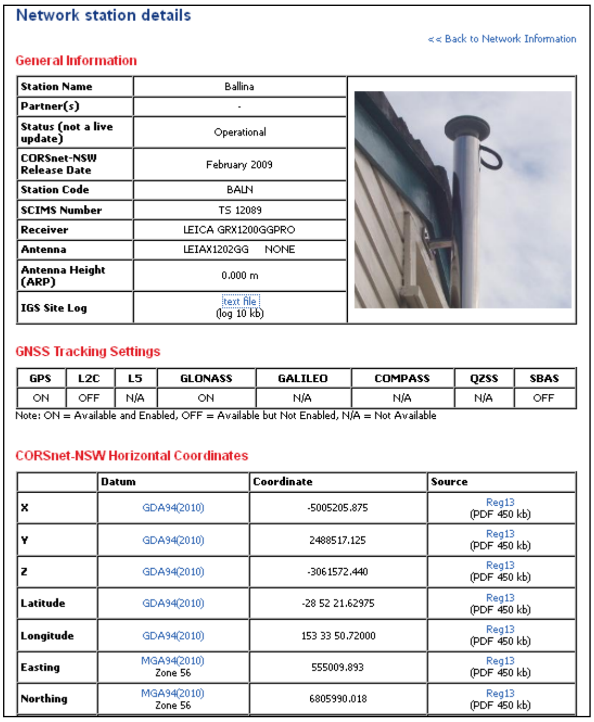
As explained in Janssen and McElroy (2010), it was also required to store the coordinates obtained from the Regulation 13 certification process performed by Geoscience Australia (GA, 2012b) because these coordinates were not necessarily compatible with the GDA94 values of local surrounding permanent marks. The essential attributes of the CORS site such as receiver type and serial number, antenna type and serial number, and monument description must also be meticulously managed. The database is the ‘source of truth’ for entry of data into the CORSnet-NSW management software. Each CORS is connected by precise GNSS survey to the existing horizontal geodetic network and levelled marks through a ‘local tie survey’. An adjustment is completed and the TS number is updated in SCIMS2K with local GDA94(1997) values and an AHD71 height (Gowans and Grinter, 2013).

The CORSnet-NSW database (Table 1), which is essentially a password-protected spreadsheet held on network storage, includes links to the current Regulation 13 certificates. There are currently 60 data elements in the system, including several derived data types. For example, latitude and longitude as well as Easting and Northing can be derived from the Cartesian coordinates. For each CORS, the CORSnet-NSW database also provides a link to an International GNSS Service (IGS) site log, i.e. a text file containing CORS metadata in an international standard format. The site log includes some information not contained in the spreadsheet but duplicates other data elements such as the current receiver and antenna employed.

It has been usual practice by GNSS CORS operators to publish the details of the individual reference stations on their website (see example in Figure 5). This enables users downloading data to access the coordinates, antenna type and other information needed for post processing. A semi-manual process is currently carried out to transfer the information held in the CORSnet-NSW database to the relevant style and location on the LPI website.

Table 1: CORSnet-NSW database elements.

ID	AHD71_98	GLONASS
Name	AHD71_09	GALILEO
Code	AUSGeoid98	COMPASS
Date_Install	AUSGeoid09	QZSS
Status	GDA_Source	SBAS
Partner	EHeight_Source	SCIMS_Latitude
Location	Coords_Source	SCIMS_Longitude
SCIMS_No	Remark_Source	SCIMS_Ellipsoidal_Height
DOMES_No	AHD_Source	SCIMS_Easting
DOMES_Source	AUSGeoid98_Source	SCIMS_Northing
IGS_Site_Log	AUSGeoid09_Source	SCIMS_Zone
Latitude	Mark_Description	SCIMS_AHD_Height
Longitude	Receiver	SCIMS_Source
Ellipsoidal_Height	Receiver_SN	Graph_Source
Easting	Firmware	
Northing	Antenna	
Zone	Antenna_RINEX_name	
Easting2	Antenna_SN	
Northing2	Antenna_Height	
Zone2	Antenna_Alignment_from_TN	
X	GPS	
Y	L2C	
Z	L5	



Network station details

<< Back to Network Information

General Information

Station Name	Ballina
Partner(s)	-
Status (not a live update)	Operational
CORSnet-NSW Release Date	February 2009
Station Code	BALN
SCIMS Number	TS 12089
Receiver	LEICA GRX1200GGPRO
Antenna	LEIAX1202GG NONE
Antenna Height (ARP)	0.000 m
IGS Site Log	text file (log 10 kb)

GNSS Tracking Settings

GPS	L2C	L5	GLONASS	GALILEO	COMPASS	QZSS	SBAS
ON	OFF	N/A	ON	N/A	N/A	N/A	OFF

Note: ON = Available and Enabled, OFF = Available but Not Enabled, N/A = Not Available

CORSnet-NSW Horizontal Coordinates

	Datum	Coordinate	Source
X	GDA94(2010)	-5005205.875	Reg13 (PDF 450 kb)
Y	GDA94(2010)	2488517.125	Reg13 (PDF 450 kb)
Z	GDA94(2010)	-3061572.440	Reg13 (PDF 450 kb)
Latitude	GDA94(2010)	-28 52 21.62975	Reg13 (PDF 450 kb)
Longitude	GDA94(2010)	153 33 50.72000	Reg13 (PDF 450 kb)
Easting	MGA94(2010) Zone 56	555009.893	Reg13 (PDF 450 kb)
Northing	MGA94(2010) Zone 56	6805990.018	Reg13 (PDF 450 kb)

Figure 5: CORSnet-NSW station information example on the internet (LPI, 2013a).

Geoscience Australia (GA) is responsible for the information on all CORS contributing to the National Geodetic Reference System (NGRS) and the definition of the national datum. The NGRS database maintained by GA holds all the necessary metadata on each CORS, which must be kept current with the help of the CORS operator. Therefore, when any significant piece of equipment is changed (e.g. a receiver is replaced) or firmware is updated at a CORSnet-NSW site, the changed details needs to be updated in each of the following:

1. CORSnet-NSW database.
2. CORSnet-NSW webpage.
3. CORS network management software.
4. IGS site log (GA must be notified and sent an updated site log).

2.4 Geodetic Measurements

The reference or linkage between the coordinates in SCIMS and the measurements used to derive them as well as the reference to the project report, raw data, field notes and other relevant data, is the Source Identifier (source ID). Figure 6 shows the link between the source ID in SCIMS2K and the folder on LPI's network storage where all the related data are stored. An LPI surveyor with access to the SCIMS maintenance application generates a new source ID for each survey project, and selects from pull down lists other information required about the project. The attributes of a source ID are source type, source method and datum.

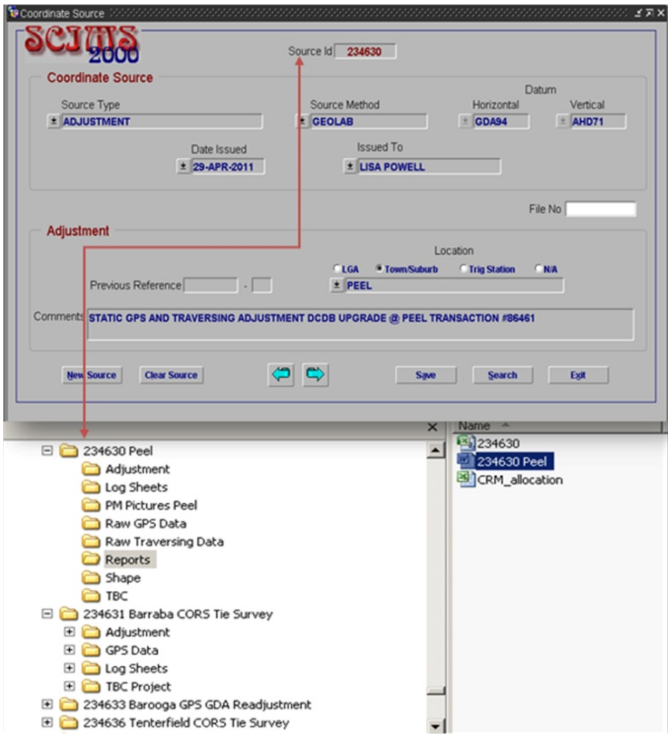


Figure 6: Source ID – the link between coordinates in SCIMS and measurements.

The least squares adjustment input files from the majority of network adjustments carried out by LPI over the last 20 years are archived on network storage within a folder named as the source ID. However, there are a number of disadvantages in only archiving measurements as input text files. The data are often difficult to retrieve and manipulate, due to not necessarily being stored in just one source folder. Measurements for a selected area of interest may be contained in several different input files, requiring time-consuming text editing to extract specific sets of observations or the deployment of data mining applications (Haasdyk and Watson, 2013). Another serious weakness is that in most cases, very limited information about the measurement is contained in the input text file. The attributes of measurements in input files usually includes the 'from' and 'to' station identifiers, the measurement itself and the a priori standard deviation, i.e. the minimum required to perform the mathematics of estimation by least squares. There is usually no reference to the source of the measurement, the instrument used or the date of the measurement, making it difficult to investigate outliers.

In the mid 1990s, just prior to the GDA94 national adjustment, a Geodetic Observation Management System (GOMS) was designed (Kinlyside, 1994) and implemented but only for GPS measurements. The basic schema is shown in Figure 7.

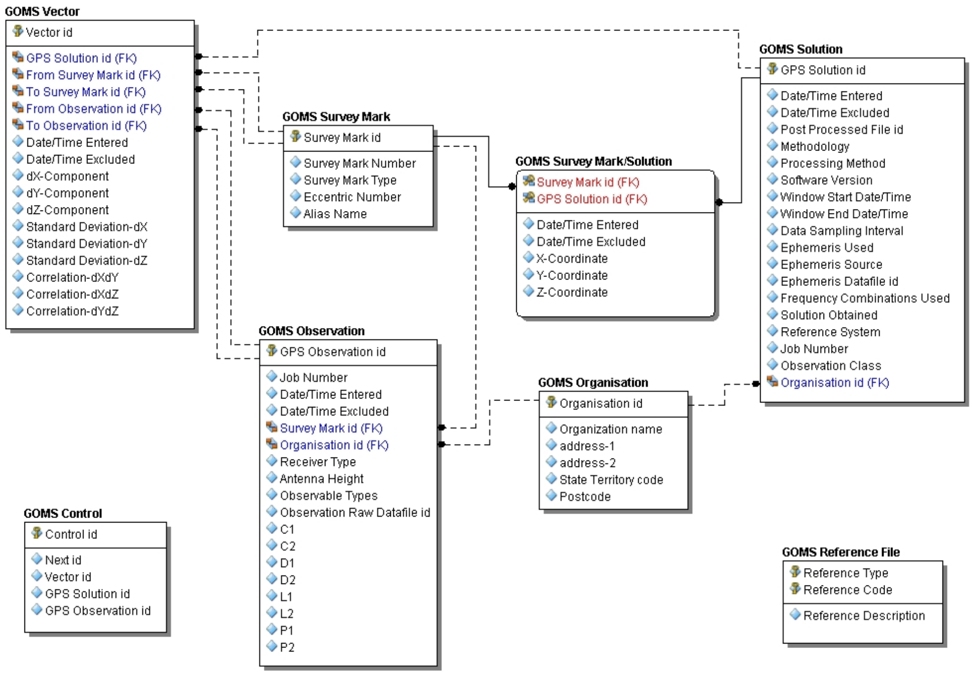


Figure 7: The GPS-related attributes of the Geodetic Observation Measurement System.

GOMS was based on an Oracle database platform, but the extraction of the relevant attribute data from the various post-processing software (predominantly) text output files and the interface to the Oracle tables were based on an MS Access customised interface. The system and interface was developed by an LPI contractor. Similarly, extraction of the vectors from Oracle to produce a GeoLab or other adjustment package input file relied on the MS Access application.

As GPS post-processing software output from most vendor packages became propriety binary format, the interface through MS Access became increasingly difficult to maintain. About 2,000 GPS vectors were loaded into GOMS prior to 1997. However, due to the difficultly in maintaining the system and the additional work involved in loading and retrieving the data, unfortunately, a decision was made in the late 1990s to abandon the process. If LPI survey had persevered with the system, it is likely that the current data-mining efforts described by Haasdyk and Watson (2013) would have been considerably easier.

2.5 Survey Mark Images

As discussed in section 2.2, locality sketch plans of survey marks are added, maintained and accessed in DIIMS, but only as bi-tonal 200dpi TIFF images. While DIIMS can also hold colour TIFF and PDF files, there is no provision in DIIMS for storing JPG images at this time. As at January 2013, there were 6,346 trigonometrical stations (Mark Type = 'TS') in SCIMS. Over many decades, TS surveyors and maintenance piling overseers have taken photos of their work, especially at unusual TS sites. Many of these photos have now been scanned and stored on LPI's network. With the introduction of low-cost digital cameras, smart phones and with cameras even embedded in GNSS receivers and controllers, LPI survey staff are now requested to collect a series of images whenever they visit a trigonometrical station. The convention used for naming these images is '9999 trigname yyyymmdd direction.jpg' where:

9999	= TS number.
trigname	= name of the Trigonometrical Station.
yyyymmdd	= year month and day of the month in which the image was taken.
direction	= cardinal direction in which the image was taken.

These images are particularly useful for assessing requests from government agencies and private companies to construct objects (typically communication towers and buildings) near the trigonometrical stations. As at January 2013, approximately 12,000 images have been stored covering about 3,000 TSs. The images are stored in the TS number and name folder on LPI network storage (see example in Figure 8).

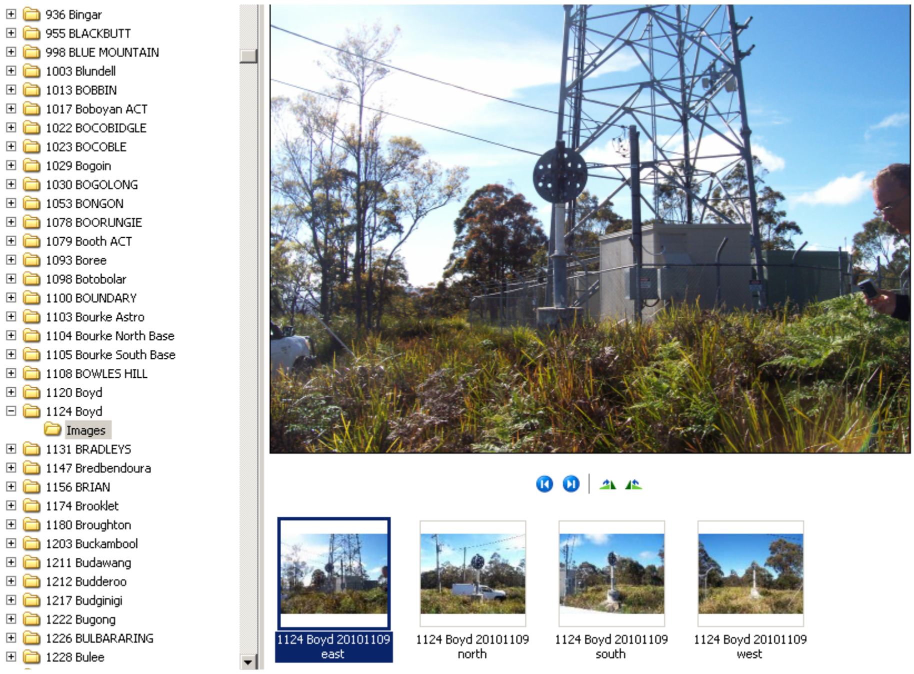


Figure 8: Example of TS images stored on the LPI network drive.

Occasionally, individuals or organisations contribute to the collection. Historical societies particularly may be interested in particular TSs in an area of interest to publish historical research such as described by Dawson (2007). An increasing number of images are taken of permanent survey marks, particularly if the mark was difficult to find using the LSP or if the mark appears to have been disturbed. LPI Cadastral Integrity staff will often take photos of marks during audit surveys; especially if there is evidence the marks do not comply with standards of marking. A similar folder as the TS image collection will be established to manage these images.

Collecting near and close images of marks placed for mapping control is now standard practice within LPI survey operations. Selected terrestrial images of the marks are embedded in the mapping control point record, which can aid the photogrammetrist in identifying the control point on the aerial image. PMs are usually placed at these control points and if they are not, Control Punts (CPs) are also a valid mark type in SCIMS. However, there is no direct link between SCIMS and a CP record, although it may be feasible to store a PDF version of the CP record in DIIMS.

3 THE CASE FOR CHANGE: SCIMS3

3.1 General

From the previous section, it should appear obvious that greater efficiency would be gained by integrating several related systems with SCIMS. Why SCIMS3? It was initially intended as a project name following SCIMS2000, but it does reflect the intention to develop a 3-dimensional system as opposed to the current SCIMS2K 2D + 1D system. While SCIMS2K holds foundation position and height information, the Oracle based maintenance system is not spatially enabled. Only when the subset of 22 SCIMS data elements are refreshed nightly in the delivery system, are the stored coordinates extracted and converted to a spatial ‘point’ in the Informix based delivery system (cf. Figure 3). It should be noted that updates between maintenance and delivery databases of the other primary LPI spatial systems happen in real time.

3.2 Enabling Technologies

A significant effort has been made over the last decade in integrating LPI systems in titling, valuation and mapping following the formation of LPI in 2000. Web services, Application Programmer Interfaces (API) and transfer of Simple Object Access Protocol (SOAP) data packets between maintenance and delivery systems and between delivery servers and client systems have certainly increased complexity but have very much improved currency and accessibility of many LPI spatial systems such as the SIX portal (LPI, 2013b).

3.2.1 XML Schemas and eGeodesy

Extensible Markup Language (XML) is an internationally established method of describing data for transferring data from one system to another. LandXML is one example of such a schema and LPI has been an ardent adopter of the Intergovernmental Committee on Surveying and Mapping’s (ICSM’s) form of LandXML, primarily for the objective of implementing a fully automated Electronic Deposited Plan (ePlan) lodgement, plan examination and Digital Cadastral Data Base (DCDB) update processes. A SCIMS web service was developed and implemented for the validation of SCIMS information contained in a deposited survey plan submitted for lodgement. The service enables the ePlan validation process on LPI’s website to search for SCIMS marks and coordinates (existing and historical) in the Oracle maintenance database to ensure the marks and coordinates at the date of the plan are valid.

Many of the survey equipment manufacturers now support the capability of exporting data directly from the instrument or from the processing software via various forms of XML. Much of the required metadata about each measurement (e.g. instrument type, serial number, date of measurement) are now available in the XML export along with the measurement and the variance or standard deviation of the measurement.

Members of ICSM’s Permanent Committee on Geodesy (PCG) have also been developing a GeodeticXML schema since 2005 (Fraser and Donnelly, 2010). Although jurisdictions have built many applications around LandXML, many geodetic data types are not supported in the LandXML schema. The Geodetic XML schema is close to being adopted nationally by the PCG (Donnelly et al., 2013).

3.2.2 Least Squares Software

LPI Survey has been using GeoLab software as its primary 3-dimensional least squares adjustment software since 1987 and currently holds nearly 40 licences. The 2-dimensional in-house software package, HAVOC, has been used since the early 1970s and is still used for adjusting measurement data between permanent marks that appear on Deposited Plans. Both software packages are limited in the number of stations and number of measurements that can be included. As such, it is difficult for LPI to rigorously determine positional and local uncertainty for the complete network of about 250,000 points.

DynaNet network adjustment software (Geocomp, 2013), developed from the University of Melbourne's DNA software, is capable of the least squares adjustment of survey networks of any size. The phased least squares adjustment techniques enable very large networks to be adjusted using a fraction of the time and resources required for a more traditional simultaneous adjustment. Over the last few years, Dynanet has been rewritten in C++ and extensively tested by PCG member organisations. Input and output formats are being designed around the proposed Geodetic XML standard.

3.2.3 Geodetic Measurements

Many sources of accurate geodetic measurements are now readily produced by surveyors and engineers, especially position measurements from Real Time Kinematic (RTK) GNSS, AUSPOS and CORS networks. As discussed in Kinlyside (1994), the main benefits arising out of implementing a geodetic measurement database are:

- More effective management of geodetic measurement, especially handling the increasing volumes of GNSS data.
- Minimising the risk of disaster recovery cost by having all measurement data in a form that can be easily backed up and transferred off site to other agencies.
- Developing uniform standards and formats for measurements, enabling external contributors to submit data in a more efficient way.
- Providing a common format interface (e.g. GeodeticXML) for transferring to adjustment software and, following adjustment, providing a more efficient controlling mechanism for faster updates of coordinates in the spatial information system.
- Creating a measurement control system that will enable measurements to be excluded from future epoch adjustments because of mark movement detection.
- Enabling sets of transformation parameters to be included in the system, giving a choice which reference frame coordinates are supplied to users.
- Providing more efficient access to geodetic measurements for special projects and for external users.

3.2.4 Digital Images

The capture of digital images is now easier than ever before. For images of survey marks and trigonometrical stations to be useful both internally and to the public, the SCIMS3 design is required to include the capability of storing and retrieving photographic images. Perhaps, Locality Sketch Plans in the future may consist of photographic images annotated with measurements.

4 CONCLUDING REMARKS

In the authors view, there is considerable scope for improving survey control information management. In mid 2012, LPI engaged a data architect contractor to examine the 'as is' data model for SCIMS and related systems, and LPI has now engaged a business systems analyst to develop the use cases for SCIMS3. Ideally, the basic data flow of SCIMS3 may appear similar to Figure 9, in which a least squares adjustment engine is constantly operating between a measurement database and a coordinate database to possibly allow in future the availability of fully dynamic coordinate sets.

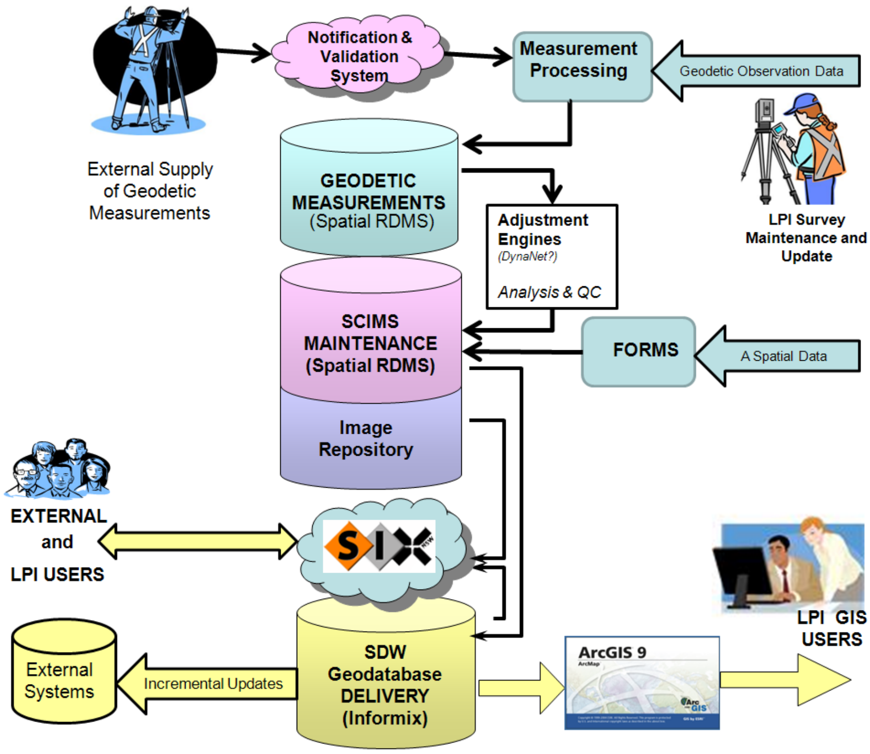


Figure 9: Data flow of a proposed SCIMS3.

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