RAIL MAPPING PROJECT

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ABOUT THE AUTHOR

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- Bachelor in Surveying (UNSW) 1980
- Registered Surveyor NSW 1983
- Graduate Diploma in Management - Charles Sturt University - 1990
- 21 years as a Surveyor with the State Rail Authority
- Started as a cadet surveyor in the railways
- Has been the Surveyor in Charge of Field Offices at Bathurst and Cootamundra
- Currently is the Manager Surveying for Freight Rail
- Was the Project Manager for the Rail Mapping Project

INTRODUCTION

The Train Radio and Train Order Projects in Freight Rail are introducing new technology to significantly improve train management and communication. These projects require the position of kilometre posts and other infrastructure features such as turnouts, signals and level crossings for the whole Freight Rail network. Initially the Rail Mapping Project was to collect the required data for these projects alone. However, the opportunity to position and capture additional infrastructure data for the proposed Geographic Information System (GIS) for Freight Rail was taken for marginal extra cost.

The centreline of one track along every operational corridor of Freight Rail was mapped - some 7,000 km. A map showing the lines mapped is shown in Figure 1.

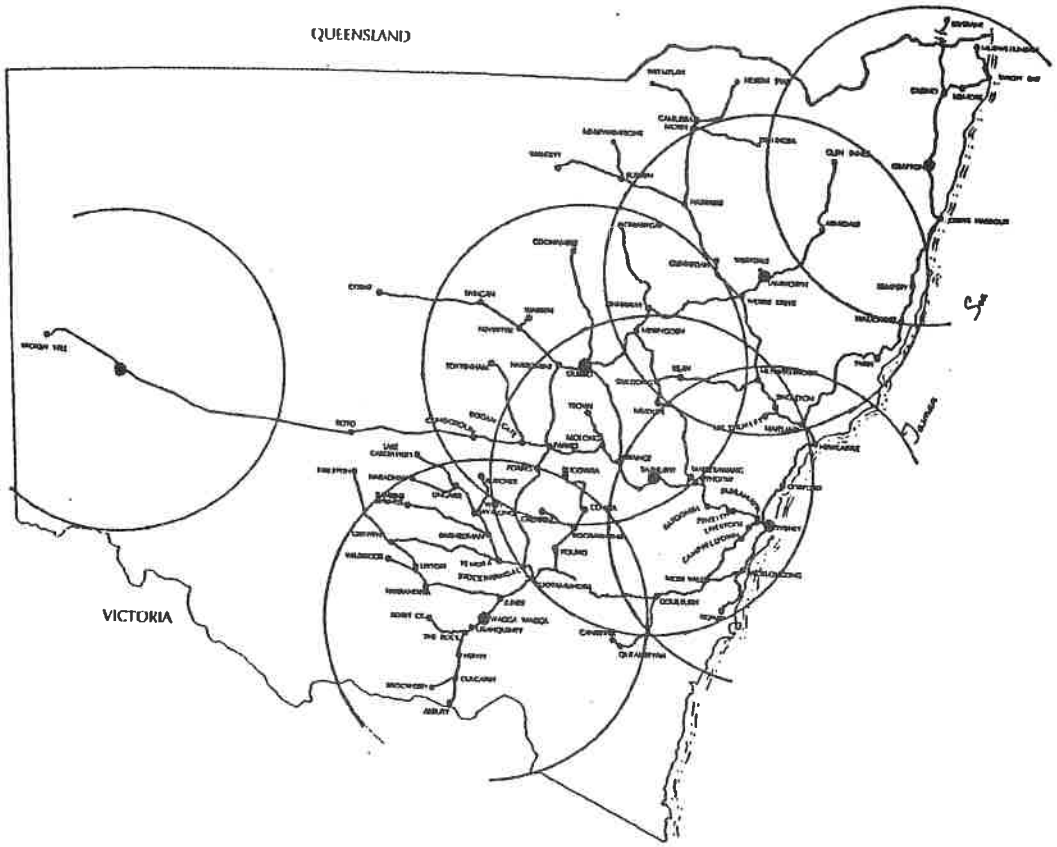


Figure 1 Map of Lines Mapped and Base Station Locations

SURVEY SPECIFICATIONS

Accuracy

The specifications for the survey were driven by the GIS data requirements that were the most stringent of all. GIS plan accuracy requirements were ± 1m for track geometry and ± 2m for asset features. The Train Radio project required a plan accuracy of ± 100m while Train Orders would eventually need ± 2 - 5m.

The vertical track profile was not an immediate need. Potential future requirements for train movement simulators for train driver training, timetabling and planning would need a gradient accuracy of ±0.01%.

Ground Control

Primary control was established by placing ground truth marks about every 50 km throughout the Freight Rail network. These marks were fixed from the local control with a SCIMS horizontal accuracy classification of 3 or better whenever possible. The ground truth marks were usually located in a railway yard at; the Sydney end of the platform, or opposite a kilometre post or at the switch points to a loop. Figure 2 shows the distribution of the 133 ground truth marks.

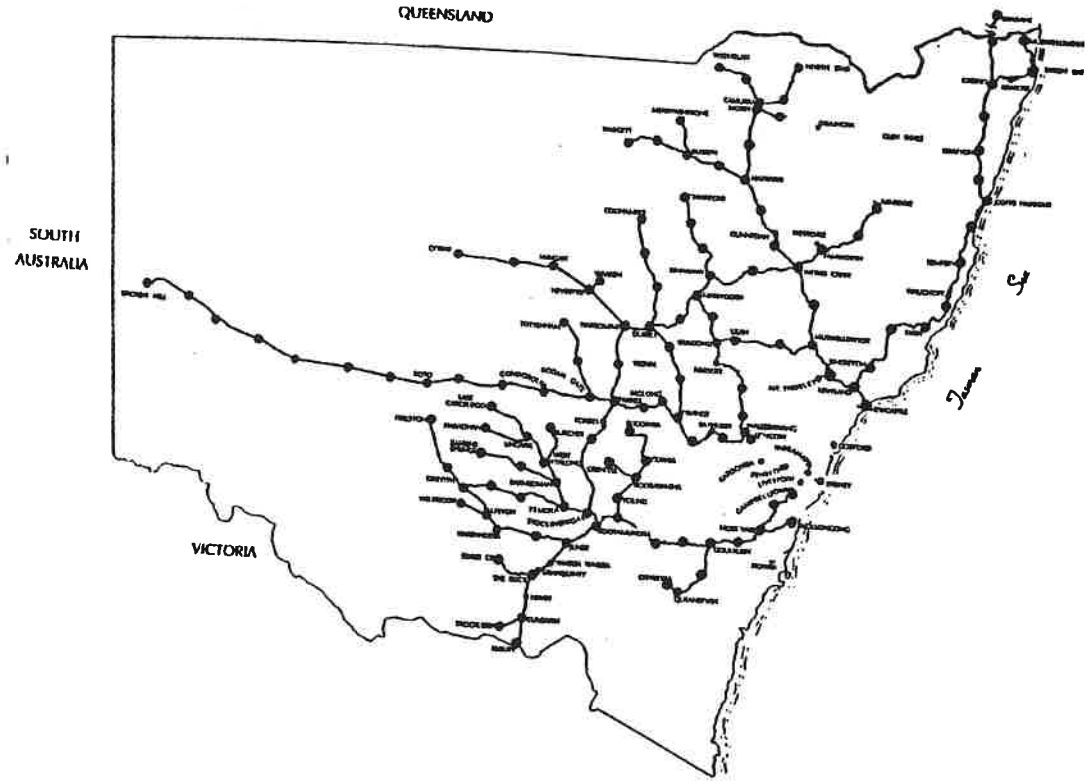


Figure 2 Ground Truth Marks

Datum

The reference datum for the final results was to be WGS84 because the Train Orders and Train Radio projects would be using GPS positioning and it would avoid changing from one datum to another. At the time the GIS was aiming to also use WGS84. However it was subsequently decided to use AGD66 with a longer term aim to move to a geocentric datum. Conversion will not be a huge problem because the ground truth mark co-ordinates were provided in ISG with AHD heights. From this information good transformation parameters are being calculated for the mapping co-ordinates by Melbourne University.

TENDER PROCESS

Freight Rail did not have the technology nor the resources to complete the project in the time required - by December 1994. A detailed tender was developed for the actual mapping. This tender was advertised on 23 February 1994. Four conforming tenders were received. Only MITS could demonstrate previous success in a similar project with an existing system. On 1 June 1994 the contract was awarded to MITS to utilise their GPS based Rapid Rail Mapping System (RRMS). MITS offered a co-operative approach to the project with a significant cost advantage to Freight Rail.

One of the offers received proposed to use conventional aerial photography to provide the data. Although it had strengths in some areas it cost about 4 times more than the MITS offer and it would have taken a year to complete (5 times longer than by MITS).

RAPID RAIL MAPPING SYSTEM

The RRMS is a relatively new surveying and data capture technology that combines measurements recorded by a vehicle mounted configuration of inertial sensors with GPS. The measurements are recorded simultaneously on board the moving survey vehicle and at one or more GPS base stations positioned on known locations. The system diagram is shown in Appendix 1.

The GPS data is differentially corrected in a post-processing exercise and then integrated with smoothed inertial data and ground truth control co-ordinates using a least squares adjustment suite called Railnet. The result is a homogeneous set of coordinated points that describe the horizontal and vertical profile of the track.

Feature information is attached to the coordinated points as an attribute tag during the field survey. A more detailed description of the system can be found in Judd et al. (1).

STEREOSCOPIC PHOTOGRAMMETRIC VIDEO

In addition to the RRMS two SVHS video cameras were mounted inside the front windows of the survey vehicle to simultaneously record all the lines to be mapped. The GPS from the RRMS recorded a time tag on each video to allow future analysis of video frame pairs in much the same way as aerial photograph stereo pairs. Computer systems exist which will facilitate photogrammetric measurements to be taken from the video pairs. This will allow the capture of other feature positions and attributes not captured using the RRMS. It also provided a check on the logging of attributes by the RRMS. For example if some attributes such as kilometre posts have been logged incorrectly, the videos could be used to verify what was actually on the ground.

ADVANTAGES OF AN INTEGRATED SYSTEM

The use of the kinematic GPS technique based on carrier phase measurements would routinely achieve the desired precision. However, this process requires continuous lock on at least four satellites. This is impossible in a railway environment with high cuttings, tunnels and frequent overbridges that mask the satellite signals. The use of GPS alone would have meant stopping the survey vehicle every loss of lock and re-initialising the survey by static fixation. This would have required extended track occupation times that are just not available.

The use of differential pseudo-range GPS technique would have overcome some of the above lock problems but 100% coverage would still be impossible. Also the horizontal accuracy would be around 2 - 5m which was outside the desired project tolerance. Complete coverage plus improved relative positioning of points can be achieved by the integration of other positioning data such as grade, distance and bearing. The RRMS provides this orientation data from the inertial instruments. These instruments are accurate over short baselines, but due to noise and datum drift they significantly degrade over longer distances. GPS on the other hand is the opposite, being more accurate over longer baselines. Integrating the technologies optimised the strengths of each and allowed a reduction in the required track possession times.

A project example of this integration is given later in the results.

SYSTEM SET UP

Survey Platform

The RRMS was set up on the historical 56 year old rail car HPC402 which was leased from CityRail. Fortunately the rail car was already fitted out for radio testing and had a large central table for equipment and good observation seating.

RRMS Equipment

All RRMS equipment was installed within easy reach of the central table for easy monitoring during mapping.

MITS configured a 386 and a 486 PC processor and the inertial equipment. It was all prefabricated into two boxes that were made to be screwed to the floor under the central table. The GPS receiver and two PC monitors and a video monitor were strapped to the top of the central table.

The SVHS video recorders were also prefabricated in a box that was mounted behind the seating at the central table.

A distance pulse generator was fixed to the front axle below the driver. There was a spare available for every piece of equipment except for this pulse generator (which later proved a mistake).

Electrical

An invertor (24 volt to 240 volt) was installed to function as an uninterruptible power supply for the RRMS computers. Some other old electrical wiring on the rail car was rewired to avoid potential problems during the project.

Logging Position & Terminals

Two logging terminals consisting of a PC keyboard and monitor were set up. The main terminal was located at the very front of the rail car across from the driver's seat. The back up terminal was located on the central table 2.9 metres behind the first.

The GPS antenna was fixed to the roof directly above the front logging position and above the track centreline. A mark was also placed on the front bogie in line with the front logging position and the GPS to help position the rail car over the ground truth marks.

DATA CAPTURE PROCEDURES

System Monitoring

The rear data logger used the central 486 PC monitor to ensure the RRMS was functioning properly. Each part of the RRMS; the GPS, gyroscope, Trim-cube, pulse generator, and video; was represented on the 486 monitor by a boxed icon. An icon was coloured green when that part was functioning properly and red when it was malfunctioning. The main monitor also duplicated the front logging terminal inputs as a check on the feature logging.

Initialisation

Before a logging session commenced the front logging position mark of the rail car would be positioned over a ground truth mark previously placed by the regional Freight Rail surveyors. This was often difficult to achieve for the driver and so an offset and direction would be measured and recorded in the session sheet. This offset was accounted for in the final calculations.

The equipment would then all be turned on and a static GPS observation for at least 5 minutes would be observed. The gyroscope would be turned on at least an hour beforehand to warm up. During this time all the equipment was checked using a standard checklist devised for the project. A standard logging sheet was filled out for each observation session. This contained details such as date, track name, starting kilometrage, front logging offset, and direction of travel. This information was input into the RRMS session file.

Data Logging

After initialisation the rail car would move off. The front data logger would commence using his keyboard to log attributes of features as they passed opposite his window. The keys used for each feature logged are listed in **Appendix 2** along with feature descriptions and entity codes used in the final data.

The kilometre value attribute would be incremented automatically by the RRMS and two indicators on the logging monitors gave a warning of an approaching km post. The warnings were set to indicate 50m and 20m before the expected km post. If a km post was missing on the ground then the km value could be easily incremented ready for the next expected km post.

The rail car would normally travel at 30kph (8.3m/s) while mapping. It would slow down through railway yards to about 10kph to improve the logging accuracy of critical features at these locations.

Closing the Survey.

About every 50 km the rail car would stop and observe a static GPS session over a ground truth mark. Again an offset to the front logging position mark would be measured and recorded. The session file would then be closed and a new one opened for the next leg of mapping.

At the end of a day's run the rail car would notify the SRA base station that it was OK to turn off their GPS.

Staffing

Two people were needed for the actual data capture. A Freight Rail surveyor did all of the data logging at the front terminal. A MITS contractor controlled and monitored the RRMS at the central table and assisted in the data logging as required.

A field hand in a 4WD vehicle acted as the ground support. He would go ahead of the rail car and mark up the ground truth mark and stand beside it as the rail car approached to assist the train driver to stop directly over the mark. The field hand was usually in radio contact with the rail car in case of breakdown. He was also responsible for booking forward accommodation for the mapping staff.

GPS BASE STATIONS

Two GPS base stations were used when mapping. The LIC base station in Bathurst was used for the project duration. The other SRA base station was located at different sites around the state depending on where the rail car was mapping (see Figure 1). Each base station consisted of an Ashtech Z12 GPS receiver recording all observables at 1 second intervals directly into a PC or laptop. The SRA GPS stations were powered by a car battery and a GPS battery. Mains power was used for the PC and the car battery if the laptop was used.

The LIC base station receiver was fitted with the remote option and downloaded the receiver each half hour. We obtained receiver image files instead of the usual RINEX files from the LIC base station. These contain extra data required for the Ashtech PNAV processing.

The SRA base stations located at Dubbo, Grafton, Parramatta, and Wagga consisted of fixed marks mounted on the roof of a secure railway building. These marks will be given PM numbers and be made available for general use. The base station at Werris Creek was a temporary mark on a portable building. At Menindee a High Precision PM was used. At Newcastle a SRA mark in the survey compound was used.

All these base stations would normally be turned on by local staff a half hour before mapping commenced. The rail car schedule was usually known and any changes were notified by telephone on the day. Standard procedures were developed for the local staff operating the base stations to check that the GPS was logging as required.

The logistics of transferring the SRA base station receiver from one location to the next without holding up the mapping schedule was often challenging.

There were a few times when one of the base stations was not recording because of power problems or receiver problems. Fortunately one base station was always operational to give a differential correction to the roving GPS on the rail car.

This was the main reason for operating two base stations at once. The other reason was that with redundant data an improved solution with checks would result. This method generally worked well and saved having to remap a section on several occasions.

A spin off of the project was that all the Freight Rail surveyors learnt how to use the Ashtech GPS receivers.

PROJECT MANAGEMENT

The project was divided into three main phases:

1. Mobilisation
2. Data Capture
3. Data Processing

Data management issues figured in all three phases and will be dealt with separately.

Mobilisation

Mobilisation took about 12 weeks and included:

- planning and organisation of staff and resources
- purchase of equipment
- scheduling of the survey vehicle
- control survey search for the ground truth marks
- marking up and GPS control survey planning for the ground truth marks
- setting up and calibration of equipment on the rail car
- three trial runs in Sydney before the next phase.
- development of quality assurance procedures and plan.

Installation, testing and calibration of the equipment were done during the fortnight commencing 1 August 1994. This phase really brought out all the skills of the project team. In particular, we had surveyors acting as carpenters, fitters, electricians, train timetablers, negotiators, searchers and project managers.

Searching over 130 locations for good survey control marks was done using the SCIMS bulletin board service. LIC also assisted by searching the Geodetic Register that sometimes had better values than those in SCIMS. At each location we were looking for two marks near the proposed ground truth mark that we could use for azimuth marks. Ideally these points would have good co-ordinates and height but mostly they did not. Often there were no marks within total station range. At some locations there were no marks within 10km to 50 km of the proposed ground truth marks.

A list of about 6 potentially suitable marks for each location were then recommended to regional surveyors for field reconnaissance to check they still existed and were suitable for GPS if required.

The assistance of the LIC in GPS surveys planning and in choosing which marks would be beneficial to co-ordinate to suit both LIC & SRA requirements was greatly appreciated. They also carried out some of the control survey for the ground truth marks.

Data Capture

Data capture commenced on 15 August 1994 and took a total of eleven weeks. The schedule for this phase is shown in **Appendix 3**. This phase was divided into three, one for each region. The West Region was completed first then the North, and then the South. The Metropolitan Goods lines were done over three days at the end. Generally twelve days straight in every fortnight were worked, then two days off. Some of the long legs took more than twelve hours. This was mainly due to the lack of track possession time. We always seemed to be low on the train controller's priority.

The rail car mapped an average of 200 km per day for most of the project. A maximum of 270 km was achieved on both the Broken Hill and North Coast lines. This maximum was really a function of; track possession allowed, a 12 hour working day and daylight available.

Data Processing

The Surveying Unit was responsible for the GPS differential processing.The PNAV software combined all the GPS data for each day. It was able to resolve ambiguities while the railcar was moving, using about 2 minutes of data. It would calculate positions every second both in the forward and backward direction and output the best solution. This is extremely useful for the railway environment where GPS signal outages are common. Figure 3 (page 16) shows the GPS RMS values for plan co-ordinates on a typical run. The inertial data collected simultaneously with the GPS was used to fill in any 'gaps' of GPS data. This was a major factor that made the RRMS attractive.

The handling of such big files (up to 40 mb) was very cumbersome. Preparing a day's data for PNAV processing took about an hour. Most of this time was taken in loading and combining files. Standard PNAV calculation sheets and a checklist were prepared to assure that data was in the correct format. Apart from the fact you wanted to do it right the first time, some long mapping days took up to 14 hours to calculate. If you got it wrong it was a lot of time wasted.

Two staff worked on the processing. It was common for them to have four computers working at once. Two computers were PNAV processing while the other two were used to prepare the next day's data for processing.

It was also common to have two computers processing overnight. The number being constrained by the fact that we only had two PNAV dongles. The PNAV results were checked for completeness and residual values. Also the height values were checked to assure antenna heights were input correctly. Once satisfied with the PNAV output a copy was sent to Geomatic Technologies (the MITS sub-contractor) in Melbourne for integration with the inertial data using Railnet.

DATA MANAGEMENT

Data management was a major issue. The main areas requiring management of data were:

1. the survey control search and observations
2. the rail mapping car and the GPS base stations
3. the data processing.

Syquest cartridges were used throughout the project for mapping and base station data transfer. These are like removable hard disks that can store 105mb of data. (270mb cartridges are also available but were not used). Eighteen Syquest cartridges were used during the project which at times was not enough. A shortage of cartridges delayed the delivery of data from LIC for just over one week in the middle of the project.

Searching

When searching for control to fix the ground truth points and their pair of azimuth marks over 5000 points were downloaded from the SCIMS bulletin board. The data format from the bulletin board is an ASCII file looking very similar to the print outs normally obtained. This format was not very useful to manage in a computer so it was converted to an Excel spreadsheet format. A further complication was that the format from the bulletin board was different for a single point search to that for a radial search. The conversion routine therefore had to detect the type of file and use the appropriate conversion. The converted data was placed in a single file containing one row for each point. (We did intend to place this in a data base but never found the time.)

GPS Control Surveys

GPS was used for about 75% of all the control surveys. At the start of the project a file naming standard was developed in conjunction with the LIC. The standard allows the LIC to easily import the GPS data and results electronically into their existing GPS computer systems. The SRA can also use it to easily manage GPS data from all of its offices in a standard way.

Mapping & Base Station Data

All mapping and base station data were backed up at the end of each day onto Syquest cartridges. When full, the cartridges were sent for GPS post-processing to the Freight Rail Surveying Unit at Parramatta by Express Post. Formal document transmittal forms were used to quality manage the movement of data as part of the QA plan.

Each hour of GPS recording generated about 3mb of data. For a common ten hour day, that is about 30mb of GPS data from each of the 3 GPS receivers. On top of this the inertial and attribute data added another 1mb. This adds up to about 90mb for a 10 hour day. Because of operational requirements the Surveying Unit did not begin data processing until day 11. By this time they had accumulated about 500mb of data!

Data Processing

At the Sydney office we backed up each Syquest cartridge onto a tape and onto an optical disk. The raw data was then sent to Melbourne. The field source was informed that we had received the data and backed it up so they could then re-use their backup cartridge.

At the Melbourne office of Geomatic Technologies the original Syquest cartridges were copied onto another optical disk.

Processing began when all the data for a day's mapping had been received in the Sydney office. The first step was to gather the times when each base station and the mapping car were receiving data and then determine the periods of overlap. Then the appropriate files were transferred to the processing computer. This was important because we generally had LIC base station data from 5:00am to 7:00 pm in half hour blocks. We only transferred those blocks that coincided with the mapping car data.

The second step was to "down load" the receiver files from LIC base station. These files are images of the data in the receiver and the same software used for down loading receivers is used. The difference being the data is on file not in a receiver. One interesting point on this stage is that the software defaults to the same file name for each down load and can not be batch driven. Therefore the operator needs to set the name for each file.

The third step was to concatenate these "down loaded" files from the LIC data to one file. That way the software would not need to resolve for ambiguities at the end of each half hour of data.

The final steps before processing were the setting of known co-ordinates, height of antenna and type of processing mode.

Data, Data, Data...

During the period of the data collection phase of the project we amassed over 3500mb of GPS, inertial & attribute data. This amount of data stretched everyone's' data storage capacity to the limit.

To be able to access any particular file amongst such a large amount of data we had to be particular with the file naming. In the field (rail car and SRA base station) each file was named with a convention that showed the session in day, day of month, month of year and location. A file naming convention was devised to correctly identify these files as logged by the GPS receivers and the mapping system. These files were then organised on disk in the following directory structure that made them easy to find:

\ddmm —LIC files
—Railcar files
—SRA base files

In addition to file naming and directory structure we kept a spreadsheet showing when each day's data was received and what was done with it.

Recommendations

Every minute spent on planning data management procedures is well spent. We could have done with even more time in this area as is the case with many projects.

PROBLEMS AND CHALLENGES

Mapping Schedule

The biggest challenge of the whole project was keeping the rail car on schedule. It can be seen from the schedule in **Appendix 3** that there was not much slack in the programme. This was governed by the availability of the rail car for the project. The main problems in this area came from train crews not showing up on time or at all and thus effecting train paths for the rest of the day. (You may notice that the schedule is numbered version 10.) Only one day was cancelled completely and only three line sections were rerun due to equipment or power failure on the rail car. In hindsight it would have been beneficial to have had more slack in the programme particularly in the first week or two.

Making Up Lost Time

All lost time was made up within the available schedule mainly due to the contacts of a Mr Graham Ball who journeyed with the rail car for the whole project as the fitter on board.

Graham is worth a special mention for without him the project schedule would have been overrun several times. He not only kept the 56 year old rail car going, he kept the Train Operations people honest as well. He often found train crew when none were available and he had all the contacts when we needed to get to a location before sunset. He had railways in his blood and he loved that rail car.

Extra Time

Four weeks before the end of the original project, the scope was increased to include about 100 km of the Metropolitan Goods lines. This was a very busy time planning and organising train crews and train paths through the CityRail system.

Rail Car Problems

Problems on the actual rail car were less frequent and demanding. During the trial runs we damaged circuits in the pulse generator on two occasions before we fixed the problem. This pulse generator also failed near Condobolin due to a short circuit caused by water penetration in a storm (about 500 km from Sydney). It was the only piece of equipment for which we did not have a spare (Murphy's Law). We were able to rerun this section on the way back from Broken Hill.

Another early problem was the power supply failed on day 2 due to the 24 volt battery being low on power and cutting out the invertor. The problem was overcome by recharging the main battery at night.

An intermittent problem was the Ashtech GPS receiver would occasionally stop calculating position. We put this down to overheating because the receiver box would get quite hot when in continuous use for 6 hours or more and the rail car was not air conditioned.

Many of the equipment failures occurred when the project manager was on board and there was talk of banning him from the train.

Communications

Communication to and from the rail car was also a problem at times. We could not complain however because the rail car was equipped with every conceivable type of radio in use by the SRA because it usually functions as the radio test car for the SRA. We found that the mobile phone was usually the best service to use.

RESULTS & EVALUATION

The final results for the rail mapping project generally exceeded specification. The final products include for at least one track on every operational railway corridor at the time of mapping;

- a centreline xyz co-ordinate (WGS84) every 8-10m.
- a centreline xyz co-ordinate at kilometre and half kilometre posts
- a centreline xyz co-ordinate at signals, level crossings, turnouts, tunnels, overbridges, underbridges, platforms, and some other infrastructure features
- a centreline xyz co-ordinate at most cuttings and approximately at most curve geometry frame points
- up to date SVHS video capable of providing further data capture if required.

The RRMS results and all the raw data were handed over by MITS. The results were provided in a standard format specified in the contract. Part of this format required an estimate of the precision of every co-ordinate.

The project specification for the precision was ±1m. However more than 50% of the results have a precision (1 sigma) of better than ±0.3m. Some line sections far exceed this. For instance 50% of the line from Menindee to Broken Hill was mapped to ±0.05m. Here one base station was located in Menindee and the GPS ambiguities were resolved at the first static session and lock on the satellites was maintained for the whole section

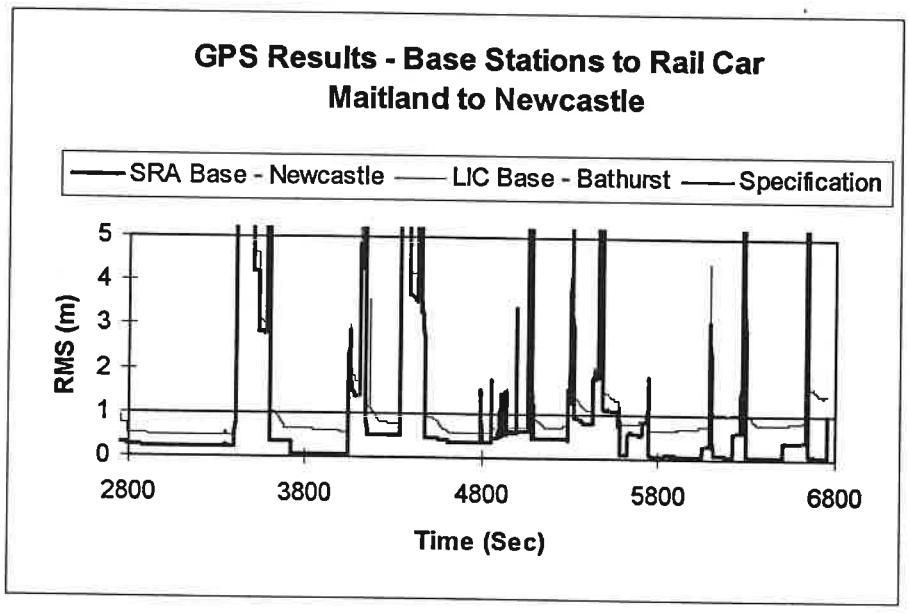


Figure 3

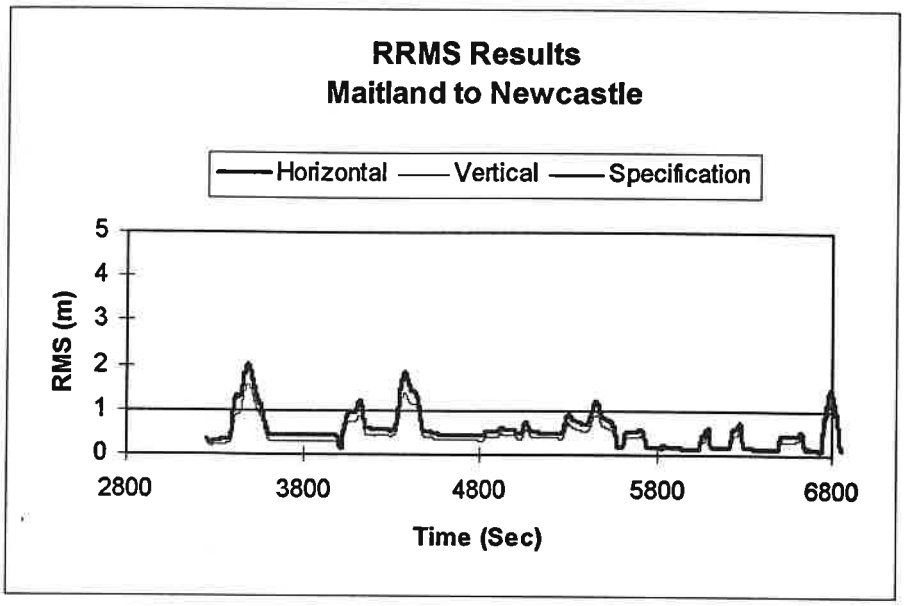


Figure 4

Figures 3 & 4 both show the precision results of the section from Maitland to Newcastle. Figure 3 shows the difference between the position precisions using only the individual base stations to differentially correct the GPS. As expected the results using Bathurst were less accurate because of the longer baseline. Also note how the RMS dramatically increases whenever GPS lock is lost and is slowly restored as the ambiguity is resolved again.

Figure 4 shows the significant improvement made by the RRMS integrating the other inertial sensors. Notice also the 100% coverage. This integration generally gave better precisions for height than for plan co-ordinates which is the opposite to that expected using GPS alone.

FURTHER DEVELOPMENTS

Data Cleaning

Currently the integrity of the data on every line section is being examined. We have found that the data logger sometimes missed a feature (in particular a kilometrage post) or logged it incorrectly. Most of these were flagged and corrected during the data processing but some have escaped the net and need to be rectified. An application in the new Freight Rail GIS has been developed to help 'clean' this data.

GIS

As mentioned GIS technology is currently being introduced to Freight Rail. The Rail Mapping Project data has been loaded into the GIS and will form the 'base map' for future information. Applications are being developed to manage the Rail Mapping data. The SRA property group Rail Estate is using the Rail Mapping data in conjunction with the LIC cadastre as a base for inputting SRA property records.

Change Control

One can imagine that the day after the rail car mapped a line section that someone could come along and change the position or configuration of the features mapped. Change control of the data is an important and for some data, safety critical issue. The integrity of the data will be relied upon for the safe passage of trains around the network using the new Train Order system.

Interim change control procedures have been developed which require field changes to be recorded so that the Surveying Unit can maintain the mapping data. These procedures are not being strictly adhered to and some work is required before it is too late and the data becomes obsolete.

It is planned to devolve the maintenance of the mapping data to the regional engineering/ survey offices when the GIS is implemented in the regions.

CONCLUSION

At first the task of mapping over 7000 km of railway centreline including infrastructure features in just 11 weeks seemed daunting, even impossible. It would have to be one of the biggest railway surveys ever undertaken in the world and certainly in the time frame. But this project has shown what technology and dedication can achieve in a short time. Overall the Rail Mapping Project has been very successful. All of the main requirements of the specification - 100% coverage, an accuracy of $\pm$1m and all within 11 weeks for data capture; have been achieved. It has been an exciting and challenging project.

ACKNOWLEDGMENTS

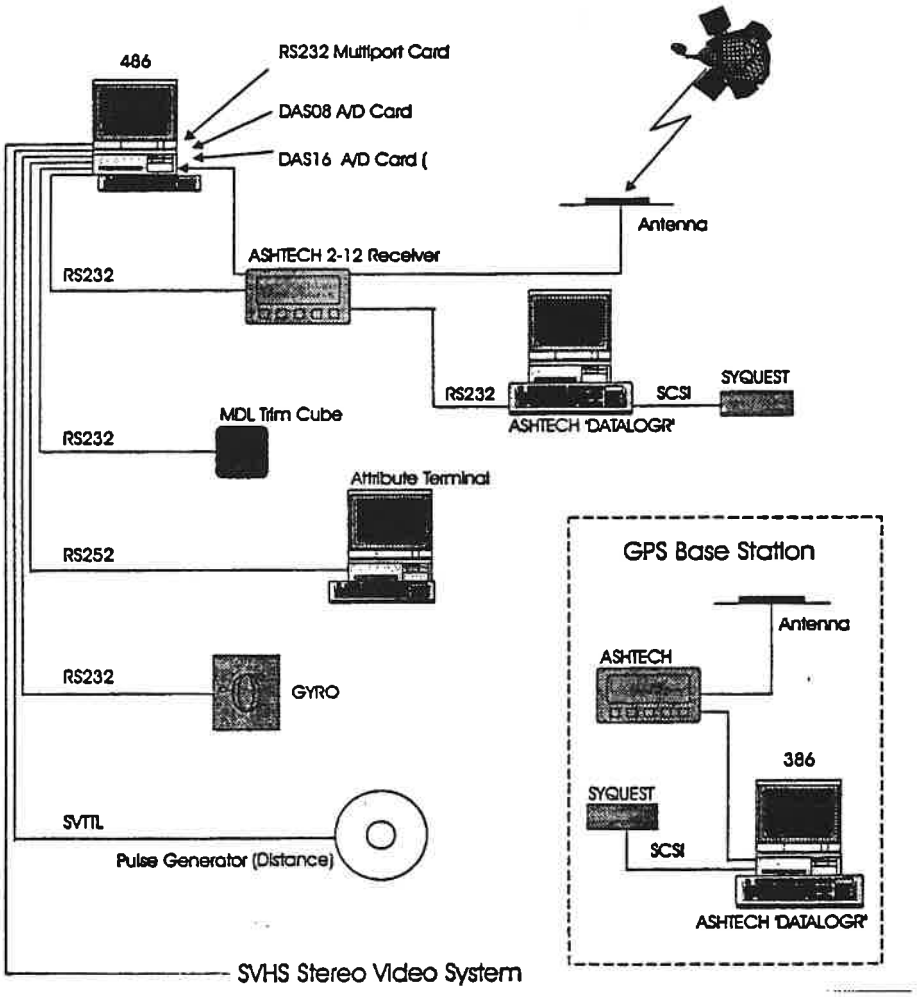
The dedication of the rail car crew Allan Mansfield, Robyn Douglas and Graham Ball really made the project a success. Allan may well be psychologically scarred for life as a result of being away from home pushing keyboard buttons for 8 hours a day for 11 weeks. Certainly his wife enjoyed the break. Thanks to Mark Butler for the control searching and giving many late nights GPS processing and moving base stations.

Thanks to the Freight Rail and LIC surveyors for the control surveys and operating the base stations. Also thanks to Geomatic Technologies and MITS staff for their assistance and dedication to the project and this paper.

REFERENCES

A.M. Judd, F.J. Leahy & M.R. Shortis, "Rapid Rail Mapping with GPS and Other Sensors", Proceedings of the Satellite Navigation Technology Conference, UNSW, Sydney, July 1993.

Appendix 1: RAPID RAIL MAPPING SYSTEM



Appendix 2: FEATURE ENTITY CODES AND KEYS

FEATURE NAME	KEYBOARD KEY USED FOR MAPPING	GEOCOMP ENTITY NUMBER
Track centreline	Not applicable	801
Level crossing	L	802
Signal	S	803
Train Order post	X	807
Platform end	[	810
Turnout crossing	Y	811
Turnout points	T	812
Speed board	Z	813
Overbridge	B	814
Km post	Space Bar	820
Ground truth mark	Not applicable	821
Underbridge start	U	830
Underbridge end	I	831
Tunnel start	F	832
Tunnel end	G	833
Cutting start	Q	835
Cutting end	W	836
Platform start	P	840
Curve start	C	850
Curve end	V	851
Straight start	N	852
Straight end	M	853

Appendix 3: RAIL MAPPING SCHEDULE

Version 10

1994

		August		September		October
Mon	1	Install equipment			1	Young Koorawatha Greenthorpe(M) Cowra (M)
Tue	2	Install equipment			2	
Wed	3	Install equipment			3	P/H
Thu	4	Install equipment	1	Tamworth Dumresq (M) Werris Creek (N)	4	Cowra Trajere (N) Cowra (M)
Fri	5	Test Run	2	W/Creek Narrabri (M) W/Creek(N)	5	Cowra Harden (N) Coota (M) Temora (M)
Sat	6		3		6	Temora Rankin Springs (M)
Sun	7		4		7	Rankin Springs Barmedman (N) Burcher (M)Wyalong (N)
Mon	8		5	Travel to W/Creek	8	Wyalong Narradhan (M) Ungarie (N)
Tue	9	Test Run	6	Werris Ck Narrabri(N) Binjiguy (M) Moree (N)	9	Ungarie Lake Car.(M) Temora (N)
Wed	10		7	Moree North Star (M) Moree (N)	10	Temora Griffith (M)
Thu	11	Test Run	8	Moree Weemelah (M) Narrabri (N)	11	Griffith Hilston (N) Griffith (M)
Fri	12		9	W/Creek Narrabri(N) Walgett(M)	12	Griffith Yanco (M) Wilbriggle (N) Narrandera (M)
Sat	13		10	Wgat Burren(N) Merriwinebone (M) Narrabri(N)	13	Narrandera Coota (M) Frampton (N) Bethungra (M) Junee (N)
Sun	14	ACDEP-Coolamundra (N)	11	Narrabri W/Creek (N)	14	Travel Home
Mon	15	Coota Stock (N) Parkes (M) Dubbo(N)	12	W/Creek Coonabarabran (M)	15	
Tue	16	Dubbo Orange (M)	13	Coonabarrabran Gwabegar (M) Binnaway (N)	16	
Wed	17	Orange Lithgow (M)	14	Binnaway Gulgong (M)	17	Travel to Junee
Thu	18	Lithgow Kandos (N) Lithgow (M)	15	Gulgong Maitland (M) Broadmeadow(N)	18	Junee Boree Ck (M) The Rock (N) Albury (M)
Fri	19	RDO	16	Broadmeadow Gloucester(M)	19	Albury Parkes (N)
Sat	20	Lithgow Orange (N) Parkes (M) Condo(N)	17		20	Parkes Dubbo (N) Orange(M)
Sun	21	Condo Ivanhoe (M)	18		21	Orange - Molong (M) Orange - Lithgow (M)
Mon	22	Ivanhoe Menindee (M)	19	Gloucester Macksville (M)	22	Lithgow - Granville - Campbelltown (N)
Tue	23	Menindee Broken Hill (M)	20	Macksville Casino(M)	23	Campbelltown -Moss Vale - Unanderra (M) ACDEP (N)
Wed	24	Broken Hill Euabalong (N) Condo (M)	21	Casino Murwillumbah (M) Casino (N)	24	CityRail Train Radio runs
Thu	25	Condo Bogan (M) Tottenham (N)Parkes (M)	22	Casino Acacia Ridge (M)	25	CityRail Train Radio runs
Fri	26	Parkes Narromine(M) Cobar (N)	23	Brisbane Kempsey (N)	26	CityRail Train Radio runs
Sat	27	Cobar CSA (N) Warren (M)	24	Kempsey Broadmeadow (N)	27	
Sun	28	Warren Dubbo (M)	25		28	ACDEP - Meeks Rd - Belmain - ACDEP
Mon	29	Dubbo (N) Coonamble (M) Dubbo (N)	26	RDO	29	ACDEP - Belmain - Botany - Enfield - Liddcombe
Tue	30	Dubbo Merrygoen (M) Muswellbrook (N)	27	Broadmeadow ACDEP (N) Fuel/Service	30	Liddcombe - Pippita - Chullora - Sefton - ACDEP
Wed	31	Muswellbrook Westdale (M) Tamworth (N)	28	ACDEP Goulburn (M)	31	
Thu			29	Goulburn Canberra (M) Goulburn (N)		
Fri			30	Goulburn Young (M)		
Sat						
Sun						
Mon						

(M) Mapping at 30kph (N) Normal Running