ANNUAL AND FINAL REPORT OVER THE ECLIPSE URANIUM-IRON PROJECT

NGALIA MINERAL FIELD,

NORTHERN TERRITORY

Eclipse Project

Exploration Licence: 24637

BY

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DISTRIBUTION

1. *Northern Territory Department of Minerals & Energy*
2. *Eclipse Metals Limited*

PROJECT NAME:	ECLIPSE		
TENEMENTS:	Exploration Licences 24637		
MINERAL FIELD:	Ngalia Mineral Field		
LOCATION:	NAPPERBY HERMANNSBURG	SF5309	1:250 000
	Napperby	5452	1:100 000
	Aileron	5552	1:100 000
	Narwietooma	5451	1:100 000
	Anburla	5551	1:100 000
COMMODITIES:	Uranium		

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1.0 ECLIPSE PROJECT

1.1 Copyright Statement:

2.0 INTRODUCTION

The Eclipse project comprises Exploration Licence 24637 and covers 464.7 km^2 of carboniferous rocks of the Ngalia Basin, approximately 182km northwest of Alice Springs. The project is prospective for sandstone type uranium mineralisation similar to the southern New Well uranium deposit.

This report describes the results of all the exploration work carried out during the tenure of the Licence.

On 17th February 2012, the date of listing with the ASX, Eclipse Uranium became owners and operators of EL24625, EL24637 and EL 24808, which was previously owned by Cauldron Energy Limited. Over the past 2 years Cauldron and Eclipse have been part of the CSIRO Joint Systems Uranium study of the Ngalia basin. As a result of this study there has been an increased understanding of the geology and mineralisation styles across the basin.

Exploration conducted within the relinquished parts of 24637 included three Aircore drilling programs comprising 274 holes for 6,247m (ECAC001 – 004, ECAC007 – 050, ECAC065 – 068 and ECAC184 – 405).

A trail airborne Tempest EM survey was conducted during July 2007. A total of 42 line km was completed within the relinquished parts of EL 24625 including one 30km long E/W line and three isolated N/S line segments 3 to 5 km long. Within the relinquished parts of EL 24637, a total of 57 line km was completed, including one 18km W/W line and five isolated N/S line segments 5 to 9 km long.

An airborne radiometric/magnetic survey was completed by UTS Geophysics in November 2007 as part of a larger survey conducted in association with neighbouring explorers Toro Energy Ltd and Energy Metals Ltd. The survey on 100m line spacing' comprised 16,939 line kilometres (approx 1,500 km^2) over Cauldrons tenements. Only a small section of the survey covers the central and southern part of the relinquished area.

During March 2013 consulting geologists Kastellco Geological Consultancy ("**KGC**") conducted a review of existing historical exploration data within the Northern Territory Geological Survey Database. This was conducted for the Project area in order to identify any potential associated with uranium. The results were negative with no exploration targets identified. Based on the review, it was recommended the exploration licence area was to be relinquished upon very little to no mineral prospectivity.

3.0 LOCATION AND ACCESS

The Eclipse Project exploration licence area is located 182km southwest from Alice Springs in the Northern Territory. Access to the area is provided by Tanami Road on the Napperby and Narwietooma Pastoral Leases – please refer to Figure. 1)

4.0 TENEMENTS

The project is comprised of one granted exploration licence (EL) with the tenement details summarised in Table 1 prior to this relinquishment and their location are shown in Figure 1.

Table 1: Eclipse Project - Tenement Summary

Project	Tenement Number	Status	Current Area Blocks	(sq km)	Current Holder	Granted Date
Eclipse	EL24637	Granted	416	1,315 km^2	Cauldron Energy Limited	08/12/2005

5.0 REGIONAL GEOLOGY MINERALISATION

The Eclipse project covers parts of the Ngalia Basin and parts of the surrounding Arunta Block. The Ngalia Basin is a large 300 km long by 70 km wide east west trending intra-cratonic basin, which contains up to 5000 metres of late Proterozoic to Carboniferous aged fluvial and marine sediments. These sediments were derived from the surrounding uranium enriched early to mid Proterozoic granites and metamorphic rocks of the Arunta Block. (Figure. 2)

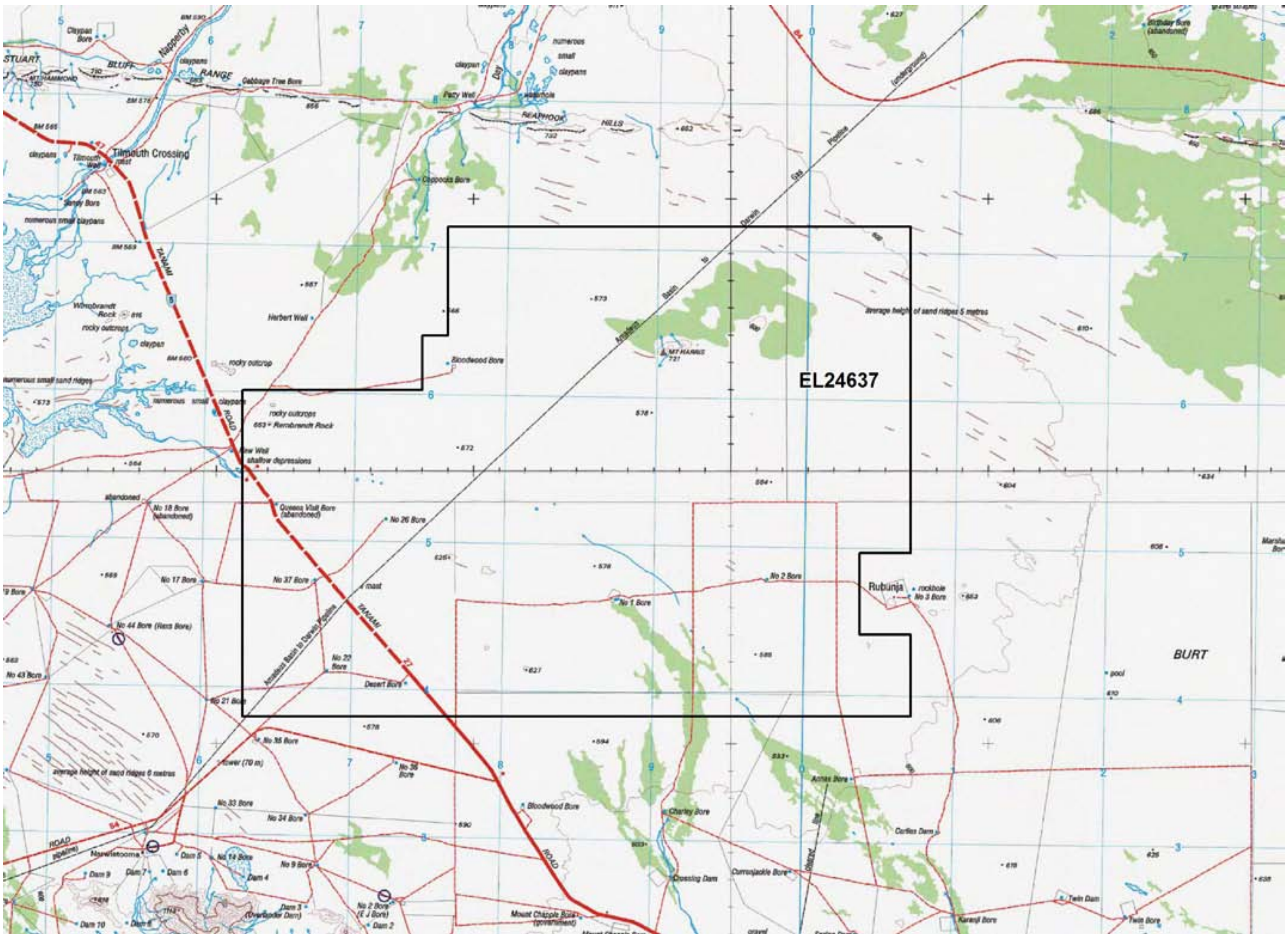
The Ngalia Basin developed around 900mya and comprises a succession of basal late Proterozoic continental and possibly marine sediments overlain by continental fluvioglacial sediments. Later sedimentation during the Cambrian and Ordovician resulted in epicontinental sediments including carbonates. Uplift during the Alice Springs Orogeny resulted in the deposition of Devonian to Carboniferous fluvial sediments. Subsequent deformation of the basin has resulted in folding and faulting, with major thrust faults, strong folding and over turning of lithology along the northern margin of the basin. Deformation in the south is less intense with only gentle folding along the southern margin. (Freeman etal 1990)

The Arunta Block is composed of metamorphic basement lithology's, which have been intruded by later granites. Three areas are recognised within the Arunta Block, The northern, central and southern provinces. The Ngalia basin sits between the northern and central provinces. Formation of the Arunta Craton is divided into three stages. The earliest phase (2000mya) comprises mafic, felsic and aluminous granulite and calc-silicate rocks of the Strangways Metamorphic Complex, which comprises most of the Central Province. The second phase of formation is dominant in the northern and southern provinces and comprises aluminous and silicious sediments with a few mafic flows and sills. The third phase is less extensive and is found as ortho-quartzite outliers scattered around the northern and southern provinces. (Shaw 1990)

The Arunta Block underwent deformation and metamorphism during the Proterozoic, including the intrusion of granites, some of which are highly uraniferous, particularly those from around 1750mya. During the late Devonian and early Carboniferous the Arunta Block was extensively disrupted by thrust faulting, particularly along the boundary between the northern and central provinces. (Shaw 1990).

Sandstone-type uranium mineralisation occurs in the northern and central parts of the Ngalia Basin, within the uppermost preserved unit, the Mount Eclipse Sandstone. This is medium- to coarse-grained feldspathic sandstone, with carbonate cement, that can contain significant amounts of carbonaceous material. Minor surficial (calcrete) uranium mineralisation also occurs within Cenozoic calcrete near the southern margin of the basin.

Figure 1 - Eclipse Project – Location Map



6.0 LOCAL GEOLOGY & MINERALISATION

The project area is typified by flat sandy plains overlying granites of the Arunta Block. Sandy and calcrete soils are found extensively within the Ngalia basin to the North and overlying the Arunta Block of the tenement area. A number of isolated granite hills emerge from the plain within the project area, especially in the east where granite hills, including Mount Harris, appear to flank a buried salt lake. The vegetation in the area consists of acacia scrubland associated with grasslands and minimally modified pastures in places. Taller eucalypts are present within and along the main drainage systems.

The project area includes the northern part of the Lake Lewis salt lake. This lake is fed by two large ephemeral creek systems, the Napperby and Day Creeks, which drain uranium enriched granites along the northern boundary of the Ngalia Basin. A number of smaller less continuous drainages feed the lake along its western margin.

7.0 PREVIOUS EXPLORATION

Historical work conducted during the 1970’s and 1980’s involved broadly spaced drilling targeting sandstone and calcrete hosted uranium mineralisation within the Ngalia basin and overlying the granites of the Arunta Block.

In 1973, CRA Exploration Ltd. (CRAE) undertook exploration over the north eastern part of EL24625, around Mount Harris. A program of mapping and sampling over the outcropping granites indicated that they were uraniferous and hence potential source rocks for secondary uranium mineralisation. Sampling returned values up to 40ppm uranium from the granites. Mapping of the surrounding plains failed to locate any suitable sediments or calcrete likely to host secondary uranium mineralisation. (Hughes 1973)

During 1981 Alcoa Australia Ltd. (Alcoa) held a large exploration licence covering the southern parts of EL 24636 and 24637. The company was targeting sandstone and calcrete hosted uranium within calcrete and tertiary sands of the Narwietooma Basin, which overlies the granites of the Arunta Block. Eleven mud rotary holes (NA001NA011) were completed for 1,555m within and to the south of EL 24636 and 24637. The drilling intersected a thick sequence of oxidised tertiary sediments, clays, sandy clays and minor unconsolidated sand units. This suggested that oxidising fluids had moved through all the permeable beds in the area, diminishing the prospect of locating uranium mineralisation. All holes were gamma probed and a number of sections were assayed for uranium. The highest result was 2m @ 7ppm uranium from hole NA011. (Howard 1981)

The most detailed and successful exploration within the immediate project area was carried out by Uranerz at the New Well uranium prospect, adjacent to Cauldrons licences. Shallow auger drilling conducted during the 1970’s identified a mineralised near surface palaeodrainage system over 20 km long and up to 4km wide that drains into Lake Lewis along the Day creek. An economic scoping study on the New Well prospect, indicated that it could contain up to 6,000 tonnes of U_3O_8, based on a grade range of 360-380ppm U_3O_8. This prospect is in the drainage adjacent to Cauldrons licences and is currently the focus of resource drilling by Toro Energy Ltd. (Toro), the current operators of the project.

8.0 ECLIPSE EXPLORATION HISTORY

Exploration over EL 24637 was undertaken as part of field investigations on the Eclipse project by Cauldron Energy. The work included a number of reconnaissance field trips, a trial Tempest EM survey, an airborne Radiometric/Magnetic survey and Aircore drilling programs.

Office studies included acquisition of historical reports and associated data. Collation and reinterpretation of historical data has continued throughout the year and compiled within a project database. The company has completed a Radiation Management Plan, Environmental Management Plan and Mining Management Plan for the Eclipse project Investigation of open file reports and the available geophysical data and imagery identified a number of target areas that are prospective for calcrete hosted uranium mineralisation, similar to that at the adjacent New Well uranium deposit. The Day and Napperby Creeks drain uranium enriched granites from the northern margin of the Ngalia Basin. Airborne radiometric data indicates that uranium enriched material is present in these drainages and is depositing around the margins of Lake Lewis and at trap sites along the drainage system.

Interpretation of Landsat TM imagery indicates that these two drainages debouche into Lake Lewis and also into areas formerly covered by salt lakes to the east, below Mount Harris. This indicates that the present Lake Lewis has migrated over time and was probably rather more extensive than its present location suggests. This interpretation provides further potential mineralisation sites for Cauldron in areas overlooked by previous workers and is backed up by geological information from recent drilling.

Work completed by the company included an initial Aircore drilling program, during early December 2006, comprising 48 holes for 1,144m (ECAC001 - 004 and ECAC007 - 050). A follow up program was undertaken during November and December 2007. A total of 19 Aircore holes (ECAC065 - 068 and ECAC184 - 198) for 711m were completed, targeting calcrete hosted uranium mineralisation at the Tilmouth Well and Bloodwood Bore prospects. (Figure 2) The drilling intersected a general stratigraphy comprising

1. Red brown sandy silty soil (thickness 1-10m)
2. Calcrete (acid fizz). Grey or cream in colour, closely resembling the calcrete gravel and cobbles found on the surface. (thickness 2-12m)
3. Silcrete. Resin-like and with conchoidal fracture. The silcrete is nearly always present within the calcrete layer, but ranges greatly in thickness and development. Partly silicified light brown or grey green silty clay (thickness 2-8m)
4. In some holes, silt, sand and clay beds with multiple lithologies (for the coarser sands) were present. These are interpreted to represent a wandering river channel. (thickness 46m)
5. Brown clay with grey to green mottling. Although this thick clay sequence is quite consistant, there are changes in the proportion of brown and green mottling. Such changes are often on the scale of 3-8m with one color dominant, then the other. (thickness 20-40m)
6. Silt, sand and clay sequence. This unit varies between the holes. It consists predominantly of 1 or more silt beds up to several metres thick, usually separated by brown clays that are identical to the overlying beds. Well-sorted fine to medium sand beds occur in some, but not all, holes. Sands have multiple lithologies including granite, quartz and FeOx. Calcrete paleo-surfaces are also present in some holes, developed on top of the silt or the underlying gypsum-halite beds. The sequence is interpreted as deposits from a wandering river channel system with clay deposited during periods of low energy. (thickness 4-9m)
7. Evaporite sequence. This consists of an upper 1-4m thick layer of medium to large gypsum crystals (c-axes to 3cm) overlying dark greenish black clay. Highly saline water infiltrates the holes when these beds are encountered, so halite is almost certainly present with the gypsum. In some holes the dark greenish black clay is interbedded with the gypsum-halite. The unit clearly represents a palaeo-salt lake that was subsequently buried by the channel deposits and clay.

Results from this second phase of drilling returned some encouraging uranium values. Elevated uranium results were associated with a buried calcrete horizon (at between 615 metres in depth) to the east of the New Well deposit at the Bloodwood Bore Prospect. Results included 55 ppm U from 9-12m in drill hole ECAC 192 and 34 ppm U from 12-15m in drill holes ECAC 190 and 191. (Figure 4)

During April and May of 2008, a third Aircore drilling program was conducted over EL 24625 and EL 24637 comprising a total of 207 holes for 4392 metres (ECAC199 – 405). The drilling targeted near surface calcrete hosted uranium mineralisation (similar to the adjacent New Well Uranium Deposit) within a large regional drainage system and potential targets interpreted from the 2007 TEMPEST electromagnetic survey including buried channels and palaeo-lake margins.

The drilling intersected surficial red-brown sandy soil (thickness 1-6m), overlying up to 9m of red-brown calcrete and silts with a basal calcrete layer. This horizon is the host to uranium anomalism at Bloodwood Bore and overlies transported silts, clays and sands which in some places attain depths of greater than 70m. Best results from this program included 50 ppm U from 6-9m from drill hole ECAC 199, 44 ppm U from 6-9m in drill holes ECAC 200 and 217, and 42 ppm U from 6-9m from drill hole ECAC 251. (Figure. 3)

Figure 2 - Eclipse Project Drill Collar Locations

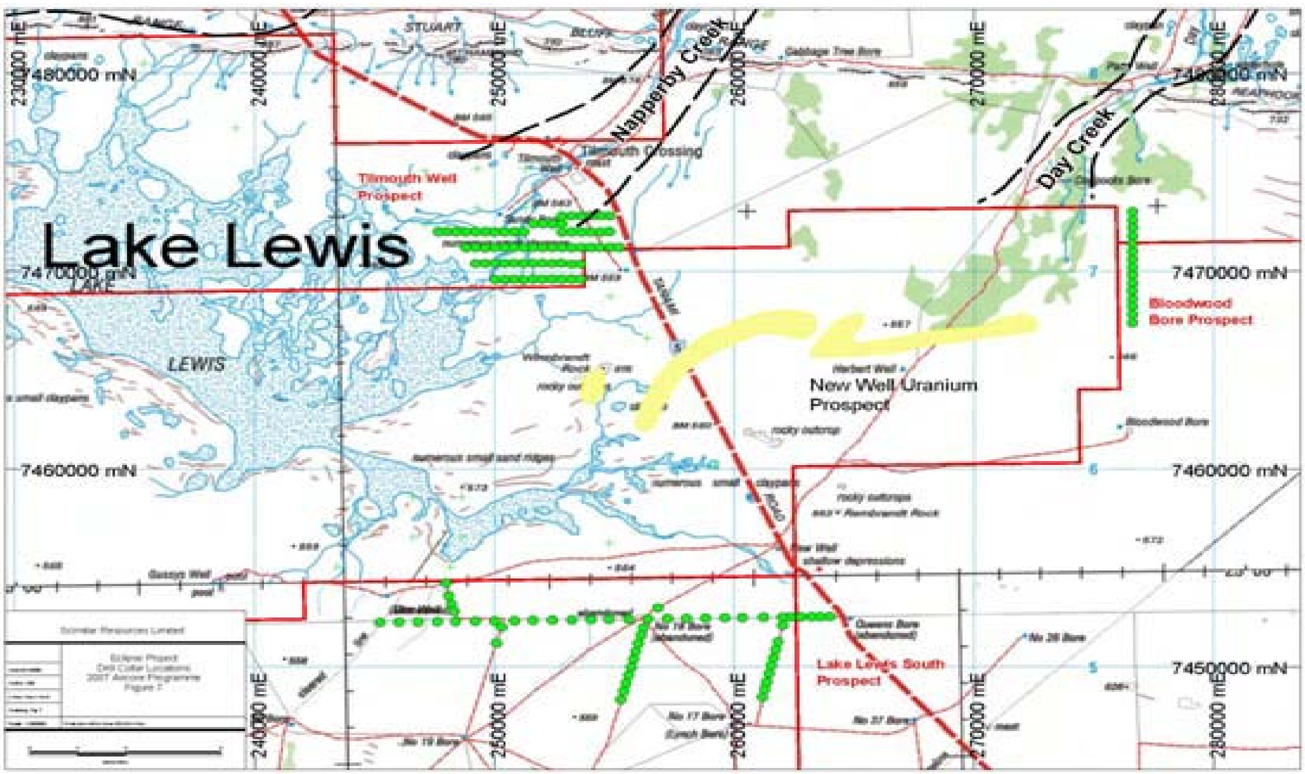
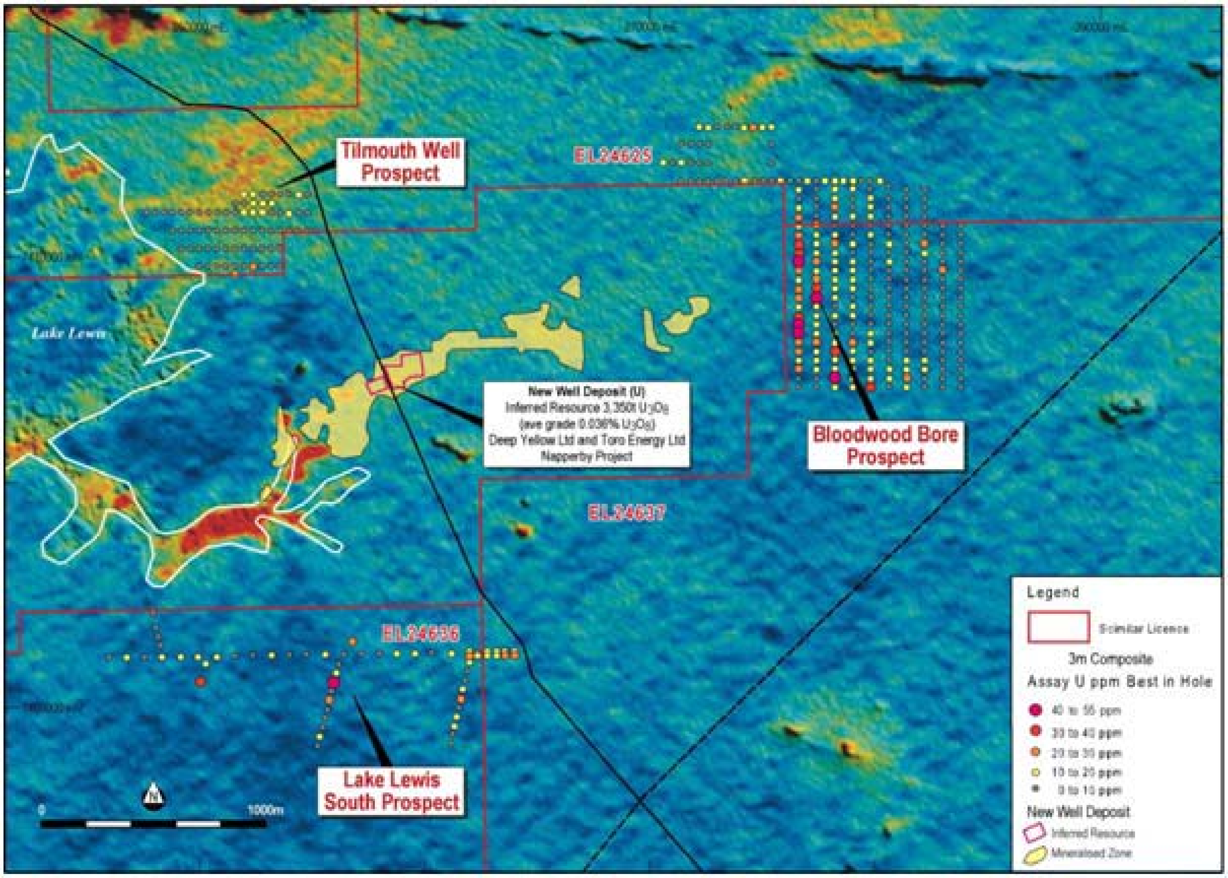


Figure 3 - Drill collar positions and Uranium Intersections

The drilling was completed by Pine Creek based Johannsen Drilling P/L, with a Gemco H13 rig mounted on an Isuzu 4 x 4 truck utilising both an onboard compressor and occasionally a separate truck mounted compressor.

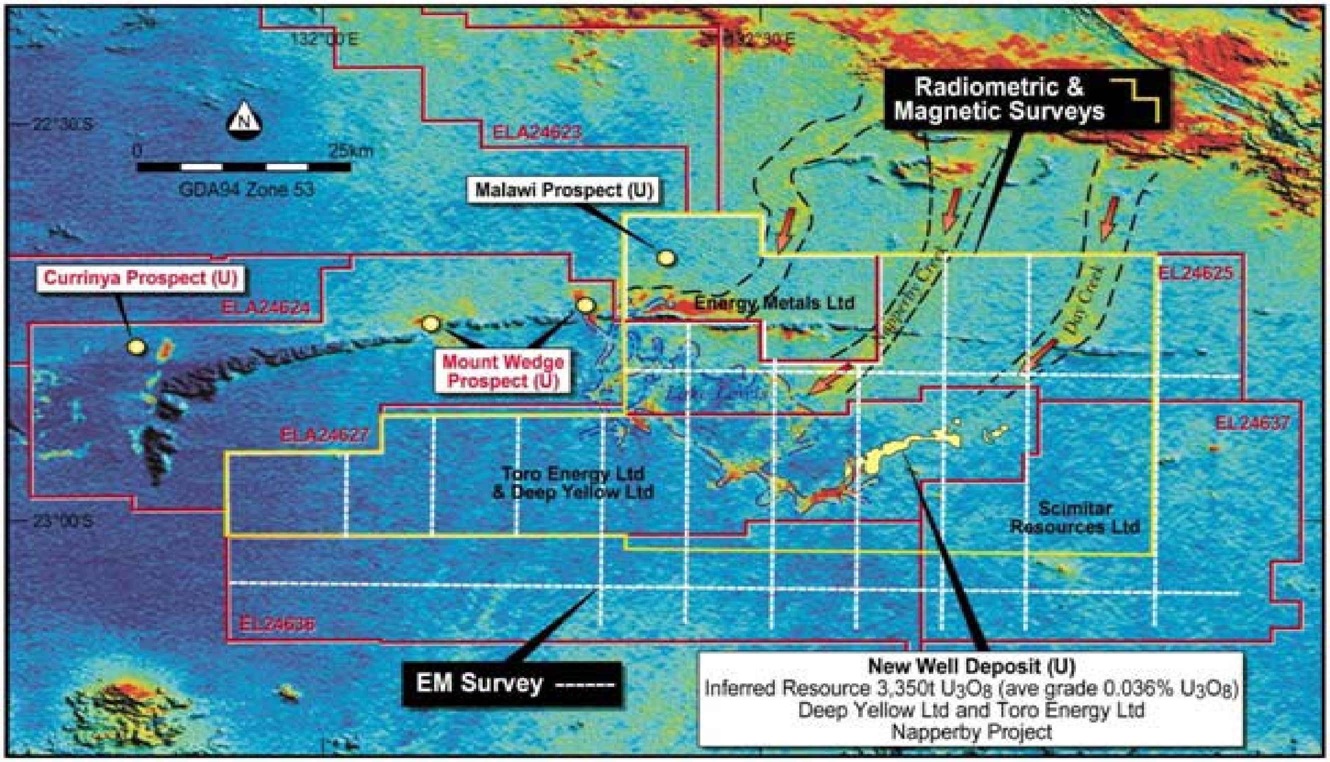
Holes were drilled using a 4 inch open face coring bit. In areas where hard calcrete or silcrete was encountered near the surface, the first 6-12m was drilled using reverse circulation (RC) before switching back to Aircore. The average hole depth was approximately 38 metres, although a few holes were drilled deeper (up to 78 metres) to intersect basement. The holes were collared using 1-2 metres of PVC pipe, which was removed at the completion of each hole. All holes were immediately capped below ground using plastic cone plugs, in accordance with Northern Territory Guidelines. Spoil from the drill collar and outside return was returned to the drill hole before capping. Drill hole collar co-ordinates were recorded using a Garmin 12XL GPS which has a horizontal accuracy of ± 5 metres.



Drill cuttings were collected, via a rig mounted cyclone, into green plastic mining bags. Sample was collected over one metre intervals and laid out sequentially at the drill site. A total of 930 three metre composite samples (ECC 014-028, ECC 528-1069 and ECC 1601-1979) were collected on EL 24636 using an aluminium sampling scoop to give a sample of approximately 3 kg.

The three metre composite samples were collected into individual 10 x 14 inch calico bags. The calico bags were then collected into green plastic mining bags, with five samples per bag. These bags were placed into black plastic No. 10 Nally crates (52 litres) with sealable lids for transport to ALS Laboratories in Alice Springs. The samples were analysed by ALS. The method included drying and pulveriseing to 85% passing 75 µm (Method Code PREP121) before being analysed for the full suite of analytes available using multi acid digest with HF, ICPAES and ICPMS finish (Method code ME-MS61).

Figure 4: Area covered by 2007 Radiometric, Magnetic and Electromagnetic Surveys.



In July 2007, Fugro Airborne Surveys Pty Ltd undertook a broadly spaced trial airborne TEMPEST electromagnetic survey for Eclipse Metals Ltd over part of the Eclipse Project to further define basement topography. This survey was part of a larger survey involving Cauldron's neighbour Toro Energy Ltd. The total coverage for the survey amounted to 550 line kilometres, of which 413 line kilometres was over Cauldrons licences. Interpretation of results from this survey identified additional buried channels and potential target areas for uranium mineralisation, which were tested by drilling (Figure 4.)

A total of 42 line km was completed within the relinquished parts of EL 24625 including one 30km long E/W line and three isolated N/S line segments 3 to 5 km long. Within the relinquished parts of EL 24637, a total of 57 line km was completed, including one 18km W/W line and five isolated N/S line segments 5 to 9 km long. (Figure 4)

An airborne radiometric/magnetic survey was completed by UTS Geophysics in November 2007 as part of a larger survey conducted in association with neighbouring explorers Toro Energy Ltd and Energy Metals Ltd. The survey on 100m line spacing' comprised 16,939 line kilometres (approx 1,500 km^2) over Ecilpse tenements. Only a small section of the survey covers the central and southern part of the relinquished area. (Figure 4)

During 2010 Eclipse Uranium Limited entered into an Option Agreement with Cauldron, whereby Eclipse will become the operators and manager of the Eclipse Project, including EL 24625 and EL 24637, upon Eclipse's successful listing on the ASX.

Over the last year unseasonal weather patterns have led to a shortened field season which has resulted in proposed field activities; such as rehabilitation and site visits being postponed until early 2011.

In March 2011 Eclipse completed a drilling program on EL24625 of 35 holes for 1397m. The program targeted two radiometric holes and encountered anomalous values in nine holes, including 1m at 64ppm U3O8

Some of these historical lines show a number of conductive zones for example at the margin of the Vaughn Springs Quartzite and the Tertiary basin sediments. There are also variations in conductivity within the Tertiary basin sediment.

In 2011, Eclipse Uranium became owners and operators of the Eclipse Project after their successful listing on the ASX on February 17th. In this year Eclipse completed their first drilling program on the Eclipse Uranium Project. A Fugro TEMPEST AEM Program has also been flown for the project which is co –funded by the NTGS Bringing Forward Initiative scheme for EL24625. In conjunction with this Eclipse is also flying lines over the rest of the granted licences in the project which includes EL24637

In September 2011 of a Fugro Tempest Airborne Electromagnetic program on the Eclipse Project (Fig. 5). The program was designed to be flown at 1000m line spacing with tie lines at between 2500m and 4750m depending on the area. A 400m line spaced infill was completed over the conductive target zone in EL24637.

The latest Tempest program was designed to expand on a trial program (a.k.a. Tempest 2007) completed by Scimitar Resources Ltd in July 2007. At the time an anomalous zone was also identified on EL24637.

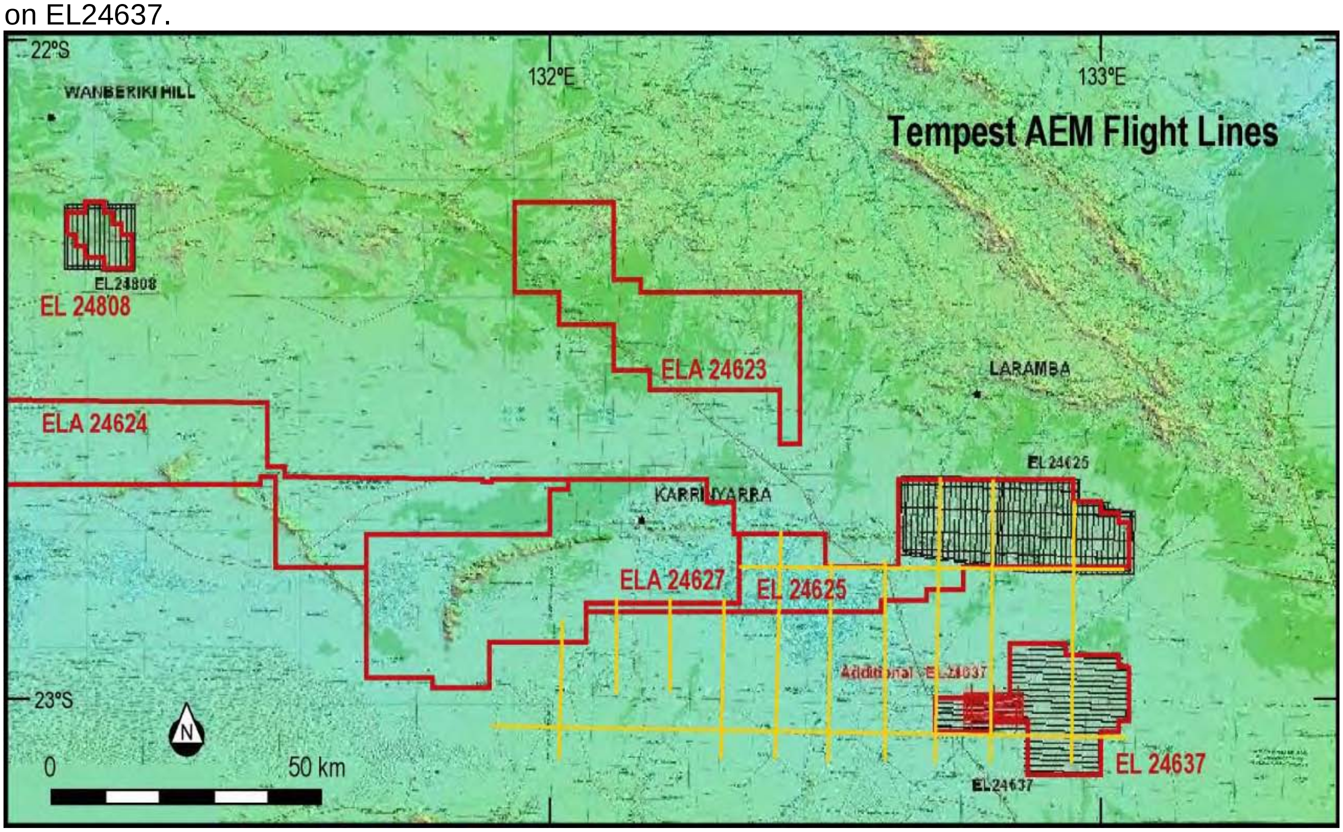


Figure 5: Tempest AEM Flight Lines

Processing of the 2011 Tempest data has defined a series of conductive targets for further investigation on each of the three granted tenements (Fig. 4 & 5). At this stage it is considered that the targets may represent both structure related conductive features as well as interpreted sedimentary targets, for example palaeo-channel environments.

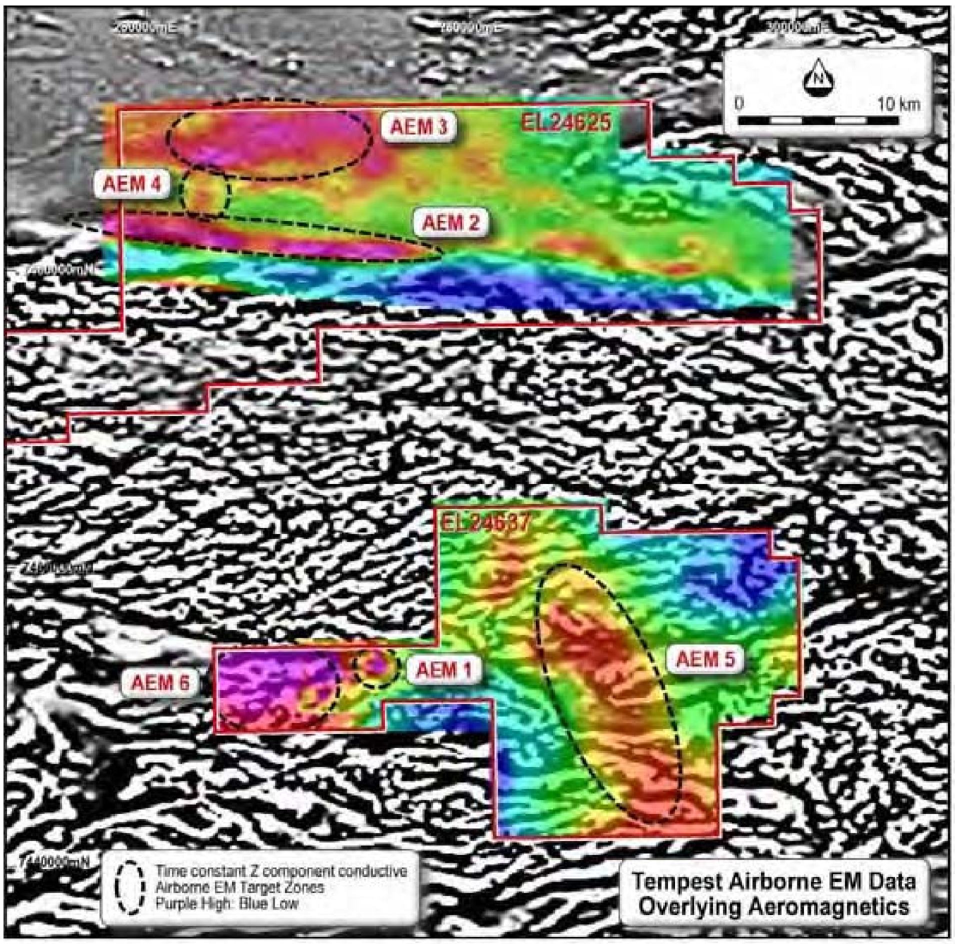


Figure 5: AEM Target outlines in EL24637

June 2012, a major managerial and geological staff change took part in the company with a completely new team taking over key positions. The new team was keen to explore the Ngalia Basin and has since taken office been involved in a thorough desktop geological analysis and re-assessment of all of Eclipse tenements, including the Eclipse Uranium Project (EL24637). Due to time constrains, since taking office 8 months ago, no follow field work was feasible on the ground by the new technical team of Eclipse. This time has been used to start an in-depth desktop analysis of EL24637's geology and associated data. None of this data can be located for the purposes of this report.

10.0 CONCLUSIONS AND RECOMMENDATIONS

During March 2013, consulting geologists Kastellco Geological Consultancy ("KGC") identified high potential uranium and magnetic exploration targets which resulted in the identification of several targets that warrant no further work, thus the tenement is to be relinquished.

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Appendix A - Tempest AEM Processed Data & Survey Report

Ngalia Basin, Northern Territory
TEMPEST
Geophysical Survey

Acquisition and Processing Report

for

Eclipse Uranium Limited

Prepared by :	S. Mulè L. Stenning
Authorised for release by :	………………………….. …………………………..

Survey flown: September 2011

by

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FAS JOB # 2247

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1. SURVEY OPERATIONS AND LOGISTICS

1.1 Introduction

Between the 4th September 2011 and the 23rd September 2011, Fugro Airborne Surveys Pty. Ltd. (FAS) undertook an airborne TEMPEST electromagnetic and magnetic survey for Eclipse Uranium Limited, over the Ngalia Basin Project area in the Northern Territory. The survey consisted of 4 areas. Total coverage of the survey area amounted to 1610 line kilometres flown in 16 flights. The survey was flown using a Shorts Skyvan SC-3-200 aircraft, registration VH-WGT owned and operated by FAS. This report summarises the procedures and equipment used by FAS in the acquisition, verification and processing of the airborne geophysical data.

1.2 Survey Base

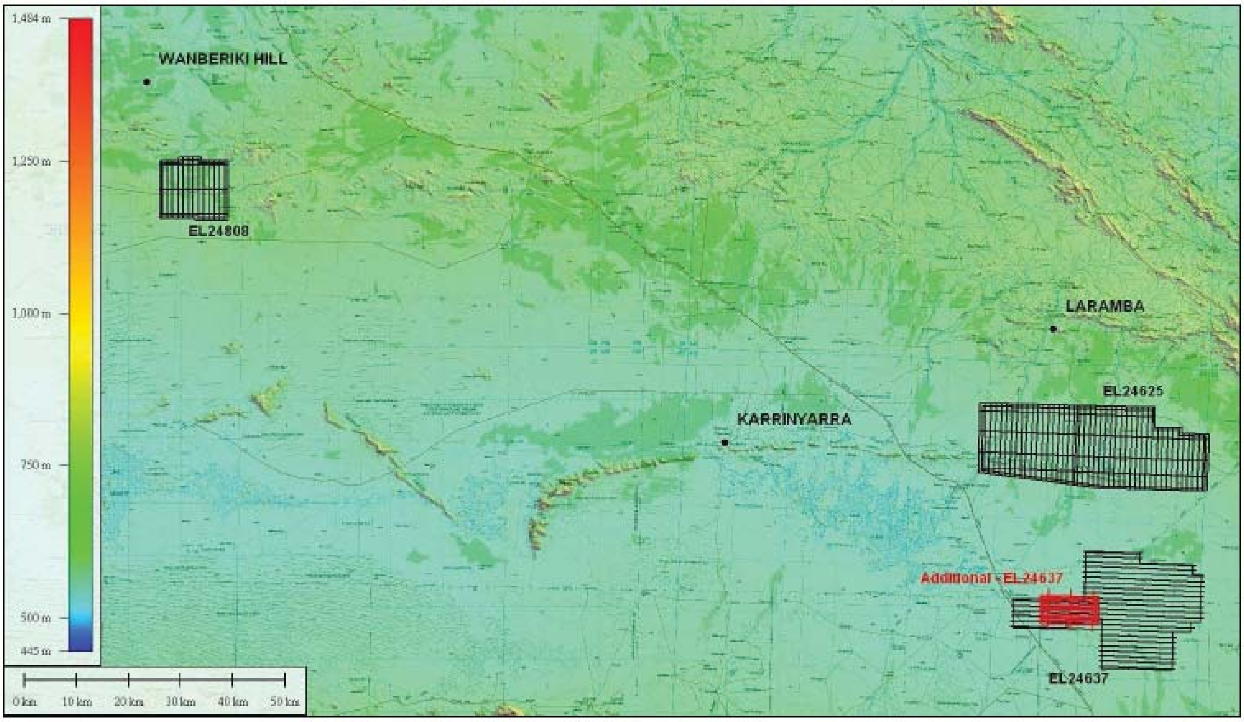
The survey was based out of Alice Springs, Northern Territory. The survey aircraft was operated from Alice Springs Airport with the aircraft fuel available on site. A temporary office was set up at the Elkira Resort, Alice Springs where all survey operations were run and the post-flight data verification was performed.

1.3 Survey Personnel

The following personnel were involved in this project:

Project Supervision	- Acquisition	Bart Anderson
	- Processing	Denis Cowey
On-site Crew Leader		Ben Riggs
Pilot/s		Til Ribarich, Peter Hiskins
System Operator/s		Ben Riggs, Mike Wiriski, Steve Faragalli
Aircraft Engineer		John Remmington Gerney
Field Data Processing		Mohamed Abubeker Shane Mulè
Office Data Processing		Shane Mulè

1.4 Area Map



Ngalia Basin survey areas
GDA94 MGA 52

1.5 General Disclaimer

It is Fugro Airborne Survey's understanding that the data and report provided to the client is to be used for the purpose agreed between the parties. That purpose was a significant factor in determining the scope and level of the Services being offered to the Client. Should the purpose for which the data and report is used change, the data and report may no longer be valid or appropriate and any further use of, or reliance upon, the data and report in those circumstances by the Client without Fugro Airborne Survey's review and advice shall be at the Client's own or sole risk.

The Services were performed by Fugro Airborne Survey exclusively for the purposes of the Client. Should the data and report be made available in whole or part to any third party, and such party relies thereon, that party does so wholly at its own and sole risk and Fugro Airborne Survey disclaims any liability to such party.

Where the Services have involved Fugro Airborne Survey's use of any information provided by the Client or third parties, upon which Fugro Airborne Survey was reasonably entitled to rely, then the Services are limited by the accuracy of such information. Fugro Airborne Survey is not liable for any inaccuracies (including any incompleteness) in the said information, save as otherwise provided in the terms of the contract between the Client and Fugro Airborne Survey.

2. SURVEY SPECIFICATIONS AND PARAMETERS

2.1 Area Co-ordinates

The survey areas were located within GDA94 MGA Zone 52S and 53S, Central Meridian = 129 and 135 (Note - Co-ordinates in GDA94/MGA Zone 52S and 53S)

(Zone 52 S) (Zone 53 S)

EL24808		EL24637						Additional – EL24637		EL2465	
716301	7535442	300060	7460688	281391	7451198	277920	7454839	270002	7450650	257017	7479079
719767	7535453	300085	7458843	279683	7451173	277892	7456685	269936	7454992	256820	7491443
719827	7536105	300110	7456997	277974	7451147	277865	7458531	279998	7455142	289369	7491927
723263	7536056	300134	7455151	274557	7451096	277838	7460377	280061	7450801	289420	7488236
723281	7535453	300159	7453305	274585	7449250	277811	7462223			294557	7488306
728305	7535521	300183	7451460	272877	7449225	277783	7464069			294438	7487310
728254	7524907	298475	7451437	271169	7449199	279493	7464094			299778	7487227
723104	7524982	298500	7449591	269460	7449173	281203	7464119			299841	7477300
723127	7525371	295083	7449545	267752	7449146	282913	7464143			279995	7476991
716162	7525482	295109	7447699	266044	7449120	284623	7464168				
		295134	7445853	264335	7449093	286333	7464192				
		295159	7444007	264306	7450939	288043	7464216				
		295185	7442162	264277	7452785	288069	7462371				
		293477	7442138	264248	7454631	289778	7462395				
		291770	7442114	265957	7454658	291488	7462418				
		290063	7442090	267666	7454684	293198	7462442				
		288355	7442066	269375	7454711	294907	7462465				
		286648	7442042	271084	7454737	296617	7462488				
		284941	7442018	272793	7454763	298326	7462511				
		283233	7441993	274502	7454788	298351	7460666				
		281526	7441968	276211	7454814						

2.2 Survey Area Parameters

Job Number	-	2247
Survey Company	-	Fugro Airborne Surveys Pty Ltd
Date Flown	-	4th September – 23rd September 2011
Client	-	Eclipse Uranium Limited
EM System	-	25 Hz TEMPEST
Navigation	-	Real-time differential GPS
Datum	-	GDA94
Projection	-	MGA Zone 52S and 53S
Project Name	-	Ngalia Basin, Northern Territory
Nominal Terrain Clearance	-	100 m
Total Survey Line Kilometres	-	1610 km

Area	3	4	7	8
EL	EL 24625	EL 24808	EL 24637	EL 24637 (additional)
Projection	MGA Z53S	MGA Z52S	MGA Z53S	MGA Z53S
Traverse Line Spacing	1000 m	1000 m	1000 m	Various
Traverse Line Direction	000 – 180 deg	000 – 180 deg	090 – 270 deg	090 – 270 deg
Traverse Line Numbers	30001 – 30044	40001 – 40013	70001 – 70023	80001 – 80010
Tie Line Spacing	4000 m	4750 m	N/A	2500 m
Tie Line Direction	090 – 270 deg	090 – 270 deg	N/A	000 – 180 deg
Tie Line Numbers	39001 – 39004	49001 – 49003	N/A	89001 – 89003
Line KMs	767 km	188 km	520 km	135 km

2.3 Job Safety Plan

A Job Safety Plan was prepared and implemented in accordance with the Fugro Airborne Surveys Occupational Safety & Health Management System.

3. AIRCRAFT EQUIPMENT AND SPECIFICATIONS

3.1 Aircraft

Manufacturer	-	Shorts Skyvan
Model	-	SC-3-200
Registration	-	VH-WGT
Ownership	-	Fugro Airborne Surveys Pty Ltd

3.2 TEMPEST System Specifications

Specifications of the TEMPEST Airborne EM System (Lane et al., 2000) are:

- Base frequency - 25 Hz
- Transmitter area - 186 m^2
- Transmitter turns - 1
- Waveform - Square
- Duty cycle - 50%
- Transmitter pulse width - 10 ms
- Transmitter off-time - 10 ms
- Peak current - 300 A
- Peak moment - 55800 Am^2
- Average moment - 27900 Am^2
- Sample rate - 75 kHz on X and Z
- Sample interval - 13 microseconds
- Samples per half-cycle - 1500
- System bandwidth - 25 Hz to 37.5 kHz
- Flying height - 100 m (subject to safety considerations)
- EM sensor - Towed bird with 3 component dB/dt coils
- Tx-Rx horizontal separation - 115 m (nominal)
- Tx-Rx vertical separation - 40 m (nominal)
- Stacked data output interval - 200 ms (~12 m)
- Number of output windows - 15
- Window centre times - 13 µs to 16.2 ms
- Magnetometer - Stinger-mounted cesium vapour
- Magnetometer compensation - Fully digital
- Magnetometer output interval - 200 ms (~12 m)
- Magnetometer resolution - 0.001 nT
- Typical noise level - 1.0 nT
- GPS cycle rate - 1 second

3.2.1 EM Receiver and Logging Computer

The EM receiver computer was an EMFASDAS. The EM receiver computer executes a proprietary program for system control, timing, data acquisition and recording. Control, triggering and timing is provided to the TEMPEST transmitter and Digital Signal Processing (DSP) boards by the timing card, which ensures that all waveform generation and sampling is accomplished with high accuracy. The timing card is synchronised to the Global Positioning System (GPS) through the use of the Pulse Per Second (PPS) output from the system GPS card. Synchronisation is also provided to the magnetometer processor card for the purpose of accurate magnetic sampling with respect to the EM transmitter waveform.

The EM receiver computer displays information on the main screen during system calibrations and survey line acquisition to enable the airborne operator to assess the data quality and performance of the system.

3.2.2 TEMPEST Transmitter

The transmitted waveform is a square wave of alternating polarity, which is triggered directly from the EM receiver computer. The nominal transmitter base frequency was 25 Hz with a pulse width of 10ms (50 % duty cycle). Loop current waveform monitoring is provided by a current transformer located directly in the loop current path to allow for full logging of the waveform shape and amplitude, which is sampled by the EM receiver.

3.2.3 TEMPEST 3-Axis Towed Bird Assembly

The TEMPEST 3-axis towed bird assembly provides accurate low noise sampling of the X (horizontal in line), Y (horizontal transverse) and Z (vertical) components of the electromagnetic field. The receiver coils measure the time rate of change of the magnetic field (dB/dt). Signals from each axis are transferred to the aircraft through a tow cable specifically designed for its electrical and mechanical properties.

3.3 FASDAS Survey Computer

The Survey computer executes a proprietary program for acquisition and recording of location, magnetic and ancillary data. Data are presented both numerically and graphically in real time on the Video Graphics Array (VGA) Liquid Crystal Display (LCD) display, which provides an on-line display capability. The operator may alter the sensitivity of the displays on-line to assist in quality control. Selected EM data are transferred from the EM receiver computer to the SURVEY computer for quality control (QC) display.

3.3.1 Cesium Vapour Magnetometer Sensor

A cesium vapour magnetometer sensor is utilised on the aircraft and consists of the sensor head and cable, and the sensor electronics. The sensor head is housed at the end of a composite material tail stinger.

3.3.2 Magnetometer Processor Board

A FASDAS magnetometer processor board is used for de-coupling and processing the Larmor frequency output of the magnetometer sensor. The processor board interfaces with the survey computer, which initiates data sampling and transfer for precise sample intervals and also with the EM receiver computer to ensure that the magnetic samples remain synchronised with the EM system.

3.3.3 Fluxgate Magnetometer

A tail stinger mounted Bartington MAG-03MC three-axis fluxgate magnetometer is used to provide information on the attitude of the aircraft. This information is used for compensation of the measured magnetic total field.

3.3.4 GPS Receiver

A Novatel GPScard 951R is utilised for airborne positioning and navigation. Satellite range data are recorded for generating post processed differential solutions.

3.3.5 Differential GPS Demodulator

The OMNISTAR differential GPS service provides real time differential corrections.

3.4 Navigation System

A FASDAS Navigation Computer was used for real-time navigation. These computers load a pre-programmed flight plan from disk which contains boundary co-ordinates, line start and end co-ordinates, local co-ordinate system parameters, line spacing, and cross track definitions. The World Geodetic System 1984 (WGS84) latitude and longitude positional data received from the Novatel GPS card contained in the SURVEY computer is transformed to the local co-ordinate system for calculation of the cross track and distance to go values. This information, along with ground heading and ground speed, is displayed to the pilot numerically and graphically on a two line LCD display, and on an analogue Horizontal Strip Indicator (HSI). It is also presented on a LCD screen in conjunction with a pictorial representation of the survey area, survey lines, and ongoing flight path.

The Navigation computers are interlocked to the SURVEY computer for auto selection and verification of the line to be flown. The GPS information passed to the navigation computer is corrected using the received real time differential data from the OMNISTAR service, enabling the aircraft to fly as close to the intended track as possible.

3.5 Altimeter System

3.5.1 Radar Altimeter

Model:	Collins RL 50 radio altimeter system
Sample interval:	0.2 second
Accuracy:	+/- 1.5 % of indicated altitude.

The Collins radio altimeter is a high quality instrument whose output is factory calibrated. It is fitted with a test function which checks the calibration of a terrain clearance of 100 feet, and altitudes which are multiples of 100 feet. The aircraft radio altitude is recorded onto digital tape as well as displayed on the aircraft chart recorder. The recorded value is the average of the altimeters output during the previous second.

3.5.2 Laser Altimeter

Model:	Optech 501SB (WGT)
Sample interval:	0.2 second
Accuracy:	± 0.05m at survey altitude

3.5.3 Barometric Altimeter

Output of a Digiquartz 215A-101pressure transducer is used for calculating the barometric altitude of the aircraft. The atmospheric pressure is taken from a gimbal-mounted probe projecting 0.5 metres from the wing tip of the aircraft and fed to the transducer mounted in the aircraft wingtip.

3.6 Video Tracking System

The video file recorded by the digital video system is synchronised with the geophysical record by a digital fiducial display. It is also labelled with GPS latitude and longitude information and survey line number.

3.7 Data Recorded by the Airborne Acquisition Equipment

With the FASDAS acquisition system the raw EM data including fiducial, local time, X and Z axis sensor response, current monitor and bird auxiliary sensor output are recorded on the EM receiver computer as “*.raw” EM files. Logging to the files is continuous, however, a new *.raw EM file is created when the size of the previous one reaches 1Gb.

The FASDAS Survey computer records a continuous MSD file which contains all other ancillary data including magnetic, altimeter, GPS and analogue channels.

4. GROUND DATA ACQUISITION EQUIPMENT AND SPECIFICATIONS

4.1 Magnetic Base Station

A CF1 and a Scintrex ENVI magnetometer were used to measure the daily variations of the Earth's magnetic field. The base stations were established in an area of low gradient, away from cultural influences. The base stations were run continuously throughout the survey flying period with a sampling interval of 1 and 5 seconds respectively, at a sensitivity of 0.01 nT. The base station data were closely examined after each day's production flying to determine if any data had been acquired during periods of out-of-specification diurnal variation. The base stations were located approximately 80 m apart at Alice Springs Airport.

4.2 GPS Base Station

A GPS base logging station was set up at Alice Springs Airport. The sensor was contained in the CF1 unit.

The GPS base system was comprised of a Novatel GPS PC card mounted in a portable IBM computer. The computer is connected to a mains UPS backup, with a reserve capacity of approximately 100 minutes, to ensure continuous data logging in the event of mains power interruptions.

The GPS base station position was calculated by logging data continuously at the base position over a period of approximately 11 hours. These data were then statistically averaged to obtain the position of the base station using GrafNav software.

The calculated GPS base position was (in WGS84):

Lat: 23° 47' 53.36386" S
Long: 133° 53' 6.54147" E
Height: 558.222 m. (WGS84 Ellipsoidal Height)

5. EM AND OTHER CALIBRATIONS AND MONITORING

At the beginning and end of each individual survey flight, the EM system is checked for background noise levels and performance. All of these checks are conducted at a nominal terrain clearance of 600 m (2000 ft) to eliminate ground response.

These checks include:-

5.1 GPS Repeat Point

Where possible, the aircraft is parked in the same position after every flight and the GPS position recorded pre and post flight, to allow for checks on GPS quality and repeatability. *Note: FFFF is the flight number and PP is the attempt number.*

Pre-Flight GPS Repeat Point: Line 505FFFFPP
Post-Flight GPS Repeat Point: Line 605FFFFPP

5.2 Transmitter-off

These lines are recorded in straight and level flight with the system in standard survey geometry, with the transmitter turned off and bird response turned on to observe ambient noise and to check for noise in the receiver system (bird/coils → tow cable → winch → computer). *Note: FFFF is the flight number and PP is the attempt number.*

Pre-Flight Transmitter-off: Line 900FFFFPP
Post-Flight Transmitter-off: Line 906FFFFPP

5.3 Noise Additive

These lines are recorded in straight and level flight with the system in standard survey geometry, with the transmitter on and the bird response turned off at the tow cable winch. This is to check the noise contribution from the acquisition system and is used in deconvolution of survey line data. *Note: FFFF is the flight number and PP is the attempt number.*

Pre-Flight Noise Additive: Line 901FFFFPP
Post-Flight Transmitter-off: Line 904FFFFPP

5.4 Zero

These lines are recorded in straight and level flight with the system in standard survey configuration with transmitter and receiver turned on. This is used to determine the system's response in the absence of ground signal and is used to determine a standard waveform for deconvolution of survey lines. *Note: FFFF is the flight number and PP is the attempt number.*

Additionally, through all these calibrations the airborne operator can assess the system and ambient noise levels.

Pre-Flight Zero: Line 902FFFFPP
Post-Flight Zero: Line 905FFFFPP

5.5 Swoops

This line is recorded immediately after the pre-flight zero. During this manoeuvre the pilot conducts a series of 'swoop' manoeuvres (pitch up/pitch down) over approximately 30-40 seconds to vary the position of the towed sensor relative to the aircraft. The EM data are monitored by the airborne operator to confirm correct operation of the system during the manoeuvre. This data is used to determine coefficients used in the processing to compensate for such variations in the survey data. *Note: FFFF is the flight number and PP is the attempt number.*

Pre-Flight Swoop: Line 903FFFFPP

5.6 Dynamic Magnetometer Compensation

To limit aircraft manoeuvre effects on the magnetic data that can be of the same spatial wavelength as the signals from geological sources, compensation calibration lines are flown in a low magnetic gradient area close to the survey. This involves flying a series of tests on the survey line heading and approximately 15 degrees either side to accommodate small heading variations whilst flying survey lines. The data for each heading consists of a series of aircraft manoeuvres, including pitches, rolls and yaws. This is done to artificially create the most extreme possible attitude the aircraft may encounter whilst on survey. Data from these lines are used to derive compensation coefficients for removing magnetic noise induced by the aircraft's attitude in the naturally occurring magnetic field.

Compensation data were acquired on the dates below.

18th and 22nd September 2011

5.7 Parallax Checks

Due to the relative positions of the EM towed bird and the magnetometer instruments on the aircraft and to processing / recording time lags, raw readings from each vary in position. To correct for this and to align selected anomaly features on lines flown in opposite directions, magnetics, EM data and the altimeters are 'parallaxed' with respect to the position information. System parallax is checked occasionally or following any major changes in the aircraft system, which are likely to affect the parallax values.

Variable	Parallax Value
Magnetics	0.2 s
GPS	0 s
Radar Altimeter	0 s
Laser Altimeter	0 s
EM - X	- 1.2 s
EM – Z	- 1.4 s

5.8 Radar Altimeter Calibration

The radar altimeter is checked for accuracy and linearity every 12 months or when any change in a key system component requires this procedure to be carried out. This calibration allows the radar altimeter data to be compared and assessed with other height data (GPS and barometric) to confirm the accuracy of the radar altimeter over its operating range.

Absolute radar and barometric altimeter calibration was carried out over water at Mandurah, Western Australia, and was successful in calibrating the radar altimeter to information provided by the GPS and barometer instrument. Calibration factors were as expected. The calibration procedure also provides parallax information required for positional correction of the radar and GPS altimeters.

5.9 Heading Error Checks

Historically, heading error checks have been part of the aeromagnetic data acquisition procedure but they are no longer used. Fugro Airborne Surveys now calculates these effects using the aircraft magnetic compensation system and specially developed software. The precision to which these effects are now calculated and corrected for is far in excess of the manual methods used in the past.

6. DATA PROCESSING

6.1 Field Data Processing

6.1.1 Quality Control Specifications

6.1.1.1 Navigation Tolerance

The re-flight specifications applied for the duration of the survey were:

Electronic Navigation - absence of electronic navigation data (e.g. GPS base station fails).

Flight Path - where the flightpath deviates from the flightplan by more than 50% of the nominal line spacing for more than 5 kilometres or where lines cross. The line spacing measurements to be used in determining such reflights will be made from the field flight path recovery

Altitude - terrain clearance continuously exceeds the nominal terrain clearance by plus or minus 30 m over a distance of 5 km or more unless to do so would, in the sole opinion of the pilot, jeopardise the safety of the aircraft or the crew or the equipment or would be in contravention of the Civil Aviation Safety Authority regulation such as those pertaining to built up areas.

6.1.1.2 Magnetics Noise and Diurnal Tolerance

The re-flight specifications applied for the duration of the survey were:

Magnetic Diurnal - where the magnetometer base station data exceeds a 10 nT change in 10 minutes.

6.1.1.3 Electromagnetic Data

The quality control checks on the electromagnetic data were:

Noise - where RMS noise in the last channel of the EM data exceeds 0.1 fT over 3 km for B-field (assessed in a resistive region) or where FAS believes an important anomaly is rendered un-interpretable.

Sferics – where sferic activity renders a potential anomaly un-interpretable.

6.1.2 In-Field Data Processing

Following acquisition, multiple copies of the EM data are made onto DVDs or CDs. The EM, location, magnetic and ancillary data are then processed at the field base to the point that the quality of the data from each flight can be fully assessed. Copies of the raw and processed data are then transferred to Perth for final data processing. A more comprehensive statement of EM data processing is given in section 6.2.3.

6.2 Final Data Processing

6.2.1 Magnetics

Magnetic data were compensated for aircraft manoeuvre noise using coefficients derived from the appropriate compensation flight. Base station data is edited so that all significant spikes, level shifts and null data are eliminated.

A diurnal base value was then added.

Area	Base Value
Ngalia Basin	53200nT

A lag was applied to synchronise the magnetic data with the navigation data.

The International Geomagnetic Reference Field (IGRF) 2010 model (updated for secular variation) was removed from the levelled total field magnetics. An IGRF base value was then added to the data.

Area	Base Value	Updated Model
Ngalia Basin	52695 nT	7/8/2011

Where appropriate the magnetic data was tie line levelled. A FAS proprietary microlevelling process was then applied in order to more subtly level the data.

6.2.2 Derived Topography

Aircraft navigation whilst in survey mode is via real time differential GPS, obtained by combining broadcast differential corrections with on-board GPS measurements. Terrain clearance is measured with a laser altimeter.

The ground elevation, relative to the WGS84 spheroid used by GPS receiver units, is obtained by finding the difference between the terrain clearance (from the final processed and edited laser altimeter) and the aircraft GPS antenna altitude above the ellipsoid (GPS height derived from post-processing of the DGPS data using the field base station data), and taking into account that the laser altimeter is mounted 2.3 metres below the GPS antenna.

The digital elevation model derived from this survey can be expected to have an absolute accuracy of +/- several metres in areas of low to moderate topographic relief. Sources of error include uncertainty in the height of the GPS base station, variations in the laser altimeter characteristics over ground of varying surface characteristics (ie. false and non-returns are more prevalent over dense vegetation and water, respectively), and the finite footprint of the laser altimeter.

Following this, where appropriate, tie line and micro-levelling was applied in order to more subtly level the data. The algorithms are FAS proprietary operations used to remove the small across-line corrugations that may appear in the gridded data. The micro-levelling process attempts to de-corrugate the data without destroying the data's integrity. This is achieved by confining the changes to very small values and applying them as a correction to the along-line data.

An N-Value is then subtracted to correct the final data to the Australian Height Datum (AHD).

The accuracy of the elevation calculation is directly dependent on the accuracy of the two input parameters, laser altitude and GPS altitude. The GPS altitude value is dependent on the number of available satellites, plus the accuracy of the averaged GPS base position. Although post-processing of GPS data will yield X and Y accuracies in the order of 0.5 metres, the accuracy of the altitude value is usually much less, but generally still within 1-2 metres. Further inaccuracies may be introduced during the interpolation and gridding process as only 1 out of every 5 points across-line is real data. Furthermore, along line obstructions may cause the pilot to veer laterally and so data interpolated between lines may vary significantly from real topography, and do not show artificial vertical obstructions.

Because of the inherent inaccuracies of this method, no guarantee is made or implied that the information displayed is a true representation of the height above sea level. Although this product may be of some use as a general reference, THIS PRODUCT MUST NOT BE USED FOR NAVIGATION PURPOSES.

6.2.3 Electromagnetic Data Processing

Details of the pre-processing applied to TEMPEST data can be found in Lane et al. (2000).

6.2.3.1 Standard EM Processing

Calibration
High altitude calibration data are used to characterise the system response in the absence of any ground response.

Cleaning and Stacking
Routines to suppress sferic noise, powerline noise, VLF noise, coil motion noise (collectively termed “cleaning”) and to stack the data are applied to the survey line data. Output from the stacking filter is drawn at 0.2 second intervals. The stacked data are saved to file as an internal data management practice.

Deconvolution and Binning
The survey height stacked data are deconvolved using the high altitude reference waveform. The effect of currents in the transmitter loop and airframe (“primary”) are then removed, leaving a “pure” ground response. The deconvolved ground response data are then transformed to B-field response for a perfect 100% duty cycle square wave. Finally, the evenly spaced samples are binned into a number of windows.

Table of TEMPEST window information for 25Hz base frequency

Window #	Start sample	End sample	No of samples	start time (s)	End time (s)	centre time (s)	centre time (ms)
1	1	2	2	0.000007	0.000020	0.000013	0.013
2	3	4	2	0.000033	0.000047	0.000040	0.040
3	5	6	2	0.000060	0.000073	0.000067	0.067
4	7	10	4	0.000087	0.000127	0.000107	0.107
5	11	16	6	0.000140	0.000207	0.000173	0.173
6	17	26	10	0.000220	0.000340	0.000280	0.280
7	27	42	16	0.000353	0.000553	0.000453	0.453
8	43	66	24	0.000567	0.000873	0.000720	0.720
9	67	102	36	0.000887	0.001353	0.001120	1.120
10	103	158	56	0.001367	0.002100	0.001733	1.733
11	159	246	88	0.002113	0.003273	0.002693	2.693
12	247	384	138	0.003287	0.005113	0.004200	4.200
13	385	600	216	0.005127	0.007993	0.006560	6.560
14	601	930	330	0.008007	0.012393	0.010200	10.200
15	931	1500	570	0.012407	0.019993	0.016200	16.200

The data are reviewed after windowing. Any decisions involving re-flights due to AEM factors are made at this point.

Raw and Final EM Data
The “raw” or “uncorrected” EM amplitudes reflect, not only the variations in ground conductivity, but the variations in geometry of the various parts of the EM measurements (i.e. transmitter loop pitch, transmitter loop roll, transmitter loop terrain clearance, transmitter loop to receiver coil horizontal longitudinal separation, transmitter loop to receiver coil horizontal transverse separation, and transmitter loop to receiver coil vertical separation) during the survey. For example, the largest influence on the early time EM amplitude is the terrain clearance of the transmitter loop. The larger the terrain clearance, the smaller the amplitude. Later window times (larger window number) show diminished variations due to terrain clearance.

“Final” or “geometry-corrected” located data are produced for optimum presentation of the EM amplitude data in image format (e.g. window amplitude images, principal component analysis images derived from the window amplitudes (Green,1998b)). Between “raw” and “final” states, the ground response data undergo an approximate correction to produce data from a nominated standard geometry. A dipole-image method (Green, 1998a) is used to adjust the data to the response that would be expected at a standard terrain clearance (100m), standard transmitter loop pitch and roll (zero degrees), and a standard transmitter loop to receiver coil geometry (115m behind and 40m below the aircraft). These variables have been set to their respective standard values in the “final” located data (whereas the “raw” located data file contains the variable field data). Zero parallax is applied to transmitter loop pitch, roll, terrain clearance, X component EM and Z component EM data prior to geometry correction. Over extremely conductive ground (e.g. > 100 S conductance), the estimates for transmitter loop to receiver coil separation determined from the primary field coupling factors may be in error at the metre scale due to uncertainty in the estimation of the primary field. This will influence the accuracy of very early time window amplitude information in the “geometry-corrected” located data. Receiver coil pitch has a significant effect on early time Z component response and late time X component response (Green and Lin, 1996). Receiver coil roll impacts early time Z component response.

Levelling
Limited range micro-levelling may be applied to the final window amplitudes for presentation purposes, principally for multi-flight surveys or when isolated re-flight lines are present.

6.2.3.2 Factors and Corrections

Geometric Factor
The geometric factor gives the ratio of the strength of the primary field coupling between the transmitter loop and the receiver coil at each observation relative to the coupling observed at high altitude during acquisition of reference waveform data. Variations in this factor indicate a change in the attitude and/or relative separation of the transmitter loop and the receiver coil.

Transmitter-Receiver Geometry
Transmitter to receiver geometry values for each observation are derived from the high altitude reference waveforms and knowledge of the system characteristics. These data are available in the located data (see section 6.2.6.1 for “standardised” values)

GPS Antenna, Laser Altimeter and Transmitter Loop Offset Corrections
The transmitter loop was mounted 0.1m above the GPS antenna on the aircraft. The GPS antenna is 3.3m above the belly of the aircraft. The laser altimeter sensor is mounted in the belly of the aircraft. Therefore a total of 3.05m (-0.25m + 3.3m) was added to the laser altimeter data to determine the transmitter loop height above the ground.

Transmitter Loop Pitch and Roll Correction
Measured vertical gyro aircraft pitch and roll attitude measurements are converted to transmitter loop pitch and roll by adding 0.45 degrees for pitch and 0.6 degrees for roll. Nose up is positive for pitch, and left wing up is positive for roll.

6.2.3.3 Primary Sources of EM Noise

A number of “monitor” values are calculated during processing to assist with interpretation. They generally represent quantities that have been removed as far as is practical from the data, but may still be present in trace amounts. These are more significant for interpretation of discrete conductors than for general mapping applications.

Sferic Monitor
Sferics are the electromagnetic signals associated with lightning activity. These signals travel large distances around the Earth. Background levels of sferics are recorded at all times from lightning activity in tropical areas of the world (eg tropical parts of Asia, South America and Africa). Additional higher amplitude signals are produced by "local" lightning activity (ie at distances of kilometres to hundreds of kilometres).

The sferic monitor is the sum of the absolute differences brought about by the sferic filter operations, summed over 0.2 second intervals, normalised by the receiver effective area. It is given in units of uV/sq.m/0.2s. Many sferics have a characteristic form that is well illustrated by figure 2 in Garner and Thiel (2000). The high frequency, initial part of a sferic event can be detected and filtered more easily than the later, low frequency portion. The sferic monitor indicates where at least the high frequency portion of a sferic has been successfully removed, but it is quite possible that lower frequency elements of the sferic event may have eluded detection, passing through to the window amplitude data. Thus, discrete anomalies coincident with sferic activity as indicated by the sferic monitor should be down-weighted relative to features clear of any sign of sferic activity.

Low Frequency Monitor

The Low Frequency Monitor (LFM) makes use of amplitudes at frequencies below the base frequency which are present in the streamed data to estimate the amplitude of coil motion (Earth magnetic field) noise at the base frequency in log10(pV/sqrt(Hz)/sq.m). The coil motion noise below the base frequency is rejected through the use of tapered stacking, but the coil motion noise at the base frequency itself is not easily removed. A sharp spike in the LFM can be an indicator of a coil motion event (eg the bird passing through extremely turbulent air). Note that the LFM will also respond to sferic events with an appreciable low frequency (sub-base frequency) component. This situation can be inferred when both the LFM and sferic monitors show a discrete kick.

Powerline Monitor

The powerline monitor gives the amplitude of the received signal at the powerline frequency (50 or 60 Hz) in log10(pV/sqrt(Hz)/sq.m). Careful selection of the base frequency (such that the powerline frequency is an even harmonic of the base frequency) and tapered stacking combine to strongly attenuate powerline signals. When passing directly over a powerline, the rapid lateral variations in the strength and direction of the magnetic fields associated with the powerline can result in imperfect cancellation of the powerline response during stacking. Some powerline-related interference can manifest itself in a form that is similar to the response of a discrete conductor. The exact form of the monitor profile over a powerline depends on the line direction, powerline direction, powerline current, and receiver component, but the monitor will show a general increase in amplitude approaching the powerline.

Grids (or images) of the powerline monitor reveal the location of the transmission lines. Note that the X component (horizontal receiver coil axis parallel with the flight line direction) does not register any response from powerlines parallel to the flight line direction since the magnetic fields associated with powerlines only vary in a direction perpendicular to the powerline. Note also that the Z component (vertical receiver coil axis) shows a narrow low directly over the powerline where the magnetic fields are purely horizontal.

Very Low Frequency Monitors

Wide area VLF communication signals in the 15 to 25 kHz frequency band are monitored by the TEMPEST system. In the Australian region, signals at 18.2 kHz, 19.8 kHz, 21.4 kHz and 22.2 kHz are monitored as the amplitude of the received signal at these frequencies in log10(pV/sqrt(Hz)/sq.m). The strongest signal comes from North West Cape (19.8 kHz). The signal at 18.2 kHz is often observed to pulse in a regular sequence. These strong narrow band signals have some impact on the high frequency response of the system, but they are strongly attenuated by selection of the base frequency and tapered stacking. The VLF transmissions are strongest in amplitude, in the horizontal direction at right angles to the direction to the VLF transmitter. This directional dependence enables the VLF monitors to be used to indicate the receiver coil attitude.

6.2.3.4 Other Sources of EM Noise

Man-made periodic discharges

If an image of the Z component sferic monitor shows the presence of spatially coherent events, then pulsed cultural interference would be strongly suspected. Since sferic signals are much stronger in the horizontal plane than in the vertical plane, few sferics of significant amplitude are recorded in Z component data. In contrast, evidence of cultural interference is generally swamped by true sferics in X component sferic monitor images.

Electric fences are the most common source of pulsed cultural interference. Periodic discharges (eg every second or so) into a large wire loop (fence) produce very large spikes in raw data. These are attenuated to a large degree by the sferic filter, but a residual artefact can still be present in the processed data.

Coil motion / Earth field noise
A change in coupling between the receiver coil and the ambient magnetic field will induce a voltage in the receiver coil. This noise is referred to as coil motion or Earth field noise. Receiver coils in the towed bird are suspended in a fashion that attempts to keep this noise below the noise floor at frequencies equal to and above the base frequency of the system. Severe turbulence, however, can result in 'coil knock events' that introduce noise into the processed data.

Grounded metal objects
Grounded extensive metal objects such as pipelines and rail lines can qualify as conductors and may produce a response that is visible in processed data. Grounded metal objects produce a response similar to shallow, highly conductive, steeply dipping conductors. These objects can sometimes be identified from good quality topographic maps, from aerial photographs, by viewing the tracking video, from their unusual spatial distribution (ie often a series of linear segments) and in some circumstances from their effect on the powerline monitor. A powerline running close to a long metal object will induce a 50 Hz response in the object.

6.2.4 Conductivity Depth Images (CDI)

CDI conductivity sections for TEMPEST data were calculated using EMFlow and then modified to reflect the finite depth of investigation using an in-house routine, *Sigtime*.

The *Sigtime* routine removes many of the spurious conductive features that appear at depth as a result of fitting long time constant exponential decays to very small amplitude features in the late times. For each observation, the time when the response falls below a signal threshold amplitude is determined. This time is transformed into a diffusion depth with reference to the conductivity values determined for that observation. Anomalous conductivity values below this depth are replaced by background values or set to undefined, reflecting the uncertainty in their origin. The settings and options applied are indicated in the appropriate header files for *Sigtime* output. This procedure is different to that which would be obtained by filtering conductivity values using either a constant time or constant depth across the entire line.

The "final" Z component EM data were input into version 5.10 of EMFlow to calculate Conductivity Depth Images (CDI). Conductivity values were calculated at each point then run through *Sigtime.*

EMFlow was developed within the CRC-AMET through AMIRA research projects (Macnae et al, 1998, Macnae and Zonghou, 1998, Stolz and Macnae, 1998). The software has been commercialised by Encom Technology Pty Ltd. Examples of TEMPEST conductivity data can be seen in Lane et al. (2000), Lane et al. (1999), and Lane and Pracillio (2000).

Conductivity values were calculated to a depth of 500 m below surface at each point, using a depth increment of 5 m and a conductivity range of 0.1-100mS/m.

6.2.5 System Specifications for Modelling TEMPEST Data

Differences between the specifications for the acquisition system, and those of the virtual system for which processed results are given, must be kept in mind when forward modelling, transforming or inverting TEMPEST data.

Acquisition is carried out with a 50% duty cycle square transmitter current waveform and dB/dt sensors.

During processing, TEMPEST EM data are transformed to the response that would be obtained with a B-field sensor for a 100% duty cycle square waveform at the base frequency, involving a 1A change in current (from -0.5A to +0.5A to -0.5A) in a 1sq.m transmitter. Data are given in units of femtotesla (fT = 10^{-15} Tesla). It is this configuration, rather than the actual acquisition configuration, which must be specified when modelling TEMPEST data.

Window timing information is given above (see section 6.2.3).

6.2.5.1 Standard Height and Geometry

The "final" EM data have been standardised through an approximate transformation to a standard transmitter loop terrain clearance, transmitter loop pitch and roll of zero degrees, and a fixed transmitter loop to receiver coil geometry (roughly equal to the average "raw" geometry values). Transmitter loop pitch, transmitter loop roll and transmitter loop terrain clearance values for each observation have been modified to reflect the standard values. Hence, the "final" (fixed) geometry values should be used if modelling with the final X- and Z-component amplitude data - the following table summarises the values used to correct the transmitter height/pitch/roll/geometry to.

Table of values used to standardise transmitter loop height, pitch, roll and geometry

Variable	Standardised value
Transmitter loop pitch	0 degrees
Transmitter loop roll	0 degrees
Transmitter loop terrain clearance	100 metres
Transmitter loop – to – receiver coil geometry	115 m behind and 40 m below the aircraft

6.2.5.2 Parallax

The located data files utilise the following parallax values :-

- magnetics = 0.2 fiducials (1 observations from the zero parallax position),
- radar altimeter = 0 fiducials (0 observations from the zero parallax position),
- EM X-component = -1.2 fiducials (6 observation from the zero parallax position),
- EM Z-component = -1.4 fiducials (7 observations from the zero parallax position),

For the Tempest Airborne EM system, due to the asymmetry in the transmitter loop-receiver coil geometry with respect to flight direction, there is no single EM parallax value which will align the peak response for all conductivity distributions for lines flown in opposite directions.

The choice of EM parallax value depends on the intended usage, but with the predominance of broad, shallowly dipping conductors, and the client's desire to grid the data, parallax has been applied so that data are optimised for gridding. The 'optimum' depends on the conductor depth, the acquisition geometry and the delay time, and hence, the selected value will be a compromise.

(NB negative parallax values are defined in this case as shifting the indicated quantity forward along line to larger fiducial values. Location information remains in the zero parallax state)

6.2.6 Delivered Products

Appendix III contains a complete list of all data supplied digitally.

Digital ascii located data and a Geosoft GDB format was produced, containing the raw and final, X and Z EM data, conductivity data as well as magnetics and digital terrain.

Stacked CDI sections and CDI-multiplots (Z component) in Adobe PDF format.

Grids (in ER Mapper format) of all X and Z EM windows, total magnetic field and digital elevation were produced.

A flight path map was delivered in Oasis ".map" format and "png" image format.

Acquisition and processing report in hardcopy and digital format.

7. REFERENCES

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