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The Tellus Airborne Geophysical Survey of Northern Ireland: Phase 1 Logistics Report

National Geoscience Framework Programme

Internal Report IR/06/032

JAC

Joint Airborne-geoscience Capability

Geological Survey of Finland/British Geological Survey

BRITISH GEOLOGICAL SURVEY

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INTERNAL REPORT IR/06/032

The Tellus Airborne Geophysical Survey of Northern Ireland: Phase 1 Logistics Report

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Front cover

JAC aircraft OH-KOG in Newtonards, with Scrabo tower in background

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Foreword

This report describes the Tellus airborne geophysical survey of Northern Ireland. The survey is being conducted in two Phases over the period 2005 to 2006. Phase 1 took place in 2005 and Phase 2 is planned for 2006. This report describes the logistics of the Phase 1 survey that took place between July and October 2005. A separate processing report will describe the final processing of the data. The processing report will accompany the final delivered data.

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Summary

This report provides an overview of the Tellus airborne geophysical survey conducted in 2005 in Northern Ireland. The survey requires a two year programme of data acquisition and the present report covers the first year, referred to as PHASE 1. The BGS, as part of the Joint Airborne Geoscience Capability (JAC) established with the Geological Survey of Finland (GTK), carried out the survey under contract to the Department of Enterprise, Trade and Investment (DETI), Northern Ireland. The survey is being conducted at high resolution (a flight line spacing of 200 m) and at low altitude (56 m) across the geopolitical landmass of Northern Ireland.

The three main data sets being acquired are magnetic, radiometric (gamma ray spectrometry) and active frequency domain electromagnetic. The aim of the present report is to provide data and descriptions of the logistical elements of the survey operations conducted in 2005. The summary details of the PHASE 1 survey operation are as follows:

Survey line spacing				200 m
Survey line direction				345 degrees
Tie line spacing (trial)				2000 m
Tie-line direction				75 degrees
Minimum survey altitude (rural)				56 m
Minimum survey altitude (other)				244 m
Typical survey speed				70 m/s
Magnetic sampling				0.1 sec
Electromagnetic sampling				0.25 sec
Radiometric sampling				1 sec
GPS positional sampling				1 sec
Magnetic/GPS base station sampling				1 sec
PHASE 1 survey duration				01 July to 05 October 2005
Total line-km acquired (ideal lines)				47,608 km
Lines acquired in survey blocks				
BLOCK	**Line Start number**	**Line END number**	**Number of lines**	**Line-km**
Survey Lines (345 and 165 degrees, 200 m separations)				
A	0002	0354	353	11,496
B	0518	0854	337	9,561
C1	1001	1215	216	10,390
D1	2001	2215	216	8,622
E1	3031	3215	216	6,294
Tie Lines (255 and 75 degrees, 2 km separations)				
A & B	5002	5031	30	1,245

Table 1. Summary details of the Tellus PHASE 1 (2005) survey.

The survey acquired 47,608 ideal on-line flight-line km in 363.35 operational flight hours. The actual on-line line-km obtained during the PHASE 1 survey was 49,799 line-km. This figure includes tie-lines. The concept of 'ideal' (planned and actual) flight lines is explained in the text. These figures indicate that the net productive line-km/hr was 131. The statistical number of flying hours per day was 4.38 as an average figure across the operational duration of the survey. The figure is based on 83 operational days (i.e. 6 day week) rather than the 93 days that define the duration of the PHASE 1 survey.

1 Introduction

The airborne geophysical survey described here resulted from a scoping study undertaken by the CSA Group Ltd in 2003 (O'Neill, 2003). The study reported its findings to the Department of Enterprise Trade and Investment (DETI), Northern Ireland. The report indicated that the principal objective of the airborne geophysical survey is to acquire high-resolution magnetic, radiometric and electro-magnetic (EM) survey data, which can be used to generate interpretation products, for the benefit of public and private development in the resource and environmental sectors. The airborne survey should yield information on geological structure and lithology, surficial geology, overburden characteristics, shallow geological characteristics, hydrology, vegetation, topography and possibly air and water quality. The derived datasets can also be used to support government policy decisions in economic and sustainable development, social infrastructure, environment and human health.

Previous airborne geophysical surveys in Northern Ireland were predominantly flown in the 1970's, as shown in Table 2. Although these earlier surveys would have been considered high-tech at the time, they are now regarded as low-resolution surveys with respect to line spacing, flight altitude, geophysical equipment sensitivity, spatial resolution, and processing and interpretation technology.

Date	Technique	Line kms	Area	Client	Contractor
1959-1960	Mag	17,500	Whole of NI	NI Govt.	Canadian Aero Service Ltd
1965	Input EM ?	400	Tyrone	Tara	Barringer Research Ltd
1971-1972	Mag	1,920	Tyrone / Fermanagh	Amax	Geoterrex
1978	Mag / TEM	2,000	Tyrone	Moydow	Geoterrex
1997	Mag / TEM	5,000	Sperrin Mts.	Billiton	Tesla

Table 2 Previous aerogeogeophysical surveys conducted in Northern Ireland.

Using an estimated total requirement of about 90,000 line-km for the whole survey (including tie-lines), a two season survey was considered the most sensible option. It should be noted that different survey plans give rise to different totals of flight line-km. Different survey directions give rise to different zonations with respect to both the political border and coastline.

The contract to the BGS, Natural Environmental Research Council, to perform the airborne survey was awarded towards the end of 2004. The contract runs from 01 April 2004 to 31 March 2007. The Geological Survey of Northern Ireland (GSNI) performs the management of the Tellus project. The principal interfaces with the airborne survey are the Project Manager (Mike Young), the Assistant Project Manager (Marie Cowan) and the Project Geophysicist (Chris Van Dam). The Tellus project team together with the BGS-GTK JAC are responsible for the design, implementation and delivery of the airborne geophysical survey programme.

A specific element of the project brief was a major outreach programme. A firm of PR consultants (Weber-Shandwick) was employed to design and undertake this activity. Among their tasks was a programme of public information (advice, distribution of circulars, maintenance of the information line and arrangements of strategic mentions in the local press) prior to and during the ground and airborne surveys. The Tellus project team provided the interface with the consultants. In practice, the remit of acquiring low level airborne data in parallel with close to real-time communications with the public, added difficulties and extra dimensions to the usual quality control and management of survey operations. Exceptions to the survey flight specification, were generated at intervals throughout the survey as requested by the Tellus project team. Essentially this entailed fly-high or other deviations from the flight plan in order to avoid existing or potential public annoyance.

A full set of flying permits was acquired in order to conduct the survey. Permissions were obtained from the Department of Transport (permission to operate a foreign registered aircraft in the UK), the UK Civil Aviation Authority (CAA), (special events and unusual aerial activity) and Aerial Work permissions from the Irish Aviation Authority. The airspace coordination notice, issued by the CAA, included exemptions from the restrictions of flying in South Armagh and over security establishments. Permission was granted by the CAA to undertake surveying at a minimum height of 185 feet (minimum separation distance of 500 feet) in the absence of structures. Elsewhere, a minimum height of 800 feet (minimum separation distance of 1000 feet) was permitted. The conditions required a routine flying height of 56.4 m with increases to heights above 244 m, when structures such as conurbations were encountered.

2 Survey: Location and details

2.1 ORIGINAL SURVEY SCHEME

The Tellus high resolution airborne geophysical survey was designed using the boundary of the geopolitical landmass of Northern Ireland. Flight lines were extended about 2 km across the landmass border, both across the land/sea interface and into the Republic of Ireland. Flight line spacing was set at an interval of 200 m. The flight line direction (345 degrees geographic) was set by GSNI on the basis of geological trends. The survey flight plan was designed by the JAC Manager, Maija Kurimo. The original survey area was divided into 5 survey blocks labelled A to E. These are shown, schematically, in Figure 1.

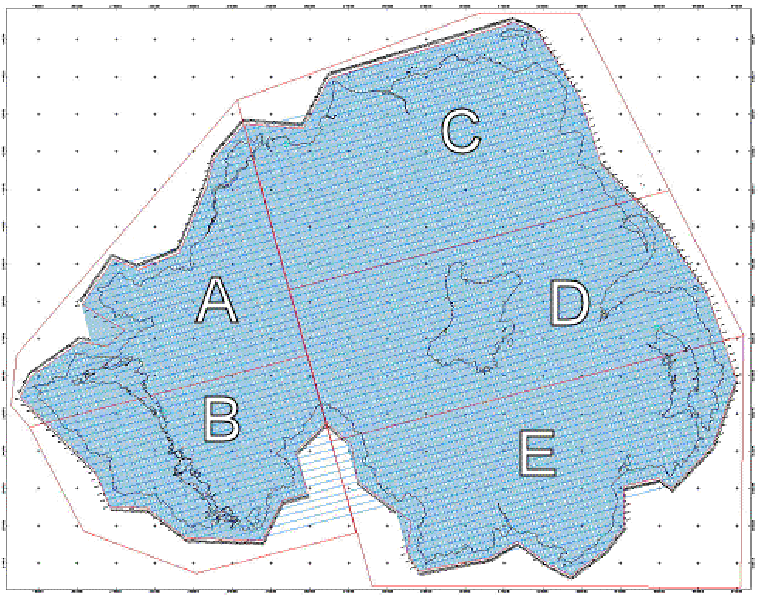


Figure 1. Original, ideal, 5 block survey flight plan for Tellus. The diagram is schematic due to the density of lines at the scale shown.

Flight line lengths of about 50 km were considered optimum in terms of this specific systematic mapping programme. In order to minimise ferry flights, the use of 3 base airports (Enniskillen, Londonderry and Newtonards) was established. The complex nature of the border resulted in some short flight line lengths, particularly in the west of the survey area.

The idealised survey lines provided the parameters of the survey shown in Table 3.

BLOCK	Line Start number	Line END number	Number of lines	Line-km
Survey Lines (345 and 165 degrees, 200 m separations)				
A	0002	0354	353	11,496
B	0518	0854	337	9,561
C	1001	1463	463	21,597
D	2001	2526	526	20,698
E	3031	3527	497	17,107
Tie Lines (255 and 75 degrees, 2 km separations)				
A&B	5002	5031	30	2098

Table 3. Idealised 5-block Tellus survey line parameters (plan)

The above scheme is referred to as the idealised or planned survey. This plan provides an estimate of 80,459 line-km (increasing to 81,704 line-km with the tie-lines for Blocks A&B). It is again worth noting that different survey plans give rise to different totals of flight line-km. Different survey directions give rise to different zonations and different numbers of lines (and line lengths) with respect to both the political border and coastline. The above idealised plan includes the overlaps and extensions discussed above. As an example, with a 200 m line spacing and the given outline plan of Northern Ireland (coast and border), planning schemes can give rise to totals of between 77,850 and 82,000 line km for different survey flight directions.

Flight line overlaps between Blocks in the flight line direction (i.e. between Blocks A and B, Blocks C and D and across Blocks D and E) were specified to be 500 m. This figure was extended to a typical overlap length of 1 km during the survey.

A trial into the utility of acquiring tie-lines (orthogonal to flight lines) for use in the processing (levelling) of the magnetic survey data was conducted. Tie-lines were flown orthogonal to the main survey line direction. The flight directions were 255 and 75 degrees geographic. A flight line separation of 2000 m was used. Tie-lines were flown only across Blocks A and B, contiguously. Summary statistics for the tie-lines are provided in Table 4.

2.2 PHASE 1 SURVEY (2005)

The PHASE 1 survey data acquisition was conducted between 01 July 2005 and 05 October 2005. Two airfields were used as operational bases. The survey used Enniskillen airport (formerly St. Angelo) during the period 01 July to 03 September. The survey base transferred to Londonderry Airport (West Apron) on 03 September and continued from that base until the termination of data acquisition on 05 October.

The chronological flying sequence was subject to modifications during the course of operations. This was due, in part, to the outreach/public awareness programme, conducted by Weber-Shandwick. In overview, concerns about over-flying the eastern-most area of Northern Ireland resulted in restricted progress eastward. In broad terms the sequence of data acquisition was BLOCK B, BLOCK A, block AB tie-lines, block E, Block D, Block C. Three Blocks (C, D and

E) were only partially completed as progress eastwards was curtailed at the request of the outreach programme. The tie-line acquisition is shown in Figure 2.

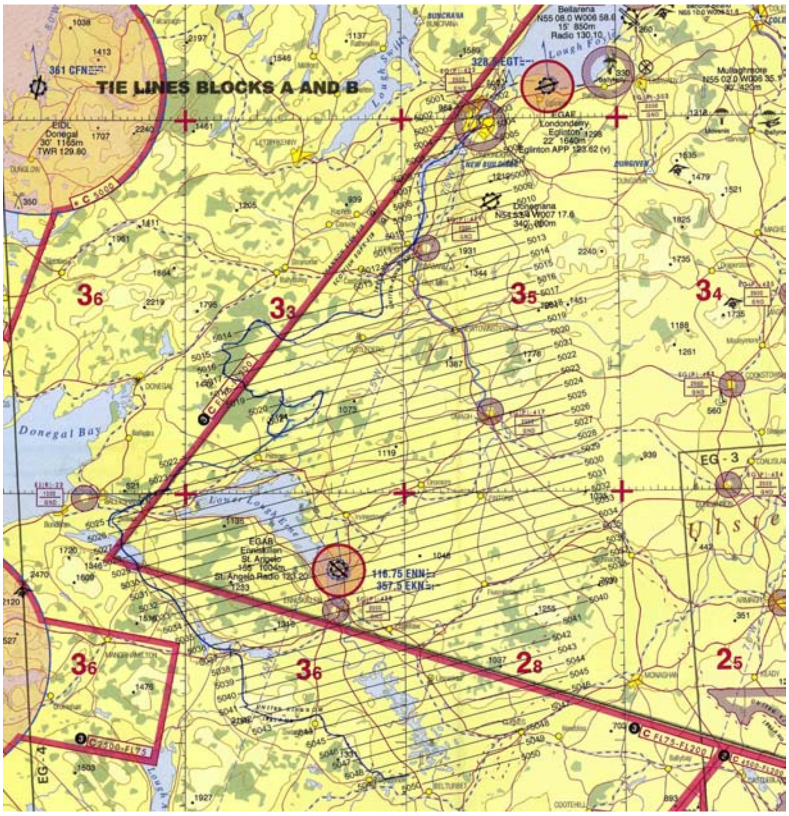


Figure 2.Tie-line flight lines (5002 to 5144) traversing Blocks A and B, shown on a background aeronautical chart (part) from the CAA.

Operationally, a target of two 4 hour sorties each day was specified. The typical times were 08:00 to 12:00 and 14:00 to 18:00. Flight operations occupied a six day week with Sunday designated a rest day.

The operational chronology of data acquisition is provided in Appendix 1. The table summarises the dates, the time duration, the number of lines flown and the on-board personnel for each sortie. The survey comprised 116 operational flights with Flight/Material numbers from 005 to 121. The longest sortie was for 4 hrs 39 minutes (Flight 038 on 25 July) when 41 lines of data were acquired totalling 659 line-km.

The coverage achieved during the PHASE 1 survey is shown in Figure 3. Blocks A and B were completed according to the original plan. Partial coverage was achieved in Blocks C, D and E. In each case, the western-most areas were completed to avoid extending the survey activities into the eastern sector of the area. The partial blocks completed have been designated Blocks C1, D1 and E1. The final lines of the 3 blocks form a contiguous survey line formed by Lines 1215 (Block C1), 2215 (Block D1) and 3215 (Block E1).

The parameters of the PHASE 1 survey are summarised in Table 4. The survey acquired 47,608 ideal (on-line) flight-line km in 363.35 operational flight hours.

BLOCK	Line Start number	Line END number	Number of lines	Line-km
Survey Lines (345 and 165 degrees, 200 m separations)				
A	0002	0354	353	11,496

B	0518	0854	337	9,561
C1	1001	1215	216	10,390
D1	2001	2215	216	8,622
E1	3031	3215	186	6,294
Tie Lines (255 and 75 degrees, 2 km separations)				
A&B	5002	5050	49	2092

Table 4. Idealised 5-block Tellus survey line parameters completed during PHASE 1.

In practice, it is typical that during surveys, the 'on-line' condition is maintained for longer than that defined on the idealised flight plan (i.e. the plan being flown by the air-crew). This can be considered a 'safety margin' in the acquisition of the specified survey data. Actual on-line-km is always larger than planned on-line-km. For the Phase 1 survey, ideal and actual line-km were Block A (11,496, 12,097), Block B (9,561, 10,074), Block C1 (10,390, 10,802), Block D1 (8,622, 8,950) and Block E1 (6,294, 6,631). Flight line data along actual flight lines can be trimmed (at both ends) to meet the ideal line-km survey specifications, if required. Such trimming is usually undertaken in the later data processing procedures (not described here). In summary, the actual line-km obtained during the PHASE 1 survey is 50,710 line-km. This figure includes tie-lines.

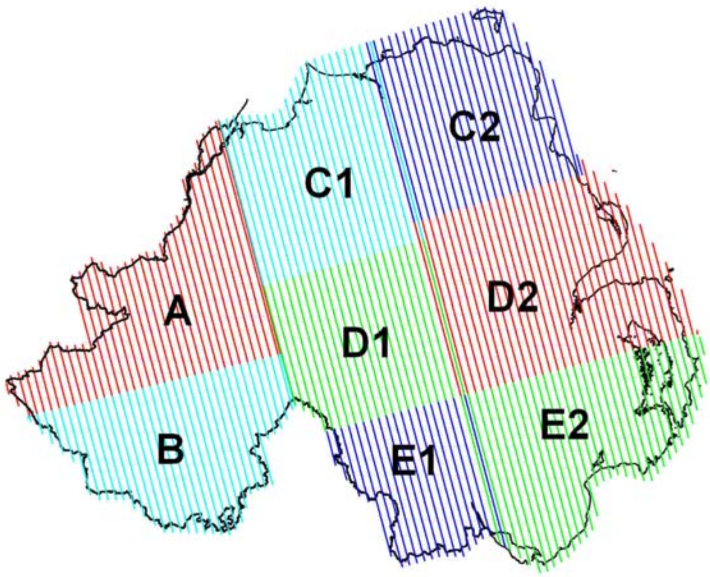


Figure 3. Block scheme amended at the close of PHASE 1 surveying. Blocks completed are A, B, C1, D1 and E1. Blocks remaining are C2, D2 and E2.

Block C1 was the last area to be surveyed during 2005. At the northern end of the survey, a military coastal firing range proved difficult to overfly given the time restrictions on overflights (together with deteriorating weather conditions). A sub-block division of flight lines allowed the block to be overflown in one sortie. The original C-block flight lines 1148 to 1163 (inclusive) were reduced to about 15 km in length from their original planned northern end points. The remaining (long) sections of the flight line sequence were renamed 7148 to 7163 (inclusive). Although a 500 m overlap, along the flight-line direction, was specified, an overlap of about 1 km was achieved in practice.

The areas remaining to be surveyed have been designated Blocks C2, D2 and E2 as shown in Figure 2. In order to tie together the PHASE 1 and PHASE 2 surveys, 2 existing flight lines from each block will be repeated during PHASE 2. These are lines 1214 and 1215 (Block C2), 2214 and 2215 (Block D2), 3214 and 3215 (Block E2). There has been an adjustment to the overlap position of Blocks C2 and D2 for operational reasons. This has resulted in Block C2 having a reduced end flight line of 1435 to avoid short flight line lengths in the east. The idealised parameters of the PHASE 2 plan are listed in Table 5.

BLOCK	Line Start number	Line END number	Number of lines	Line-km
Survey Lines (345 and 165 degrees, 200 m separations)				
C2	1214	1435	221	10,059
D2	2214	2526	313	13,413
E2	3214	3527	314	10,904

Table 5. Idealised 3-block Tellus survey line parameters remaining for PHASE 2

In order to record the survey flight parameters, on a block-by-block basis, a series of text files have been produced and placed on the Report Data CD. There is one file for each of the PHASE 1 Blocks A, B, C1, D1 and E1, together with the Block A,B tie-lines. The text files provide line number, start and end coordinates together with total (idealised) flight length.

2.3 REFLIGHT SPECIFICATIONS

Conditions for reflights were agreed in the survey specifications. The conditions were as follows:

i. Where flight line spacing is greater than 130% of the nominal spacing over a distance of 2 kilometres or more or over any distance where flight line spacing is greater than 150% of the nominal spacing (except where ground conditions dictate otherwise, for example to avoid radio-masts etc).

ii. Where terrain clearance exceeds ± 20 metres from the nominal survey height for more than 5 continuous kilometres or +/- 50% of nominal survey height at any time on any line.

iii. Where the nominal survey flying speed (210 kph) is exceeded by more than 30% (i.e. survey flying is faster than 270kph) for more than 5 continuous kilometres.

iv. Where the noise envelope of the magnetic records exceeds 0.1nT as determined by the normalised fourth difference.

v. If, during data acquisition, magnetic variations recorded at the local base magnetometer exceed 12 nT over any 3 minute chord or exceed 2 nT over any 30 second chord, on flight lines or tie lines. These limits may be revised by agreement in the light of experience gained during the first few weeks of data acquisition. The base magnetometer must be fully operational during all on-line data collection.

vi. Where the average line gamma spectra for any line fails to meet acceptable standards or otherwise appears anomalous by comparison with neighbouring data, as demonstrated by the JAC proprietary software SPEKTNT, then the data of that line will be investigated in detail and re-flown if necessary.

vii. If the in-flight EM signal/calibration check on phase orthogonality, at each measured frequency, indicates non-orthogonality or incorrect amplitude.

Conditions i, ii and iii above may be exceeded without reflight where such constraints would breach air regulations, or in the opinion of the pilot, put the aircraft and crew at risk.

2.4 PROJECT MANAGEMENT & PERSONNEL

The airborne project was developed using the BGS Intranet-based Project Management System (PMS). The project name is Aerogeophysical Survey of Northern Ireland and has a PMS entry of 1369. The current Project Code is E2168R75. The project plan was developed by Roger Peart and David Beamish of the BGS. The geophysical project sits within the larger TELLUS Project (The Resource and Environmental Survey of Ireland, PMS entry 649), which was conceived originally as a comprehensive and integrated geophysical and geochemical survey of the whole island of Ireland, with the objective of providing state-of-the-art geo-science information to inform government development decisions.

The aerogeophysical project plan includes a wide range of project information, together with detailed Health and Safety Guidance Notes. The personnel involved in Phase 1 planning and operation are listed in Table 6.

Position	Name	Affiliation
Programme Manager	Mr Garth Earls	GSNI
TELLUS[1] Project Manager	Mr Mike Young	GSNI
TELLUS Deputy Project Manager	Ms Marie Cowan	GSNI
HOD GMG	Dr Russ Evans	BGS
HOD GGP	Dr John Powell	BGS
HOD IS	Dr Chris Evans	BGS
HOD GMH	Dr Dave Harrison	BGS
TELLUS geophysicist	Mr Chris van Dam	GSNI
TELLUS coordination	Mr Alex Donald	GSNI
TELLUS Technical Supervisor	Dr Alan Reid	Consultant
JAC Manager/Party Chief	Ms M Kurimo	GTK[2]
JAC Deputy Manager/Party Chief	Dr D Beamish	BGS
BGS JAC co-ordinator	Mr R J Peart	BGS

[1] The Resource and Environmental survey of Northern Ireland (funded by the NI Department of Enterprise, Trade and Investment), of which the aero-geophysical survey is a major component.

[2] Geologian Tutkimuskeskus (The Geological Survey of Finland)

Party Chief	Dr R J Cuss	BGS
Party Chief	Ms M Lahti	BGS
BGS Trainee operator	Mr S Brearley	BGS
BGS Trainee operator	Ms L Nelder	BGS
BGS Trainee operator	Mr R Cooper	BGS
BGS Trainee operator	Mr D Morgan	BGS
BGS Trainee operator	Mr A Hulbert	BGS
BGS Trainee operator	Mr Ed Haslam	BGS
GTK geophysicist/Party Chief	Ms H Levaniemi	GTK
GTK electronics engineer	Mr V Leinonen	GTK
GTK operator/instructor	Mr V Leinonen	GTK
GTK operator/instructor	Mr O Halonen	GTK
GTK operator/instructor	Mr J Piispanen	GTK
GTK operator/instructor	Mr K Nyman	GTK
GTK operator/instructor	Ms H Ojamo	GTK
FAA[3] Captain	Capt R Vartiainen	FAA
FAA Captain	Capt R Loukkola	FAA
FAA Pilot	Mr H Laitinen	FAA
FAA Pilot	Mr M T Kanto	FAA
FAA Navigator	Mr E Tiainen	FAA
FAA Navigator	Mr V Wetterstrand	FAA
FAA a/c Engineer	Mr S Janis	FAA
BGS H&S Advisor	Mr T Prescott	BGS

Table 6. List of project personnel. Rows with infill denote personnel actively involved in data acquisition and public outreach/coordination during PHASE 1 operations.

3 Equipment

The airborne survey equipment used on the Tellus project comprises a geophysically equipped De Havilland Twin-Otter aircraft (OH-KOG). The details of the aircraft are provided in

[3] The Finnish Aviation Academy (the company operating the JAC survey aircraft OH-KOG)

Appendix 2. The aircraft is owned by the NERC/BGS and the geophysical equipment is owned by GTK. The BGS and GTK undertake airborne geophysical survey work in a partnership venture known as the Joint Airborne geoscience Capability (JAC). The aircraft is operated by the Finnish Aviation Academy (FAA) who are based in Pori, Finland.

A background to the development of the geophysical equipment used by the JAC is given by Hautaniemi et al., (2005). The main components of the geophysical measurement system are summarised in Table 7.

Electromagnetic system:	GTK EM95 dual frequency (3.125 and 14.368kHz)
Aircraft Magnetometer:	2 Scintrex CS-2 caesium vapour sensors, currently located in each wing tip. (separation of 21.36 m)
Magnetic Compensator	RMS Instruments Automatic Aeromagnetic Digital Compensator (AADCII)
Gamma-ray spectrometer	Exploranium GR-820/3 gamma-ray spectrometer 256-channels, self-calibrating
Altimeter	Collins radar altimeter
Navigation/data location system	Real time DGPS based on Ashtech GG-24 GPS+GLONASS receiver, when RDS signal available
Data acquisition system	GTK proprietary: control unit including server, power unit, alarm box, Local Area Network

Table 7. Outline specification of the main geophysical systems.

Standard ancillary equipment includes an external temperature sensor and barometric height sensor and a power-line (50/60 Hz) sensor (housed in the nose of the aircraft). Details of these devices are included in Appendix 2.

3.1 JAC R&D EQUIPMENT

JAC is currently undertaking an R&D programme to provide additional ancillary data during surveys. Two such items were operational during Phase 1 of the Tellus survey. Although operational, the two data sets (laser altimeter and digital video) are not yet incorporated into the main data processing stream. Laser data were recorded separately to the main data acquisition. The sampling interval was 200 Hz. The video data were recorded as .JPG images with a sampling interval of about 3 per second. The time reference of each frame formed the file name of each image. The images were transferred to a DVD (typically one per sortie). The DVD is identified by flight number.

Figure 4. Base station. Magnetometer, GPS unit and control PC inside a tent. Magnetometer sensor, GPS sensor in the field. Photo: Kai Nyman.

3.2 GROUND-BASED EQUIPMENT

Ground-based equipment comprised two identical base magnetometer/GPS stations. One of the stations is termed the primary base station and records magnetic and GPS data prior to, during, and after each flight. The data from this station are used to post process the airborne data. The base magnetic data are used to correct diurnal variations of the airborne magnetic field records. The base GPS records are used to perform differential processing of the airborne GPS recordings. The second (identical) base station is termed the secondary base station and is operated in parallel with the primary base station. The secondary base station acts as a back-up in the case of malfunction/noise of the primary base station data.

The base station magnetic/GPS sensors are equivalent to those installed on the aircraft. A Scintrex CS-2 sensor and an MEP-710 base station processor together with an Ashtech GG24 GPS receiver are used for observation and correction of the diurnal magnetic variation and DGPS post processing respectively

The magnetic data are logged at 1 second intervals and displayed on a base station laptop that controls data acquisition. The continuous display of the base station data (rolling screen) provides a capability for monitoring the magnetic disturbance conditions that would lead to a reflight condition.

Three primary base station locations were used during the PHASE 1 survey. Two of the locations were within the perimeter of Enniskillen Airport. The original base station at Enniskillen had to be moved due to the construction of a new hangar at the airfield. The details of the move of the base station at Enniskillen Airport are given in Appendix 3.

In September a new survey base was established at Londonderry airport. This third survey base station was deployed near to the west apron of the airport. Details of the deployment are given in Appendix 4. Complete base station operations and precise locations are summarised in Table 8. The primary magnetic base station data acquired during the survey are shown as individual (flight) images on the Report Data CD.

Primary Base Stn	Start Date (Julian Day)	End date (Julian Day)	Geographic latitude	Geographic Longitude	Elevation (m)
Enniskillen 1	01 July 2005 (183)	01 August 2005 (214)	54 degrees 23 minutes 36.38434 sec	07 degrees 38 minutes 51.55448 sec	104.2994
Enniskillen 2	01 August 2005 (214)	02 September 2005 (246)	54 degrees 23 minutes 36.22515 sec	07 degrees 38 minutes 41.21993 sec	106.0473
Londonderry	03 September 2005 (247)	05 October 2005 (279)	55 degrees 02 minutes 16.31572 sec	07 degrees 10 minutes 0.62752 sec	64.5058

Table 8. Summary of primary base stations used during the Phase 1 survey.

4 Magnetic Calibration Data

The calibration of the two survey magnetometers was undertaken at the beginning of (e.g. compensation) and during (e.g. determination of lag) the survey operations. The following four sections describe measurements relating to the compensation, heading correction, noise levels and lag correction of the magnetic sensors.

4.1 MAGNETIC COMPENSATION

The effect caused by the movements of the aircraft is removed/diminished automatically during the flight by use of the compensation data. The compensation flight was made near Londonderry at 3 km altitude. The aircraft flew in all flight line directions (255, 165, 075 and 345) and performed pitch (+/-5 deg), roll (+/-10 deg) and yaw (+/-5 deg) movements separately along each direction. After recording the magnetic effects of all twelve movements, the AADCII compensator (RMS Instruments) computed the compensation coefficients, and stored the results to provide real-time corrections during the actual survey.

The effectiveness of the compensation was verified by Figure-Of-Merit (FOM) survey immediately after the compensation during the same flight. The same movements were repeated and the new compensation parameter file was utilized. All three compensated movement effects were summarized in all four directions, and the FOM parameter is thus the sum of these 12 peak-to-peak anomaly values of the compensated magnetic field. The FOM parameter was 2.2 nT for the left magnetometer and 3.5 nT for the right magnetometer. The procedure is illustrated in Figure 5.

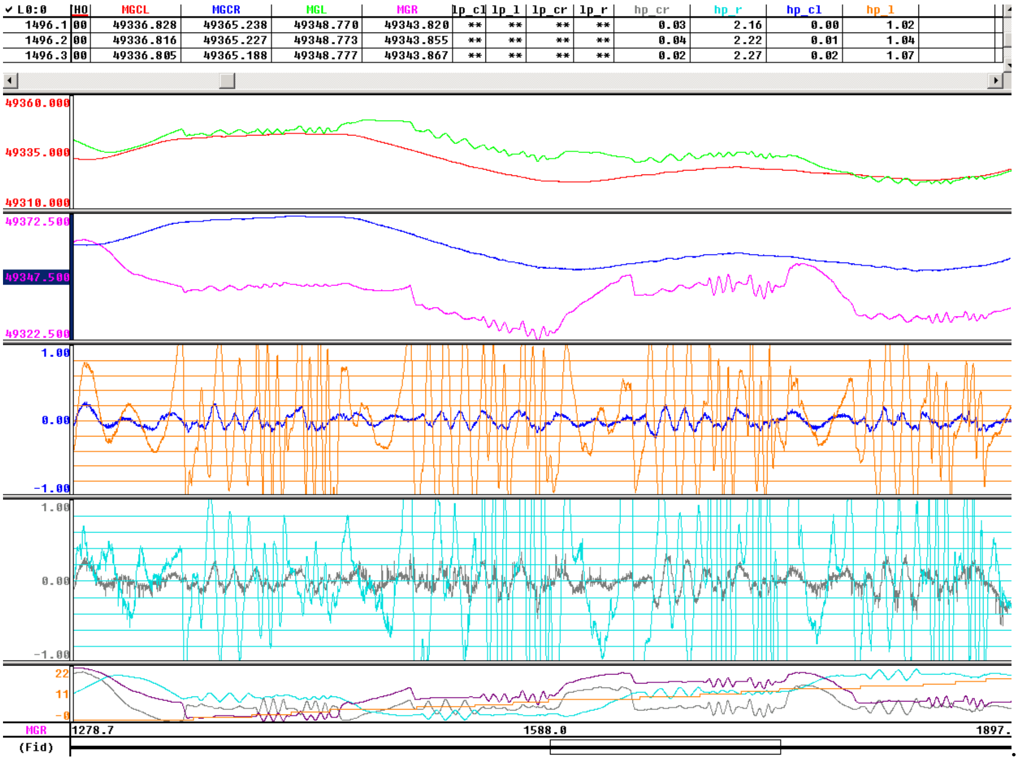


Figure 5. The profiles of magnetometer compensation flight. Panel 1 :left mag: total field measurements, uncompensated and compensated, Panel 2 :right mag: total field measurements, uncompensated and compensated, vert scale 50 nT. Panel 3 and 4: Residual compensated readings, upper left and lower right mag. Panel 5: fix-points (steps) and the three flux-gate magnetometer readings.

The FOM parameters of each direction and each movement are summarised in Table 9.

Dir:movement	Left nT	Left sum	Right nT	Right sum
255: pitch	0.32		0.34	
Roll	0.12		0.15	
Yaw	0.13	0.57	0.16	0.65
165: pitch	0.26		0.40	
Roll	0.06		0.30	
Yaw	0.19	0.51	0.28	0.98
075: pitch	0.42		0.59	
Roll	0.10		0.26	
Yaw	0.10	0.62	0.20	1.05
345: pitch	0.28		0.44	
Roll	0.08		0.26	
Yaw	0.15	0.51	0.10	0.80
SUM		2.21 nT		3.48 nT

Table 9. FOM calculations for left and right wing magnetometers.

A second compensation was carried out on 25th of July after the right wingtip magnetometer sensor had been replaced. The FOM parameters of this second compensation were 2.4 nT for the right magnetometer and 1.8 for the left magnetometer.

4.2 MAGNETIC HEADING CORRECTION

After the compensation the remaining heading correction is made using three different flight lines, which were flown in opposite directions. The correction parameters determined by the procedure are shown in Table 10.

Direction (degrees)	Left mag, nT	Right mag, nT
345	0.0	-10.5
165	-3.5	-32.0

Table 10. Magnetic heading corrections for left and right wing magnetometers.

4.3 MAGNETIC NOISE

The noise envelope should be less than 0.1 nT as determined by the normalised fourth difference. The normalised 4th difference of mag recordings of line 520 is shown below in Figure 6.

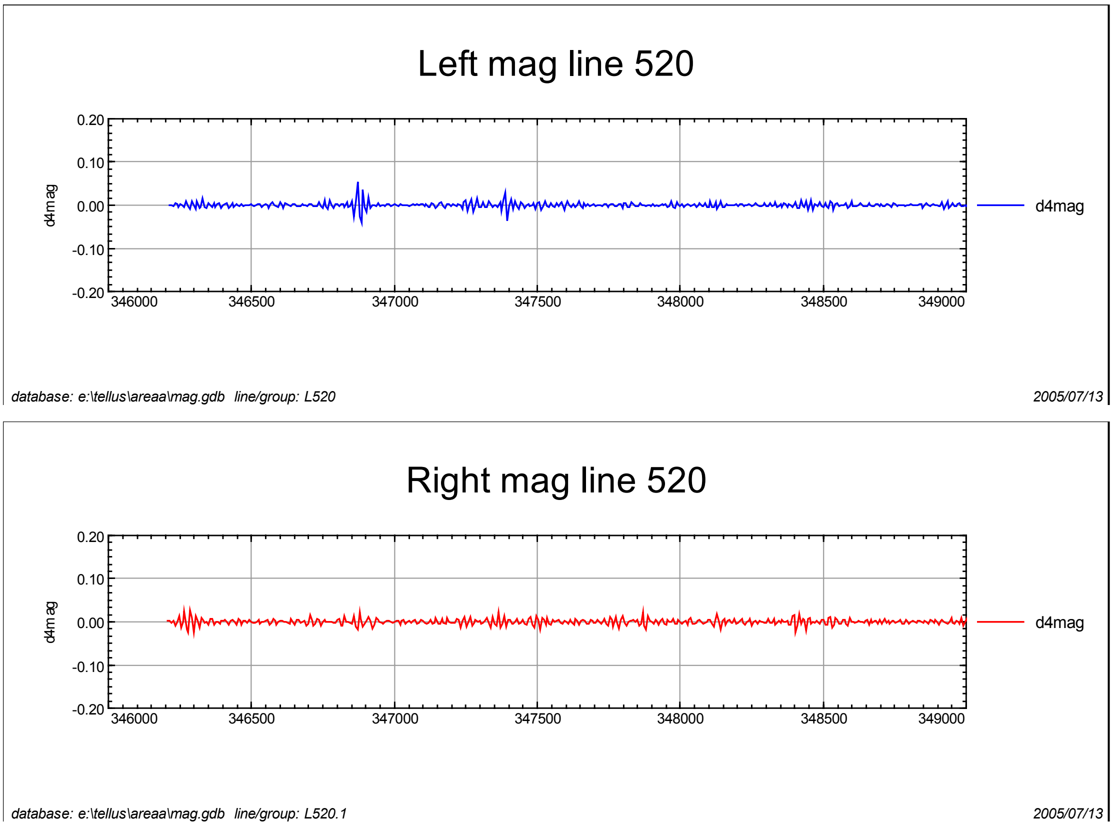


Figure 6. Example of normalised 4'th differences for left and right wing magnetometers (Flight line 520).

The noise induced by EM transmitter was tested on flight 007. Flying at 3 km altitude the EM transmitter was switched off. The level of left mag (EM receiver wingtip) changed less than one nT. The level of right mag (transmitter side) decreased about 15 nT. The noise envelope of the right mag changed from 0.02 to 0.01 (normalised 4th difference). The behaviour is shown in Figure7.

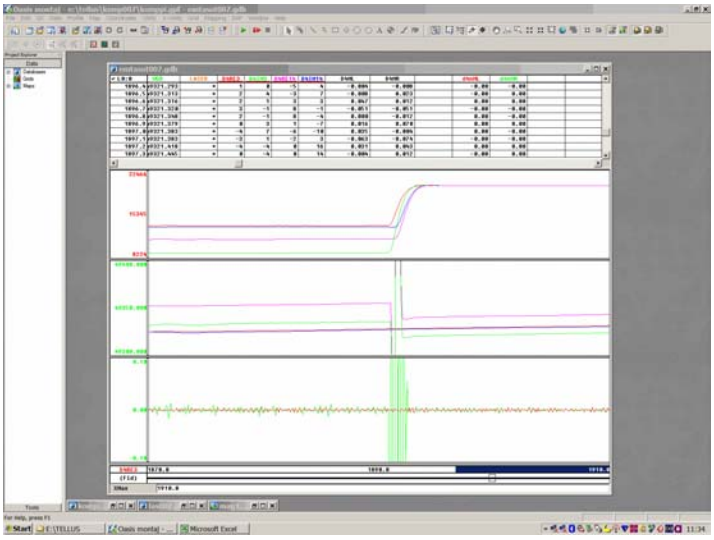


Figure 7. Noise test of noise introduced by EM transmitter on magnetic data

4.4 MAGNETIC LAG CORRECTION

The magnetic lag of the system is normally 0.3 seconds, and it was verified on survey line 566, which was flown in opposite directions of 345 and 165 degrees.

5 Radiometric Calibration data

As noted previously the radiometric instrument employed is the Exploranium GR-820. In this instrument gamma scintillation in the NaI crystal is amplified with photomultipliers. In the spectrometer each pulse is analysed, over a 1 second interval, and sorted within a 256 energy channel sequence according to energy and amplitude. The width of each channel is 12 keV. The majority of natural gamma radiation originates from Potassium (K-40) and the decay series of Uranium (U-238) and Thorium (Th-232). The potassium is measured at 1.46 MeV of K-40. U-238 is measured at the 1.76 MeV of Bismuth (Bi-214) that belongs to the disintegration series of U-238. Th-232 is measured at 2.62 MeV of Tl-208 that arises from the decay series of Th-232. The recommended (IAEA) energy rates of the windows used are shown in Table 11:

Window	Energy Range MeV
Thorium	**2.41-2.81**
Uranium	**1.66-1.86**
Potassium	**1.37-1.57**
Total	**0.41-2.81**

Table 11. The recommended (IAEA) energy rates of the spectral windows.

The commonly adopted standard in carrying out airborne gamma-ray measurements is to calibrate and process the data in a manner presented in AGSO and IEAE reference manuals (Grasty and Minty, 1995; IAEA, 1991). The radiometric system was calibrated prior to the survey using locations and calibration ranges in Finland that have been used for over 25 years. The following sections summarise the calibrations that were performed prior to the Tellus survey.

5.1 RADIOMETRIC CALIBRATIONS PRIOR TO THE SURVEY

5.1.1 Cosmic and aircraft background

To determine the aircraft and cosmic background, a test flight was carried out over the sea near the city of Porvoo, Finland on 02/05/2005, at flight surfaces from 5000 to 10000 ft. Linear regression from the mean counts in each channel and equivalent cosmic channel count rate provide the constant and linear coefficients. The constant represents the background radiation from the aircraft and the linear coefficient is used to calculate the varying part of background radiation because of cosmic radiation.

The cosmic coefficients were found to be:

cos_tot	85.5 (0.827)	Total counts
cos_kal	7.3 (0.036)	Potassium
cos_ura	2.2 (0.028)	Uranium
cos_tho	0.0 (0.036)	Thorium
cos_Ur	0.6 (0.007)	Uranium upward

The numbers in parentheses are the linear coefficients

5.1.2 Stripping Ratios

The stripping ratios were determining using 4 transportable calibration pads (1m x 1m x 0.3m) on 14/4/2005 in Helsinki. Each pad was measured for 10 minutes and the stripping ratios were calculated using the Padwin program provided by the manufacturer of the pads. The calculated values are very close to the manufacturer's and IAEA's ideal values. The results are listed here:

STRIPPING RATIOS:

TH INTO U (ALPHA = A23/A33): .2375 (.0998)

TH INTO K (BETA = A13/A33): .3765 (.1982)

U INTO K (GAMMA = A12/A22): .7259 (.2731)

U INTO TH (A = A32/A22): .0621 (.1090)

K INTO TH (B = A31/A11): .0033 (.0575)

K INTO U (G = A21/A11): .0060 (.0627)

The background count rates were:

K WINDOW : 7.412E+01 (3.603E+00) COUNTS/M

U WINDOW : 1.775E+01 (1.701E+00) COUNTS/M

TH WINDOW : 1.482E+01 (1.560E+00) COUNTS/M

The numbers in parentheses are estimated standard deviations.

5.1.3 Height Attenuation

For determining height attenuation, a series of heights from 100 to 800 ft was used to take measurements on 24/06/2005 near Porvoo, Finland. This test line has been used for more than 25 years. Background and strip corrections were applied and the attenuation was calculated using the logarithmic values of corrected Tot, K, U and Th, and flight altitude.

The attenuation coefficients were calculated as:

Total counts	-0.006387
K	-0.007556
U	-0.005577
Th	-0.006313

5.1.4 Concentration coefficients

The same Porvoo test line was used to determine the system sensitivities. This same line has been measured for more than 25 years from the air with OH-KOG. The sensitivity parameters have been applied yearly to the radiometric data measured. Comparisons have been made also between different areas measured during different years to find out the possible variations. The variations are mostly due to different methods used earlier for sensitivity determining, e.g. pads, runaway. For the last few years the sensitivity parameters have been varied by just a few percent.

All the corrections were made to the radiometric test flight data and the concentrations were compared to earlier measurements and new sensitivity parameters were calculated as:

K: 0.0077 %K/(pulses/s)

U: 0.0695 ppm eU/(pulses/s)

Th: 0.1237 ppm eTh/(pulses/s)

Dose rate: whole spectra technique, approved by SGU 2003.

5.1.5 Resolution of the spectrometer

The Spectrometer resolution was measured with a Cs-137 source on the 22/06/2005 in Hyvinkää, Finland. Background was also measured and after a background correction, the Cs peak was measured and the FWHM determined. The FWHM is across 5.0 channels, each with an energy of 12.1 keV, which makes 60.5 keV. Thus we obtain a spectrometer resolution of

R = 100*60.5 keV/662 keV = **9.1 %**

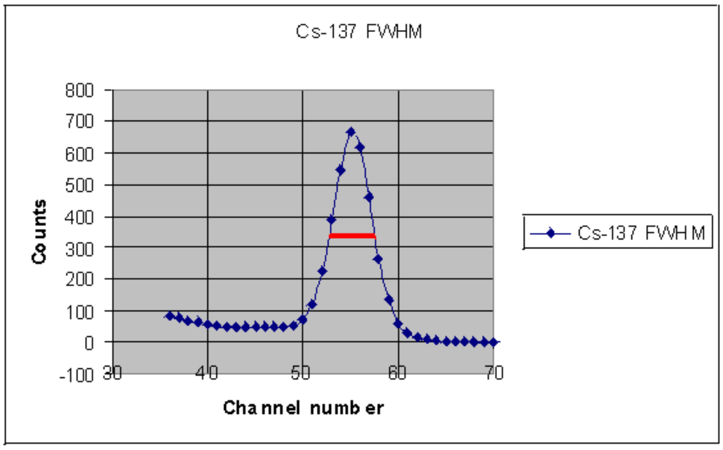


Figure 8. Resolution of the spectrometer using a Cs-137 source.

This Cs-137 resolution 9.1% corresponds to a Th resolution of around 6 % (Grasty and Minty, 1995).

Individual crystals were measured on 14/04/2005 at Helsinki-Vantaa airport. The downward looking spectra was stabilized using K-40 and the upward looking with Cs-137. The results are given as Crystal Number with %Resolution in parentheses:

D1(6.6%), D2(8.8%), D3(7.4%), D4(6.2%), D5(5.6%), D6(5.9%), D7(6.2%), D8(5.7%), U13(9.7%), U14(7.6%)

D refers to downward and U to upward.

5.1.6 Summary

A summary of the standard ROI limits (keV) used in the PHASE 1 survey is given in Table 12.

Aircraft Background	K-40	7.3
	U-238	2.2
	TH-232	0.0
	TC	85.5
	Uup	0.6
Cosmic Background	K-40	0.036
	U-238	0.028
	TH-232	0.036
	TC	0.827
Correct for STP altitude of 30 m	Uup	0.007
Attenuation by air	K-40	-0.007556
	U-238	-0.005577
	TH-232	-0.006313
	TC	-0.006387
Sensitivity for STP altitude of 30 m	%K	0.0077
	ppm eU	0.0695
	ppm eTH	0.1237
	nGy/h	-(0.0032 for Ur units)
Stripping coefficients	ALPHA	0.2375
	BETA	0.3765
	GAMMA	0.7259
	A	0.0621
	B	0.0033
	G	0.0060
Stripping Coefficient Altitude Increase	ALPHA	0.00049
	BETA	0.00065
	GAMMA	0.00069
	A	0.0

Table 12. Summary table of the radiometric calibration parameters.

5.2 DAILY RADIOMETRIC CHECKS

The Exploranium GR-820/3 system used on the survey incorporates dynamic stabilisation using an internal Th-232 source. As part of the survey specification, it was agreed that daily tests on the stability of the crystals should be undertaken. The procedure adopted was to perform 3 minute recordings using hand-samples placed at a known location on the fuselage of the aircraft (below the crystal packs). The procedure was undertaken at a fixed parking location at each survey base. Three sets of tests were carried out. The first test recorded background, with no hand-samples present. The second test used a hand sample of Cs-137 and the third test used a

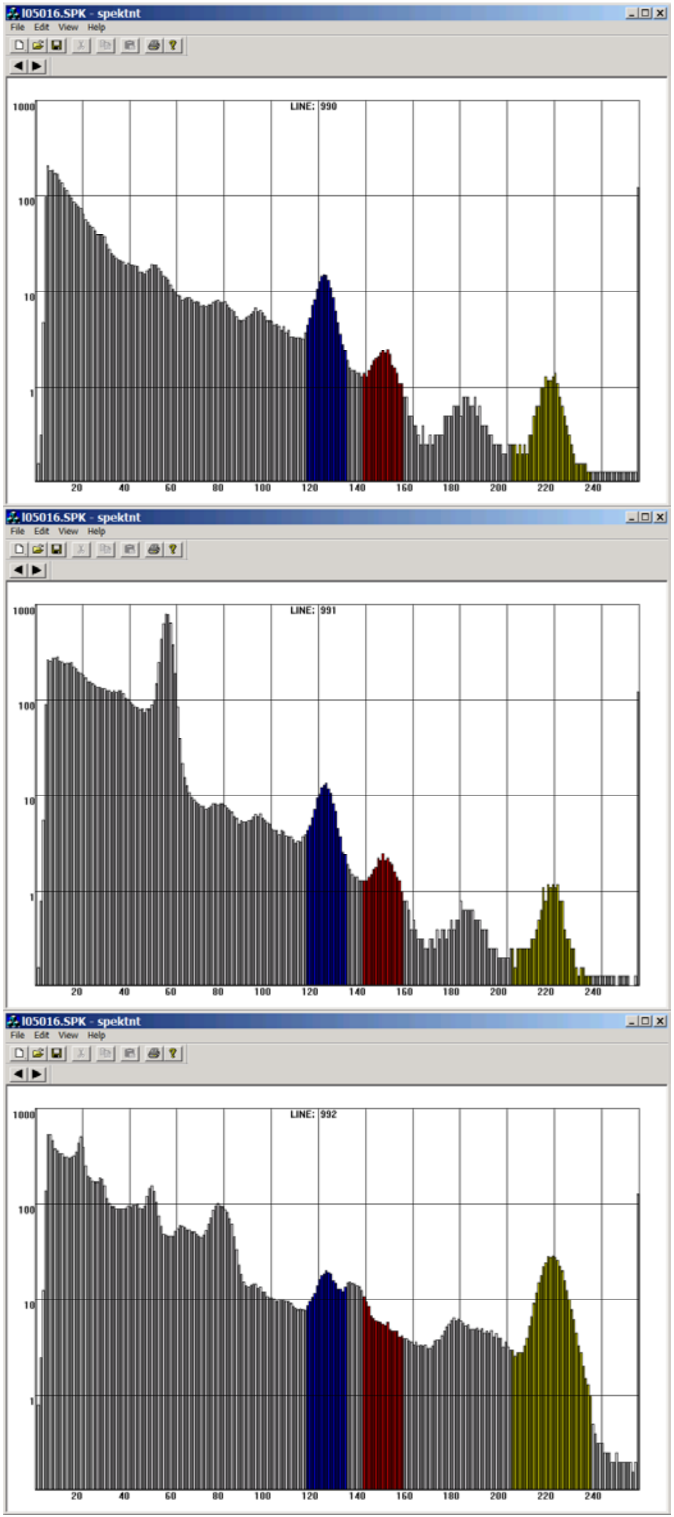


Figure 9. Example of daily hand-sample tests. Upper frame: background. Middle frame: Cs-137. Lower frame: Th-232.

hand sample of Th-232. The records were processed with the JAC software module SPECNT that displays the spectra of the 3 tests. An example is shown in Figure 9. The tests were carried out daily when the survey was operational (i.e. radiometric data were being acquired). The data (images) obtained have been incorporated into the Report Data CD. The images are identified by the Julian Day Number of the test.

6 Electromagnetic Calibration data

6.1 ELECTROMAGNETIC CALIBRATIONS PRIOR TO THE SURVEY

The calibration of the JAC AEM-95 system used in the Phase 1 survey is described by Hautaniemi et al. (2005). The system specifications are also presented in more detail by Poikonen et al. (1998) and by Suppala et al. (2005). The EM was calibrated by flying a test line over the sea (Gulf of Finland) on 26/06/2005 at different heights from 25 to 100 m. The conductivity of the sea was measured by a CTD sensor on 25/06/2005 at 4 different points along the test line, from the surface to the sea bottom.

The conductivity of the sea was estimated by a model, which contains 4 layers with a different conductivity for each layer. The results are displayed in Figure 10.

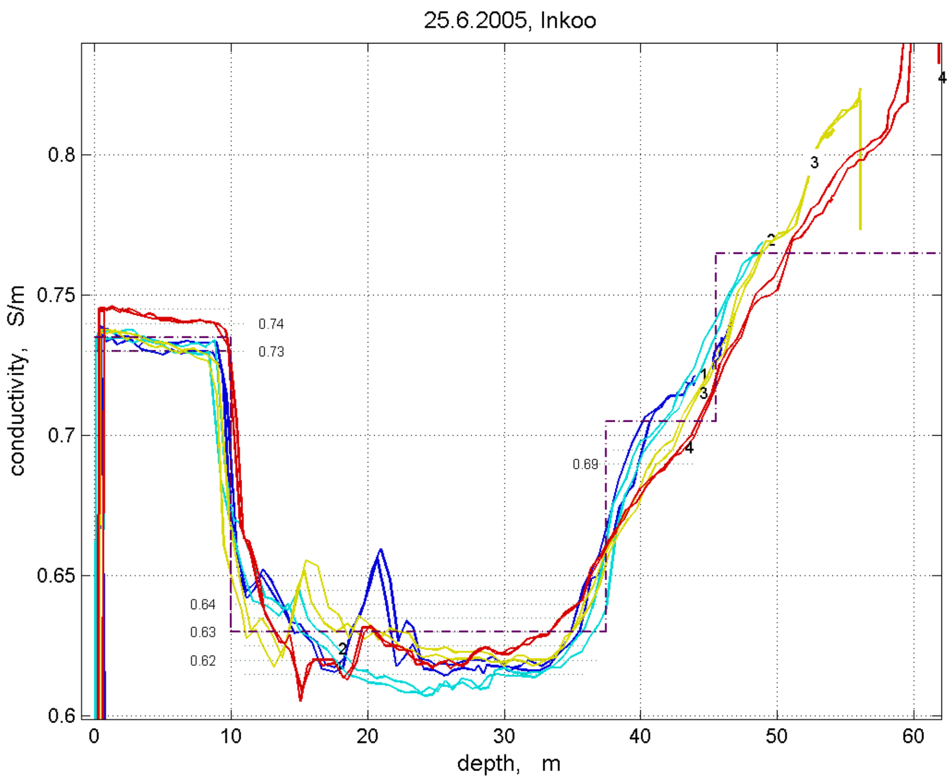


Figure 10. The sea conductivity profiles recorded along the test line in the Gulf of Finland (coloured lines) and the 4 layer model used in the model response calculation.

The theoretical responses of the airborne EM to the model described above were calculated using the Leroi-air program developed by AMIRA. Non-linear optimization was used to obtain a best fit to a complex, scalar coefficient. The coefficients obtained at each frequency enables measured units to be converted to coupling ratios (Hs/Hp, meaning secondary over primary) in ppm. The coefficients obtained and the fit to the test line data are shown in Figures 11 (3125 Hz) and 12 (14368 Hz)

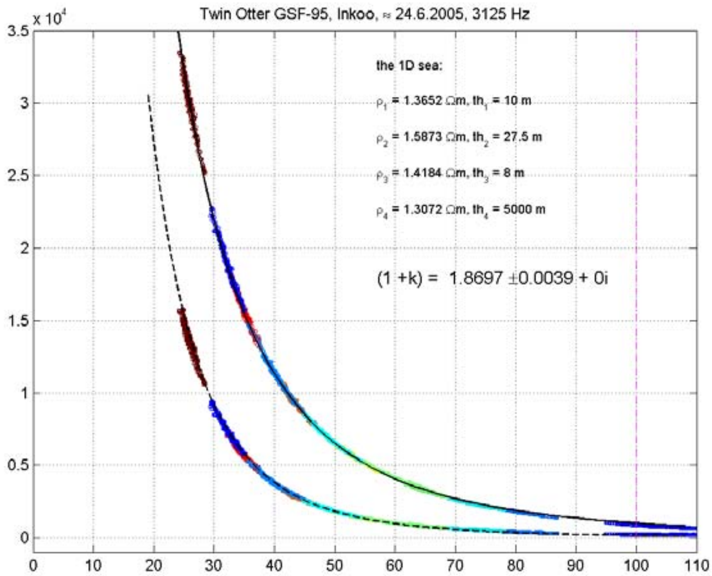


Figure 11. EM optimisation results for the calibration at 3125 Hz

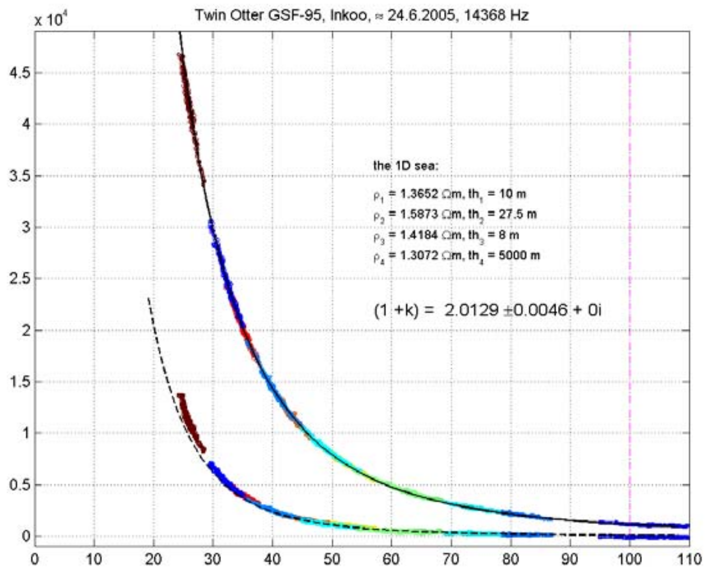


Figure 12. EM optimisation results for the calibration at 14368 Hz.

6.2 ELECTROMAGNETIC CALIBRATIONS DURING THE SURVEY

6.2.1 EM System orthogonality

The phase shift between in-phase (real) and quadrature (imaginary) components is checked and adjusted in the beginning and end of each survey flight. The test is undertaken at an 'out-of-ground-effect' elevation (e.g. 300 m). As the phase shift is 90 degrees, there should not be any trace in the quadrature component as an artificial 1900 ppm signal is applied to in-phase component and vice versa. This procedure is done separately on each frequency to in-phase and quadrature components. At the end of each survey flight this same procedure is repeated to check for any possible phase drift during the flight. An example of the calibration pulses observed at the start of a flight is shown in Figure 13.

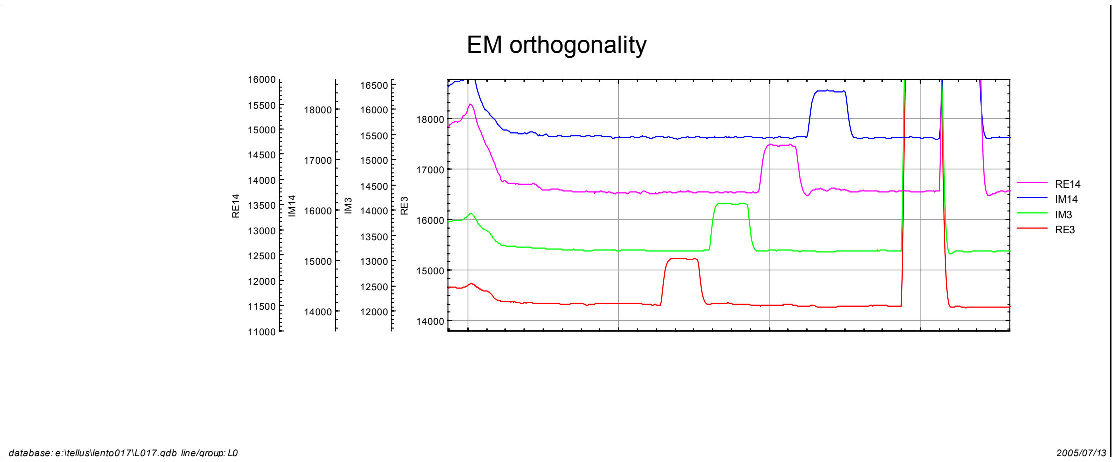


Figure 13. The orthogonality test for Real and Imaginary components, at 3125 and 14368 Hz of the Twin Otter EM configuration at the beginning of Flight 017. Re3=Low Freq Real. Im3=Low Freq Imag. Re14 = High Freq Real. Im14 = High Freq Imag. The larger pulses on the right are 'start condition' signals for the measurement.

The data pulses form part of the basic data recording and are part of quality control checks both in the aircraft (geophysical operator) and later during the daily QC applied to the data from each flight. The data form part of the survey record store.

6.2.2 EM system Lag

The EM lag is normally 0.75 seconds, and it was verified on survey line 566, which was flown in opposite directions, 345 and 165 degrees.

7 Other calibrations

7.1 NAVIGATION AND FLIGHT PATH RECOVERY (DAILY CHECKS)

GPS positional checks were performed daily, with the aircraft in the same parking location at each survey base. A two minute recording of the on-board GPS system was made. The sampling interval was 1 second. The results of the test were displayed as a scatter plot using analysis software provided by the manufacturer of the system. The scatter plot also shows statistical parameters of the measurements. No differential corrections are applied. An example of a scatter plot is shown in Figure 14. The data (images) obtained have been incorporated into the Report Data CD. The images are identified by the Julian Day Number of the test.

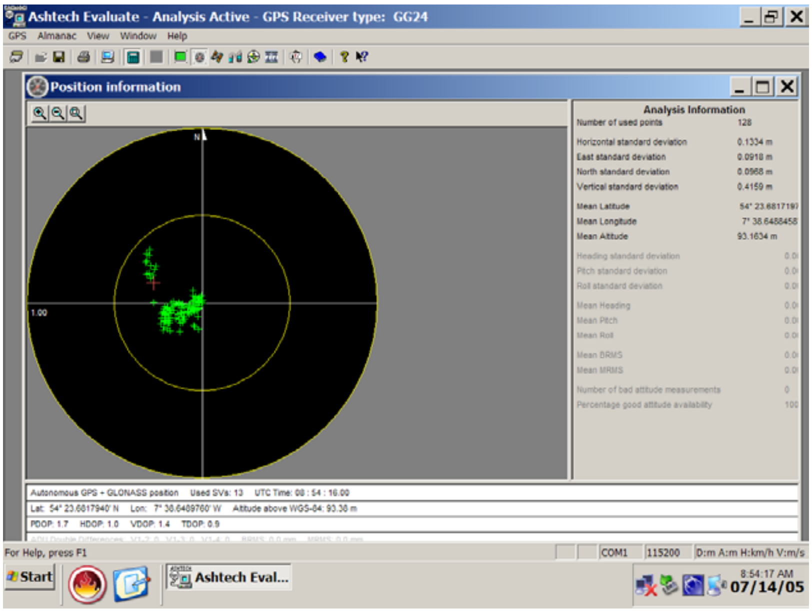


Figure 14. Example of GPS scatter plot

7.2 RADAR AND BAROMETRIC ALTITUDE

The linearity between the radar and barometric altitude measurement sensors was checked using data, which was measured over the sea at different altitudes from 25 to over 100 meters. These are the same data, which were used for determining the EM calibration coefficients. The results are shown in Figure 15.

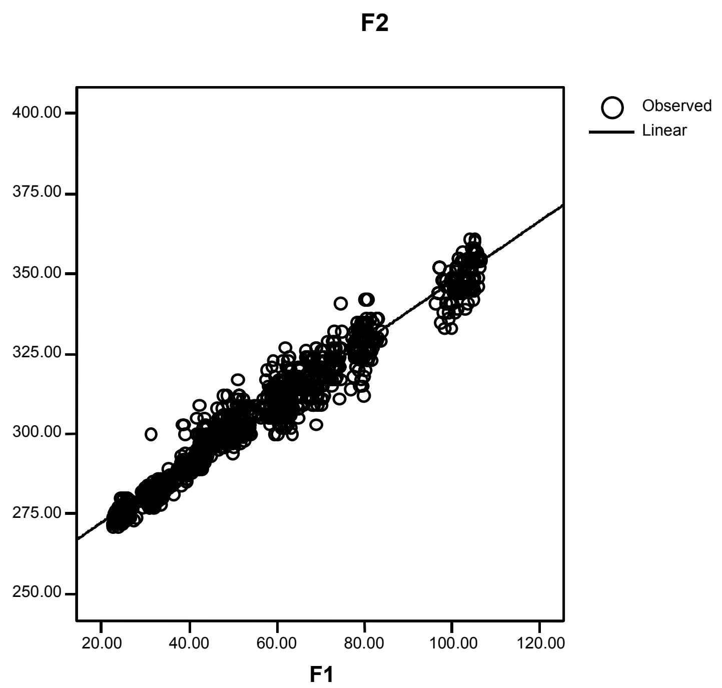


Figure 15. Radar altitude (abscissa) against barometric altitude (ordinate).

The correlation between radar and barometric altimeter was 0.979. The linearity is good. The accuracy, in meters, is somewhat worse with higher altitudes, as expected.

8 Data handling and QC procedures

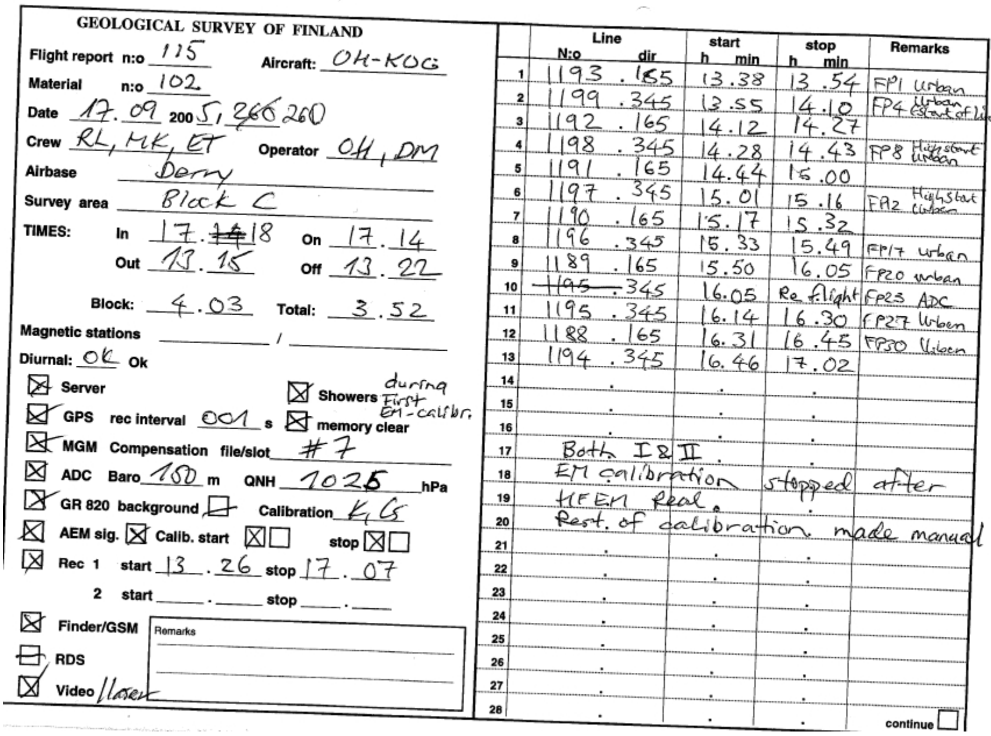
The data handling and QC procedures used by the JAC are fully described by Hautaniemi et al., (2005).

The geophysical and avionic data acquired during each flight is monitored by a geophysical operator as shown in Figure 16. The geophysical operator monitors all the instruments and the data being acquired using a laptop computer. Each instrument is connected to a dedicated microprocessor. The microprocessor controls data transfer to a Local Area Network (LAN). A GPS-based synchronisation pulse is provided through the LAN at a frequency of 40 Hz.

Figure 16. Geophysical operator and main instrument rack.

The operator is responsible for maintaining the flight logs, which summarise all the required parameters for each survey flight. An example log from Flight 115 of the survey is shown in Figure 17. Noteworthy factors (e.g. urban fly-high conditions) and exceptions are digitally logged using a fixed-point (FP) number data channel that ties the operator’s notes to the recorded data stream. Fixed points also define on-line and off-line conditions. Three copies of each flight log are retained (one each for the BGS, GTK and the FAA). The flight logs for the survey have been scanned and assembled in two .pdf files and placed in the Report Data CD.

A processing flow diagram for the field processing and QC of the acquired data is shown in Figure 18. The basic processing of the recorded data is undertaken immediately after each flight and before the start of the next flight. Figure 18 shows 3 initial entry points into the scheme. The 3 streams allow for the processing of (a) the geophysical data, (b) the GPS data and the magnetic base station data.



GEOLOGICAL SURVEY OF FINLAND

Flight report n:o 115 Aircraft: OH-KOG

Material n:o 102

Date 17.09 2005, ~~266~~ 260

Crew RL, MK, ET Operator OH, DM

Airbase Derry

Survey area Block C

TIMES: In 17.~~14~~18 On 17.14

Out 13.15 Off 13.22

Block: 4.03 Total: 3.52

Magnetic stations ______ / ______

Diurnal: OK Ok

☒ Server ☒ Showers during first EM-calibr.

☒ GPS rec interval 001 s ☒ memory clear

☒ MGM Compensation file/slot #7

☒ ADC Baro 150 m QNH 1025 hPa

☒ GR 820 background ☐ Calibration K, Cs

☒ AEM sig. ☒ Calib. start ☒☐ stop ☒☐

☒ Rec 1 start 13.26 stop 17.07

2 start ___.___ stop ___.___

☒ Finder/GSM Remarks

☐ RDS

☒ Video/laser

	Line N:o	dir	start h min	stop h min	Remarks
1	1193	165	13.38	13.54	FP1 urban
2	1199	345	13.55	14.10	FP4 urban (start of line)
3	1192	165	14.12	14.27	
4	1198	345	14.28	14.43	FP8 High start urban
5	1191	165	14.44	15.00	
6	1197	345	15.01	15.16	FP2 High start urban
7	1190	165	15.17	15.32	
8	1196	345	15.33	15.49	FP17 urban
9	1189	165	15.50	16.05	FP20 urban
10	~~1195~~	345	16.05	Re-flight	FP23 ADC
11	1195	345	16.14	16.30	FP27 urban
12	1188	165	16.31	16.45	FP30 urban
13	1194	345	16.46	17.02	
14					
15					
16					
17	Both I & II.				
18	EM calibration		stopped after		
19	HFEM peak.				
20	Rest of calibration		made manual		
21					
22					
23					
24					
25					
26					
27					
28					

continue ☐

Figure 17. Example of flight log.

The first stage in processing the geophysical data involves the programme ALKU2000 (see Figure 19). The program reads and examines all the flight data and flags alarms and data and file errors. The data obtained can be visually replayed and assessed. The program provides an output Geosoft database file (.gdb) containing all the data and ancilliary channels. The Geosoft Oasis Montage™ programme is used to further examine the data in a linked database environment. Standard processing and QC involves the use of fourth differences in the magnetic and electromagnetic channels. The apperance, quality and noise levels of all data components together with EM calibrations, drift levels and noise peaks are examined. Separate programs (MAGcor, RADcor and ELcor) are then applied for the calibration and the application of methodological corrections to the geophysical data. These procedures provide an initial, but still preliminary, set of text files (termed .xyz) for each flight and for each of the three geophysical data sets. These data sets are finally assembled into a Geosoft database for further QC assessments according to those required by the survey specifications. An example of the QC database windows arranged in an Oasis Montaj™ screen is shown in Figure 20. In the interests of clarity, the example does not include all the possible QC windows available to the processor.

The JAC program MAG32 is used to process the magnetic data recorded at the base station. The program compares the recorded data against specification conditions for reflights (e.g. the magnetic variation exceeding 12 nT over any 3 minute chord or exceeding 2 nT over any 30 second chord). Any noise, or features that can be regarded as 'local' are filtered by a combined median and averaging filter.

The outcome of the application of the above procedures, together with the DGPS corrections (see below), result in flight-line by flight-line xyz text files for each geophysical parameter. These are transferred to Geosoft databases where further QC control is applied. Altitude deviation is checked statistically and also by plotting colour profiles. The line paths are compared to the specified line paths and the flight path deviation is analysed. Flight line separation is verified visually and by the Oasis Montaj™ Airborne QC module. Sampling intervals and survey speed are also checked.

Processed data for each successive flight are appended to the survey area databases. Geophysical parameters, errors and noise levels of all measurements are examined on a line-by-line basis. Geophysical parameters are also interpolated to grids and examined. All these grids are preliminary but they form useful updated summaries of the behaviour of the survey data. Although the final levelling of the EM data is performed after the whole area (block) has been surveyed, preliminary levelling is carried out by the JAC program Emprelev. This initial levelling step, carried out in the field, is important in that it allows for a greater degree of QC on the EM coupling ratios acquired.

Average radiometric spectra and the main energy windows are plotted for each flight (e.g. Figure 9) using the program SPEKNT. This allows an assessment of any spectral drift. Spectral stability and overall functioning of the spectrometer is controlled during the survey in real-time (geophysical operator), together with the programs ALKU2000 (e.g. Figure 19) and by SPEKNT. During the Tellus project, daily radiometric calibration checks were also carried using hand-samples, as previously described.

It should be noted that the subsequent processing (e.g. that undertaken post-survey in the JAC processing offices) of the survey data is beyond the scope of this logistics report.

8.1 COORDINATE SYSTEM

A commercial GPS processing program (Javad Pinnacle™) is used to perform differential GPS processing. It uses both GPS and GLONASS satellites. The inputs are the flight and base station satellite recordings. The quality of the satellite coordinates is verified by observing the number of satellites and by using a quality (PDOP, Position Dilution of Precision) parameter. The JAC program GPS2KOG uses the differentially corrected GPS WGS84-coordinates to transform to a local grid (planar) coordinate system. The local geographical grid system used for the Tellus data is the IRISH GRID 1975 used as a national reference system by both The Republic of Ireland and Northern Ireland.

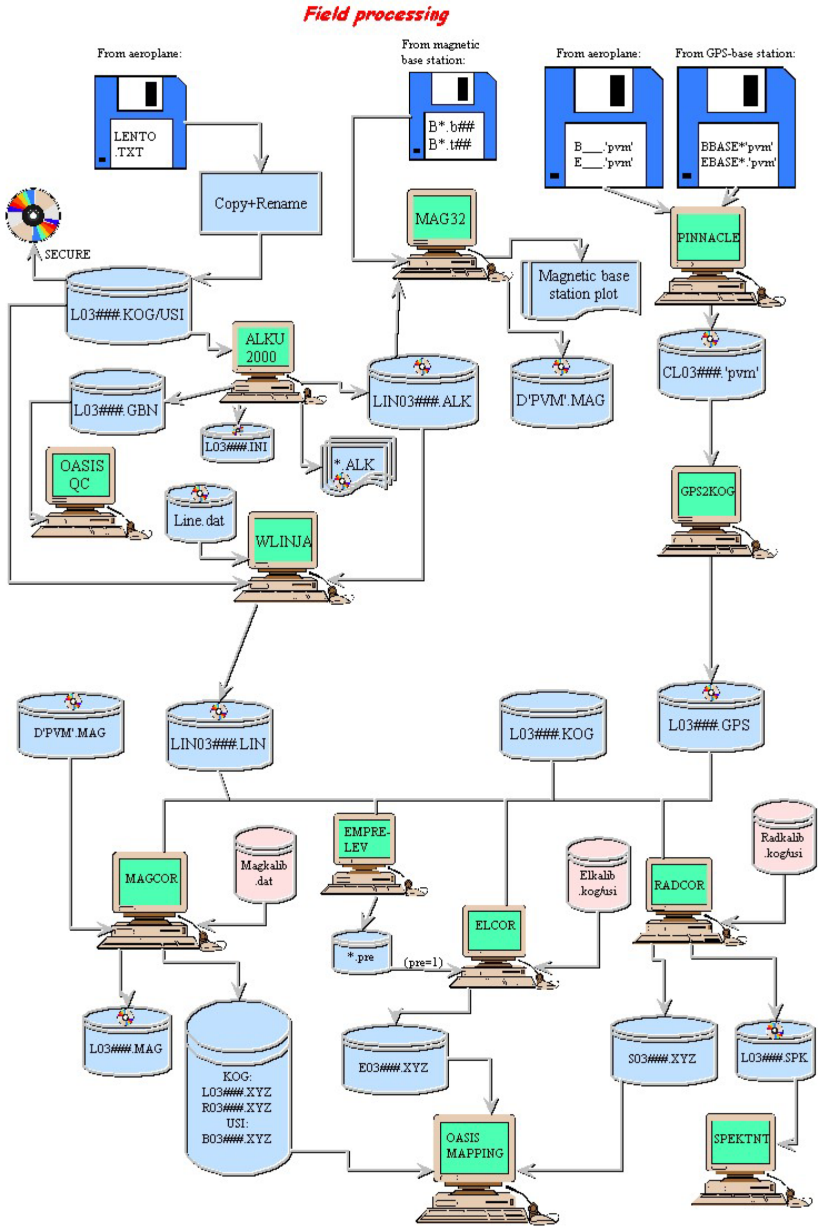


Figure 18. The flow diagram for the initial, in-field processing and QC of the survey data.

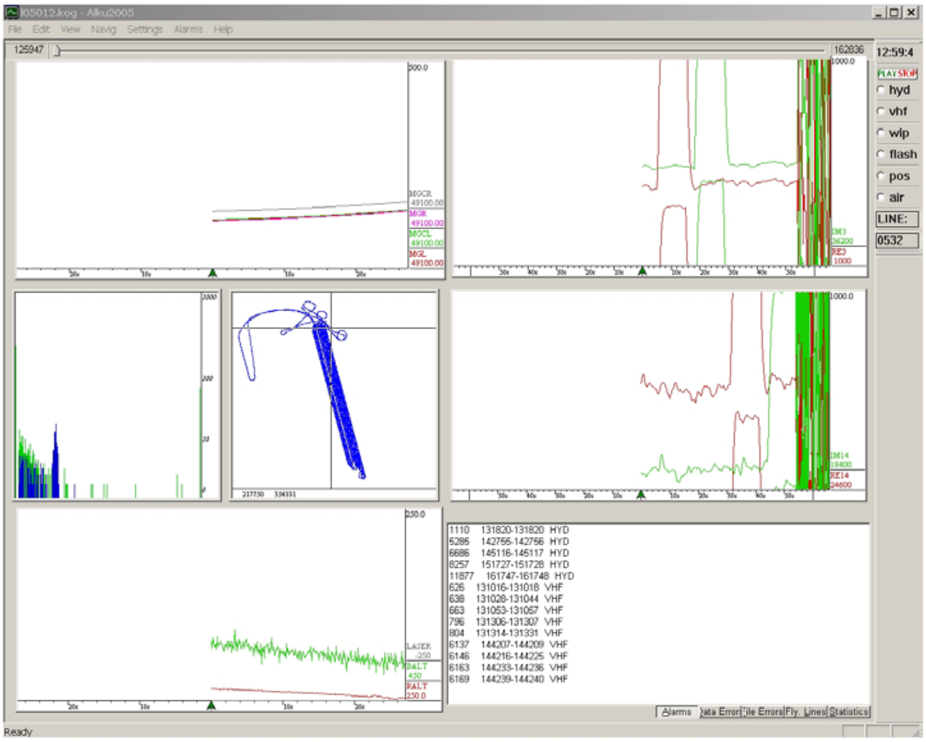


Figure 19. Screen capture of ALKU2000m program, showing survey data panels at the start of a flight.

Figure 20. Example of quality control of one survey flight. Starting calibration and first 3 survey lines. First (upper) panel: EM components. Second panel: uncompensated and compensated magnetic channels. Third panel: Forth differences in compensated magnetic channels. Fourth panel: Fourth differences in 4 EM channels. Fifth (lower) panel: Off/on-line channel.

Details of the system can be found on the Ordnance Survey of Northern Ireland Web site. Table 13 provides a main summary.

IRISH GRID (1975) National Datum	
Projection	Transverse Mercator (Gauss Conformal)
True Origin	Lat. 53° 30´North, 8° 00´ West of Greenwich
False Origin	200,000 m W, 250,000 m S, of true origin
Scale factor on central meridian	1.000035
Reference Ellipsoid	Airy (modified)
Semi-major axis (a)	6 377 340.189 m
Eccenctricity (e^2)	0. 0006 670 540

Table 13. Summary parameters for the IRISH GRID (1975) that define the local grid coordinates (Easting and Northing) used in the Tellus aerogeophysical project.

8.2 DGPS ACCURACY AND QUALITY CHECKS

The quality of the satellite positioning system was investigated on selected flights that took place in August 2005. The flights were chosen both randomly and when the positioning was suspected to be of lower quality. The quality parameters are the number of satellites used (SVs) and the Position Dilution of Precision (PDOP).

The satellites in comparison (SVs) are those, which both the aircraft and the base station used simultaneously. Both GPS and GLONASS satellites are in use, which improves both the real time and differentially corrected coordinates. It is considered to be of very good quality, if the SV number is greater than eight (8). Four or more satellites must be visible to calculate a 3D position (in latitude, longitude, altitude and time).

The unitless, computed parameter PDOP reveals the geometry of the satellites. If the satellites are high above the horizon and scattered evenly all around the sky, the number is small. If all the satellites are in the same direction, or many of them are near the horizon, the PDOP number is bigger. Satellites that are low on the horizon typically produce weak and noisy signals. It is considered that PDOP below 3 is of good quality, and below 1-1.5 is very good quality.

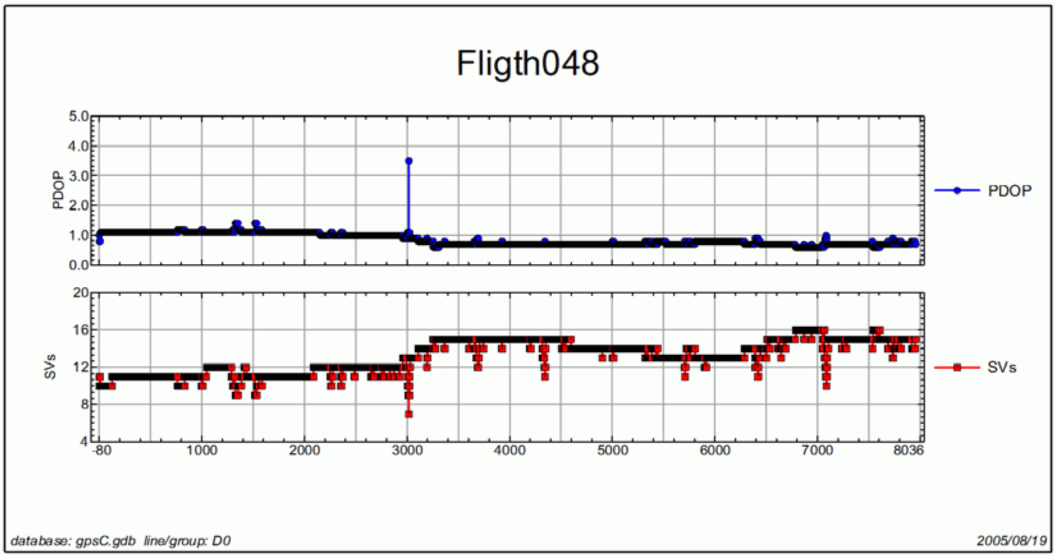


Figure 21. DGPS quality control parameters, SV and PDOP (see text), on Flight 048.

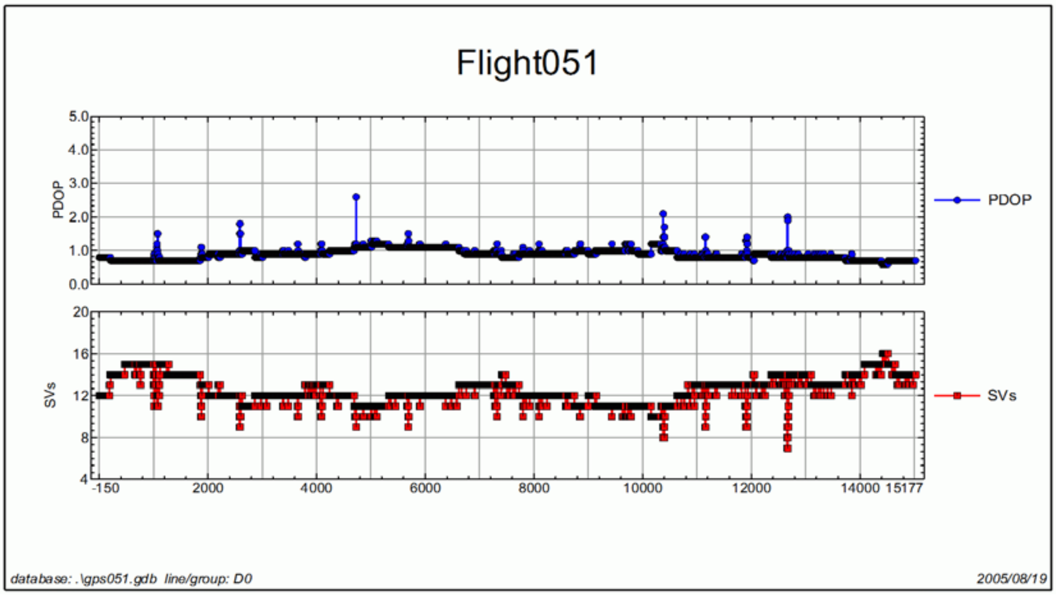


Figure 22. DGPS quality control parameters, SV and PDOP (see text), on Flight 051.

Figures 21 and 22 display the results obtained for two flights. Each figure shows the recording during a whole flight. The horizontal axis is seconds from the start of the data recording.

The number of satellites is typically around 12 or more, and in a few cases 8-10. These figures imply good or very good quality. The PDOP parameter is generally very small, around 1, so that the implied satellite geometry is very good. In summary, the investigations indicate that the differentially corrected coordinates (X, Y) obtained during the survey are of sub-meter accuracy.

8.3 EXTERNAL QC

An independent assessment of the equipment, procedures and data qualities was carried out by an independent consultant (Dr. Alan Reid). The consultant reported to DETI via the Tellus project management at GSNI. Reports were provided by the consultant at various stages throughout the project. Field visits were made by the consultant at both the beginning and end of the survey operations. The original start-up report was largely formed by the calibration material supplied by JAC.

At the request of the Tellus management, preliminary data, obtained at various points through the in-field preliminary processing procedures (e.g. Figure 18), were supplied for assessment. These data were used by the consultant to provide quality assessments of the preliminary data acquired across the Block sequences of PHASE 1. As far as we are aware, and despite the problems associated with this approach, all the reports produced satisfactory certifications.

8.4 DATA ARCHIVES

The raw geophysical and ancillary data comprise 3 components as indicated in Figure 18. The 3 components are

(a) the geophysical data,

(b) the GPS data (airborne and base),

(c) the magnetic base station data

The airborne geophysical data (a) exist on an original Zip disk, as recorded during the flight by the data logging procedures. The form of this data is a text file referred to by its extension (.kog). These Zip disks are retained and archived at the JAC processing centre (GTK, Helsinki). During field operations, all three data sets are copied into a flight directory (e.g. Flight012). This directory forms a folder in which the raw data (e.g. (a), (b) and (c)) is retained. The in-field processing is also carried out in this directory so that all activities are recorded (the processing programs produce statistics and listings files). During operations, backups of all such directories are made to external devices. While in the field these directories are 'work in progress' folders. At the end of a survey season, the working Flight directories are used to undertake both revised and additional processing of the survey data. At the conclusion of the final processing, the directories will be classified as 'definitive' and will be archived as a record of the raw data files and the processing activities carried out.

As noted in Section 2.4, the airborne project was developed using the BGS Intranet-based Project Management System (PMS). The aerogeophysical project plan includes a data Management Plan. At present, work at BGS on the survey data is carried out within a Project Workspace that has corporate backup facilities in place. Although the final delivered data will be owned by DETI (NI), it will be the responsibility of BGS/JAC to archive the 'definitive' survey folders discussed above. Statements regarding final processed data files are not relevant in the context of the present logistics report.

8.5 REPORT DATA CD

As noted throughout the report, in order to provide a full description of the details of the survey operation, it is necessary to include a Report Data CD. The contents of the CD are a series of five directories as outlined below.

Daily_magbase: Contains a series of .jpeg images of the base station recordings. These are the graphical outputs from the program MAG32 used during in-field processing. The files are named by Julian day (e.g. D186a.jpeg). Time is in U.T. Since there is the possibility of two flights per day, a second base station recording to cover the second flight would be called D186b.jpeg. An example of a magnetic base station graphical plot is shown in Figure 23. In the plot the magnetic variation is shown together with flight line information (vertical lines). The vertical lines indicate the start and end of the airborne on-line acquisition together with the duration of individual flight lines.

Flight_logs: Contains two .pdf files with the scanned Flight Logs for the survey. The files are named Tellus_flight_reports_2005.pdf and Tellus_flight_reports2_2005.pdf. The flight logs are discussed earlier in this section and an example was shown in Figure 17.

GPS_scatterplots: Contains the plots of the daily GPS functionality checks performed with the parked aircraft. A two minute recording of the on-board GPS system was made. The sampling interval was 1 second. The results of the test were displayed as a scatter plot using analysis software provided by the manufacturer of the system. The scatter plot also shows statistical parameters of the measurements. No differential corrections are applied. The graphical files (.png) are labelled according to Julian day (e.g. Scatterplot189.png). An example of the images was shown in Figure 14.

Hand_sample_tests: Contains the daily radiometric checks on the stability of the crystal packs of the Exploranium GR-820/3 system. The procedure adopted was to perform 3 minute recordings using hand-samples placed at a known location on the fuselage of the aircraft (below the crystal packs). The procedure was undertaken at a fixed parking location at each survey base. Three sets of tests were carried out. The first test recorded background, with no hand samples present. The second test used a hand sample of Cs-137 and the third test used a hand sample of Th-232. The records were processed with the JAC software module SPECNT that displays the spectra of the 3 tests. An example of the graphical output was shown in Figure 9. The images are contained within Word documents. The document images are identified by the Julian Day Number of the test (e.g. Hand sample test Julian Day 183.doc)

Line_definitions: Contains the ideal survey line coordinates (beginning and end) of each flight line of the survey. These are recorded in Irish National Grid coordinates (X-minimum, X-maximum, Y-minimum, Y-maximum). The total distance of each line is also recorded. The files (e.g. LINES_A.txt) are simple text files for each block (e.g. A) of the survey.

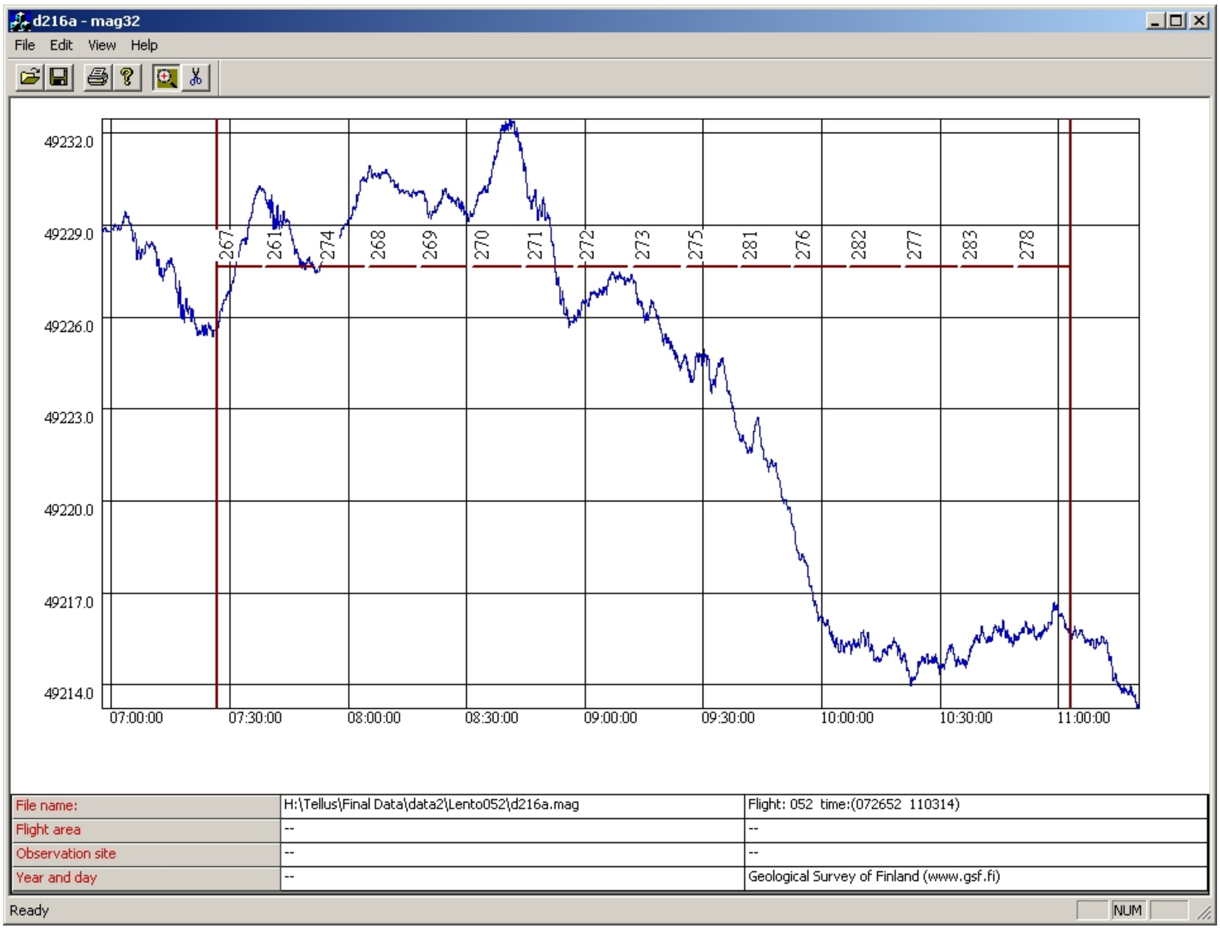


Figure 23. Example of plot from Daily_magbase directory on Report Data CD. Example shown is file d216a.jpeg.

9 References

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Appendix 1. Chronology of the Tellus PHASE 1 survey operations of 2005.

Material No.	Date	Area	Base	Duration	No. Lines	Personnel
11	01-Jul	Comp/FOM	Enniskillen	01:17	4	RL RV ET VL OH
12	02-Jul	Comp/FOM	Enniskillen	01:01	4	RV RL ET VL KN
13	04-Jul	Comp/FOM	Enniskillen	01:03	4	HL RV VW VL
14	04-Jul	Block A	Enniskillen	03:47	44	RV HL VW VL KN
15	05-Jul	Block B	Enniskillen	01:46	26	RV HL VW VL SB
16	06-Jul	Block B	Enniskillen	00:21	0	RV HL VW KN SB
17	06-Jul	Block B	Enniskillen	02:44	24	RV HL VW KN SB
18	07-Jul	Block B	Enniskillen	03:37	16	RV HL VW KN SB
19	08-Jul	Block B	Enniskillen	02:25	10	RV HL VW KN
20	09-Jul	Block B	Enniskillen	01:17	5	RV HL VW VL
21	09-Jul	Block B	Enniskillen	03:06	14	RV HL VW VL
22	11-Jul	Block B	Enniskillen	00:48	3	RV HL VW VL ML
23	13-Jul	Block B	Enniskillen	04:08	18	RV HL VW VL JP
24	13-Jul	Block B	Enniskillen	04:02	25	RV HL VW VL
25	14-Jul	Block B	Enniskillen	03:48	16	RV HL VW JP
26	14-Jul	Block B	Enniskillen	01:03	2	RV HL VW JP
27	15-Jul	Block B	Enniskillen	04:26	16	RV HL VW JP
28	15-Jul	Block B	Enniskillen	03:00	12	HL RV VW JP
29	16-Jul	Block B	Enniskillen	00:49	4	HL RV VW JP
30	16-Jul	Test	Enniskillen	00:26	0	RV HL SJ VW JP
31	16-Jul	Test	Enniskillen	00:31	0	RV HL SJ VW JP
32	16-Jul	Block B	Enniskillen	02:39	16	RV HL SJ VW JP
33	18-Jul	Block B	Enniskillen	03:57	16	RL MK ET JP
34	18-Jul	Block B	Enniskillen	03:24	15	RL MK ET JP
35	19-Jul	Block B	Enniskillen	02:13	9	RL MK ET JP RC
36	19-Jul	Block B	Enniskillen	03:37	18	MK RL ET RC OH
37	20-Jul	Block B	Enniskillen	03:55	20	RL MK ET OH
38	20-Jul	Block B	Enniskillen	04:00	25	MK RL ET RC JP
39	21-Jul	Block B	Enniskillen	04:11	34	RL MK ET RC JP
40	21-Jul	Block AB	Enniskillen	03:17	32	MK RL ET OH
41	22-Jul	Block AB	Enniskillen	01:44	14	MK RL ET RC JP
42	22-Jul	Comp/FOM	Enniskillen	01:19	4	RL MK ET JP OH
43	23-Jul	Comp/FOM	Enniskillen	01:00	4	MK RL ET OH
44	23-Jul	Block AB	Enniskillen	00:36	3	MK RL ET JP RC
45	25-Jul	Comp/FOM	Enniskillen	00:23	2	RL MK ET JP
46	25-Jul	Comp/FOM	Enniskillen	01:09	4	RL MK ET JP
47	25-Jul	Block AB	Enniskillen	04:31	41	RL MK ET RC JP
48	26-Jul	Block AB	Enniskillen	04:13	37	RL MK ET RC JP
49	26-Jul	Block AB	Enniskillen	03:48	20	MK RL ET OH
50	27-Jul	Block AB	Enniskillen	03:56	21	MK RL ET RC JP
51	27-Jul	Block AB	Enniskillen	03:50	20	RL MK ET OH
52	28-Jul	Block AB	Enniskillen	04:04	22	MK RL ET OH RC
53	28-Jul	Block AB	Enniskillen	00:34	2	RL MK ET OH
54	29-Jul	Block AB	Enniskillen	03:58	20	MK ET RL RC
55	29-Jul	Block AB	Enniskillen	02:53	14	MK ET RL OH
56	30-Jul	Block AB	Enniskillen	02:44	14	RL MK ET RC
57	01-Aug	Block AB	Enniskillen	02:04	10	RL HL VW OH DM
58	02-Aug	Block A	Enniskillen	01:38	7	RV HL VW VL LN
59	03-Aug	Block A	Enniskillen	03:46	16	RV HL VW OH DM
60	03-Aug	Block A	Enniskillen	03:41	16	RV HL VW VL DM
61	04-Aug	Block A	Enniskillen	03:54	16	RV HL VW VL LN
62	04-Aug	Block A	Enniskillen	00:43	1	HL RV VW OH DM
63	05-Aug	Block A	Enniskillen	04:07	16	RV HL VW DM VL
64	05-Aug	Block A	Enniskillen	04:08	14	RV HL VW DM VL
65	06-Aug	Block A	Enniskillen	04:07	13	RV HL VW DM VL

66	06-Aug Block A	Enniskillen	03:16	10 RV HL VW DM VL
67	08-Aug Block A	Enniskillen	04:10	12 HL RV VW VL
68	08-Aug Block A	Enniskillen	04:13	12 RV HK VW VL AH
69	09-Aug Block AD	Enniskillen	04:10	18 HL RV VW VL HO
70	09-Aug Block D	Enniskillen	01:39	6 RV HL VW HO AH
71	10-Aug Block D	Enniskillen	04:01	16 HL RV VW HO AH
72	10-Aug Block C/A	Enniskillen	03:45	14 RV HL VW VL
73	11-Aug Block D	Enniskillen	04:05	16 HL RV VW HO
74	11-Aug Block D	Enniskillen	03:13	12 RV HL VW VL AH
75	12-Aug Block D	Enniskillen	04:06	16 HL RV VW VL AH
76	12-Aug Block D	Enniskillen	04:15	17 RV HL VW VL
77	13-Aug Block D	Enniskillen	04:19	15 HL RV VW HO AH
78	13-Aug Block D	Enniskillen	01:59	5 RV HL VW HO
79	15-Aug Block D	Enniskillen	04:14	16 MK RL ET HO
80	15-Aug Block D	Enniskillen	04:10	16 RL MK ET HO
81	16-Aug Block D	Enniskillen	04:06	16 RL MK ET JP
82	16-Aug Block D	Enniskillen	03:07	12 RL MK ET HO
83	17-Aug Block D	Enniskillen	04:06	16 MK RL ET HO
84	18-Aug Block D	Enniskillen	04:18	16 RL MK ET JP
85	18-Aug Block D	Enniskillen	04:15	16 RL MK ET HO
86	19-Aug Block E	Enniskillen	03:31	30 RL MK ET HO
87	19-Aug Block E	Enniskillen	04:05	20 MK RL ET JP
88	20-Aug Block E	Enniskillen	04:15	18 MK RL ET JP
89	20-Aug Block E	Enniskillen	04:16	18 RL MK ET HO
90	22-Aug Block E	Enniskillen	03:57	16 MK RL ET HO
91	22-Aug Block E	Enniskillen	03:56	16 MK RL ET JP
92	23-Aug Block E,D	Enniskillen	03:16	12 MK RL ET JP EH
93	23-Aug Block E	Enniskillen	02:45	10 RL MK ET HO
94	24-Aug Block E	Enniskillen	00:41	0 MK RL ET HO
95	25-Aug Block D,E	Enniskillen	04:06	16 MK RL ET JP EH
96	25-Aug Block E	Enniskillen	02:18	8 RL MK ET EH JP
97	26-Aug Block E	Enniskillen	04:01	16 RL MK ET EH JP
98	26-Aug Block E	Enniskillen	03:57	16 RL MK ET EH JP
99	27-Aug Block E	Enniskillen	00:27	0 MK RL ET EH JP
100	27-Aug Block E	Enniskillen	03:25	13 MK RL ET EH JP
101	27-Aug Block A,B Tielines	Enniskillen	01:49	6 RL MK ET JP
102	29-Aug Block C	Enniskillen	03:34	14 RV HL VW EH JP
103	30-Aug Block A,B Tielines	Enniskillen	03:58	10 HL RV VW EH JP
104	30-Aug Block A,B Tielines	Enniskillen	03:19	10 RV HL VW EH JP
105	31-Aug Block A,B Tielines	Enniskillen	01:46	7 RV HL VW JP
106	01-Sep Block A,B TielinesEnniskillen7:17		01:05	0 RV HL VW KN
107	01-Sep Block A,B Tielines	Enniskillen	03:54	12 RV HL VW KN
108	01-Sep Block A,B Tielines	Enniskillen	01:51	14 RV HL VW KN
109	02-Sep Block A,B Tielines	Enniskillen	03:23	14 RV HL VW KN
110	02-Sep Block C	Enniskillen	01:30	4 RV HL VW KN
111	03-Sep Block C	Enniskillen	03:51	14 RV HL VW KN
112	03-Sep Block C	Enniskillen	00:22	0 RV HL VW
113	05-Sep Block C	Derry	00:50	0 RV HL VW KN
114	17-Sep Block C	Derry	01:11	2 RL MK ET VL OH
115	17-Sep Block C	Derry	03:52	12 RL MK ET OH
116	19-Sep Block C	Derry	00:52	2 RL MK ET RC OH
117	20-Sep Block C	Derry	03:09	11 RL MK ET RC OH
118	20-Sep Block C	Derry	03:52	14 RL MK ET OH
119	21-Sep Block C	Derry	03:49	14 RL MK ET OH RC
120	21-Sep Block C	Derry	01:30	4 RL MK ET OH
121	22-Sep Block C	Derry	04:21	14 RL MK ET RC
122	22-Sep Block C	Derry	02:02	5 RL MK ET OH
123	24-Sep Block C	Derry - Ennis	02:05	5 RL MK ET OH
124	26-Sep Transfer	Ennis - Derry	00:19	0 RV HL VW OH

125	27-Sep Block C	Derry	01:03	2 RV HL VW OH
126	27-Sep Block C	Derry	02:26	6 RV HL VW VL
127	28-Sep Block C	Derry	00:23	0 RV HL VW VL
127b	29-Sep Block C	Derry	03:27	14 HL RV VW OH
128	29-Sep Block C	Derry	02:33	10 RV HL VW VL
129	30-Sep Block C	Derry	03:44	12 RV HL VW OH
130	01-Oct Block C	Derry	00:42	1 HL RV VW VL
131	03-Oct Block C	Derry	00:29	0 HL RV VW VL
132	03-Oct Block C	Derry	04:12	13 HL RV VW VL
133	04-Oct Block C	Derry	03:53	14 RV HL VW OH
134	04-Oct Block C	Derry	03:16	22 HL RV VW VL
135	05-Oct Block C	Derry	03:57	14 RV HL VW VL
136	05-Oct Block C	Derry	04:19	22 HL RV VW OH

APPENDIX 2. Existing Equipment Outline Specification

The JAC is currently engaged in an R&D project to upgrade several items of the geophysical and avionics equipment installed in OH-KOG. The PHASE 1 survey of 2005 was flown with a 2 frequency system. Certain items of the R&D project were under evaluation during 2005, These were a laser altimeter, and digital video. A decision as to whether or not to fly the second and final season of the survey using the upgraded EM system will be made in consultation with the TELLUS team and the Technical Supervisor during the early part of calendar year 2006.

Listed immediately below are the specifications of the equipment used in the PHASE 1 survey. These lists are followed by the proposed specifications of the components to be upgraded.

Outline specifications of existing equipment

Electromagnetic system:	GTK EM95 dual frequency (3.125 and 14.368kHz)
Aircraft Magnetometer:	2 Scintrex CS-2 caesium vapour sensors, currently located in opposite wing tips
Magnetic Compensator	RMS Instruments Automatic Aeromagnetic Digital Compensator (AADCII)
Gamma-ray spectrometer	Exploranium GR-820/3 gamma-ray spectrometer 256-channels, self-calibrating
Altimeter	Collins radar altimeter
Data location system	Real time DGPS based on Ashtech GG-24 GPS+GLONASS receivers in aircraft and at base station
Data acquisition system	GTK proprietary: control unit including server, power unit, alarm box, Local Area Network

Existing Equipment Detailed Specification

Two frequency EM system (GTK EM95):

Coil configuration	Vertical-coplanar
Frequencies (kHz)	3.125 and 14.368
Coil separation (m)	21.36
Magnetic dipole moment (Am^2)	115 (LF) and 55 (HF)
Measuring range (ppm)	0- 40,000
Noise (STD) In-phase ppm	4 (LF) and 8 (HF)
Noise (STD) Out-of-phase ppm	3 (LF) and 8 (HF)
Sampling interval (samples/s)	4

Aircraft Magnetometer & AADCII (Automatic compensator) :

• Magnetometer configuration	Dual sensor, wing-tip mounted to facilitate horizontal gradiometry
• Sampling interval	0.1 second (10 Hz)
• Resolution	0.001 nT
• Gradient tolerance	10,000 nTm^{-1}
• System noise envelope	< 0.1 nT
• Manoeuvre noise	< 0.2 nT peak-to-peak (for each of 10° rolls, 5º pitches & 5º yaws). The sum of these for the 12 manoeuvres not to exceed 3 nT.
• Heading error	Typically ± 2 nT
• Total noise envelope	< 0.2 nT peak-to-peak after compensation.

Gamma-ray Spectrometer :

• Gamma-ray detector	2 Sets of NaI(Tl)-crystals: 32L downward looking and 8L upward looking
• Sampling interval	1 second
• Number of channels	256
• Overall system resolution	< 12% (fwhm of ^{137}Cs peak at 662 keV) (IAEA[4])
• Potassium window limits	1370 - 1570 keV (to nearest whole no. of channels)
• Uranium window limits	1660 - 1860 keV (to nearest whole no. of channels)
• Thorium window limits	2410 - 2810 keV (to nearest whole no. of channels)
• Total count window limits	400 - 2810 keV (to nearest whole no. of channels)
• Cosmic limits	3000 keV - ∞ (to nearest whole no. of channels)
• Upward crystal U window	1660 – 1860 keV
• System deadtime	± 0.1% measurement accuracy

[4] International Atomic Energy Agency, 1991 - Airborne Gamma Ray Spectrometer Surveying. Section 2.2.3 p12) *International Atomic Energy Agency Technical Reports Series Number 323*, IAEA Vienna. (

Ancillary equipment :

• DGPS	AshtecGG24, 12-channel L1 GPS + 12-channel L1 GLONASS, updates to 2Hz, Post processing accuracy (95%) to 75 cm (GPS+GLONASS), 1 m (GPS only).
• Radar altimeter	Range: 0- 300 m; Precision: 0.3 m; Accuracy: ±4%
• Temperature sensor	Precision: 0.1 degree Celsius outside, 1 degree inside
• Power line monitor	3 orthogonal fluxbars summed to give total field across a bandwidth centred on 50-60 Hz. Uncalibrated units.
• Barometric height sensor	Precision: 0.1%
• Video tracking system	Digital video coverage of flight path
• Monitor	No overlap; corrected for Compton Scattering before display
• Sampling interval	Typically 1 second or less

Specification of R&D items used during PHASE 1 survey :

Laser altimeter: manufactured by Riegl (Austria): range from 1 to 400 m, repetition rate 2 kHz, single shot accuracy < 5 cm. Laser safety class 1. Laser data were recorded separately to the main data acquisition. The sampling interval was 200 Hz.

Digital video with software to link compressed images to Geosoft Oasis Montaj database. The video data were recorded as .JPG images with a sampling interval of about 3 per second. The time reference of each frame formed the file name of each image.

Specification of items to be upgraded:

EM:

Coil configuration	Vertical coplanar
Frequencies (kHz, nominal)	0.9, 3, 12 and 25
Coil separation (m)	21.4
Magnetic dipole moment (Am^2)	150, 116, 42 and 38 (LF to HF)
Measuring range (ppm)	0-40,000

Magnetic gradiometer: wing-tip sensor currently on EM transmitter side to be housed in nose mounted stinger assembly, some 7 m forward of current position. This will allow a range of horizontal gradients to be observed/calculated.

GPS: Javad JNSGyro-4 GPS gyroscope with four GPS+GLO antennae to allow precise location of all sensors at all times during survey. In view of the complexity of the fit of this item to the aircraft its installation may or may not proceed during the current R&D project, according to available time and resources.

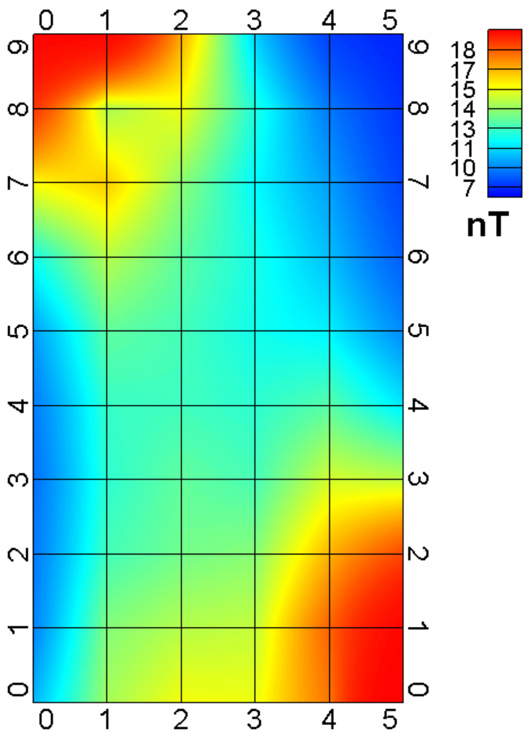
It is emphasised that, by the very nature of R&D projects, their successful and timely outcome cannot be guaranteed.

APPENDIX 3. Establishing the Second Base Station at Enniskillen Airport

3.1 Finding the Location

Measurements for the new base station were done 1st August 2005. A portable magnetometer (Geometrics G858) was used for finding a suitable location for the base magnetometer sensor. The following readings were recorded:

9	10.6	14.1	15.2	15.2	17.9	27.6
8	9.7	13.7	14.3	14.5	18.4	24.2
7	9.4	12.8	13.4	13.7	16.7	19.2
6	9.2	12.4	13.2	12.8	14.8	14.4
5	9.5	12.6	12.7	12.4	13.0	11.4
4	10.2	13.2	12.8	12.0	11.6	9.7
3	12.1	14.3	13.1	12.1	10.7	8.7
2	15.4	16.2	13.7	11.7	10.2	7.9
1	19.8	14.1	15.2	12.2	9.4	7.2
0	24.3	23.8	16.7	11.0	7.7	6.5
X/Y	**0**	**1**	**2**	**3**	**4**	**5**



There was some diurnal variation (±2 nT) during the measurements. Considering this the results are acceptable and the base station sensor was set up in the middle of the area measured with a portable magnetometer.

3.2 Level Difference

The levels at the new and old primary base station were compared to the secondary base station:

	Difference between base levels at the old primary base station and secondary base station				Difference between base levels at the new primary base station and secondary base station			
Time (day, version)	**206a**	**207b**	**208a**	**208b**	**215a**	**215b**	**215c**	**214a**
Number of items:	11774	5194	14697	14039	16682	17189	35583	23886
Standard deviation:	0.2	0.2	0.4	0.3	0.2	0.3	0.1	0.3
Standard error:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean value:	44.7	44.6	45.0	45.1	28.7	28.6	28.4	28.4
Median value:	44.7	44.6	44.8	45.2	28.7	28.5	28.4	28.5

Mode value:	44.6	44.7	44.8	45.3	28.6	28.4	28.4	28.5

The difference between the old primary and the secondary base stations is 44.7 nT (median of modes) and the difference between the new and the secondary base stations is 28.5 nT. Thus the level difference between the old and new primary base stations is 16.2 nT.

APPENDIX 4. Base Station at Derry Airport

MAGNETIC Base Station

A magnetically quiet location for the magnetic base station was established by a roving ground magnetic survey in a grassed area in the vicinity of the West Apron. The survey instrument used was a Geometrics G-858 Caesium Vapour magnetometer. The roving survey located a 10 x 10 m area having low magnetic gradients. Test recordings indicated the area was free of electromagnetic interference. The magnetic base station was located in the centre of a 10 m x 10 m rectangle having a magnetic variation of 8 nT in the North direction, 4 nT in the South direction, 11 nT in the West direction and 1 nT in the East direction.

The base stations at Derry and Enniskillen airports were recording simultaneously during the night 30th – 31st August 2005. In Figure 4.1 and Figure 4.2 a 6-hour long example of the recordings is shown. The statistics of the difference between the two base station levels are –141.8 nT (average) and –141.9 nT (median). The level difference between the base stations is 141.8 nT (mode value), thus a value of 49183.8 nT + 141.8 nT = 49325.6 nT will be used for base station corrections for the Derry airport base station.

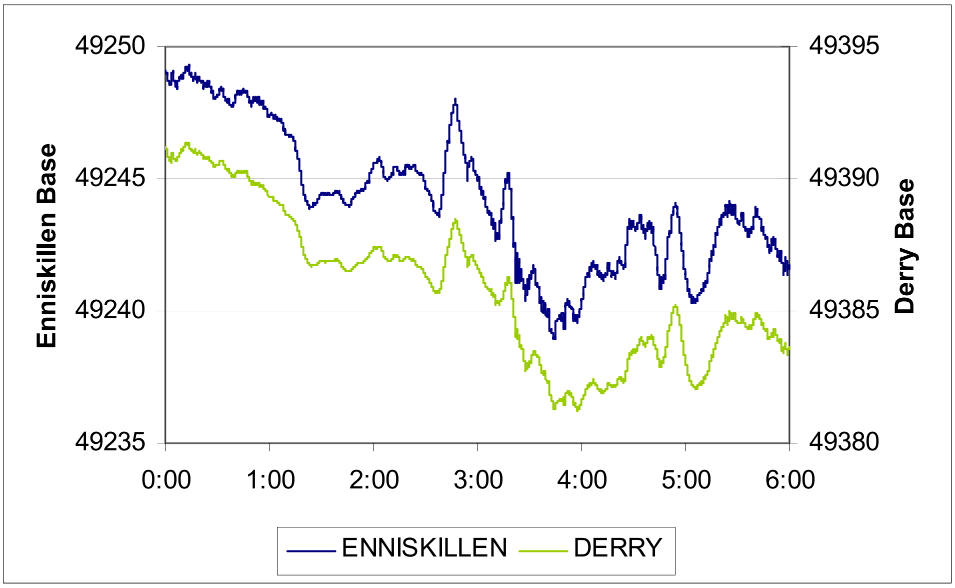


Figure 4.1. Simultaneous base station measurements (an example)

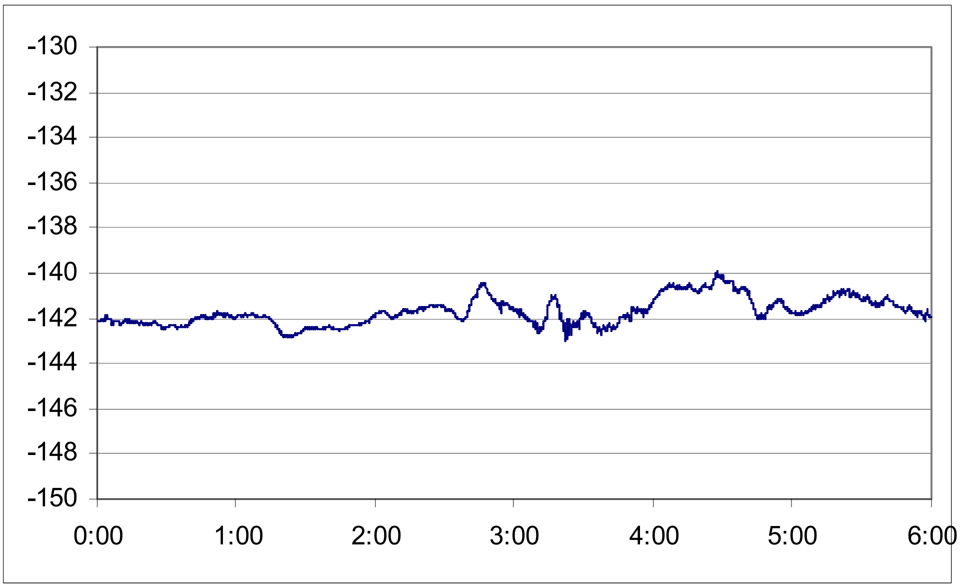


Figure 4.2. Difference between the base stations (an example)

GPS Base Station

Example of calculation of accurate base station location at Derry. Procedure uses RINEX GPS) data from a reference station (IA02 Kilrea) operated by Ordnance Survey of Northern Ireland.

IA02 Kilrea	Lat: 54° 57' 53.77044" Long: -6° 37' 4.92271"	E: 288563.01 m N: 413917.907 m	36.04	147.927 m

17 September calculation with pinnacle:

Program: PINNACLE,V1000

IA02 Kilrea 54.57.53.77044 -6.37.04.92271 147.9270

BASE 55. 02. 16.31572 -7.10.0 0.62752 64.5058

Date: 1.Sep.05 Time: 06:00:00 Duration:05:59:30

Solution Type: Static Data type: L1/Fixed Diff: Double

Ambiguities: Solution Std. Dev: 15.03 mm

Fixed: 15 Position Std. Dev: 24.45 mm

Float: 0 Rdop: 1.63

Ratio(best/2nd best): 100

dX -10864.6305 14.08

dY -34061.9785 -0.25 8.13 Distance: 36045.9576

dZ 4588.2983 0.60 -0.21 18.26

The GPS base station coordinates for the Derry Airport Base Station are:

Latitude: 55 deg 02 min 16.31572 sec

Longitude –7 deg 10 min 0.62752 sec

Elevation 64.5058 m

The figure below shows the primary (P) and secondary (S, backup) magnetic and GPS sensors established at the West Apron.


P
S
P
S