PREVIEW

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

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October 1992, Issue # 40

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Introduction

The ASEG Conference, charged our batteries, and confirmed the vigor of the ASEG. The Gold Coast Conference also enabled ideas to be tossed around, for our magazine. Several ideas surfaced; two that are being implemented this issue are: firstly publication of the ASEG membership (see back of this issue) with phone and fax contacts in every October PREVIEW, rather than in Exploration Geophysics .

Secondly, PREVIEW will publish occasional tutorial articles in a continuing education tutoral series. The first of these (p 15) is on GPS surveying for geophysicists by Terry Boyd of RIA.

A Geophysicist asks "Where am I?"

Other ideas are to have a special theme for each PREVIEW: GPS this issue; December will be the AGSO geophysical program. Other themes contemplated include ground radar, data standards, gravity, petrophysics, airborne geophysics, computer graphics, environmental geophysics. We need your ideas and support for themes and offers of tutorial articles to carry this all through.

In line with the themes PREVIEW will be going colour starting next issue and as advertising support allows. More details in the December issue.

We pay tribute in this issue to both Bob Thyer and Phil Hallof, two highly respected geophysicists whose passing has saddened their many ASEG friends and colleagues.

Editor

President's Page

The Ninth ASEG Conference was a technical and financial success and congratulations must go to the Queensland Branch for organising it so well. All the geophysicists who presented papers should be proud that they have contributed to the greater knowledge of the profession: and all those who listened will realise that they have gained further insight into some of the puzzling but exciting aspects of geophysics. It gives one a warm glow of importance at the time. But how long does it last? What happens when we arrive back in the home state, into that familiar office with the empty map-rolls in the corner and an in-tray full of requests that seem to have very little to do with geophysics. This is a long way from the lofty ideas that were espoused over a few beers during the warm evenings on the Gold Coast; this is back to the world of the exploration manager and the geologist (and the accountant). Yet, we are the people who can see through rock, identify its composition, and predict where it is broken, faulted or folded; all this without even touching it! We are the ones who can locate a sulphide deposit and decide whether it is massive or disseminated mineralisation, and much more.

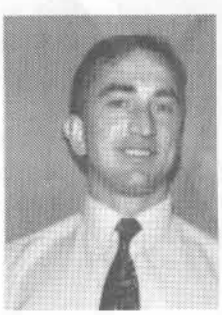
In which case why aren't we the leaders , the exploration managers, the chief explorers? There is no reason at all, and I encourage all geophysicists to have faith in their profession and their ability to lead an exploration program to success. The presenters and presentations at the conference convince me that this is possible. Take courage Australian geophysicists, lead, and success will follow.

At the Conference, the federal executive took the initiative to support the ASEG Research Foundation by committing funds to the foundation in advance. This was confirmed at a subsequent federal committee meeting when $15,000 was allocated for 1993 and a similar sum promised for 1994.

Hugh Rutter
President

ASEG People Profile

Brenton Oke, Honorary Secretary 1992



Brenton graduated with a B.Sc. degree in geology and an Honours degree in geophysics from the University of Adelaide in 1983. He began his exploration career with Adelaide-based Delhi Petroleum in 1984 and spent two years supervising seismic acquisition and processing field crews in the Cooper-Eromanga region of northeast South Australia and southwest Queensland before joining Delhi's field evaluation group.

In 1987 Esso Australia became the new owners of Delhi and subsequently moved many of the Adelaide personnel to their Sydney head office or Brisbane office. Brenton became a member of a Queensland exploration team, based in Brisbane, where he worked mainly on the gas and oil fields and surrounding areas of southwest Queensland.

In late 1990 after a decision to gain offshore exploration experience and work in new areas, Brenton joined BHP Petroleum in Melbourne where he is a member of the offshore Otway Basin exploration team.

Brenton served as QueenslandBranch secretary in 1990, is a member of the ASEG, SEG, AAPG and PESA and is married with two children.

☆☆☆☆☆☆☆☆

ASEG Branch News

Victoria

August

Grahame Smith, from the Australian Artificial Intelligence Institute spoke on Artificial Intelligence and Geophysics.

From one perspective, Artificial Intelligence can be viewed as a collection of generic problem-solving technologies that are adapted to applications in many domains. Two of these technologies are computer vision and expert systems. The presentation discussed how computer vision and expert systems can be applied to geophysical data interpretation.

The Australian Artificial Intelligence Institute commenced operations four years ago to perform strategic research and development in advanced computing technology. It works with clients in business, industry, and government to maximise the exploitation of research through the development of prototype systems and new products.

September

Dr Andy Green, Director of the CRC for Australian Mineral Exploration Technologies, spoke on the role and objectives of the new Cooperative Research Centre, and discussed the research strategy for the Geophysical Methods Program - in particular EM.

October

Doug Fraser, Chairman of DIGHEM Surveys, Canada, gave a very interesting overview of case studies involving DIGHEM's frequency-domain airborne EM systems. He talked on the history and evolution of the current DIGHEM-V system, its advantages over other EM systems, and its uses in highly-conductive overburden terrain.

Bob Harms
Secretary

Western Australia

Thanks to the following guest speakers who have all talked recently. Alfredo Eisenberg from Chile, Peter Vaughan, Mark Dransfield, Patrick Okoye, Alan Trench, Milovan Urosevic and Mike Dentim.

Don Steeples (Geol. Survey of Kansas) and David De Pledge will be giving talks during the week following the ASEG conference, the same week as the 3D Seismic workshop is being held in town (R. Malcolm Lansley and Alfonso Gonzalez).

Andie Lambourne
Secretary

New South Wales

September in Sydney saw the arrival of Spring and the ASEG NSW Branch Annual Student Night. Three students from local universities gave very good presentations to a full house at the Lord Nelson Hotel.

Sue Godesar (University of Sydney) "Seismic Stratigraphy of the Copper Basin Section within PEL's 5 & 6, Patchawarra Central Block, SA".

Steve Wright (UNSW) "An integrated geophysical investigation of a coastal aquifer on North Stockton Beach, NSW."

E. Stolz (Macquarie University) "Summer of Applied Geophysical Experience, ongoing investigation of the Rio Grande Rift, New Mexico, USA".

Each student received an AMF book voucher valued at $100 for their efforts.

Upcoming events include a presentation by Associate Prof. P R Evans (consultant) and the NSW Branch Annual Christmas Party.

Juliet Salmon
Secretary

South Australia

The September meeting of the SA Branch featured two talks which were subsequently presented at the ASEG Conference on the Gold Coast. The first was a talk by Cvetan Sinadinovski of Flinders University on "Non linear inversion travel time tomography: imaging high contrast inhomogeneities", followed by Matthew Rutti, also of Flinders University, who presented his paper titled "Multi Component seismic event correlation in coherent noise". Both talks were well received by those present and the evening judged a success.

The October meeting featured Alistair Brown of IHRDC who was in Adelaide to present his course "Interpretation of 3-D seismic data". Alistair presented his SEG distinguished lecturer talk "Seismic Interpretation yesterday, today and tomorrow". The discussion centred around how the fields of seismic interpretation have evolved from 2-D, paper sections in black and white to the current workstation environment utilising intensive graphics and colour displays. He then touched on the future developments towards totally integrated systems with multi-disiplinary teams. This was an excellent talk however the poor turnout was a disappointment.

As a general comment regarding Alistair's course on 3-D interpretation, a number of local attendees at the course have stated this was one of, if not the best, course they have ever been on. So to all interested geophysicists, look out for this course in future.

Future events of the SA Branch are as follows:

November 3	Melbourne Cup luncheon & Calcutta sweep
November 17	Student night
November 26	Don Robinson of Grant Tensor (formally Oklahoma Seismic)

Also on November 26, the student talks are to be completed and the winners of the best thesis and best presentation awards announced.

December 8	Annual Christmas BBQ

Finally, I encourage all ASEG members to get their wine orders in by the deadline on the order form to enable us to ensure delivery before Christmas.

Ashley Duckett
Secretary

ACT

The ACT Branch will be holding a branch meeting on Wednesday 28th October 1992 in the Ground Floor meeting room of AGSO commencing with drinks and nibbles at 6pm with the guest speaker being Colin Reeves (AGSO) with a talk titled "A geophysical ramble through the East African Rift Valley System".

In conjunction with AGSO, the AGSO-ASEG Spring Classic Golf Tournament will be held on Friday 6th November at the Belconnen Golf Course for those who would like to spoil a good walk hitting a small white ball.

The ASEG Branch in cooperation with the ACT Branch of GSA will be holding a Christmas function on Thursday 3rd December 1992 at the Athenian Restaurant commencing at 7pm with the guest speaker being Mike Smith (AIG). The cuisine is a little different from traditional Australian Christmas tucker, but in the current times of multi-culturalism a good night should be had by all who attend the Christmas function.

Kevin Wake-Dyster
Secretary

Queensland

The September Branch meeting held in Brisbane was addressed by Cam Wason, Consultant Geophysicist and formerly the Research Director for Halliburton, in Texas. The topic of Cam's talk was "Offshore Seismic Exploration in the Northwest Shelf", where he presented a review of geological factors that concern the geophysicist exploring the Northwest Shelf, and highlighted some of the problems affecting offshore seismic exploration.

Forthcoming events for the remainder of the year are:

Students Night	Last week in November
Christmas Function	First week in December

Voya Kissitch
Secretary

****

ASEG RESEARCH FOUNDATION

Post to: Treasurer, ASEG Research Foundation
Peter Priest, 39 Ningana Ave, KINGS PARK, SA 5034

NAME: ....

....

COMPANY: ....

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ADDRESS: (for receipt purposes)

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AMOUNT OF DONATION: $ ....

Do not detach - To be completed by ASEG Research Foundation

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In accordance with Income Tax Assessment Act S73A, this donation to the ASEG Research Foundation is tax deductible.

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ASEG 9th Geophysical Conference & Exhibition

ASEG 9th Geophysical Conference and Exhibition

Cloistered Australian Geophysicists Preserve Ancient Techniques

Australia's leading profile in mineral geophysics was highlighted by several of the keynote speakers at the ASEG 9th Conference & Exhibition at the Gold Coast.

Sven Treital of Amoco Production Research, commenting on the use of EM techniques in borehole geophysics, lamented the lack of knowledge of these methods in the US where seismic dominated all other techniques. By contrast Australian geophysicists nurtured and advanced other geophysical techniques like "monks in cloisters".

This theme was advanced by Jack Corbett in his keynote address. He stated that in the US the number of practicing mineral geophysicists may have fallen below a critical mass. By stark contrast, Alan Davies of BHP Coal, foresaw a bright future for geophysics in the coal industry. The reliability of many techniques had been proven and could be applied from exploration through to underground mining.

Other keynote speakers advised geophysicists to broaden their perspectives. Don Zimmerman of MIM predicted that geophysicists would become more involved in the management of mineral exploration projects because of the expanding use of geophysical techniques. However they would have to go beyond their purely technical scope. Bill French, of Grant Tensor Geophysical and President of the SEG, felt that the specialisation of geophysicists in the past would change. The power of modern computers meant that data could be interpreted almost as soon as it was acquired and that the geophysicist could once again determine the exploration programme from the field.

The highlight of the Conference for many people was the Mt. Isa Symposium. Sessions were packed as exploration companies revealed for the first time the geophysical methods used at the Century, HYC and Eloise deposits. In establishing specialist one day symposia the Conference Organising Committee (COC) hoped to attract a broader audience who had not previously thought of attending ASEG conferences. Over 50 delegates, mainly geologists, registered to attend on the day of the Symposium.

The general quality of the technical programme was very high and a great deal of credit is due to the presenters, the Technical Papers Committee (led by **Steve Hearn**) and the Conference Editor, **Jim Dooley**. Many of the foreign delegates admitted they were surprised at the quality and the informality of the session. This informality, partly inspired by the Gold Coast venue, enabled good feedback from the audience and many speakers found themselves giving expanded explanations outside of the sessions.

Another innovation at this Conference was the short oral presentation of the poster programme. This received good feedback from many delegates and could be retained for future conferences.

The trade exhibition was held outside the main Conference venue in a hoecker. This may be described as a large marquee or tent and was another first for the ASEG. There were some teething problems associated with the air conditioning but these were overcome and the response from exhibitors was that the exhibition ran well. A total of 55 companies exhibited in 90 booths, with the provision of a permanent supply of coffee not lost on the delegates.

The pre-Conference workshop on Airborne Geophysics had over 90 participants and received high praise. Numbers had to be curtailed such was the popularity. Contractors must be gladdened by the interest shown in airborne techniques. The post-Conference workshop on shallow seismic techniques was also well received.

A pre-Conference publicity programme was attempted and resulted in a great deal of interest from the general media. Some of the ASEG members will have seen some of our efforts in the trade journals. I believe that raising the profile of our conferences reinforces the contribution that geophysics makes to the industry. Certainly Tony McGrady, Queensland Minister for Minerals and Energy, was pleased to be photographed at the controls of a seismic vibrator during the Conference.

Although the dust had not settled at the time of writing this report, it appears that a profit of over $50,000 will be realised. The financial success of the Conference is the key to financial viability of our Society as a whole. The Society's conferences are a very good place for suppliers to market and promote their products and this has been shown by the sponsorship obtained.

The social programme was (apparently) fantastic. The Calypso Welcome was luxuriously catered for and set the scene for a memorable Conference. Steve Haddon had dinner guests falling out of chairs although having insulted both Conference Co-Chairman he may be struggling to gain a return appointment. Some people who didn't know any better thought Barry Long was the comedian, with Derecke Palmer the butt of his jokes.

Negative comments passed back to me were that the lunches were too big and that there were no biscuits with afternoon tea. I think that this highlights just how well the Conference was run.

I would like to thank my Co-Chairman, **Richie Huber**, and other members of the COC who provided the inspiration for the Conference. We would also like to pay tributes to Intermedia personnel who provided the perspiration. As well as a final report, we hope to ship a box load of aspirins to Perth in lieu of the geophysical flame. Good luck to them and we look forward to meeting you in February 1994.

Awards

Technical Excellence Award

Whereas previous conferences had awarded Best Paper and Best Presentation awards, the COC felt single award was more appropriate. Papers were shortlisted by the Technical Papers Committee and judges attended these presentations.

Winner:

"Geophysical response of Eloise Cu-Au deposits North West Queensland" presented by :

Richard Brescianinni, BHP Minerals

Co-authors: M. Asten, N. McLean.

Best Exhibitor -

Australian Geological Survey Organisation (AGSO)

Laric Hawkins Award -

This award is for innovative us of geophysical technique.

Winner:

"A novel VSP method for fault proximity detection using low velocity waveguide".

Shunhua Cao, Flinders University

Co-author: S. Greenhalgh

Graeme Sands Award -

Derecke Palmer - University of New South Wales (see report following).

H. van Paridon
Co-Chairman
ASEG 9th Conference

ASEG Grahame Sands Award

Derecke Palmer received the Grahame Sands Award for Innovation in Applied Geoscience at the 9th Conference and Exhibition of the Australian Society of Exploration Geophysicists held on the Gold Coast in October, 1992. The award is made to a person who has been responsible for a significant practical development of benefit to Australian applied geoscience, in the fields of instrumentation, data acquisition , data processing, interpretation or theory.

Derecke (on the left) accepts the award from Barry Long of the ASEG Honours and Awards Committee.

Derecke's innovation is the method for processing and inverting seismic refraction data known as the generalised reciprocal method or the GRM. Refraction methods were the first seismic techniques applied to the petroleum exploration more than 70 years ago. and currently they find extensive use in geotechnical and groundwater investigations, and in the processing of seismic reflection data for coal and petroleum exploration.

He was nominated by Bruce Goleby of the Australian Geological Survey Organisation in Canberra, and Dennis Sweeney of GECO-PRAKLA in Brisbane. In their nomination, they stated that "the GRM is one of the most significant innovations in exploration refraction seismology in more than fifty years. It has achieved international acceptance, a claim which very few other Australian innovations can make. It satisfies the criterion of being a significant Australian innovation, that has achieved international acceptance by both academia and industry, and which is being used regularly by Australian and International explorationists."

The GRM was first described in Derecke's masters thesis which later became the basis for a monograph on the GRM published in 1980 by the Society of Exploration Geophysicists in Tulsa. This monograph has been through several reprints and it is widely regarded as a seminal work on exploration refraction seismology. He wrote a more extensive book "Refraction Seismics" as part of a twenty volume series on seismic exploration published in 1986 by Geophysical Press and later, by Pergamon Press.

Derecke graduated from The University of Sydney in 1967 with first class honours in geophysics, and with a Master of Science in 1976. He was recently appointed Senior Lecturer in Geophysics at The University of New South Wales.

ASEG Financial Statement for 1991

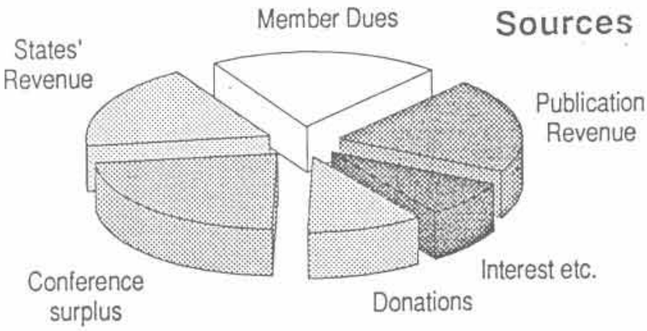
The ASEG's accountants (Slee & Stockden of Wembley, WA) have produced the financial statements for the year ended 31 December 1991 as required by both the Society and the Australian Securities Commission. A copy of the report, which runs to 19 pages including the Auditor's clean bill of health, can be obtained from your State Branch Executive, but the main items are summarised in the table below and the graphics following. This summary in intended to give an overall picture of the Societies finances in a smaller space.

Division	Income	Expenditure	Current Assets
	$	$	$
Federal Executive			
Memberships	55965		
Other Transactions	48479	40097	204974
Sydney Conference	62638		3746
Research Foundation		17247	27031
Awards Funds			41767
Publications	57830	108111	2606
Branches			
ACT	1150	500	2069
New South Wales	19171	8870	18178
Queensland	3179	2938	4060
South Australia	17333	18648	19230
Tasmania	60	0.20	582
Victoria	3618	2423	21265
Western Australia	5923	4672	11820
Receivables less Liabilities			5836
Totals	$275346	$203506	$363164

The lines below "Federal Executive" subdivide some of the areas dealt with by the Executive for the Society. The "Current Assets" column reports the cash balances in various accounts operated by divisions of the Society.

The overall income to the Society was just over $275,000, and exceeded expenditure by $71,800. The distribution of income and expenditure by major divisions is illustrated here, with some comments.

Income Sources



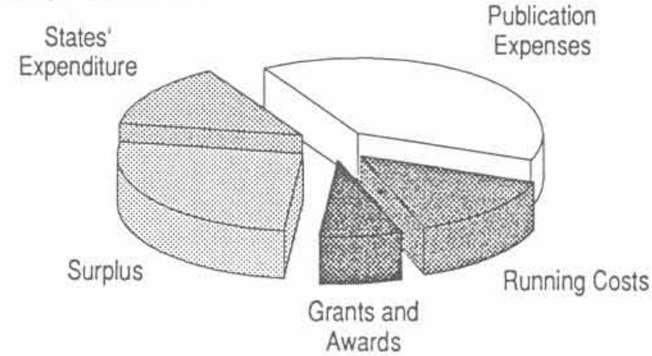
Donations were mainly to the Research Foundation, but were not broken down by the Accountants.

Publications income and expenditure includes both Preview and Exploration Geophysics. These were also not separately isolated by the Accountants in the Financial Statement.

The membership income offsets roughly the losses incurred in publishing Exploration Geophysics and Preview.

The Conference surplus is that from the Sydney, 1991, Conference.

Expenditure Distribution



The "Running Costs" item includes secretariat expenses and accounting fees. The latter, with bank charges, are over a quarter of the running costs in 1991.

A significant item in the Publication Expenses area was the writing off of more than $10,000 in bad advertising debts accumulated during the previous few years.

Further broad points can be made from the above:

- Most of the running costs are met from interest on the Society's capital.
- The Society has healthy cash reserves, a quarter of which are held by the State Branches. (The Federal Executive has had a policy for several years of building the reserve up to insure against a calamitous loss over a Conference). However, over 40% of the operating profit (excess of income over expenditure) is in the hands of the States.
- The States' funds component is legally part of the responsibility of the Federal Executive. The Executive has no wish to interfere with the States' operations except to ask for cooperation in supplying details for the annual financial statement as soon as it becomes necessary.

The Auditor, Mr Colin Johnson, was extremely helpful to the Society in advising the Treasurers through the last year or so. I express my gratitude to him for this.

Lindsay Thomas
Honorary Treasurer, ASEG

KEY CENTRE FOR
TEACHING AND RESEARCH IN
STRATEGIC MINERAL DEPOSITS

CALL FOR PAPERS

Geophysical Signatures of Western Australian Mineral Deposits

The Key Centre for Strategic Mineral Deposits (Geology Department), at The University of Western Australia, and the *Australian Society of Exploration Geophysicists (W.A. Branch)* are producing a publication on the use of geophysics in mineral exploration in Western Australia. The book will be number 26 of the Key Centre Publication Series and will be edited by Mike Dentith, David Groves and Julie Bennett (University of W.A.), Allan Trench (Western Mining Corporation) and Kim Frankcombe, President of the A.S.E.G. in W.A. (Normandy Poseidon Ltd). The provisional title for the book is **Geophysical Signatures of Western Australian Mineral Deposits.**

It is envisaged that the book will contain a series of short papers describing the geophysical signatures of individual deposits, i.e. case studies. All papers will be refereed.

Papers from company personnel are especially welcome.

About 20 company authors have already agreed to contribute to the volume. These papers will cover a diverse variety of deposit-types and styles, including gold, base-metals, diamonds and mineral sands.

Potential contributors should contact:

Ms Julie Bennett
Key Centre for Strategic Mineral Deposits,
Department of Geology,
The University of Western Australia, Nedlands, 6009
Telephone: (09) 380 2636; Fax: (09) 380 1037

or

Dr Mike Dentith
Department of Geology,
The University of Western Australia, Nedlands, 6009
Telephone: (09) 380 2676; Fax: (09) 380 1037

with a provisional title by DECEMBER 18, 1992

Skin Depth Estimates for the TEM Method

Jim Cull
Monash University

Along with Roger Henderson (Preview, June 1992) I have also found great difficulty in explaining to students the nature of TEM propagation. The smoke ring analogy is commonly used to visualise the migration of an equivalent current filament. However the true physical model based on an infinite medium is much more complicated.

Roger has reproduced a diagram by Spies (Geophys, 54 872-888) demonstrating variations in the depth of investigation for different survey parameters. This diagram relates to a layered earth and is based on representative noise levels with stacking over 15 minutes. These conditions are seldom encountered in mineral exploration programs.

In FEM surveys skin depth is readily accepted as a reasonable indication of penetration. Spies suggests a lower bound for penetration equal to 1.5 skin depths but precise estimates for any site will vary with local noise levels. Similar expressions have been developed for the time domain based on the concept of a diffusion depth for current filaments but these give no indication of maximum penetration.

An alternative expression for skin depth in the time domain has been proposed by Sternberg et al (Geophys, 53, 1459-1468) for the elimination of static shift in MT surveys. Adopting a comparable definition ($h_v/H_0 = 1/e$) they derive an expression

$$\delta = 1.28 \text{ SQRT } (t/\sigma\mu) \qquad (1)$$

this can be simplified to give

$$\delta = 40 \text{ SQRT } (t\ \rho) \qquad (2)$$

where t (m sec) is the delay time and ρ(ohm m) is the resistivity.

An even closer comparison can be made with FEM systems by equating the two expressions for skin depth. In these circumstances an 'equivalent frequency' can be defined for each delay time using the expression

$$f = C\ /\ t \qquad (3)$$

where the constant C = 194 (analytical) or C = 200 (empirical).

This expression has been confirmed experimentally using overlap between MT and TEM soundings.

For the example used by Roger (ρ = 100 ohm m and t = 6 msec) equation (2) indicates a skin depth of 979 m similar to the previous prediction. However effective penetration must also depend on adequate coupling. Consequently target geometry and loop configuration must be considered separately. Loop size can be related to noise limits and flux dispersion but the concept of skin depth should be extended to provide a reasonable comparison with FEM systems.

SEG International Exposition Moscow '93

Call for Papers

The Society of Exploration Geophysicists in conjunction with its colleagues in the former republics of the USSR will organise and produce an international exposition in Moscow, Russia in August 1993. Expanding on the widely acclaimed July 1992 SEG/Moscow '92, the program for 1993 will address a broad range of technical subjects including:

- Environmental, Engineering and Groundwater Geophysics
- Oil and Gas Exploration and Development and
- Mineral Exploration and Development

Authors around the world are encouraged to submit abstracts for papers in these subject areas by March 1, 1993.

Authors interested in participating in this historic international exposition should send a 300 word abstract (no figures or equations please) to the Society of Exploration Geophysicists.

Technical Program Committee: J. P. (Pete) Johnson, Texaco; Phillip R. Romig, Colorado School of Mines; and Robert J. Smith, CRA Exploration.

Mail abstracts before March 1 to:

Moscow '93
C/- Society of Exploration Geophysicists
P.O. Box 70240
Tulsa, Oklahoma 74170-2740
USA
Fax: 918-493-2074
Tel: 918-493-3516

WMC - Chief Geophysicist - New Post

In January 1993, Dr. Peter Fullagar, who is currently Chief Geophysicist - Minerals with Western Mining Corporation - Australasia, will take up the new chair of Borehole Geophysics for Mineral Exploration at the Ecole Polytechnique in Montreal.

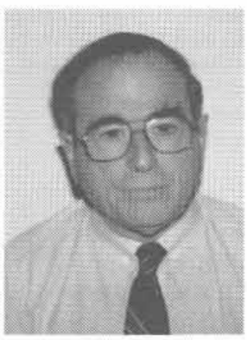
As Professor, Peter will be liaising with researchers and graduate students involved in borehole geophysics using resistivity and EM techniques in surface-to-hole and cross-hole modes. The research program will include numerical concepts to new exploration technologies. This chair is sponsored by TVX Gold Inc. the Teck Mining Group Ltd. and the Natural Sciences and Engineering Research Council of Canada (NSERC), and will work closely with the existing Metalloprobe Group of researchers.

During Peter's 12 year association with WMC he ably carried out the roles of Geophysicist, Senior Research Geophysicist, Manager - WMC Geophysical Processing Service and for the past three years has been Chief Geophysicist - Minerals, Australasia. We take this opportunity in wishing him the best with this new appointment and encourage Peter to continue his liaison with Australian companies and with the ASEG and its members.

Peter Williams, who recently completed his M.Sc. at the Colorado School of Mines, will take over the position of Chief Geophysicist - Minerals, Australasia.

Dave Robson
WMC Melbourne

Humboldt Award to Prof. Vozoff



Keeva Vozoff, Professor of Geophysics at Macquarie University, Sydney since 1972, recently was elected recipient of a Humboldt Research Award, for scientific cooperation between Australia and Germany. The award is granted in recognition of past accomplishments in research and teaching, and provides an amount of DM90000 to allow the recipient to work at a research institute in Germany for a period of 12 months.

Prof Vozoff has virtually a lifetime history of research collaboration and project initiation with colleagues in Germany, firstly in magneto-telluric studies (mid 1960's +), in-seam seismic numerical modelling (1982-1986) and LOTEM (long-offset transient electromagnetic) modelling and interpretation (1984-present). We warmly congratulate him on this award.

Prof Vozoff will implement the Humboldt Award by spending calendar 1993 at the University of Cologne, on leave from Macquarie University, after which he will be retiring from his existing Chair of Geophysics.

☆☆☆☆☆☆☆☆☆

CRC for Australian Mineral Exploration Technologies

Dr. A.A. Green, Director   Macquarie University, NSW 2109, Australia

DHEM WORKSHOP/SEMINAR

FIRST ANNOUNCEMENT

June 21-22, 1993

Sydney

There have been a number of significant advances in Drill Hole EM since the successful Workshop organised by Tom Eadie and Guido Staltari in 1985, but there is still much to learn and further improvements to be made in instrumentation, application and interpretation. A two-day meeting in the same format will be held at the CRC's Macquarie University venue. It is expected that the following aspects will be addressed:

* Survey techniques & constraints
* Probe self-response
* Recognition and removal of background
* Quantitative interpretation of off-hole and in-hole conductors
* Multicomponent probes
* Wish lists
* Inversion applications & pitfalls
* Interpretation for 3D sources in a conductive earth

As before, attendance will be limited, with preference given to those offering interesting problems or case histories. It is expected that participants will benefit from stimulating discussion and ideas, and that they will write up their papers for submission to Exploration Geophysics.

For further information and submission of brief Abstracts please contact one of the Convenors:

Dr John Bishop or
Mitre Geophysics Pty Ltd
Buggs Lane,
ELLIOTT TAS 7325
Ph/Fax: (004) 363 143

Dr Roger Lewis
Geology Department,
University of Tasmania
GPO Box 252C
HOBART TAS 7001
Ph: (002) 202 474; Fax: (002) 232 547

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Obituaries

R.F. Thyer, 1908 - 1992

Robert Francis (Bob) Thyer had a long and distinguished career in geophysics, and his death on 30 April 1992 in Canberra ended a unique link with the very early pioneering days of geophysical prospecting in Australia.

Bob came from a South Australian family. He was educated at Adelaide High School and Adelaide University, and as a young Physics graduate in 1929, he joined the Imperial Geophysical Experimental Survey (IGES), a project set up by the British and Australian Governments, for the purpose of testing the applicability of various geophysical exploration methods under Australian field conditions. Many of these methods were previously unknown in Australia, and the IGES was a landmark in the history of mineral exploration in Australia. It laid the foundations of geophysical prospecting in this country, and its results aroused considerable interest in other parts of the world.

After a period (1930-33) working as a Demonstrator in Physics at Adelaide University, Bob resumed geophysical work, this time with Western Mining Corporation, for whom he carried out field surveys in Victoria and Western Australia.

In 1935, he was appointed to the Aerial, Geological and Geophysical Survey of Northern Australia (AGGSNA). This was another significant project, in which the Commonwealth, Queensland and Western Australian Governments combined to investigate various mineral fields in northern Australia, using the most modern methods available at the time. Bob was the leader of several geophysical parties, which worked in the more remote and inaccessible parts of northern Australia. The parties generally operated from camps, living and working in harsh outback conditions. The success of these surveys is a tribute to their initiative, dedication and resourcefulness.

When the AGGSNA was wound up in 1941, Bob, with other geophysical staff, was transferred to the recently formed Mineral Resources Survey, with headquarters in Canberra. This survey formed the nucleus of the Bureau of Mineral Resouces (BMR), formed in 1946, in which Bob became a Supervising Geophysicist, and from 1952 to 1962 held the position of Chief Geophysicist in charge of the Geophysical Branch, then located in Melbourne.

During this period, the Geophysical Branch underwent considerable expansion in order to carry out an increasing number and diversity of geophysical programmes in Australia and its territories. BMR also kept abreast of the rapidly advancing technology in geophysical methods, and introduced and developed new approaches to mineral exploration to the

Australian scene. Bob played a key role in these activities. He is remembered as a leader with great energy and enthusiasm, an efficient administrator, and always approachable and helpful to his staff.

In 1962, he returned to Canberra to take up the mainly administrative position of Assistant Director (Operations). He continued in this position until his retirement in 1973, except for a period of two years (1969 - 1971) when he was the Commonwealth Geological Liaison Officer in London, and a brief period as Assistant Director (Geophysics) just before his retirement.

He was a fellow of the Institute of Physics (London) and of the Australian Institute of Physics, and a member of the Society of Exploration Geophysicists (USA), the Geological Survey of Australia and ANZAAS.

Bob had a range of interests outside his official duties. His leisure activities included golf (he was a member of Royal Canberra Golf Club from 1953), lawn bowls, billiards, gardening, and beekeeping. He travelled widely in Australia and overseas. In 1937, he married his first wife Janet, who died in 1960. He is survived by his second wife, Flora, whom he married in 1967.

He will be affectionately remembered by a wide circle of friends in Canberra, and by many former colleagues in BMR.

****

Phil Hallof, 1930 - 1992

Phillip George Hallof, one of mining geophysics' more colourful characters, died on September 22nd after a long fight with a disabling illness. Phil played a major part in the introduction of Induced Polarisation to Australia, among other parts of the world. He was 61 years old.

Phil was born in a small town in Missouri, the son of a specialist shoemaker. His introduction to geophysics was at MIT, where he did both his undergraduate and postgraduate degrees. His PhD research, supervised by Ted Madden, was to numerically model the resistivity and IP responses of vertical bodies to give the first 2D IP/resistivity model results. When he finished, in the heady days of a Canadian mineral exploration boom, Stan Ward brought Phil to work with the McPhar group in Toronto. Phil became a Canadian citizen and spent the rest of his life in Toronto. At this same time the Newmont Alumni, notably Harry Seigal, Jim Wait and Don Wagg, to name a few, were promoting the style of IP developed under Arthur Brant. Newmont's IP was in time domain while that done by Hallof was in frequency domain, and a very active competition developed between the two. The arguments, sharpened by enthusiasm on both sides, brightened exploration meetings around the world for many years. They were doubtless responsible for the rapid adoption of the IP method, and for the popularity of the IP equipment made both by McPhar and by Seigal's companies, Sharp and Scintrex.

During this time, in the late fifties-early seventies, McPhar with Phil as President became firmly entrenched in Australian mineral exploration, and Phil and his wife Lois made many trips to Australia. He met with most Australian mineral explorers and geophysicists during that time and retained a keen interest in Australia and Australian geophysics.

In the mid-seventies Phil was involved in the formation and success of Phoenix Geophysics and broadened his interests to Magnetotellurics and Spectral IP.

Since 1987 Phil had operated a successful consultancy in Toronto. In 1988 he was diagnosed as having an aneurysm of the brain. This caused slurring of speech and increased loss of muscular control. Despite this, and with strong support of Lois, Phil continued his consulting through earlier this year. He will be deeply missed by Lois and their two daughters Amy and Debbie, and by his wide circle of friends in the international mining and exploration industries.

****

Review of the AGSO

Composition, Structure and Administrative Arrangements

On 13 August 1992 the Minister for Primary Industries and Energy, the Hon. Simon Crean and the Minister for Resources, the Hon. Alan Griffiths announced the Federal Government's intention to conduct the above review into arrangements for the Australian Geological Survey Organisation (AGSO), formerly the Bureau of Mineral Resources, Geology and Geophysics. The review will be chaired by Dr. Max Richards.

The terms of reference are:

1. To examine and report on the appropriate composition and structure of the Australian Geological Survey Organisation and its relationship to CSIRO research activities, and the activities of State Geological Survey organisations.

2. On the basis of the response to the first term of reference, to advise on the administrative arrangements and geographic location of the geological survey organisation, including whether it should be established as a separate Institute within CSIRO, remain within the Department of Primary Industries and Energy, or some other arrangement.

3. To examine and report on the mechanisms for co-ordinating geoscientific and resource Information from AGSO and CSIRO in providing advice to client departments.

4. To advise on the most appropriate funding arrangements for AGSO, taking into account the June 1992 report of the joint Committee of Public Accounts.

5. To examine arrangements for reporting and accountability to Government to ensure the continuing relevance and high quality of AGSO activities.

Written submissions are invited which should be forwarded to the following address by 30 October 1992.

AGSO Review
C/- Department of Primary Industries and Energy
GPO Box 858
CANBERRA ACT 2601
Enquiries: Mr Geoff Gorrie
PH: (06) 272 4636

(Ed. Note - Although the 30th October, deadline has passed, late submissions may be accepted. The ASEG Executive is presenting a submission).

Preview Tutorial # 1

An Annotated Outline of GPS.

Terence J.Boyd
L.S. B.App.Sc.(Surveying)
Director: Resource Industry Associates

1. Introduction

For some years now, geophysicists have been at the forefront in the adoption and use of Global Positioning Systems (GPS) technology to efficiently add position information to their various sampling and data collection field work. Whether it be in grid setout, point positioning, mapping new areas, control of airborne, marine or land based programs, GPS has already proved it can provide position, anywhere and anytime, in an accurate, cost effective and simple manner.

This article, which is a geophysicist's guide to GPS, has been written in a tutorial style to provide the reader with an understanding of:

- the design and structure of the system,
- the capabilities of the system,
- the current user equipment
- and the observation techniques with resulting achievable accuracies.

The article has been written on two levels: firstly giving basic information (shown in normal font) and secondly giving more detailed, technical information (*shown in italic font*). Less technically minded people can skip the technical details (italics) if they wish.

This article is also biased to portable handheld GPS receivers as these are the most accessible types in use and suit the general requirements of geophysicists for use in remote areas by unsupervised staff.

Two global GPS systems are currently in the deployment phase :

- **GLONASS** by Russia (which is not covered by this article)

- **NAVSTAR** by The United States of America (the commonly used system and the subject of this article)

2. NAVSTAR - Schematics

The **Navstar Global Positioning System (Navigation Systems using Time and Ranging)** (Fig. 1) resulted from the United States Department of Defence's requirement to satisfy the navigation needs of it's air, sea and land forces with one all encompassing system.

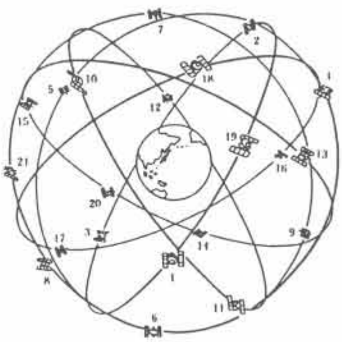

Fig. 1 - NAVSTAR GPS Constellation
24 (21 + 3 spare) satellites in 6 planes

All NAVSTAR GPS satellites transmit their coded navigation and position signals on two microwave frequencies referred to as L1 and L2 bands. The navigation message contains information which enables a receiver to compute the satellite's exact position at a particular time.

The US military provides two levels of GPS service - Standard and Precise.

The **Standard Position Service, (SPS)** is transmitted solely on the L1 band with the navigation message being described as the Coarse/Acquisition (C/A) code. SPS, which is intended as a civilian service, provides the user a position accuracy of better than 100 metres for 95% of readings. Provision of this service has been guaranteed until at least the year 2002 and is available to the general community with no fees or charges being levied.

A second message, the **Precise Position Service (PPS)**, provides a greater position accuracy using a navigation message described as the Precise (P) code which is transmitted on both the L1 and L2 bands. Whilst civilian users have been able to use this message during the deployment phase, the US military intend to further encrypt this message (to be called the Y-code) upon full deployment of the system and restrict its use to the US military and its allies.

As well as the frequency differences between SPS and PPS, the major difference for navigation users is the control exercised over the system by the US military using a device called Selective Availability (SA). In essence SA allows the military to manipulate the satellite time and position message to limit the accuracy achievable by C/A code receivers.

Most manufacturers claim their GPS receivers could achieve an accuracy of better than 15 metres (RMS) if SA was switched off and often quote such an accuracy in their specifications. A note, usually at the bottom of the specifications, qualifies the specification by stating that "position and velocity accuracies are subject to change under the Department of Defence imposed Selective Availability

(SA)". However there is little point in dwelling on what might be - the military is insistent that SA is required for 'National Security' purposes and that it is better to implement SA in peacetime rather than risk confusing or upsetting the navigation community at some later date when a situation arises that dictates that it must be implemented. In practice SA is switched on an estimated 95% of the time, so we must assume that GPS receivers will mostly be operating in the lower accuracy mode.

The US military's public guarantee that NAVSTAR GPS will be maintained and provided within its SPS specification until at least 2002, enables confident planning to ensure maximum advantage can be taken of this quantum leap in positioning and navigational technology. Section 3 gives technical aspects of the NAVSTAR GPS signals and section 4 covers the NAVSTAR GPS system in greater detail. Before giving more details on NAVSTAR it is necessary to consider GPS measurement theory.

3. GPS Measurement Theory

NAVSTAR GPS is based on the one way ranging of a coded electromagnetic signal. Ranging (Fig. 2) is the computation of a distance by the measurement of the elapsed time between the transmission and receipt of a radiowave according to the following formula:

Distance (p) = Velocity of Propagation X elapsed time.

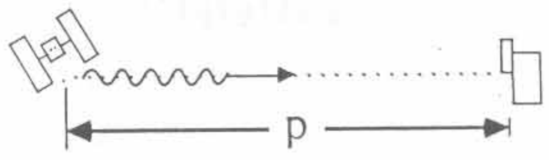

Fig.2 - Ranging Principle

It is the basic principle behind most remote distance measurement devices and is most commonly seen in EDM equipment used by surveyors.

Two methods of ranging are available : Two-way ranging and one-way ranging.

3.1 Two-Way Ranging:

Two way ranging uses a combined transmitter/receiver which measures the elapsed time between when a signal is sent and when its reflection from a passive device (prism) is received. The range distance is then computed as half the time by the speed of light (c). The technique is limited because the interaction between the transmitter/ receiver station and the reference station (reflector) usually restricts the number of users to only one at a time. This method is used by surveyors but has not been adapted for GPS.

3.2 One-Way Ranging:

One-way ranging systems (used in GPS) use separate transmitters and receivers, but rely on both devices having synchronised clocks. The NAVSTAR system employs one clock in the satellite to generate the signal. A second clock in the receiver detects the arrival of this signal. The difference in time multiplied by the speed of light is the range/distance. A microsecond error between the two clocks equals 300 metres in the range/distance. Whilst it is practically impossible to physically synchronise all the clocks in the GPS system it can be done mathematically. GPS ground stations carefully monitor the satellite clocks and include mathematical corrections for each clock in the broadcast message. GPS users can therefore assume that all the simultaneous GPS ranges measured by their receiver are related to the same 'clock'. The receiver clock can also be easily referenced to this same 'clock'.

Because all receivers can operate independently of each other with the time and range calculations there is no limit to the number of system users.

Two techniques of one-way ranging are available with GPS : **Pseudo-ranging** and **Carrier Phase** measurement.

3.2.1 Pseudo-ranging.

GPS satellites transmit a 'pulse' or time related code made up of defined series of +1 and -1 values. An exact replica of this code can also be generated in the GPS receiver. (Fig. 3).

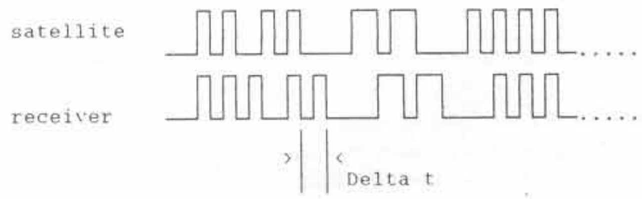

Fig. 3 - GPS Pulse Code

Within the receiver a delay lock loop maintains the alignment or correlation between the receiver-generated replica code and the actual incoming code. The pseudo-range measurement is therefore the delay which must be added to the epochs of the receiver clock to keep the replica and incoming codes aligned (correlated). The epoch (pulse or code period) for the C/A-code is 1 millisecond and 0.1 millisecond for the P-code. A rule of thumb for the precision of pseudo-range measurements (i.e. the precision of correlation) is 1% of the period between successive code epochs.

When multiplied by the speed of light this translates to 3 metres for C/A-code and 0.3 metres for P-code.

The term pseudo-range derives because of the separate time references used in the measurement - satellite clock and receiver clock, resulting in a biased time delay measurement.

3.2.2 Carrier Phase Measurements.

The second method of GPS range measurement is Carrier Phase signal measurement to at least 4 satellites.

The GPS L1 carrier signal has a wavelength of 0.2 metre and so using the "1% of wavelength precision" rule of thumb a precision of 2 millimetres is implied.

With carrier phase measurements, the receiver replicates the continuous L1 wave transmitted by the satellite. At a particular time the receiver is able to measure the difference in phase between the incoming signal and that generated internally (i.e. between 0^o and 360^0 or part of one cycle). The total range measurement requires the total count of whole wavelengths between the transmitter and the receiver. The determination of the number of whole wavelengths is called the Carrier Phase Ambiguity problem . Several solutions have been developed to solve this problem, but principally they rely on using significant changes in position of the satellites over time. These techniques include long measurement times (50mins.) or antenna swaps, between two receivers, which alters the earth based geometry rather than the satellite geometry (this is called differential mode (Section 6.).

4. NAVSTAR GPS Signals

All GPS satellites transmit their signals on two microwave frequencies. The frequencies are 1575.42 MHz and 1227.6 MHz referred to also as L1 and L2 bands, respectively.

These frequencies mean that the signal cannot penetrate water, soil, walls or other objects very well. Therefore GPS cannot be used for subsurface marine navigation nor for underground positioning and surveying - such as in mines and tunnels. In surface navigation the signal can be obstructed by trees, buildings and bridges.

Both signals, in every satellite, are coded with a different pattern (frequency shift) using phase modulation with an (artificial) noise signal (pseudo random noise - PRN) to enable discrimination by the receiver. The coded signals are the Coarse/Acquisition (C/A) code and Precise (P) code. The P code is transmitted on both L1 and L2 bands, but the C/A code is only transmitted on the L1 band.

Transmission of the P code signal on both L1 and L2 bands enables P code users to accurately determine the effects of signal propagation through the atmosphere (ionosphere & troposphere) and so eliminate this error source.

The pseudo-random noise (PRN) is a carefully specified algorithm which enables both the satellite and receiver to independently generate identical codes in order to track the signal of a particular satellite.

The C/A code modulation is at a frequency of 1.023 MHz and repeats every millisecond.

The P code modulation is at a frequency 10.23 MHz and repeats every 267 days (38 weeks approx.) The period is divided into 38 segments with each segment being assigned to a different satellite. This segment is called the satellite's PRN and is the common method of satellite identification. (The second *numbering system (eg. PRN 6) is the NAVSTAR SV number which relates to the launch sequence).*

A third modulation at 50 Mhz contains a data stream designed to inform the user of the health and position of the satellites.

The Standard Positioning Service (SPS), intended as a civilian service with an accuracy of 100m for 95% of fixes, is provided using the C/A code.

The SPS accuracy is controlled by the US Department of Defence using Selective Availability (SA). The code message transmitted from the satellite contains information of the satellites position at a precise time. SA introduces small errors called dither into both or either of the position and time. The amount of introduced error is randomly variable and unpredictable. The effects of SA can only be eliminated using differential observing techniques (Section 6.2.4).

The Precise Positioning Service (PPS) provides a greater position accuracy using the P code but is only intended for the US military. Some commercially available GPS receivers can currently receive and use the P code. However the US Department of Defence has warned that it intends to further encrypt the P-code to form the Y code, and use of this will be restricted to the US military and its allies.

5. NAVSTAR System Description

The NAVSTAR GPS system is divided into three segments : **Ground Control Segment; Space Segment** and **User Segment** (Fig. 4).

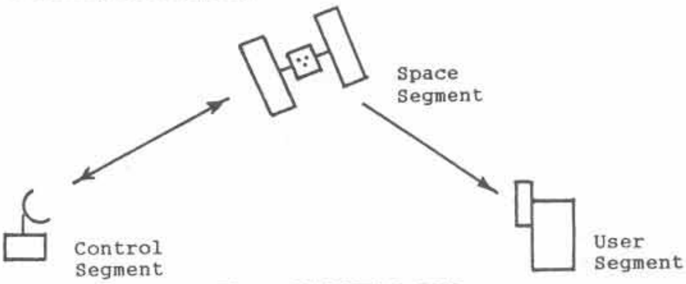

Fig.4 - NAVSTAR GPS

5.1 The Space Segment:

The Space Segment currently comprises 19 satellites.

The US Department of Defence is rapidly installing its Global Positioning System (GPS). Currently 19 satellites (Fig. 5) are available (September 92) of which 15 are designed to be part of the full constellation of 24 satellites expected to be available mid-1993.

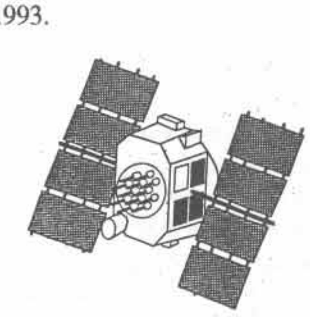

Fig. 5 - GPS Satellite

The next satellite was due to be launched around 22nd October 1992 and another around 1st December 1992.

The deployment of GPS vehicles is currently in the second of three phases. The initial phase was the deployment of 11 Block I satellites between 1978 and 1985. These satellites were designed to evaluate, test and prove the GPS theory. Of the initial 10 successfully launched vehicles, 4 are still operating.

Phase 2 was the deployment of 28 Block II satellites. The primary function of each of these satellites is to receive information on its position from the 'ground control segment', interpolate this information over time, maintain an accurate time reference (up to 4 atomic clocks are available in each satellite) and transmit this information reliably. The main difference to the user between Block I and Block II satellites is the inclusion of Selective Availability (SA).

Phase 3 will be the deployment of satellites to replace Block II satellites as they are removed from service. The design life of Block II satellites is 7.5 years. The oldest Block I satellite still useable is in excess of 9 years old. PRN 6 was useable for around 14 years.

User interaction with the space segment is through analysis of receiver outputs for signal quality and the strength of the satellite geometry (DOP). Both these outputs affect the reliability and accuracy of a GPS position fix.

5.1.1 Satellite Signal Strength

Most GPS receivers display the signal quality or strength for each satellite in view. Because GPS is a "line of sight" system local features such as vegetation or terrain can shield or mask a satellite - this would be indicated by a low signal quality. Many receivers are able to calculate the satellite's approximate position in the sky and so if a poor signal quality is shown for a particular satellite, a simple look in the direction of satellite might indicate a hill on line. The choice can then be made to wait for the satellite to rise above the hill or to override the automatic selection of satellites and to choose a set of satellites which are 'visible' to the receiver.

The system is designed to have 24 satellites (21+3 spares orbiting the earth every 11 hours 58 mins (half a sidereal day) at 26,560 kilometre radius. A sidereal day is the rotation period of the earth and is equal to a calender day less 4 minutes. This orbital period means that satellite configurations are repeated day after day but always 4 minutes earlier than the previous day. This has the benefit of changing the available satellites over time, as satellites do have varying performances, due mainly to age. Availability of satellites is discussed further in Section 9.

5.1.2 Satellite Geometry

Four satellites are placed unevenly into 6 orbital planes with each plane being inclined at 55 degrees to the equator. This configuration will provide visibility of at least 6 and up to 11 satellites at any point on earth.

The geometric strength of the available satellites is defined by their Geometrical Dilution of Precision (**GDOP**).

GDOP is quantified by the largest spatial tetrahedron volume formed by the unit vectors from the receiver to four available satellites.The **GDOP** can be divided into **PDOP** *(Position Dilution of Precision)* and **TDOP** *(Time Dilution of Precision). The* **PDOP** can be further divided into Vertical (**VDOP**)and Horizontal components (**HDOP**).

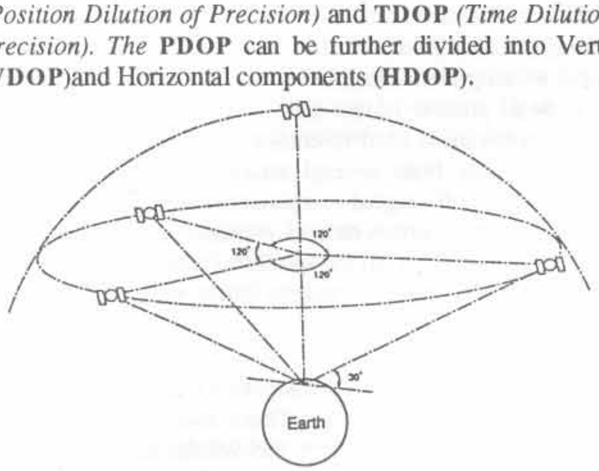

Fig. 6 - Good Satellite Geometry (GDOP 3.0)

Satellite geometry is usually displayed in GPS receivers as a Dilution of Precision (DOP), either Geometrical Dilution of Precision (GDOP) or Position Dilution of Precision (PDOP). The accuracy of a satellite fix is dependant on the strength of the angular intersection of the 'lines' between the receiver and the satellites. A good GDOP/PDOP is better than 4 whereas a poor GDOP/PDOP is greater than 7.5. At any time 'good' or 'bad' is dependant on your application, but GDOP/PDOP is the most common standard in making such an assessment.

5.2 Ground Control Segment

The Ground Control Segment relates each satellite's position and time to a common reference. Five monitoring stations have been established to constantly track the satellites in the GPS constellation. They are located at Colorado Springs, Ascension Island in the South Atlantic Ocean, Diego Garcia in the Indian Ocean, Kwajalein and Hawaii in the Pacific.

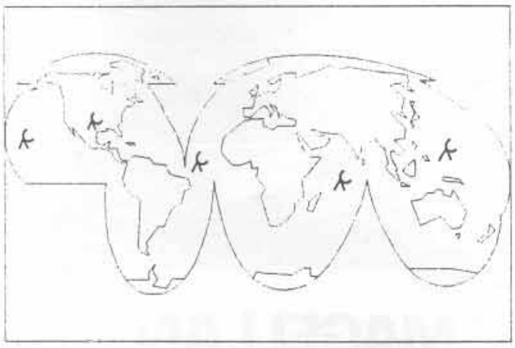

Fig. 7 - Ground Control Stations

The location of stations relative to the satellite reference datum (WGS84) is very accurately known. The monitoring stations use dual frequency receivers equipped with a caesium clock to track all satellites in view. This information, together with meteorological data, is collated at the Master Control Station (MCS) in Colorado Springs. Using this information MCS is able to compute the satellite orbits and clock corrections which it uploads to every satellite for broadcast to GPS users. MCS also sets the health status of the satellites and coordinates the repositioning and repair of vehicles within the system.

MCS provides a prediction of the orbital parameters (ephemeris) for the satellites for a certain moment in time (epoch). A more precise ephemeris post-computed from the satellites position in the past is also available for precise positioning calculations.

5.3 The User Segment

The User Segment comprises the receivers and antennas, observation techniques and data processing methods. The users include all branches of the armed forces, merchant marine, surveyors geodesists and land management professionals, satellite controllers, yachtsmen, bushwalkers, computer & communication network controllers, vehicle tracking and fleet monitoring for maintenance and security and many more users for new applications which seem to be growing exponentially as the broader community becomes familiar with GPS.

The principle component of the User Segment is the GPS receiver.

6. GPS Receivers

GPS receivers vary in size, weight, performance factors such as speed of acquisition and processing, display type and susceptibility to environmental considerations. The range of available receivers has grown enormously in the last couple of years as more and more manufacturers enter this potentially huge market.

6.1 Receiver types and costs

Prices for receivers vary between tens of thousands of dollars for geodetic survey receivers to several hundreds of dollars for basic board sets. The price you need to pay for a GPS receiver depends on your application and required accuracy. Receivers can be categorized into three basic types based on features and cost as illustrated in Fig. 8.

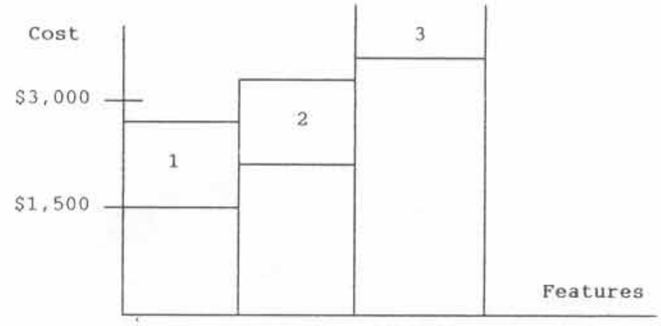

Fig. 8 - Graph - Receiver Features vs. Cost

Type 1 receivers. Type 1 receivers are low cost ($1300 - $2500) navigation units (eg. Sony Pyxis, JRC, Trimble Ensign).

All units have Latitude & Longitude displays with a few also having Universal Transverse Mercator (Grid) coordinate display.

As well as position display, other navigation messages such as velocity, direction, time to go are usually available. The ability to store 100 or more waypoints and to use these in creating navigation routes is also a general feature.

Type 2 receivers. These receivers (around $2,500 - $4,500) include the type 1 features plus averaging, a data port and the ability to perform a basic form of differential calculation using 2 units.(eg. Trimble Pathfinder Basic and Garmin 100 svy.)

Type 3 receivers. These receivers include the features of type 1 & 2 but have the ability to receive and download pseudo-range data thus enabling a more reliable and greater accuracy differential calculation. Some can also receive carrier data and have the ability to use data received by other manufacturer's equipment via the RINEX (Receiver INdependent EXchange) format. (eg. Magellan Nav 5000 PRO, Trimble Pathfinder)

6.1 Receivers - Satellite Tracking Methods

The basics of GPS dictate that a receiver must be able to receive information from 4 satellites to calculate an accurate position.

For all types of receivers there are two basic categories of operation - **Sequencing** and **Non sequencing** units.

6.1.1 Sequencing Receivers

Sequencing units have less than 4 parallel channels or correlators and so must interrogate the system by locking onto a particular satellite, collecting some data, releasing the satellite to lock onto the next in the sequence. This procedure can be executed in either a **fast** or **slow** mode. The **fast sequencing** receiver interrogates the satellites very rapidly extracting only a very small portion of the satellite message at each pass. Complex software is used to collate the information so as to process the data from several satellites continuously. This technique trades off a signal-to-noise ratio for a lower hardware cost. The signal-to-noise ratio is a measure of the receivers ability to maintain lock on the satellite. In desert conditions or on open waters these receivers perform adequately for navigation purposes.

Slow sequencing units trade off a higher signal to noise ratio for a slower update rate. These receivers lock onto a particular satellite and collect the whole of the available position message before cycling to the next satellite. In marginal conditions such as with tree canopy the higher signal-to-noise ratio may ensure a position fix is obtained.

Sequencing units are gradually decreasing in the market as competition and higher production runs force down the cost of non-sequencing units.

6.1.2 Non Sequencing Receivers

Non-sequencing units have at least 4 parallel channels or correlators which each continuously lock onto one particular satellite. The position data can be processed continuously enabling update rates of position every one second for code correlation receivers. Non-sequencing or continuous-tracking receivers have a superior signal-to-noise ratio over sequencing units as the satellite signal is continuously available and can be sampled more frequently. A further advantage is the built-in redundancy which may allow the receiver to continue navigating with a decreased number of satellites when one channel fails.

In dynamic situations, such as in aircraft or moving cars, multi-channel units are better able to cope with signal interruptions due to vehicle movements or signal obstructions such as tall buildings,bridges or heavy tree canopies.

6.2 Receivers - Observation Techniques

Several other variables related to observation technique affect positioning accuracy. These include:

- instantaneous readings
- averaging
- single receiver mode
- differential receiver mode
- pseudo-ranging or carrier phase capability
- post processing

For navigation purposes an accuracy of better that 100 metres will ensure that you arrive at the right airport or the right marina but in landing a Jumbo jet it is vitally important to know your relationship to the runway to a much greater accuracy.

An examination of basic GPS positioning error sources reveals the following components:

Clock (Space Segment)	3.0 metres
Ephemeris (Control Segment)	2.7 metres
Ionospheric Delay	8.2 metres
Tropospheric Delay	1.8 metres
Selective Availability	27.4 metres

Total	43.1 metres
	====

As a rule of thumb heighting accuracy is 3 times x-y accuracy.

6.2.1 Instanteous Readings

"Instantaneous" readings are achieved in a few seconds with an accuracy of 30-100 metres with SA switched on and 15-30 metres with SA switched off, using a single receiver.

Using differential receiver mode (Section 6.2.) "instantaneous" readings (a few seconds) have an accuracy of 5-10 metres (SA off).

In practice we must assume selective availability (SA) is always on. The US Department of Defence has set the achievable accuracy for the Standard Positioning Service (ie SA on) as 100 metres for 95% of fixes.

Figure 9 shows the variation of x-y position with time with SA on and Figure 10 shows the SA off case.

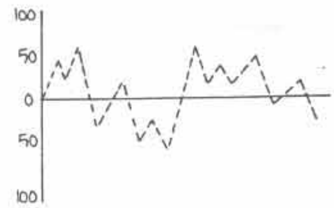

Fig. 9 - Graph showing Position with SA on

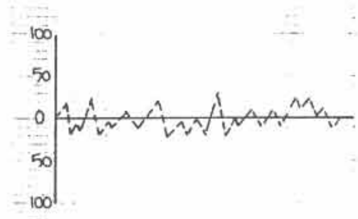

Fig.10 - Graph showing Position with SA off

SA on deliberately introduces error into GPS positioning. The US Department of Defence has used several patterns of SA with the predominant one replicating a worm gnawing through an apple. The change in position is small over short period but the position relative to the true location can still be 100 metres in error.

The worm effect is illustrated in Figure 11.

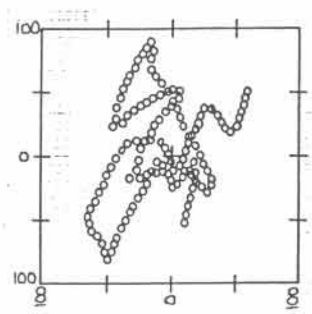

Fig. 11 - Position Plot relative to known point

6.2.2 Averaging

Some receivers allow the automatic averaging of position fixes. This effectively filters the data to ensure that the accuracy is within the SPS limits bearing in mind that 5% of readings are in excess of the 100 metre range.

Averaging does not totally eliminate the effects of Selective Availability but gives a marginal improvement in accuracy. Averaging over long periods (10 minutes) can improve your level of accuracy to better than 50 metres for a single receiver.

6.2.3 Single Receiver Mode

Single receivers generally employ the C/A code and pseudo-ranging.

Independent of the receiver price or type, when you use a single receiver, your accuracy expectation should be 100 metres. In practice you may expect an accuracy of between 30 - 100 metres but you generally have little indication from the receiver as to where you are in this accuracy range.

Some receivers, however allow the display of the satellites User Equivalent Range Error (UERE) or User Range Accuracy (URA). The UERE or URA indicates to the user whether Selective Availability (SA) is on and to what extent. If SA is on then the user must assume an accuracy of 100 metres; if SA is off then the user can assume an accuracy of 30 metres.

6.2.4 Differential Receiver Mode

Relative positioning using GPS (differential receiver mode) is very much more accurate than absolute positioning (single receiver mode).

Where the ionosphere and troposphere are regarded as homogenous (up to 50 kilometres between receivers) and the satellites observed at the particular time are identical it is possible to eliminate these error components by measuring them at a known location and applying the resultant delta correction to the receiver-computed position at the unknown location. This technique is known as differential positioning.

The only means of minimising or eliminating the effects of Selective Availability and other propagation errors is to use differential techniques.

Differential techniques require at least two receivers, one of which is located at a known location. Both receivers collect data for the same four satellites at exactly the same time. The amount of SA and other errors can be directly determined by differencing the satellite computed position with the true location. This difference can then be applied directly to the second receivers position fix.

Differential techniques can be now undertaken in real-time in the field or with post-processing.

Real time procedures require the transmission of the comparison between the satellite derived position and the true location to be available for processing with the roving or remote receiver.

In its simplest form the control station operator radios the delta corrections to the roving unit operator who keys in or applies these to the remote position. More complex systems that use radio telemetry links constantly transmit the GPS data to a computer for processing.

Using differential mode, pseudo-ranging and simple averaging positioning accuracies of 3-5 metres are readily achievable for a 1 minute recording time.

6.2.5 Carrier Phase Measurements

Another variable between receivers is the ability for Carrier Phase measurements. Where differential accuracies of 3-5 metres are readily achievable with pseudo-range calculations, accuracies better than between 1 metre for simple handheld receivers and 5 mm ± 1 ppm for dual frequency geodetic instruments are achievable. These accuracies can be achieved with from 10 - 20 minutes observation and post processing of the data, depending on the satellite DOP.

Geodetic receivers using higher quality clocks are capable of centimetre accuracy with specialist observing techniques.

6.2.6 Post Processing

Some receivers have data ports to connect to DOS data loggers or PC's. The data is recorded as a DOS file and post processing can be achieved in a few minutes with a 386 coprocessor machine.

7. GPS For Heighting

The use of GPS for heighting principally for gravity surveys is an emerging technology. GPS must prove to be competitive in accuracy and price, with optical and barometric levelling to gain acceptance. In practice differential mode, carrier phase and post processing must be used to achieve desired accuracies (<0.3 metres in height). Corrections must be made between the satellite height calculation and the Australian Height Datum. For gravity surveys 1-3 stations per hour are achievable which is slower than the gravity acquisition rate.

8. Accuracies - A Summary

The achievable accuracies and necessary acquisition times for various GPS configurations and field techniques is summarised below. (assuming SA is on - which is 95% of the time).

	Position	Height (m)	Time
SINGLE RECEIVER (C/A CODE)			
Instantaneous	30-100	90-300	Few Secs
Averaging	<50	<150	7-10 mins
DIFFERENTIAL RECEIVER (PSEUDO RANGING)			
Instantaneous	5-15	10-45	<1min
Averaging/ post processing	3-5	9-15	~1min
DIFFERENTIAL RECEIVER (CARRIER PHASE) WITH POST PROCESSING			
Hand held receivers	≤1	≤1	10-20mins
Geodetic receiver	0.010	0.010	50+ mins

9. Available Satellites

For xyz GPS measurements in differential mode at least 4 satellites are needed. This service is currently available 20-22 hours a day. By June 1993 this will be a 24 hour service. If only 3 satellites are needed at any one time then GPS can be used 24 hours a day now.

10. Conclusions

Even though GPS is still in the development stage, lower cost and smarter receivers are quickly pushing to the stage of being a 'ho-hum' technology where its use will be as common as a pick is to a geologist.

NAVSTAR GPS provides a system which gives the geophysicist the ability to control and manage the collection and merging of many different data types through the linkage of very accurate position and time. Satellite images can be accurately warped to replace poor quality maps. Airborne surveys can be undertaken without the need for setout of extensive ground control networks. Fieldwork can be designed knowing that the sampling locations can be accurately located and relocated inthe future as required.

GPS makes redundant the often asked question "Where am I ... ?", and now someone must work towards solving the remaining portion of this age old dilemma - " ... and why are they doing this to me?"

11. Bibliography

This article has drawn on the following publications :

- Guide to GPS Positioning - Wells et al.1986. Canadian GPS Associates
- GPS World magazine - various
- Magellan Operation Manual - Magellan Systems Corporation.
- SONY GPS Operation Manual - SONY Corporation

Membership

NEW MEMBERS

We welcome the following new members to the Society. Their details need to be added to the relevant State Branch database:

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CHANGE OF ADDRESS

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