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Kuala Lumpur, 11- 14 April 2000
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REPORTS ON ACHIEVEMENTS IN SURVEYING, MAPPING AND CHARTING IN ADDRESSING NATIONAL, SUBREGIONAL, REGIONAL AND GLOBAL ISSUES, INCLUDING: TECHNICAL COOPERATION AND TRANSFER OF TECHNOLOGY

The Role of IAG in Densification of Global Geodetic Networkst**

(Submitted by The International Association of Geodesy (IAG))

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** Prepared by Mr. John Manning, Chairman IAG Sub Commission on SE Asia and the Pacific

15th UNITED NATIONS REGIONAL CARTOGRAPHIC CONFERENCE FOR ASIA AND THE PACIFIC

Incorporating the 6th Meeting of the Permanent Committee on GIS Infrastructure for Asia and the Pacific

"A MILESTONE FOR SUSTAINABLE DEVELOPMENT"

INVITED PAPERS SESSION 3 :
INTERNATIONAL SCIENTIFIC BODIES

THE INTERNATIONAL ASSOCIATION OF GEODESY

"THE ROLE OF IAG IN DENSIFICATION OF GLOBAL GEODETIC NETWORKS"

John Manning

**Chairman IAG Sub Commission on
SE Asia and the Pacific**

KUALA LUMPUR MALAYSIA 11-14TH APRIL 2000

THE ROLE OF THE INTERNATIONAL ASSOCIATION OF GEODESY IN DENSIFICATION OF GLOBAL GEODETIC NETWORKS

John Manning, Chairman IAG Sub Commission on
SE Asia and the Pacific (johnmanning@auslig.gov.au)

1. INTRODUCTION

The International Association of Geodesy (IAG) is the peak scientific organisation in the discipline of geodesy. It promotes scientific cooperation and research in geodesy on a global scale and contributes to various research bodies. IAG is an active member of the International Union of Geodesy and Geophysics (IUGG) which itself is a member of the International Council for Science (ICSU).

Traditionally based in Europe it has taken the lead in coordination of global research and applications such as the determination of the parameters of the Earth, temporal variations of the Earth's orientation, its surface and its gravity field for over one hundred years.

Whilst Geodesy has been defined as the science of determining the size and figure of the earth, and its gravity field, the advent of Space Geodesy has seen a dramatic development in the scope of geodesy and its application. In the last quarter of the 20th century considerable advances have taken place and a series of IAG services have blossomed producing products for use by the general global community to realise the benefits of these developments. These services provide positional control information for application for Agenda 21 data gathering for sustainable development.

The IUGG is one of the 25 unions of ICSU and consists of seven associations. Besides geodesy, the following disciplines of geophysics are represented by associations: Seismology and Physics of the Earth's Interior (IASPEI), Volcanology and Chemistry of the Earth's Interior (IAVCEI), Geomagnetism and Aeronomy (IAGA), Meteorology and Atmospheric Sciences (IAMAS), Hydrological Sciences (IAHS), and Physical Sciences of the Oceans (IAPSO). Joint research between the IAG and the other associations has considerably increased since space methods have become a major tool. It is especially strong with IASPEI, IAMAS, and IAPSO. Some of this interaction is channelled into specific organisational structures, but much of it comes about by scientists cooperating on topics of mutual interest. This cooperation has been strongly encouraged by the IUGG, which promotes inter-association symposia at its general meetings where results of interdisciplinary research can be presented. IAG links within IUGG and ISCU are shown in figure 1. (Schwarz, 1996).

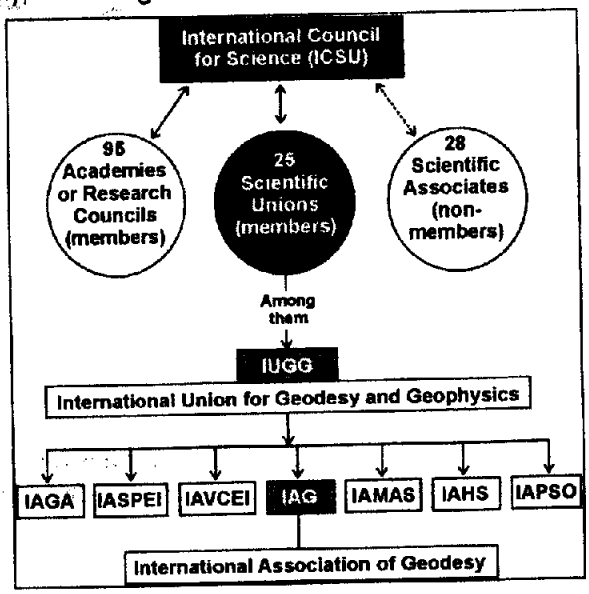

Figure 1: IAG Linkages

2. HISTORICAL BACKGROUND

Whilst Geodesy is part of the geosciences it has historical links to astronomy, surveying, navigation, cartography and even engineering which go back thousands of years to cadastral and engineering surveys in Mesopotamia and Egypt. When the sphere was accepted as a reasonable figure for the earth, the determination of its diameter was approached by combination of astronomical and ground measurement, such as the meridian arc measurement of Eratosthenes (276 - 195 BC). Other arc measurements followed in early Greek, Chinese, and Arabian cultures but a wider international collaboration to this problem only started in the 18th century.

The history of IAG is closely related to the recent history of geodesy in Europe where the origin of modern geodesy arose from servicing the needs of both national and scientific interests. These required reference networks to be established in order to map topography for military purposes, and for civilian land tax inventories. In the seventeenth century the ellipsoidal form of the Earth was accepted in theory but still lacked precise geometric proof by measurement. When the Academy of Sciences of Paris sponsored arc-measurements in Peru (1735-1744) and in Lapland (1736-37), the results generally proved the oblate spheroid theory but the observational methods needed to be improved if accurate parameters were to be obtained. Activity continued with this as a primary objective for the next hundred years and was the driving force for international cooperation. The work of George Everest and the Survey of India 1799 to 1843 resulted in the longest arc of meridian measured at that time and delivered improved values for the earth's parameters (Smith 1999).

Significant international cooperation began in Europe 1861, when General J.J.Baeyer, a collaborator of Bessel in the East Prussian arc measurement (1831-1836), submitted a proposal to the Prussian War Ministry to connect Central European astronomical observatories through various triangulation networks. This project required considerable international cooperation within Europe and in 1864 the first General Conference of the "Mitteleuropäische Gradmessung" " (Central European Arc Measurement) took place, and established a permanent organisational structure with a Central Bureau in Prussia. In 1886 its scope was widened to "Internationale Erdmessung" (Association Internationale de Geodesie). Activity continued but the intergovernmental agreement lapsed in European disharmony, twenty years later in 1916.

After the First World War, international science was slowly reorganised in a less governmental form and in 1932 the International Union for Geodesy and Geophysics (IUGG) was formed. Geodesy remained specifically identified as the International Association of Geodesy (the successor to the German form"Internationale Erdmessung"). For details on the early history of the Association, see Perrier (1939), Tardi (1963), Levallois (1988), and Torge (1993).

3. IAG STRUCTURES AND OBJECTIVES

The current framework and operational aspects of IAG are well described by Schwarz (1996) on the IAG web site *http://www.gfy.ku.dk/~iag/*. Details are summarised below.

3.1 Objectives

Since its formation the IAG has been very successful in furthering research into the physical parameters of the Earth. In the last one hundred years of its existence, the role of the IAG has considerably changed within the framework of international science. While the principal role of IAG originally was to pioneer international scientific cooperation in arc measurements, the role changed when it became a partner with geophysics and it now plays a more significant role for science as a whole. The objectives of the IAG have subsequently been widened to embrace the whole field of geodesy with special recognition of the importance of space geodesy. The current statutes are published in the Geodesist's Handbook (1996) and are available on the web at http://www.gfy.ku.dk/~iag/HB2000/summary.htm.

The stated objectives of the IAG (Geodesists Handbook ,1996) are:

- to promote the study of all scientific problems of geodesy and to encourage geodetic research
- to promote and coordinate international cooperation in this field, and promote geodetic activities in developing countries;
- To provide, on an international basis, for discussion and publication of the results of the studies, research and work indicated above.

So whilst the IAG had its formation history based on activities relating national organisations in Europe, it has evolved to be science based with a wide global and regional focus. It is notable that it has a specific objective to promote geodetic activities in developing countries.

3.2 Administrative Structure

The IAG structure can be subdivided into administrative and scientific components. The Administrative structure consists of the Council; the Executive Committee; and the Bureau as shown in Figure 2.

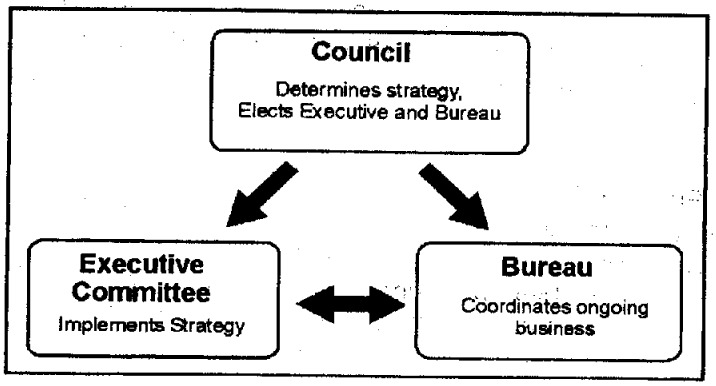

Figure 2: IAG Structures (Schwarz,1966).

The Council is made up of national delegates accredited by member countries. It meets once every four years and determines the overall strategy of the Association. One of its major tasks is the election of officers for the Executive Committee and the

Bureau. Another is the approval of major changes in the scientific structure of the Association.

The Executive Committee consists of officers elected by Council and generally meets once a year. It implements the strategy adopted by Council by providing coordination between the numerous scientific bodies of the Association and by making major policy decisions.

The Bureau consists of three elected officers – the President, the First Vice-President, and the Secretary General. It meets in conjunction with each Executive Committee meeting and otherwise as required. The Bureau coordinates the ongoing business, as defined by Council and Executive Committee decisions.

3.3 The Scientific Structure

The scientific work of the IAG is pursued through quadrennial General Assemblies and through its organisational structure, which is divided into five distinct Sections:

Section I: *Positioning*
Section II: *Advanced Space Technology*
Section III : *Determination of the Gravity Field*
Section IV : *General Theory and Methodology*
Section V : *Geodynamics*

The scientific research work within the five Sections is specifically defined and undertaken by Commissions, Sub Commissions, Special Commissions, Special Study Groups, and linkages to services bodies. The Section steering committee coordinates interaction between the research arms, organises collaboration across sections, and represents the section in the Executive Committee

Commissions are formed where global or regional cooperation is required to achieve long-term goals. Special Commissions are more topical in nature and are formed where the solution of a specific scientific problem requires the cooperation of scientists from different countries.

Special Study Groups are research units formed to solve specific scientific problems of limited scope. Their lifetime is usually restricted to one period of four years. They are the units in which highly technical and specialised research is done and where young scientists often make their entrance into the Association. (Schwarz 1996)

4. IAG SERVICES

Services play an important role in IAG, in monitoring and making available to the general public (and the global scientific community), results of fundamental research and specially generated products. These outlets are increasingly important as the fruits of long term research and space geodesy technique development offer huge potential benefits to the global community in general. Whilst the International Earth Rotation Service (IERS) and the International GPS Service (IGS) are the best known services there are a number of other services associated with IAG as shown in Table 1 below :

Acronym	Section Linkage	Service Title
IERS	V	International Earth Rotation . Service
IGS	II	International GPS Service
ILRS	II	International Laser Ranging Service
IVS	II	International VLBI Service
IDS	II	International DORIS Service
BIPM	V	International Bureau of Weights & Measures
PSMSL	V	Permanent Service for Mean Sea Level
BGI	III	International. Gravimetric Bureau
ICET	V	International Centre for Earth Tides
IGeS	III	International Geoid Service
IBS	General	IAG Bibliographic Service
IIS	General	IAG Information Service

Table 1: IAG Services and key Section relationships

IERS was a new ,major, service created in 1988 to take over from the former ILS (International Latitude Service); IPMS (International Polar Motion Service); and BIH (Bureau International de l'Heure). The IERS mission is to determine the best time series of transformation parameters between the International Celestial Reference Frame (ICRF) and the International Terrestrial Reference Frame (ITRF). Though it is an IAG/IUGG/IAU multi service organisation, it also has undertaken a traditional role of IAG, in the leadership/coordination of global reference systems and the selection/adaptation of the related conventional fundamental constants. The IERS generates combined products from a number of technique specific observations VLBI, SLR, GPS, DORIS in the way of coordinates, and transformation parameters. Further details are available on the IERS web site http://hpiers.obspm.fr/.

Whereas the IERS requires multi technique inputs, IGS is a single technique service specifically for GPS. The extent and reliability of the IGS products is based on a worldwide tracking network sponsored by many agencies for a global benefit. It is essentially operational rather than science driven research. It generates official IGS products which bind together the results from all users into the ITRF. IGS was approved by IAG in 1994 and this service delivery approach was recently followed by ILRS (International Laser ranging Service) in 1998, the IVS (International VLBI Service) in 1999 and, in the near future, the IDS for DORIS.

IGS draws observational data from a network of permanent GPS sites on a daily basis for the generation of rapid orbits, precise orbits to meet the objectives of a wide range of scientific studies and other applications. The Global Data Centers archive and provide on-line access to tracking data and data products. The online data are employed by the Analysis Centers to create a range of products, which are then combined for public use. The IGS Central Bureau Information System provides GPS orbits, tracking data, and other high-quality GPS data and data products on line in near real time . This provides both IGS member organisations and the public with a gateway to all the IGS global data and data product holdings, as well as other valuable information. See IGS web site at http://igscb.jpl.nasa.gov/. The global network of contributing stations is shown in figure 3 below.

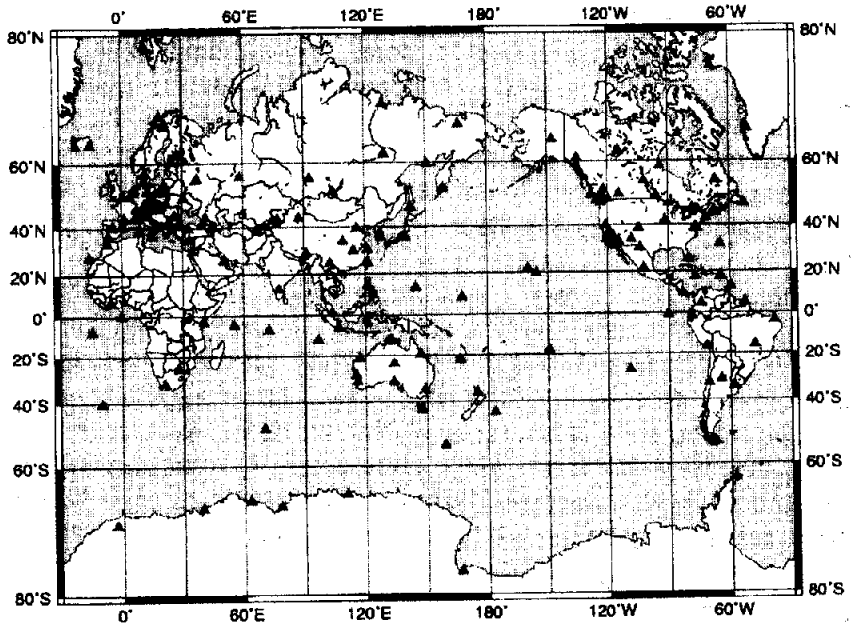

Figure 3: The IGS contributing network of GPS Base stations

With the development of international programs that rely on geodetic space techniques, the services also make a valuable contribution to various fields of geoscience with their technical expertise, scientific knowledge for example :

- IERS for the monitoring of global geophysical fluids, IGS for troposphere and ionosphere monitoring,
- ILRS for multi-purpose orbitography,
- ICET (International Center for Earth Tides) for the GGP (Global Geodynamics Project) network of cryogenic gravimeters,
- PSMSL (Permanent Service for Mean Sea Level) and
- IGS for international sea level monitoring projects.

The global products of the services are also used daily in the wide scientific community. As an example, crustal deformation studies in all countries rely heavily on the IGS orbits of the GPS satellites and are performed in the ITRF devised and maintained by IERS. (Kouba, et al 2000). The results from these studies can be used to gain an understanding of tectonics for specific areas that are at risk from natural hazards, when planning for sustainable development.

5. IAG AND THE ASIA PACIFIC REGION

In a contemporary timeframe IAG is looking to more closely integrate the very successful services and to revitalise the traditional research base to become more integrated with the wide global community. At the XX IUGG Assembly in Birmingham in July 1999, an extensive review was commissioned. This review is now in progress, headed by Prof. Beutler from Berne, and a special retreat for the review committee was hosted by Jet Propulsion Laboratory USA, in February 2000. The review will present its report firstly to the IAG executive before going to the IAG Council in Budapest in 2001.

Whilst based on its traditional strength in Europe, and more recently in North America, IAG has been increasingly involved in global and regional issues. Currently there are a number of study groups and sub-commissions which have active participants involved in studies in the Asia Pacific region, although the Pacific nations are very poorly represented in such research. IAG is addressing this issue in the Beutler review, as it is clear that to study the whole planet an enhanced global network of well distributed observational sites is vital.

The Asia Pacific region covers a very large geographic area ,so separated individual observation sites are particularly valuable to a fundamental reference observation framework. It is recognised that it is not enough for these systems to be exclusively operated from the other side of the globe, local knowledge transfer for the operation and local use of the data is essential. Although IGS draws upon a global network of permanent GPS sites there are many sites which are not currently able to download or otherwise contribute data on a daily or regular basis. These sites may be involved in long term research such as sea level rise or tectonic studies in specific areas rather than having a requirement for real time use for local surveying or navigation. This is the case in the Pacific Islands as shown in figure 4 and requires regional coordination. All these sites are very important to achieve a global densification of monitored ground positions within a global reference frame.

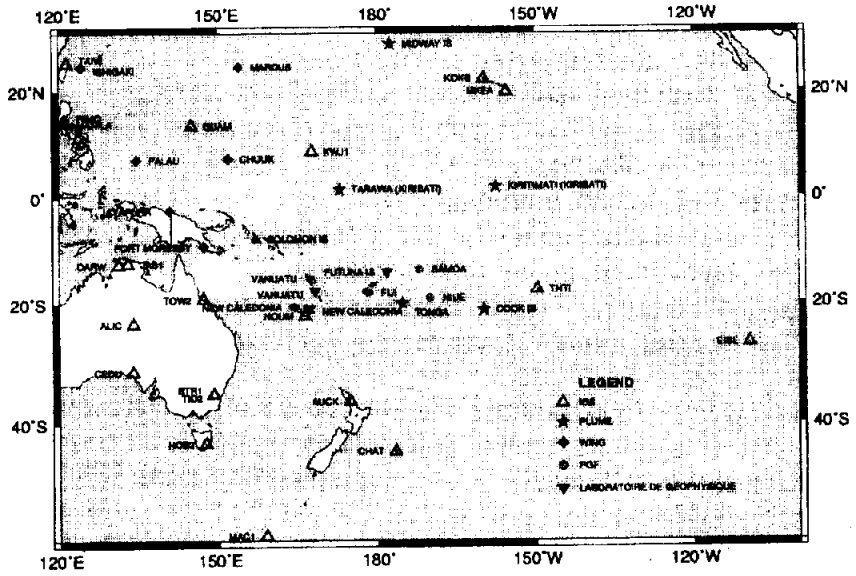

Figure 4 : Pacific GPS Networks

IAG endorses the work of the Permanent Committee for GIS Infrastructure in the Asia and the Pacific (PCGIAP) Working Group on Regional Geodetic Network which has already undertaken three excellent field campaigns and held two regional geodesy workshops to present results. A third workshop will be hosted by Mongolia in UlaanBaatar in August 2000 and will be supported by IAG as a technology transfer opportunity.

The homogeneous framework which this Working Group is providing is the basis for a compatible spatial data infrastructure so necessary for sustainable development decisions relating to Agenda 21 objectives for the planet. This was encapsulated in resolutions of the 14th UNRCC-AP which recognised the fundamental role played by

the spatial data infrastructure in ensuring the successful implementation of the initiatives of Agenda 21 and in facilitating sustainable development in the region.

IAG has recently sponsored a very successful Geoid school at Johor hosted by Malaysia in association with IGeS. Another "hands-on" Geoid workshop for the marine environment supplemented with an IGS tutorial is planned in the next twelve months in the Pacific.

The computed solutions of the extensive GPS data collected in the APRGP field campaigns 1997-1999 will be submitted to the ITRF2000 densification project through the work of the PCGIAP Working Group, as precise ITRF positions and velocities for key sites of the Asia Pacific region.

6. CONCLUSION

The need for IAG was historically based on research into the size, shape and motion of the earth. This has over time been broadened to include all research aspects of geodesy and the delivery of services to make available data and results from operations and research. Whilst its roots come from Europe its focus is global and its activities are threefold:

- Participation in high level global research
- Development of Services for product generation and distribution
- Application of results to meet Agenda 21 objectives

IAG has an important ongoing objectives with direct relevance to the Asia Pacific region:

"to promote and coordinate international cooperation and promote geodetic activities in developing countries"

This shows a strong commitment to assist the geodetic based work in the developing countries of the region within their resources.

It also has the objective of building a more comprehensive and homogeneous global geodetic infrastructure. This is important to the Asia Pacific region and facilitates the densification of compatible regional and global networks for use in spatial data infrastructures for subsequent sound sustainable development decision making on land and sea.

Involvement of nations from the Asia Pacific region is vital to the IAG to obtain data on a well distributed observational network, and for the generation of products by the relevant services. IAG supports the work of the PCGIAP Working Group on Regional Geodetic networks and the Asia Pacific Space Geodynamics Project (APSG) and looks forward to increased participation and opportunities for technology transfer facilitation to the Asia Pacific communities.

IAG offers much potential benefit to the communities in the Asian Pacific region in the provision of services and products for use by the regional community. The information available from the IAG services has great potential for the Asia Pacific user community especially the IGS with reliable up to date, precise products for GPS application.

Acknowledgment

The general description of the operational aspects of IAG has been extensively paraphrased from the paper by the then President of Prof. K.P. Schwarz "What is IAG " as published on the IAG web site.

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Appendix 1

Current structure and officers of the IAG

Bureau

President Fernando Sanso (Italy)
First Vice President Gerhard Beutler(Switzerland)
Secretary General C. C. Tscherning (Denmark)
Second Vice President Denizar Blitzkow (Brasil)
Attends any meeting of the Bureau on invitation of the President.

Excecutive committee.

- The Bureau and the Second Vice President
- The Past President: K.-P. Schwarz
- The Section Presidents:

Other officers

Editor in Chief of the Jounal of Geodesy - P. J. G. Teunissen (The Netherlands)
Assistant Secretaries of the Association
Ole Baltazar Andersen (Denmark)
Kristian Keller (Denmark)
Honorary Presidents:
H. Moritz (Austria).
P. V. Angus-Leppan (Australia)
I.. I. Mueller (USA)
W. Torge (Germany)
K.-P. Schwarz (Canada)
Honorary Secretaries General
J.-J. Levallois (France)
M. Louis (France)
Secretaries on the sections and the other officers may attend any meeting of the Executive Committee of the Association in an advisory capacity.

Sections, Commissions, Special Commissions, Special Study Groups, International Services.

Section I: Positioning -http://www.gmat.unsw.edu.au/snap/gps/iag_section1.htm

President: Alan Dodson, U
Secretary: Chris Rizos, Australia
Claude Boucher (France)

Commissions of Section I:
Comm X: Global and Regional Geodetic Networks President: Claude Boucher (France)
Sub Commissions
Antarctica Co Chairs : John Manning, (Australia) Reinhard Dietrich (Germany)
South East Asia and the Pacific Chair : John Manning, (Australia)
South America Chair: Luiz Fortes (Brazil)

Special Commissions of Section I:
SC4: Application of Geodesy to Engineering President: Heribert Kahmen (Austria)
Secretaries: Zhenglu Zhang (China)
Günther Retscher (Austria)

Special Study Groups of Section I:
SSG 1.179: Wide Area Modelling for Precise Satellite Positioning Chair: S Han (Australia)
SSG 1.180: GPS as an atmospheric remote sensing tool Chair: H van der Marel (The Netherlands)
SSG 1.181: Regional Permanent Arrays Chair: R. Weber (Austria)

SSG 1.182: Multipath Mitigation Chair: M P Stewart (Australia)

Section II: Advanced Space Technology

President: C. K. Shum *(USA)*
Secretary: Pascal Willis *(France)*
Comm VIII: H. Drewes (Germany)

President: C. K. Shum (USA)
Secretary: Pascal Willis (France)

Commissions of Section II:
Comm VIII: International Coordination Of Space Techniques For Geodesy And Geodynamics (CSTG)
President: H. Drewes (Germany)
Secretary: W. Bosch (Germany)

Special Commissions of Section II:
SC7: Satellite Gravity Field Missions Chair: Karl-Heinz Ilk (Germany)
Co-Chair: Pieter Visser (The Netherlands)
Secretary: Jürgen Kusche (Germany)

Special Study Groups of Section II:
SSG 2.162: Precise Orbits Using Multiple Space Techniques Chair R. Scharroo (The Netherlands)
SSG 2.183: Spaceborne Interferometry Techniques Chair: Ramon Hanssen (The Netherlands)
SSG 2.192: Spaceborne GNS Atmosphere Sounding Chair: Rob Kursinski (USA)
Co-chair: Klemens Hocke (Germany)
SSG 2.193: Gravity field missions: calibration and validation Chair: Pieter Visser (The Netherlands), Co-chair: Christopher Jekeli (USA)
SSG 2.194: GPS Water Level Measurements Chair: Gerry Mader (USA), Co-chairs: Tilo Schöne (Germany), Doug Martin (USA)

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Director of the CB: Ruth Neilan (USA)
ILRS The International Laser Ranging Service Chair of the Governing Board: John Degnan (USA)
Director of the Central Bureau: John Bosworth (USA)
IVS International VLBI Servicefor Geodesy and Astrometry Directing Board Chair: W. Schlüter (Germany)

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Secretary: Gerd Boedecker (Germany)
Comm XIII: Martin Vermeer (Finland)

President: Michael G. Sideris (Canada)
Secretary: Gerd Boedecker (Germany)

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SSG 3.177: Synthetic Modelling of the Earth's Gravity Field Chair: Will Featherstone (Australia)
SSG 3.184: Use of Remote Sensing Techniques for Validating Heights and Depths Chair: Philippa Berry (UK)
SSG 3.185: Merging data from dedicated satellite missions with other gravimetric data Chair: Nico Sneeuw (Germany)
SSG 3.186: Altimetry data processing for gravity, geoid and sea surface topography determination Chair: C. Hwang (Taiwan)

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IGeS International Geoid Service Director: F. Sansò (Italy)

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Secretary: Christopher Jekeli (USA)
Yuanxi Yang (China) Special Study Groups of Section IV:

Special Commissions of Section IV
SCI : Mathematical and Physical Foundations of Geodesy Chair :P..Holota (Czech Republic)

Special Study Groups of Section IV :
SSG 4.187: Wavelets in Geodesy and Geodynamics Chair: W. Keller (Germany)

SSG 4.188: Mass Density from Joint Inverse Gravity Modelling Chair: G. Strykowski (Denmark)

SSG 4.189: Dynamic theories of deformation and gravity fields Chair: D. Wolf (Germany)

SSG 4.190: Non-probabilistic assessment in geodetic data analysis Chair: H. Kutterer (Germany)

SSG 4.191: Theory of Fundamental Height Systems Chair: C.Jekeli (USA)

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Secretary: Veronique Dehant (Belgium)
Comm V: President: Shuzo Takemoto(Japan)
Comm XIV President: S. Zerbini (Italy)

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President: Shuzo Takemoto(Japan)
Vice-President: Jacques Hinderer(France)
Secretary: Oliver Francis(Belgium)

Comm XIV Crustal Deformation
President: S. Zerbini (Italy)
Vice-Presidents: B. Richter (Germany)
H.G. Kahle (Switzerland)
Secretary: T. Van Dam (USA)

Special Commissions of Section V:

SC3: Fundamental Parameters Chair: E. Groten

SC8: Sea Level and Ice Sheets
President: Michael Bevis (USA)
Vice President: Reinhard Dietrich (Germany)

Joint Working Groups of Section V:
IAG/IAPSO Joint Working Group "Geodetic Effects of Non-Tidal Oceanic Processes "
Chair: R. S. Gross (USA)

International Services of Section V:

IERS International Earth Rotation Service Chair: Christoph Reigber Director, Central Bureau, Daniel Gambis
PSMSL The Permanent Service For Mean Sea Level Director: P. L. Woodworth (UK)

BIPM Bureau International des Poids et Mesures - Time Section Director Time Section : E.F. Arias (BIPM)

Committees Out of Section:

ABLOS Committees reporting to the Bureau:
Committee Geodetic and Marine Geo-Scientific Aspects of the Law of the Sea Chair: Bjorn Geirr Harsson