Summary of the IGS Symposium and
Panel Discussion – 'Visions for the Future'
Bern Switzerland March 3, 2004

Over the past decade, the IGS has convened many technical workshops organized to generate recommendations that drive the evolution of the IGS. At this 10th anniversary celebration, it was decided to include a symposium day devoted to broader influences of the IGS. The agenda for this day included key people critical to defining science, policy, and programmatic directions for GNSS as complimentary to the in-depth technical discussions throughout the rest of the week. This venue was also an opportunity for these people to have a better understanding of what the IGS is and 'who' comprises IGS, the many impressive people from hundreds of organizations that contribute to the IGS for the greater benefit of all. The theme for the IGS symposium had three focus areas:

Celebrate the history, development and accomplishments of the IGS over the last decade and how this has benefited Earth and Space Science, and multi-disciplinary applications.
Provide a view of the evolution and future of Global Navigation Satellite Systems (GNSS) over the next 10-20 years.
Explore the future of international cooperation, the envisioned uses of GNSS and the role of IGS.

The meeting hall at University of Bern was at full capacity when Prof. John Dow, current Chair of the IGS Governing Board, welcomed the audience and introduced the first speaker, Prof. Gerhard Beutler who has been active in IGS for many years. He chaired the IGS Oversight Committee from 1991- 1993, and then was elected the first Chair of the IGS Governing Board from 1994 through 1998. In 1994, Beutler was elected President of the International Association of Geodesy (IAG). His paper included in this section provides an excellent summary of the IGS and future directions. He is also the head of the Astronomical Institute of the University of Bern, the organization hosting the IGS10th anniversary meeting.

Prof. John Dow (ESA/ESOC) addressed the IGS Strategic Plan in the second talk, reviewing the aspects of the plan outlined in the document, *'IGS Strategic Plan 2002-2007'*[1], available from the Central Bureau. Dow's term as Chair began in 2003 and he has been assessing the progress of the IGS compared to the strategic plan. He is intent on updating the plan during his term and ensuring that the organization is achieving stated goals and objectives. His paper outlines the status to date and future plans.

Bjorn Engen (Norwegian Mapping Authority) gave an interesting and timely presentation on the relation between the IGS and national mapping agencies. It was co-authored by Norman Beck of the Natural Resources of Canada and touches on the global infrastructure afforded by the IGS and the increasing necessity of understanding policies and national priorities to sustain or expand geodetic activities, a topic that is generally challenging with many groups facing diminishing resources.

[1] *IGS Strategic Plan 2002-2007*, IGS Central Bureau, http://igscb.jpl.nasa.gov, see publications

The next four presentations focused on how the IGS and GNSS has fostered and supported scientific research and applications. Dr. Andrea Donnellan (JPL) represented Dr. Ghassem Asrar, head of NASA Earth Science. Her presentation, included on the CD accompanying this proceedings, was visually stunning and summarized many points contained in NASA's Solid Earth Science Working Group report *"Living on a Restless Planet*[2]*."* Next, Dr. Robert Serafin (UCAR/NCAR) gave an excellent overview on the use of GPS for atmospheric science and weather forecasting. He addressed space based occulation missions, which carry a GPS receiver on board the satellite, such as GPSMet, COSMIC, CHAMP; and observations for weather forecasting derived from ground based GPS stations such as demonstrated by NOAA's Forecast Systems Laboratory. Prof. Christoph Reigber's presentation on gravity and space missions, such as CHAMP and GRACE, provided a remarkable overview on what GPS has enabled for low Earth orbiter science missions[3]. Dr. Kosuke Heki (Director of Mizusawa Astrogeodynamics Observatory, Japan) provided a unique presentation on earthquakes and deformation that included humorous animations to portray the scientific aspects[4,5].

The IGS is keenly interested in the developments of Global Navigation Satellite Systems (GNSS) and the next set of invited speakers were experts on the future developments, policies and plans for GPS, GLONASS and the future Galileo. Dave Turner, head of the secretariat office of the US Inter-Agency GPS Executive Board (IGEB) gave a very complete and detailed briefing on where GPS is headed. Jörn Tjaden, head of the Technical Division, Galileo Joint Undertaking described the process and policies of the new EU Galileo system, the new GNSS intended to be fully interoperable and compatible with GPS. He was followed by Steen Houg from ESA, France who represented Rene Osterlink, head of the ESA Navigation Department. Houg addressed technical aspects of the Galileo system and schedule. Sergey Revinivykh from Russian Mission Control described the plans for GLONASS, and recognized the IGS' incorporation of GLONASS observations and the pilot service within the IGS that produces the suite of classic products for GLONASS alongside GPS products (see Session 8 of these proceedings).

The day concluded with a session on international cooperation, education and outreach. Ken Hodgkins (US Department of State), who co-chairs the GNSS Action Team of the United Nations Office of Outer Space Affairs (UN-OOSA), gave an overview of the recent negotiations between the US and EU and prospects for reaching an agreement. He also summarized the progress of the GNSS Action Team highlighting its recent final

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[2] *Living on a Restless Planet*, NASA Solid Earth Science Working Group (SESWG) Report, October 2003, http://solidearth.jpl.nasa.gov/seswg.html

[3] *Christoph Reigber, Hermann Luehr, Peter Schwintzer and Jens Wickert (eds), Earth Observation with CHAMP - Results from Three Years in Orbit, Springer-Verlag Berlin Heidelberg New York, 628 pp., 2005. ISBN 3-540-22804-7*

[4] Heki, K., Dense GPS array as a new sensor of seasonal changes of surface loads, in "The State of the Planet", edited by S. Sparks, Geophys. Monograph, American Geophysical Union, in press.

[5] Heki, K., Secular, transient and seasonal crustal movements in Japan from a dense GPS array: implication for plate dynamics in convergent boundaries, in "Seismogenic Zone Volume of SEIZE Theoretical Institute", edited by T. Dixon, Columbia University Press, in press.

report[6] and expressing thanks for the participation of the IGS/IAG in the working meetings. Gordon Johnston (private consultant) presented a compelling presentation on IGS relationship to industry. It is interesting to note that at one of the first IGS workshops, the *'1995 Special Topics and New Directions'*, he presented a paper on using IGS information[7]. His latest paper is included here and worthy of reflection. Prof. Chris Rizos (UNSW, Australia), one of the newest members of the IGS Governing Board, provided a unique perspective on IGS and education. He questioned if the IGS is ready to fully address the needs of education, the cultivation of user communities, and the next generation of geodesists and geoscientists. Dr. Peizhen Zhang (Institute of Geology, China Seismological Bureau) presented GPS activities in China and how this related to deformation studies in the Tibetan plateau. He showed the GPS infrastructure in China, a 25-station permanent, continuous, state-of-the-art network, the Crustal Motion Observation Network of China (CMONOC) and how the global IGS enables geodynamics research of this accuracy level. The final speaker was Dr. Thomas Stansell who presented plans for the improved L1 signal and sought IGS feedback on this issue.

Panel Discussion Summary – 'Visions for the Future'

The final session of the day was an hour-long panel discussion moderated by Dr. Robert Serafin. He posed the following questions:

> *What is your vision for the future of GNSS and the breadth of its uses?*
> *How should IGS evolve in order to meet the operational and scientific challenges of the future?*

Panel members:

- Prof. Gerhard Beutler, University of Bern
- Prof. Geoff Blewitt, University of Nevada – Reno
- Prof. Dorota Brzezinska, Ohio Sate University
- Dr. Hans-Juergen Euler, Leica Geosystems AG, Switzerland
- Dr. John LaBrecque, NASA Solid Earth and Natural Hazards Program Manager
- Prof. Markus Rothacher, Technical University of Munich
- Dr. Hans Van der Marel, Delft University of Technology

Rothacher summarized his considerations noting that in a few years 80+ satellites will be available realizing a robust GNSS infrastructure of which the IGS is integral. The IGS as part of this global effort should strive to work at the level of the UN, i.e., recognized as an international entity. He expressed the vision that the Earth is a moving, breathing system that can be monitored with the 10,000+ sites located around the world. This speaks to needing real-time communications and data which will enable the detection of new signals, such as high density observations for tomography. He observed that to understand Earth's processes, one must encompass and integrate other techniques such as

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[6] United Nations Office of Outer Space Affairs Final Report of the Action Team on Global Navigations Satellite Systems, A/AC.105/C.1/L.274, Vienna, Austria, December 2003

[7] *Special Topics and New Directions, Workshop Proceedings, Potsdam Germany, May 1995*, available from the IGS Central Bureau, http://igscb.jpl.nasa.gov, see publications

GNSS, VLBI, SLR, DORIS, altimetry, INSAR, gravity missions, and this will be most challenging in the coming years.

Van der Marel considered that GNSS will be broadly based in the future, data products will become very common and students will learn more about concepts than purely focusing on the techniques. Climate and weather will benefit from the dense networks and radiosondes will likely be replaced. Students do need to know how to discriminate however, and need to have a fundamental understanding of the observations and how they are generated. Galileo will be both difficult and exciting, and perhaps the IGS can assist in utilizing Galileo and extending the IGS standards.

Brzezinska felt that is was important to emphasize the desire for overlap between GPS and Galileo at L2. User equipment of the future will be a box that can simultaneously observe all GNSS satellites in view. She noted that the average user is not aware of the IGS or the excellent products. The IGS should evolve into a 'one-stop' shop, perhaps for even more than the global products.

Euler provided the view of industry for the panel stating that multi-system applications will be common with receivers observing multi-satellite GNSS simultaneously and with increasing complexity of receivers, algorithms, and analysis. These advances, combined with the availability of the internet everywhere, will spawn numerous applications. People want real-time accuracy at the mm level, demanding calibration and monitoring of the reference system with implied maintenance of standards. He sees the IGS quickly moving towards the provision of real-time services.

Blewitt noted that the evolution of the IGS to meet scientific needs of the future is key. IGS should ask itself, "What can we do differently to serve science?" Rather than just improving products from each, it will be critical to integrate all components of the GNSS constellations and to produce even better products from the integrated observations. How IGS evolves organizationally is also important, and noted that IGS is a very natural fit in the organizational concept of the Global Geodetic Observing System (GGOS)[8]. IGS should move towards integrating physical characteristics of different geophysical processes, such as sea level, solid Earth deformation and gravity.

LaBrecque commended the IGS on tremendous success and sees an IGS-like entity helpful and necessary in unifying space geodesy: GNSS/ VLBI/SLR/INSAR. The precision and balance of techniques will continue to improve and will be driven by the pressure of friendly competition. He noted that collocation of the techniques at a subset of fiducial sites is important so that all can refer to the same geodetic 'benchmarks'. He expressed concern about the ability of IGS to sustain its activities since most tasks and organizations depend on under funded research programs in order to contribute to the IGS. The whole is clearly much more than the sum of its parts and each contribution is critically important. He also questioned how to sustain real-time operations in this environment and noted that integrity monitoring is clearly important now and in the future as GNSS evolves.

[8] Global Geodetic Observing System (GGOS)

Beutler summarized key reasons for the success of IGS, and noted that the robustness stems from redundancy of all components, with the exception of the Central Bureau. . IGS *really* understands its business, which leads to new users and applications. The IGS really exploits GNSS which further leads IGS into multi-disciplinary science. To date he notes that the IGS has not established a business entity, and thinks that IGS should perhaps attach itself to another established international organization, e.g., the UN Office of Outer Space Affairs. IGS must incorporate the new GNSS and he thought that the next ten years will be difficult; in the past, IGS activities have been integral to the research of various IGS contributors but there is now an increasing focus on applications and projects. He notes that it will be challenging to manage all of the technical aspects of integrating the new GNSS into IGS while also retaining the strong research focus of the groups.

Open discussion

Tom Stansell addressed the panel asking what is the advantage of additional GNSS signals; Beutler stated that combinations of multiple sources invariably improve products.

Dave Turner asked how closer ties to the UN would work and if this was a good approach? He also asked whether the IGS could assume the role of providing integrity monitoring for other communities. Ruth Neilan noted that IGS should not look to the UN as a funding source, but as an alliance in promoting the importance and visibility of GNSS and geodesy in applications benefiting society. Van der Marel responded that IGS could certainly perform integrity monitoring with the sub-network of real-time stations. LaBrecque pointed out that IGS is composed of members who are self-funded and that getting the resources to make the real-time data available must be addressed, the flow of funding must be stable so that members can sustain their activities. Serafin said that there are certain difficulties in structuring operational services, but believes that IGS should attempt to facilitate such operations by brokering links between its members and operational users. Blewitt responded to the UN question by stating that such links also enable locating stations in difficult locations by developing key connections. Reigber emphasized that the point here is funding, and the IGS does not have a coordinated effort for seeking and obtaining resources, he asserted that this is what is really needed.

Serafin noted that in numerical weather predictions and climate monitoring the IGS has already proven its value. There are other exciting atmospheric and earth science applications such as understanding the global water cycle, and measuring snowpack. Atmospheric science prediction and simulations seem to ahead of similar activities in the solid earth science but believes that numerical prediction of solid earth processes is soon to come and that the assimilation of IGS data into numerical models will be central to these advances.

Serafin closed by thanking the panel and the audience for a stimulating ending to the Symposium, and thanked the local organizers again for all their work which was met with loud and enthusiastic applause by all.

Note: Session 8, convened on March 4, was planned as a follow-on to the symposium sessions, presenting more technical details of the GPS modernization, use of GPS in international time transfer, architecture of the Galileo system, and progress of the IGS working group on GNSS.