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Integration of space geodesy: A US National Geodetic Observatory

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Abstract

In the interest of improving the performance and efficiency of space geodesy a diverse group in the US, in collaboration with IGGOS, has begun to establish a unified National Geodetic Observatory (NGO). To launch this effort an international team will conduct a multi-year program of research into the technical issues of integrating SLR, VLBI, and GPS geodesy to produce a unified set of global geodetic products. The goal is to improve measurement accuracy by up to an order of magnitude while lowering the cost to current sponsors. A secondary goal is to expand and diversify international sponsorship of space geodesy. Principal benefits will be to open new vistas of research in geodynamics and surface change while freeing scarce NASA funds for scientific studies. NGO will proceed in partnership with, and under the auspices of, the International Association of Geodesy (IAG) as an element of the Integrated Global Geodetic Observation System project. The collaboration will be conducted within, and will make full use of, the IAG's existing international services: the IGS, IVS, ILRS, and IERS. Seed funding for organizational activities and technical analysis will come from NASA's Solid Earth and Natural Hazards Program. Additional funds to develop an integrated geodetic data system known as Inter-service Data Integration for Geodetic Operations (INDIGO), will come from a separate NASA program in Earth science information technology. INDIGO will offer ready access to the full variety of NASA's space geodetic data and will extend the GPS Seamless Archive (GSAC) philosophy to all space geodetic data types.

Keywords: Space geodesy; National Geodetic Observatory; INDIGO; Global Geodetic Observing System; Global Positioning System; Very Long Baseline Interferometry; Satellite Laser Ranging; GPS; VLBI; SLR; NGO; GGOS

Abbreviations: AGU, American Geophysical Union; CDDIS, Crustal Dynamics Data Information System; CDP, Crustal Dynamics Project; CHAMP, Challenging Minisatellite Payload for Geophysical Research; CRF, Celestial Reference Frame; ΔDOR, Delta Differential One-way Ranging; DoD, Department of Defense; DORIS, Doppler Orbitography by Radiopositioning Integrated on Satellite; DOSE, Dynamics of the Solid Earth; DSN, Deep Space Network; ERS, Earth Resources Satellite; GGOS, Global Geodetic Observing System; GIS, Geographic Information Systems; GNSS, Global Navigation Satellite Systems; GPS, Global Positioning System; GRACE, Gravity Recovery and Climate Experiment; GSAC, GPS Seamless Archive; GSFC, Goddard Space Flight Center; IAG, International Association of Geodesy; IDS, International DORIS Service; IERS, International Earth Rotation and Reference Service; IGGOS, Integrated Global Geodetic Observing System (recently renamed GGOS); IGS, International GPS Service; ILRS, International Laser Ranging Service; INDIGO, Inter-service Data Integration for Geodetic Operations; InSAR, Interferometric Synthetic Aperture Radar; IPO, Integrated Program Office; IVS, International VLBI Service; LEO, Low Earth Orbiter; LLR, Lunar Laser Ranging; LOD, Length of Day; NASA, National Aeronautics and Space Administration; NGO, National Geodetic Observatory; NOAA, National Oceanic and Atmospheric Administration; NPN, NASA Polar Network; POD, Precise Orbit Determination; REASoN, Research, Education and Applications Solutions Network; SCIGN, Southern California Integrated GPS Network; SENH, Solid Earth and Natural Hazards program at NASA; SES, Solid Earth Science; SESWG, Solid Earth Science Working Group; SLR, Satellite Laser Ranging; STDN, Spaceflight Tracking and Data Network; TDRSS, Tracking and Data Relay Satellite System; TRF, Terrestrial Reference Frame; VLBI, Very Long Baseline Interferometry

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1. Introduction

The story of space geodesy is one of dramatic advance that has seen global measurement accuracy improve from multiple meters with satellite Doppler positioning in the 1960s to just a few millimeters with an assortment of techniques today. In the late 1970s, when global accuracies hovered near a meter, a speaker at the fall AGU meeting was asked, "When will we see a direct measurement of tectonic plate motion?" At the time, the idea that continents drifted over the earth's surface, though an old one, had been widely accepted for only about a decade, and no direct observation of the (presumed) steady motion of plate interiors had been made. "Sometime within the next 1–100 years" was the speaker's cautious reply. That was also about the time NASA, in response to this revolution in geophysics, formed its Crustal Dynamics Project (CDP) (Bosworth et al., 1993) with the express goal of devising the needed technologies and charting the motion of the tectonic plates. The speaker's reply neatly captured the sense of the community, which, mindful of the challenges in finding the required two orders of magnitude improvement, could not be confident of early success. As it happened success came fairly soon, with both very-long-baseline interferometry (VLBI) and satellite laser ranging (SLR) offering definitive confirmation of ongoing plate motion by the mid 1980s, joined by the Global Positioning System (GPS) a few years later.

This rapid progress was abetted by the hospitable climate within the CDP, which brought together researchers from the three technology disciplines in workshops twice each year, fostering a vigorous commerce of ideas and a constructive, if often intense, competition among research groups. From there the history of our science might have proceeded rather differently than it did. The structures established by the CDP, which was joined by many international partners, might have been consolidated into an International Space Geodetic Service with continued joint workshops leading to tight coordination and thoughtful integration of the techniques. Instead, having accomplished their chartered objectives, NASA in effect declared victory and dissolved the CDP in 1991. In its place they instituted the Dynamics of the Solid Earth (DOSE) program, which emphasized geophysical research. Joint technology workshops disappeared and the three techniques in the US – VLBI, SLR, and GPS – were left to pursue their interests separately, refereed by the funding agencies, rather than as cooperating elements of a unified space geodetic enterprise. We then saw the independent establishment of the individual technique-based services: the IGS in 1992 (Mueller and Beutler, 1992; IGS Central Bureau web site: http://igscb.jpl.nasa.gov/), the ILRS in 1998 (Pearlman and Taggart, 2000; ILRS Central Bureau web site: http://ilrs.gsfc.nasa.gov/ilrs_home.html), and the IVS in 1999 (Vandenberg and Baver, 2001; IVS Coordinating Center web site: http://ivscc.gsfc.nasa.gov/). As a result, the sense of community across techniques eroded, rivalries solidified, and efficient grass-roots coordination gave way to increasingly fractious and self-interested scrapping for scarce sponsor funds. This has led to inefficiency and is one reason for the now precarious status of SLR within NASA. In the end, Earth science is the loser.

Things are now beginning to turn around. In its report, *Living on a Restless Planet* (Living on a Restless Planet, 2002), NASA's Solid Earth Science Working Group (SESWG) highlighted the critical functions served by the geodetic networks:

> Precise 3D crustal motions are determined by all three networks, with dense GPS arrays particularly useful for regional tectonic and earthquake cycle studies. Beyond their scientific value, these data, together with precise determination of the 3D geocenter motion by SLR and GPS, constitute the geodetic elements that define the International Terrestrial Reference Frame (ITRF), which is the basis for all geodetic measurements described in this report. The ITRF is geometrically connected to the Celestial Reference Frame via Earth Orientation Parameter (EOP) time series, which are determined primarily by the VLBI technique and contain a wealth of geophysical and climatic information. The ITRF and EOP, and hence the networks, should continue to be maintained and improved and their data routinely acquired at the best possible accuracy and temporal resolution.

NGO and IGGOS (Rummel et al., 2000, 2001; Scharroo et al., 2005; Beutler et al., 2005; Rothacher, 2005; Plag, 2005; Lambeck, 2005; Rummel, 2005) offer a thoughtful response to this mandate. IGGOS is a broadly based movement to integrate the activities of an increasingly diverse international roster of space geodetic techniques. But IGGOS cannot by itself address the peculiar internal challenges facing NASA in sustaining a mature program in space geodesy while directing adequate resources to the scientific research that program is meant to support. Consolidation, coordination, and cooperation at the deepest levels among NASA-supported groups are vitally needed.

It was with that purpose that a diverse team representing the major space geodetic techniques submitted a proposal to NASA in 2002 to establish a National Geodetic Observatory. The NGO would bring together all major players