National Aeronautics and Space Administration

A Proposal To
The Global Geodetic Core Network Call for Participation

NASA's Next Generation
Space Geodesy Project

A Core Contribution to the
Global Geodetic Observing System

Submitted by

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Abstract

This proposal describes NASA's Space Geodesy Project. This two-year project will contribute to the Global Geodetic Core Network by: (1) Completing ongoing Network Design Studies that describe the appropriate number and distribution of next generation Space Geodetic Stations for an improved global network; (2) Establishing and demonstrating the operational capability of the prototype NASA next generation integrated Space Geodetic Station at Goddard's Geophysical and Astronomical Observatory, including next generation SLR and VLBI systems along with GNSS and DORIS; and (3) Generating an Implementation Plan for a new NASA Space Geodesy Systems Project which would build, deploy and operate a next generation integrated NASA Space Geodetic Network that will contribute to the improved global GGOS network.

Introduction

We measure and monitor the Earth's environmental system (its oceans, ice, land, atmosphere) not only to understand the processes of global change, but also to enable educated decisions on how to cope with these changes. Space agencies have launched and will continue to launch billions of dollars worth of satellites to make these measurements. Many of these depend on a highly accurate and stable geodetic reference frame within which to interpret the data and understand trends in the processes of change.

The measurement reference frame is maintained though a global network of ground stations with co-located SLR, VLBI, and GNSS, and is realized as the international standard through the International Terrestrial Reference Frame (ITRF). A combination of systems in a well distributed global network is essential because of basic differences in the measurement techniques and the different data products that each brings to the reference frame.

Requirements for the ITRF have increased dramatically since the 1980s. The most stringent requirement comes from critical sea level programs: a global accuracy of 1.0 mm, and 0.1mm/yr stability is required. ***This is a factor of 10 to 20 beyond current capability***. Current and future satellites will have ever increasing measurement capability and should lead to increasingly sophisticated models to explain what is happening, yet the ability to maintain the necessary reference frame ***even at its present level of accuracy and stability*** is in severe jeopardy due to the deteriorating condition of the ground networks. The core NASA elements have declined in numbers, distribution, and relative quality from their heyday in the 1980s. Decades-old subsystems and components are no longer available for these legacy systems, and new more modern technology has not yet been deployed to meet the more stringent measurement accuracy and the number of satellite missions to be supported.

New measurement systems are needed to meet these requirements. This has been recognized for some time, and prototypes of these next generation systems are under development.

Guided by the recommendations from the National Research Council's Committee on the National Requirements for Precision Geodetic Infrastructure[1], the long range goal of the Space Geodesy Project (SGP) is to build, deploy and operate a next generation NASA Space Geodetic Network (NSGN) of integrated, multi-technique next generation space geodetic observing systems. This new NSGN will serve as NASA's core contribution to a global network designed

[1] "Precise Geodetic Infrastructure: National Requirements for a Shared Resource," (National Academies Press, Washington, D.C., 2010)."

to produce the higher quality observational data required to maintain the Terrestrial Reference Frame and provide other data necessary for fully realizing the measurement potential of the current and coming generation of Earth Observing spacecraft. The goal of this Project is to demonstrate that NASA is ready to begin building and deploying those systems and establishing those stations.

To accomplish this, the SGP has three major activities:

(1) **Complete ongoing Network Design Studies** that describe the appropriate number and distribution of next generation Space Geodetic Stations for an improved global network, with appropriate trade studies demonstrating the effects of increasing or decreasing the number of stations and changing their possible locations;

(2) **Establish the prototype next generation integrated NASA Space Geodetic Station**, comprised of next generation SLR (NGSLR) and next generation VLBI (VLBI2010) systems co-located with GNSS and DORIS systems, and demonstrate the ability of this station to operate as an integrated system including the routine measurement of vector ties between individual observing systems; and

(3) **Produce a Project Implementation Plan (IP) for the build out, deployment and operation of a proposed next generation integrated NASA Space Geodetic Network** that will contribute to the next generation global network needed to meet the requirements of the current and coming generation of Earth observing satellites.

Network Design Simulation Studies

A network simulation capability was developed over the past several years by the Joint Center for Earth Systems Technology (JCET) at University of Maryland Baltimore County (UMBC) with participation from NASA Goddard and the University of Texas. More extensive and focused studies are required and will be carried out over the next two years. Simulations using different spatial distributions of stations will be examined to determine their effect on the determination of the ITRF. *The goal is to determine not only the necessary number and distribution of next generation observing stations, but also to establish reliable limits on the sensitivity of the chosen network to outages or loss of stations, individually and in combination with others.* It is important to understand how the proposed network will behave if portions become inoperable over extended periods of time (e.g. due to inclement weather or significant equipment failure occurs).

The success of the multi-technique station network depends on a design of the campus for each site that takes into account the strict requirement of monitoring the “tie vectors” between the different systems. Simulations will be conducted to examine the effect of errors in these “ties” and will be used to define possible scenarios that may minimize their effect on the realization of the ITRF. At present the various techniques are tied through ground survey measurements, which are infrequent and may not be consistently performed. Newer partially automated survey techniques are now available that will make vector monitoring to the systems (with proper accommodation and fixtures for the surveys) more systematic and routine.

Prototype GGOS Station

Essential to the ability to properly specify, procure and deploy a number of next generation multi-technique stations is the establishment and operation of a prototype station. This task includes: (a) completion of prototype next generation SLR and VLBI systems, and their installation at a common site along with modern GNSS and DORIS systems; (b) practical experience in their individual and mutual operation, including the ability to tie together the invariant reference points of the different systems; (c) testing of a proposed continuous monitoring system that measures the tie vectors between elements of the prototype stations; and (d) development of enhanced data analysis and data product generation based on the operations of the prototype station. Inherent in this operation is the co-location with existing systems and participation in observational activities with the rest of the global network, and subsequent analysis of the data collected.

This station will serve as a proof-of-concept testbed to validate the approach to be used for the larger global network and to guide NASA's acquisition process and the subsequent deployment of the operational network in the field.

Next Generation VLBI Prototype (VLBI 2010)

To address problems with the current VLBI system and to improve VLBI data to meet increasingly demanding requirements, an end-to-end redesign called VLBI2010 is in progress. The key concepts are a broadband signal acquisition chain (2 – 12 GHz) with digital electronics and fast, small antennas. By placing up to four carefully chosen RF bands in the 2–14 GHz range, RFI should be ameliorated and the requisite precision achieved. Fast antennas will provide higher temporal and spatial resolution for estimating the troposphere at each station, which simulations show as the largest noise source, as well as many more observations. High recording bandwidths are required to achieve the necessary sensitivity.

NASA's VLBI2010 system is being developed to be minimally staffed, remotely controllable, broadband, RFI avoiding, fully digital, fast slewing, and capable of producing VLBI delays with uncertainties of 4 ps. The system is designed to observe continuously.

Two complete signal acquisition chains are needed for testing and validation. Proof-of-concept systems have been successfully tested using the MV-3 antenna at GGAO and the Westford antenna at the Haystack Observatory in Massachusetts. A fast 12-m antenna been installed at GGAO and is currently being commissioned.

Next Generation SLR (NGSLR)

NASA undertook the development of a Next Generation SLR (NGSLR) because it recognized the older systems were literally "falling apart' and that the older technologies were not capable of satisfying projected performance requirements. The NGSLR is being built to demonstrate that a system using existing commercial off-the-shelf technology can satisfy the performance requirements as an autonomous, photon-counting SLR station with normal point precision at the mm level. The system is intended to provide continuous 24 hour tracking coverage of artificial satellites up to GNSS altitudes. NGSLR has already demonstrated much of its new technology and performance capability. Some developmental work remains to be completed to fully demonstrate the technologies can be integrated into a realizable system that meets the required performance criteria. Based on this experience, specifications then need to be written for a production system that can be built by industry.

The NGSLR system is now operating at GGAO near MOBLAS-7, one of the early NASA systems still in operation after nearly 30 years. Over the past year, NGSLR has taken over 250 passes of data, over the full range of capability for engineering, diagnostic, and operational testing, during both nighttime and daylight conditions. Over the next two years, NASA will complete the NGSLR prototype and make it part of the prototype GGOS station at GGAO.

Next Generation GNSS

The GNSS ground station element of the future Next Generation NASA Space Geodetic Network will be an extension of the current implementation at NASA's existing, fully automated, remotely administered, GNSS sites. Modern receivers, capable of multi-constellation tracking, best-practice antenna monumentation, and inter-technique baseline vector measurement support are to be incorporated.

A next generation GNSS system capable of advance tracking of multiple satellite systems will be installed at GGAO as part of the prototype GGOS Station, and operated in concert with the other systems. This will include co-location with the existing GNSS system and vector ties to the other technique elements

Co-location between elements

To take full advantage of the integrated nature of the GGOS Stations, it will be necessary to implement an economical approach that will routinely measure and/or monitor the inter-system vectors. NASA's SGP will carry out a thorough evaluation of the utility and feasibility of the commercially available Robotic Total Station (RTS) survey systems for monitoring the vector ties between station elements. This work will include considering observational strategies, developing methodologies for VLBI and SLR systems which may incorporate an accessible reference point, and address issues related to site layout and delivery of vector tie data and data processing techniques.

Data Center Archive Support

NASA, through its Earth Science Data Systems Core Program, funds the Crustal Dynamics Data Information System (CDDIS), an active archive supporting the international user community's space geodesy activities, particularly through the IAG Services. The CDDIS is an outgrowth of the successful archival system developed during NASA's Crustal Dynamics Project (CDP). The CDDIS provides easy, timely, and reliable access to a variety of data sets (particularly, GNSS, laser ranging, VLBI, and DORIS), products, and information about these data. As part of SGP, the CDDIS will be augmented with additional computer resources to support the archiving and distribution of the vector tie data and resulting analysis.

Project Implementation Plan for NASA's Space Geodesy Systems Project (SGSP)

The goal of the SGP is to demonstrate that NASA is ready to deploy a network of next generation integrated space geodetic stations as a contributor to an improved global network. A major SGP product is a Project Implementation Plan (PIP) for the next generation NASA Space Geodesy Systems Project (SGSP). The PIP will be the blueprint for building NASA's next generation SLR and VLBI systems, establishing the new integrated next generation NASA Space Geodetic Stations, operation of these stations as part of the global network, and processing, analysis, archiving and distribution of data derived from these and other stations. It will include a management structure, procurement strategy, schedule and budget for acquisition and deployment of the systems, strategies for both individual and shared development of cooperative sites with international partners, plans for operations and data acquisition, the processing, analysis, archiving and distribution of data, and proposed interactions with major international organizations such as GGOS.

SGP will begin the process of selection of sites for future NASA GGOS Stations by examining which of the existing NASA and NASA partner sites may be suitable. Specific studies include:

1. Develop site selection criteria and requirements,
2. Determine which if any of the currently available VLBI and SLR sites belonging to NASA meet these criteria (for all systems) and also satisfy the results of the Network Design Simulations and the Generalized Station Design,
3. Where opportunities permit, begin discussions with existing and possible new partners on possible availability of alternative existing or new sites and the requirements for use of those prospective sites. No binding agreements or MOUs will be established during the study period, nor until such time as NASA commits to funding future GGOS stations.

Points of Contact

The Space Geodesy Project has a PI, Deputy PI, Project Manager, nine CoIs and two collaborators. These are listed below along with their contact information:

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