PART 1 OF 4

Recent Activities at the National Geodetic Survey

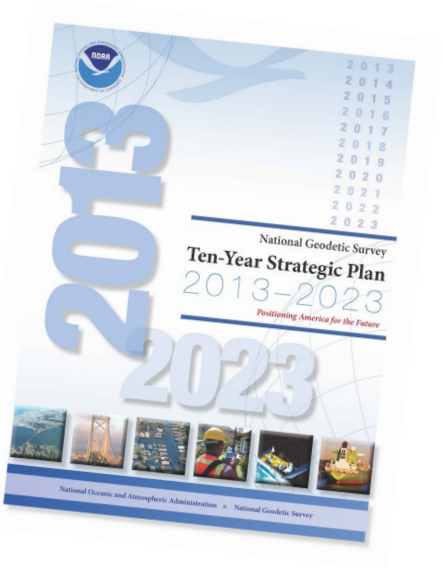
The last few years have seen a flurry of innovative new work from the National Geodetic Survey (NGS). Many of these activities have their own in-depth papers and related materials, so the point of this article is merely to throw a wide net and outline as many activities as possible that would be of interest to the readers of American Surveyor.

OVERVIEW

The Ten-Year Strategic Plan

Guiding all of NGS's activities is the Ten Year Strategic Plan. Historically, NGS has codified the direction of the agency into long-term plans, with the intent to highlight future directions for the agency based on stakeholder feedback, scientific progress and available resources. Previous plans were released in 1994 and 2007. The most recent version was released in 2013, and provides a road map of critical activities from 2013 through 2023. The most significant element of that plan is the replacement of NAD 83 and NAVD 88 in 2022. Coincident with these, and in coordination with NOAA's Center for Operational Products and Services (CO-OPS) and our parallel agencies in Canada, the replacement of IGLD 85 will also occur.

Encompassing a complete gravity survey of the USA (the Gravity for the Redefinition of the American Vertical Datum, or GRAV-D project), the replacement for NAVD 88 will be a GNSS and GEOID based datum, developed in three regions: First, North and Central America (pole to equator, covering Alaska, Hawaii, CONUS, Greenland, Canada, Mexico, Central America and the Caribbean); second, American Samoa and third the region encompassing Guam & the Commonwealth of the Northern Mariana Islands (CNMI). The primary method of defining and accessing the datum will be through GNSS technology, not passive control, and the known biases and tilts in NAVD 88 will be removed in order to align the geoid with data from the GRAV-D project and satellites such as GRACE.



The replacements for NAD 83(2011, PA11 and MA11) will remove the current nongeocentricity in those three frames, and will align with ITRF at the epoch of their release, though they will contain a plate-fixed component which will allow them to drift away from ITRF. The current "residual rotations" in NAD 83(2011) will be removed at the definitional level so that the plate-fixed nature of the new frames will be maintainable.

The new plan isn't all about the new datums, however. Many of the activities mentioned below are also a direct outcome of the new plan. For full details, the plan may be read online at *www.ngs.noaa.gov/web/news/Ten_Year_Plan_2013-2023.pdf*

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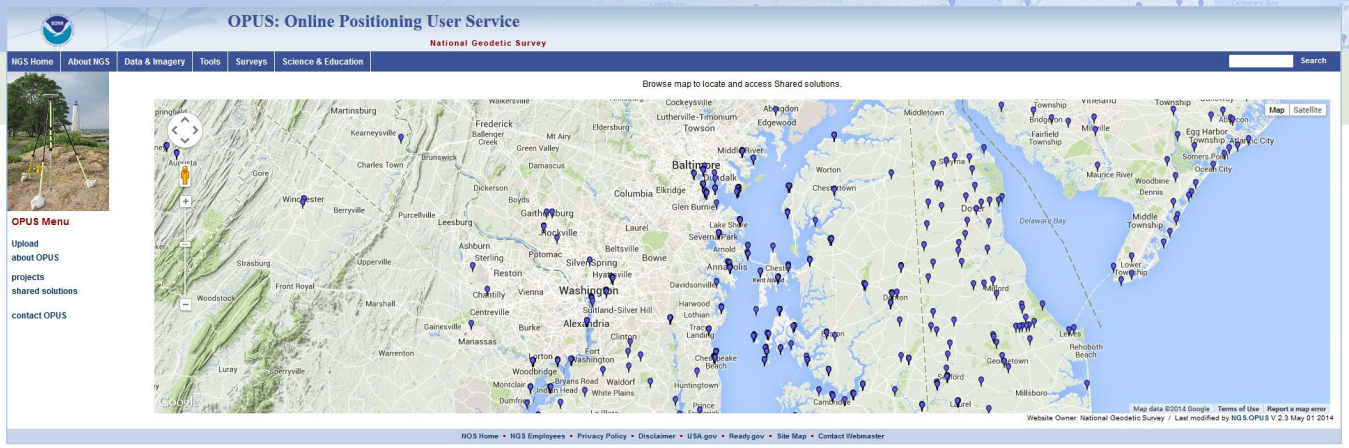


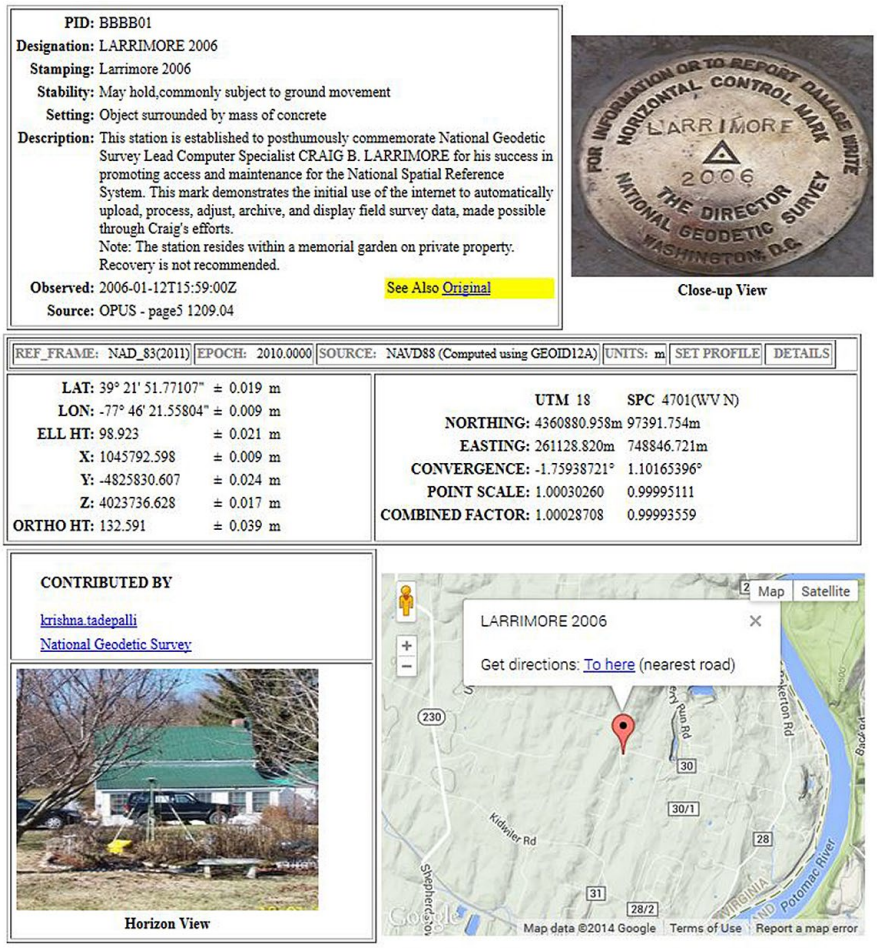
A distribution of OPUS-S solutions which have been "shared" on the NGS website.

OPUS AND CORS

OPUS-Database (OPUS-DB)

The tool sometimes known as "OPUS-DB" continues to be one of NGS's more popular services. Users of OPUS-Static (aka "OPUS-S") may recognize OPUS-DB under its functional moniker of "shared solutions". The OPUS-DB is a holding place (an online "database", thus "OPUS-*DB*") for storing OPUS-S solutions that have *not* been submitted to NGS for inclusion in the National Spatial Reference System. The long-term goal of NGS (See the Ten Year Strategic Plan, Goal 2, Objective 3) is to make OPUS-DB, in combination with OPUS-Projects (see below) the common method by which data is *submitted* to NGS (and not simply *shared* with the world). When this happens, the submission of data through OPUS-Projects and OPUS-DB will give NGS the chance to provide initial evaluation of the submitted data for eventual loading into the NGS Integrated Database (IDB). Currently, the only method approved by the Federal Geodetic Control Subcommittee (FGCS) of submitting Global Positioning System (GPS) data to NGS for these purposes is through the process described in the document Input Formats and Specifications of the National Geodetic Survey Data Base, also known as "the NGS Blue Book". (Note that, while the Blue Book is an NGS publication and concerns the NGS database, the FGCS (specifically the Methodology Working Group) has been the approving body for changes to the NGS Blue Book since the late 1990's, due to the adoption of the Blue Book as the federal standard for geodetic data entering the National Spatial Reference System (NSRS), in accordance with the government-wide geospatial standardization effort first established by the Office of Management and Budget in their 1990 circular "A-16".)

To reflect the current state of things, the OPUS-DB tool has been given a slight facelift. Users no longer see "publish my results" as an option. The option to "share my solution" is now offered, which more properly describes what users have been doing all along—*sharing* a solution with the world, but *not submitting* it to NGS for its evaluation, consideration to become part of the NSRS and thus have NGS distribute published solutions on these points.



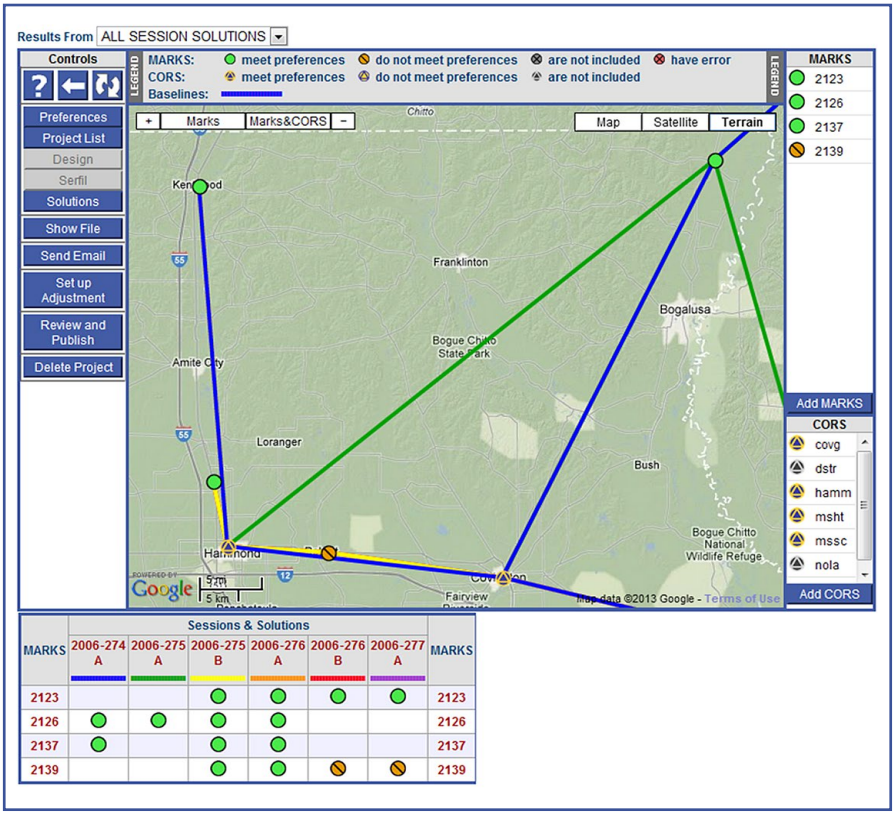
An example of an OPUS-S shared solution page. While similar to an NGS datasheet, such shared solution pages represent only one occupation on a point without any formal NGS evaluation and without considering other occupations on that same point, and are therefore not part of the NSRS.

OPUS-Projects

OPUS-Projects is an online browser-based tool for managing and analyzing network (or "campaign") GNSS projects. It continues to grow in popularity, while it undergoes further development and improvement. In September 2013, beta testing ended and it became an official product of NGS. Final documentation to support the tool was released in March of 2014.

Like the "share" option (of OPUS-S into OPUS-DB, as mentioned above), the intent of NGS is to eventually have users share their network solutions from OPUS-Projects. Even further down the road, NGS plans to turn OPUS-Projects into the primary replacement to Bluebooking for submission of surveys to NGS. OPUS-Projects data currently does not fulfill the requirements of the NGS Blue Book, and therefore cannot currently be submitted to NGS for evaluation, eventual loading into the NGS IDB and thus cannot become part of the NSRS. Two major efforts must occur for this situation to change: First, there must be a rigorous scientific comparison of "Bluebooking" against the tools in the OPUS suite to ensure that OPUS is equivalent or superior to the Bluebooking process. Second, the FGCS must approve a new method of entering data into the NGS IDB rather than Bluebooking. When these two actions are complete, NGS anticipates that tools in the OPUS suite will become the norm for submitting data to NGS.

Data for OPUS-Projects are actually loaded through the OPUS-S tool. When data are uploaded to OPUS-S, there is an option to provide a project name. By adding a project name, the data are tagged for use in the OPUS-Projects tool. Inside OPUS-Projects, adjustments are performed at multiple levels. The initial submission via OPUS-S results in both the initial data harvest and a rudimentary adjustment, based solely on ties to the CORS network. Data collected at multiple sites simultaneously may then be adjusted together for a "Session solution". Finally, after appropriate weights and constraints are applied, a final



The OPUS-Projects tool allows users to not only see their projects graphically, but to interact with the data, and quickly retrieve metadata, edit data, and perform computations.

"Network adjustment" of all sessions is performed to produce refined positions. The expectation is that this process will eventually be proven equal to or superior to the current method of coordinate determination (using PAGES and ADJUST in a project that has been Bluebooked for submission to NGS). Until that time, and in support of the current method of submitting data to NGS, OPUS-Projects currently supports the creation of b- and g-files that are used for input into the Bluebooking process to determine final reference frame coordinates. Using OPUS-Projects to generate b- and g- files should result in a much more streamlined submission process than current Bluebook submissions, until the entire Bluebooking and submission process has been re-invented.

NGS requires those interested in using OPUS-Projects complete a two-day training class. A full list of upcoming classes is available through the website of NGS's Corbin Training Center (*www.ngs.noaa.gov/corbin/*) The program is not complicated but there are a lot of features in OPUS-Projects. Optimal use of the program along with proper data processing procedures does require some interactive classroom training. Recently, an additional day on "Bluebooking with OPUS-Projects" has been appended to the usual training classes. NGS has a number of OPUS-Projects Trainers and there are usually 1 or 2 training sessions every week somewhere in the US. In fiscal year 2014, over 1,000 people received training in the use of this tool. Most of the training was done by NGS' Geodetic Advisors, in 26 states and Puerto Rico.

One final note—In January of 2014, NGS began to store GLONASS data from those CORS sites that are capable of observing GNSS data, which is approximately 40% of the existing CORS sites (roughly 760). While GLONASS data have not yet been utilized in any of the programs of the OPUS suite,

the NGS Strategic Plan calls for use of such GNSS data in positioning by 2022. Hence, commencing the archival of such data will permit future work to reach back to 2014 for purposes of GNSS positioning using the next-generation OPUS suite of tools.

Foundation CORS

Most stations in the CORS network are neither owned nor operated by NGS. Yet through the cooperation of those various station operators, NGS is able to collect and use the GNSS data from those CORS stations to define the National Spatial Reference System (NSRS). This has worked successfully for many years, but as accuracy requirements from both the users as well as in the definition of the NSRS itself continue to grow more demanding, the long-term stability and operational continuity of some of these sites may prove to be insufficient.

NGS therefore plans to add 10–20 Global Navigation Satellite System (GNSS) stations that are designed specifically for long-term stability, long-term operational continuity and to be built to satisfy the needs of the International GNSS Service (IGS) network and the International Terrestrial Reference Frame (ITRF). NGS will be the primary operator of these sites, though the sites themselves might be either built by NGS or else adopted by NGS from the original site owners. The exact location of this network would be geographically broadly distributed in a way that can provide mm level precision over the long-term. NGS has therefore begun to upgrade existing sites, plan for the establishment of entirely new GNSS CORS or discuss the adoption of existing CORS that provide the highest level of stability to define the most essential definition of the NSRS and meet one of the requirements of the Ten-Year Plan. This network of stations are termed "Foundation CORS" and will serve as the backbone of the NSRS and support the ITRF and IGS.

By the end of 2014 NGS will have established the first Foundation CORS. It will be located in Richmond, Florida in close proximity to a decommissioned VLBI station (antenna destroyed by Hurricane Andrew in 1992). This site will provide critical coverage for the ITRF in the SE United States, an area that only has ITRF coverage much further south at St Croix, US Virgin Islands. Additional sites that are being considered include:

The first Foundation CORS: A Short Drilled braced monument anchored to bedrock in Richmond, Florida.

- Sites co-located with existing VLBI and SLR instruments
- Sites where the ITRF has limited geographic coverage e.g. Mid-continent US.

Good sky visibility, low RF environments and a cost-saving preference to install sites on existing government facilities have represented significant challenges in identifying suitable sites. The next installment will cover NGS activities on GRAV-D, geoid models, and geoid slope validation surveys. ■

Dr. Dru Smith has been the Chief Geodesist at NGS since 2005, and most recently led the development of the NGS Ten Year Strategic Plan. During his years at NGS, he has been involved in geoid modeling, ionosphere research and most recently in updating the datum transformation software GEOCON.

Dr. Gerald Mader is Chief of the Geosciences Research Division at NGS and has worked extensively developing static and kinematic GPS data processing techniques and software. He has been the driving force behind the development of the entire OPUS suite of tools as well as the NGS antenna calibration program.

Dr. Giovanni Sella has a background in crustal deformation geology, which he applied to the improvement of NGS products and services. He has been the NGS CORS Program Manager for the last 8 years.