2019

GEOSPATIAL

SUMMIT

Modernization of the National Spatial Reference System (NSRS)

Sponsored by NOAA/National Geodetic Survey

ABSTRACT

The recent Geospatial Summit provided a wealth of information valuable to anyone who is interested in accurate horizontal and vertical positions in the United States and its territories.

Dave Newcomer, PE, PLS

This summary paper sponsored by the Florida Surveying and Mapping Society, Geospatial Users Group.

2019 Geospatial Summit

The Geospatial Summit Was Held in Silver Spring, Maryland on 6 – 7 May 2019. Most of the speakers were from the National Geodetic Survey; however, there were some outside speakers who relayed information about their specific projects or subjects.

Overall the Summit was very informative, providing information on the 2022 change of datums to a system compatible with the rest of the world. In order to obtain accurate elevations, a new geoid will be produced based on gravity measurements rather than the current hybrid geoid which is created from gravity measurements and ground measurements.

The people who attended this conference varied from scientists to users to educators, all of whom were aware of the changing datums for 2022. Most side discussions were how to reach the people who were not aware of the impact of the changes due in the next three years.

Prior to the summit, there was some recommended reading for the people who attended by webinar or in person:

Blueprint for 2022 Part 1: Geometric Coordinates

Blueprint for 2022 Part 2: Geopotential Coordinates

Blueprint for 2022 Part 3: Working in the Modernized NSRS

Blueprint for 2022 Part 1 and Part 2 was explained by Dan Roman, the NGS Chief Geodesist. These two Blueprints are quite detailed with the mathematics of the geometric and geopotential coordinates. During the Summit Dan went over the reasons for the changes to the coordinates but did not go into the mathematics behind the changes.

As the title states, Blueprint for 2022 Part 3: Working in the Modernized NSRS, is the guide to working within the new system. This document should be read by any surveyor who will be using GNSS, state plane coordinates for accomplishing level projects to include elevation certificates.

The object of the summary is to give an overview of the conference. The reader is encouraged to follow the suggested links to learn more about the datum change coming in 2022.

Geometric and Geopotential Coordinates

Geometric Coordinates

The crux of the change in geometric coordinates is depicted below:

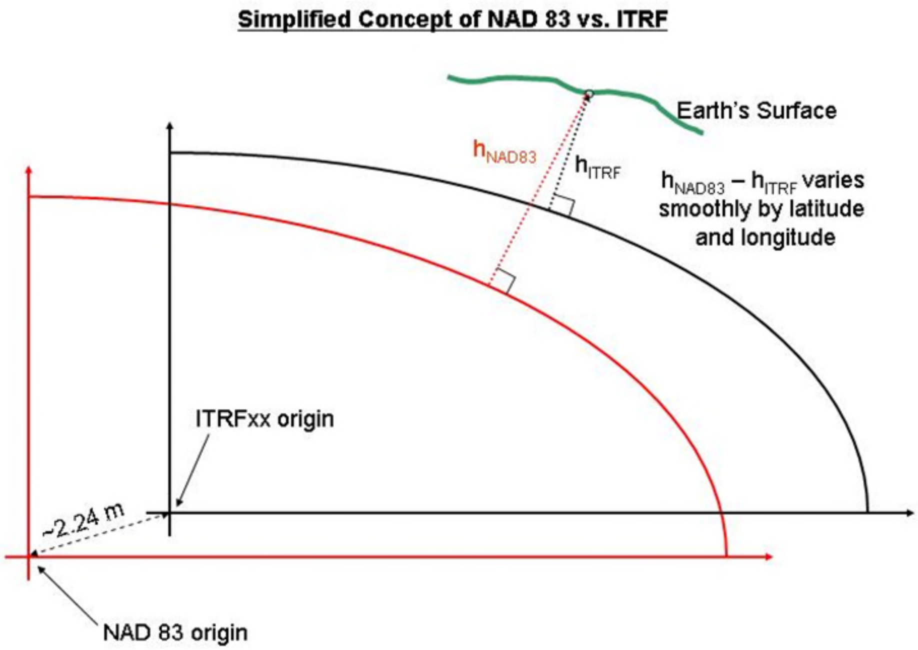


Figure 1

When originally conceived, NAD 83 and ITRF were essentially coincident. Over the years NAD 83 remained static while ITRF constantly moved as more information was gained about the center of the earth. The non-geocentric aspect of NAD 83 is not acceptable since we live in a dynamic world, and a static set of geometric coordinates are no longer appropriate. Making this change will remove ambiguities in positioning dependent on the reference frame.

In order to make this happen a new terrestrial reference frame will be required. Below is a chart showing the new reference frames and intended names of the frames. As can be seen in the chart there are additional parameters being added to coordinate calculations for the new terrestrial frames. ITRF2014 will have increased density and the Euler Pole Parameter (EPP) will be included in the calculation. An in-depth discussion of the EPP can be found in Blueprint for 2022 Part 1: Geometric Coordinates.

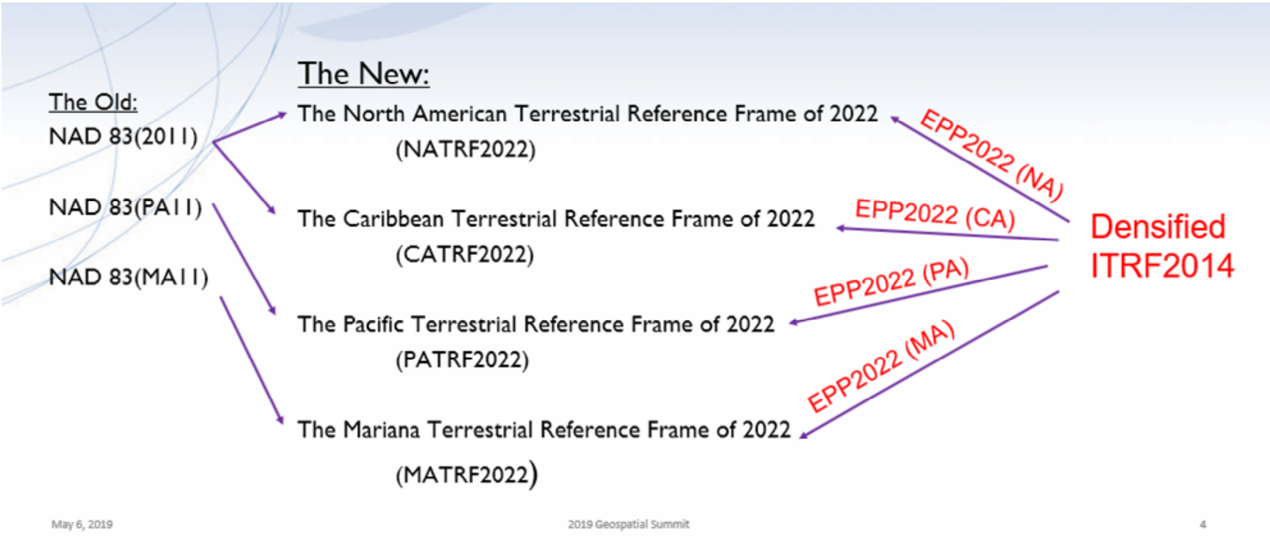


Figure 2

Geopotential Coordinates

Moving the reference frame as shown in Figure 1 will include a horizontal shift, a rotation and a tilt which will change the vertical position. This will require a replacement of NAVD88 with a new datum for orthometric heights.

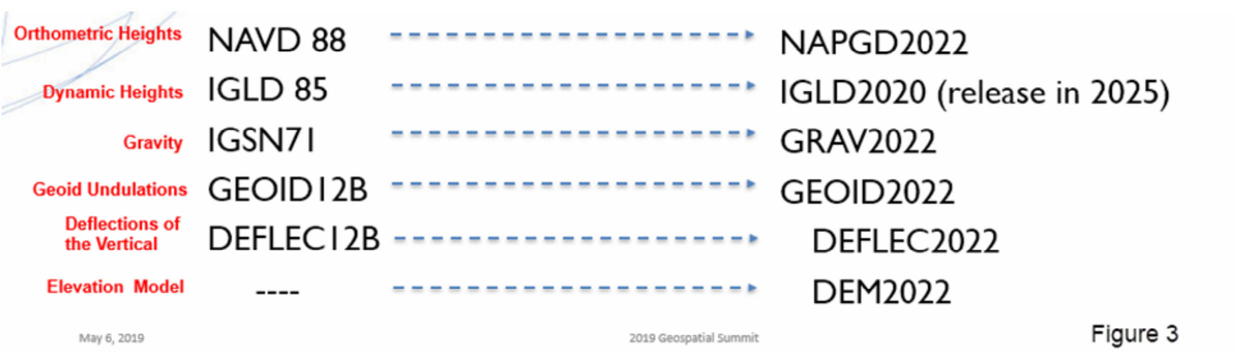


Figure 3

NAPGD2022 = North American-Pacific Geopotential Datum of 2022

In order to reach the goal of a 1 cm geoid, the National Geodetic Survey instituted the program called GRAV-D. The GRAV-D project has an overall goal of a 2 cm orthometric height which includes 1 cm of uncertainty from GNSS and 1 cm of uncertainty from the geoid model. There are two aspects to the program, one is the airborne gravity survey of the entire country and its holdings and a second aspect is long-term monitoring of any geoid change. The GRAV-D program is progressing on schedule; however, completion is dependent on funding.

Performance Metric
For Airborne Surveys

FY09 Baseline	Targets vs Actual												
	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
6.14%	7.5%	12%	20%	28%	36%	45%	53%	62%	70%	79%	87%	96%	100% and Implement
6.14	8%	15%	24%	31%	38%	45%	55%	64%	72%	75.8%			

- **Measure**: Percentage of the U.S. and its territories with GRAV-D data available to support a 1 cm geoid supporting 2 cm orthometric heights.

Figure 4

For additional information on the program please see GRAV-D.

The expected changes in orthometric heights in Florida range from -0.3 m to +0.1 m as shown in the figure below. The changes shown in Figure 5 are the anticipated deviations caused by the change from a hybrid geoid to a gravimetric geoid. There will be additional variations due to the change shown in Figure 1.

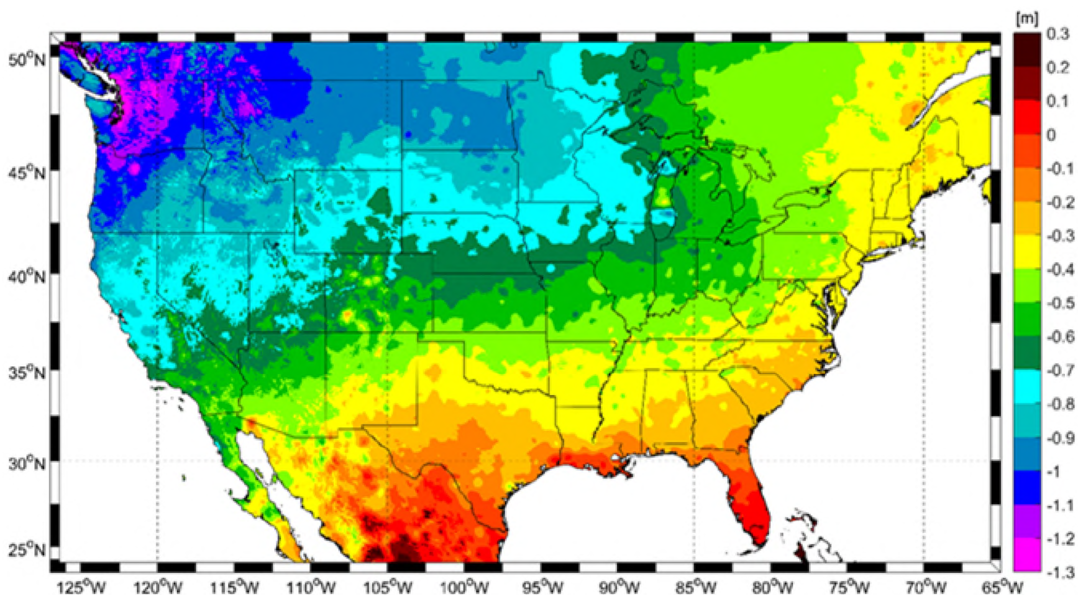


Figure 5

Geoids

Hybrid Geoid18 (Beta) is available on the NGS website and there are some changes in Florida. The changes are attributable to the GPS on Benchmarks campaign and the GRAV-D project. Below is a map showing the differences between Geoid12B and Geoid18.

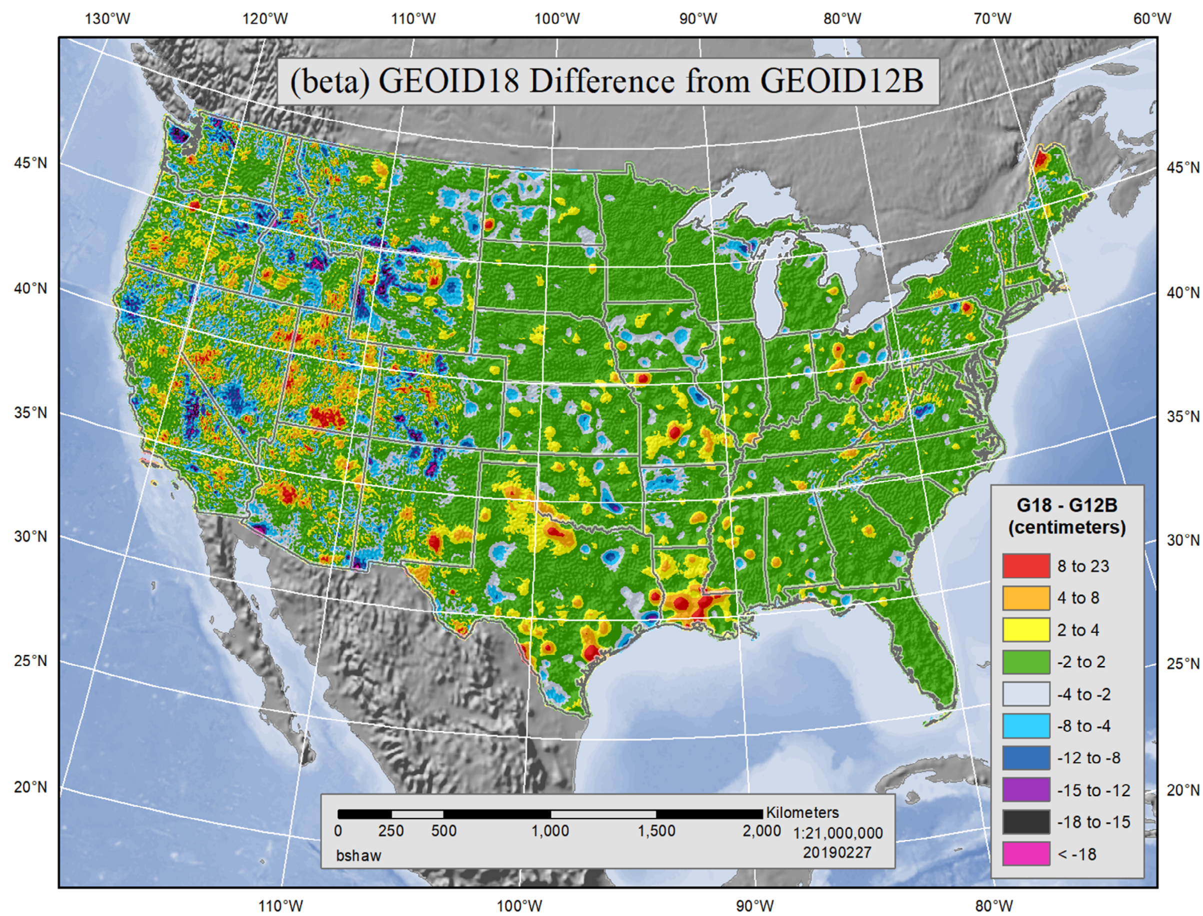
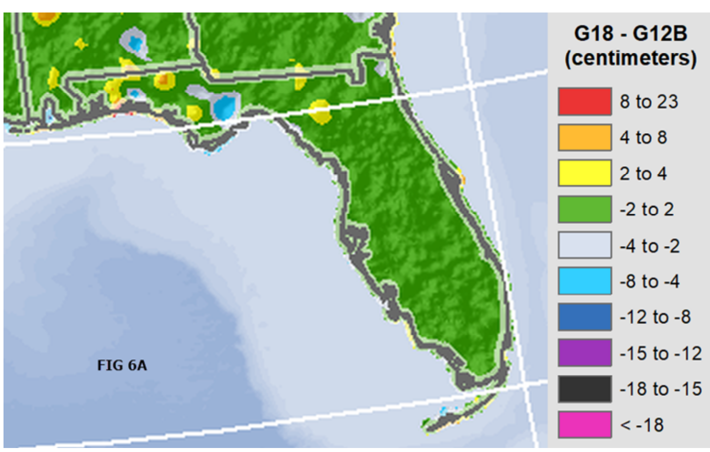


Figure 6



GEOID18 will be the last hybrid geoid model that NGS will create before NAVD 88 is replaced by the North American-Pacific Geopotential Datum of 2022 (NAPGD2022). Hybrid geoid models convert NAD 83 ellipsoid heights to NAVD 88 orthometric heights by constraining a gravimetric geoid to published heights at bench marks. Specifically, GEOID18 is intended for use with coordinates in the NAD 83 (2011) reference frame. NGS will replace GEOID12B with GEOID18 in 2019. GEOID18 only covers CONUS, Puerto Rico, and the US Virgin Islands. Users in Alaska, Hawaii, Guam, American Samoa, and CNMI should continue to use GEOID12B.

Since 2014, NGS has sponsored annual crowd sourced data collection campaigns called GPS on Bench Marks (GPSonBM) to help improve the accuracy and geographic coverage of GEOID18. For many of these years, NGS has worked with the National Society of Professional Surveyors to promote participation during National Surveyors Week each March. In 2018 alone, nearly 600 people and agencies from across CONUS and Puerto Rico submitted over 3,800 4-hour GNSS observations on about 2,500 bench marks. This additional data has significantly improved the model by closing data gaps and resolving conflicts in older data.

Most of the difference in this hybrid geoid model comes from the GPSonBM data pinning the model to the surface of NAVD 88, but there are also improvements in the underlying gravimetric geoid model. These improvements include:

- better elevation data and improved digital elevation modeling techniques,
- new gravity data from satellite gravity missions,
- new airborne gravity data from the NGS GRAV-D program, and
- improved geoid modeling techniques.

These improvements will be realized more directly in the future when NGS switches to a purely gravimetric geoid model with the new datums in 2022.

Blueprint for 2022 Part 3

Part 3 of the Blueprint, BP3, is the part that will mean the most to those who are working with the new datums. This part was presented by Dru Smith, the former Chief Geodesist for the National Geodetic Survey, who is now the NSRS Modernization Manager. BP3 is critical reading for anyone who will be working with the new datums. Not only are there going to be new datums introduced but there will also be new terminology, new coordinate names as well as new ways and time periods to process data. See the Appendix for the Executive Summary of BP3 as well as a list of new terminology.

As an example of the terminology change, ARP (antenna reference point) will still exist but may not necessarily be the point to which the CORS is referenced; that point will be called the GRP (geometric reference point). The ARP and the GRP may coincide, or they may not coincide.

There will also be five types of coordinate names:

- Reported: These are from any source where the coordinate is directly reported to NGS without the data necessary for NGS to replicate the coordinate.

- Preliminary: These are coordinates at survey epoch that have been computed from OPUS, but not yet quality checked and loaded into the National Spatial Reference System Database (NSRS DB).

- Reference Epoch: These are coordinates which have been estimated by NGS, from time-dependent (final discrete and final running) coordinates, and at an Official NSRS Reference Epoch (ONRE).

- Final Discrete: These are coordinates computed by NGS using submitted data and metadata, checked and adjusted and referenced to one survey epoch.

- Final Running: Of all types of coordinates on a mark, these are the only ones which will have a coordinate at any time.

These are just two examples of the types of changes that are coming soon. In addition to the above two examples, there will be a new name for and method of operating in the NOAA CORS Network (NCN), GNSS surveys will be done by "GPS Month", there will be a new way for users to process GNSS projects and a new way for users to process leveling projects; therefore, it is important that all surveyors familiarize themselves with BP3.

Products and Services for 2022 and Beyond (Some available now)

Of interest to surveyors will be the products and services available by 2022. The following charts indicate the current status of the product and services.

Name	Status (2019 Alpha status in BLUE)
NSRS Database	2019: Alpha version exists with basic information and data models
"The NOAA CORS Network" (NCN) : Modernized	2019: Alpha version using only piecewise linear ITRF2014 coordinate functions will be available by Summit (May)
OPUS: "For Everything" (for customers)	2019: Alpha version of should be available by the Summit (May)
OPUS: Mark Recovery (for customers)	2019: Alpha version should be available by the Summit (May)

Name	Status (2019 Alpha status in BLUE)
OPUS: **GNSS single-occupation processing** **(for customers)**	2019: Alpha version is effectively "OPUS-S" running on ITRF2014 coordinates in the NOAA CORS Network (NCN), though with alpha versions of EPP2022 and GEOID2022 available, an addendum to OPUS-S output could easily add alpha versions of NATRF2022, PATRF2022, MATRF2022, CATRF2022 and NAPGD2022 coordinates.
OPUS: **GNSS (including RTK/N ; vectors) project processing** **(for customers)**	2019: Alpha version allowing for RTK/vector input should be available by the Summit (May). Will rely upon ADJUST for now.
OPUS: **Leveling project processing** **(for customers)**	2019: Alpha version not available

Name	Status (2019 Alpha status in BLUE)
OPUS: RTN Alignment Service (for customers)	2019: No alpha version will be available
Comprehensive Coordinate Conversion and Transformation Engine (in two tools: NCAT and VDatum)	2019: Alpha version will be current versions of NCAT and VDatum. The current NCAT functionality is shown in blue in the list to the left.
The NGS Toolkit: Modernized	2019: No alpha version will be available

Name	Status (2019 Alpha status in BLUE)
Manual: GNSS	2019: The manual may be complete before the Summit, but will definitely be complete before the end of the calendar year.
Manual: Leveling	2019: Alpha version will be the leveling chapters from BP3
OPUS: GNSS GPS Month-based processing (internal)	2019: No alpha version expected
OPUS: Leveling project and/or multi-project processing (internal)	2019: No alpha version expected
OPUS: Reference-Epoch processing for lat/lon/eht/oht (internal)	2019: No alpha version expected

Name	Status (2019 Alpha status in BLUE)
NADCON: Connecting NAD 83(**11) epoch 2010.00 to **TRF2022 epoch 2020.00 (internal)	2019: CORS data will be used to compute a simple alpha version
VERTCON: Connecting NAVD 88 and other vertical datums to NAPGD2022 epoch 2020.00 (internal)	2019: GPSBM data (from GEOID18 etc.) used to generate an alpha version
SPCS2022	2019: No alpha version will be available

OPUS for Everything

Improvements to OPUS are in the planning stage. The ultimate idea is to have OPUS and OPUS Projects accomplish more than their current capabilities. The existing software that operates OPUS is more than 20 years old and only processes GPS. With the number of satellite constellations available it is time for an upgrade to PAGES, the current software operating OPUS and OPUS Projects.

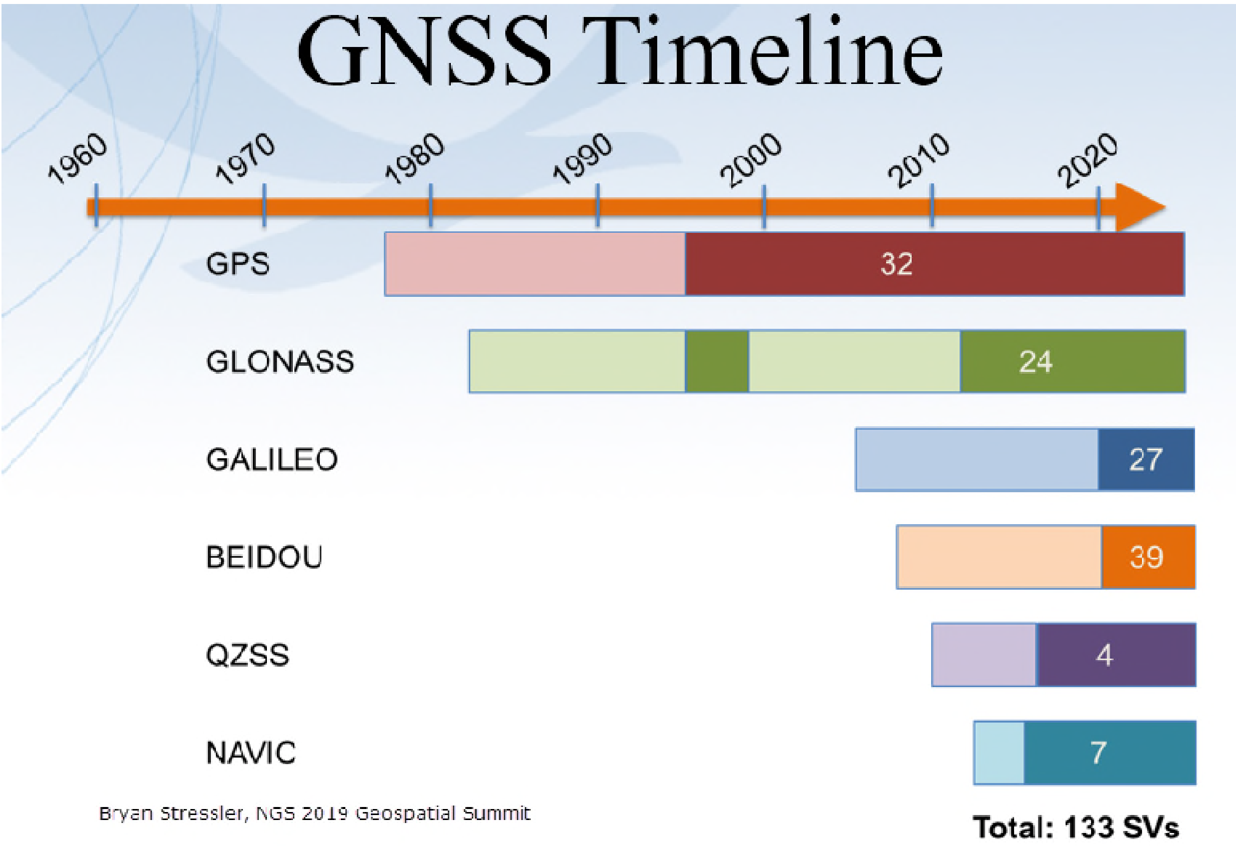


Figure 7

Multi-constellation GNSS processing will dramatically improve positioning in non-ideal surveying conditions (See Figure 8).

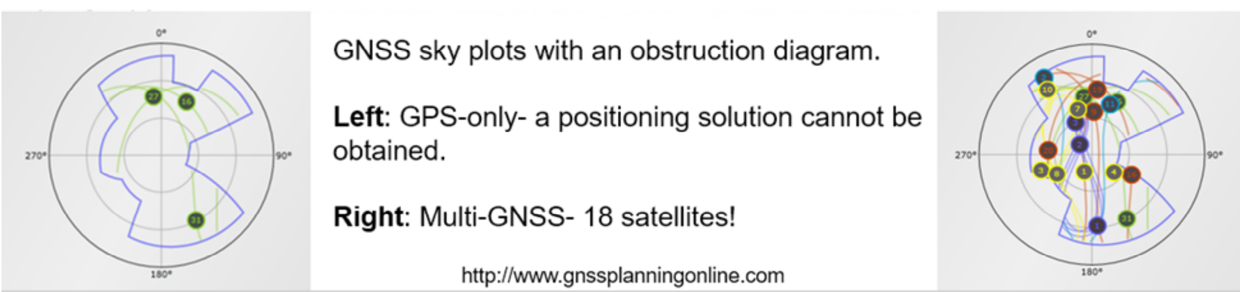


Figure 8

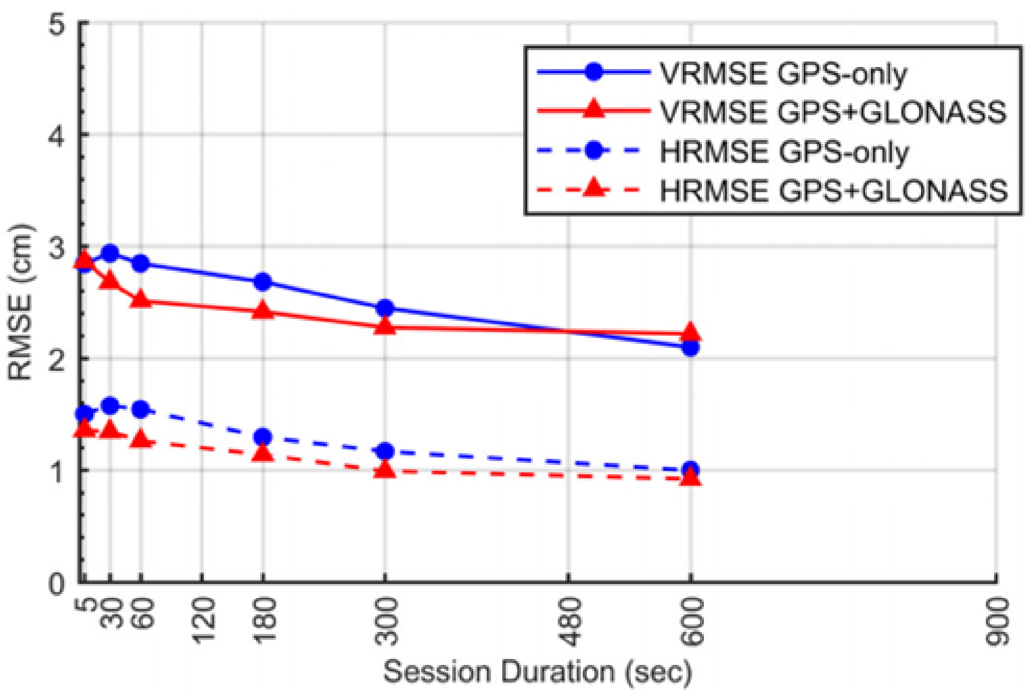
NGS is in the process of building a suite of multi-constellation GNSS capable software to replace PAGES. The new software will accomplish baseline processing and orbit production with a planned release of June 2021.

OPUS uses the IGS08 reference frame and Geoid12B for processing data. Beta OPUS is available on the NGS website and uses the ITRF2014 reference frame and Geoid18. To align NAD83 with the IGS08 reference frame, NGS completed a multiyear CORS solution (MYCS1) that incorporated data from 1994 to 2010.

On January 29, 2017 (GPS week 1934), the International GNSS Service (IGS), released the new coordinates and corresponding antenna calibrations in the IGS realization of the ITRF2014 reference frame (hereafter, referred to as ITRF2014). As part of this transition, products in the IGS08 frame are no longer updated. Instead, all the updates will be in the ITRF2014 frame. Although NGS did not participate in the 2nd IGS reprocessing campaign, they have completed the reprocessing of the CORS stations. The newly reprocessed CORS solution, called the MYCS2, is aligned to the ITRF2014 frame and supersedes the previous reference frame and realization, which was released in 2011 under the name MYCS1. See Multi-Year CORS Solution 2 (MYCS2) Coordinates for additional information.

INCORPORATING RTK DATA INTO OPUS PROJECTS

NGS will NOT be a network RTK provider; however, to assist the surveyor NGS has completed studies on incorporating kinematic data from a real-time network into OPUS Projects. This is part of the OPUS for Everything initiative. The errors that were encountered during the studies were greater than what one would expect with a static session but were well within kinematic expectations.



[Allahyari et al. 2018]

Figure 9

To use real-time data in OPUS Projects one would process the static data in the normal fashion as shown below and then upload the RTN vectors prior to running the least squares adjustment.

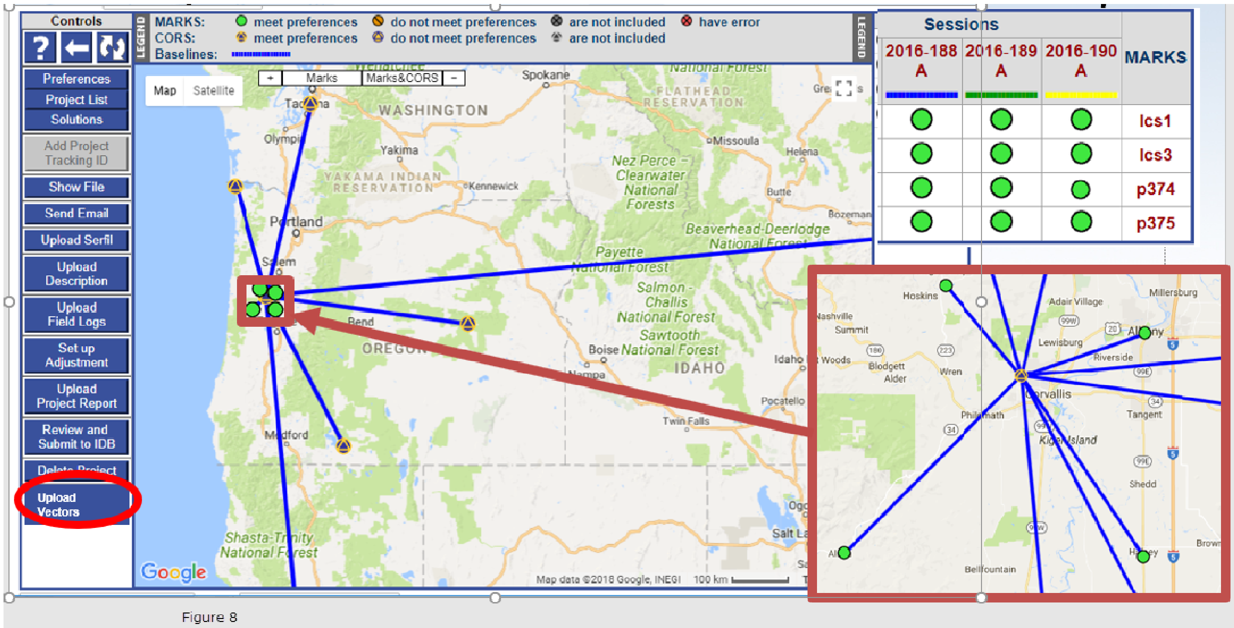


Figure 10

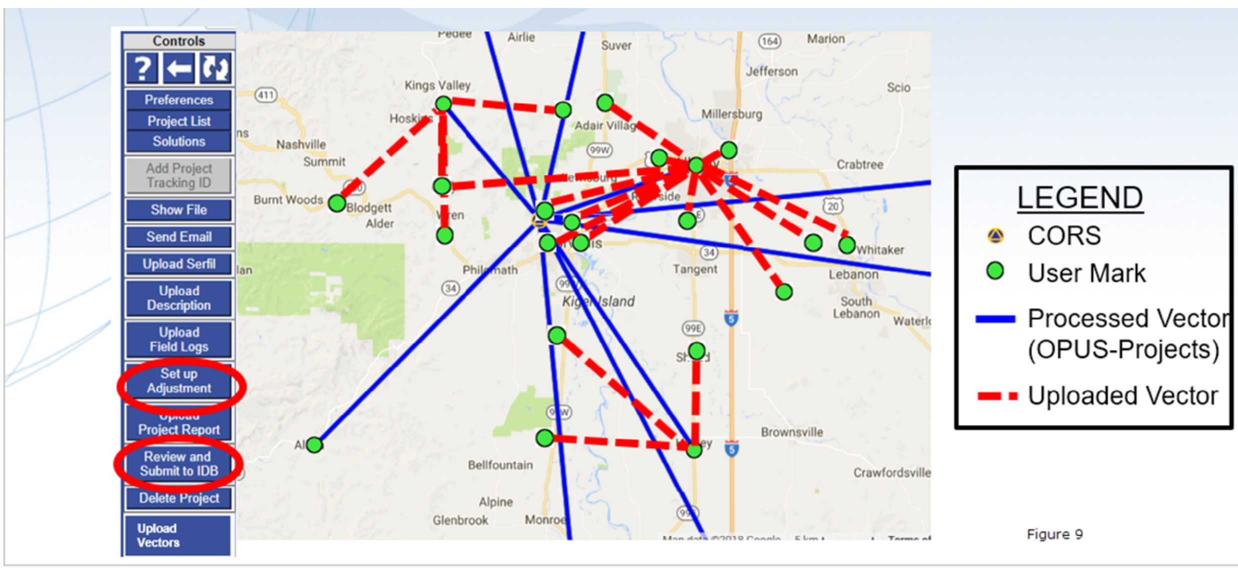


Figure 11

Eventually, data will be allowed into the NGS database using RTN vectors. This will make it much easier and faster to "Bluebook" a GNSS project.

OPUS Projects

The planned improvements to OPUS will carry through to OPUS Projects with the update of the reference frame and geoid. Additional improvements are anticipated later this year:

- Improved CORS information from inside your project.
- Improved automated selection of hub(s).
- Automated selection of nearby CORS.
- Automated selection of distant CORS.
- "One-click" clean-up of unused CORS.

Incorporating RTK results in static GPS survey projects is anticipated in early 2020. This will be the next step in ingesting other types of vector survey results into OPUS Projects and will be the next step in OPUS Projects for Everything.

Coordinate Conversion

A coordinate conversion tool, NCAT, went into service in February 2018 and is available on the NGS website. Conversions between LLh, SPC, UTM, XYZ, USNG and Nadcon transformation can be done with NCAT. It is anticipated that a Vertcon conversion will be available soon. Deflection models and geoid models will be available in late 2019 or 2020.

[NCAT Coordinate Conversion]

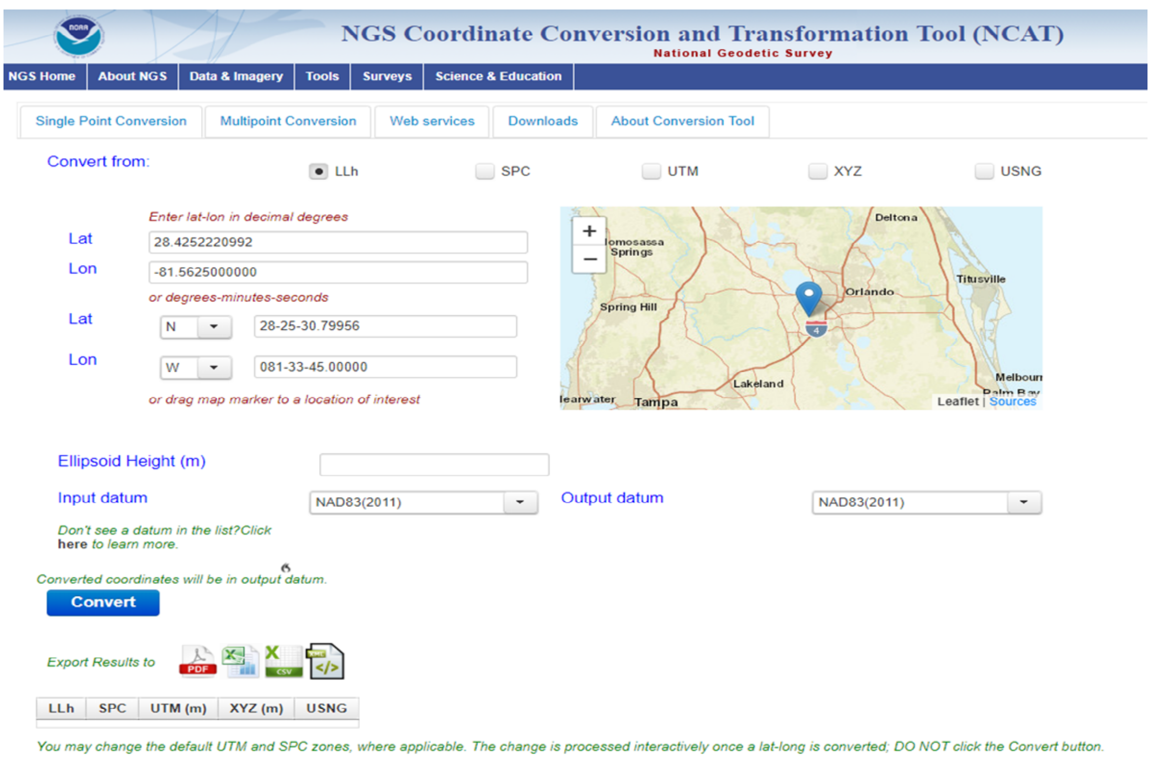


Figure 12

Foundation CORS

NGS will be designating Foundation CORS which is a set of federally-operated, ultra-high-quality, high-reliability stations with the longevity to guarantee citizens access to official NSRS positions and support international positioning consistency efforts. There will be 26 Foundation CORS in North America, 4 in the Pacific, 3 in the Caribbean, and 3 in the Marianas.

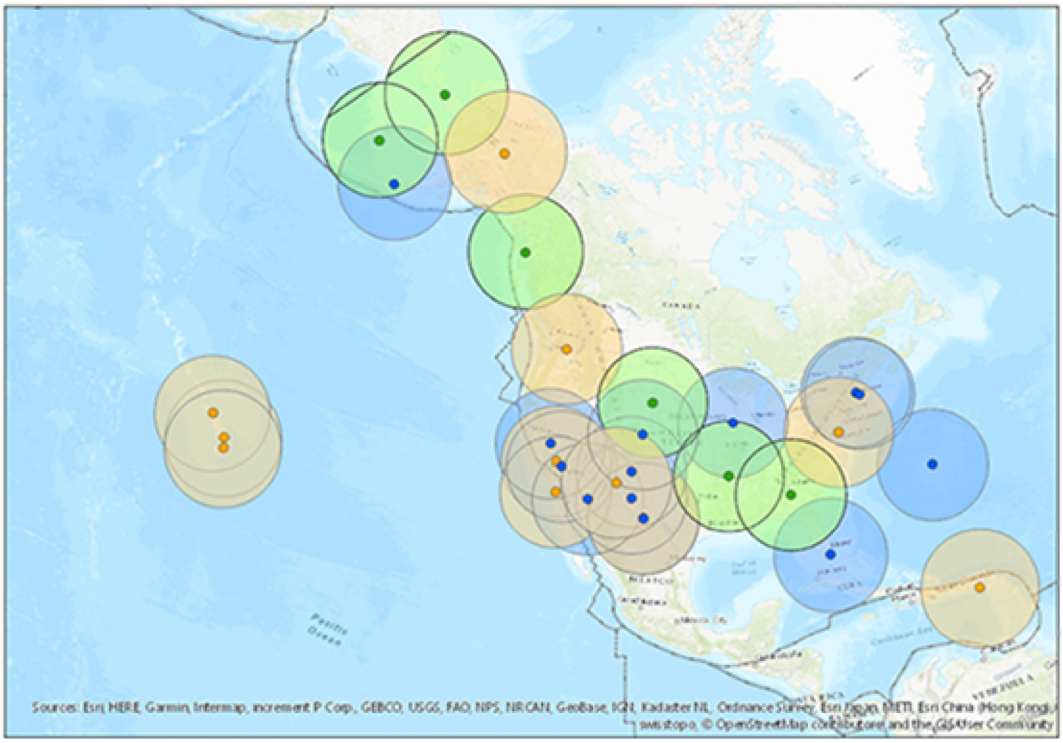


Figure 13

Federal Partners	Site ID	Location
National Science Foundation (NSF) Existing Sites Program: EarthScope Plate Boundary Observatory (PBO)	AB09	Wales, AK
	P777	Dennard, AR
	P804	Georgia
	AB51	Petersburg, AK
	ATQK	Atqasuk, AK
	P043	Wyoming
National Aeronautics and Space Administration (NASA) Existing Sites Program: Global GNSS Network (GGN), operated by Jet Propulsion Laboratory	CRO1	Saint Croix, VI*
	BREW	Brewster, WA*
	FAIR	Fairbanks, AK
	GODE	Greenbelt, MD*
	GOL2?	Goldstone, CA*
	MDO1	McDonald Observatory, Texas*
	MONP	Mount Laguna, CA*
	PIE1	Pie Town, NM*
	GUAM	GUAM
	KOKB	Kauai, HI*
	MKEA	Mauna Kea, HI*
	HAL1	Haleakala, HI*
NOAA- National Geodetic Survey (NGS) Existing and New Sites Program: Continuously Operating Reference Stations (CORS)	ASPA	American Samoa
	CNMR	Saipan, TQ
	GUUG	GUAM*
	BRSG	Bermuda
	FLF1	Richmond, FL*
	WES2	Westford, MA*
	TMG2	Boulder, CO
	NEW	Apache Point, NM*
	NEW	Fort Davis, TX*
	NEW	Fort Irwin, CA*
	NEW	Hancock, NH*
	NEW	Los Alamos, NM*
	NEW	Kitt Peak, AZ*
	NEW	Owens Valley, CA*
	NEW	Cold Bay, AK*
	NEW	North Liberty, IA*
TBD	TBD	Existing location in Caribbean
	TBD	Existing location in Caribbean

How is the Foundation CORS different from other CORS?

- Federally-owned and operated "backbone"
- Chosen for location, longevity, and high quality
- Operational Goals:
  - Non-operational time minimized for each station
  - 90% of NOAA Foundation CORS Network available at any time (no more than 4 stations non-operational)

- All stations are critical to some function of the new NSRS
- 22 out of 36 stations are (currently or will be) co-located with other space geodetic stations supporting the IGS/ITRF
- Local tie surveys ("IERS site survey") will link together all geodetic instruments/marks at the site every 5 years.

Figure 14

Why do we need Foundation CORS?

The Foundation CORS targeted locations provide:

1. A geographic distribution no greater than 800 km to provide 1.5 cm accuracy ellipsoidal height results through NGS' OPUS tools anywhere in the U.S.
2. Support for the ITRF by co-locating at existing space-based geodetic sites.
3. Favorable geometry to monitor tectonic plate (Euler Pole) rotation.
4. Gap Filling in international areas where foundational stations are needed to support the U.S. NSRS, e.g. the Caribbean

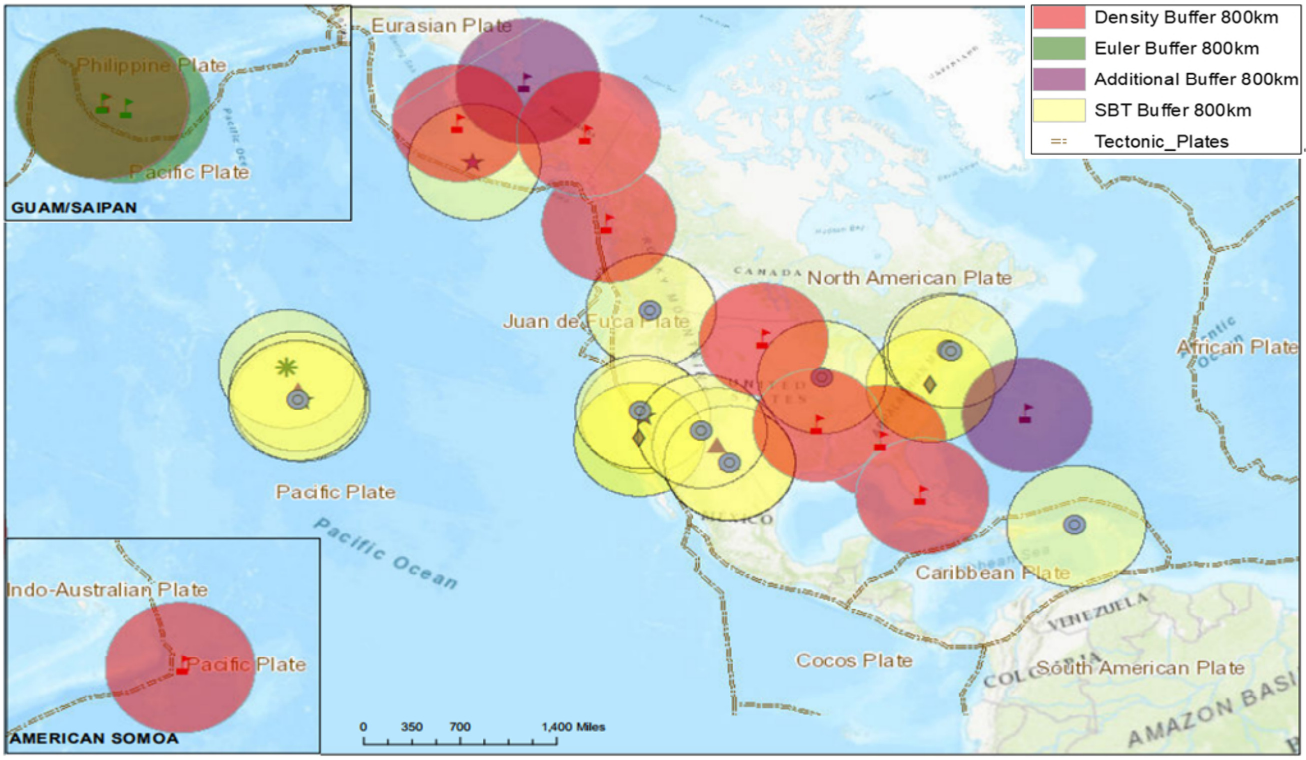


Figure 15

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APPENDIX

Executive Summary

NOAA Technical Report NOS NGS 67

Blueprint for 2022, Part 3: Working in the Modernized NSRS

In year 2022, the National Spatial Reference System (NSRS) will be modernized. This document addresses how geospatial professionals can expect to work within the newly-modernized NSRS.

At the forefront of these NSRS changes, we will embrace time-dependency, an issue NGS has not completely implemented as of yet. Beginning in 2022, points in the NSRS with defined coordinates will have epochs associated with them, based upon the time actual data were collected at those points. Such coordinates will be known as "Final Discrete" coordinates (if associated with finite timespans of data collection) or "Final Running" coordinates (if associated with continuous data collection). Consequently, passive control will have less reliability than active control, and NGS will treat the NOAA CORS Network as having the definitive, up-to-date coordinates within the NSRS. A change of business will result: both leveling and classical surveys will require Global Navigation Satellite System (GNSS) components to ensure coordinates computed in those surveys are up-to-date and are connected to the NSRS through the NOAA CORS Network.

In order to bridge users into a time-dependent NSRS, NGS will also be estimating, and providing to the public, coordinates on points at five-year reference epochs. While such *estimates* will mimic the current status quo [the 2010.00 epoch of NAD 83(2011), for example], they will not be considered the "definitive" NSRS coordinates. Whereas users will have the option, via an updated OPUS, to take any campaign survey at any date and adjust their surveys to such reference epochs, we at NGS will not do this. Rather, if your survey data is submitted to NGS, we will compute Final Discrete coordinates at the epoch of your survey. Then, in the future, those Final Discrete coordinates will be used to estimate Reference Epoch coordinates.

We will be providing tools to users, under the catch-all name "OPUS," for uploading, processing, analyzing, and submitting survey data of all types, such as: GNSS, RTK (Real Time Kinematic), RTN (Real Time Network), leveling, gravity, or classical. Additionally, OPUS will have tools for ingesting and analyzing continuous data (e.g. GNSS, gravity). The tool will be browser-based and will fully integrate all data types, whereby a single project, containing both GNSS and leveling could be uploaded and processed under the same project name. Users processing their data in OPUS will always receive "Preliminary" coordinates from OPUS. We hope to encourage users to submit that data so that NGS can provide quality control, internal national processing, and creation of Final Discrete coordinates from their data. Only data submitted to NGS will make it into the NSRS database and be processed and re-distributed to the public using an updated Data Delivery System, previously known as "datasheets."

Please find this entire report here:
https://geodesy.noaa.gov/PUBS_LIB/NOAA_TR_NOS_NGS_0067.pdf

Terminology Guide

Throughout this document, many of the following terms are used. For purposes of definition consistency, we shall adhere to the usages found in this guide. Readers are strongly encouraged to familiarize themselves with the definitions described below before reading the remainder of the document. Additionally, these terms are defined in consideration of their *geodetic* usage, not within their *broader* usage within the English language.

Antenna Reference Point (or ARP): The antenna reference point (ARP) is the **point** on a GNSS antenna from where antenna calibration values are referenced. The **ARP** is preferably, but not always, an easily accessible **point** on the plane that contains the antenna's lowest non-removable horizontal surface. The ARP could be physically identifiable on that (above-mentioned) surface of the antenna; or it may be the center of a mounting axis, and thus co-planar with that surface, without being on the surface itself. The **ARP** can, but is not required to, coincide (in space) with the geometric reference point (**GRP)** when the antenna is mounted as part of a **CORS.** For this reason, NGS has for decades erroneously described the coordinates at a **CORS** as referring to the **ARP,** and not the **GRP,** a practice we ceased in 2019. Note that the **ARP** is a **point** that is part of an antenna, but it is *not* a point on a **mark.** Therefore, a **CORS** only has an **ARP** at those times when an antenna is mounted at it, whereas a **CORS** always has a **GRP.**

Bluebooking: A phrase used to describe how geodetic survey data were formatted and submitted to NGS using *Input Formats and Specifications of the National Geodetic Survey Data Base* (FGCS, 2016) so they could be checked and included in the National Geodetic Survey's Integrated Database **(NGS IDB).** The term **Bluebooking** was derived from the original document that had been distributed with a blue cover.

Continuously Operating Reference Station (CORS): A **station,** composed of a variety of equipment, but usually including at least one **mark** (containing one **geometric reference point,** or **GRP),** as well as a GNSS antenna and receiver, as well as some source of power and communications. The purpose of a CORS is to continuously collect and distribute GNSS data so as to monitor the coordinates of the **GRP.** The term **CORS,** however, has grown to acquire a general use worldwide, therefore, there is no guarantee a station being referred to as a **CORS** is actually part of **the NOAA CORS Network** (plural: CORSs).

Also referred to as: *Continuously Operating GPS Reference Station, Continuously Operating GNSS Reference Station, Active Control Station*

Coordinate Function: A set of three piecewise continuous functions (one for each of the X, Y or Z coordinates with respect to time), fit to the daily or weekly coordinates implied by analyzing daily or weekly data collected at a **CORS.** Serves as the official time-dependent NSRS coordinates of the **GRP** of each **CORS.** Specific to **CORS** only, the coordinate function is identical to Final Running Coordinates (see Section 2.5).

Geometric Reference Point (or GRP): A unique **point** that is part of a particular **station.** The **GRP** is the **point** to which any coordinates of the **station** refer. The operator of each **station** identifies the **GRP** of that **station.** The GRP is sometimes independent of equipment, such when it is contained within a **mark** at a **CORS** (and thus it exists even when the antenna is removed). In other cases, such as with very long baseline interferometry (VLBI) and satellite laser ranging (SLR), the GRP is a **point** in space defined by the motion of the telescope, typically the intersection of the azimuth axis with the common perpendicular of the azimuth and elevation axis, and thus it only exists when that particular set of equipment is at that **station.**

Local Site Survey: A survey—often consisting of GNSS, leveling, and classical observations using survey-grade instruments—at one **site.** High-precision local tie vectors are determined between the **site marker** and the **geometric reference points** of co-located space geodetic technique (SGT) **stations** on that **site** so as to contribute to realizations of the International Terrestrial Reference Frame (ITRF).

GPS Month: Four consecutive GPS weeks, with the first week in the **GPS month** having a GPS week number that is a multiple of four. Thus, **GPS month** 'zero' is the consecutive period spanning GPS weeks zero, one, two, and three; **GPS month** 'one' is the consecutive period spanning GPS weeks four, five, six, and seven, etc.

Mark (or Marker): A physical structure of varying size or construction, attached to Earth's crust in some way that is presumed to be stable throughout years (or decades) and whose function is to contain a single, unique, identifiable **point** in a stable location. Such **points** are often a small divot or cross on the top of the **mark** (though even the smallest divot is not zero-dimensional, so for highest accuracy, one must clearly identify which part of the divot is the **point.** For example, the **point** on the **mark** might be the bottom of such a conical divot). Common forms of a **mark** include:

> A metal (often brass or aluminum) disk (often about 3 inches in diameter but varying from 0.5 inches to more than 12) with a stem underneath which keeps it mounted in stone, masonry or concrete.
>
> A metal rod (usually 1-2 centimeters in diameter) driven into the ground and rounded on the top.

When NGS refers to the "coordinates of a **mark,"** we are referring to "the coordinates of the **point** on the **mark."**[2]

Also called: *Bench Mark, Control Mark(er), Disk, Geodetic Control Mark(er), Monument, Passive Mark(er), Physical Mark(er), Rod, Survey Mark(er)*
See Figure 1 below.

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[2] To that end, NGS plans to change our official policy (from an unofficial practice that has been in place for approximately 10 years) that all surveying to a mark, and all coordinates of a mark, should refer to one uniquely identifiable point on that mark. The policy will be necessary to

NGS IDB (or IDB): The National Geodetic Survey Integrated Database. Prior to the modernization of the NSRS, the NGS IDB was the definitive storage place for all NSRS data. Datasheets were generated only from this database. It was “Integrated,” because two separate databases (one for horizontal and one for vertical) were combined into the **NGS IDB** in the 1990s.

The NOAA CORS Network: The name of the collection of **CORSs** whose data are collected and processed by the National Geodetic Survey. Note that many other countries and agencies around the world refer to their individual **stations** as being **CORSs.** This generic use of the term **CORS** does not, however, mean their **stations** are in **the NOAA CORS Network.**

NSRS Database (or NSRS DB): The official database built to house the modernized NSRS. Some information from the **NGS IDB** will be converted directly into the **NSRS DB.** For example, the Permanent Identifier **(PID),** of a **mark.** Other information, such as coordinates, will be re-computed from raw measurements using the modernized NSRS as their foundation.

PID: Abbreviation for ‘Permanent Identifier,’ the unique six-character alphanumeric code assigned to each **point** included in the **NGS IDB** or **NSRS DB** and residing on a **mark.**[3]

Point: A zero-dimensional location. Two **points** cannot exist in the same space at the same time. A **point** might be physically “touchable” (such as the bottom of a small conical divot on top of a **mark)** or it may not be (such as the location of an airborne gravimeter’s sensor at any given moment during a flight). *See Figure 1 below.*

Redundancy: Taking the same measurement more than once, where each measurement is taken separately and independently of the other. Strictly speaking, this is impossible, as anything measurable in the universe changes to some degree or another from one moment to the next. However, in the context of this document, **redundancy** will generally mean “collecting GNSS data at a **point** during two different occupations within the same **GPS month.”**

Site: The smallest civil location name of the area where (one or more) **stations** are located. (Legal, i.e., recognizable by deed; national- or state-recognized city, town, village, or hamlet; or geographic feature). Multiple **stations** can be on one **site.** (Example: “MacDill Air Force Base” is a **site,** and it happens to contain two **stations,** which are the **CORSs** known as MCD5 and MCD6). *See Figure 1 below.*

Site Mark(er): A single, unique **mark,** installed one per **site.** All vectors from the **geometric reference points** of every **station** on that **site** are tied to that single mark within a **local site survey.** Note that **local site surveys** often use *many* **marks,** and all may be located at a **site** (for the purpose of **redundancy** and to provide a backup of the **site marker),** but only one can be (and must be) designated as the **site marker.** *See Figure 1 below.*

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undo the official policy from the NOAA leveling manual (Schomaker and Berry, 2001) that states, “Place the rod so that the exact center of the base plate rests on the highest point of the turning point or control marker.” Such a practice meant that, on any sort of tilted mark, the “highest point” might not be the same as the point at the center of the disk to which, say, a classical or GNSS survey might refer. Furthermore, as “depth of dimple” becomes an issue (particularly with using pointed fixed-height poles in GNSS surveys), the unique point of any given mark may need to be identified as the bottom of the dimple (or cross mark).

Station: A collection of equipment located at one **site** to collect one specific type of data for a particular geodetic purpose. Within the geodetic community there are many types of **stations,** and most common are:

Continuously Operating GNSS Reference Station (**CORS)**

Satellite Laser Ranging (SLR) Station

Very Long Baseline Interferometry (VLBI) Station

Doppler Orbitography and Radiopositioning Integrated by Satellite DORIS) Station

Continuously Operating Relative Gravimeter Station

Two or more **stations** located on the same **site** may share some pieces of common equipment, but at least one unique thing should distinguish one **station** from another. *See Figure 1 below.*

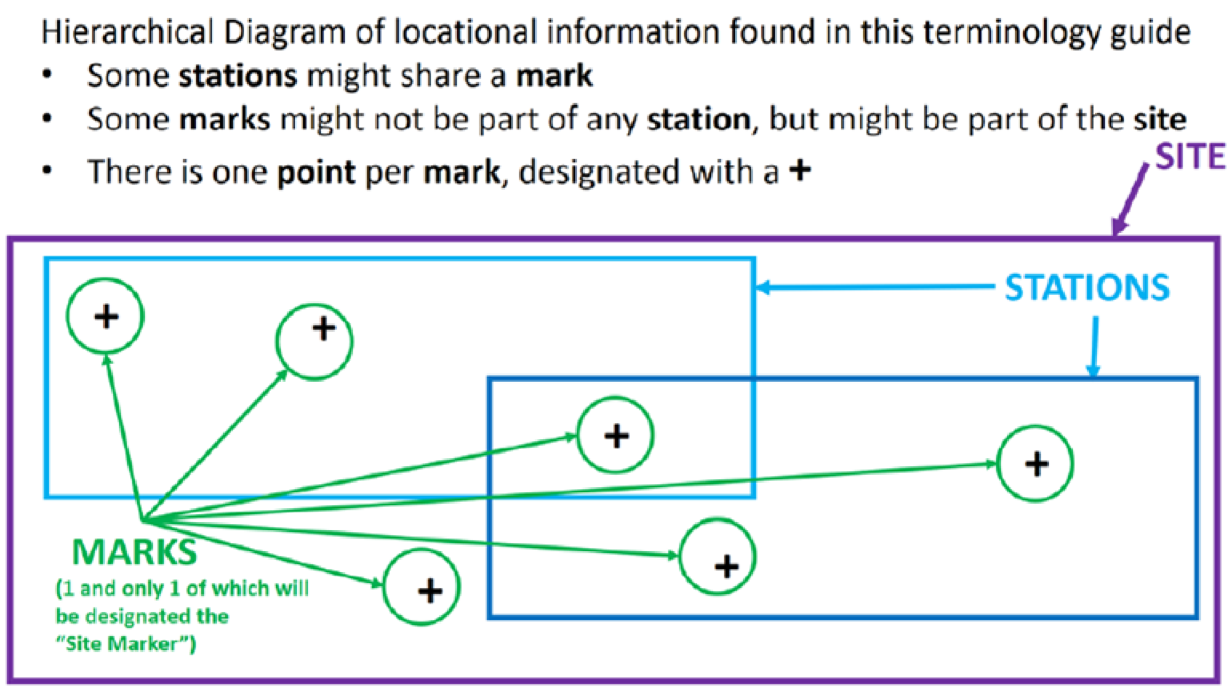

Figure 1: Site, Station, Mark, Site Marker, and Point Hierarchy

[3]Recall, **points** exist in the **NSRS DB** that are not on **marks,** such as the **points** an airborne gravimeter's sensor may have occupied during a flight. As each **mark** should hold only one unique **point,** the **PID** of a **point** may equally be considered to be the **PID** of the **mark** upon which that **point** resides.