National Height Modernization Strategic Plan
NOAA's National Geodetic Survey (NGS)
November 2012

Contents

Executive Summary

The National Height Modernization Program (NHMP) will help ensure federal, state, and public users have access to accurate heights to meet their geospatial or planning needs. Activities supporting this objective will be designed in a way that also prepares users to transition to and then use the new vertical datum, defined through a geopotential field. To attain this vision, NGS will help maintain the local users' ability to access the National Spatial Reference System (NSRS) while also finding ways to address any gaps in NSRS. Filling gaps, whether geographic, systemic, or temporal, will help maintain access to the vertical component of NSRS over time, and facilitate the transition to the new geopotential datum. Augmenting the technical capacity of local users to access the NSRS is also critical to success of this program. This strategic plan will build on mission critical activities in the current NGS Ten Year Plan (2013) and leverage partnerships that have grown from Height Modernization activities.

Background and Justification

NOAA's National Geodetic Survey (NGS) has grown out of a 200-year old requirement to provide the nation with geodetic positioning services. This set of capabilities was developed initially to serve cartographers and surveyors of the nation's coasts and waters and expanded across the continent as the nation grew. The advent of Global Navigation Satellite System (GNSS) technology revolutionized the surveying industry and introduced a new avenue for improving the NSRS. Today, NGS uses GNSS to provide a common reference system for geodetic positioning and many other geospatial applications.

During the 1980's and 1990's, there were considerable indications that the utilization of advances in GNSS technology could achieve significant efficiencies and cost savings. In 1998, the U.S. Congress directed NGS to determine the effectiveness of using GNSS techniques (at that time limited to Global Positioning System (GPS)) to establish accurate heights in California and North Carolina, and the ensuing National Height Modernization Study officially documented the needs and benefits of accurate heights. The Height Modernization Program was developed with the goal to provide access to reliable heights consistently throughout the Nation through the use of GNSS technology together with traditional surveying techniques and other gravity and remote sensing data. Since the 1998 Report, the Height Modernization Program has been funded at varying levels with most appropriations received by academic institutions or state and local governments.

Context

The NGS mission is to define, maintain and provide access to the NSRS to meet our nation's economic, social, and environmental needs, and the National Height Modernization Program (NHMP) primarily supports the vertical component of the NSRS. The goals of the program are (1) providing access nationally to accurate, reliable heights, (2) creating standards that are consistent across the nation, (3) ensuring that data, technology, and tools yield consistent

results regardless of terrain and circumstances, and (4) creating a system/process that will stand the test of time.

The Height Modernization Plan parallels the NGS Ten-Year Plan and is complementary to the goals, objectives, and strategies described in that document. Both plans' first two goals focus on maintaining current products and services, then taking actions to modernize the NSRS. The NHMP's plan necessarily focuses on the vertical component of the NSRS and its associated datums. **The official vertical datum for the Conterminous United States is the North American Vertical Datum of 1988 (NAVD 88), but U.S. territories have their own official vertical datum (e.g. Puerto Rico Vertical Datum of 2002 or PRVD 02). Therefore, when NAVD 88 is referenced in this plan, it implies the inclusion of the other NGS defined local vertical datums.**

The parallels continue as both plans include objectives regarding stakeholders, a strong internal workforce, and the need for enterprise or organizational capacity. However, some focus areas from the NGS Ten Year Plan are not directly applicable (e.g. Aeronautical Survey Program) to the NHMP, so they may not be addressed within this document. A summary of the cross-cutting nature of is included in the appendix.

National Height Modernization Program Strategic Plan

Vision: Accurate heights now and into the future.
It is critical to ensure users have cost-effective and efficient access to accurate heights across the nation. The standards, data, technology, and tools used shall yield reliable results regardless of terrain or other circumstances. Finally, the system established to measure accurate heights must be maintainable over time.

Goal 1: Support Users of North American Vertical Datum of 1988 (NAVD 88)

Supporting users of NAVD 88 includes all the challenges of the traditional passive control network, geodetic leveling, and network adjustments. It also includes the development of the hybrid geoid which encompasses gravity data collection and GNSS on bench marks. Furthermore, there is the need for accurate orbits, CORS, and accurate ellipsoid heights defined according to the most recent realization of NAD 83.

Objective 1.1: Maintain ability to publish accurate (2-5 cm or better) NAVD 88 orthometric heights within six weeks of receipt of new data.

Users need access to vertical control, and NGS maintains the largest geodetic database available. NGS uniquely accepts, adjusts, and stewards data from any outside user provided the data meets pre-defined criteria. This entire system, from acceptance of data to the maintenance of a publically available database is critical to continue supporting NAVD 88 users.

Strategy 1.1.1: Continue accepting observations into NGS operated databases (e.g. through bluebooking and OPUS).

NGS will continue to accept leveling and GNSS projects, but the processes and tools currently in place will continue to be improved, updated or replaced (e.g. LOCUS and OPUS Projects). With updated and streamlined methods to “bluebook” survey data, the user community will be better able to provide the observations that will enhance the NSRS and improve products such as geoid and crustal motion models.

Action(s)

- Update ADJUST software
- Update leveling adjustment software and process
- Implement Project Tracking software for GNSS projects
- Divert resources to mitigate growth of a backlog

Strategy 1.1.2: Continue publishing geodetic control data (e.g. through datasheets).

The maintenance and improvement of the NGS databases (e.g. NGS-IDB and OPUS-DB) will ensure users have access to accurate NAVD 88 heights. Policies regarding publication of heights over time, positional accuracy, and superseded values will also be finalized and reflected on published datasheets.

Action(s)

- Determine publication policy in dynamic regions
- Determine publication of marks with published positions in both NGS-IDB and OPUS-DB
- Improve publication options in OPUS-DB for marks with multiple published observations

Strategy 1.1.3: Maintain online tools used to establish, analyze, or transform heights. (e.g. OPUS, LOCUS, VERTCON, VDatum).

NGS will maintain and improve existing tools (e.g. OPUS, LOCUS, VERTCON, VDatum) and develop new tools to assist local users to process and analyze independently collected observations. These tools will ensure the data, and thus the NSRS, retains a high level of integrity.

Action(s)

- Evaluate existing tools and models for accessing the NSRS and identify tools that are obsolete, need to be updated, or need to be newly developed.
- Conduct formal needs assessments with stakeholders at least once every three years to ensure user needs are being met.
- At least once every five years, review products, software applications, and tools that are used more than 100,000 times each year for their effectiveness.
- Improve transformation tools (e.g. VERTCON), especially at the shoreline (e.g. VDatum). This includes providing transformations within 60 days of the release of new realizations of the national datums, as appropriate.

Objective 1.2: Maintain user capability to establish NAVD 88 heights.

Access to a database alone does not truly satisfy access to the NSRS because it may not allow users to adequately extrapolate or establish heights where there is a new local need. Some minimal infrastructure is required, but it will not all be replaced or maintained (e.g. reliance on passive control will ultimately decline). An accurate and up-to-date inventory of gaps, with their significance to local needs and applications, will facilitate wise investment in field

operations or installation of infrastructure. Immediate benefits include improved access to the infrastructure and additional data for geoid models. Future benefits will be improvements in users' ability to transition to the new datum, e.g. through improved transformation models.

Strategy 1.2.1: Enable access to NAVD 88 control data at a minimum of 2-4 cm accuracy

Whether through geodetic observations at passive control marks, or use of an accurate geoid model, users need an infrastructure in place that will allow them to establish NAVD 88 heights where they need them. NGS will ensure users have the most up-to-date information available to make smart investments to enhance the NSRS in a manner that supports greater access to NAVD 88 heights.

Action(s)

- Evaluate strengths and weaknesses of NSRS by inventorying areas where datasheets do not provide recently validated control and/or OPUS (in conjunction with the current geoid model) does not provide results with the required accuracy.
- Develop a methodology for prioritizing the significance of identified gaps as physical infrastructure fails, becomes outdated, or is destroyed over time.
- Recommend actions (e.g. completing leveling or GNSS surveys to update control; accounting for local velocities when using outdated control) the local user community can take in areas where vertical control is sparse and/or unreliable due to movement.
- Update and improve consistency of mechanisms to contact NGS to propose coordinated projects, initiate pilot projects, and request training.

Strategy 1.2.2: Maintain field operational capacity (e.g. Height Modernization surveys, Ecosystem and Climate Operations surveys, or terrestrial Lidar surveys)

NGS will perform select survey projects to retain capacity for surveying and field work while simultaneously providing new data for NGS to improve models and transformation tools. NGS will prioritize projects when they support multiple objectives, such as research activities (e.g. geoid slope validation surveys), and investigating new technologies. When funds are available, these projects will only be performed by NGS after determining what types of survey projects should be pursued (i.e. leveling, GNSS, gravity, ties to tide gages, remote sensing), costs to complete field work and data analysis, and benefits to the user community. Coordination with other state or federal agencies will promote efficiencies and facilitate in kind support or funds transfer when additional labor is required.

Action(s):

- Identify projects to fill gaps as pilot projects, opportunities to reduce error associated with models / tools (e.g. geoid, OPUS, VERTCON), and research opportunities to validate / update specifications or guidelines.
- Coordinate and select projects with other federal and state mapping agencies that also must create geospatial positioning or monitoring products (e.g. U.S. Geologic Survey, state departments of transportation) that supports research, procedure testing, and other pilot project goals
- Identify users whose products or services depend on the NSRS for their geospatial requirements (i.e. accuracy) and determine the impact adopting the new geopotential datum will have on their products or services.

Goal 2: Modernize and Improve the Vertical Component of the NSRS (i.e. replace NAVD 88)

Modernizing the vertical datum will ultimately replace both NAD 83 and NAVD 88 with a true 4-dimensional geopotential field. The vertical datum will be accessed through GNSS and an accurate geoid model rather than through publication of heights on passive geodetic bench marks. Furthermore, NGS must develop a comprehensive strategy for incorporating past and future leveling data into a GNSS/geoid based vertical datum, and provide this guidance to NGS stakeholders.

Objective. 2.1: By 2022, transition from passive control to active control as primary means to access vertical datum.

While the increased availability and access to GNSS technology has already and will continue to greatly change the surveying industry, the new definition of the vertical datum will be an even more significant change. All precautions and due diligence must be followed to ensure that user needs are still being met to the same level or better with the new datum as was the case with NAVD 88.

Strategy 2.1.1: Establish infrastructure as necessary (e.g. passive or active control) and improve mechanisms available (e.g. OPUS, PPP, RTNs) for access to highly accurate ellipsoid heights (i.e. 1 cm when using 15 minutes GNSS data).

Although now relying on the use of an accurate geoid model rather than passive control to define the reference frame, users still need an infrastructure in place that will allow them to establish accurate elevations where they need them. NGS will ensure access across the NSRS is adequate to establish accurate ellipsoid heights.

Action(s):

- Identify any gaps within a land area, political boundary, or geographic region where the infrastructure of the NSRS is not adequate to establish accurate ellipsoid heights.
- Recommend whether or not survey projects should be performed based on estimates of costs to complete any field work, and benefits to users.
- Identify partnerships that can be leveraged at the federal and local level.
- Prioritize when surveys can be planned and completed within the subsequent 1-5 year project planning cycle after a gap has been identified.

Strategy 2.1.2: Improve gravimetric geoids to reduce all definitional and access-related errors in orthometric heights in the geopotential reference frame to two cm using 15 minutes of GNSS data.

The successful transition to the new vertical datum hinges on a highly accurate gravimetric geoid model. NGS will continue to develop accurate geoid models validated by gravity data, GNSS and leveling observations. To augment satellite and terrestrial gravity data, airborne gravity data will be collected through the Gravity for the Redefinition of the American Vertical Datum (GRAV-D). NGS will also engage in a variety of testing methods to determine the actual achievable accuracy of a gravimetric geoid model, before the gravimetric geoid serves as the reference surface for the new vertical datum.

Action(s):

- Complete aero-gravity surveys as determined by the GRAV-D Project Manager and meeting the Government performance Results Act (GPRA) measure.
- Complete at least 2-3 Geoid Slope Validation Surveys in the next 6-8 years.
- Release interim gravimetric geoid models with new airborne gravity data

Strategy 2.1.3: Establish process for maintaining accurate heights in dynamic areas by monitoring vertical motion to update geoid model.

NGS will develop a consistent approach to continue validating vertical control during the years preceding the adoption of the new datum. In developing or dynamic regions of the country where annual land movement can exceed 5 mm, ensuring access to accurate data may also require the establishment of new vertical geodetic control. Where it is not possible to update the control, NGS can provide metadata to quantify the reliability of the published values. Changes being considered include applying or providing velocities (e.g. Vertical Time Dependent Positioning or VTDP), updating accuracy statements, and providing epoch tags.

Action(s):

- Update publication of control marks in the NGS database(s) using methodologies currently being developed for publication of geodetic control along the coast of the Gulf of Mexico; Harris-Galveston, Texas; and regions of uplift, such as Wisconsin.
- Support collection of geodetic data to contribute to transformations, motion models to update the vertical control network in areas where vertical control is sparse and/or unreliable due to movement.

Strategy 2.1.4: Update guidelines and specifications to ensure they account for advances in technology (e.g. as GNSS improves).

NGS will review and revise specifications and guidelines for acquiring heights using GNSS. NGS will work with existing and new users of the NSRS to develop or improve procedures for GNSS positioning that are specific to their applications, or where special circumstances (e.g. weak infrastructure) mean stricter procedures must be followed. NGS will also assist with updating specifications for stakeholders who still require use of leveling technology to establish heights. Often testing will be required before the updated procedures can be established; however, revised procedures will be distributed in a timely manner after experiments are completed (i.e. no greater than one year for review and approval).

Action(s):

- Digitize within two years any documents deemed to still be relevant and valuable that currently have no digital copy.
- Identify standards and specifications needed for users to access the NSRS, and determine what standards need to be retired, updated, or newly developed.
- Update and/or combine NGS 58 and NGS 59.
- Develop guidelines for new remote sensing technologies.
- Generate / update specifications and guidelines for users to follow based on the completion and conclusions from pilot projects.

Objective. 2.2: Modernize methods for acceptance and publication of elevation data so that external users, with the appropriate training and technical capacity, are the primary data collectors.

The amount of field surveys and primary data collection by NGS has declined over the past decades, and fortunately the dedicated user base has filled in data gaps by diligently sending data into the NGS databases. However, some areas of the country have significantly less user contributed data than others. Streamlining and simplifying the process of accepting data will help successfully implement this new paradigm that relies on external users as primary data

collectors, and the improvements may especially encourage users in areas where past data submission has been sparse.

Strategy 2.2.1: Modernize and/or replace processing software for GNSS and leveling

NGS will complete comparison between current rigorous "bluebooking" process and the new OPUS Projects application. NGS will offer OPUS Projects as an alternative to using ADJUST. NGS will provide hands-on workshops in use of OPUS Projects.

Action(s)

- Compare PAGES/ADJUST to OPUS Projects.
- Enhance functionality of LOCUS.
- NGS will provide hands-on workshops in use of OPUS Projects.

Strategy 2.2.2: Automate submission of GNSS and leveling projects with project tracking software.

NGS will continue to rely on outside users to contribute data to its databases. Reducing effort required and increasing the transparency of the process will encourage more users to submit their work to NGS. The submitters also benefit from sharing their data as NGS monitors its quality and maintains the data records into perpetuity.

Action(s)

- Integrate GNSS project tracking with OPUS-Projects.
- Develop and implement leveling project tracking software.

Strategy 2.2.3: Make transformations available for VDatum and VERTCON (or equivalent) from current vertical to new geopotential datum.

NGS will provide transformation tools between the new datum and NAVD 88 based predominantly on measurements of GNSS derived ellipsoid heights on NAVD 88 bench marks. Coordination with Center for Operational Oceanographic Products and Services (CO-OPS) and the Office of Coast Survey (OCS), together with the use of remote sensing techniques will ensure tools like VDatum accurately reflect the relationships between geodetic and water level datums in areas where land and water meet.

Action(s)

- Update all NGVD 29 heights to NAVD 88 when possible.
- Continue implementing VDatum project plan.
- Compute and publish accuracies for transformation tools.

Strategy 2.2.4: Transition to Oracle database and enable a fully geo-referenced database.

NGS will accept survey data for as long as local users wish to submit it to strengthen the vertical geodetic control network. The modernization of the NGS databases (e.g. NGS-IDB and OPUS-DB) will ensure users have easy access to the most accurate positions that have already been established as well as improving the ease with which NGS accepts and stores survey data, and delivers geodetic control to the public.

Action(s)

- NGS will publish control data and data products in other formats, such as GIS shapefiles or mapping applications, and for other media, such as smart phone applications.

Goal 3: Increase technical capacity and coordination across outside users and NGS workforce to support the National Height Modernization Program (NHMP)

NGS has enjoyed a strong user base throughout its history, and the agency has continued to rely more and more on its users. Additionally, the increased availability of high accuracy elevations through the advent of new technology has expanded the users of NGS products and services to sectors far beyond the traditional surveying community. To best serve all of these communities, NGS needs to commit to making sure information and training are well developed and accessible to the public.

Objective. 3.1: Expand the NGS stakeholder base through partnerships, education, and outreach

As technology allows users to complete more geodetic positioning work themselves, NGS needs to modify how it educates users on their private data's relationship with the NSRS. Additionally, it is in NGS' best interest to have a strong and knowledgeable user base, and the knowledge these partners have can be greatly augmented through training and outreach efforts.

Strategy 3.1.1: Determine alignment of real time GNSS network (RTN) alignment with the NSRS.

NGS recognizes that, within the user community, the demand for accurate positioning in real time will only increase. With improved technology and stronger infrastructure the

ability to determine accurate heights with real time networks will improve. NGS will work with the user community to ensure results derived from these networks are reliable and consistent with the NSRS, and thus with each other.

Action(s):

- Determine or quantify how real time GNSS network (RTN) stations agree with the NSRS.
- Provide a tool for RTN operators to determine the alignment of their reference stations to the NSRS.
- Hold RTN Symposium by January 2014.

Strategy 3.1.2: Increase educational resources for NGS products and services including in person training at Corbin Training Center, webinars, and other training videos

NGS will present workshops to keep users informed of the reason for and progress of the Ten-year Plan, proactively reaching out to every state at least once before adoption of the new datums. NGS will provide training to users of the NSRS in use of existing and new products, tools, and models to independently collect, process, and analyze data to determine accurate elevations. The content of training will depend upon both the skill being taught and the experience of the trainees. Some training for field work will be administered in person (4 workshops or 60 people / year); however, when possible all training programs will take advantage of improvements in remote-learning technologies, such as webinars (allowing for 4 trainings or 1000 people /year). NGS Corbin Training Center has the resources and experience to continue to augment training opportunities in support of Height Modernization and the new geopotential datum.

Action(s):

- Modify workshops to target the needs of new users who have benefitted from increased access to precise positioning due to the relative availability and affordability of GNSS technology.
- Sponsor training opportunities at other organizations' events or conferences (at least 10 / year, with the assistance of the regional advisors) provides an opportunity to reach new audiences at a relatively low-cost.
- Develop web video modules to explain use of NGS products and services, such as datasheets and interactive processing applications.
- Develop outreach materials including training manuals, exhibit hand out materials, display materials, and web content ranging from NGS progress reports to technical guidance and instruction.

Strategy 3.1.3: Maintain and expand the strong partnership relationships that the National Height Modernization Program has developed since the 1990s as a means to maintain open communication and facilitate collaboration. This strategy greatly relies on funding availability.

Action(s)

- Host annual National Height Modernization Partner meetings, either face-to-face or via teleconference.
- Provide research, education, or operational grants to continue fostering partnerships at state agencies and universities.
- Encourage and support for the expansion of a regional governance model, facilitating the exchange of best practices among states facing similar challenges regarding vertical control.
- Support Spatial Reference Centers as a means for regional partners to coordinate and steward data and information.

Objective. 3.2: Develop a workforce skilled in vertical control

To remain a world leader in geodesy, NGS must invest in developing and retaining a highly skilled workforce. Geospatial positioning, especially with respect to the vertical, and geodesy are highly technical areas of expertise; as a result, training and institutional knowledge are necessary and invaluable.

Strategy 3.2.1: Educate workforce at Corbin trainings, on the job during pilot projects or large scale research projects, and with partnering academic institutions

NGS's Corbin training facility will continue to hold onsite or remote-learning workshops to train users in field and processing techniques. Workshops will be modified to incorporate new or updated tools and guidelines. Additionally, large scale field surveys performed by NGS for research or to develop or test new guidelines (e.g. geoid slope validation surveys, revisions to update NGS 58 and 59) will be opportunities to mentor new or inexperienced employees in project planning, writing project instructions, field work, or data processing.

Action(s)

- Provide training for NGS employees who wish to become trainers of NGS products and services.
- Train employees in use of Microsoft Office and other presentation development tools, and in developing speaking skills.
- Train employees in geospatial and mapping software including GIS.

- Ensure inexperienced field staff assist experience field staff for any projects completed (when funds available).
- Ensure less experienced NGS trainers have the opportunity to teach and present to enjoy the side benefit of better understanding of the presented material, whether the material is technical or programmatic.

Strategy 3.2.2: Leverage partnerships at universities to excite young minds to enter geodesy and/or government service.

As funding permits, NGS will award grant funds for geodetic research that supports NGS' mission and the activities outlined in its Ten-year Plan, including a requirement to publish results of that research.

Action(s)

- Engage universities to complete research, publish papers, and use as a training resource for public users and NGS workforce.
- NGS will Award research grants or apply for collaborative research grants to test, refine and document any new or modified standards and specifications (e.g. through Height Modernization appropriations).
- NGS will work with student experience or internship programs, when available, to further engage new students.

Strategy 3.2.3: Maintain, transfer, and make transparent institutional knowledge through the publishing of papers, reports, and attendance at local conferences

NGS will publish articles describing new technological developments to accelerate the transition from a new or emerging prototype to a widely used tool (i.e. software or hardware). NGS will also publish technical papers to highlight best practices for planning strategies, field and analysis procedures, or any other insight learned from the completion of pilot projects, geoid slope validation surveys, and the release of new tools. Finally, NGS will use publications as a mechanism to document, provide results, and share lessons learned from projects within one year of a completed project and its associated press release. Publishing challenges encountered completing a project can help others in the community work efficiently by avoiding the common mistakes; additionally, it provides an opportunity to share the innovative solutions that resolved problems.

Action(s):

- Publish articles in trade magazines on the NSRS, the status of changes to the Datums, and the use of NGS models and tools.

- Work with other federal agencies to develop articles targeting their users' specific needs, leveraging the Federal Geodetic Control Subcommittee as a coordinating resource.
- Participate in national and local conferences and other training events, through presentations and workshops by proactively contacting traditional and non-traditional users, including other federal agencies.

Objective. 3.3: Improve organizational and administrative functionality of NHMP

As a federal agency, NGS strives to produce the greatest benefit for its users by most effectively using tax dollars to achieve our mission. In order to most effectively use limited resources while still retaining a talented workforce and strong work environment, NGS must manage all its programs as effectively and efficiently as possible.

Strategy 3.3.1: Implement project management protocols, critical for managing a cross-cutting or matrix program

Project management is a tool that NGS must adopt in order to properly plan, budget, execute and evaluate the various projects that have, historically, been performed in an ad hoc fashion. This is particularly important since Height Modernization is a matrix program that cuts across many different divisions and project teams at NGS.

Action(s)

- This strategy will be completed in conjunction with and supporting other actions identified throughout this plan.

Strategy 3.3.2: Increase collaboration and coordination between scientists and IT specialists to improve efficiency of database management and tool development

NGS products and services rely heavily on software development and IT support, so to maximize efficiency different groups across NGS must coordinate and collaborate. This way general surveying needs are met, science remains sound, and IT resources are used efficiently.

Action(s)

- This strategy will be completed in conjunction with and supporting other actions identified throughout this plan.

Strategy 3.3.3: Track and share the socio-economic benefits of the HMOD program.

Given reduced funding across the public sector, it is important to convey to decision makers the value of geospatial infrastructure. The benefits are far reaching and across sectors, so the challenge remains quantifying and communicating the value of NGS products and services.

Action(s)

- Work with stakeholders to document and accurately value benefits and cost-savings from geospatial infrastructure.
- Work with socio-economic experts to document and accurately value benefits and cost-savings from geospatial infrastructure.

Implementation Strategy

Since basic elements of Height Modernization support NGS's vision of a modernized geospatial reference frame, many NGS resources are already focused on activities discussed within this plan. For example, NGS is currently implementing its GRAV-D project, developing a high accuracy geoid model, and developing tools to assist with datum transformations. However, fully executing this Height Modernization plan will require targeting limited resources where they will be most impactful and growing collaborative efforts among partner and/or regional agencies and local users.

Targeting resources

Given fiscal constraints and rising costs, it will continue to be exceptionally important to careful expend resources deliberatively. The first step in making informed investments is to have a clear picture of the existing condition of the NSRS, and an outline of how a group could complete such a task is described below. Additionally, any time that a project can meet more than one need is a win-win scenario. For example pilot projects can meet research needs, build internal field experience, and increase the public's technical capacity.

Workgroup to assess the condition of the NSRS

The Height Modernization Manager will lead a workgroup to assess the condition of the NSRS systematically across the country to see where enhancements may be necessary. The group will consist of NOAA scientists with expertise in the critical components being evaluated, including the passive and active control network, geoid model requirements, NGS gravity data holdings, and the National Water Level Observation Network. "Full time" members will participate as long as the workgroup is operational. The workgroup will solicit input from occasional members whose knowledge of procedures, technologies, and regional concerns make their input critical, including NGS Geodetic

Advisors, federal agencies, partners in state and local government, and academia. Where appropriate, input from the private sector may also be solicited.

- **Overall Process***:* NGS will assess the condition of the NSRS systematically across the country to see where and what kind of enhancements may be necessary to achieve the 2 cm relative accuracy goal. Each year, NGS will evaluate at least 1/5 of the country (either by land area, political boundary, or geographic region). After the entire country has been evaluated, the national scale analysis should be revisited on a biannual basis. Analysis of the NSRS will aim to identify infrastructure gaps with consideration for (1) condition and spacing of passive control having North American Vertical Datum of 1988 (NAVD 88) heights; (2) condition and spacing of terrestrial gravity data; (3) dynamic nature of the region, i.e. velocities evident from knowledge of passive control and from Continuously Operating Reference Stations (CORS); (4) existence of ties between geodetic and tidal datums; (5) topographic relief; (6) population density and growth; and (7) special conditions that impact effective use of technology, e.g. tree cover, extreme weather. NGS will also evaluate how gaps are impacting users' ability to access the NSRS now, and what activities can best facilitate the transition to the new datum.

- **Phase 1***:* A workgroup of experts from NGS and NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) will inventory and evaluate all aspects of the NSRS and related observing systems including: CORS, airborne and terrestrial gravity data, tidal bench marks, geodetic control networks, geoid and movement modeling. This group will include: the Height Modernization Manager, representatives from the CORS team, the GRAV-D team, the geoid model team, Remote Sensing Division (RSD), Geodetic Advisors, and CO-OPS. The workgroup may reach out to users, at the local or regional level, who have particular knowledge of the weaknesses in their infrastructure. This could include previously funded height modernization partners, other federal mapping agencies, and other stakeholders.

- **Phase 2***:* A workgroup of experts from NGS will determine the necessary "condition" and "density" of all aspects of the NSRS and related observing systems that will provide a level of access that meets user needs. Requirements expected to change with the transition to the new datum will be part of this evaluation. This effort may also require testing the most recent observation and analysis procedures and technologies (e.g. additional contributions from Geodetic Research Division [GRD] and Instrumentation and Methodology Branch [IMB]).

Growing collaborations

The following groups, programs, and partnerships are examples of collaborative strategies or mechanisms that will help implement the National Height Modernization Plan.

- **Federal collaboration**

  All federal mapping agencies must use the current vertical national datum as defined by NGS, so ongoing coordination and collaboration are critical to ensure the modernization of the NSRS is implemented effectively and efficiently. For example, federal agencies should not invest in developing duplicative guidelines, products or tools to help with this transition. Additionally, when survey work is being completed by one agency, the benefits could be augmented by levering the resources with ongoing work at another agency. The Federal Geodetic Control Subcommittee (FGCS) Vertical Reference System Workgroup (VRSWG) is one example of one mechanism to facilitate this coordination.

- **Spatial Reference Centers**

  Some of Height Modernization Program partners have formed Spatial Reference Centers (SRC) to accomplish many activities in support of maintaining and providing access to the NSRS. SRCs have had varying levels of success, depending on their funding sources, the structure under which they operate, and the activities in which they engage. Nevertheless, SRCs provide an opportunity to advance Height Modernization efforts from a state to regional to national scale. They may focus on local needs, address local gaps, and contribute local knowledge to the workgroup assessing the condition of the NSRS.

- **Regional "governance" structure**

  NOAA is expanding upon existing regional coordination and communication efforts and shifting towards Regional Collaboration, integrating program activities to address NOAA's priorities and improve NOAA's productivity and value to customers. Similarly, Height Modernization partners across the country are collaborating more, leveraging their resources to have a stronger regional impact. Height Modernization Regions organize and sponsor a variety of activities building infrastructure and reaching stakeholders across state borders.

- **Geodetic advisors**

  The NGS State Geodetic Advisor Program is a program that provides a liaison between NOAA and the host state, usually with a jointly-funded NOAA employee residing in the state to guide and assist the state's geodetic and surveying programs. NGS also fosters a State Geodetic Coordinator Program wherein a federal, state, or local government agency or academic institution located within a participating state designates an employee to be its State Geodetic Coordinator, acting as a liaison between the state and NGS.

Monitoring and Measuring Success

The NGS Ten-Year Plan includes goals and objectives that directly support the National Height Modernization Strategic Plan, and significant progress must be made each year to establish a new vertical datum by 2022. To fully integrate the National Height Modernization plan with the NGS Ten-Year Plan and other NGS planning and reporting processes, each National Height Modernization Objective must have at least one annual NGS internal milestone associated with it. Evaluation will be based on the progress (ideally completion) of these established milestones.

This National Height Modernization Plan outlines strategies and actions integral to the success of the National Height Modernization Program, but tasks generally are not assigned to specific divisions or positions within this document. The National Height Modernization Program Manager will ensure these actions are incorporated within Implementation Plans (IPs) to be developed in conjunction with the NGS Ten-Year Plan. These IPs will help assign resources and set attainable milestones. Based on the completion of milestones, the National Height Modernization Program Manager will systematically monitor and evaluate NGS's performance toward the goals, objectives, strategies and actions outlined in this plan, and revise IPs as needed.

Some NGS performance measures, including those required under the Government Performance and Results Act (GPRA), are related to strategies and actions in the NHMP plan and will be reported to leadership on a quarterly or annual basis. GRAV-D, for example, is a critical component of achieving the new vertical datum, and its rate of expected progress will be defined within the context of its associated GPRA measure. Thus, evaluation of GRAV-D will be based on the completion of established targets.

Updating the plan

Several programmatic implementation plans or project plans will directly impact the success of the Height Modernization Program. Whenever a multi-year implementation or project plan with direct ties to the Height Modernization Strategic Plan is approved, the proposed timelines and outcomes should be compared to the objectives within this document. After such a comparison, the Height Modernization Strategic Plan should be updated as needed. Additionally, the plan should be reviewed and re-evaluated in its entirety mid-way between now and the projected completion of the new vertical datum in 2022 (i.e. 2017) and in parallel with any planning documents for the implementation of the new geometric datum.

References

1. National Height Modernization Study < http://www.ngs.noaa.gov/heightmod/1998heightmodstudy.pdf>
2. NGS's Ten-Year Plan <STILL IN DRAFT>
3. GRAV-D Project Plan < http://www.ngs.noaa.gov/GRAV-D/pubs/GRAV-D_v2007_12_19.pdf>

APPENDIX A: Parallel Structure between NGS Ten-Year Plan and National Height Modernization Program (NHMP) Strategic Plan

NGS TEN-YEAR PLAN		PARALLEL GOAL OR OBJECTIVE	NHMP STRATEGIC PLAN	
GOAL 1	Support NSRS users today	Yes	GOAL 1	Support NAVD 88 users today
OBJECTIVES FOR GOAL 1	"Bluebooking and datasheets"	Yes	OBJ 1.1: STRATEGIES 1.1.1; 1.1.2	Publish NAVD 88: Accept Observations; Publish Elevations
	"Shoreline"	NA		
	"Airport Surveys"	NA		
	"Field Operations"	Yes	OBJ 1.2: STRATEGIES 1.2.1; 1.2.2	Maintain access to NAVD 88: Access control data; Maintain field capacity
	"Online Tools"	Yes	OBJ 1.1: STRATEGY 1.1.3	Publish NAVD 88: Maintain online tools
GOAL 2	Modernize and Improve NSRS	Yes	GOAL 2	Modernize and Improve NAVD 88
OBJECTIVES FOR GOAL 2	"Replace NAD 83"	Yes	OBJ 2.1: STRATEGY 2.1.1	Passive Control to active control: Access to ellipsoid heights
	"Replace NAVD 88"	Yes	OBJ 1: STRATEGIES 2.1.2, 2.1.3	Passive Control to active control: Gravimetric geoid; Update in dynamic areas
	"Re-Invent Bluebooking"	Yes	OBJ 2.2: STRATEGIES 2.2.1, 2.2.2	Modernize accepting/publishing: Modernize software; Automate submission
	"Fix the Toolkit"	Yes	OBJ 2.2: STRATEGIES 2.2.3, 2.2.4	Modernize accepting/publishing: Transformations; Databases
	"Better Surveying"	Yes	OBJ 2.1: STRATEGY 2.1.4	Passive Control to active control: Update guidelines and specs
GOALS 3-5	(3) Expand NSRS stakeholder base; (4) Improve workforce; (5) Improve Organizational Functionality	Yes	GOAL 3: OBJECTIVES 3.1, 3.2, 3.3	Increase technical capacity: Expand stakeholder base; Develop skilled workforce; Improve Programmatic functions
OBJECTIVES FOR GOAL 3-5	"Validate RTNs"	Yes	STRATEGY 3.1.1	Determine alignment between RTNs and NSRS
	"Engage New Stakeholders"	Yes	STRATEGY 3.1.3	Build and maintain Height Modernization Partners
	"University Engagement"	Yes		
	"Dynamic Web Presence"	Yes		
	"Educational Portfolio"	Yes	STRATEGY 3.1.2	Increase education resources
	"IOCM"	NA		
	"Educated Workforce"	Yes	STRATEGY 3.2.1	Train workforce
	"Recruiting"	Yes	STRATEGY 3.2.2	Recruit at Universities
	"Institutional Knowledge"	Yes	STRATEGY 3.2.3	Transfer Knowledge
	"Project Management"	Yes	STRATEGY 3.3.1	Project Management
	"I.T. Support"	Yes	STRATEGY 3.3.2	Cross-skill-set-coordination
	"Socio-Economic Awareness"	Yes	STRATEGY 3.3.3	Socio-economic benefits
	"Records Management"	NA		
	"Regional Advisor Program"	NA		