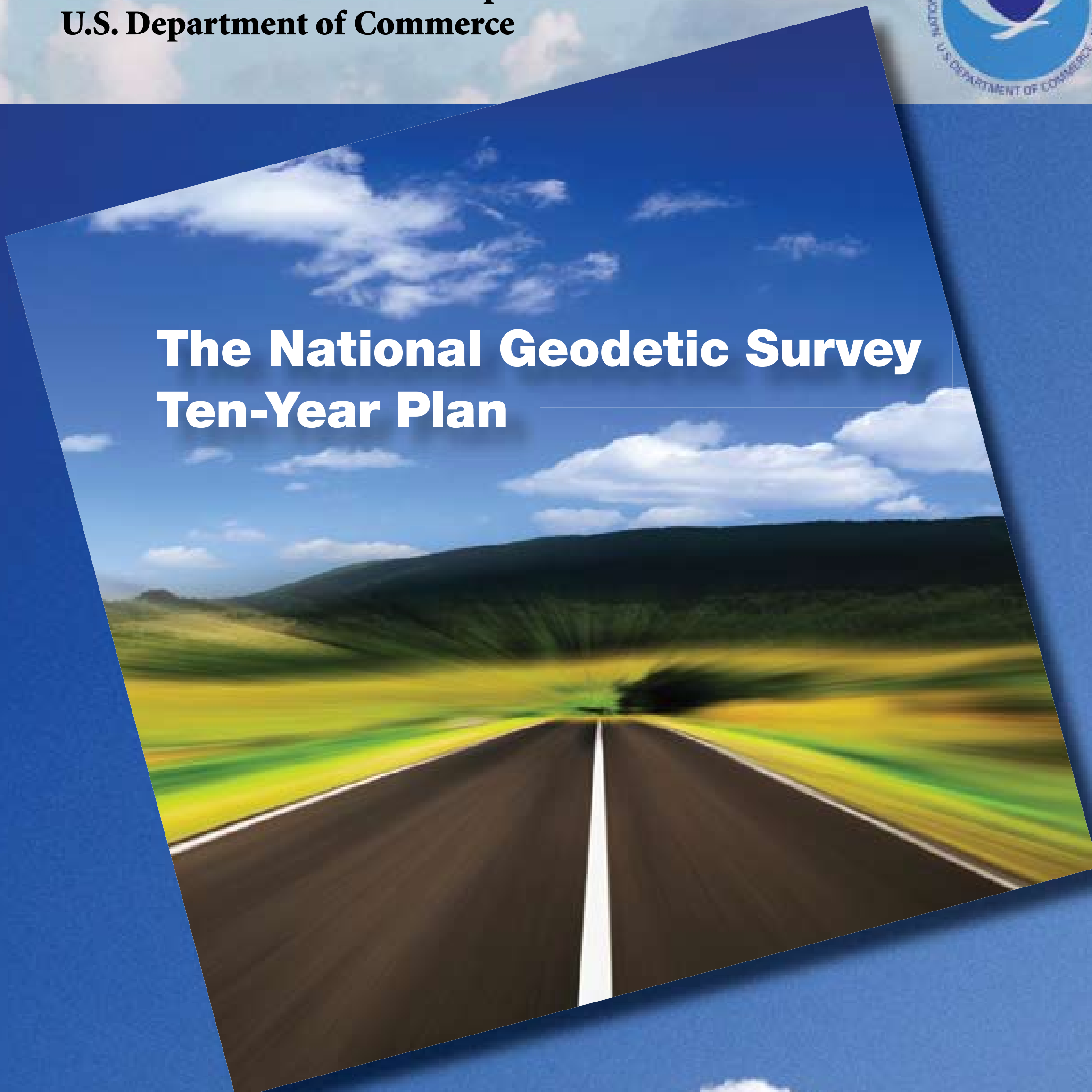
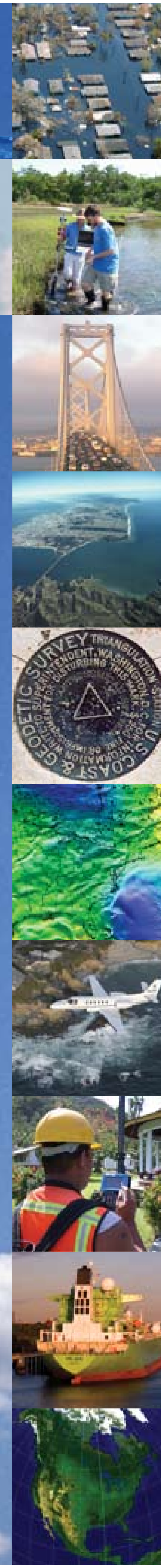
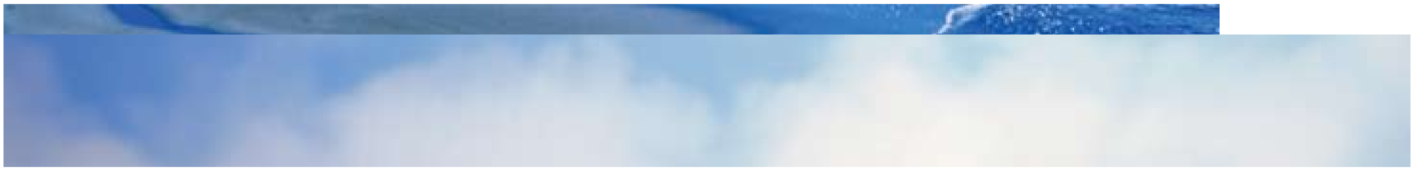
National Oceanic and Atmospheric Administration
U.S. Department of Commerce



The National Geodetic Survey Ten-Year Plan

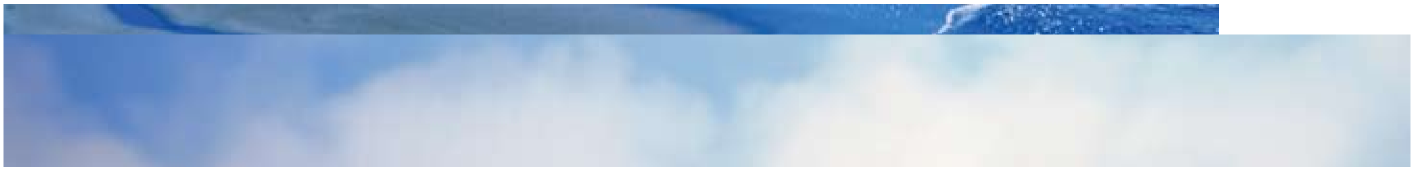
Mission, Vision and Strategy 2008-2018





The National Geodetic Survey Ten-Year Plan

Mission, Vision, and Strategy 2008-2018



Fast is fine, but accuracy is everything.

Wyatt Earp

A witty saying proves nothing.

Voltaire

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Executive Summary

It has been thirteen years since the National Geodetic Survey (NGS) fully examined and stated its mission, vision and strategic goals. Since then, technologies and public needs have changed, though agency mandates have remained mostly unchanged. Therefore, NGS has decided the time has come to revisit this topic and, through almost two years of agency introspection, has refined and restated its *mission* as follows:

1. To define, maintain and provide access to the **National Spatial Reference System (NSRS)** to meet our nation's economic, social, and environmental needs, and
2. To be a world leader in geospatial activities, including the development and promotion of **standards, specifications, and guidelines**.

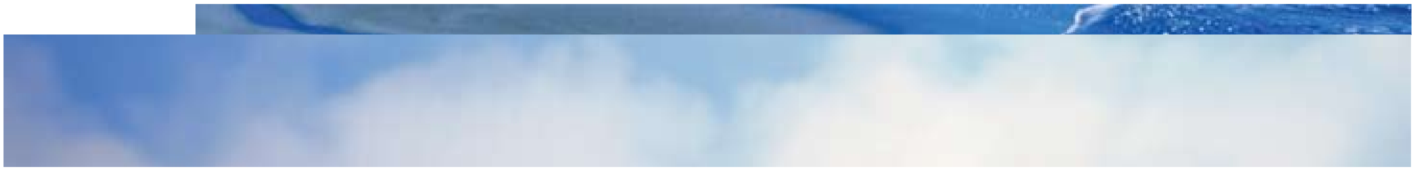
A vision of the future has been laid out wherein NGS modernizes and adapts to perform its mission successfully. Ambitious goals to achieve the mission and to better serve the public good have been defined in the vision. These goals will serve as a directional beacon to NGS over the next ten years.

In order to achieve the vision of the future, *five technical improvements* have been identified. They are:

1. Modernize the geometric ("horizontal") datum
2. Modernize the geopotential ("vertical") datum
3. Migrate the Coastal Mapping Program toward IOCM
4. Evolve Core Capabilities
5. Increase Agency Visibility

Bold initiatives will be required in all of these areas. One common theme for all of them is *change for the better*. NGS will remove systematic deficiencies in both classical datums by re-defining them and adopting the latest technology for maintenance and access. This includes transforming the Continuously Operating Reference Stations (CORS) into a fully Global Navigation Satellite Systems (GNSS)-capable system which serves as the sole *defining* points of the geometric ("horizontal") datum. The geoid modeling efforts will include new theory and data collection at levels not seen at NGS since the NAD 83 and NAVD 88 efforts, leading to a new definition and realization of the geopotential ("vertical") datum based on CORS and a gravimetric geoid, rather than passive benchmarks. Time dependencies will be both acknowledged and tracked in all components of the NSRS, from the shoreline to the gravity field, from heights to latitude and longitude. The Coastal Mapping Program, already a cornerstone of the NGS mission, will be progressed along its natural path toward integration with other coastal mapping components of the government until it serves as part of the Integrated Ocean and Coastal Mapping program.

NGS will take steps to strengthen its reputation by identifying and strengthening core capabilities and increasing visibility and interaction with the global scientific community. Special emphasis will be placed on the education of its own workforce, as well as international collaboration and outreach to the public in general. Core capabilities, such as those utilized in the long-standing Airport Survey Program, will be evolved to adopt new technologies and methods which NGS will share with the world through better tools and new field manuals.



In a word, NGS will *modernize.* Better tools, new manuals, new theories, new products and services—all in support of the NGS mission, but which do so in ways that utilize modern technologies and serve the public needs—will be developed and distributed over the next decade. Anything less than the most efficient approach to the NGS mission will be transformed into modern, efficient methods with constant vigilance toward the needs of the NGS stakeholders and respect for the cost-efficient spending of American tax dollars.

One penultimate note: This plan addresses *what* NGS will seek to accomplish, but purposefully does not attempt to answer every *"who"* and *"how"* question in accomplishing these tasks. A great deal of work in accomplishing the NGS mission is done by the private sector, as well as governmental and academic partners. NGS will continue to rely on these partners, but only while maintaining a core of intellectual skills and performing inherently governmental functions.

Finally, this is a plan, and like all plans, it shows direction as of today, but it cannot be an all-inclusive unchanging course of action. Events can, and likely will, arise altering the course of this plan over the years, and eventually new plans will be necessary as NGS moves forward.

One penultimate note:
This plan addresses **what** NGS will seek to accomplish, but purposefully does not attempt to answer every "**who**" and "**how**" question in accomplishing these tasks.

Mission

The National Geodetic Survey (NGS) of the United States is a component of the Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS). The origins of NGS stretch back 200 years to the ninth congress of the United States when legislation was passed to conduct the Survey of the Coast. Over these 200 years, the Survey of the Coast changed its name a few times, but more importantly, it broadened its mission to perform the primary geodetic functions of the Federal government. Over the last two decades, the technologies of geodesy, surveying, remote sensing, mapping and charting have changed radically. NGS has attempted to adapt to this changing environment while continuing to serve its customers and fulfill its mission. It is within this changing environment that NGS has embarked upon an effort of self-reflection and hopes to plan the next ten years of work to ensure NGS remains at the forefront of new and emerging technologies while continuing to perform its critical mission. In order to do this, the mission of NGS must be clearly articulated.

The mission of NGS finds its basis in a combination of Congressional mandates, Executive Orders, DOC/NOAA/NOS mission statements, long-standing tradition and agency introspection. A clearly stated mission not only aids NGS in defining tasks to be performed, but it is critical for prioritizing tasks. Lastly, a clearly defined mission helps identify where shortfalls occur in the current work of the agency. Budgetary requests should therefore be directly traceable to the completion of the mission.

With due consideration to existing mandates, orders, and tradition[1], the leadership of NGS has come to a concurrence on the mission to guide NGS from 2007 into the future.

The mission of NGS is hereby understood to be:

1. To define, maintain, and provide access to the **National Spatial Reference System** to meet our nation's economic, social, and environmental needs

and

2. To be a world leader in geospatial activities, including the development and promotion of **standards, specifications, and guidelines**

NGS defines the National Spatial Reference System (NSRS) as the official system of the Federal government which allows a user to determine geodetic latitude, longitude and height, plus orthometric height, geopotential, acceleration of gravity and deflection of the vertical at any point within the United States or its territories. Furthermore, the NSRS encompasses the official national shoreline of the United States. The NSRS contains information regarding its orientation and scale relative to international reference frames, as well as the precise orbits of all satellites used to define, realize, or access the NSRS. Lastly, the NSRS also contains the necessary information to describe how all of these quantities change over time.

Additionally, NGS defines "geospatial activities" as those functions which seek to access the NSRS at one or more points at any accuracy, including (but not limited to) geodesy, land and/or hydrographic surveying, remote sensing, mapping and charting.

[1] *See Appendix A for a comprehensive analysis of how this mission has arisen.*

Vision

Background—From the Past to the Present

For nearly 200 years, the primary method for the U.S. government to both *define* and *provide access to* latitude, longitude and height components in the NSRS has been through a network of passive survey monuments whose positions relative to one another had been surveyed to the highest accuracy possible at the time. Information on the coordinates and methods for finding these points was published, first in paper form, then digitally, as the method of providing access to the NSRS.

Definition of, and access to, the shoreline has similarly had an impressive history, with the primary access being paper nautical charts. Finally, modeling of, and access to, the gravity field of the U.S. as a geodetic component of the NSRS has only been pursued during the later part of the 20th century, though rarely on monumented points and therefore with less rigor than other components of the NSRS.

It is with the utmost respect that NGS looks upon its past, to the accomplishments performed in days prior to computers, GPS and many other modern tools. But, it is also with full knowledge of more restrictive government budgets and rapidly emerging technologies that NGS turns to the future. The mission has remained very similar for decades, but **the primary methods of accomplishing the mission must change**. It is with confidence that NGS strives to fulfill its mission better than it ever has, and to lead the surveying, mapping and charting community strongly through a transformation into the future.

Accuracy and Leadership—A View of the Future

In defining the path NGS will take into the future, it is vital to identify the way NGS will measure its success in achieving its stated mission. In this way, NGS can identify existing problems requiring either immediate or long-term attention.

One step is to identify essential (mission critical) tasks by considering the *function* of the NSRS—to provide a consistent coordinate system as the *foundation* for all surveying, mapping and charting activities in the United States and its territories. With this function in mind, NGS can expand upon its mission to "define, maintain and provide access to" the NSRS and to be a "world leader" in geospatial activities through the following rigorous implications. Accuracies in this section are at the 1 sigma level, but it must be emphasized that they are targets to drive future work, not necessarily assurances of performance.

Define

The NSRS is the *foundation* of all surveying, mapping, charting and positioning activities in the United States and its territories. Therefore:

The NSRS must be more accurate than all activities which build upon it, while still being practically achievable.

While the "moderate accuracy" (1 to 10 meters) users of the NSRS are arguably the largest and most steadily growing community of users, NGS must strive to make the NSRS accurate enough to serve as the foundation for *all* positioning activities relative to the NSRS, at *any* accuracy.

It should be remembered that consistent coordinate systems have existed for essentially

200 years in the United States, and the accuracy of those systems has steadily improved. The accuracies for defining the various components of the NSRS have been (and must be) regularly updated as the best *mix* of "theoretically best" and "practically achievable". GPS and other space geodetic techniques have brought the world into an era when that mix can be at sub-centimeter accuracies for some coordinates. Signals too small to have been detected and measured decades ago are now critical to **understanding our environment and tracking climate change**.

The NSRS must be more accurate than all activities which build upon it, while still being practically achievable.

For example, tracking sea level rise at rates of mm/year, measuring subsidence rates at cm/year, surveying boundary corners to the centimeter level and determining the rotation of the North American Plate at mm/year are all activities requiring a consistent coordinate system accurate enough to identify signals of this small magnitude. This means that **the geodetic latitude, longitude and height of points used in defining the NSRS should have an absolute accuracy of 1 millimeter at any time**. Obviously, such points will be actively monitored points, not passive monuments.

Data from a variety of satellite systems are used in defining components of the NSRS. Accurate orbit information is almost always a requirement for using such satellite data. In many cases, and with no detriment to their overall use by NGS, these orbits are accurately determined outside of NGS, and with latencies of months or years. However, the real-time nature of GNSS such as GPS, combined with the extensive reliance upon GPS in CORS at NGS, makes the situation of GPS orbits unique. In order to properly monitor CORS coordinates, NGS participates in the International GNSS Service (IGS) efforts to compute daily orbits for GPS.

GPS is part of a growing set of GNSS's, which include the (existing) Russian GLONASS and (upcoming) European Union's Galileo systems. Like GPS, these systems are real-time positioning systems, and NGS will likely find the CORS network utilizing them over time. As of 2007, however, NGS computes only GPS orbits. However, if other satellite systems such as GLONASS and Galileo have a direct influence on the definition of the NSRS (especially through their inclusion in the CORS network), then NGS should be directly involved in either computing, or collaboratively working on such orbits. In either case, **the three dimensional coordinates of the orbits of any satellites monitored in the CORS network should have an accuracy of about 1 centimeter at any time, and less than a centimeter with a one week latency.**

Although the tracking of *local* sea level is done through NOAA's National Water Level Observation Network (NWLON) stations run by the Center for Operational Oceanographic Products and Services (CO-OPS), NGS has a vested interest in knowing the absolute *global* sea level rates. The geoid, for example, is tied (by its very definition) to the absolute location of global mean sea level. Additionally, NOAA's *VDatum* program (used for transforming from terrestrial to water levels) can only be completely implemented at sites where the tide gauge (or water level) has been tied via leveling to the vertical datum network, and via GPS to the national horizontal datum. And since water/tide levels are monitored nearly continuously in time, it would be beneficial to be able to remove local sea level fluctuations (caused by both the rise of water level and the vertical motion of the tide/water level station) from absolute sea level fluctuations (caused only by the movement of sea level). That sort of monitoring can best be done via GNSS. NGS therefore has the responsibility to see that a scientifically useful number of tide gauge and water level stations are eventually collocated with geodetic quality continuously operating GNSS receivers. Therefore, **the geodetic latitude, longitude and height of water level and tide gauge stations for the United States which are collocated with an active GNSS receiver will have an accuracy of 1 millimeter at any time.**

The vast majority of data concerning the acceleration of gravity at the surface of the Earth is known at accuracies of 0.1-1.0 mGal (combining both relative gravity equipment error and height error). While this generally supports geodetic leveling work, the creation of an accurate geoid model requires highly accurate and continentally consistent gravity measurements tied to absolute gravity measurements at defining points. This means that **the acceleration of gravity at points used in defining the NSRS should have an absolute accuracy of 10^{-7} m/s^2 (10 microGals) at any time**. Such defining points will encompass a network of regularly monitored absolute gravity stations.

Related to this issue is the gravimetric geoid used to compute NSRS orthometric heights. NGS recognizes the strong relative accuracies of geodetic leveling, but also recognizes its impracticality as the primary tool for defining a country-wide consistent orthometric height network that is maintainable to an accuracy that meets all user needs. For years the goal has been to achieve such a network via GPS and an accurate gravimetric geoid, but at what accuracy? NGS is aware of neither an achievable method, nor a practical application of, *absolute* orthometric height accuracies better than 2 centimeters. Certainly local *relative* accuracies of 1 millimeter or better exist and are needed. These can be achieved via geodetic leveling if NGS provides access to an accurate absolute height of a starting point. As such, **the gravimetric geoid used in defining the NSRS should have an absolute accuracy of 1 centimeter at any place and at any time.**

Looking now at the shoreline component of the NSRS, the highest accuracies regularly achieved in shoreline mapping are on the order of 1 to 3 meters horizontally, primarily in the ports and other areas of man-made coastal infrastructure. While these accuracies have served the charting community (the predominant customer of the national shoreline), they are not always stringent enough to serve the needs of other customers. For example, legal marine boundaries defining wetlands, fishing areas, mineral rights, etc. can require sub-meter resolution when public and private property boundaries are considered. Additionally, the ability to determine coastal resilience and monitor coastal environmental change is directly related to how accurately one can measure shoreline change. This generally requires knowledge of a local shoreline to a few decimeters. As such, **the delineated national shoreline should have an absolute horizontal accuracy better than 1 meter anyplace at any time.**

Maintain

If one accepts that the accuracies stated above are required in defining the NSRS, then NGS must take steps to guarantee such accuracies are achievable in a dynamic world. This is part of NGS' mission to *maintain* the NSRS. Therefore, **NGS must track all of the temporal changes to the defining points of the NSRS in such a way as to maintain the accuracy of the NSRS definition continually.**

This part of the NGS mission has long been given the least attention, but it is critical to the mission. Without maintenance, the NSRS will become obsolete in a matter of years.

NGS must track all of the temporal changes to the defining points of the NSRS in such a way as to maintain the accuracy of the NSRS definition continually.

Provide Access

In addition to defining and maintaining the NSRS at the accuracies described above, NGS has the mission of providing access to the NSRS. NGS recognizes that the accuracy required in defining and maintaining the NSRS is not necessarily the accuracy which all users need in accessing the NSRS. Indeed, by way of example, those who need positions to 1 meter of accuracy far outnumber those who need positions at 1 millimeter of accuracy. Such accuracies may require vastly different methods of accessing the NSRS (in terms of equipment, field time, procedures, etc.), but if both are achievable, then NGS must provide both users with access. Therefore, **NGS must develop and maintain guidelines for users to access all components of the NSRS at a variety of accuracies.**

One important program which NGS has supported to promote access to the NSRS has been the Calibration Baseline (CBL) program for local users to calibrate electronic distance measuring (EDM) equipment. Over 200 CBL's were maintained into the 1980's, but with the rise of GPS for long line surveying, the support for CBL's at NGS has decreased. While NGS field crews and state advisors have been able to maintain some of the CBLs, many of them have fallen into disrepair. While NGS does not have plans to resurrect the CBL program as it was, it must be sure to provide expertise and "Master Baselines" for regional users to establish, re-calibrate and maintain their own CBL's. As such, **NGS must develop and issue guidelines to transition the CBL program into a useful, sustainable partnership program.**

Since NGS recognizes that the Earth's crust is a dynamic environment, that every point has some velocity relative to other points, it is imperative for NGS to fully document and make available those velocities. Therefore, **NGS will publish all coordinates of defining points of the NSRS with an epoch tag and will furthermore publish velocities relative to that epoch-tagged set of coordinates. Additionally, velocities which are modeled at passive control will be provided in addition to the coordinates on that control.**

NGS also recognizes that many users work in various datums and reference frames and that it must provide tools for these users. **NGS will therefore publish all coordinates and velocities of NSRS defining points in both the most recent official U.S. Datums and the most recent realization of the International Terrestrial Reference Frame (ITRF). Furthermore, NGS will provide simple transformation tools between historic and current datums and reference frames used by NGS, in four dimensions, wherever practical and possible.**

The tools of the NGS user base have changed over the years. The rapidly growing market of Real-Time Kinematic (RTK) surveying forces NGS to re-evaluate how it provides access to the NSRS. Post processing will continue to be a strong tool, but users demanding centimeters in real time will not be served by this existing method of access. **NGS must support real time access to the NSRS without competing with the private sector.**

Finally, in order to properly track the success of NGS in providing access to the NSRS, **NGS will validate local capacity for accurate positioning through direct interaction with municipal, county and state representatives and evaluation of those regions' access to the**

NSRS. By assessing the user needs of county surveyors, state DOTs, regional surveying and geospatial associations, etc. NGS will validate that local users have the NOAA-enabled infrastructure, tools and local capacity needed for accurate positioning.

It is important to note that for many years to come, there will be the existence of passive survey monuments that *provide access to* components of the NSRS that do not meet the accuracies of NSRS-*defining* points as stated above. Of particular note, passive marks with no known velocity or which have not been resurveyed with enough regularity to assure strict accuracy goals, will continue to be a supported method for accessing the NSRS, provided NGS makes publicly available the limitations inherent in points of questionable accuracy. Since such marks require re-surveying to maintain their accuracy, NGS will not actively pursue the installation or surveying of passive marks for the definition of the NSRS, except in cases where no other method of defining the NSRS exists (such as absolute gravity control). Additionally, NGS will not promote the use of passive marks as the *primary* method of providing access to the NSRS (except for gravity control). However, NGS will continue to make available coordinates and velocities (and their associated accuracies) on such points, if such information is available, while transitioning to a more virtual NSRS.

There will come a day when NGS will not take a bluebooked set of data about a survey performed on passive marks, but will instead rely in automated online Web tools for users to submit and process their data. Such tools will—while adding efficiency of data sharing— remove much of the NGS oversight as to the quality of the surveys performed. When that happens, such marks (while still being very useful to the public) will cease to be *part of* the NSRS and will be referred to as *tied to* the NSRS.

Be a World Leader

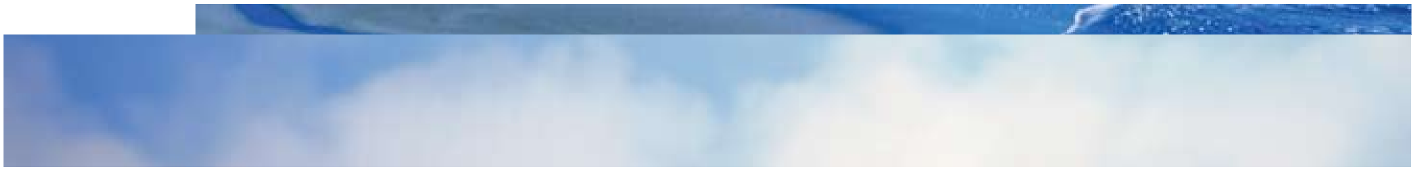
NGS is often regarded in the surveying, mapping and charting community as an authoritative source of geospatial information. The good work of NGS and its predecessors over 200 years has built a reputation that must be maintained if NGS is to remain relevant in its mission.

In order to maintain world leadership in geospatial activities, NGS must use its resources efficiently, dedicating them solely to a core set of highly important tasks. In order to focus resources appropriately, **NGS must make a concerted effort to identify and remove organizational deficiencies.**

Part of the improvement desired from an organizational perspective will be to concentrate on customer service. This means the development of user-friendly Web tools, and an easily navigable Web site. But most critically, **NGS must develop a strong and well-staffed Communications and Outreach branch which will serve as the "face" of NGS to its customers and to the world.**

Furthermore, NGS must not only recognize, but also fully embrace the changing technologies surrounding its mission. **NGS must make significant efforts to acquire (or gain access to) all modern equipment (hardware and software) which might be utilized by our customers. Furthermore, significant portions of the NGS workforce should be regularly trained (or re-trained) in the newest field technologies.**

As NGS acquires and trains a workforce in the use of the latest technologies, **NGS should completely revisit, rewrite or create new standards, specifications and guidelines documents, as well as retiring out-of-date versions of these documents.**



However, the modernization of NGS should not be limited to field technologies. The office tools for creation and dissemination of products have changed significantly in the last ten years. **NGS must therefore adopt new product creation and dissemination methods which use modern technology.**

Finally, one of the most critical (and visible) aspects of being a world leader is the publication of good scientific papers. There have been instances of good scientific work at NGS being maintained only in internal publications, or even of scientists not publishing at all. To avoid this and increase the NGS' position as a world leader, **NGS will strive to increase its publication record in both research and trade journals.** The highest emphasis will be placed on publication of peer-reviewed scientific papers, since such papers have the greatest potential to influence the future direction of the fields of geodesy, surveying, mapping, GIS and remote sensing. However, trade journal articles, conference papers, and other written materials (e.g. Web content) geared toward a general audience are also of significant value, especially to public outreach and education. Thus, all employees with a wide range of technical/scientific expertise have the potential to contribute to NGS' publications.

Achieving the Vision:
Overview

In order for NGS to accomplish its mission by achieving the vision laid out in the previous chapter, certain steps must be taken. This is the heart of the Ten-Year Plan—answering the primary question of **"What will NGS do over the next ten years in order to accomplish its mission?"** Answering the question is the very point of this document. What will be shown is that the work needing to be done over the next ten years will involve improvements and modernization among all components of NGS.

Any organization attempting to make the sort of large-scale modernization laid out in this plan must be run efficiently and effectively. NGS must therefore address existing organizational deficiencies if this plan is to succeed. These issues should be addressed soon through a comprehensive realignment initiative, but will not be addressed herein.

The following five technical improvements must be the focus of NGS for the next ten years for this plan to be achieved:

1. **Modernize the geometric ("horizontal") datum**
2. **Modernize the geopotential ("vertical") datum**
3. **Migrate the Coastal Mapping Program toward IOCM**
4. **Evolve core capabilities**
5. **Increase agency visibility**

Each of these steps will be detailed in the next five chapters. For each chapter, the basic format will be the same: first a vision summary, followed by a description of the detailed steps required within the next one to two years, and finally, broader views of where NGS should be for both five and ten years ahead in order to stay on track with achieving each component of this plan.

Under current organizational structure, NGS is composed of a Director's staff and six divisions: Observation and Analysis (OAD), Remote Sensing (RSD), Geosciences Research (GRD), Geodetic Services (GSD), Spatial Reference System (SRSD) and Systems Development (SDD). Each of these seven groups concentrates on a particular component of the overall NGS mission. As such, in the following sections, a particular group will often be named as a "Lead" for accomplishing certain tasks. This is not to imply that the work of that task must be done only by that group, but that the primary leadership should come from that group for that task.

Achieving the Vision: 1

Modernize the Geometric ("Horizontal") Datum

Vision Summary: By 2018, NGS has defined a new geometric datum (classically called "horizontal") to replace NAD 83 with its many systematic errors. The primary means of accessing this new datum is GNSS technology. While passive control continues to be used as a secondary method to access the NSRS, such control will be "tied to", not a "part of", the NSRS.

The CORS network transforms into a two-level system whose first (very small) level is made up of NGS-owned or -operated "foundation" sites treated as critical infrastructure. These foundation sites are equipped, monumented, spaced apart from one another and collocated with other space geodetic observatories in such a way as to ensure the NSRS is accurately tied to the ITRF and accessible to GNSS users in a minimally acceptable fashion anywhere in United States territory.

The second (very large) level of the CORS network is all other sites, which are positioned relative to the foundation and whose maintenance and quality control fall to the site operators. Data and relative positioning tools continue to be available for *all* CORS sites, but not at the expense of significant NGS resources. The concepts of "National" and "Cooperative" CORS disappear, in favor of "CORS". The location of stored data (one of the main distinctions between Cooperative and National CORS, will be rendered moot as NGS develops software to access and store all CORS data. NGS will work cooperatively with all CORS site operators to transition from the current system to one where roles and responsibilities are performed in a partnership-oriented model.

The coordinates of all CORS are computed daily by NGS and made available to the public through easily available charts, spreadsheets and data files. Additionally, CORS sites and all CORS access tools will be modernized as the GNSS constellations modernize.

The CORS network serves the public by supporting real-time positioning complementing (without competing against) private and local government initiatives.

Products to be developed include a suite of GNSS post-processing online tools capable of computing coordinates for any number of stations with any combination of constellations, signals and data collection times.

Finally, and most cautiously, NGS must define this new datum in a scientifically accurate way that also addresses the needs of users to have (as much as possible) stable, unchanging coordinates. Everything from tectonic plate rotation to local subsidence must be considered when NGS defines, maintains and provides access to this new datum.

The NAD 83 has been defined with the same parameters since its inception, but it has been adjusted repeatedly over 20 years. It has predominantly been accessed through coordinates on passive marks, but more recently through CORS and OPUS-GNSS. Unfortunately, as seen in the most recent adjustment of NAD 83 (known as "NSRS2007"), the discrepancies between the passive network and active network are not easily rectified. Without an accurate and perpetually updated three dimensional crustal motion model, there will never be complete coordination between the active and passive control of NAD 83.

By 2018, NGS has defined a new geometric datum (classically called "horizontal") which replaces NAD 83

With this reality in mind, the active control (CORS) will become the primary method of maintaining and accessing the geometric (Cartesian and ellipsoidal) coordinates of the NSRS when using GNSS technology. The determination of coordinates on passive marks will continue to be supported (through tools such as OPUS-GNSS), but the collection of such data by bluebooking and submitting to NGS will eventually cease, as NGS will no longer use such data in its day-to-day NSRS stewardship. Specifically, in the case of geometric coordinates on passive marks, these marks will be "tied to the NSRS" but will no longer be "part of the NSRS". This terminology reflects a change to the NGS acceptance of GNSS data on passive control; such data will be used to compute coordinates and the coordinates will be shared with the world via NGS, but only through automated tools such as the DB feature of OPUS-GNSS and not through the use of bluebooking and entry into the NGS Integrated Database (IDB). Once OPUS-GNSS is fully functional, NGS will remain committed to providing positioning tools and sharing information on passive marks, but NGS does not specifically seek such data from outside users for the accomplishment of its mission. Bluebooking of GNSS data on passive marks and the entry of that information into the NGS IDB (or "into the NSRS" as it has colloquially been known) will cease within a few years of OPUS-GNSS becoming fully functional.

What of CORS itself? The CORS program is, without question, one of NGS' most successful programs. Not only was it built up with minimal cost to the government, but it became a realistic tool for the surveying community to transform from standard terrestrial techniques to the use of GPS for accurate positioning. However, the program is also a victim of its success. The issues surrounding a large number of diverse site operators (many of whom participate for reasons that do not directly include the NGS mission) are becoming a burden to NGS resources.

In order to balance the NGS mission against the NGS resources currently required for the CORS network to grow at its present rate, NGS will change its business approach with respect to CORS. Specifically, NGS will seek to strengthen partnerships within the CORS community by entrusting greater responsibility to site operators. This transfer of responsibility will enable NGS to concentrate on day-to-day maintenance of the *foundation* CORS (defined later) in order to fulfill its mission of defining, maintaining and providing access to the NSRS. It will also mean that the CORS network can, in theory, expand indefinitely without significantly affecting the NGS workload. NGS will continue to provide access to data at all CORS sites, but the onus of quality and timeliness of that data will transfer to the site operators.

Because CORS is a communal effort, and the data are received at NGS for free, it has been difficult for NGS to apply rigorous standards on site location, monumentation, timeliness of data arrival, quality of data, continuity of hardware or status of metadata. These issues were less important at first than the greater issue of simply building up the CORS network over the years. With this network now in its second decade of existence and new site operators continually being added, NGS can turn its attention and resources to the foundation CORS.

NGS will define minimal access to the NSRS and the ITRF via CORS. These definitions will specify the number, spacing and configuration of those CORS required to perform the NGS mission. NGS will then make a concerted effort to directly own or operate such sites (preferably by transferring existing CORS into NGS operation, but in all likelihood also by building its own CORS). Because CORS is a cooperative effort, the only methods by which "voids" in CORS coverage can be addressed are encouragement of local entities constructing CORS sites in those voids or, barring that, the installation of a foundation CORS site in such a void. (This will be predicated on NGS first defining the required spacing of foundation CORS.) Because these foundation CORS will always (by themselves) allow NGS to conduct a given part of its mission at a minimal level, they will be the *only* sites which NGS will oversee directly on a daily basis. All other CORS will continue to be part of the network and will have their positions adjusted to the foundation CORS, but the onus of a CORS site's data arrival, data quality, and metadata will lie solely on the site operators, many of whom already have adopted this responsibility.

NGS recognizes that other users have tighter requirements for CORS spacings than might be defined for minimal access to the NSRS. However, since those requirements fall outside of the NGS mission, and since the building of, and direct oversight of, foundation CORS will come from the NGS budget, the only consideration for foundation CORS will be the fulfillment of the NGS mission.

In order to facilitate this new business model, the foundation CORS must be built and new automated data processing tools must be created and put in place. Within a few years, *all* CORS sites will *automatically*:

1. Make their data available to NGS in real or very-near-real time
2. Have data quality checked by NGS
3. Have coordinates computed and checked for consistency

It should be stressed that all of this should occur without NGS intervention. If a site fails to report data on time, or reports bad data, or has coordinate jumps due to unreported hardware changes, such a site will, in automated fashion, receive email notification from NGS concerning the problem. Additionally, that site's data will be temporarily removed from the list of CORS until the problem is resolved.

Under this new business style, NGS must strive to educate CORS users about the versatility of the Online Positioning User Service for GNSS (OPUS-GNSS) so that users do not rely on any particular CORS site. If a user's "preferred CORS site" isn't available, positioning should still be accomplished at the same level of confidence as before. This means NGS must regularly test the CORS data and OPUS-GNSS to ensure that all sites yield identical results within error tolerances. When a CORS site is unavailable, NGS will immediately make that information available on its Web page, and users will be directed to the *site operator*—not to NGS personnel—for questions regarding why a particular site's data are not available.

The new approach also means that the concepts of "National CORS" and "Cooperative CORS" will go away as the need for a continued separation of the two systems no longer exists for the accomplishment of the NGS mission.

Three GNSS-related issues must be addressed for the CORS network to remain a viable tool for accurate positioning in the NSRS. First, the changing world of GNSS must be accounted for. That is, as new signals and constellations become available, NGS must assure that new and replaced CORS hardware accounts for these changes. (Aside from foundation CORS,. equipment at existing CORS will not be required to be upgraded until a component fails, at which time the replaced component will need to align with NGS policy on CORS and GNSS). Second, NGS must provide users with software that will use any and all GNSS signals. That is, OPUS-GNSS must allow for every possible scenario from single frequency, pseudo-range GPS positioning with one second of data to triple-constellation, multiple-frequency, 24-hour carrier-phase surveys with multiple antennas in an array, and everything in between. Third, orbit determination software used at NGS must encompass all GNSS changes, for complete support to be possible.

Other components to modernizing the CORS network: NGS must maintain world leadership by changing from a relative antenna calibration program to an absolute antenna calibration program. And it must use its expertise to assist global sea level research by determining accurate water levels in the geodetic framework, preferably through the installation of CORS at water and tide level stations. Some of these issues have been addressed through the NGS Height Modernization program. This modernization of CORS supplements and compliments that already existing effort.

One final but critical component of modernizing CORS will be the methods it will use to support the current (and growing) field of real-time applications. One existing real-time application, RTK, has seen enormous growth in the last decade. In such an application, a base GPS station is used (either temporarily or permanently installed), and a rover GPS receiver is moved about, with a radio link between the two yielding a centimeters-precise position of the rover relative to the base. A variety of RTK applications exist today, ranging from a single base/rover pair used by a single surveyor, to city and state governments installing networks of base stations and charging fees to rover users. NGS does not envision providing a nationwide RTK product, but does fully endorse and recognize the strength of this application. The role of NGS in supporting these various RTK applications is to assure consistency within the NSRS. Consider the example of a metropolitan area being covered by two or three different competing RTK networks. These should all deliver reliable NSRS values regardless of which network is used.

NGS will support RTK applications in several ways. First, a likely scenario to develop in the next few years is for NGS to provide a service to RTK network operators to certify them as "NSRS compliant". The details will be crafted in the next two years, but what this will essentially mean is that the base stations in any given RTK network will be episodically investigated by NGS to make sure their coordinates are accurate within the NSRS, and that the coordinates computed at rovers are also accurate within the NSRS. To remain compliant with the NSRS, this will need to be accomplished in a way that does not hold NGS liable for the network. NGS will thus allow the private and local government sectors to run RTK networks while it serves the overall public good by ensuring surveys in "compliant" RTK networks are compatible with each other and with the NSRS in general.

A second support for real-time applications will come as NGS begins to provide CORS data at smaller and smaller latencies. Currently, most CORS data latency is around an hour. In the future, that latency will be reduced and real-time CORS data streams will be established. It is hoped that through such initiatives, NGS will further promote the development of RTK networks in those areas which do not have such services.

A third method of real-time support may come through a medium-accuracy real-time single-frequency CORS application. Through real-time internet data streams and real-time atmospheric modeling, a single-frequency application may be developed at NGS allowing users to achieve 1 to 2 meters of post-processed positional accuracy. In addition, NGS anticipates that its real-time data streams will enable the private sector to develop *real-time positioning applications* at around the 1 meter level. Such applications would allow greater expansion of NGS products to serve GIS users who do not require the centimeter accuracy of an RTK network. No safety-of-life mandate would exist with such real-time positioning services, so they could not replace the Department of Transportation's Nationwide Differential GPS (NDGPS) navigation service.

Finally, CORS applications (such as OPUS-GNSS) will continue to be improved so the amount of data (currently two hours) required for a solution will be reduced to a few minutes, possibly a few seconds (once other GNSS constellations are available, and/or new breakthroughs in data processing are made). OPUS-GNSS will develop into a suite of products capable of supporting multiple stations, multiple constellations and signals, and any length of data collection, with the possibility of sharing these results instantly via an online NGS database. OPUS-GNSS will continue to operate on the full set of CORS sites, not only "foundation CORS".

In the next ten years, NGS will *not* be providing any independent service yielding true real-time centimeters-accurate access to the NSRS. Rather, NGS hopes that, through its support of real-time initiatives, local RTK networks will be developed which will be consistent with the NSRS and serve the needs of local positioning experts.

Much of this section has dealt with CORS, but this is simply because it is the critical tool in providing access to the geometric datum. At this time, there is a known non-geocentricity of the NAD 83 origin by over 2 meters. This non-geocentricity affects all latitudes, longitudes and ellipsoid heights in the United States. A non-geocentric ellipsoid is not optimal for use in a geoid-based geopotential ("vertical") datum (discussed in the next section). As such, NGS will be redefining a new geometric datum in conjunction with a new geopotential datum around the year 2018.

One final note on the new datum—NGS has long realized that a balance must be struck between the needs of surveyors (who prefer coordinates that never change) and the realities of living on a dynamic planet (where coordinates change everywhere). As such, NGS will investigate the development of tools which allow users access to the NSRS in any epoch and allow the transferal of coordinates across epochs. And while the "stable" North American Plate is a significant portion of the CONUS region, NGS can not at this time commit itself to fixing the new geometric datum to that plate. The exact definition of this new geometric datum will be determined through a series of stakeholder feedback forums which will seek to achieve the best solution for all parties.

In the end, NGS must modernize the geometric datum, and especially the CORS network, by concentrating on the NSRS mission, transferring responsibility to the site operators, and educating users.

The initial steps needed to be taken **within two years** in order to achieve the vision are found in the table on the next page.

Task Lead	Description
GRD	Identify the tools and external data required, as well as the exact equipment, number, spacing, monumentation, metadata and co-location with other scientific observation sites, of those CORS sites needed to guarantee "minimally acceptable access to the NSRS". This is defined as: (1) Sub-centimeter positioning of each CORS antenna relative to the ITRF and (2) 1-cm positioning of a user's antenna relative to the NSRS, if the user's occupation meets the following conditions: 1. Uses a dual-frequency geodetic quality GPS receiver 2. Occupies a GPS-viewable site for four hours on one day 3. Does not suffer from extenuating environmental conditions These sites needed for minimal NSRS access will be known as "*foundation CORS*".
SRSD	Identify which existing CORS could be transformed into the above-mentioned foundation CORS through direct funding, MOUs, or other means.
Director's Staff	Identify funding gaps between the identified foundation CORS and existing NGS-owned or -operated CORS sites.
OAD	Develop a plan in conjunction with NOAA CO-OPS to collocate, over time, new and existing tide gauges and water level gauges with a CORS antenna.
GRD	Replace the current GNSS *relative* antenna calibration program with a fully functioning *absolute* phase center variation program for all GNSS antennas.
GRD	Develop an updated GNSS processing engine which allows post-processing of any number of receivers and any combination of constellations, signals and data collection times.
SDD **OAD**	Develop a plan for collecting (possibly storing) and disseminating all CORS data to allow for the unlimited expansion of CORS while minimizing the workload on NGS personnel and thus removing the necessity of dividing CORS into "national" and "cooperative".
Director's Staff	Develop and execute a policy on what signals and constellations new and replaced CORS antennas must support.
GRD	Develop orbit computation software for GLONASS.
SRSD	Determine, publish and implement NGS policy on the use of passive horizontal and vertical marks, specifically addressing upkeep of existing marks, installation of new marks, information presented on marks in the NGS datasheets and other relevant questions.
GRD	Issue a comprehensive evaluation of how and where NGS has the ability to provide 1 cm accurate NAD 83 *ellipsoid heights* to GPS users in the United States with only 1 hour of data. Identify and plan out all steps required (including new research, software development, installation of additional CORS, etc.) to extend this ability nationwide.
GSD	Develop and execute a workshop for CORS users which specifically addresses the large changes coming in the next ten years.
SRSD	Deploy an initial set of horizontal and vertical velocity models for the ellipsoidal coordinates in CONUS and Alaska, and distribute these coordinates on all passive marks.
SRSD	Analyze all historic CORS data and issue updated coordinates and velocities.

Table 1: Two-year Milestones toward Modernizing the Geometric Datum

In addition to these initial steps, the following **five- and ten-year milestones** are identified to transform CORS. The steps needed to get to these milestones are left for future planning documents:

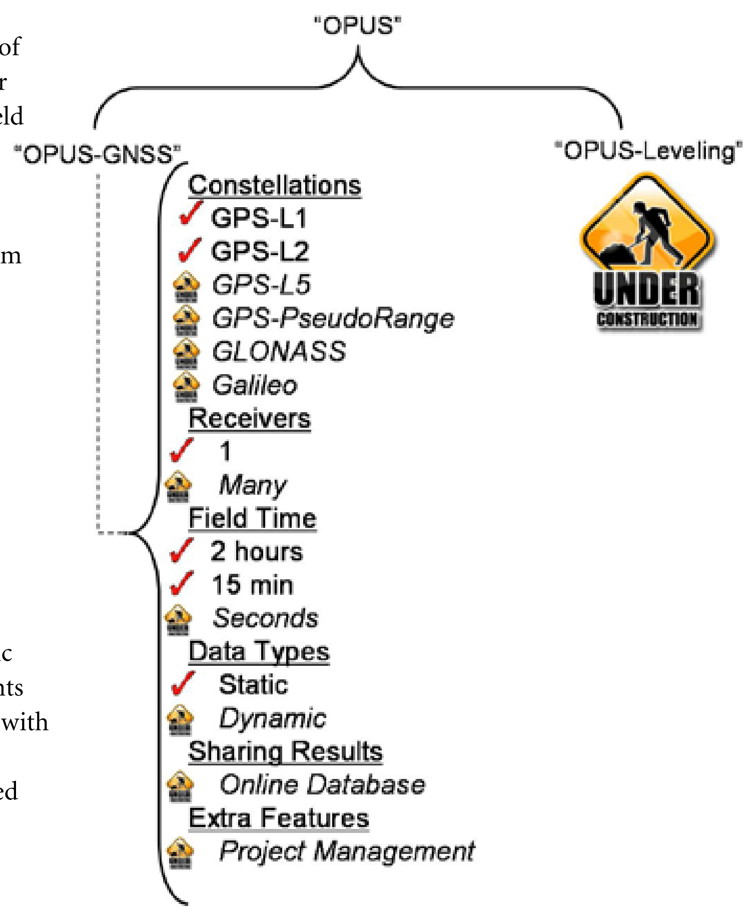
Five-Year Milestones (2013):

1. NGS owns or operates a complete set of foundation CORS sites.
2. NGS provides 1-cm access to the geodetic latitude, longitude and height components of the NSRS for *GPS-exclusive* users (with geodetic quality receivers) with *less than one hour* of data anywhere in the United States or its territories, relative to the NSRS.
3. All CORS have an epoch-tagged 3-D coordinate *and* a velocity in both the latest US Datum and the latest ITRF.
4. OPUS-GNSS works with any sort of GNSS data submitted (e.g. independent of frequencies, codes, constellation, static or dynamic nature of data, and length of field data acquisition time).
5. NGS operates a completely updated set of orbital software, computing orbits for both GLONASS and GPS with about 1-cm absolute accuracy.
6. NGS products and services directly support real-time access to the geodetic component of the NSRS without private sector competition.
7. Have a full set of crustal motion models showing velocities in ellipsoidal latitude, longitude and ellipsoid height for all territories of the United States.

Ten-Year Milestones (2018):

1. NGS provides 1-cm access to the geodetic latitude, longitude and height components of the NSRS for all GPS-exclusive users (with geodetic quality receivers) with *less than 15 minutes* of data anywhere in the United States or its territories.
2. NGS provides 1-cm access to geodetic latitude, longitude and height to all GNSS (generic) users, without regard to constellation, with *less than four hours of data* anywhere in the United States or its territories.
3. All existing NWLON sites are either collocated with a CORS antenna or else tied episodically to the ITRF using GNSS technology.
4. NGS provides 1-cm orbits for GPS, GLONASS and Galileo.
5. NGS products and services directly support real-time access to all components of the NSRS without competing with the private sector.

As a simple method of understanding the new view of "OPUS" within NGS, the following graphic tells where NGS is and where it is headed.



Achieving the Vision: 2

Modernize the Geopotential ("Vertical") Datum

Vision Summary: The era of using geodetic leveling for continent-scale vertical datum definition comes to an end. The gravimetric geoid, long used as the foundation for hybrid geoid models, becomes *the most critical model produced by NGS*. Before 2018, NGS proves that a 1-cm geoid is computable (or shows where it is not and why) and produces (in conjunction with other North American geodesists) the most accurate, continent-sized gravimetric geoid model ever seen. The model covers, at the very least, the region extending from the North Pole to the Equator and from Attu Island to Newfoundland. The model then serves as the foundation for *a new vertical datum for at least the conterminous United States*, if not the entire North American continent. Similar smaller scale geoid-based vertical datum initiatives are undertaken for those United States territories not within the neighborhood of North America.

To fully support the above work, an entirely modernized program of gravity observation, modeling, monitoring, analysis and dissemination (called *The GRAV-D Project*) is established within NGS. The gravity field becomes a *monitored* time-dependent part of the NSRS. The time-varying nature of the gravity field is considered in all products and services of NGS. The culmination of all these efforts allows fast, accurate determination of heights through GPS, and thus truly represents "Height Modernization" as originally envisioned.

By 2018, a new geopotential datum (for orthometric and dynamic heights) is defined and realized through the combination of GNSS technology and gravity field modeling. In order to support users of NAVD 88, NGS will provide transformation tools between the new datum and NAVD 88 based predominantly on the few thousand measurements of GPS derived ellipsoid heights on NAVD 88 benchmarks.

Every effort should be made by NGS to work collaboratively and come to consensus with Canada and Mexico (at the very least) on the concept of re-defining the vertical datum via a gravimetric geoid, the method of computing such a geoid and the realization of dynamic heights in such a datum. The definition of the geoid should properly account for not only the local time dependent nature of the gravity field, but also the rise of global mean sea level. The gravimetric geoid model will consist of both an epoch-tagged grid and its rate of change over time.

When such a model is achieved and has been appropriately tested, it will be used in conjunction with space geodetic techniques tied to ITRF (predominantly GNSS) to define a new vertical datum for the United States.

In order for the geoid model to remain relevant and the vertical datum to remain accurately defined, the gravity field must be monitored. This will require a combination of carefully planned absolute gravity campaigns, new relative gravity measurements, judicious placement of the superconducting gravimeter and the acquisition of airborne and satellite-based gravity data (such as GRACE and GOCE). Secondarily, data sets such as deflections of the vertical and co-located leveling and GPS can be used initially as a check on the gravimetric geoid; alternatively as input to it. Additionally, the gravity data holdings of NGS must be inventoried, cleaned and put into a more easily usable format. Gravity data collection has been planned in greater detail than is appropriate to this document. Details can be found in the NGS document *The GRAV-D Project: Gravity for the Re-definition of the American Vertical Datum.* They must be quickly accessible to the public (in both static and time varying form), and easily analyzable within NGS. Renewed efforts to acquire data from external sources must be made.

When the gravity field, and thus the geoid, is monitored in time, NGS will be able to monitor the changes to orthometric heights (since ellipsoid heights will be monitored in time via CORS). As the system is built up (representing the realization of the national Height Modernization program begun in 1998) the necessity of passive marks will decrease. Such a transition will take the full ten years of this plan, but even as GPS becomes the primary source for accurate heights and the need for passive marks decreases, NGS recognizes that some passive vertical monuments will have a role in the NSRS for the foreseeable future.

All of the above will require a tremendous number of person-years to achieve. The scientists working on the geoid have estimated that the current "to-do list" of issues to achieve the above vision is 27 person-years. With only three such scientists, that means nine years of work, presuming nothing new arises over those nine years (which is unrealistic). Bearing in mind that Canada is considering switching to a gravimetric geoid-based vertical datum by 2012 (four years away), the immediate personnel resource needs of NGS must be focused on those who work on gravity field issues.

The initial steps needed to be taken **within two years** in order to achieve the vision are found on the next page.

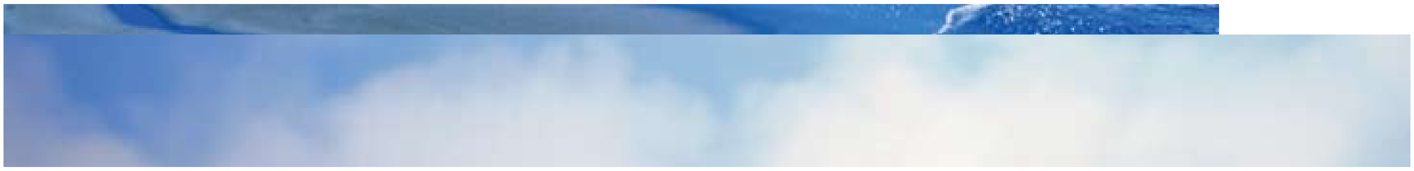


TABLE 2: Two-year Milestones toward Modernizing the Geopotential Datum

Task Lead	Description
GRD / OAD	Transfer all absolute gravity field operations from GRD to OAD.
OAD	Hire, train or contract a second absolute gravity operator.
OAD	Investigate new absolute gravity meters, and make recommendations about NGS purchasing them.
Director's Staff / OAD / GRD	Perform a cost-benefit analysis on keeping the superconducting gravimeter in Boulder, versus moving it to an area where its data can be more directly supportive of the geoid component of the NGS mission. Act on the results of that study.
OAD	Train all field operators in the operation of relative gravity meters.
SRSD	Revitalize the gravity database by: 1. Assigning or hiring at least one person to be in charge of the state of the database. 2. Creating a GIS based, user-friendly method of adding, cleaning, manipulating and distributing the gravity holdings. 3. Developing a method for tagging gravity measurements with epochs and velocities (and accelerations if needed). 4. Developing a method for entering absolute gravity data into the database.
GRD	Hire, contract or reassign three more MSs or PhDs devoted exclusively to gravity field research.
GRD	Answer the following questions about computable geoid accuracy: 1.Is a gravimetric geoid, accurate to 1 cm, computable without an impractical amount of crustal rock density surveys? 2. If so, what is NGS missing in order to achieve this? 3. If not, what accuracy can be practically achieved, broken down by geography?
GSD	Survey the NGS customer base on the best way to shift vertical datum access from a reliance on passive marks to a reliance on GPS/geoid defined vertical datum.
GRD	Answer the following questions regarding the lack of gravity data in littoral regions of the United States: 1. Does such a gravity gap affect our ability to compute a 1 cm accurate gravimetric geoid at any place(s) in the United States or its territories? 2.If the answer to question one is "yes", then will the collection of gravity via airborne sensors in those littoral regions remove, or at least partially alleviate, such inaccuracies? 3.If the answer to question two is "yes", then where, at what spacing, at what height, at what speed and with what sensors should airborne gravity be taken in the United States and its territories?
SRSD/OAD	Formalize NGS policy on the use of passive vertical marks, specifically addressing upkeep of existing marks, installation of new marks, information presented on marks in the NGS datasheets and other relevant questions.
GRD / RSD	Identify and acquire: 1. The most accurate Digital Elevation Models available for the United States and the world 2. The most accurate bathymetry models available for the oceans and the Great Lakes

By 2018, a new geopotential datum (for orthometric and dynamic heights) is defined and realized through the combination of GNSS technology and gravity field modeling.

In addition to these initial steps, the following **five- and ten-year milestones** are identified to improve the gravimetric geoid. The steps needed to get to these milestones are left for future planning documents:

Five-Year Milestones (2013):

1. NGS re-introduces a new gravity interpolation tool which works anywhere in the United States or its territories, and which shows any aspect of the gravity field (geoid, gravity, geopotential) on or above the surface of the Earth, as well as the temporal rate of change of that quantity.
2. NGS has proof that a gravimetric geoid accurate to 1 cm is computable (or details where and why it is not).
3. NGS develops a plan for redefining the vertical datum of the United States using GNSS and the geoid by 2018.
4. NGS, in collaboration with Natural Resources Canada, computes a prototype North American gravimetric geoid.

Ten-Year Milestones (2018):

1. NGS will compute a pole-to-equator, Alaska-to-Newfoundland geoid model, preferably in conjunction with Mexico and Canada as well as other interested governments, with an accuracy of 1 cm in as many locations as possible.
2. NGS redefines the vertical datum based on GNSS and a gravimetric geoid.
3. NGS redefines the national horizontal datum to remove gross disagreements with the ITRF.

Achieving the Vision: 3

Migrate the Coastal Mapping Program Toward IOCM

Vision Summary: The human subjectivity factor, a current limitation in shoreline delineation, is reduced through modern tools with greater automation. Aerial film cameras are replaced with newer technologies, such as digital cameras, LIDAR systems, thermal imagers and a variety of satellite-borne sensors.

In the near future, NGS utilizes a complementary suite of sensors to supply data for a variety of NOAA coastal projects and programs through a single flight mission, thereby assisting NOAA in efficiently meeting the requirements of the IOCM program.

As a key component of success, the VDatum tool is *completed* and used as a cornerstone of the shoreline mapping project to extract a consistent, non-interpreted shoreline.

Although aerial film-based photography has been the primary method used to map the nation's coastline, the profession is seeing increased competition from digital cameras and is likely to be phased out of existence in the future. Due to the substantially greater technical challenges and requirements, the transition from film to digital is occurring slower in airborne mapping cameras than in ordinary hand-held cameras. However, commercial unavailability of film photogrammetric supplies is not the reason for transition, but instead the effect. Digital aerial cameras offer a number of potential advantages, including: quicker turnaround time, superior radiometric performance, and improved robustness to shadows and low illumination levels. Thus, NGS is actively investigating digital aerial photography in combination with other remotely-sensed data, such as satellite imagery, light detection and ranging (LIDAR), imaging spectroscopy (hyperspectral data) and thermal imagery for mapping the shoreline.

Digital cameras have emerged into the remote sensing community with several varying designs and configurations. As part of its efforts to begin the transition from film-based cameras to digital, NGS is conducting feasibility research for utilizing such sensors for shoreline mapping. Issues that are aggressively being investigated include geometric accuracies, radiometric capabilities, calibration, stability, and data processing workflows. A related area of investigation involves the use of digital aerial cameras for post-emergency response, an activity likely to constitute an increasingly important part of NGS' mission over the next decade.

Additionally, NGS is exploring the use of LIDAR in coastal mapping. Researchers within NGS have demonstrated that this technology has the potential to be used as a method to accurately conduct shoreline mapping operations in an efficient, consistent, objective, and repeatable manner. LIDAR is an active system that provides the capability to quickly gather dense and accurate elevation information for the earth's surface. The extraction of shorelines utilizing the methodology currently under development incorporates a vertical datum transformation tool for transforming LIDAR to a specified tidally based datum. This methodology for shoreline extraction provides significant advantages over other shoreline proxies that do not provide consistent, non-interpreted shorelines. LIDAR-derived shorelines are proving to provide good results for commonly occurring natural coastline types and can allow for multiple tidally based shorelines to be derived from a single data set if properly tide coordinated. More importantly, this procedure minimizes the variability and subjectivity that have plagued more traditional shoreline delineation techniques. Furthermore, LIDAR data acquisition can be done during the day or night and in some types of weather unsuitable for aerial photography, leading to an increase in operational efficiency.

NGS is currently testing and developing a vertical datum transformation tool called VDatum. VDatum currently supports 29 vertical datums that can be placed into three categories: three-dimensional (realized through space-borne systems), orthometric (defined relative to a form of mean sea level), and tidal (based on a tidally derived surface). Utilizing LIDAR and other remotely sensed elevation datasets, it is important to have a tool that can transform the elevation information to an appropriate, consistent datum. The vertical datum transformation tool accounts for changes in tidal range which is integral to extracting a consistent, non-interpreted shoreline. VDatum allows users to convert from an easily accessed vertical datum (such as those used in GPS) to any other terrestrial or hydrographic datum. Work is currently underway to populate VDatum for the continental United States over the next five years. Developments are also being made to the tool to enhance functionality and increase ease of use.

NGS is also exploring other sensors such as imaging spectrometers, thermal imagery and other airborne and satellite borne sensors. Imaging spectroscopy allows for the acquisition of data over a wide portion of the electromagnetic spectrum in several narrow, contiguous spectral bands. Such data (often called hyperspectral data) can be used to determine the land/water interface accurately and assist with classification of the scene. This classification can aid the feature attribution of the shoreline vectors. Thermal imagers are also being examined to assist in deriving the land/water interface. This technology is particularly attractive for coastal regions with large temperature gradients across the land/water interface.

Over the next *five* years the primary focus of this research into emerging remote sensing technologies and processing/analysis techniques is to increase efficiency in the Coastal Mapping Program. The goals of these research initiatives include gaining flexibility over weather and tidal constraints and providing data to benefit multiple users supporting a variety of projects and programs. A specific area of research during this timeframe will involve multi-sensor data fusion. Through fusion of data from passive and active sensors (e.g. LIDAR data and multi- or hyperspectral imagery), we can improve the information about both "where things are" and "what they are" while simultaneously supporting multiple data needs.

Taking a longer view, NOAA leadership is implementing matrix management to more effectively manage resources and improve efficiency across the entire organization. Integrated Ocean and Coastal Mapping (IOCM) is one area where this cross cutting strategy will complement advances in remote sensing technologies. Historically, there have been numerous users of aerial remotely sensed data, and the number of requesters is constantly growing. Aside from the congressionally mandated shoreline mapping product NGS is responsible for, NOAA users need data to produce maps supporting the following activities:

- Marine navigation (bathymetry)
- Ocean exploration
- Fisheries, benthic habitat
- Non-point source and point source pollution
- Coral reef assessment
- Ocean chemistry
- Tsunami and storm surge modeling
- National Marine Sanctuary monitoring
- Wetlands mapping at National Estuarine Research Reserves (NERRs)

Two main challenges keep prospective users from realizing their data requirements: expense and expertise. Aerial remote sensing is a very expensive proposition. Aside from the high cost associated with operating aircraft and procuring state of the art sensors, most applications require very specific environmental conditions which severely limit the time available for data collection. Additionally, the time and expense needed to train personnel and maintain the required skill sets are substantial. In the current paradigm, various offices within NOAA which require mapping products are effectively on their own when it comes to data collection, processing, and production. This results in a high time and money cost for a low volume of end products that do not always meet the customer's needs.

Integrated Ocean and Coastal Mapping (IOCM) will address this problem by centralizing NOAA mapping and charting activities. As remote sensing technology advances, more and more mapping needs will be realized in this manner. Active (e.g. LIDAR) and passive (e.g. imaging spectrometers and cameras) sensors operated from aircraft have the ability to provide a plethora of information that can be used to describe the coastal zone. These sensors work very well independently, however the fusion of these datasets has the potential to produce products that are greater than the sum of their parts. Notable advances will likely be in the area of discrete object and area classification, as well as increased collection and processing efficiency (i.e. automation).

Since the navigational charting use of NGS data typically exceeds any other user's spatial accuracy requirements, NGS is uniquely suited to take the lead in meeting IOCM challenges. A variety of changes over the next few years, from new equipment to better processing techniques, should improve NGS' ability to be a fully engaged partner in the field. It is NGS' vision to:

- Be a leader in IOCM
- Use experience gained in-house to develop standards and procedures for contractors
- Quality assurance contracted data and products
- Collect production data that satisfy a broad range of NOAA customers' needs where contracting is not practical
- Streamline production work flow and prioritize areas of rapid change to better utilize in-house and contracted resources
- Keep the national shoreline up to date and within accuracy specifications

The initial steps needed to be taken **within two years** in order to achieve the vision are found in the table on the next page.

Table 3: Two-year Milestones toward Migrating the Coastal Mapping Program toward IOCM

Task Lead	Description
RSD	Develop the capability of using digital cameras for shoreline delineation and begin phasing out film cameras.
GRD / RSD	Resolve the following geodetic issues for VDatum inside CONUS: Support GEOID03, GEOID99, future GEOID models, updates to NAVD 88 and IGLD85 in UTM and Geographic Coordinate transformations. Begin work on the same tasks for OCONUS, including Caribbean, Hawaii, Alaska, and Pacific Trust Territories.
RSD	Conduct research on various remote sensing platforms and technologies and report to the Director a plan for which platform and sensor (or complementary suite of sensors) will be the predominant method of coastal mapping for the next decade.

In addition to these initial steps, the following **five- and ten-year milestones** are identified to increase the efficiency of shoreline delineation. The steps needed to get to these milestones are left for future planning documents:

Five-Year Milestones (2013):

1. NGS completes all updates to the terrestrial component of VDatum.
2. NGS completes the transition from film cameras to strictly digital sensors.
3. Efficiency of coastline delineation allows for resurvey of ports every four years and total coastline every 15 years.

Ten-Year Milestones (2018):

1. A highly automated system for extracting a delineated shoreline is in place.
2. NGS coastal missions are strongly integrated with IOCM, GGOS (Global Geodetic Observing System) and GEOSS (Global Earth Observation System of Systems).

Achieving the Vision: 4
Evolve Core Capabilities

Vision Summary: NGS identifies, maintains and improves its capability of performing core (mission-related) functions. At the same time, NGS modernizes its infrastructure, updating all specifications, guidelines and tools in order to enable NGS stakeholders to access the NSRS as simply as possible. A number of sub-tasks are associated with this overarching goal, including the education and training of NGS employees, supporting real-time applications, evaluating how or whether outside users submit data to the NGS database, modernizing all tools used by NGS and provided to the public, updating all outreach and training materials, and generally improving the quality of all NGS products and services.

Further, NGS develops a strong agency-wide Products and Services Committee tasked with the responsibility of tracking all official products and services of NGS, approving the development of prototypes, and improving or retiring existing products and services.

Lastly, NGS takes a more active approach to training and re-tooling its workforce, including succession training, long term training, supporting sabbaticals and technical transfer with visiting scientists.

NGS provides many good day-to-day *core capabilities*. Still, in this era of smaller workforces, it is critical that NGS transfer to outside users the capacity to perform good work that was often reserved for NGS to perform directly, while still maintaining the ability to perform core capabilities. This will result in a variety of small changes, and continued good works—in essence, a shift in business style from "do it all" to "enable it all; do some ourselves".

What will be critical in the future will be improving (not necessarily expanding) NGS infrastructure and focusing on a two-way communication with NGS stakeholders.

NGS must change its products and services, considering the interests of, and taking the direct input of, the stakeholders. Revitalizing the Federal Geodetic Control Subcommittee (FGCS) will be critical for developing stakeholder input. This last step is crucial, considering the number of changes being proposed in this plan to NGS specifications, guidelines, tools and manuals.

On a more internal note, NGS will empower the Products and Services Committee (PSC) with greater responsibility to directly influence the assignment of NGS resources toward developing new products, as well as ensuring that existing products and services are either updated or retired, as appropriate.

In order to increase the stakeholder feedback to NGS regarding products and services, the PSC will also be empowered to seek such input directly (within Federal Advisory Committees Act (FACA) guidelines). Furthermore, NGS will continue to make use of the County Scorecard process—a vital tool in assessing the geographic breakdown of NGS' effectiveness on a county-by-county basis, though new tools for evaluating more local or more statewide information should ultimately be developed.

Last, but certainly not least, NGS must continue to expand the knowledge base of its employees, while ensuring that critical institutional knowledge is retained. Quite simply, this will require regularly setting aside money for educational and training opportunities (including, but not limited to, annual NGS budgeting to sponsor long-term training, continuing education, sabbaticals and visiting scientists). Furthermore, critical tasks will be identified, and an *achievable* succession planning strategy will be developed and will become one of the critical documents of consideration during the development of annual performance plans.

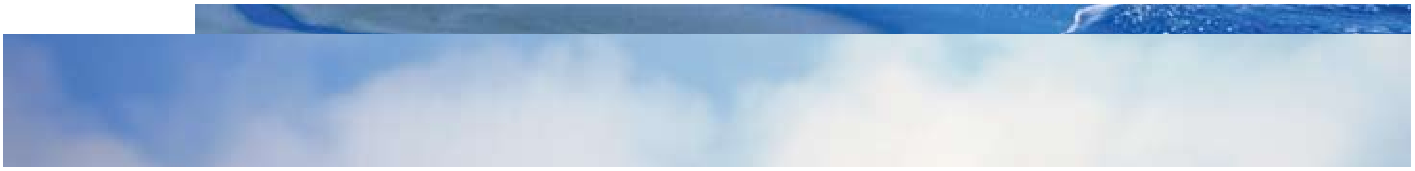
The initial steps needed to be taken **within two years** in order to achieve the vision are found below.

Table 4: Two-year Milestones Toward Evolving Core Capabilities

Task Lead	Description
GSD	Develop and deliver a GNSS RTK workshop to NGS and non-NGS persons.
SDD / SRSD	Formally adopt one geospatial graphic and analysis tool for use by all of NGS employees in their duties.
SDD	Phase out all DOS-based programs.
SDD	Redesign datasheets.
OAD / GRD / SDD	Make new tools such as PDA-based applications and non-bluebook data submittal available.
GSD	Create a branch for the state advisors.
Director's Staff / GSD	Perform a critical analysis of the state advisor program as currently executed, develop alternatives and collect stakeholder feedback on the current program weighed against alternatives.
OAD	Make all NGS field manuals and technical documents available in digital form on the internet.
SDD / GSD	Update NGS main Web page, including naming responsible parties for updating and removing all dead links.
GSD	Develop new flyers for all NGS products.
All Divisions	Deliver data in efficient, modern ways (such as ArcGIS server).
GSD	Acquire the requisite hardware and software to fully create NGS multimedia presentations, including DVDs, streaming videos and voiced-over slideshows, as well as GIS-friendly internet products and services.
GSD	Develop a new standardized Power Point template for use around NGS.

Table 4: Two-year Milestones Toward Evolving Core Capabilities

Task Lead	Description
SDD / GSD	Craft and adopt a policy linking the basic look and feel of the Web page with other outreach materials.
GRD	Overhaul the leveling program of NGS comprehensively, beginning with improving the method for users to submit leveling project to NGS. Further steps will include the establishment of an "OPUS-leveling" online tool built upon a complete and newly researched assessment of all reductions and field procedures suitable for all leveling projects. This research will yield a new manual for geodetic leveling. The final step will be to make OPUS-leveling operational, including functionality for users to submit their data through the tool.
GSD	Develop "layperson" versions of outreach materials geared for stakeholders. (For example: teach people how geodesy provides accurate heights for the determination of potential flood areas in your city).
Director's Staff	Analyze the Geodesy Program's new GPRA measure and the results of the County Scorecard to develop recommendations for improvements in NGS products and services.
SRSD	Craft and execute the official policy on NGS' role in enabling real-time access to the NSRS.
Director's Staff	Re-establish the membership of FGCS, and call for regular meetings to gain official United States Government buy-in for the updating of numerous NGS guidelines and meeting stakeholder needs.
Director's Staff	Re-establish the membership of FGCS, develop long and short-term plan for FGCS and develop the annual work plan required by FGDC.
Director's Staff	Identify the critical institutional knowledge that must be retained, and develop an *achievable* succession planning strategy for NGS to use in the development of annual performance plans.
Director's Staff	Identify critical institutional knowledge *gaps* NGS must close to successfully perform their mission in future years. Develop a plan for gaining such knowledge and provide the budget necessary to achieve it.
OAD	Continue to provide airport surveys to the FAA as ordered, through a mix of core capabilities and outside contracting (overseen by NGS).
RSD	Continue to delineate 20% of ports and 5% of the additional United States coastline annually.
SRSD	Continue to provide access to the geodetic latitude, longitude and height components of the NSRS via CORS and OPUS-GNSS or NGS datasheets.
SRSD	Continue to provide outside users the ability to determine geoid undulations (hybrid or gravimetric), NAVD 88 heights, Dynamic heights and surface gravity.



In addition to these initial steps, the following **five- and ten-year milestones** are identified to increase outside capacity while maintaining core capabilities. The steps needed to get to these milestones are left for future planning documents:

Five-Year Milestones (2013):

1. All point-based data are served to the public via a customized, colorized, hyperlinked Web-based datasheet containing images and text limited to those quantities a customer requests.
2. NGS has a vibrant Web page with updated field documents, papers and presentations, as well as comprehensive online educational materials—all easy to find and each with an identified point of contact.
3. NGS serves up a variety of products using Web services and real-time data streaming.
4. Access to the NSRS is efficiently performed via modern tools and does not *require* submission of field data to the NGS database, but which does provide an efficient and simple method for users to submit their field data to the NGS database.
5. Over 90% of all United States counties are fully or substantially enabled with the infrastructure, tools and capacity for accurate positioning (see Appendix B).
6. All NGS manuals and technical documents have been made available digitally with updates reflecting modern technology and procedures.

Ten-Year Milestones (2018):

1. All NGS standards, specifications and guidelines are updated to the latest technologies, and available digitally with an annual status check and potential update cycle.

Achieving the Vision: 5
Visibility

Vision Summary: NGS strengthens its status as a world leader in geospatial activities through increased participation in the international arena and the use of partnerships with universities, Federal agencies, state governments and other stakeholders. Some of this participation will include broad educational initiatives, a robust visiting scientist program, an improved publication record, participation and leadership in national and international scientific organizations, development of world-standard geospatial standards and specifications and cooperative working relationships with diverse partners around the country and the world.

The preceding portions of this plan have focused on specific *technical* issues surrounding large NGS programs, but this chapter will specifically address a variety of *business style* issues which must change if, in accordance with its stated mission, NGS is to strengthen and retain its position as a world leader in geospatial activities.

One of the core problems with maintaining world leadership in geospatial activities has been a shrinking NGS workforce, coupled with a lethargic approach toward retraining and retooling the existing workforce. This must change. NGS must reach out to universities to encourage the training of new geospatial experts and, in fact, must take steps to ensure basic geospatial topics are taught at the high school and middle school levels. The immediate future hires of NGS should also concentrate on highly skilled and educated scientists capable of applying modern tools to the NGS mission. One other change NGS must make is to revitalize and fully support a vibrant visiting scientist program. In the 1970's and 1980's, NGS was host to numerous international scientists. In order to improve NGS' stature as a geospatial world leader while offsetting a reduced workforce, NGS should restart a strong visiting scientist program. The program should include not only scientists visiting NGS, but also NGS employees taking sabbaticals at other institutions. Furthermore, the revitalization of FGCS, including strong liaisons with FGCS agencies, will allow NGS to lead geospatial activities on a national scale.

The participation between NGS and scientific organizations must be allowed to grow and prosper. There is a non-quantifiable but distinctly positive benefit to NGS scientists belonging to and participating in the meetings of national and international organizations. NGS should also be contributing to the knowledge base of such organizations while learning and adopting their latest findings. NGS employees should be given every opportunity to fully engage with organizations such as the International Union of Geodesy and Geophysics (IUGG), the International Association of Geodesy (IAG), the Fédération Internationale des Géomètres (FIG), the Institute of Navigation (ION), the American Geophysical Union (AGU), the American Congress on Surveying and Mapping (ACSM) the American Society for Photogrammetry & Remote Sensing (ASPRS), and the American Society of Civil Engineers (ASCE), to name a few.

On a related note, NGS must improve its participation in international scientific services. The International Earth Rotation and Reference System Service (IERS) and the International GNSS Service (IGS) are both critical services

NGS has relied upon for decades to perform its mission and tie the NSRS to the international coordinate frames. In fact, NGS should consider it a duty to be more active in both of these services. Furthermore, greater NGS participation in FIG, especially commissions Four (Hydrography), Five (Positioning and Measurement) and Eight (Spatial Planning and Development) will aid NGS in achieving global leadership in many geospatial activities.

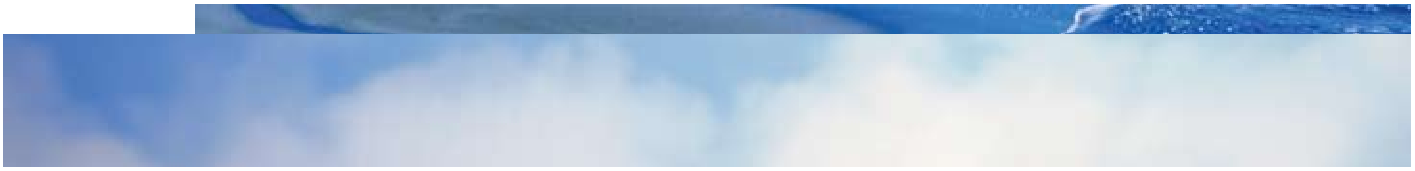
On a national level, but still part of the implementation of a global leadership strategy, NGS will have a stronger focus on nationalizing the Height Modernization program. Begun in 1998 through a report to Congress, the program has been implemented predominantly on a state-by-state basis. This has had the unfortunate effect of unbalancing NGS' ability to serve its constituents on a national level. Such a change clearly takes time to implement. The first step will be for NGS to engage with the Federal Geodetic Control Subcommittee on the change of direction. Additionally, NGS must actively engage with its current Height Modernization partners to develop a plan which transitions Height Modernization efforts in the next ten years toward a more national approach. A plan to nationalize the program will likely involve directing Height Modernization efforts toward the (previously mentioned) goals of "Modernize CORS" and "Improve Gravity Field Modeling".

Finally, the good work of NGS must be brought to light as often as possible. This means specifically publishing research and updating all standards and specification to reflect the very latest in technology and field procedures.

The initial steps needed to be taken **within two years** in order to achieve the vision are found in the table on the next page.

Table 5: Two-year Milestones toward Increasing Agency Visibility

Task Lead	Description
SRSD / OAD	Develop a plan for the update or retirement of all field guidelines and other technical documents (including, but not limited to: geodetic leveling, GPS derived orthometric heights, GPS derived ellipsoid heights, the Geodetic Glossary).
All Divisions	Acquire any/all of the most modern remote sensing, surveying and geodetic field equipment available (including, but not limited to: GLONASS and Galileo receivers, RTK network equipment, Laser Levels, GPS/Laser surveying equipment, absolute gravimeters, airborne gravimeters)
GRD	Develop and institute requirements for all researchers to publish in peer reviewed scientific journals regularly. Also included should be requirements to present findings at scientific and professional meetings.
Director's Staff / GSD	Hold a series of Height Modernization partnership meetings, and develop a plan to allow the execution of Height Modernization on a national basis.
Director's Staff	Develop at least one complete college-level course of educational materials on a geodetic topic. Deploy the material on both the NGS Web page, as well as distributing it to various surveying and mapping programs at universities worldwide.
Director's Staff	Develop and make available (in conjunction with NOS Communications and Education Division) educational materials appropriate for grades K through 12.
GSD	Develop outreach World Wide Web (WWW) materials and workshops expressing the dynamic nature of the NSRS.
GSD	Develop outreach materials for the WWW and workshops on this ten year plan.
Director's Staff	Set aside a fixed budget annually to finance graduate student research applicable to the NGS mission.
Director's Staff	Set aside a fixed budget annually to finance visiting scientists.
Director's Staff	Re-establish FGCS membership, and call for regular meetings to gain official United States Government buy-in for updating NGS guidelines and to meet stakeholder needs.
Director's Staff	Re-establish the membership of FGCS, develop a long-term plan for FGCS and develop the annual workplan required by FGDC.
GRD / SRSD	Volunteer the services of NGS to serve a standard four-year term as the "Analysis Center Coordinator" for the IGS.
Director's Staff	Participate in the National Research Council's study on the need for, and make-up of, geodetic networks.
All Divisions	Encourage NGS employee membership in scientific organizations and, to the extent fiscally possible, fund travel to national and international conferences. Special emphasis should be placed on NGS employees serving as officers and board members of IAG, AGU, TRB, ACSM, ASPRS and FIG (commissions 4, 5 and 8).



In addition to these initial steps, the following **five- and ten-year milestones** are identified to implement a global leadership strategy. The steps needed to get to these milestones are left for future planning documents

Five-Year Milestones (2013):

1. NGS has a proven record of funding and hosting visiting scientists to the extent such invitations are sought by international colleagues.
2. NGS employees directly participate in the IGS, IERS, ION, AGU, FIG, ACSM ASPRS, FGCS, PNTCO and IAG, both technically and managerially.
3. A complete set of educational tools is available on the NGS Web page for science teachers to use in the classroom.

Ten-Year Milestones (2018):

1. NGS develops strong ties to multiple universities, funding research and applying research for application to the mission.
2. NGS strongly holds a position as world leader in geospatial activities.
3. NGS provides technical support to at least two other countries in developing critical geodetic infrastructure.

Appendix A

Documentation for NGS Missions

Agencies such as NGS which are hierarchically a few levels removed from the President's cabinet, may find it difficult to find either law, orders or mandates directly ordering them to perform specific tasks. However, there are a few key documents which do address the mission of NGS directly, while indirectly assigning that mission to NGS.

In 1993 the National Research Council (NRC) performed a study entitled **Toward a Coordin–ated Spatial Data Infrastructure for the Nation.** While not a government mandate, the study led to some of the strongest documents defining the missions of NGS in existence.

One of these documents is **OMB Circular No. A-16** ("Coordination of Geographic Information and Related Spatial Data Activities"). This document directed the Federal Geographic Data Committee (FGDC) be in charge of establishing the National Spatial Data Infrastructure (NSDI). Furthermore, it directly names NOAA as the "lead agency" in providing "geodetic control" for the Federal government in support of the NSDI. The geodetic control specifically named is the National Spatial Reference System (NSRS). Because no other agency inside of NOAA deals in establishing geodetic control (nor specifically the NSRS), the naming of "NOAA" as the lead agency effectively translates into "NGS". Also, since the NSDI requires "access for all citizens to spatial data", it is specified in our latest mission statements that the NSRS be accessed by "all United States citizens."

Additionally, **Executive Order 12906** ("Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure") backs up OMB Circular No. A-16 and empowers the FGDC with development of the NSDI.

In 1994, the NRC performed another study entitled **Forum on NOAA's National Spatial Reference System.** Again, while not direct mandates, the NRC's recommendations are considered directly relevant to the NGS introspection in defining its missions as they pertain to the NSRS. This is especially true, considering how the 1993 NRC study led to Executive Order 12906 and OMB Circular No. A-16. In this report, the NRC recognized that NGS should implement the NSRS as "the single, coordinated reference system" in order to achieve "maximum returns" (economic as well as in support of the NSDI).

In the form of United States laws addressing this issue are the **U.S. Coast and Geodetic Survey Act,** as amended. This has been codified in the US Code in several sections of Title 33 of the US Code (the specific cite would be 33 USC § 883a to roughly § 888 or so). Although wording in this law is difficult at a minimum, if one studies the Statue in Sec 883a, one can see that the "Secretary of Commerce…in order to provide basic data…for scientific purposes…can conduct geodetic-control surveys…and related… measurements…investigations, and observations". This language is highly vague and at the Department of Commerce level. Still, besides NGS, no agency within the Department of Commerce deals with geodetic data, and as such, this act has been seen as giving NGS the mandate to perform the necessary field surveys and data collection to provide for the common good.

Similarly, one can take wording from another law, the **Hydrographic Services Improvement Act of 1998** and find direct relevance to the missions of NGS. In the act, the term "hydrographic" is used, but it is broadly defined within the act to *include* geodetic data. Taking nothing out of context, but by simply looking at what *geodetic* issues the Act addresses (within the broader context of hydrographic issues), the law can be read partly as:

> The Administrator of NOAA is to acquire and disseminate geodetic data, promulgate standards for both the data and services of such geodetic data, ensure comprehensive coverage of that geodetic data, maintain a national database of such data and participate in the international development of standards for geodetic data and geodetic services.

This act speaks to the third mission of NGS—the standards and specifications of geodetic data. Because the power is entrusted to the administrator of NOAA, and because no other office in NOAA deals with geodetic data, NGS understands the act to mean that NGS is to be the office in charge of geodetic standards and specifications.

Finally, the last time NGS went through a strong introspection and mission-defining exercise was in 1994. That process led to the document **National Geodetic Survey: Its Mission, Vision, and Strategic Goals.** The document stated but one mission, which in retrospect was quite broad, while failing to address either shoreline mapping or the development of standards and specifications. Also, many of the technologies used today were not in use in 1994. Additionally, that document—like this one—is based on a combination of outside influence and agency introspection, and it is therefore open to re-interpretation. All of these issues clearly indicate that a time has come for NGS to re-state the missions it will accomplish in the future.

Appendix B
Government Performance and Results Act (GPRA)

Geodesy GPRA Measure Overview

Percentage of United States counties rated as fully enabled or substantially enabled with accurate positioning capacity (Goal: Increase percentage of counties rated as substantially or fully enabled, with the infrastructure, tools, and demonstrated local capacity for accurate positioning, from 25% in 2004 to 90% in 2011).

Background

The Geodesy Program's capacity to enable state and local governments and the private sector to obtain accurate positioning is a critical factor in facilitating equity of commerce in an economy based on land ownership. This capacity is also fundamental to NOAA's continued ability to provide navigation services, conduct coastal restoration projects and support adaptation to the effects of climate change, particularly sea-level rise. To determine how well a county is enabled with accurate positioning capacity, NOAA will track county-level usage of NOAA's OPUS in its several variations—for leveling projects, GPS projects, and single-point positioning. However, NOAA recognizes that OPUS solutions in one county may have been performed by users from other counties, and so will eventually need to develop more accurate methods of determining the geographic distribution of the Geodesy Program's capacity to enable local users to access the NSRS.

Using OPUS data for the new GPRA performance measure, NOAA will feature automated data capture through a connection to the NGS database. With these data, NOAA can easily create Geographic Information Systems to visually show performance county-by-county on a map of the United States. County level is the most appropriate geographic unit, because it offers coverage for the entire United States, and there is an existing county-level infrastructure for addressing spatial issues. Land records are maintained at the county level and the supporting local survey projects, relying on geodetic control, are typically at the county level. NOAA's constituents for the Geodesy Program can readily identify with counties.

However, U.S. counties differ in population, size, land use, and other characteristics, and NOAA is investigating its differing geodetic needs. NOAA will validate a county's capacity for local positioning through direct coordination with localities, such as new stations from that county submitted and loaded into the NGS database, or OPUS project acceptance by NOAA. By assessing the user needs of county surveyors, counties, and their associations, NOAA will validate that the Geodesy Program is meeting local positioning needs. The Geodesy GPRA measure will track progress toward these goals.

Indicator

The *level* of capacity varies across the nation. This variation is measured as deficient, sufficiently enabled, and fully enabled as follows:

1. *Deficient* capacity to conduct accurate positioning

   a. Indicates county has not demonstrated it has the NOAA-enabled infrastructure, tools, and local capacity needed for accurate positioning. This is indicated by fewer than 25 OPUS solution generations in a given county in the last year and no capacity validation (such as by OPUS project submission).

   b. Color indicator on county map—Red or Blank.

2. *Substantially enabled* capacity to conduct accurate positioning.

a. Indicates county has demonstrated it has the NOAA-enabled infrastructure, tools, and local capacity needed for accurate positioning. This is indicated by 25 or more OPUS solution generations in a given county in the last year.

b. Color indicator on county map—Yellow.

3. *Fully Enabled* to conduct accurate positioning.

a. Indicates county-validated NOAA-enabled infrastructure, tools, and local capacity needed for accurate positioning. This is indicated by having the four following elements:

i. NGS has identified a county designated representative; such as: County Surveyor, County Engineer, GIS Administrator, or equivalent.

ii. The county participates in the State Advisor/Coordinator program or has a state designated equivalent.

iii. County has submitted accepted "blue book" data to NGS through activities such as: leveling project software, GPS projects and OPUS.

iv. County completes a county-based, accurate-positioning scorecard (County Scorecard).

b. Color indicator on county map—Green.

Unit of Measure

Percentage of counties.

Baseline

By the end of FY 2004, 25% of counties are substantially enabled (Yellow) by NOAA to conduct accurate positioning. This figure is based on Online Positioning User System (OPUS) use in FY04. OPUS use statistics is the major component of the GPRA measure. The capability for OPUS-GNSS for project submission and other validation methods is still under development, therefore as of 2004, 0% of counties were fully enabled (Green) by NOAA to conduct accurate positioning.

Based on NOAA data to date and consultation with stakeholders, 25 OPUS solutions per county per year is an appropriate threshold value. NOAA has found that surveying projects involving OPUS can be expected to produce one to three OPUS solutions over several days as marks are verified or established, and 25 OPUS solutions represent eight to 25 individual surveying projects. Number of projects shows a sustained activity of use over time. Preliminary discussions concerning this threshold value with the National Association of County Surveyors found that usage lower than 25 solutions would not be indicative of consistent OPUS use and would indicate a county has not demonstrated local capacity for accurate positioning.

Measure	FY 2004 (baseline)	2005	2006	Target 2007	2008	2009	2010	2011
Percentage of U.S. counties rated as substantially enabled or fully enabled with accurate positioning capacity	25%	28%	39%	49%	60%	75%	82%	92%

- By 2011, 92% of all U.S. counties have substantial infrastructure, tools, and capacity in place for accurate positioning (i.e., score of Yellow or Green).
- Ultimate target: 100% of U.S. counties are fully qualified, NOAA-enabled Geodetic Communities (i.e., score of Green).

Components Defining Ranking

Percentage of counties having demonstrated capacity for accurate positioning—a measure of the NOAA capability to build outside local capacity for accurate positioning:

- *Deficient* capacity to conduct accurate positioning—Red or Blank.
- *Substantially enabled* capacity to conduct accurate positioning—Yellow.
- *Fully Enabled* to conduct accurate positioning—Green.

Targets vs Actuals

Ranking	FY 2004 (baseline)	Targets 2005	2006	2007	2008	2009	2010	2011
Yellow	25.34%	28%	37%	44%	52%	62%	62%	62%
Green	0%	0%	2%	5%	8%	13%	20%	30%
Total GPRA (Green and/or Yellow)	25.34%	28%	39%	49%	60%	75%	82%	92%

Ranking	FY 2004 (baseline)	Actual 2005	2006	2007	2008	2009	2010	2011
Yellow	25.34%	32.2%	42.73%	TBD	TBD	TBD	TBD	TBD
Green	0%	0%	2.01%	TBD	TBD	TBD	TBD	TBD
Total GPRA (Green and/or Yellow)	25.34%	32.2%	43.25%	TBD	TBD	TBD	TBD	TBD

Appendix C
Glossary

Geodetic Height
The distance measured positively outward from the reference ellipsoid along the normal to the reference ellipsoid to the point of interest. As such it is a geometric, not physical, coordinate.

Geodetic Latitude
The angle formed by the equatorial plane and the perpendicular to the reference ellipsoid which passes through the point of interest. As such it is a geometric, not physical, coordinate.

Geodetic Longitude
The angle formed by the prime meridian plane and the plane which contains the semi minor axis of the reference ellipsoid and the point of interest. As such it is a geometric, not physical, coordinate.

Geometric Geodesy
That branch of geodesy concerned with the determination of coordinates which have no direct dependence on the gravity field of the Earth. (e.g. Earth-centered, Earth-fixed Cartesian coordinates, or geodetic latitude, geodetic longitude and geodetic height)

Dynamic Height
A number representing the difference between gravity potential at the geoid and at a point of interest, scaled into units of length through an arbitrarily chosen constant.

Ellipsoid(al) Height
see Geodetic Height

Equipotential Surface
A closed smooth surface of Earth's gravity field formed by a locus of points all having the same gravity potential. Has the interesting properties of not intersecting any other equipotential surface and also having the local direction of gravity everywhere perpendicular to itself.

Geocenter
The coordinate of the center of a reference frame, often associated with the center of mass of the Earth.

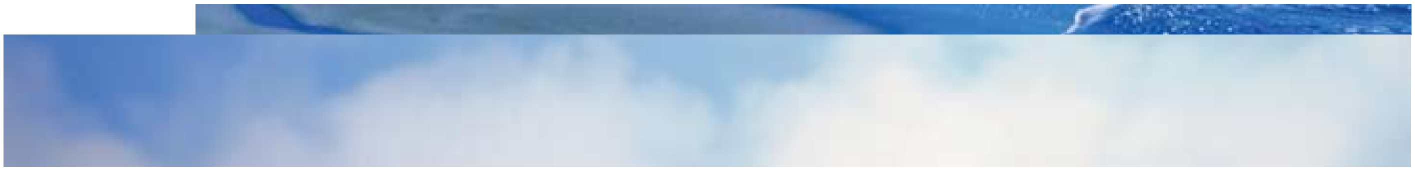
Geoid
The one equipotential surface of Earth's gravity field which best fits global mean sea level in a least squares sense.

Gravity Potential
The amount of potential energy due to both the gravitational attraction of Earth's masses and spin of the Earth.

OPUS
The NGS Online Positioning User Service. This is a generic term for the suite of software packages which allow users of various geodetic methodologies (including GNSS and leveling) to process their data and access the NSRS through the internet. (This was originally the name of a GPS processing service run by NGS, but that service is now called "OPUS-Original")

OPUS-GNSS
A suite of online GNSS processing tools, which will allow a user to input various GNSS data (multiple receivers, multiple signals, multiple constellations, static or dynamic) and have the data processed and adjusted and coordinates returned via email, and has the ability to share said results with the world, thus allowing the user access to the NSRS.

OPUS-Original
An online GPS processing tool, with PAGES as the core processing engine, which takes a single 2 hour static GPS data set and returns coordinates via email, thus allowing a user access to the NSRS. It is one of the many tools in the OPUS-GNSS suite.



OPUS-Leveling

An online geodetic leveling processing tool, which will allow a user to adjust geodetic leveling projects and return coordinates, thus allowing a user access to the NSRS.

Orthometric Height

The distance measured upward from the geoid along the curved plumb line connected to a point of interest.

Physical Geodesy

That branch of geodesy concerned with the determination of coordinates which have a direct dependence on the gravity field of the Earth.

Reference Ellipsoid

The singular ellipsoid of defined shape (determined by two parameters) which is used in a datum for the determination of geodetic latitude and geodetic longitude.

Appendix D
Acronyms

ACSM	American Congress on Surveying and Mapping
AGU	American Geophysical Union
ASCE	American Society of Civil Engineers
ASPRS	American Society for Photogrammetry & Remote Sensing
CONUS	Conterminous United States
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Station
DOC	Department of Commerce
ESC	Executive Steering Committee
FACA	Federal Advisory Committee Act
FGCS	Federal Geodetic Control Subcommittee
FGDC	Federal Geographic Data Committee
FIG	Fédération Internationale des Géomètres
GEOSS	Global Earth Observation System of Systems
GGOS	Global Geodetic Observing System
GNSS	Global Navigation Satellite Systems
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRD	Geosciences Research Division
GSD	Geodetic Services Division
IAG	International Association of Geodesy
IERS	International Earth Rotation and Reference System Service
IGS	International GNSS Service
IOCM	Integrated Ocean and Coastal Mapping
ION	Institute of Navigation
ITRF	International Terrestrial Reference Frame
IUGG	International Union of Geodesy and Geophysics
LIDAR	Light Detection and Ranging
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSRS	National Spatial Reference System
NWLON	National Water Level Observation Network
OAD	Observation and Analysis Division
OCONUS	Outside of CONUS
OMB	Office of Management and Budget
OPUS	Online Positioning User Service (See Glossary for more details)
PNTCO	Position, Navigation and Timing Coordination Office
PSC	Products and Services Committee
RSD	Remote Sensing Division
RTK	Real-Time Kinematic
SDD	Systems Development Division
SRSD	Spatial Reference System Division
TRB	Transportation Research Board