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REPORT FROM THE 2015 GEOSPATIAL SUMMIT ON IMPROVING THE NATIONAL SPATIAL REFERENCE SYSTEM

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The intent of this report is to capture a snapshot of the presentations and discussions that were part of the National Geodetic Survey's (NGS) 2015 Geospatial Summit. This report is not intended to take the place of a formal proceedings document or an official transcript. Within some sessions, speakers referred to each other's presentations and reiterated important messages. In such cases, the materials presented at the meeting may have been slightly reordered within this report to improve readability. The summit was video recorded in its entirety and can be viewed for a more thorough analysis of the event. NGS has created a Web page containing detailed information regarding the 2015 Geospatial Summit, including links to presentations and the video recordings from the event:

http://www.geodesy.noaa.gov/2015GeospatialSummit/

Immediately following the summit, two additional meetings were held: the quarterly Federal Geodetic Control Subcommittee (FGCS) meeting and annual Height Modernization partner meeting. Since both of these groups continued to discuss the impacts the new references frames will have on the user community, brief summaries of these meetings are also included in this report.

An event the size and scope of the 2015 Geospatial Summit cannot succeed without the hard work and dedication of many individuals. NGS wishes to acknowledge and sincerely thank the following people who contributed to the overall success of the Summit.

First, our special thanks and appreciation goes to Dr. Russell Callender, Acting Assistant Administrator of NOAA's National Ocean Service. Dr. Callender's opening remarks were key in highlighting the importance of the National Spatial Reference System (NSRS) and its relevance to NOAA's national priority of improving community resilience.

To all the NGS speakers who took time to prepare and participate, we give sincere thanks and praise. Your contributions were the heart of NGS' message to our constituents. We especially thank Dr. Neil Weston for his excellent work moderating the entire event.

Event logistics were successfully coordinated by the dedicated efforts of the summit planning team. A big "thank you" goes to Brett Howe, Lucy Hall, Sonita Tiwari, Sonja Bowen, Simon Monroe, Erika Little, Brian Shaw, and Christine Gallagher. We also thank the many NGS volunteers who staffed tables, ran errands, and simply did everything necessary behind the scenes to help make the summit a success.

NGS also wishes to thank our conference partners: the Management Association for Private Photogrammetric Surveyors (MAPPS) and the National Society of Professional Surveyors (NSPS). The 2015 Geospatial Summit was part of a larger "National Surveying, Mapping and Geospatial Conference" organized and led by MAPPS and NSPS, and this partnership successfully drew a diverse and talented audience to the week-long series of meetings and events.

Last, but absolutely not least, we deeply thank the attendees who participated in the 2015 Geospatial Summit. We greatly appreciate the agencies and individuals who invested their time and provided their feedback. The engagement of the summit attendees is our most valuable resource as we move toward the future and an improved National Spatial Reference System.

Throughout its history, the National Geodetic Survey (NGS)—previously the Survey of the Coast, the Coast Survey, and the Coast and Geodetic Survey—has performed the mission of establishing a consistent coordinate frame for the mapping of the Nation. This mission was refined in recent years to reflect today's terminology:

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

Beginning in 2008, NGS issued a Ten-Year Plan announcing its intent to improve the National Spatial Reference System (NSRS) in a manner that will include the replacement of two key elements of the NSRS, known historically as the horizontal datum (North American Datum of 1983 [or NAD 83]) for determining latitude and longitude, and the vertical datum (North American Vertical Datum of 1988 [or NAVD 88]) for determining heights.

In 2010, NGS published a white paper titled "Improving the National Spatial Reference System" containing detailed information on both the nature and causes of the systematic errors and deficiencies in the current datums of the NSRS. The same year, NGS hosted a Federal Geospatial Summit to further explain the problems with NAD 83 and NAVD 88 and the plans NGS has proposed to fix them. NGS also used the event as an opportunity to answer questions from the audience regarding the reference frames that will replace the current datums.

The 2015 Geospatial Summit provided an opportunity for NGS to share updates on the planned replacement of NAD 83 and NAVD 88 with other federal agencies and the broader mapping community. It was the first such event since 2010, and it allowed agencies and constituents in attendance to voice their comments, questions, and concerns regarding the replacement reference frames.

NGS presented a series of talks on the first day of the summit. Additional presenters on day two discussed the legislative hurdles necessary for successful adoption of the new reference frames. The Canadian Geodetic Survey recently updated its Canadian vertical geodetic reference frame, and their efforts were also discussed on day two. Additionally, there was an opportunity to present feedback from a variety of stakeholders on the second day of the event. The summit agenda is reproduced in Appendix B.

NGS Director Juliana Blackwell commenced the Geospatial Summit by welcoming the attendees and introducing the Acting Assistant Administrator of the National Ocean Service (NOS) Dr. Russell Callender. Dr. Callender's opening remarks clearly communicated the significance of the event and highlighted the importance of the National Spatial Reference System (NSRS) in providing foundational information critical for community resilience. Improving community resilience—the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies—is a national priority strongly supported by both NOAA and NOS. Dr. Callender also stressed that the successful modernization of the NSRS depends on assistance from NGS' partners: other federal agencies, state and local governments, and the private sector.

Ms. Blackwell then highlighted key points from 2010 Federal Geospatial Summit, the last large-scale meeting NGS hosted to discuss with stakeholders the replacement of NAD 83 and NAVD 88. Following previous efforts to replace national datums, NGS understands it must expect to invest years of effort, as well as significant geodetic expertise, to complete a successful transition. NGS has also learned from experience that some stakeholders may be slow-adopters of new datums; in fact, some users may never adopt a newly-released datum. This reluctance to change can be ascribed to the fact that users often care more about differential accuracy than absolute accuracy in their surveying and mapping work. NGS believes it can overcome these obstacles with strong communication and the development of support tools for the stakeholder community.

In summary, Ms. Blackwell described attendees at the 2010 Federal Geospatial Summit as "cautiously optimistic" after hearing about the proposed endeavor to replace NAD 83 and NAVD 88. While NGS expects the adoption of true time-dependent coordinates to be slow, some users already need this type of information. NGS hopes to build on this interest and excitement within its stakeholder community to successfully replace NAD 83 and NAVD 88 in 2022.

PROGRESS TOWARDS NEW REFERENCE FRAMES

Dr. Dru Smith and Mr. Joe Evjen provided updates on NGS' progress toward the new geopotential and geometric reference frames, respectively. NGS plans to replace the most recent realizations of the horizontal datum, NAD 83. There were separate realizations of NAD 83 for the coterminous United States (CONUS), the Pacific Plate, and the Marianas Plate, referred to respectively as NAD 83(2011), NAD 83(PA11), and NAD 83(MA11). Note that for consistency, all of California is referenced to NAD 83(2011), even though southwest California rests on the Pacific plate. Replacing this "horizontal" datum will change latitude, longitude, ellipsoid heights, and state plane coordinates.

NGS will replace the national vertical datum, NAVD 88, as well as a series of island datums, including the Puerto Rico Vertical Datum of 2002 (PRVD 02), the Virgin Islands Vertical Datum of 2009 (VIVD 09), the American Samoa Datum of 2002 (ASVD 02), the Northern Marianas Datum of 2003 (NMVD 03), and the Guam Vertical Datum of 2004 (GUVD 04). Additionally, an updated International Great Lakes Datum (IGLD) is planned to replace IGLD 85 and will be co-defined with the replacement of NAVD 88. Replacing these "vertical" datums will change orthometric heights and dynamic heights that reference an International Great Lakes Datum.

Next, Dr. Smith spent time defining some key terminology for the audience. He explained that during this summit NGS would use the term "geometric reference frame" to describe what will ultimately replace NAD 83. This new "geometric reference frame" will allow users to define a geocentric X, Y, and Z coordinate as well as latitude, longitude, and ellipsoid heights for any position. Similarly, NGS would use the term "geopotential reference frame" to describe what will ultimately replace NAVD 88. The new "geopotential reference frame" will encompass more than simply a datum to reference heights; it will include geoid undulation (synonymous with geoid height), orthometric height, gravity, and deflection of the vertical for any coordinate.

Both Dr. Smith and Mr. Evjen described specific components that must be completed to replace NAD 83 and NAVD 88. Specifically:

1. For any point in or above the United States and its territories, all OPUS products will use GNSS data to yield consistent latitude, longitude, ellipsoid height, orthometric height, and dynamic height in the new geometric and geopotential reference frames at the epoch of the survey.

2. A transformation tool exists to convert latitude, longitude, and ellipsoid height between each NAD 83 epoch 2010.00 realization (i.e. NAD 83[2011], NAD 83[PA11], or NAD 83[MA11]) and the new geometric reference frame, at some reference epoch (such as 2022.0.)

3. A transformation tool exists to convert orthometric heights or normal orthometric heights (as appropriate) between NAVD 88 or PRVD02 or VIVD09 or ASVD02 or NMVD03 or GUVD04 (at their as-published values, prior to 2022 at a mix of epochs) and the new geopotential reference frame at some reference epoch (such as 2022.0.)

4. A transformation tool exists to convert dynamic heights between IGLD 85 (at their as-published values, prior to 2022 at a mix of epochs) and the new geopotential reference frame at some reference epoch (such as 2022.0.)

5. The Federal Geodetic Control Subcommittee approves the new reference frames.

While not required to make the official transition, there are additional components that would reflect a more complete transition to, rather than just availability of, new reference frames. With this in mind, additional measures of success to consider are:

1. All NOAA geospatial products are consistent with the new reference frames.

2. NOAA geospatial products are understood and accepted by users.

3. New reference frames replace NAD 83 and NAVD 88 in state and local regulations, documentation, etc. as applicable.

PROGRESS TOWARDS A NEW GEOPOTENTIAL REFERENCE FRAME

Dr. Smith further explained that completing the five required components described above will require numerous intermediate steps, and he provided an update regarding NGS' progress in preparing for the new geopotential reference frame. Unfortunately, NGS has lost significant expertise in the last few years, so some tasks still require extraordinary work to adopt the new reference frames by 2022 as planned.

1. **Availability of complete airborne and terrestrial gravity[1] data set** over the United States and its territories at epoch 2022.0, in IGSxx is well underway. To complete a self-consistent airborne gravity data set, NGS' Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project is underway and on track for completion in 2021. Forty-two percent of planned data collection has been completed to date.

   However, re-processing airborne gravity into a new reference frame (such as whichever version of the IGS frame is available in 2022, called "IGSxx") is a time-consuming process that may require substantial contract work immediately prior to 2022. Additionally, an agreement has not yet been reached regarding how NGS will move all airborne gravity surveys into epoch 2022.0.

   NGS also has two million surface gravity points at epochs spanning a century, but no comprehensive effort is currently underway to adjust terrestrial gravity data sets to be consistent with airborne gravity data.

2. **Availability of a digital elevation model (DEM) of ellipsoid heights** in IGSxx/GRS-80 at 30-meter resolution, for epoch 2022.0, over the United States and its territories should be achieved. A DEM exists from Shuttle Radar Topography Mission (SRTM) data covering all needed areas at the correct resolution. However, the DEM epoch is 2000, so other DEMs (e.g. TerraSar-X) may need to be adopted to achieve a DEM nearer to the 2022.0 epoch.

3. **Production of three final geoid models and geoid secular velocity models for North America, Guam/CNMI, and American Samoa.** NGS expects to produce these geoid models on time, but NGS has not yet finalized the method used to combine all gravimetric data sources into the final geoid model. Additionally, the work necessary to ensure Canada and Mexico are in agreement to arrive at a mutually acceptable North American geoid model in 2022 is still underway.

   The task of producing geoid secular velocity models is on track because the data collected by satellite missions (e.g. GRACE) adequately provides a secular view of geoid shape change through time. NGS has decided that episodic geoid shape changes, such as earthquakes, will be re-surveyed at a to-be-determined threshold. Additionally, NGS decided not to track periodic geoid changes (e.g. annual melt/thaw cycles of glaciers) as part of the geoid. However, NGS does need to provide contingency plans for geoid monitoring, should GRACE-like satellites be unavailable in the future.

4. **Development of software to interpolate geoid undulations** is on track, because NGS has many products and services that require interpolation from either random points or off a grid. Before 2022, NGS hopes to provide one consistent interpolator in all products and services.

[1] "Gravity" will mean "vertical acceleration of gravity" unless stated otherwise.

5. **Development of dynamic heights software** to compute dynamic heights from ellipsoid heights, geoid undulations, and surface gravity requires additional investment to remain on track, because the resources have not been allocated to study the accuracies achievable from GNSS-derived dynamic heights or to convert that research into functioning software.

6. **GNSS survey on NAD 83, NAVD 88, and IGLD 85 marks will need to be undertaken closer to 2022** to properly support a transformation tool. While NGS supports an annual "GPS on bench mark" campaign, a national campaign should occur between 2018 and 2021 to support the greatest nationwide accuracy.

PROGRESS TOWARDS A NEW GEOMETRIC REFERENCE FRAME

International Frame

The greatest change required in moving from NAD 83 realizations to the new geometric reference frame will be in shifting to a geocentric ellipsoid. This shift will simultaneously align the U.S. system with the international and global reference frames. It is, therefore, important NGS stays informed of the work being done to define the best international reference frames.

The International Terrestrial Reference Frame (ITRF) uses four global independent positioning technologies: International Global Navigation Satellite Systems Service (IGS), International Laser Ranging Service (ILRS), International Very Long Baseline Service (IVS), and International DORIS Service (IDS). ITRF frames are stable, and the coordinate shifts caused by updating to the most recent realization continue to get smaller over time. To contribute to this effort, NGS supports the International Earth Rotation and Reference System Service (IERS) Site Survey (ISS) Program. In the last four years, NGS has completed four surveys to improve the ties between various ITRF techniques.

Additionally, NGS directly contributes to the international reference frames by computing GPS satellite orbits, accurate to centimeters. NGS is one of the processing centers that contribute to the IGS final solution of GPS satellite orbits.

The new geometric reference frame will be based on the most recent IGS reference frame prior to 2022 (i.e. IGSxx). The effort is expected to progress without difficultly as each IGSxx iteration is created under the auspices of the IGS (part of the IERS). While NGS participates in and contributes to this process, we are not in control of it, and in the absence of any future IGSxx's, NGS will use IGS 08.

Continuously Operating Reference Station (CORS)

Mr. Evjen highlighted efforts more directly in support of the current NSRS. Just as the Continuously Operating Reference Station (CORS) Program is an important component in maintaining the NSRS today, it will also be a foundational component of the new geometric reference frame. As more GNSS constellations are coming online and being built out, many CORS sites have upgraded their equipment to GNSS stations. While NGS software does not yet incorporate GNSS data, NGS has begun to record GNSS data for many stations within the CORS network, and the data is available for users.

Foundation CORS are permanent reference stations NGS is installing across the country to better connect the National Spatial Reference System to the International Terrestrial Reference Frame. This year, NGS installed our first foundation CORS at a Coast Guard site in Richmond, Florida.

Online Positioning User Service (OPUS)

OPUS has proven itself to be an excellent tool for providing users access to the NSRS, and we believe it will become more important in the future. At the time of the summit, OPUS used the most current reference frames of NAD 83(2011)(EPOCH: 2010.0) and IGS08. It was also using GEOID12A to derive orthometric heights and HTDP 3.2.3 to determine velocities. To replace NAD 83 and NAVD 88 successfully, OPUS will need to seamlessly make the transition to the new reference frames.

Another important advancement in OPUS is the development and release of OPUS Projects. This tool gives users Web-based access to simple management and processing tools for projects involving multiple survey sites and multiple occupations. The advantages of OPUS Projects are: data uploading through OPUS, customizable data processing via the PAGES software suite, and visualization and management aids.

OPUS static also continues to be updated and improved. The most recent development is that it now computes five baselines and uses the best three. Users submitting to OPUS static can also share their solution, and there are almost 10,000 such solutions available to the public today.

Another OPUS advancement still in development is OPUS-NET, which more fully implements the available processing models in conjunction with changing the CORS selection criteria. This improvement significantly reduces the scatter in the north and east components and causes no degradation in the scatter in the height produced by OPUS Static.

LOOKING AHEAD

The geometric reference frame is directly tied to the new geospatial frame, because its ellipsoid heights will be combined with an improved geoid model to determine GNSS-derived orthometric heights. With this in mind, geoid-based orthometric heights are now available in the extended output of NGS' Online Positioning User Service (OPUS).

Metadata will be exceptionally important in making a good transition to the new reference frames. Positional metadata should include datum, epoch, and source to facilitate transforming from current to new datums. Maintaining original survey data will provide more accurate results.

BENEFITS OF THE NEW REFERENCE FRAMES

Next, Dr. Smith and Mr. Evjen highlighted the benefits of the new reference frames by outlining the existing problems they will help repair. NGS is eager to fix what is currently causing us to fail to provide positions/heights, provide inaccurate positions/heights, put undue burden on users, and/or waste resources. The problems and improvements listed below are organized by the current datum that will be most improved with the changes.

"Fixing" NAVD 88, PRVD 02, ASVD 02, NMVD 03, GUVD 04, and VIVD 09

1. Bench marks today are fragile and can be disturbed or destroyed over time. Bench mark locations are also sometimes inconvenient to reach, and there are areas of the country with a sparse bench mark network. In the new geopotential reference frame, orthometric heights will be equally available to GNSS receivers everywhere in the United States and its territories, without the need for bench marks.

2. Today, the movement of bench marks goes generally un-checked. However, in the new geopotential reference frame, orthometric heights at the epoch of the survey will be available to GNSS receivers due to time-dependent geoid models and time-dependent CORS positions.

3. Using today's vertical datums, the absolute accuracy of heights is dependent on distance from origin. In the new geopotential reference frame, the absolute accuracy of orthometric heights will have greater consistency throughout the country.

4. Today's vertical datums have a bias and tilt because the "zero height surface" of the datum is not the geoid. In the new geopotential reference frame, the geoid will be the zero height surface, and it will be built upon global satellite models.

"Fixing" NAVD 88 Only

1. Accuracy statistics today are limited, because heights rely on a first-order approximation (i.e. Helmert approximation), which has not been propagated into accuracy statistics. In the new geopotential reference frame, approximations are being quantified and bounded and will be reflected in accuracy statistics.

2. NAVD 88 uses inconsistent surface gravity surveys; more specifically, 2 million surface gravity measurements spanning decades and reflecting no time dependency. In the new geopotential reference frame, the gravity field will be consistent and epoch dependent, thereby directly influencing the time-dependent geoid and time-dependent orthometric heights.

"Fixing" PRVD 02, ASVD 02, NMVD 03, GUVD 04, and VIVD 09 Only

Island vertical datums today provide *normal* orthometric heights; heights which do not rely on actual gravity measurements. In the new geopotential reference frame, orthometric heights using local gravity information will be available to GNSS receivers on these islands.

"Fixing" International Great Lakes Datum of 1985 (IGLD 85)

IGLD 85 does not reflect glacial isostatic adjustment (GIA) changes, but in the new geopotential reference frame, dynamic heights at the epoch of the survey will be are available to GNSS receivers because of time-dependent geoid models, time-dependent CORS positions, and time dependent gravity field models.

"Fixing" NAD 83

Today, the NAD 83 frame is not geocentric. As a result, it is not aligned with the ITRF, satellite orbits frame, satellite product frame, GPS and Wide Area Augmentation System (WAAS) navigation frames, or international geodetic frames. This inconsistency can cause confusion, and many geodetic tools assume ITRF as a default frame. The new geometric reference frame will align with all of these other existing systems, greatly reducing confusion and the need for transformation.

Additional Height Improvements

1. Heights in the United States (with the exceptions of Guam, CNMI and American Samoa) will have continental consistency from pole to equator and Aleutians to Greenland. This is supported by the much larger extent of the 2022 geoid model used for the new geopotential reference frame.

2. Currently, a published height is held constant even when it may be moving with land motion. For the new geopotential reference frame, NGS will store and distribute heights on passive control, and changes over time will be reflected as actual changes, when the data supports detection of such changes.
3. In the new geopotential reference frame, dynamic heights will be available from GNSS surveys, rather than only from leveling surveys.

Additional Geometric Improvements

1. NAD 83 has a series of realizations both to account for land motion over time, as well as to take advantage of improvements in positioning technology. Moving to a new geometric reference frame will allow users to leave behind the cascade of NAD83 realizations.
2. NAD 83 can accommodate velocities, but only if it is regularly used in areas with significant land motion (e.g. western United States). As a result, surveying practices and the use of tools such as Horizontal Time-Dependent Positioning (HTDP) vary across the country. With the new geometric reference frame, velocities will be computed everywhere, allowing surveying and mapping professionals to adopt consistent techniques.

Dr. Neil Weston provided an overview of the international geospatial activities NGS participates in and that are relevant to the transition to new reference frames.

The International Association of Geodesy (IAG) has a commission on reference frames. This group works toward the definition, establishment, maintenance, and improvements of geodetic reference frames. They also work to advance terrestrial and space observation techniques, as well as collaborate internationally for the deployment of geodetic networks.

The United Nations Global Geospatial Information Management (UN-GGIM) aims to develop a global geodetic reference frame, develop a global map for sustainable development, and use geospatial information to support development. Recently, the United Nations General Assembly adopted a resolution recognizing the importance of a globally-coordinated approach to geodesy.

The International Committee on Global Navigation Satellite Systems (ICG) includes a United Nations Office for Outer Space Affairs engaged in many issues, including enhancing the performance of GNSS services, as well as reference frames, timing, and applications.

The U.S. Group on Earth Observations (USGEO) coordinates plans and assesses federal Earth observation activities. These activities include the development of sensor systems used to collect data that monitor earth systems. These data then contribute to models, simulations, and information products.

Finally, Dr. Weston mentioned NGS' participation with the International Federation of Surveyors (FIG) as an important community of practice to advance mapping and surveying practices around the world.

Dr. Smith and Mr. Brian Shaw presented information about accessing the new reference frames, including a discussion about new or planned NGS products, services, models, and tools. Today, people access the NSRS through coordinates at published geodetic control marks. When the new datums are adopted, however, this common practice will change. The information below describes how NGS envisions providing primary, secondary, and transformational access to the NSRS in the future, as well as a summary of how existing products and services may change.

Primary Access

Since 2008, NGS has clearly and publicly stated that, "The primary means of accessing this new reference frame will be GNSS technology." This means that to access to the new reference frames, the public will use CORS positions, velocities, and discontinuities in the latest IGS reference frame; tools including OPUS-S, and the defined relationship between the IGS reference frame and new geometric reference frame, both spatially and temporally.

Accessing the new reference frame could also include the availability of a real time network (RTN) validation service, which would quantify levels of agreement between the RTN and the NSRS. Tools and policies could evolve allowing the public to also use OPUS-RS and OPUS-Projects to access the NSRS. Finally, there is a possibility that in the future, NGS could run a precise point positioning (PPP) service as another means of accessing the NSRS.

Secondary Access

Also since 2008, NGS has clearly and publicly stated that, "While passive control will continue to be used as a secondary method to access the NSRS, such control will be 'tied to', not a 'part of', the NSRS." This means that GPS surveys on marks after 2022 can still be bluebooked and submitted to NGS. Ideally, NGS will also overhaul the bluebooking process by that time. Such an overhaul would include the creation of a fully-enabled geospatial database to hold the new data, as well as the development of a methodology to deal with geodetic data time dependencies.

Transformational Access

NGS considers actual readjustment of survey measurements, and not coordinate transformations, as best practice. Thus, NGS will recommend users readjust their data observations and survey measurements when the new reference frames are adopted. Nevertheless, NGS will continue to provide transformations between historic datums and the new reference frames. NGS is currently beginning an effort to re-build all NGS transformation software as a Web-based service.

Table 1: Today's NGS products or services, and how they may change by 2022

Product / Service	Today	Priority	2022 minimum	2022 target
Submit your passive control surveys to NGS for evaluation, loading into NSRS, and publication	Bluebooking and ADJUST (PC executables)	Required in 2022	Update Bluebooking and ADJUST	Rebuild existing databases as a fully enabled geospatial database with a re-invented bluebooking process
Submit your GPS data to NGS to obtain a coordinate as a highly automated process, which does not include additional evaluation or incorporation into the NSRS	OPUS-S, OPUS-RS, OPUS-DB, OPUS-Projects	Modify before 2022	Update OPUS to work in new geometric reference frame	Envelop these tools into a re-invented bluebooking process
Transform coordinates between datums or datum realizations	NADCON, GEOCON, GEOCON11, VERTCON, parts of VDATUM, and parts of HTDP	Append before 2022	Add a new tool to this suite for the new reference frames	Re-build all transformation tools into a common, easy-to-use engine
Transform coordinate types	UTMS, SPC83, GPPCGP, USNG, XYZWIN, HTDP, VDATUM, DYNAMIC_HT	Append before 2022	Add tools to this suite to support new reference frames	Re-build all transformation tools into a common, easy-to-use engine
Download data	Datasheets, CORS, UFCORS, NGS Data Explorer, Imagery, Shoreline, AntCal, Geoid models, GRAV-D, etc	Append before 2022	Status Quo	Overhaul all NGS data distribution, using web and GIS based tools pulling from a geospatial database
Education and outreach	Papers, Presentation Library, Videos, Classes	Continue through 2022	Status Quo	Create a searchable online library of 200+ years of publications, and expand video lessons

Next, Mr. Shaw described work already underway to improve NGS products and services. These efforts will continue to grow and evolve, so that NSRS users will have a robust set of tools available to access the new reference frames.

Web Services

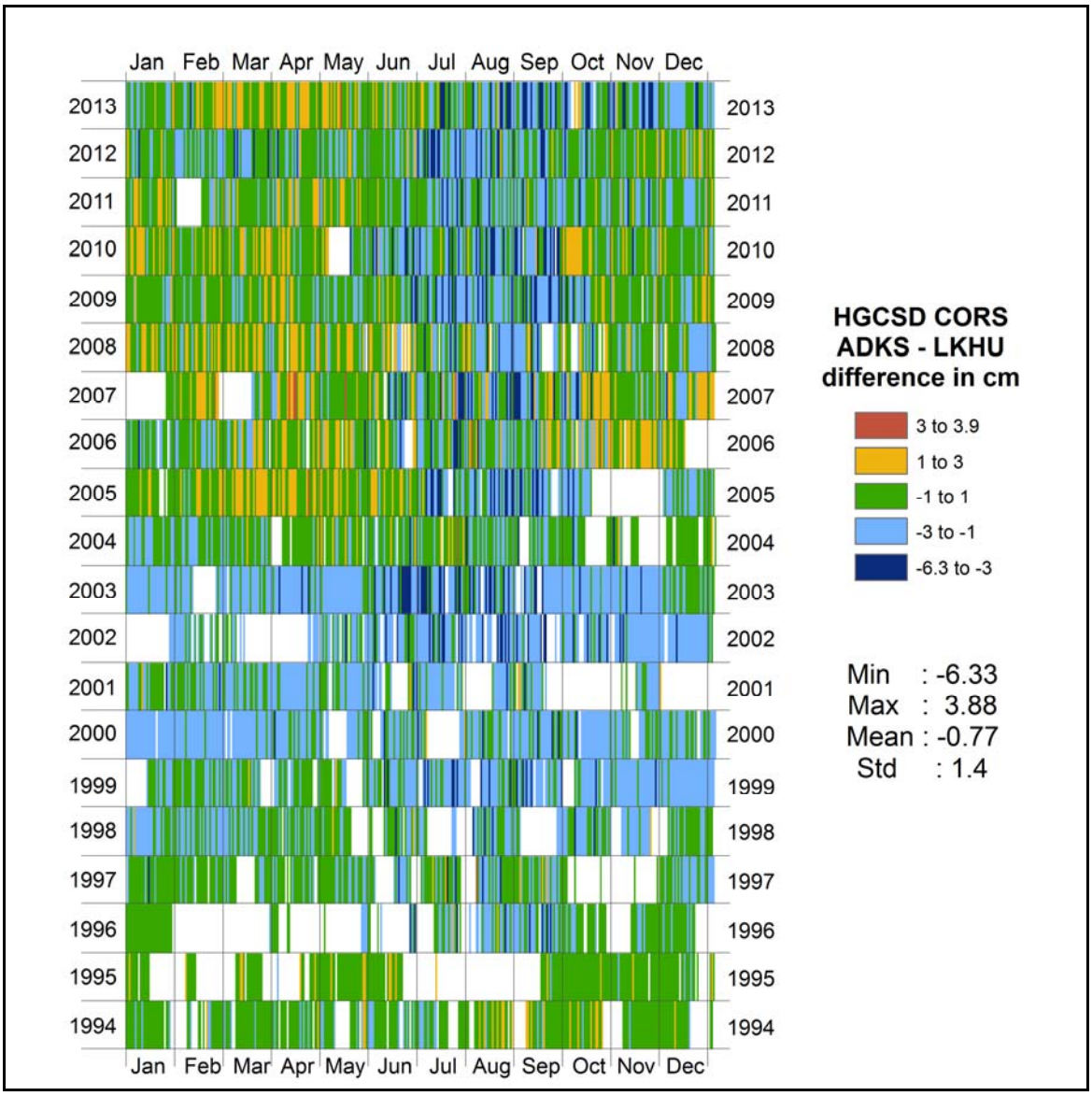
For example, NGS has already begun to develop Web services to access its existing datasets. The NOAA Shoreline Data Explorer can be accessed through the Continually Updated Shoreline Product (CUSP) map service to retrieve

the most recent shoreline lidar and ortho-imagery. Additionally, NGS has begun developing a new Java-based Geodetic Toolkit that will be much easier to use than today's options.

GIS Tools

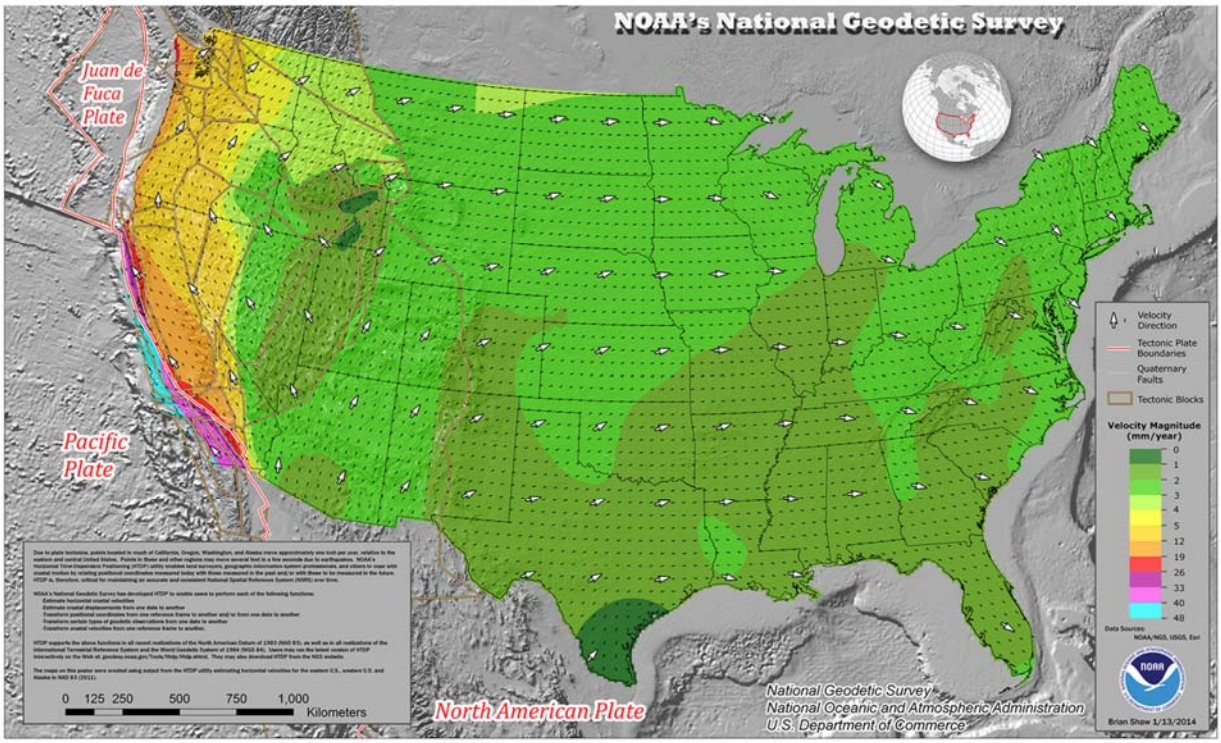
Next, Mr. Shaw discussed how GIS provides new ways for visualizing spatiotemporal information, and he highlighted a few projects that utilized GIS to analyze data more effectively. NGS recently developed GIS tools to analyze both GPS and leveling network adjustments, and we hope to make those available to the public soon. Continuing to develop GIS tools and using its powerful data analysis functionality will be critical in preparing for and transitioning to the new datums. In fact, GIS often allows everyone to be more productive by using graphical plots of existing data to greatly improve current workflows. The images below show graphical representations of data that could not be generated without GIS.

Image 1: Comparison of elevations between two CORS sites



This table visualizes the differences in elevation position between two CORS sites in the Harris-Galveston Subsidence District. You can easily note data gaps, seasonal effects, or other trends in the data.

Image 2: Average Horizontal Plate Motion



Horizontal plate motion in the image above is calculated with respect to the North American Datum of 1983 (NAD 83), which is "fixed" to the North American Plate. Due to plate tectonics, points located in much of California, Oregon, Washington, and Alaska move approximately one inch per year, relative to the eastern and central United States. Points in these tectonically active regions may move several feet in a few seconds due to earthquakes.

Capacity Building

Stakeholder capacity building will also be critical in transitioning from NAD 83 and NAVD 88 to the new datums. For example, over the past few years, NGS has organized a volunteer "GPS on Bench mark" project. By providing GPS observations on existing NAVD 88 bench marks today, the public is helping NGS improve the next hybrid geoid model, increase access to NAVD 88, and enable conversions to the new vertical datum in 2022. A Web map was debuted this year to help volunteers coordinate their efforts and reduce the risk of two surveyors unnecessarily visiting the same mark.

NGS will also continue to develop outreach and training materials. In-person trainings are offered at NGS' Corbin Training Center near Fredericksburg, Virginia, and more resources are becoming available online. NGS has partnered with COMET© to develop short videos and self-paced online lessons. Additionally, in May 2015, NGS began hosting a monthly webinar series to share information about NGS products and services.

Ultimately, NGS will also have to develop guidelines to instruct NSRS users on best practices with respect to accessing the new reference frames. Endeavors are already underway to update existing guidelines in a manner that best takes advantage of new technology, but further research and documentation will be required as we move into the future.

Mr. Dave Doyle, speaking on behalf of the National Society of Professional Surveyors, discussed how specific legislative issues need to be addressed in order to complete a successful adoption of the new reference frames. Updating references to the new datums will be fairly simple at the federal level. The Federal Geodetic Control Subcommittee (FGCS) will draft and publish a notice in the Federal Register, and from that point forward, federal mapping agencies should use the new datums.

There could, however, be greater difficulty updating the datums with respect to state regulations and laws. In many cases, language specifically referencing NAD 83 was published in state legal code, and support to make legal change may vary from state to state. The groups that typically advocate for legal changes of this nature are Land Surveyors Professional Societies in collaboration with state Departments of Transportation. Today, state GIS organizations may have a greater interest in these issues and could help advocate for the change.

The effort required to make these changes is not insignificant. Mr. Doyle made a series of recommendations to facilitate this transition:

1. Horizontal/geometric and vertical/geopotential datums should be defined in the same Federal Register Notice (FRN)/state legislation.
2. References to old proportional part orders of accuracy should be removed.
3. References to triangulation/traverse control points should be removed.
4. References to limits on distance to control points should be removed.
5. NSPS should collaborate with NGS to develop model legislation, which should include requirements for metadata. Minimally, the metadata should include datum, realization, units, and accuracy.

The United States must coordinate its national reference frames with Canada, and Mr. Marc Véronneau provided an update with respect to Canada's current standards. Mr. Véronneau is the team leader of the Gravity and Height Systems Unit at the Canadian Geodetic Survey of Natural Resources Canada. For their geometric reference frame (i.e. latitude, longitude, and ellipsoidal height), the Canadian Geodetic Survey (CGS) publishes coordinates in NAD83(CSRS) v6 epoch 2010.0 (equivalent to NAD 83[2011] epoch 2010.0), and currently there are no plans to replace NAD83(CSRS). However, CGS is collaborating with NGS in the realization of the new (North) American geometric reference frame and will publish coordinates in the new geometric reference frame (e.g. station reports, TRX software).

Mr. Véronneau explained that Canada adopted the Canadian Geodetic Vertical Datum of 2013 (CGVD2013), a geoid-based vertical datum, in November 2013. This transition was made because the cost of maintaining and expanding a leveling network is prohibitive, and there is no access to CGVD28 (the predecessor vertical datum) in remote areas. Note that Canada did not adopt NAVD 88. Additionally, the availability of new technologies made this transition possible. The new vertical datum corrected known distortions in CGVD28 (i.e. ~1.2 m at the national

scale). Canada has the support from the provinces in the implementation of the new vertical reference system, and, overall, Canadian users acknowledge that the benefits of a geoid-based datum outweigh disadvantages.

It is interesting to note that CGVD28 continues to co-exist with CGVD2013 during the transition period. Before adopting CGVD2013, the national levelling network was adjusted with constraints to coincide with CGVD2013, so today's bench marks are published in both CGVD2013 and CGVD28. However, GNSS-derived orthometric heights prevail over the heights from the leveling adjustment in CGVD2013. In fact, CGS discontinued maintenance of the bench marks of the national first-order leveling network since 2002, and bench marks are not maintained by GNSS observation, either. Therefore, CGS cannot confirm stability of the bench marks.

CGS continues to coordinate with NGS in support of a unified height system for North America based on the equipotential surface $W_0 = 62{,}636{,}856\ m^2/s^2$. This definition is already adopted in Canada (CGVD2013), and Mexico, as well as Central American and Caribbean countries, have agreed on this definition. The Coordinating Committee for the Great Lakes and St-Lawrence River System proposed to define IGLD2020 on this surface, too. Both IERS as well as IAU already adopted this reference surface in their conventions prior to CGS and NGS.

Finally, Mr. Véronneau mentioned some of Natural Resources Canada's (NRCan's) tools.

1. **CSRS-Precise Point Positioning (PPP)** processes GPS RINEX files to provide stand-alone coordinates (latitude, longitude, ellipsoidal height, and orthometric height). This online tool works anywhere in the world.

2. **GPS-H** converts ellipsoidal heights to orthometric heights by making use of any geoid models, working with different types of coordinate systems (e.g. geographic, UTM, MTM and Cartesian), and referencing different geometric reference frames (e.g. NAD 83(CSRS) and ITRF). It can also convert between vertical datums. GPS-H accepts NGS binary file format for geoid models (e.g., Geoid12A).

3. **TRX** transforms coordinates between different geometric reference frames (e.g., NAD83[CSRS], ITRF), epochs and coordinate systems (e.g., geographic, UTM, MTM, Cartesian).

NGS invited representatives from various organizations that are expected to be impacted by the adoption of new datums. These delegates were asked to present a brief 10- to 15-minute talk to discuss the impacts, concerns, and preparations their organizations are making in anticipation of the replacement of NAD 83 and NAVD 88. The presentations made it apparent that adopting new reference frames will affect many products and services across the private and public sector, and at every level of government.

Nearly every presentation emphasized the need for user-friendly transformation tools or routines, built into a modern programming language. It was also repeatedly stressed that ensuring major commercial GPS, geoprocessing, and GIS vendors integrate these transformation tools into their software will be critical to successful implementation of the new datums. Some presentations outlined additional requirements to create a truly robust transformation tool; for example, the tool should include accuracy, allow user-defined epoch for output datasheets, and create a command line application for transformations. The tools must be user-friendly, because there will be a tremendous amount of legacy data to manage that is referenced to earlier datums.

Multiple speakers also suggested that NSPS should distribute sample language to update state legislation that references NAD 83. Each speaker also highlighted the importance of consistent communication with NGS, whether through bi-annual summits or more regular webinars. Many organizations also identified a need for more training and tutorials, covering specifics about datum transformations, but also geodesy basics that could be taught at all geomatics schools and programs. Finally, there was also a request for a formal publication describing the differences between NAD 83 / NAVD 88 and the new datums. The following summaries do not repeat some of these overarching comments; rather, they highlight points that were unique to speaker's organization.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

Mr. Paul Rooney, a mapping technology specialist in the Risk Analysis Division of the Federal Emergency Management Agency (FEMA), explained that the major FEMA product/service to be affected by the new datums will be the National Flood Insurance Program (NFIP) Flood Maps. NFIP insures approximately $1.3 trillion in property, and to be eligible, communities must agree to minimum building standards in high-risk areas. Property owners in high-risk areas must purchase insurance to be eligible for various federal program and conventional mortgages. To implement these requirements, FEMA publishes flood maps that define: the boundaries of the high-risk area and the elevations that buildings must be built in the high risk areas. Flood-risk analysis and mapping depends on good data, particularly accurate elevations.

FEMA's preparations to date have been minimal, since most of the transition will need to occur after the new datums are available. FEMA is currently working on transitioning from NAD 83(1986) to NAD 83(20011), and this transition may provide a template for the future.

FEMA is excited about NGS' plans moving forward, because implementation of NFIP requires thousands of precise horizontal and vertical measurements of buildings. Horizontal locations of high-risk boundaries and minimum building elevations are referenced to the NSRS to facilitate these determinations. FEMA is concerned, on the other hand, because changing the datum on maps requires administrative actions by communities. A large map revision will typically take three to five years and can sometimes take much longer.

The National Flood Hazard Layer is a large GIS dataset currently in NAD 83(1986). Esri currently has transformations only through HARN, but hopefully improvements will be made when Geocon and Geocon11 grid transformations will be added later this year. Outreach is difficult, because the issues are so complex, and most NFIP end-users will not understand the training that is offered.

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (NGA)

Mr. Stephen Malys, NGA senior scientist for geodesy and geophysics, described how the Homeland Security Infrastructure Program will be affected by the new datums. Homeland Infrastructure Foundation-Level Data (HIFLD) is collected and managed collaboratively (e.g. NGS, DHS, and USGS), so data management across datums will be critical. Geodetic surveys on CONUS weapons test ranges will continue to use WGS 84 (Gxxxxx) and EGM 2008, and NGA has made no preparations to date to prepare for the new datums.

NGA is excited because the replacement to NAD 83 will be closely aligned with the ITRF and therefore closely aligned with the current (and future, 2022) realizations of WGS 84. Similarly, the replacement to NAVD 88 will be more closely aligned with our best global geoid: EGM 2008. Overall, these NGS efforts represent significant

milestones toward a common, global geodetic reference frame for all geospatial data, which has been a major goal of geodesy for many decades and will reduce confusion for most practical surveying applications.

NGA is concerned, because the differences between NAD 83's replacement and WGS 84 (Gxxxxx) will likely be very small (i.e. 1 – 10 millimeter level). While this difference is of scientific interest, it may be of no practical interest to the broader surveying community who may deem the differences as statistically insignificant.

Finally, NGS highlighted its interest in GPS and other GNSS data sets from "Foundation CORS," because it will facilitate direct comparison with the WGS 84 reference frame. To ensure a smooth transition, NGA promoted continued close collaboration between NGS, NOAA, and NASA, as well as broader support to maintain the health of the geodesy discipline within the U.S. government.

U.S. GEOLOGICAL SURVEY (USGS)

Ms. Kari Craun, Director of the National Geospatial Technical Operations Center, introduced a number of USGS products and services that will be affected by the new datums. All information spatially referenced to a datum will be affected to some degree. The following list includes some of the types of information collected, processed, managed, and distributed by the USGS that will be affected by a datum change: The National Map databases; U.S. Geological Survey topographic map products, ISO 19111 Geographic Information Spatial referencing by coordinates (international standard); geomagnetic observatory time-series data; landslide hazard assessments; 3D Elevation Program (3DEP) data, including high-resolution lidar and ifsar measurements; seismic information collected and managed by the USGS Earthquake Program; and USGS water information.

USGS has started to prepare by raising awareness and educating people on possible impacts. Additionally, there has been significant effort to justify revising ISO 19111 to incorporate modern and dynamic geodetic reference frames. A report will be prepared to justify work on required revisions. This report will be distributed to TC211 by April 2015, and a new work item project may begin in June 2015. Ms. Craun recommended that NGS actively participate in the revision of ISO 19111.

For USGS users, the new datums will provide closer alignment with global reference systems, improved locations for magnetic observatory reference points, and a more accurate representation of the physical world in elevation (and other georeferenced) products. USGS is excited about the new datums because new data collected using sensors, such as lidar, ifsar, and other remote sensing data will be associated with the new datums and thus accurate adoption of these datums in commercial and government-developed software will be critical.

USGS also expects there to be challenges moving to the new datums. Conversions of large national spatially-referenced datasets, such as The National Map databases, including all 3DEP products, will be demanding. These data, including national seamless elevation layers at multiple resolutions, will have to be converted. Many of these datasets are derived by integrating a variety of data sources. Metadata will also need to be updated. We will need to decide whether to convert lidar point cloud data and digital surface models. If we do not convert these to the new datums, then we will need to make it clear to users what the differences will be in the datums of legacy products versus new products, and if used together, a datum conversion will be necessary.

U.S ARMY CORPS OF ENGINEERS (USACE)

Mr. Jim Garster, the lead of the Survey Engineering and Mapping Technical Center of Expertise with the US Army Corps of Engineers (USACE) Army Geospatial Center, explained that the major USACE products and services affected by the new datums will be existing project maps, designs, and studies, as well as project Operations and Maintenance (O&M) manuals. The USACE has been preparing its organization to better understand datums with the development of Engineer Regulation (ER 1110-2-8160) Policies for Referencing Project Evaluation Grades to Nationwide Vertical Datums; Engineer Manual (EM 1110-2-6056) Standards and Procedures for Referencing Project Evaluation Grades to Nationwide Vertical Datums; and U-SMART (USACE Survey Monument Archival & Retrieval Tool). U-SMART keeps track of project control and ties to NSRS and National Water Level Observation Network (NWLON). See http://usmart.usace.army.mil to learn more.

Mr. Garster expressed excitement in this project because it will improve consistency of vertical datums across the country, improve the relationship between geodetic and hydrologic datums, and improve the accuracy for GPS-derived elevations. However, there is the potential for confusion about yet another vertical datum as well as the relationship between existing or older datums and the new datums. Additionally, small changes might get ignored. Finally, the potential of a dynamic datum with constantly changing coordinates could make conversion tools far more complex. He added that superseded values need to be documented, and that OPUS will remain a critical tool to connect to the NSRS.

FEDERAL AVIATION ADMINISTRATION (FAA)

Aeronautical Information Specialist and Air Traffic Safety Inspector for the FAA's Air Traffic Safety Oversight Service, Mr. George Sempeles, outlined the many FAA products and services that could be affected by the new datums. U.S. Instrument Flight Procedures, millions of surveyed obstacles, tens of thousands of airport safety critical points (e.g. runway ends, displaced thresholds), thousands of NAVAIDS, FIXs and waypoints could all be affected. No preparations have been made to date, but the FAA will need to prepare an implementation plan with the roll-out of the new datums to prevent a shutdown of instrument flight procedures National Airspace System (NAS)-wide.

Even with these large potential impacts, the FAA is enthusiastic about the proposed change because we will finally have a national geocentric reference frame that is more coincident with WGS 84. Potential concerns depend on the magnitude of the shift between datums. Until the magnitude of the shift is known, it is difficult to prepare in terms of resources, and the impact will not be known until periodic flight inspection of procedures.

If the shift is small, then the difference cannot be drawn on a chart, and neither a pilot nor an automated navigation system can fly that difference. On the other hand, if the shift is large, we may be faced with having to recalculate all geodetic data used to support all aeronautical navigation products used in the U.S. NAS.

With these impacts and uncertainties in mind, the FAA would most benefit from advanced notice regarding the estimated shift magnitude between datums along with updated vertical and horizontal calculators for CONUS, Alaska, and U.S. territories. FAA would also benefit from bi-annual summits, monthly updates, and increased frequency in summits as the new realization because reality.

SEATTLE PUBLIC UTILITIES

Mr. Gavin Schrock, administrator of the Washington State Reference Network, was the first speaker to share information from a state, rather than federal, perspective. The major impacts to his organization will be changes to

existing passive control networks, both horizontal and vertical; state and local GIS reference frameworks, which are often codified; and surveyors' calibrations.

There has already been significant investment in preparing for the transition. Outreach has been extended to affected user-groups; upgrades have helped add key local CORS to the NGS CORS network. There has also been a local effort to augment vertical data for hybrid geoids with the local occupations of bench marks, and Height Modernization surveys have been completed for areas with ancient or non-existent control values. Washington is also beginning to develop a velocity-based schedule for CORS coordinate updates and to test precise point positioning (PPP) services for integrity monitoring for OPUS-challenged areas.

Expected advantages of the new datums include improved height information for areas with ancient or non-existent control, removing reference system differences between disciplines, removing "noise" in legacy reference frameworks, and improving fidelity to outputs from other global positioning services.

On the other hand, concerns regarding the new datums exist because entire state and local reference systems have been built around noisier legacy systems, and there is a general lack of understanding of geodesy, especially with respect to velocity. A lack of tools for converting legacy values to new values could present challenges, and NGS thresholds for updating CORS values are a bit too large to maintain the integrity our network requires to yield optimal precision. Finally, there is a danger in getting side-tracked, as some folks are trying to bundle too many initiatives with the datum change (e.g. pushing purely xyz-based systems).

The biggest need to prepare the user community is to educate end-users how to work in 4D, meaning resolving temporal displacements via tools or calibration. It will also be important to implement transformation databases via vendor software and possibly leveraging Radio Technical Commission for Maritime Services (RTCM) 3 transformation parameters. Guidelines for estimating accuracy for real-time precise point positioning (RT-PPP) observations would also be helpful.

NORTH CAROLINA DEPARTMENT OF PUBLIC SAFETY

Mr. Gary Thompson, chief of the North Carolina Geodetic Survey/Risk Management/NC Emergency Management, outlined a large number of state products and services that would be impacted by adopting new national datums in North Carolina (NC). The NC Floodplain Mapping Program, NC Land Records Management System, NC CORS/Real Time Network (RTN), statewide lidar and aerial imagery programs, NC Department of Transportation (DOT) projects, statewide GIS clearinghouse and all GIS programs in state and local governments, precision farming applications, and any programs or projects with a geospatial component.

North Carolina is working to prepare itself for the new datums by organizing an agency advisory committee, the NC Geodetic Survey Advisory Committee (GSAC) with representatives from state surveying agencies, professional societies, universities, and private industry. North Carolina also provides 2022 datum information to constituents via workshops and speaking engagements. They are also requesting additional feedback from the NC Society of Surveyors, NC Property Mappers Association, and Carolina Urban and Regional Information Systems Association.

North Carolina is expecting the new datums will provide improved height information in areas lacking NAVD 88 bench marks, areas of crustal movement, as well as improved geoid and gravity information in coastal and mountainous areas.

Mr. Thompson is also looking forward to NGS leadership actively engaging with state and local surveying and mapping communities during the next seven years.

Nevertheless, North Carolina has concerns because the 2022 datums transition will be an unfunded mandate for most state and local agencies as well as the private sector. Additionally, the 2022 vertical datum's 2 centimeter accuracy, while a major improvement in areas without vertical control, will not meet high precision (sub-centimeter) vertical control requirements (e.g. coastal work in North Carolina). In addition, NGS does not plan to improve the accuracy of the geoid beyond 2 centimeters. Mr. Thompson's concern is that, due to budget and personnel constraints, NGS may focus more on the scientific community's issues and less on state or local agency issues.

Mr. Thompson outlined extensive recommendations with regard to the tools, products, and services needed from NGS. Beyond transformation tools, he suggested NGS create tools to incorporate gravity data into the NGS database, tools to perform leveling network adjustments to incorporate leveling data into NAVD 88 and the future vertical datum, and tools for retrieving all of NGS geodetic data in GIS data formats. He also suggested that NSG develop a cooperative program with state and local government agencies to complement NGS's decreasing resources as well as providing plate-fixed positions to requesting states.

Mr. Thompson's final recommendations were that NGS leadership should meet with state and local governments and participate at the state land surveying and GIS conferences to seek input concerning the impacts of the 2022 datums. One way to ensure the surveying, mapping, and GIS communities are included in the decision making process is to establish an ad hoc group to document and address issues with the new datums, with representation from NGS leadership, state surveying agencies, professional societies, academia, private industry, and GIS professionals.

DEWBERRY

Mr. Amar Nayegandhi, associate vice president and director of Remote Sensing at Dewberry, described the products and services that will be impacted by the new reference frames, many of which were referenced by client organizations earlier in the session; specifically, all lidar products in support of the 3D Elevation Program (3DEP), digital orthoimagery and planimetric maps for all clients, and flood insurance studies for FEMA. In preparation for the new reference frames, Dewberry's digital terrain models (DTMs) and digital surface models (DSMs) of Alaska are also being delivered with ellipsoid heights so we can apply the new geopotential reference frame to easily re-compute new orthometric heights.

Mr. Nayegandhi explained that with new reference frames, remote sensing users hope to be able to compute orthometric heights accurate to 1 centimeter when mapping ellipsoid heights from lidar and ifsar and adding the geoid height. Another hope is that NGS data sheets and survey monuments will become relics of the past as the user community comes to rely on the new National Spatial Reference System (NSRS). GPS users will be forced to rely on CORS as the prior use of inaccurate and un-maintainable survey monuments are phased out. Another potential benefit is the standardization of vertical datums offshore (e.g., Hawaii, PR, USVI). Finally, Mr. Nayegandhi expressed a desire to more easily link to the dynamic ITRF, recognizing that the land continues to move horizontally and vertically.

Despite these potential benefits, Mr. Nayegandhi described the biggest challenge to be updating all the elevation data, orthoimages, and other geospatial datasets produced with prior datums. For example, FEMA often revises flood insurance studies by updating prior hydrologic and hydraulic (H&H) models prepared with older datums, so given this process, updating maps may take decades. Finally, he suggested that NGS will need a "full court press" to get other federal and state agencies to act proactively to prepare for the future and to implement the new reference frames when ready.

ESRI

Mr. Brent Jones, who oversees Esri's worldwide strategic planning, business development, and marketing activities for land records, cadastral, surveying, and land administration, explained that adopting new datums will affect the entire ArcGIS suite of software products as well as the Projection Engine (PE) geodetic code base. To prepare, Esri has commenced development of dynamic datum functionality. This will include time-based datum transformations and tools to correct for a features' trajectory over time due to secular and episodic motion (i.e. crustal motion and earthquakes).

Esri is excited because this presents an opportunity to modernize their geodetic models and tools, and the process should improve awareness regarding the importance of geodesy in GIS. On the other hand, it is expected that many users will misunderstand and misuse dynamic datum tools; as a result, a substantial demand will arise for user education. Mr. Jones expressed that a consistent grid format for all NGS products would be very valuable.

Overall, NGS found the participation in the 2015 Geospatial Summit on Improving the NSRS to be outstanding. With over 200 in-person attendees, and another 100-plus attending via the webcast, NGS felt that both the "word got out" and also that NGS received some much needed feedback. However, the summit was only another intermediate step in the long road to replacing NAD 83 and NAVD 88.

Similar to the outcome of the 2010 Federal Geospatial Summit, NGS heard one generally overarching message from the summit attendees, which might be summed up as follows: ***the NSRS user community supports NGS's plan to improve the NSRS, but urges caution, communication, and cooperation due to the scope of impact this will have.***

An overwhelming majority supported the datum change, but there were obviously a variety of concerns raised. Interestingly, the audience seemed somewhat segmented on opinions regarding a few critical issues.

The role of passive control: Many constituents recognized the limitations of passive control. Geodetic marks can be destroyed or disturbed over time, they may not exist in areas where control is needed, or their published coordinates may not reflect land motion over time. On the other hand, they do provide a critical means to access the NSRS in areas where GPS solutions or IT infrastructure is not as reliable.

NGS concurs with those who believe there will continue to be a role for geodetic survey marks. For example, local projects that require sub-centimeter precision may need to establish a local network of survey marks and level between them. However, these marks will be a means of secondary, rather than primary, access to the NSRS.

NGS will work to improve its consistency in communicating about the role of passive control in the future. NGS will also work with our stakeholders to understand the requirements that have been met historically by using passive control, so that these requirements are still met after the adoption of the new reference frames.

Plate-fixed reference frame vs. ITRF style coordinates: Some summit attendees were excited at the prospect of ITRF style coordinates that would better align with international reference frames and better reflect the changing positions of the Earth's surface. It was even suggested that surveyors ultimately will learn how to function in a four-dimensional world, rather than the three-dimensional world with which we are more accustomed. On the other hand, this paradigm shift will certainly cause confusion and may be difficult or impossible for some user communities to adopt.

NGS will find an approach to ensure the NSRS is accurate and meets the requirements of NSRS users. It may take further discussion to determine the best approach for moving forward, but the feedback from the summit was invaluable.

NGS ACTIVITIES

In order for NGS to stay on track with the issues raised by the summit attendees, the next section contains action items that are being used by NGS to plan for the next few years. The following checklist represents a mix of those requests heard from customers at the summit, as well as actions to take that can be inferred from the overall concerns.

Action 1: Adopt formal project plans and complementary communications plans to outline all activity that must occur between 2015 and the adoption of the new reference frames.

Action 2: Determine the frequency of recurring large summits. These will be supplemented by other communication efforts, including but not limited to: quarterly meetings with surveyors associations, participation in large surveyor and GIS conferences, a monthly NGS Webinar Series, continued and expanding training opportunities, and ever-growing Web resources.

Action 3: Regular communication regarding policies as they are adopted by the Executive Steering Committee regarding the definition or access to the new reference frames.

Action 4: Continued improvement to the Geodetic Toolkit, in anticipation of a geospatially enabled database with robust transformation tools to link NAD 83 and NAVD 88 to the new reference frames.

CONSTITUENT ACTIVITIES

Action 1: Provide feedback and engage with NOAA and NGS through summits and other NGS efforts, monthly meetings, guest columns in trade publications, and through regular NGS website visits.

Action 2: Engage with professional societies such as our summit co-sponsors, NSPS and MAPPS. These societies have a tremendous national and local reach, and NGS will meet with them consistently to best take advantage of their communication networks that translate to the state and local levels.

Action 3: Take ownership of this project of transitioning to the new datums, tackling how you manage your data today, change processes moving forward, and prepare for a smooth (as possible) transition.

Action 4: Volunteer and share your data when the opportunities arise. There are some data-sharing options already in place, and NGS will be sure to identify opportunities that are amenable for you to engage in. Most recently NGS has encouraged the public to collect GPS observations on bench marks in conjunction with National Surveyors week, and we expect opportunities like this to recur and expand.

FEDERAL GEODETIC CONTROL SUBCOMMITTEE QUARTERLY MEETING (FGCS)

The FGCS meets quarterly to provide a venue for federal agencies to coordinate and plan the execution of geodetic surveys, the development of related standards and specifications, and the exchange of other technical information. The open meeting held at the summit provided an opportunity to hear how federal agencies are exercising their responsibilities to address today's surveying and mapping issues.

First, Colonel Christopher Eagen, the deputy director of the National Coordination Office for Space-Based Positioning, Navigation and Timing (PNT), gave a presentation on GPS modernization and interoperability. Specifically, he provided updates on Nationwide Differential GPS (NDGPS) and complementary activities. NGS presenters also provided updates on OPUS Projects and the FGDC Geographic Information Framework Data Content Standard Part 4: Geodetic Control.

Most relevant to the Geospatial Summit, Dr. Dru Smith lead a discussion about actions needed to coordinate the release of new reference frames in 2022. Similar to feedback at the Geospatial Summit, transformation tools were discussed as a priority. NGS representatives also discussed developing more robust project plans with milestones that may include updating the bluebooking process, developing a geospatial database, further analyzing OPUS Projects results, and developing field procedures for leveling in the new reference frames.

Representing the U.S. Geological Survey, Mr. Larry Hothem recommended NGS provide agencies with a standard data format to use in submitting sample data sets collected for testing the batch transformation process. Requiring the use of a standard format for data input should avoid problems with data submitted to NGS in a variety of formats.

Overall, FGCS representatives thought the summit was well done and well organized. There was strong interest and support for "Web services" transformation tools, as well as new modular software and customizable datasheets. Partners also want to share data through OPUS Projects. Finally, FGCS members urged NGS to consider impacts and applications with respect to Precise Point Positioning when implementing the new reference frames.

As already discussed, the new reference frames must be adopted by the FGCS so they can replace NAD 83 and NAVD 88. NGS plans to work closely with its federal partners to understand their requirements, to ensure the tools are available to transform existing data, and to update field procedures so that everyone can work successfully within the new reference frames.

Annual partner meetings allow state and university partners to explain the best practices they develop and challenges they encounter when determining accurate heights in their local regions or communities. The meeting was also an opportunity for stakeholders to express their requirements as NGS continues to develop geodetic models and tools in preparation for the replacement of NAD 83 and NAVD 88.

To begin the meeting, Ms. Christine Gallagher presented an overview of the Height Modernization Program, and Dr. Vicki Childers communicated that Height Modernization will be a critical component of transitioning from NAVD 88 to the new vertical reference frame. Then, a panel of NGS scientists answered numerous questions from the audience about specific technical components defining the new reference frames, from determining the extent of the geoid model to the impacts of sea level rise.

Next, representatives from state partners provided updates on work being completed in their states or regions. Each partner agency or university approaches the task of providing accurate elevation information in a manner that best meets its needs. For example, North Carolina's Geodetic Survey directly supports its Floodplain Mapping Program, so the state is re-collecting lidar and orthoimagery, directly tied to accurate geodetic control. As another example, the coast along the northern Gulf of Mexico is facing unique challenges because parts of the region are subsiding. In this area, state partners are collaborating to install CORS stations on tide gauges to assist in accurate 3D positioning and to monitor subsidence rates adjacent to accurate sea level observations.

A series of speakers then provided overviews of specific projects that will help advance the goals of Height Modernization: to establish accurate elevation information for a wide range of activities. Specifically, research is underway to update "Guidelines for Establishing GPS-Derived Ellipsoid and Orthometric Heights" (i.e. NOS-NGS 58-59) and "River Crossing Procedures" (i.e. to revise Geodetic Leveling, NOS-NGS 3). The document "Accurate Elevations for Sea Level Change Sentinel Sites" was previewed, and an overview was also provided concerning efforts already underway for the replacement of IGLD 85.

Most relevant to the Geospatial Summit, the Height Modernization partners highlighted how they use survey marks (i.e. passive control), even in the age of increased availability of GPS and real time networks. Passive control is needed when there are no open skies or when no cellular service is available, and also to retain the value already invested in establishing geodetic control. Height Modernization partners are leaders in finding ways to best leverage the advances in technology (e.g. GPS and lidar) in combination with existing survey marks to establish geodetic control, and they want to work with NGS to continue updating and improving guidelines and procedures.

Finally, these Height Modernization partners are an active and engaged group of stakeholders who can work with NGS to ensure a smooth transition to the new reference frames. Some regions have strong regional coordination, and this could also enable NGS to communicate with many stakeholders in the surveying and academic communities. Collaborating with the academic partners will be important in the development of a new generation of surveyors and geodesists prepared to work in the new reference frames.

3DEP	3D Elevation Program
ASVD 02	American Samoa Datum of 2002
CGS	Canadian Geodetic Survey
CGVD2013	Canadian Geodetic Vertical Datum of 2013
CGVD28	Canadian Geodetic Vertical Datum of 1928
CORS	Continuously Operating Reference Station
CSRS	Canadian Spatial Reference System
CUSP	Continually Updated Shoreline Product
DEM	digital elevation model
DHS	Department of Homeland Security
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DSM	digital surface models
DTM	digital terrain models
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FGCS	Federal Geodetic Control Subcommittee
FGDC	Federal Geographic Data Committee
FIG	International Federation of Surveyors
FRN	Federal Register Notice
GIA	glacial isostatic adjustment
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRAV-D	Gravity for the Redefinition of the American Vertical Datum

GUVD 04 Guam Vertical Datum of 2004

HARN High Accuracy Reference Network

HIFLD Homeland Infrastructure Foundation-Level Data

HTDP Horizontal Time-Dependent Positioning

IAG International Association of Geodesy

ICG International Committee on Global Navigation Satellite Systems

IDS International DORIS Service

IERS International Earth Rotation and Reference Frame Service

IGLD International Great Lakes Datum

IGS International GNSS Service

ILRS International Laser Ranging Service

ISS IERS Site Survey

ITRF International Terrestrial Reference Frame

IVS International Very Long Baseline Service

Lidar Light Detection and Ranging

NAD 83 North American Datum of 1983

NAS National Airspace System

NAVD 88 North American Vertical Datum of 1988

NDGPS Nationwide Differential GPS

NFIP National Flood Insurance Program

NGA National Geospatial-Intelligence Agency

NGS National Geodetic Survey

NMVD 03 Northern Marianas Datum of 2003

NOAA National Oceanic and Atmospheric Administration

NOS National Ocean Service

NRCAN Natural Resources Canada

NSRS National Spatial Reference System

NWLON National Water Level Observation Network

OPUS Online Positioning User Service

PNT National Coordination Office for Space-Based Positioning, Navigation and Timing

PPP precise point positioning

PRVD 02 Puerto Rico Vertical Datum of 2002

RTCM Radio Technical Commission for Maritime Services

RTN Real Time Network

SPCS State Plane Coordinate System

SRTM Shuttle Radar Topography Mission

UN-GGIM United Nations Global Geospatial Information Management

USACE U.S. Army Corps of Engineers

USGEO U.S. Group on Earth Observations

USGS U.S. Geological Survey

U-SMART USACE Survey Monument Archival & Retrieval Tool

VIVD 09 Virgin Islands Vertical Datum of 2009

VLBI Very Long Baseline Interferometry

WAAS Wide Area Augmentation System

WGS 84 World Geodetic System of 1984

GEOSPATIAL SUMMIT, DAY ONE: MONDAY, APRIL 13, 2015

12:00 – 1:00	**Arrival and Registration**
1:00 – 1:15	**Welcome and Introduction to the New Reference Frames** Juliana Blackwell Director, NOAA's National Geodetic Survey Dr. Russell Callender Acting Assistant Administrator, NOAA's National Ocean Service
1:15 – 1:30	**Overview of 2010 Geospatial Summit** Juliana Blackwell, National Geodetic Survey
1:30 – 2:15	**Progress towards a New Geopotential Reference Frame** Dr. Dru Smith, National Geodetic Survey Dr. Dan Roman, National Geodetic Survey Dr. Vicki Childers, National Geodetic Survey
2:15 – 2:45	**Progress towards a New Geometric Reference Frame** Joe Evjen, National Geodetic Survey
2:45 – 3:00	**Break**
3:00 – 4:00	**Benefits of the New Reference Frames** Joe Evjen, National Geodetic Survey Dr. Dru Smith, National Geodetic Survey
4:00 – 4:30	**International Geospatial Activities** Dr. Neil Weston, National Geodetic Survey
4:30 – 4:45	**Closing Remarks / End of Day** Dr. Neil Weston, National Geodetic Survey

GEOSPATIAL SUMMIT, DAY TWO: TUESDAY, APRIL 14, 2015

8:00 – 9:00	**Accessing the New Reference Frames: New Products, Services, Models, and Tools** Brian Shaw, National Geodetic Survey Dr. Dru Smith, National Geodetic Survey
9:00 – 9:30	**Adopting the New Reference Frames: Legislative Issues** Dave Doyle, National Society of Professional Surveyors
9:30 – 9:40	**Break**
9:40 – 10:00	**Canada's Geodetic Reference Frames: Geometric and Vertical** Marc Véronneau, Canadian Geodetic Survey
10:00 – 11:45	**Feedback from Stakeholders** Stakeholders speak for 10 minutes each: Paul Rooney, FEMA Stephen Malys, NGA Kari Craun, USGS Jim Garster, USACE George Sempeles, FAA Gavin Schrock, Seattle Public Utilities Gary Thompson, North Carolina Department of Public Safety Amar Nayegandhi, Dewberry Brent Jones, Esri
11:45 – 12:00	**Closing Remarks / End of Day** Dr. Neil Weston, National Geodetic Survey

Participants were invited to vote in live polls about their preferences regarding geodetic issues, products, and tools. This feedback will help inform NGS' long-term planning, especially with respect to replacing NAD 83 and NAVD 88. Questions were open to in-person and webinar attendees, and responses could be submitted via text or using a Web browser. Responding to the questions was optional, and all responses were anonymous.

LIVE POLL QUESTIONS

The question-and-answer choices are listed below. Questions 1-4 and questions 6-7 were single-response, multiple-choice questions; questions 8-9 allowed up to three responses; and questions 5 and 10 were open-response, and are not included in this summary.

1. Do you work for NOAA's National Geodetic Survey?
   A: Yes
   B: No

2. How "plate fixed" do you want your latitude and longitude?
   A: Not at all - give me ITRF style coordinates
   B: Remove only the average plate rotation for my points
   C: Remove plate rotations and earthquakes
   D: Remove every signal possible - never let my point change
   E: Other
   F: No opinion

3. If the height of a point is changing, what do you want NGS to do about it?
   A: Make the point unpublishable
   B: Hold the last known height fixed until a new survey is done
   C: Model and publish the vertical motion
   D: Both B and C
   E: Other
   F: No opinion

4. If you had access to orthometric heights at 2 cm accuracy in an RTN rover, how will this impact your need for passive control?
   A: Not at all
   B: Reduces it somewhat
   C: Reduces it significantly
   D: Takes away all need for passive control
   E: Other
   F: No opinion

5. What remaining questions do you have about the information you heard today?

6. Which term best describes your role?
   A: Land surveyor
   B: Engineer
   C: Researcher/Geodesist
   D: Educator/Student
   E: GIS user
   F: Cartographer/mapping user
   G: General Public
   H: other

7. If a State Plane Coordinate System (SPCS) NAD 83-like coordinate system is defined for the new datum, then:
   A: I would adopt/use it without major changes
   B: I would adopt/use it only if the new SPCS significantly evolves from SPCS83
   C: I would convert back to and remain in SPCS83
   D: I do not use SPCS83 and would not use the new
   E: Other
   F: No opinion

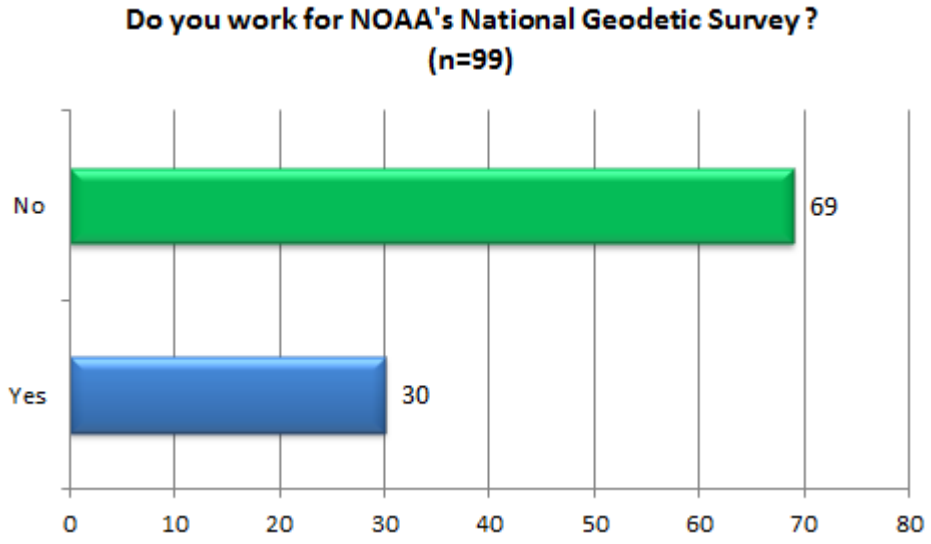
8. In what format would you prefer that NGS provide geodetic data? (vote up to 3 times)
   A: Web services
   B: shape files
   C: XML
   D: HTML
   E: binary
   F: ASCII text
   G: Other
   H: No opinion

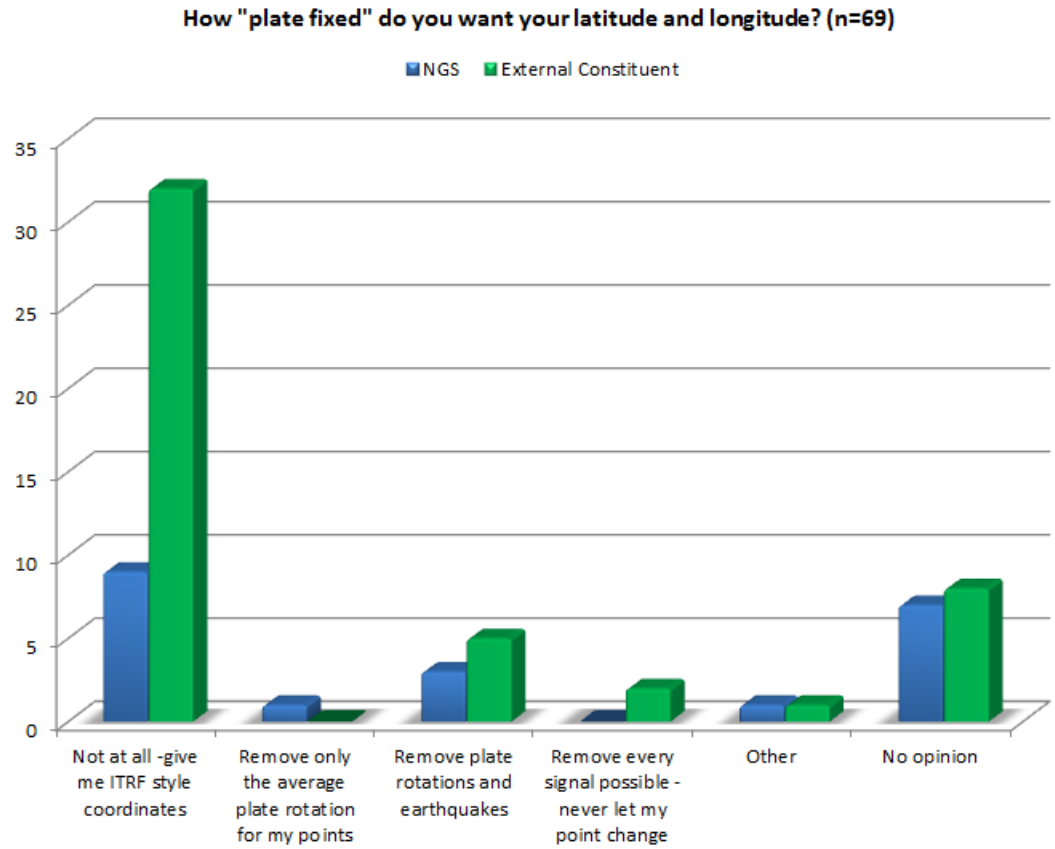
9. Which type of products and services do you most value from NGS? (vote up to 3 times)
   A: Submit your passive control surveys to NGS
   B: Submit your GPS data to NGS to get a coordinate
   C: Transform coordinates between datums or datum realizations
   D: Transform coordinate types
   E: Download Data
   F: Education and Outreach
   G: Other
   H: No opinion

10. What remaining concerns do you have regarding the new datums?

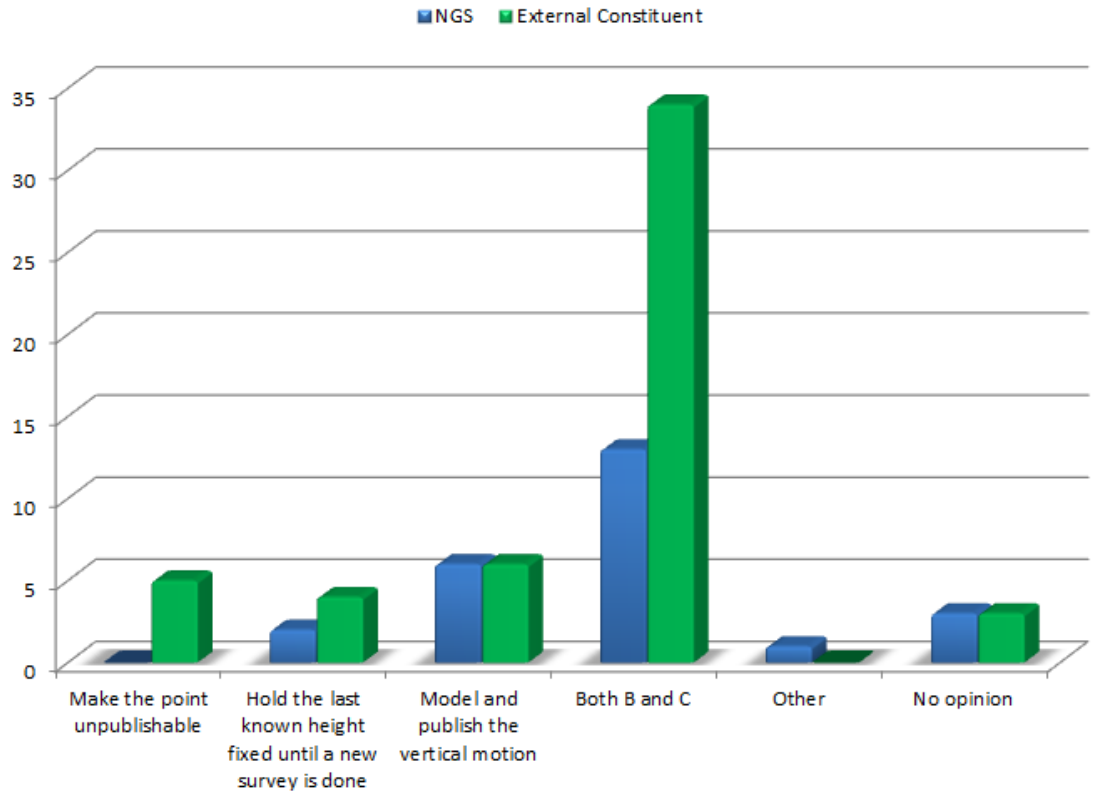
RESULTS

The first poll question allowed NGS to segment responses from NGS employees and external constituents to discern any bias between the two groups. The results were separated between NGS and external constituents when possible, although no strong bias was detected between the two groups.

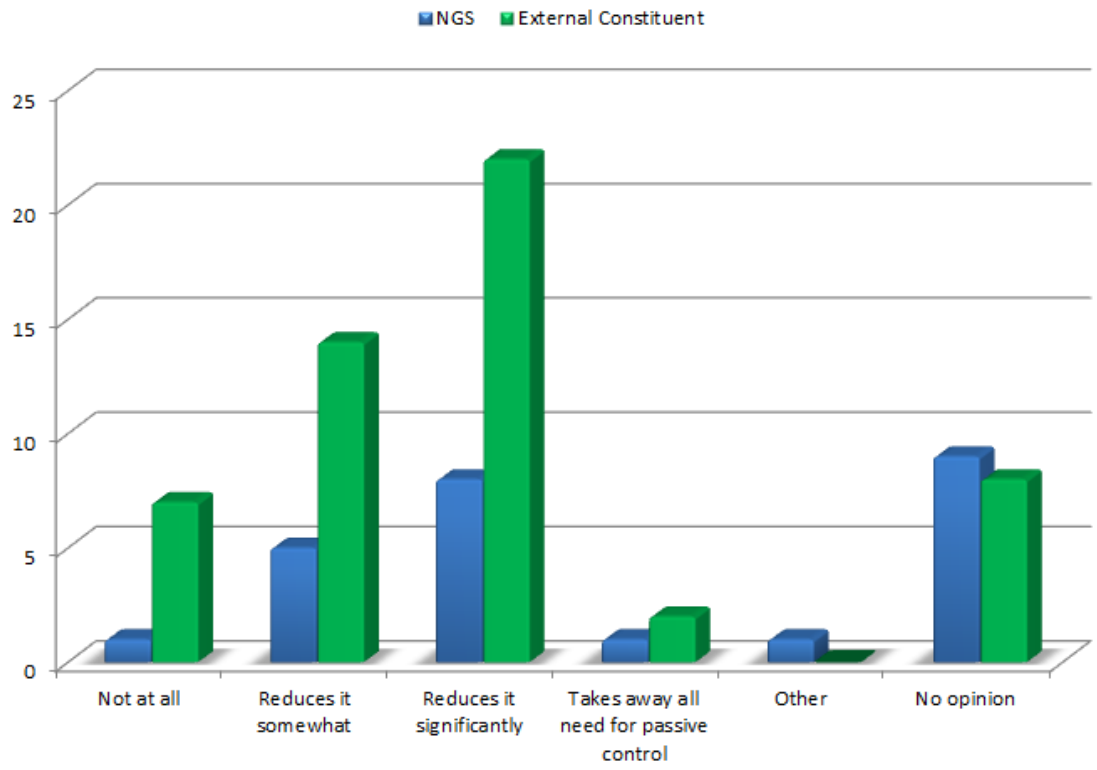


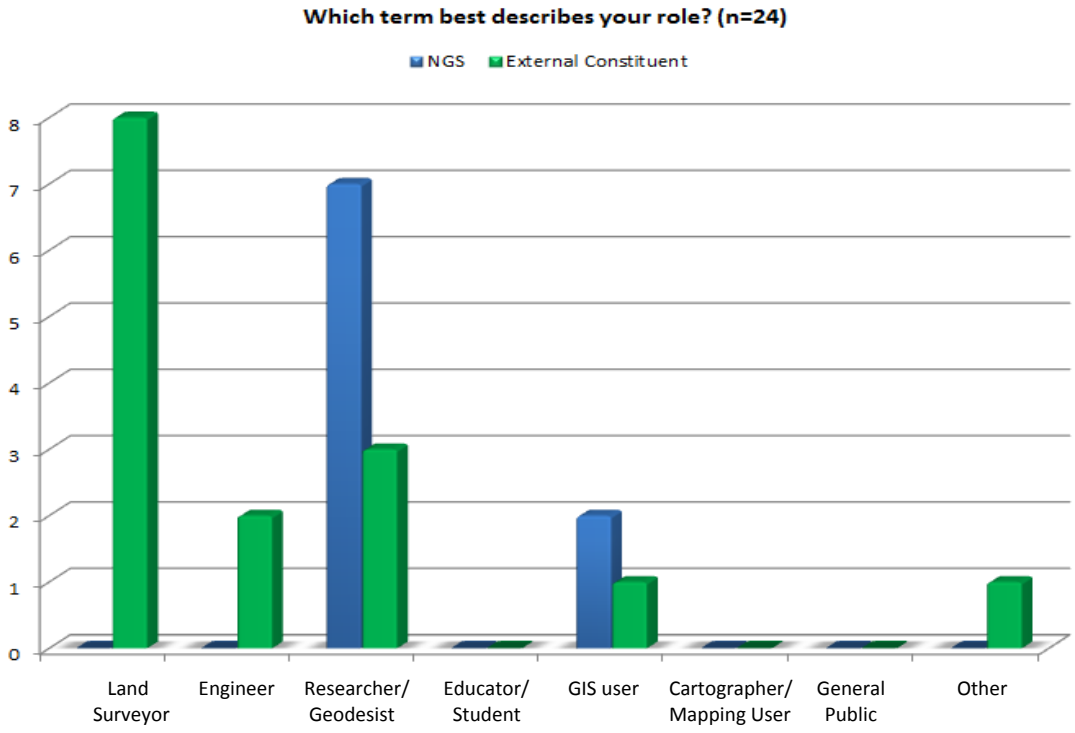


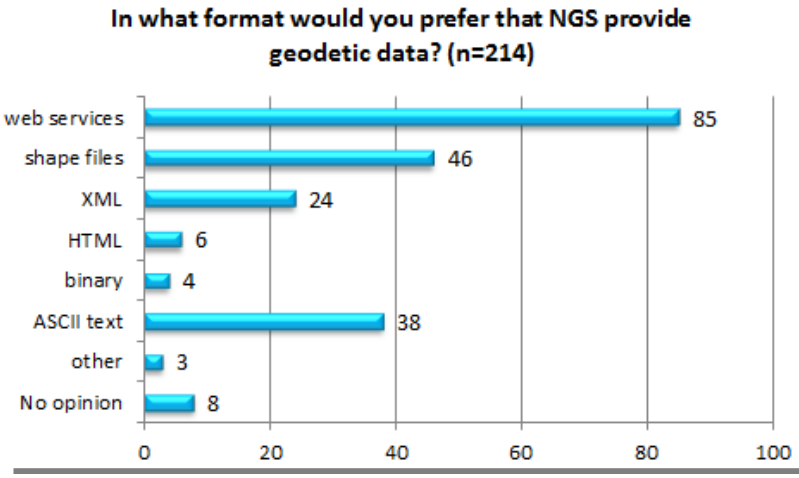
If the height of a point is changing, what do you want NGS to do about it? (n=77)

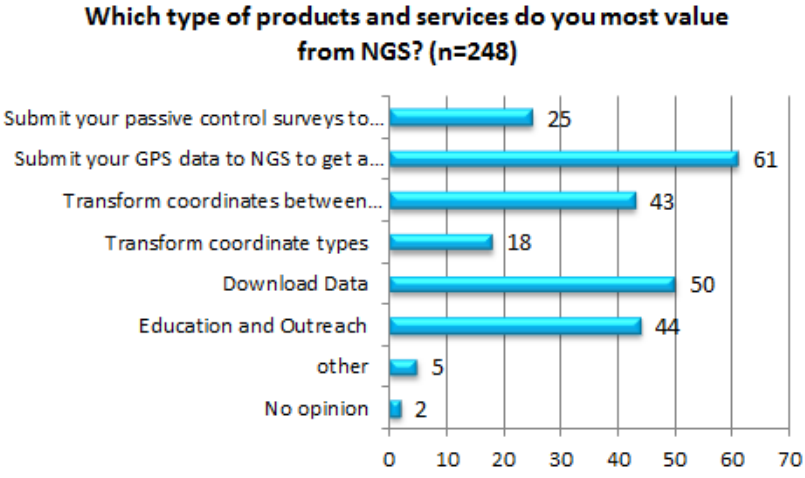


If you had access to orthometric heights at 2 cm accuracy in an RTN rover, how will this impact your need for passive control? (n=78)




Which term best describes your role? (n=24)
NGS
External Constituent
8
7
6
5
4
3
2
1
0
Land Surveyor
Engineer
Researcher/ Geodesist
Educator/ Student
GIS user
Cartographer/ Mapping User
General Public
Other


In what format would you prefer that NGS provide geodetic data? (n=214)
web services
85
shape files
46
XML
24
HTML
6
binary
4
ASCII text
38
other
3
No opinion
8
0
20
40
60
80
100


Which type of products and services do you most value from NGS? (n=248)
Submit your passive control surveys to...
25
Submit your GPS data to NGS to get a...
61
Transform coordinates between...
43
Transform coordinate types
18
Download Data
50
Education and Outreach
44
other
5
No opinion
2
0
10
20
30
40
50
60
70

APPENDIX D: EVALUATION RESULTS

Participants were invited to complete evaluation forms after the Geospatial Summit to provide feedback and help inform the planning of future events. Identical questions were distributed to in-person and webinar attendees, and completing the evaluation was completely options.

Table C1: Audience Profile and Response Rate

	MONDAY			TUESDAY		
	In-Person	**Webinar**	**Total**	**In-Person**	**Webinar**	**Total**
Constituent completed eval.	**43**	**45**	**88**	**47**	**32**	**79**
NGS employee completed eval.	**4**	**6**	**10**	**4**	**7**	**11**
(blank employment)	**1**	**-**	**1**	**1**	**-**	**1**
Total completed eval. forms	**48**	**51**	**99**	**52**	**39**	**91**
Meeting attendance	**228**	**111**	**339**	**241**	**87**	**328**
Response rate	**21%**	**46%**	**29%**	**22%**	**45%**	**28%**

**People that attended both days are included in both totals (i.e. there is overlap, so do not sum)*

EVALUATION QUESTIONS:

The question-and-answer choices are listed below. Questions 1-8 required one response per question; question 9 allowed up to nine responses; and question 10 was open-response, and is not included in this summary.

1. Which day of the Summit are you evaluating?
   - A. Only Monday, April 13
   - B. Only Tuesday, April 14
   - C. Both days

2. Do you work for NOAA's National Geodetic Survey (NGS)?
   - A. Yes
   - B. No

3. How clear were the objectives of the event?
   - A. Extremely clear
   - B. Very clear
   - C. Moderately clear
   - D. Slightly clear
   - E. Not at all clear

4. How beneficial was the information presented at the event?
   - A. Extremely beneficial
   - B. Very beneficial
   - C. Moderately beneficial
   - D. Slightly beneficial
   - E. Not at all beneficial

5. How organized was the information presented at the event?
   A. Extremely organized
   B. Very organized
   C. Moderately organized
   D. Slightly organized
   E. Not at all organized

6. How would you describe the amount of technical information covered during the event?
   A. Much too much
   B. Somewhat too much
   C. About the right amount
   D. Somewhat too little
   E. Much too little

7. How organized was the event?
   A. Extremely organized
   B. Very organized
   C. Moderately organized
   D. Slightly organized
   E. Not at all organized

8. Overall, how satisfied were you with the event?
   A. Extremely satisfied
   B. Moderately satisfied
   C. Neither satisfied nor dissatisfied
   D. Moderately dissatisfied
   E. Extremely dissatisfied

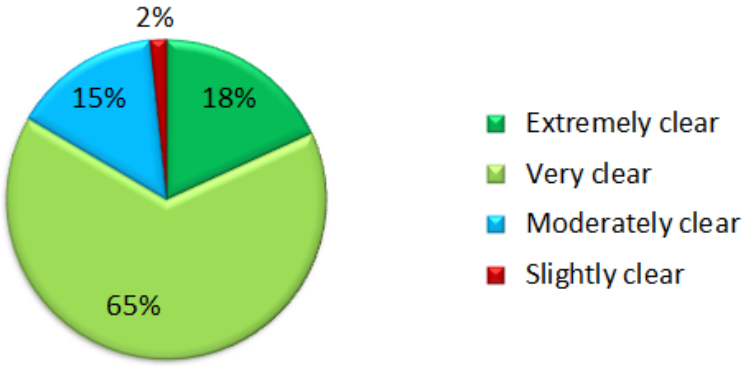
9. What sessions did you find most useful? (circle as many as you like)
   A. Overview of 2010 Geospatial Summit
   B. Progress toward New Reference Frames
   C. Benefits of New Reference Frames
   D. International Geospatial Activities
   E. New Products, Services, Models and Tools
   F. Legislative Issues
   G. Canada's Geodetic Reference Frames
   H. Feedback from Stakeholders
   I. Other _____

10. Do you have any other questions, comments, or suggestions?

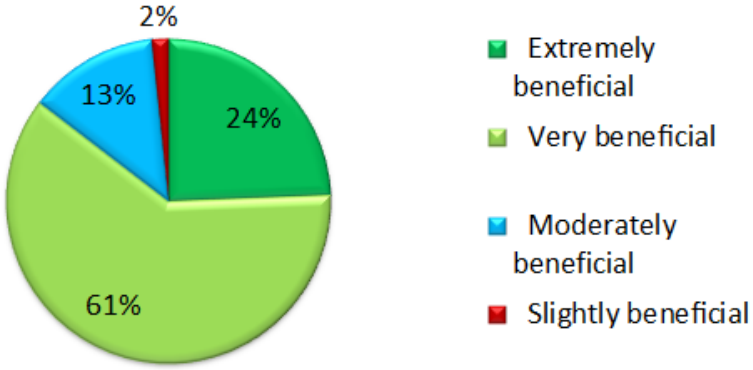
RESULTS:

Summary charts combine responses from in-person and webinar attendees, as well as external stakeholders and NGS employees. Overall, attendees were very satisfied with the event.

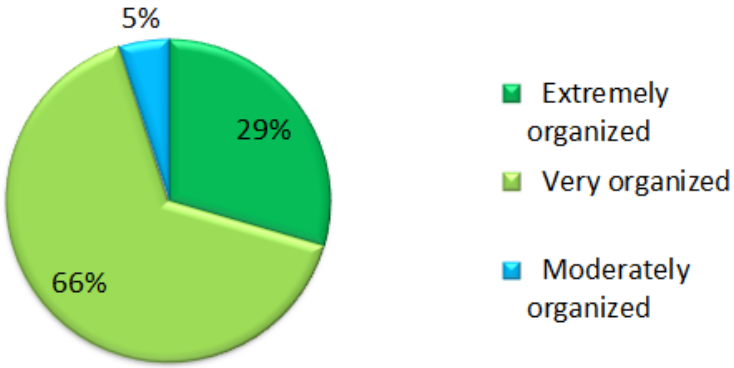
How clear were the objectives of the event? (n=121)



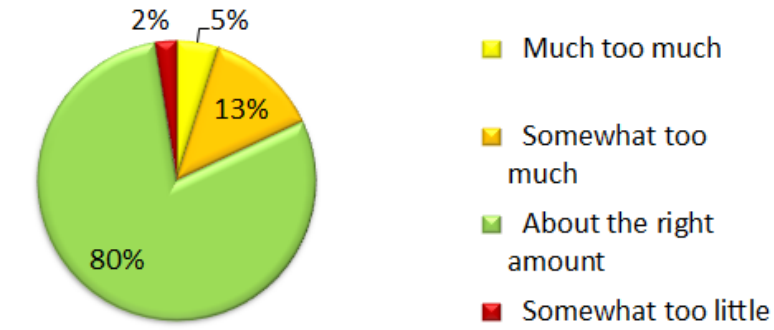
How beneficial was the information presented at the event? (n=123)



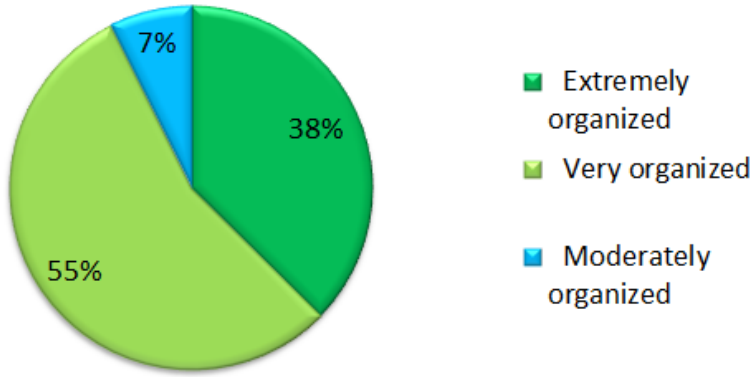
How organized was the information presented at the event? (n=122)



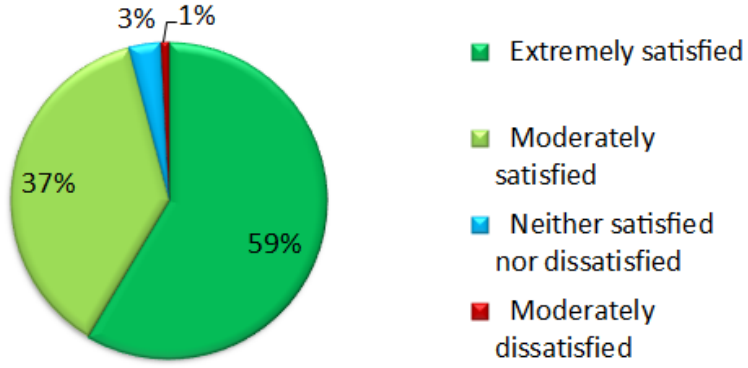
How would you describe the amount of technical information covered during the event? (n=122)



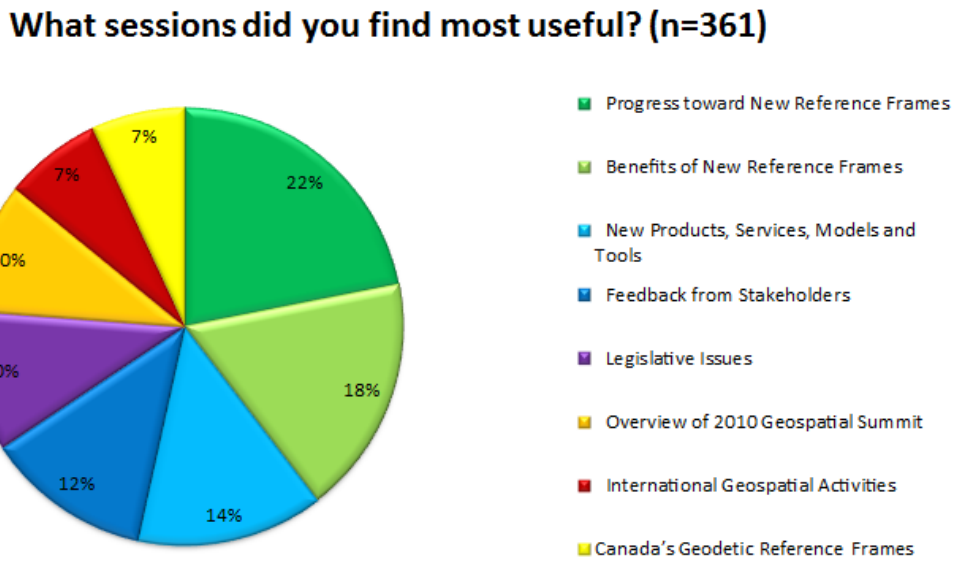
How organized was the event? (n=123)



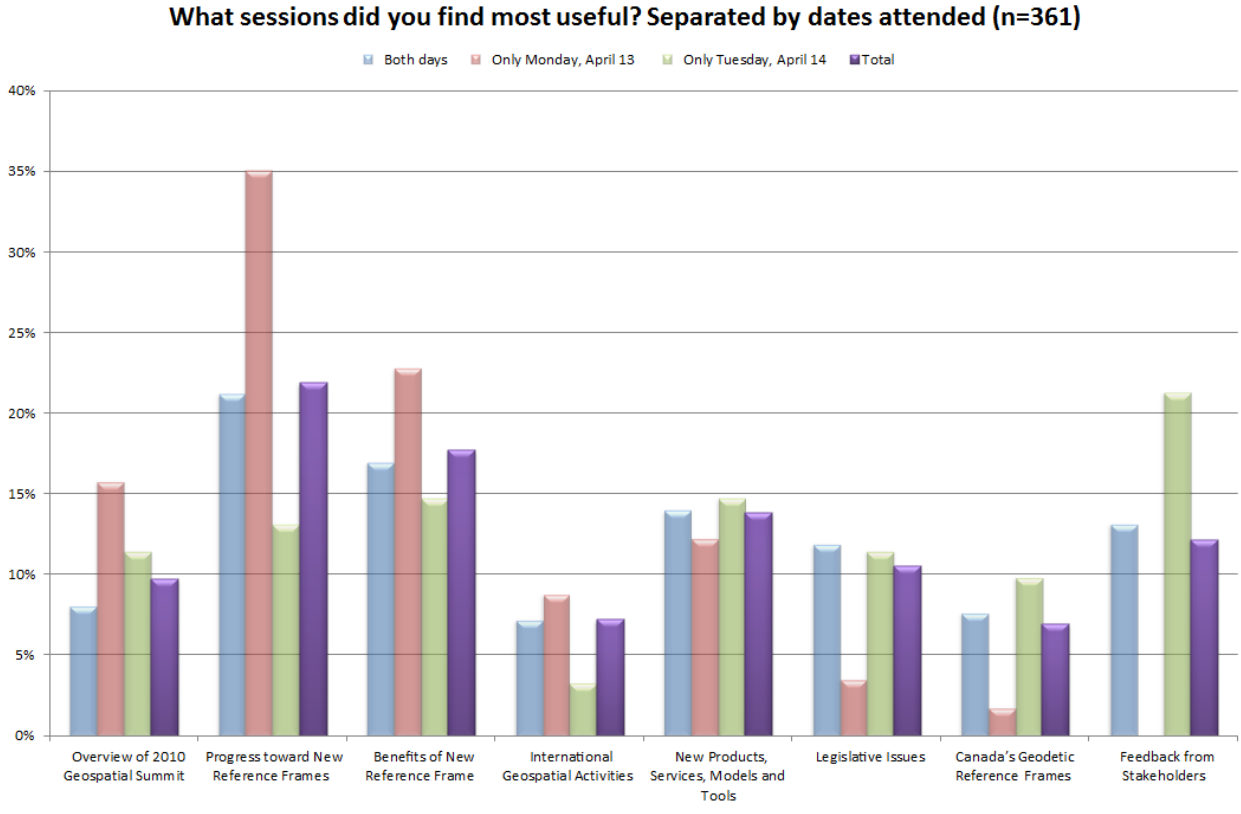
Overall, how satisfied were you with the event? (n=123)



All sessions were useful to attendees, with the greatest interest in hearing about the "Progress toward New Reference Frames" and "Benefits of New Reference Frames." Additionally, attendees who only attended one day of the Geospatial Summit tended to vote for sessions on the day they attended.



**Percent of votes, recognizing attendees could select multiple sessions*



**Percent of votes, recognizing attendees could select multiple sessions.*

National Executive Committee for Space-Based Positioning, Navigation, and Timing (PNT) National Coordination Office briefing
Colonel Christopher Eagan, National Coordination Office for Space-Based PNT

Brainstorm actions needed to coordinate the release of New Reference Frames
Dr. Dru Smith, National Geodetic Survey

Discuss or collect fresh feedback from the Geospatial Summit (No presentation, discussion)
Juliana Blackwell, National Geodetic Survey

OPUS Projects: Users and Statistics
Mark Armstrong, National Geodetic Survey

OPUS Projects Update
Rick Foote, National Geodetic Survey

FGDC Geographic Information Framework Data Content Standard Part 4: Geodetic Control
Rick Foote, National Geodetic Survey

Height Modernization Overview
Christine Gallagher, National Geodetic Survey

Height Modernization: Future Directions
Dr. Vicki Childers, National Geodetic Survey

Panel Discussion on New Datums
Dr. Vicki Childers, National Geodetic Survey
Steve Hilla, National Geodetic Survey
Dr. Dan Roman, National Geodetic Survey

State and Regional updates

North Carolina / Gary Thompson, North Carolina Geodetic Survey
Gulf Coast Region / Dr. Gary Jeffress, Texas A&M University, Corpus Christi
Wisconsin / Diane Arendt, Wisconsin Department of Transportation
Illinois / Sheena Beaverson, Illinois Geological Survey
New York / Steve Roden, New York Department of Transportation

Height Modernization Related Projects

Guidelines for Establishing GPS-Derived Ellipsoid and Orthometric Heights (NOS-NGS 58-59) /
Dr. Dan Gillins, Oregon State University

River Crossing Procedures (to revise Geodetic Leveling, NOS-NGS 3) /
Kendall Fancher, National Geodetic Survey

Accurate Elevations for Sea Level Change Sentinel Sites /
Dr. Philippe Hensel, National Geodetic Survey

International Great Lakes Datum of 2020 /
Laura Rear McLaughlin, Center for Operational Oceanographic Products and Services