Changes Afoot After 2022: State Plane and the Death of the U.S. Survey Foot
Q&A doc
November 10, 2022
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Questions and comments have been grouped into categories, and similar questions have been combined and given a single answer.

SPCS2022 implementation and documentation

Q: Will there be a new ellipsoid and Geoid definition for use with SPCS 2022?
The same ellipsoid used for SPCS 83 (GRS 80) will also be used for SPCS2022, and for all other components of the modernized National Spatial Reference System (NSRS). A new gravimetric geoid model (GEOID2022) will be implemented in 2025 as part of NSRS modernization, which will include rollout of SPCS2022 at the same time.

Q: I am not understanding how it is decided why states just have one projection...Like Montana and North Carolina.
Both Montana and North Carolina only have a single zone for current State Plane (SPCS 83), as do several other states. For SPCS2022, NGS will design a statewide zone for every state. These are likely most useful for applications such as statewide GIS, although that varies for different states. In addition, most states will also have one or two multiple-zone layers. Most of the zones in the multiple-zone layers were designed by the states themselves to meet their needs for lower distortion. North Carolina chose to have only a single statewide zone (as it has currently). Montana designed a partial-coverage layer consisting of 19 zones. The status for layers and number of zones for SPCS2022 is summarized in slides 20-23 in the presentation.

Q: Has Washington State added more than two zones yet?
No, Washington State will only have a north and south zone (and, of course, a statewide zone) when SPCS2022 is rolled out in 2025. However, after the rollout, the state will be able to either replace those two zones with a complete-coverage layer of more zones, or to add a third layer of partial-coverage zones.

Q: Will OPUS solutions return values in both the State Plane values and LDP values?
After the rollout of the modernized NSRS in 2025, OPUS will be able to give coordinates in all SPCS2022 zones. This will include those zones that would be considered “low distortion projections” (LDPs), and in such cases SPCS2022 and LDPs will be one and the same. The mechanism for how OPUS will choose SPCS2022 zones in states with multiple layers has not yet been determined. Note, however, that OPUS will only give coordinates for LDPs that are part of SPCS2022.

Q: What are the extra two years for?
Although the design of the State Plane Coordinate System of 2022 will be done by next year, a great deal of work remains to complete the new modernized national spatial reference system. For detailed information on this remaining work, see our recording of the June 2022 webinar:
https://geodesy.noaa.gov/web/science_edu/webinar_series/2022-are-you-done-yet.shtml

Q: Using SPCS2022 without the new reference frame seems like a slippery slope.
The risk of using SPCS2022 definitions with NAD 83 (or other existing reference frames) is that it could lead to confusion, since the difference in coordinates for these frames would be on the order of 1 to 2 meters. NGS agrees that this is a potential problem. However, there is nothing we can do to prevent people from using SPCS2022 definitions with NAD 83, and we know that at least a few states plan to do so. The best we can do in such cases is to strongly recommend that they change grid origin (false northing and/or easting) by a large amount, say more than 10,000 meters. That will at least help prevent mixing up coordinates based on NAD 83 with those based on the 2022 terrestrial reference frames.

Q: Will a projection registry be created by NGS for SPCS2022?
NGS is not planning on creating a projection registry as part of the 2025 rollout of the modernized NSRS. However, NGS will provide SPCS2022 zone definitions to the ISO Geodetic Registry and the EPSG Geodetic Parameter Dataset. Both of those can be used by software vendors and others to access SPCS2022 zone definitions. In addition, all zone definitions will be in the NSRS Database that will be implemented as part of the NSRS modernization rollout.

Combined questions:

Q: Similar to the NGS NOAA Technical Memorandum No. 5 for SPCS 83, will there be a new technical memorandum that will publish the new formulas including the 1-parallel lambert parameters?

Q: Doesn't support for SPCS imply support for education/training in its proper use? For example the t-T correction, how to use combined factors, etc. Will NGS Advisors provide such training?

Answer to combined questions:
NGS plans to publish a technical memorandum with the projection equations used for SPCS2022 by about the end of 2023. We also plan to publish a more comprehensive report or manual about SPCS2022 before the NSRS modernization rollout in 2025. Together, these documents will replace NOAA Manual NOS NGS 5, and they will include information on combined factors (and linear distortion in general), convergence angles, arc-to-chord (t-T) corrections, zone parameters, and other relevant aspects of SPCS2022. Such information will serve as a valuable educational resource, both for customers to use directly and for NGS Regional Geodetic Advisors (and other NGS employees) to provide training.

Linear distortion, combined factors, and low distortion projections

Q: Is the linear distortion formula also the percent error formula (without converting to a percent, of course)?
Yes, indeed they are the same formula (except, like you noted, the percent error formula also includes multiplying by 100 to convert to a percent). Because distortion is usually very small, it is more convenient to multiply by 1 million to get values on parts per million (ppm) rather than percent. For example, a common distortion value for SPCS2022 is 50 ppm, which is only 0.005%.

Q: Looking at your linear distortion maps, there seems to be a strong correlation between high elevation areas and large linear distortion. Can accurate results be obtained without adopting the more rigorous procedures regarding how to apply CFs and t-T described in J. Stem's manual?

Yes, there is a strong correlation between topographic relief and linear distortion. The effect due to topographic height is easy to compute accurately, and is a pretty much constant linear value of 15.7 ppm per 100 m (4.8 ppm per 100 ft) change in height. But it is also affected by Earth curvature, which increases by the square of distance from the projection axis (see slide 14 in the presentation). Computing distortion due to curvature is much more complicated, but it can be approximated as 0.0123 ppm times the squared distance from the projection axis (in km). But for best results, it is better to use the more accurate computations in Stem's manual (NOS NGS 5). The arc-to-chord (t-T) correction is not related to the linear distortion/combined factor. Although it is a function of distance from the projection axis as well as direction, methods for approximating it are given in Stem's manual. But it is small and can be neglected in many situations.

Q: Why, for example in Alabama, would you need the small specific zones if the 3 large zones that cover the state basically achieve the same amount of distortion accuracy?
For the most part, the small partial-coverage zones in Alabama actually have considerably less distortion than the three complete-coverage zones. In comparing slides 27 and 28, it looks like the distortion is the same because the distortion color ramp step size is in increments of 50 ppm. If it were smaller, say 20 or 10 ppm, you would see a difference. However, one of the small Alabama zones (for the Mobile area) does perform about the same, so it will not be included in SPCS2022.

Q: Is there a way to use an unofficial local low distortion zone? and tie it to NSRS?
At this time, NGS does not intend to support any projected coordinate systems other than State Plane and UTM in our products and services. That means local low distortion zones that are not a part of SPCS2022 will not be supported in things like OPUS, NCAT, Datasheets (or their counterpart in the modernized NSRS). However, you can still use such systems in the NSRS for your own purposes, simply by using NSRS latitude and longitude values. This is currently done for low distortion systems throughout the country, for example the Oregon Coordinate Reference System.

Combined questions:

Q: I had a hard time tracking what the difference between all the distortion maps was. Before they are released could more context be added to those maps

Q: What are the distortion differences in Alaska?

Q:What was the color pattern on Montana on the last slide?

Answer to combined questions:
The fairly large number of distortion maps and the pace they were displayed can make it hard to make comparisons. But if you download the slides, one thing that helps is to be able to toggle back-and-forth between slides at your own pace. All maps have the same distortion color ramps, which makes it easier for visual comparison. The first set of distortion maps are for CONUS (slides 24-29), and the second set is for Alaska (slides 30-34). Updated versions of these maps (and many others) will be available for download beginning in early 2023 at https://www.ngs.noaa.gov/SPCS/download.shtm. Having a larger set should also help provide better context.

Combined questions:

Q: How "large" an area makes a difference in combined factor?

Q: Could you discuss the impact on accuracy of the use of a single combined factor for all of a county? Any rule of thumb?

Answer to combined questions:
The combined factor is a function of both the distance from the map projection axis (as a result of Earth curvature) and changes in height. See slide 14 of the presentation to see how both of these variables affect linear distortion. That will give you a sense of how the size of an area can affect linear distortion, where distortion is simply the combined factor plus 1 (see slide 11). Because linear distortion magnitude increases with the square of distance from the projection axis, it is not recommended to use a single combined factor for a large area, such as a county. The errors will be eleven greater if the county has a lot of topographic relief. Slide 14 gives two simple equations for estimating the linear distortion due to distance from the projection axis and change in height. Table 2 in the SPCS2022 Procedures document gives zone width and height ranges for specific linear distortion ranges. The slide 14 equations and this table can serve as “rules of thumb.” But keep in mind that both Earth curvature and change in height contribute to distortion.

Deprecation of the U.S. survey foot

Combined questions:

Q: NGS is moving to the international foot. WHY?
A: Please review this webinar to find the answer to your question:
https://geodesy.noaa.gov/web/science_edu/webinar_series/ending-us-survey-foot.shtml

Q: My question is: we are eliminating the U.S. Survey foot in favor of the International foot when the vast majority of DOT's and surveyors use the U.S. Survey Foot. The only three countries which still use Imperial measurements are the U.S., Liberia and Myanmar. Therefore, why are we changing to a standard that only exists for a smaller population instead of holding the U.S. Foot which is in the majority use? Justifying that by saying the international foot has an exact conversion is somewhat trivial in that the conversion is not like the transcendental value for Pi. The conversion for the U.S. survey foot from meters is exact at 39.37/12 which of course divides out to 3.2808333333 with infinitely repeating 3's. Since the NGS is metric, what difference does it make to you as to which foot is being used?

Answer to combined questions:
The main reason for deprecating the U.S. survey foot (sft) and adopting the international foot (ift) nationwide is that the ift was adopted as the official version of the foot in 1959 by the U.S. (and several other countries at about the same time). The previous foot was named the sft at that time and was allowed to persist temporarily for one and only one reason: for continued use in geodetic survey applications (such as State Plane). It was not intended for use in boundary surveys or any other application, and its use was supposed to end when NAD 83 was adopted in 1986. But that did not occur, and an unintended outcome was the continued use of two nearly identical versions of the foot. It has nothing to do with the ift being “better” or having an exact metric equivalent; it is simply an effort to standardize a unit of measurement. And although most states use the sft for surveying applications, surveying represents only a small fraction of overall usage. Every other part of the U.S. society (and the world) that uses the U.S. customary system uses the ift. The difference it makes to NGS, and to the National Institute of Science and Technology (NIST), is that having two versions of the foot in concurrent is at odds with the idea of standards, and it causes errors and confusion.

There is much more to this than the above paragraph conveys. If you want to learn more, we recommend that you read the “final determination” Federal Register Notice in

its entirety. NGS also gave two webinars in 2019 that give details about the history and reasons for deprecating the sft, the first on April 25 and the second on December 12.

Q: We have a new contract with the Army Corp, they are requiring we use US Feet in Oregon, are they being updated?
We would need more information to give a good recommendation. However, assuming your contract is not based on the use of the State Plane Coordinate System of 2022 (which seems like a safe assumption), then the contract may not need to be updated. Are you using State Plane Coordinates for your project? It's important to note that Oregon uses international feet in the current State Plane Coordinate System of 1983.

Q: What level of involvement, if any, did BLM have with the new State Plane systems and foot definition?
BLM is aware of deprecation of the U.S. survey foot, but as far as we know has not formally or officially raised any concerns with NGS or NIST. Some informal comments indicate that they are not very concerned because the effect on mark-to-mark distances is small (only about 0.01 ft per mile), and because it can be handled with metadata. It's worth pointing out that there have so far been nine editions of the manual of instruction for the survey of the public lands, and that three of those predate the original 1893 definition used for what we now call the U.S. survey foot.

Q: States that have been using the U.S. survey foot for decades are likely to have ensuing errors by the mandated use of the International Foot. It is inevitable.
Yes, it seems likely that some mistakes will occur as a result of this change. However, such errors will diminish over time as the U.S. survey foot fades into obscurity. But if both versions of the foot are maintained, the mistakes that occur now will never end. It is worth noting that six states switched to the international foot in the late 1980s, but it appears that change did not cause many problems. In addition, we have so far not been shown even one example of where the change caused a problem for boundary surveys in those six states.

Q: Do ruler makers in the USA know they'd better make the change?
We think the "ruler makers" are on board! The National Institute of Standards and Technology (NIST) has the authority to deprecate the U.S. survey foot, and they will do so after Dec. 31, 2022 :) Levity aside, the graduations on rulers and even steel tapes and leveling rods used in surveying are not manufactured (and cannot be used) to a precision of 2 ppm. In addition, it is highly likely that most high-precision industrial and metrological applications that use the U.S. customary system already use the international foot, since it has been the U.S. standard since 1959. Keep in mind that

only surveyors (and not all surveyors) use the U.S. survey foot, and that surveying represents a small portion of U.S. economic activity.

Q: 2 ppm is a big deal when coordinates have values of 500,000 and 2,000,000.
Yes, even though the 2 ppm difference between the U.S. survey foot and international foot is “small”, it can create large errors for coordinates. The error of mixing up versions of the foot can exceed 50 feet for current State Plane coordinates (the largest differences occur in the Nevada East Zone of SPCS 83).

Q: When the NSRS 2022 and iFT comes about in 2025, can you still use CORS with NAD 83 sFT?
Upon the rollout of the modernized NSRS, official coordinates for stations in the NOAA CORS Network will no longer be in NAD 83. State Plane Coordinates for these stations will also be in SPCS2022, which will be given in meters and international feet only (not U.S. survey feet). It’s also important to note that our software, OPUS, will produce coordinates in the 2022 terrestrial reference frames and not in NAD 83.

Q: Is there a link to the CBS Sunday Morning segment on the foot change?
We don’t know of a CBS show about the foot change. Maybe you mean “The Daily Show with Trevor Noah”? The link to the “Thank Me Later” episode “America has a Foot Problem” is https://www.cc.com/video/zvx3zs/the-daily-show-with-trevor-noah-thank-me-later-america-has-a-foot-problem.

Combined questions:

Q: Is it recommended to stick with U.S. Survey foot with NAD83 until we move to SPCS 2022?

Q: So to clarify: in the time between beginning 2023 to 2025 (when the new SPCS datums are rolled out) are we to use international feet with SPCS 83? Or continue to use US survey feet with SPCS 83 until the year 2025? Thanks

Q: To be clear, starting on Jan 1st 2023 (and until SPCS2022 is adopted) should US-foot states start using International Feet with their existing NAD83 zones? (e.g. California Zones 1-6 with Int Feet?)

Q: So what is the best way to switch to the new foot? And when is SPCS2022 coming out since these two things seem tied together?

Q: So starting Jan 1st, will services like OPUS and CORS only report data in meters and Int. Feet only?

Q: Can surveyors just continue using US Survey foot for private surveys and/or public utility route surveys after this year?

Q: Why not make the foot definition and SPCS2022 release happen together. Won't it kind of happen by default?

Q: If you publish coordinates for monuments should you update the database come 2023?

Answer to combined questions:
You should continue to use the U.S. survey foot (sft) for SPCS 83 after 2022. You should NOT make the switch to the international foot (ift) definition while using SPCS 83 (or SPCS 27). States currently using the sft for SPCS 83 should continue to do so. The ift will be used for all zones in every state for SPCS2022, and every other component of the National Spatial Reference System (NSRS), but that won't be implemented until 2025.

The reason for continuing to use the sft for SPCS 83 is that it is an existing "legacy" system, and it would cause too much disruption to change the foot definition. NGS will always support the sft for SPCS 83 in states that have officially adopted the sft for SPCS 83, even after SPCS2022 has been implemented. The same is true for SPCS 27 in all states.

Until NSRS Modernization is done, all NGS products and services (such as OPUS, CORS coordinates, and Datasheets) will continue to use NAD 83 and will provide SPCS 83 coordinates using the official foot version recognized by NGS. The NGS database will also not be updated for public release until the rollout of the modernized NSRS in 2025.

NGS and NIST originally intended to deprecate the sft and roll out the modernized NSRS at more-or-less the same time. When NSRS modernization was delayed, we decided to remain on the same schedule for sft deprecation. One reason for that was the difficulty of going through the deprecation process. Another reason is that it gives people more time to prepare for the change when NSRS modernization occurs (for example by updating state legislation).

People will continue to use SPCS 83 at least until SPCS2022 is rolled out in 2025. Those states using the sft for SPCS 83 should continue to do so. That means they should continue to use the sft in their equipment and associated software (such as GIS and CAD). Situations may occur after 2022 where an organization uses custom (non-SPCS) coordinate systems. In such cases, my recommendation is to use the sft if it is also being used for SPCS 83. Trying to manage a partial switch (where some things use the ift and others use the sft at the same time) could cause confusion and lead to mistakes. This is in keeping with the "orderly transition" idea stated in the final determination FRN. We understand that the transition may take some time for certain organizations, and that's OK. The most important part is that it occur in an orderly fashion. Over time use of the sft will diminish, and we expect that to accelerate after SPCS2022 is released in 2025.

It's important to also point out that although NGS will always support the sft, it will only do that for the legacy SPCS 27 and 83 systems. Once Modernization is done, NGS will not provide any tools (like OPUS) which allow users to work within NAD 83. At best, NGS will allow users to find old NAD 83 coordinates, and use NCAT to transform to/from NAD 83. But, in general, NGS will not support NAD 83 after modernization.

Below are links to additional information that may prove helpful:

- The "final determination" Federal Register Notice on deprecation of the sft issued on 10/5/2020. We recommend reading it closely and in its entirety.
- The initial Federal Register Notice on deprecation of the sft issued on 10/17/2019.
- The NIST sft website and the NGS New Datums FAQ web page.
- The 40 states that officially adopted the sft for SPCS 83 are listed in Table C.1 of Appendix C of NOAA Special Publication NOS NGS 13, "The State Plane Coordinate System History, Policy, and Future Directions"

Impacts of SPCS2022 and foot change on equipment and software

Combined questions:

Q: Will this require modifications of surveying instrument settings? (EDMs)

Q: HOW WILL THIS AFFECT MY EXISTING GPS UNITS?

Q: how is GPS 4 going to affect spcs 2022?

Answer to combined questions:
Because there are many different equipment and software manufacturers, NGS cannot say definitively how they will handle SPCS2022 or deprecation of the U.S. survey foot. However, it is likely that equipment manufactured within the last few decades uses the metric system internally, with software and/or firmware that performs the conversions to feet. If the software and/or firmware are reasonably up-to-date, then you should have no problem in selecting the correct version of the foot. This applies to total stations (i.e., EDMs), GNSS units, digital levels, scanner, and other electronic surveying equipment, as well as associated software. GNSS itself (including GPS) is metric and does not include projected coordinate reference systems; all positioning is based on global geodetic frames

As for SPCS2022, individual manufacturers will have to decide how they want to add that to their equipment and software. We will try to make it as easy as possible for them, by providing SPCS2022 definitions in standardized machine-readable format. We will also help ensure the definitions are included in datasets widely used by software vendors, such as the ISO Geodetic Registry and the EPSG Geodetic Parameter Dataset.

Adoption of metric system

Combined questions:

Q: Why not just support metric and provide a tool for end users to select between foot and US Survey Foot. The sooner the USA goes metric the better.

Q: Should we be moving USA into the metric system once and for all?

Q: If NGS is metric, then why did the US foot need to be retired?

Answer to combined questions:
We agree with the use of the meter. In fact, NGS has been a metric shop since 1977. It's our customers who are requesting US customary units, which is part of the reason

NGS wants to support only one version of the foot. We believe that the new SPCS2022 provides an opportunity to eliminate the confusion and ensuing errors associated with using two different definitions of the foot.

A comprehensive adoption of the metric system (SI) requires support from the public. Only the public can influence politicians on this matter. If you are interested in promoting such a change, we recommend joining a group that advocates for going fully SI, such as the U.S. Metric Association.

State legislation

Combined questions:

Q: Where can I find the definitions of zones for a give state so that they may be defined in legislation?

Q: can you post the link to the updated legislation web page from the last few slides.

Answer to combined questions:
Information on NSRS legislation that includes foot definitions is available under item #5 on the new datums "Get Prepared" web page. There is also a legislation template, as well as actual new legislation from several states that can serve as examples.

Regarding zone definitions, they are still preliminary. But final definitions will be available in mid-2023. However, NGS strongly recommends that projection parameters (and other such technical information) NOT be included in legislation. Instead, the definition should be incorporated by reference, for example to NGS. Including such information in legislation itself will make it harder to update or modify it in the future. This recommendation is reflected in the legislation template and examples mentioned above. Another advantage of not including zone definitions in legislation is that the legislation can be updated now, rather than waiting for final definitions. That's why several states were already able to update their legislation for the modernized NSRS.

Coordinate conversions and transformations

Combined questions:

Q: what program should be used to convert between coordinate systems?

Q: Will NGS have some sort of translation tool to help translate between old SPC to SPC2022

Q: Will NGS tools such as NCAT will continue to support NAD 27 and 83?

Answer to combined questions:
The NGS Coordinate Conversion and Transformation Tool, or NCAT, allows users to easily convert between different coordinate systems and/or transform between different NSRS reference frames and/or datums, in a single step. For coordinate conversions, NCAT allows conversion between lat/long/height, State Plane, UTM, US National Grid, and geocentric (XYZ) systems. As part of NSRS modernization, NCAT will be updated to support conversions between existing State Plane and SPCS2022, and NCAT will continue to support both NAD 27 and 83 (and their associated versions of State Plane).

General information on NSRS modernization

Combined questions:

Q: Will monument data sheets be updated a little at a time before the rollout, or the new ones released all at once with the rollout?

Q: When will the Coordinates of the CORS Stations be adjusted to the new NSRS and published?

Q: Is the new American vertical datum (Grav-D) project also going to roll out in 2025?

Answer to combined questions:
NGS plans to update everything all at once at the rollout of the modernized NSRS in 2025, including published coordinates for passive marks and coordinate functions for CORSs. This includes coordinates based on the 2022 terrestrial reference frames, such

as the North American Terrestrial Reference Frame of 2022 (NATRF2022), SPCS2022 coordinates, and heights based on the North American-Pacific Geopotential Datum of 2022 (NAPGD2022). Coordinates based on NAD 83, SPCS 83, NAVD 88, and other vertical datums will no longer be supported as current geodetic control. The GRAV-D project will end by the time of the rollout, because its purpose is to collect and process data needed to create NAPGD2022.

GPS on Bench Marks

Q: Is the GPS on Benchmark campaign still being used or is the data collection already complete?
A: NGS will keep the doors open for submissions of GPSonBM data for the transformation tools through the end of September 2023. Data submitted before the doors are closed will be considered for use in the 2020.00 Reference Epoch Coordinate (REC) adjustments. Data that passes through the adjustment quality-control process will be used to assign REC coordinates on marks in the Modernized NSRS. Marks with valid coordinates in both NAVD 88 and NAPDG2022 will be used to create the transformation grids that will be released with the modernized system.

Q: I'm in a state where the DOT still relies heavily on HARN passive control. How will GPS on BM help transition from HARN to SOCS2022?
A: GPSonBM data will be used primarily to create the transformation grids between NAVD 88 and NAPDG2022. The horizontal transformation grids between NAD83 (2011) and NATREF2022 will primarily be created using CORS data, but GPSonBM data may be used in areas where CORS coverage is sparse.