Responses to questions and comments for the March 8, 2018, NGS webinar
"The State Plane Coordinate System: History, Policy and Future Directions"

NOAA's National Geodetic Survey

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First and foremost, on behalf of the people who helped make this webinar, I want to express our gratitude at the many compliments and kind words that were posted and emailed by the attendees. The positive and uplifting impact cannot be overstated. Thank you all.

There were about 200 pertinent questions and comments, depending on how they are counted, which includes some that were sent by email shortly after the webinar. Of those, 128 were classified as "actionable", i.e., that required a response or some action or awareness on the part of NGS. In an attempt to make the task of responding more organized, the 128 questions and comments were grouped into 13 categories in the outline below.

Many of the questions and comments were very good, and they most definitely will influence content and implementation of the April 12 webinar (you can register at https://geodesy.noaa.gov/web/science_edu/webinar_series/state-plane-coordinates-2.shtml).

I have tried to answer every question and address every comment, apart from a few specific ones that require me to directly contact the individuals. If a question was not answered, or if the answer given still leaves you puzzled, there is a good chance it will be addressed in the April 12 webinar. And of course there will be the opportunity to post questions and comments at that webinar as well. In the meantime, if there is something you'd like addressed sooner, please feel free contact us at NGS.SPCS@noaa.gov.

1. Comments and questions about webinar execution

a. *How many people attended the webinar?* A total of 802 registrants logged on, and 758 attended for at least 30 minutes.

b. *Are the recording and the slides from of the webinar available?* The recorded webinar and PowerPoint presentation are available for viewing or download at https://geodesy.noaa.gov/web/science_edu/webinar_series/2018-webinars.shtml .

c. *Where can I find the new State Plane report? NOAA Special Publication NOS NGS 13*, "The State Plane Coordinate System: History, Policy, and Future Directions", is available at https://geodesy.noaa.gov/library/pdfs/NOAA_SP_NOS_NGS_0013_v01_2018-03-06.pdf.

d. *It would be helpful if the slides were available before the webinar.* For the next April 12 webinar, a preliminary Adobe Acrobat (PDF) version will be provided at least 30 minutes prior to the scheduled start time of 2 pm Eastern Time.

e. *Can I use the webinar for continuing education?* Attendance certificates are provided about one week after the webinar. Let us know if you did not receive one.

f. *I had trouble hearing the webinar.* It was noted there were audio problems for at least one attendee. We will check system configuration and options on our end.

g. *A longer webinar with more information would be helpful.* More webinars (beyond the one on April 12) are being planned, including possibly a SPCS2022 question & answer webinar.

h. *We would like a webinar on SPCS2022 for our state.* Although such webinars are not currently planned, it may be possible to provide more state-specific information, especially through your Regional Geodetic Advisor (see https://geodesy.noaa.gov/ADVISORS/index.shtml for information on the advisor program).

2. **More map projection fundamentals.** About 20 attendees expressed a desire for more background concepts on map projections. Some of that will be included in the April 12 webinar, although the overall emphasis will be on providing more details about SPCS2022.

a. *This webinar was too technical. It would be helpful to have webinars the cover map projections fundamentals.* NGS is considering providing webinars on projected coordinate system fundamentals, to cover essential concepts at a more relaxed pace.

b. *Are webinars or training on map projection fundamentals available on the NGS web site?* NOAA's Official for Coastal Management Digital Coast has produced an online training called "Understanding Map Projections, Datums, and Coordinate Systems" at https://coast.noaa.gov/digitalcoast/training/datums.html.

c. *Where can I find more documents on map projections?* There are several good books on map projections. Although we cannot recommend specific privately published books, there are government published texts that are freely available online. The following two are quite technical, but are widely referenced:

i. "Map Projections ─ A Working Manual", *U.S. Geological Survey Professional Paper 1395*, pubs.er.usgs.gov/djvu/PP/PP_1395.pdf.

ii. "State Plane Coordinate System of 1983", *NOAA Manual NOS NGS 5*, National Oceanic and Atmospheric Administration, National Geodetic Survey, http://geodesy.noaa.gov/library/pdfs/NOAA_Manual_NOS_NGS_0005.pdf.

3. **General comments and questions on content**

a. *When will SPCS2022 be available for use by the public?* SPCS2022 will be available when the 2022 Terrestrial Reference Frames (TRFs) are released, which is planned for sometime in calendar year 2022. However, the technical characteristics of the SPCS2022 zones will be provided prior to 2022, likely during 2021. And before that, regular updates will be given as SPCS2022 evolves.

b. *There was too much history content; I just wanted to know about future plans.* We felt it was important to provide some background about the history and evolution of State Plane before delving into the details planned for SPCS2022. More information on SPCS2022 will be provided in the April 12 webinar. But even in that webinar there will not be time to go through everything in depth. In addition, it appears some map projection fundamentals may need to be addressed. More webinars are tentatively planned for later, which can delve into greater detail. But please keep in mind that SPCS2022 characteristics will not be finalized until after August 31, 2018, so it is not possible to provide all details at this time (although we will provide as much information as we can).

c. *Have any states designed their own State Plane zones?* Most existing SPCS 83 zones were designed by NGS (although a few were designed by others). For SPCS2022, NGS will design zones for states, with a design criterion of 50-400 parts per million (ppm) at the topographic surface. For design distortion of less than 50 ppm, states must design their own zones. States can also design zones in the 50-400 ppm distortion range, but they must let NGS know so that it can be reviewed and approved, and the design must meet (the soon-to-be-released) SPCS2022 policy and procedures.

4. **Conformal map projections.** Conformality was not covered in much detail in the March 8 webinar. In response to user questions and comments, more information will be provided in the April 12 webinar.

   a. *What is a conformal map projection?* A conformal (or orthomorphic) map projection is one that satisfies a specific pair of differential equations (called the *Cauchy-Riemann equations*). Without going into the mathematics, this can be described by saying that the magnitude of change in the projected coordinates with respect to the change in the geodetic coordinates is the same in all directions at a point. Some characteristics of conformal map projections are:

      i. Projected lines intersect at the same angle as on the Earth. For example, projected meridians and parallels intersect at right angles.

      ii. The **linear distortion** (scale error) is the same in all directions from a point. So an infinitesimally small circle on the Earth is also a circle when projected. For all non-conformal projections, such circles are projected as ellipses (i.e., distortion varies with direction), except at a few specific locations. These distortion ellipses are also called *Tissot's indicatrices*.

      iii. Shapes are ***locally*** preserved (i.e., "small" areas have the same shape when projected as on the Earth).

      iv. Projected (grid) north and geodetic north differ by a single number (the **convergence angle**). This is also approximately true for azimuths, which differ by the convergence angle, plus a small second-order ("arc-to-chord") correction which varies with distance and direction and can be ignored in many applications.

b. *Why are conformal map projections important?* In the context of designing State Plane zones, the most important characteristic of conformal projections is that they are the ***only*** type that makes sense for minimizing linear distortion. This cannot be done for other projections because distortion varies continuously with direction. Note that a projection cannot be both conformal and equal area. For a projection to be equal area, the "average" distortion at a point must be zero, so distortion cannot be minimized. This is necessary to preserve area, but it cannot preserve angles or shapes locally.

c. *Equal area projections are used by some state agencies, such as the Albers Equal Area projection in Alaska. Can such projections be part of SPCS2022?* Because it is not conformal, the AK Albers Equal Area projection cannot be used for SPCS2022. However, a Lambert Conformal Conic (LCC) projection could be designed for statewide coverage of Alaska.

5. Lambert Conformal Conic (LCC) projections

a. *What is the "projection axis"?* The "projection axis" of the LCC projection is its central standard parallel. That is the line of latitude along which the linear distortion (scale error) with respect to the ellipsoid is both constant and minimum. This is also true of the projection axis (central meridian) for the Transverse Mercator (TM) projection, and it is approximately true of the skew axis for the Oblique Mercator (OM) projection; its linear distortion is minimum and nearly (but not quite) constant.

b. *If the 1- and 2-parallel LCC are mathematically identical, why does the 2-parallel version exist?* The only reason the 2-parallel LCC exists is to provide a method for ***implicitly*** defining the scale on the projection axis, which can instead be done ***explicitly*** by assigning a numeric scale factor value to the projection axis (i.e., the central standard parallel). It is merely a convention, likely adopted because of a tendency in the pre-computer era to avoid fractional values, especially when represented as repeating decimal values of less than 1. Note that a 1-parallel LCC with a projection axis scale of less than 1 also has north and south "standard" parallels (i.e., parallels where the scale with respect to ellipsoid is exactly 1). However, these two parallels must be calculated, and so that can't really be called "standard." That is, they are not used to explicitly define the projection.

For LCCs that are "non-intersecting" (not tangent or secant), only the 1-parallel definition makes sense (with the projection axis scale greater than 1). This type is usually used for LCCs where it is desired to reduce projection at the topographic surface, when that surface is significantly above the ellipsoid.

c. *Please explain more about the two ways that scale is specified for an LCC projection.* If no scale factor is specified for an LCC projection, it will be a "tangent" projection that "touches" the ellipsoid along the parallel of its projection axis (i.e., it linear distortion will be zero with respect to the ellipsoid at that latitude). A projection axis scale factor of less than 1 can be used. This makes it a "secant" projection where the cone surface "cuts" through the ellipsoid, so that part of the cone is "below" the ellipsoid surface. There are two ways to do this:

i. Set the scale factor value on the projection axis (central standard parallel) to a number less than 1 (e.g., 0.9999 for a scale of 1:10,000).

ii. Define two (north and south) standard parallels along which the scale factor is exactly 1. Then the scale factor of the projection axis (which is still the central parallel) ***must*** be less than 1. In this case, the central parallel is approximately (but not exactly) half way between the north and south standard parallels, and both its latitude and scale must be calculated. A projection axis scale of 0.9999 (1:10,000) corresponds to a standard parallel latitude difference of between 1°37' and 1°38' (the required difference decreases slightly with increasing latitude).

6. Distortion at the topographic surface

a. *What is the benefit of using distortion at the topographic surface for designing a map projection?* Since topography is above the ellipsoid in most places (sometimes by a significant amount), it is reasonable to design projections that minimize distortion at the topographic surface. Map projection linear distortion can be computed anywhere, including at the topographic surface. This is usually of more practical interest, especially for surveyors and engineers, since that is where nearly all work is done. Conceptually, the distortion can be thought of as being due to the departure of the topographic surface from the developable surface (mapping plane), which is due to ***both*** Earth curvature and variation in topographic ellipsoid height.

b. *How do you design map projections that minimize linear distortion at the topographic surface over large areas in mountainous regions?* The overall distortion is reduced by increasing the projection axis scale, changing its location, and/or changing the projection type until the linear distortion is minimized. However, for large regions and areas with significant topographic relief, there can still be substantial distortion – it's just that the variation and/or mean distortion has been minimized (although the magnitude at certain locations can still be large).

c. *The "ground coordinates" concept is confusing; please elaborate.* Although distortion at the topographic surface can be reduced, there is no such thing as "ground coordinates." Projected coordinates scaled "to ground" are still planar map grid (projected) coordinates. They are just projected coordinates with low linear distortion (you can think of it as due to the mapping plane being near the ground surface).

d. *What is a "ground" distance?* There is no universally accepted rigorous definition of a "ground" distance. A commonly used general approach is to represent ground distance between two points as the curved distance parallel to the ellipsoid and at the average ellipsoid height of the end points (in our case the GRS 80 ellipsoid, presently referenced to NAD 83). This is essentially the geodesic ellipsoid distance scaled to ground, although there are various ways to perform the scaling.

e. *How do you go from grid to ground?* A common way to scale projected coordinates from "grid" to "ground" is to divide them by the "combined factor" (the combined distortion due to curvature and ellipsoid height) at that point. Linear distortion at the topographic surface is the combined factor minus 1.

f. *Is it better to scale coordinates or distances?* Instead of scaling projections or projected coordinates, some users prefer to scale distances so that they represent "ground" distances. The choice of which approach to use depends on the situation, which may be specified for certain projects or by some agencies. A disadvantage of scaling distances is that it breaks the relationship between the coordinates and the distance. But this can be handled with appropriate metadata.

g. *Will NGS provide linear distortion maps for all SPCS2022 zones?* NGS will likely provide such maps for all zones that we design. But NGS will probably not have the resources to provide maps for zones defined by states (such as low-distortion projection zones).

7. Default SPCS2022 designs

a. *In what situations will NGS design "default" projections, and how will they differ from SPCS 83?* NGS will design "default" SPCS2022 zones for states that provide no input, or for states where the stakeholders disagree with what they want for their state. For most zones, the default will be the same extents and projection type as existing SPCS 83 zones. The main differences will likely be:

   i. The projections will be scaled (and the projection axis possibly shifted) to minimize distortion at the **topographic surface** (not at the ellipsoid surface). This will be done for all projection types. Note that the scaling is with respect to the ellipsoid surface. That is, the projections will still refer to GRS 80 ellipsoid, which will be referenced to the new 2022 Terrestrial Reference Frames.

   ii. LCC projections will be defined using the 1-parallel definition.

   iii. SPCS2022 coordinates will differ from SPCS 83, SPCS 27, and UTM by at least 10,000 meters.

   iv. A few zones may have their zone extents and/or projection types changed.

   v. Zones may be added to a few areas that do not have SPCS 83 zones (such as Washington D.C. and American Samoa).

b. *How will default SPCS2022 zones be designed in mountainous states?* Many states have large variation in topographic height, especially in the western US (such as Colorado). These will be handled the same as elsewhere for the default designs. The linear distortion will be reduced (often by a large amount), although in mountainous states the variation in distortion will still be significant. Nonetheless, the distortion magnitude at the topographic surface will be less than it is for SPCS 83, and in many cased the variation in distortion will be reduced, at least somewhat.

c. *What kind of distortion was shown in the maps in the webinar?* For all distortion maps shown in the presentation, the distortion was with respect to the topographic surface.

d. *What areas are most difficult for designing default zones?* Design of default zones will typically by easier in smaller, flatter states, and more challenging in larger, more mountainous states. Techniques are being developed to make the process simpler for all states.

e. *Will NGS provide default design distortion maps for all SPCS2022 zones?* NGS is in the process of creating example distortion maps for preliminary default designs. This likely won't be done in advance for all zones, but we will create enough distributed throughout the US to give an idea of what to expect. Although we cannot guarantee that we can make example preliminary default SPCS2022 maps for every zone, if there are particular zones you would like to see, email us at NGS.SPCS@noaa.gov and we will try to create maps for those zones.

f. *In SPCS 83, it's not clear why some states use LCC versus TM projections; it doesn't always correspond with the shape of the state.* The types of projections used for large SPCS zones is usually dictated by which dimension is longer ("large" here is roughly more than about 100 km in the long direction). For example, TM projections are used for zones that are long in the north-south direction, and LCC projections for zones long in the east-west direction. For states with multiple zones, the projection type is selected based on aggregated county boundaries. In some states, the county boundaries are such that they are easier to group in east-west bands or north-south bands. That is why Colorado uses the LCC for its zones, whereas Wyoming uses the TM, even though the states are nearly the same size and shape. A similar thing occurs in other states, such as Utah and California. Note that for SPCS 27 and 83 that ***only*** the horizontal extent was considered for zone dimensions; topography was completely ignored. For example, although a TM zone could reduce distortion along the Front Range of Colorado, that was never considered for SPCS 27 and 83 because topographic height was not used in the design process. Only distortion with respect to the ellipsoid was considered, which is purely a function of horizontal location.

8. Statewide zones

a. *Why did some states change from multiple- to single-zone State Plane systems?* Three states (Montana, Nebraska, and South Carolina) switched from multiple to single zones in the transition from SPCS 27 to SPCS 83. All three use the LCC projection. It appears that at least part of the reason for this change was a recognition that computer land information systems (now called GIS) would grow in importance. For a statewide GIS, it is advantageous to have a single geometry, especially for certain geospatial operations and analyses. In addition, the projection scale factors for Nebraska and Montana were reduced (by increasing the separation between the standard parallels) such that linear distortion at the topographic surface is negative everywhere in Nebraska and nearly everywhere in Montana (i.e., projected distances are shorter than ground distances). This was done for consistency, so that the "grid to ground" combined factor is always less than 1. More information about the change from multiple to single zone system in Montana is provided in *NOAA Special Publication NGS NOS 13* (https://geodesy.noaa.gov/library/pdfs/NOAA_SP_NOS_NGS_0013_v01_2018-03-06.pdf)

b. *How will large single-zone states change from SPCS 83 to SPCS2022?* If SPCS2022 default designs are used for the single-zone states, they will remain single zones. The only difference will be in coordinate values (they must differ by at least 10,000 meters) and in the linear distortion, which will be minimized at the topographic surface. The change in distortion will be most pronounced in Nebraska and (especially) Montana, because of the large state size, high elevations, and the small projection axis scale factors used for these states in SPCS 83 (as described in the previous item).

c. *Why do some states have a large number of LDP zones plus "regular" State Plane zones?* Some states have a large number of multiple small "low distortion projection" (LDP) zones, such as Wisconsin, Minnesota, Oregon, Iowa, Indiana, and Kansas. However, these LDP zones are ***not*** part of SPCS, even though they are used internally by the states and in some cases are adopted in state statute. Consequently, these states also have two or three SPCS 83 zones. For SPCS2022, these states may be able to have LDP zones, ***or*** SPCS 83-like zones, but they cannot have both. They will be able to have a statewide zone in addition to one set of non-overlapping subzones, which can be LDPs ***or*** something similar to traditional SPCS zones. LDPs are discussed further in the following question category.

9. Low distortion projections (LDPs)

a. *Will NGS allow LDP zones, and if so will guidance and standards be provided for designing them?* The draft SPCS2022 policy and procedures, as currently written, allow states to define SPCS2022 in their state using "low distortion projection" (LDP) zones. These LDP zones are intended to reduce linear distortion at the topographic surface to a level where the difference between "grid and ground" is negligible for most surveying and engineering applications. The draft SPCS2022 procedures provides guidance and limitations. To discourage creation of an excessive number of small zones, there is a minimum distortion design criterion of 20 parts per million (ppm), and a minimum zone width of 50 km (except in areas where the topographic height range in the zone exceeds 250 meters). More details are in the draft SPCS2022 policy and procedures, which will soon be released for public comment. Additional information will also be given in the April 12 webinar.

b. *A problem with LDPs is that their small size means crossing of zone boundaries will occur more often.* A large number of small zones increases the possibility that individual projects will be in more than one zone. This problem can be reduced by creating the largest zones possible that meet the distortion design criterion, defining zones with boundaries that do not pass through major metropolitan areas, aligning zones with transportation corridors, etc. Such decisions will be the responsibility of states that elect to use LDP systems for SPCS2022.

c. *What is the issue with creating LDPs by modifying the ellipsoid?* LDPs based on "scaled" ellipsoids will not be permitted for SPCS2022. LDPs must reference the GRS 80 ellipsoid directly, and only manipulation of projection parameters can be used to reduce distortion. The reason for this restriction is that scaling the ellipsoid significantly complicates the LDP definition without a corresponding improvement in performance. To use a scaled ellipsoid design correctly requires a datum transformation, which makes design and implementation more complex and error-prone.

d. *Can states that already have LDP systems use those systems for SPCS2022?* Several states already have LDP coordinate systems established. These systems can become part of SPCS2022, as long as they meet the requirements in the official SPCS2022 policy and procedures (which will be finalized shortly after the public comment period ends on August 31, 2018). Of course, the SPCS2022 LDPs must be referenced to the 2022 terrestrial reference frames (not to NAD 83). In addition, it is recommended that the grid origins of existing LDP systems be changed such that the resulting SPCS2022 coordinates differ substantially from current NAD 83 LDP coordinates. In addition, it is required that the SPCS2022 coordinates differ by at least 10,000 meters from previous SPCS and from UTM coordinates.

e. *NGS will not design LDPs, but what is the cutoff for a zone that is considered an LDP?* Because NGS does not have the resources to design LDP systems, states that choose to have LDPs must design the system or hire others to do so. More specifically, NGS will not design zones with a distortion design criterion of lower than ±50 ppm, which corresponds to a zone with of less than 180 km (112 miles) in flat terrain.

f. *Since NGS will not design LDPs, does NGS have any guidance on design and will they provide more assistance and resources in the future for LDP design?* Assistance in the future is expected to include webinars, workshops, and a technical manual. General design specifications are also in the soon-to-be released SPCS2022 procedures. In addition, an existing LDP design workshop is available from the NGS Presentations Library at https://geodesy.noaa.gov/web/science_edu/presentations_library/ (titled "Ground Truth: Optimized Design of Low Distortion Projections" and given by Michael Dennis on 2/14/2017 in Anchorage, Alaska). Another workshop will be given at the UESI 2018 Surveying & Geomatics Conference in Pomona, California, on April 22 (https://www.surveyingconference.org/). The PowerPoint and workbook from that workshop will also be available from the NGS Presentations Library shortly after the conference.

g. *What is the cost of designing LDP systems for a state?* NGS does not know the cost of designing LDP systems, in part because the cost will depend on the size of the state, the topographic relief, how zones will be defined, and how much design will be done "in house" by a state versus contracted out. It is recommended that states interested in finding out more about cost (and other issues with performing the work or having it done by others), contact states or other organizations that have recently had such systems designed. Some of these are listed in the references of *NOAA Special Publication NOS*

NGS 13 (https://geodesy.noaa.gov/library/pdfs/NOAA_SP_NOS_NGS_0013_v01_2018-03-06.pdf). These and several other LDP systems are shown in Table 2 and Figure 7 of that report. An online search of organizations that have solicited and performed LDP designs may also yield useful information.

10. Coordinate values, convergence angles, and linear units

a. *What linear units will be used to define SPCS2022?* Grid origins (false northings and eastings) must be defined in meters using whole numbers evenly divisible by 1000 meters and selected such that SPCS2022 coordinates are positive everywhere within a zone.

b. *Will SPCS2022 coordinates be provided in feet?* If output of SPCS2022 coordinates in feet are desired, the type of foot (international or U.S. survey) must be specified by stakeholders. The type of foot used cannot conflict with relevant state statute. If default designs are used, the type of foot (if any) for output coordinates will be based on existing statute, as given in Appendix C of *NOAA Special Publication NOS NGS 13* (https://geodesy.noaa.gov/library/pdfs/NOAA_SP_NOS_NGS_0013_v01_2018-03-06.pdf).

c. *Will SPCS2022 coordinates differ from existing State Plane?* SPCS2022 coordinates must differ by at least 10,000 meters from SPCS 27 and 83, as well as from UTM coordinates referenced to NAD 27 or NAD 83. If the SPCS2022 version of a zone does not meet that requirement, the grid origins (i.e., false northings and/or eastings) will be modified until that difference is achieved (which has no effect on distortion).

d. *Will SPCS2022 grid north be the same as it is for SPCS 83?* SPCS2022 convergence angles (i.e., the angular difference between geodetic north and grid north) will generally differ from SPCS 83, because in most cases the parameters affecting convergence angles will change, at least by a small amount. Any change of the central meridian will change convergence angles. For LCCs, the convergence angle also changes if the central parallel changes, which will occur for all LCC zones (due to changing from 2- to 1-parallel definitions), although such a change will be small for most default designs, usually within a few arc-seconds (if the central meridian is not changed). Changing the latitude of origin for the TM projection has no effect on convergence angles. And of course, convergence angles will usually be much different if the SPCS2022 zones are completely different from SPCS 83 (for example LDP zones).

11. Coordinate conversions and transformations

a. *Will NGS provide tools for computing SPCS2022 coordinates?* NGS will provide tools for converting between latitude and longitude and projected coordinates for all SPCS2022 zones, both direct (from lat/lon to grid) and inverse (from grid to lat/lon). The tools will also compute the grid point scale factor and convergence angle, as well as the height factor and combined factor (i.e., total linear distortion) for points with ellipsoid heights. In addition, NGS will provide the algorithms used for performing the computations. An existing tool already does this for SPCS 83, the NGS Coordinate

Conversion and Transformation Tool (NCAT), available at https://geodesy.noaa.gov/NCAT/.

b. *How can I transform my existing SPCS 83 coordinate to SPCS2022?* NGS will provide transformation tools between the 2022 TRFs and NAD 83 (2011) epoch 2010.0. These will augment the existing tools that transform between the various realizations of NAD 83, as well NAD 27, the US Standard Datum, and various pre-NAD 83 island datums. These are currently available in the NCAT tool. Like the existing NCAT tool, later versions that support 2022 TRFs and SPCS2022 will combine map projection conversions and coordinate transformations into a single interface. So, for example, it will be possible to input an NAD 83 "HARN" State Plane coordinate and have the tool compute SPCS2022 coordinates. The transformation part of the tool (that goes between NAD 83 and the 2022 TRFs) will also give transformation error estimates. This is important, since the transformations are not of sufficient accuracy for all applications. In contrast, the map projection conversions will be essentially errorless (when used within their defined zones).

c. *Will I have to transform all of my data to SPCS2022?* At the time of release of SPCS2022, all organizations will have datasets defined in previous coordinate systems (such as SPCS 83). A common question is whether they will be required to transform their SPCS 83 data to SPCS2022. NGS does not have the authority to require any person or organization to use the National Spatial Reference System (NSRS). Users of geospatial data will have to determine how and when they want to make the change. Federal agencies are required to use the current NSRS, but even in those cases it may take considerable time for some organizations to migrate to the 2022 systems, especially those with large data holdings. NGS recommends that all organizations with geospatial data begin the process of planning for these upcoming changes now, so that they have an efficient and well-defined path forward when the 2022 systems arrive. A major goal of NGS is that the 2022 NSRS will be such an improvement over the existing NSRS that most organizations will be willing to make the change as soon as feasible.

12. Stakeholders, SPCS2022 policy, and state statute

a. *When can we provide input about SPCS2022 policy, and who can provide that input?* Draft SPCS2022 policy and procedures have been finalized, along with a Federal Register Notice (FRN) that will announce their availability for public comment. The FRN should be published sometime in April 2018, and the deadline for public comment is August 31, 2018. Any person or group can respond to the FRN; it does not have to be one of the identified "stakeholder" groups.

b. *Who can represent a state when requesting or proposing what a state wants for their SPCS2022 zones?* Stakeholders are groups within a state or territory that can request or propose SPCS2022 characteristics for their zones. NGS will only act on ***consensus*** stakeholder input. If stakeholder groups disagree, NGS has sole authority to design zones for a state. NGS will not act on input from individuals; input must come from a stakeholder group. Below is a list of the state groups that have been identified as stakeholders (stakeholders and the process are more fully described in the SPCS2022 procedures document):

i. State departments of transportation

ii. State GIS or cartographer offices

iii. State professional surveying and engineering societies

iv. State GIS or other professional geospatial organizations

v. Universities or other post-secondary educational institutions within a state that perform geospatial education or research.

c. *What are "special purpose" zones?* The FRN includes "special purpose" zones, which are not mentioned in the policy and procedures. The intent is to determine whether special purpose zones should be included as a part of SPCS2022, based on the public responses to the FRN. The three categories of special purpose zones are listed below, along with examples:

i. Major urbanized areas: New York City, Chicago, Los Angeles, St. Louis, Cincinnati, Kansas City, Denver, Portland, and many others cross zone (and often state) boundaries.

ii. Large American Indian reservations: The Navajo Nation is about the same area as West Virginia and falls within five existing SPCS zones (and three states).

iii. Regional federal applications: The Atlantic coast from the Florida-Georgia border to the Maine-Canada border is a region that spans 14 existing SPCS zones but could be covered by a single zone.

d. *Can "special purpose" zones exist in addition to another SPCS2022 subzone layer?* If special purpose zones are allowed, they will not count as a subzone layer, and they could exist in addition to a statewide and subzone layer. The main reason is that subzones will often cross state boundaries. For example, consider a special purpose zone for the Navajo Nation. Arizona, New Mexico, and Utah could each have a statewide zone and a system of subzones, while at the same time a special purpose zone for the Navajo Nation could overlap zones in those three states.

e. *What states have contacted NGS about SPCS2022, and is there a common theme to what they want for SPCS2022?* The 16 states that have contacted NGS about SPCS2022 so far are: Alaska, Arizona, California, Colorado, Florida, Iowa, Kansas, Maine, Montana, North Carolina, Ohio, Oklahoma, Oregon, Texas, Washington, and Wyoming. The types of organizations and the nature of the contact has varied. Some have been very specific, for example by saying they want an LDP system. But most simply want to establish communication with NGS and have not yet decided how they want to move forward with SPCS2022.

f. *What is the role of state statute in development of SPCS2022 zones?* NGS encourages the adoption of the NSRS as defined in 2022 within state statute, including SPCS2022.

But state statute is not required for NGS to design SPCS2022 zones for a state. The reason is that NGS cannot force a state to use SPCS2022, and so no burden is placed on a state; they can simply not use it. The same thing was done for SPCS 27 and 83 (Alabama, Hawaii, and the U.S. Virgin Islands still have not legislatively adopted their SPCS 83 zones, yet they have SPCS 83 zones). Likewise, a state cannot force NGS to adopt SPCS2022 zones merely because they have defined it in statute; any proposed zones must follow NGS policy and procedures.

g. *The "reference frame" and "coordinate system" terminology being used is unclear; perhaps "reference system" should also be used for SPCS2022.* NGS has tried to be as consistent as possible with conventions used throughout the world for adopting terminology, and we have attempted to coordinate naming with Canada and Mexico. The name "terrestrial reference frames" was adopted for the geodetic geometric system, which formerly has simply gone by the name "datum." "Reference frame" cannot be used for SPCS2022 because it is not a reference frame, but instead is derived from the reference frame using map projection equations and a specific ellipsoid. SPCS2022 is a continuation of the naming used for its predecessors. It is also widespread practice to call such systems "projected coordinate systems." The name is intended to indicate that it is based on map projections referenced to a specific "datum" (reference frame) and corresponding ellipsoid. Perhaps there is a better name to use, but at this time SPCS2022 seems the most appropriate. For those who wish to suggest something different, they can do so during the FRN comment period, since the SPCS2022 name itself is part of the draft policy.

13. Reference frames, datums, and passive marks

a. *How does the datum type (e.g., NAD 27, NAD 83, WGS 84) affect the accuracy of SPCS?* SPCS is derived from the underlying datum (reference frame). So any inaccuracy in the datum, or difference between datums, is directly manifested in the projected SPCS coordinates. Consider SPCS 83. Part of why makes it SPCS 83 is that it is referenced to NAD 83. The NAD 83 latitude and longitude values are mathematically converted to northing and easting, with essentially no error. But any error in the NAD 83 latitude and longitude values will also be in the northing and easting values. Carrying this further, if WGS 84 latitude and longitude values are projected with the SPCS 83 algorithms, it is not correct to call the resulting coordinates SPCS 83, because the datum is part of the definition. And the resulting projected coordinates will differ from SPCS 83 by the same amount that WGS 84 differs from NAD 83 (by about 1 meter horizontally, depending on location).

b. There were several comments and questions about reference frames, datums, and passive marks. These do not directly relate to the SPCS2022 topic, but they are of course very relevant to the NGS mission and the products and services we are developing as part of the transition to the 2022 NSRS. Some are listed below (without answers), and resources are provided in the next item.

i. *Where can I learn more about the new datums, how they will be defined, and how to make use of them, especially when there is a time component to how the system is defined and on the coordinates themselves?*

ii. *What is the role of passive marks, especially in a dynamic, time varying coordinate system?*

iii. *How do I ensure that work performed in flood hazard areas (including preparing elevation certificates) is spatially consistent with the FEMA Flood Insurance Rate Maps (FIRMs)?*

iv. *What is the relationship between various geometric datums (reference frames), such as NAD 27, NAD 83, WGS 84, and the various ITRF and IGS realizations – including considerations of their relative accuracies?*

c. NGS has produced various presentations, webinars, and publications that provide information about the 2022 terrestrial reference frames and geopotential datum:

i. Webinar on the 2022 terrestrial reference frames: "Blueprint for 2022, Part 1: Geometric Coordinates" (https://geodesy.noaa.gov/web/science_edu/webinar_series/blueprint-2022-geometric-coordinates.shtml).

ii. Webinar on the 2022 geopotential ("vertical") datum: "Blueprint for 2022, Part 2: Geopotential Coordinates" (https://geodesy.noaa.gov/web/science_edu/webinar_series/blueprint-2022-geopotential-coordinates.shtml).

iii. Report on the geometric reference frame: *NOAA Technical Report NOS NGS 62*, "Blueprint for 2022, Part 1: Geometric Coordinates" (https://geodesy.noaa.gov/library/pdfs/NOAA_TR_NOS_NGS_0062.pdf).

iv. Report on the geopotential ("vertical") datum: *NOAA Technical Report NOS NGS 64*, "Blueprint for 2022, Part 2: Geopotential Coordinates" (https://geodesy.noaa.gov/library/pdfs/NOAA_TR_NOS_NGS_0064.pdf).

v. Various presentations listed in the NGS Presentations Library (https://geodesy.noaa.gov/web/science_edu/presentations_library/).