



## **NGS Geodetic Toolkit, Part 7: Computing State Plane Coordinates**

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In 1933, the North Carolina Department of Transportation asked the Coast and Geodetic Survey to assist in creating a comprehensive method for converting curvilinear coordinates (latitude and longitude) to a user-friendly, 2-dimensional Cartesian coordinate system. This request developed into the State Plane Coordinate System (SPCS), which is now the most widely used expression of coordinate information in local and regional surveying and mapping applications in the United States and its territories. Originally computed by Dr. Oscar S. Adams, SPCS consists of 130 zones related to the North American Datum of 1927 (NAD 27), Old Hawaiian, Puerto Rico, American Samoa 1962 and Guam 1963 datums, and 124 zones on the North American Datum of 1983 (NAD 83) (Figure 1). Unlike the Universal Transverse Mercator (UTM) grid, that is defined by very rigorous geometric boundaries, the dimensions of SPCS zones are typically very irregular and are defined by international, state, and county boundaries to ensure that a zone does not cut through a county. Those states or parts of states that are more north-south in orientation (*e.g.*, Illinois, Indiana, eastern Florida) are defined using a Transverse Mercator map projection. Conversely, those states or parts of states that are more east-west in direction (*e.g.*, Tennessee, Kentucky, the Florida panhandle) are computed using a Lambert Conformal Conic projection with two standard parallels. The only exceptions to this rule-of-thumb are the Alaska panhandle (Oblique Mercator projection), American Samoa (Lambert Conformal Conic with a single standard parallel), and Guam (Azimuthal Equidistant projection).

The equations and geometric parameters for each zone can be found in C&GS Special Publication 235 *The State Coordinate Systems (A Manual for Surveyors)* and C&GS Publication 62-4 *State Plane Coordinates* by Automatic Data Processing for NAD 27, and NOAA Manual NOS NGS 5 *State Plane Coordinate System of 1983 for NAD 83*. All three publications are available in hard copy for a nominal fee from the NGS Information Center ([info\\_center@noaa.gov](mailto:info_center@noaa.gov), 301-713-3242). Electronic copies are freely available

online from the NGS website at [http://www.ngs.noaa.gov/PUBS\\_LIB/pub\\_index.html](http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html).

Users of coordinate information are often required to convert from one coordinate system to another, such as SPCS to geographic positions (GP) expressed in latitude and longitude, or vice versa. In addition, there is sometimes a misconception that representing data in SPCS is less accurate than in latitude and longitude. The process of converting coordinates between SPCS and GP has come a long way since the days of interpolating by hand from tables. Programs written by NGS can easily and accurately perform the conversions on both NAD 27 (GPPCGP) and NAD 83 (SPCS83). As part of the NGS Geodetic Toolkit (<http://www.ngs.noaa.gov/TOOLS/>), both of these programs can be run interactively online by selecting "State Plane Coordinates."

The programs can also be downloaded directly to the user's own computer from the NGS PC Software page ([http://www.ngs.noaa.gov/PC\\_PROD/pc\\_prod.shtml](http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml)). In addition, both programs are in public domain and users are free to download the source code for integration into their own systems.

Users should be aware that there were several significant changes to SPCS from NAD 27 to NAD 83. Specifically:

- California zone 7 was removed and its area, Los Angeles County, was included in zone 5.
- Michigan zones were changed from Transverse Mercator to Lambert zones.
- Montana eliminated three zones in favor of a single zone system.
- Nebraska, South Carolina, Puerto Rico, and the Virgin Islands eliminated two zones in favor of single zone systems.
- American Samoa and Guam are not defined with NAD 83 SPC in NSRS.

In addition, with NAD 83, all states adopted new false easting and northing values for the origin, ensuring significant coordinate differences between the state plane coordinates derived from NAD 27 and those derived from NAD 83. These differences, in some cases, are tens of millions of feet to ensure detection of error when mixing SPCS types.

Performing computations with the Toolkit is very straightforward. After selecting "State Plane Coordinates," the Toolkit provides the user with three interactive options: (1) latitude and longitude to SPC, (2) SPC to latitude and longitude, and (3) find the SPC zone (Figure 2).

To convert a GP to SPC (Figure 3), the user is first prompted to select the appropriate datum, either NAD 27 or NAD 83. For Old Hawaiian, Puerto Rico, American Samoa 1962, and Guam 1963 datums, the user should select NAD 27. The user will then be prompted for the coordinate values in degrees, minutes, and seconds without separation between digits. The latitude must have a leading N or S (North or South) that is not case sensitive, and the longitude must have a leading W or E (West or East).

In addition, both values must contain the decimal point following the seconds, and the longitude must have a leading 0 if it is less than 100 degrees. The user is provided a block to input the appropriate SPC zone 4-digit identifier. If the identifier is unknown, it can be obtained from the "Find Zone" application listed under "Interactive Conversions," which will then prompt for either the county or the coordinate value. The user may opt to allow the program to select the most appropriate zone by leaving the prompt box empty. If the point is very close to a zone boundary, the program might have some difficulty in selecting the correct primary zone due to the many irregular geographic boundaries of states and counties in the United States.

The output (Figure 4) will be identical for both NAD 27 and NAD 83, except that the SPC derived from NAD 27 are always shown in U.S. Survey Feet (1200/3937 m = U.S. Survey Foot) while SPC derived for NAD 83 coordinates are provided in meters only. If the user wishes to convert from meters to feet, they should apply the appropriate conversion value as legislatively defined by the respective state (Figure 5). Users of coordinate data should always be sure to identify the appropriate coordinate units (e.g., meters, U.S. Survey Feet, or International Feet). The results of the conversion will include the input GP, datum and SPCS zone number, northing (Y) and easting (X) coordinates, SPCS zone (Area), convergence angle, and the grid scale factor. The sign of the convergence angle is always from grid azimuth to geodetic azimuth.

The conversion of SPC to GP can be accomplished by selecting the SPC -> Latitude/Longitude option under "Interactive Conversions," as shown in Figure 2. As in the previous description, the user will first need to select the appropriate datum, NAD 27 or NAD 83, then enter the northing (Y) and easting (X) coordinates values (in meters for NAD 83 and U.S. Survey Feet for NAD 27) and the appropriate SPCS zone in the boxes provided. Unlike GP, the SPCS coordinate values are not necessarily unique, so the program will be unable to determine which specific zone a point is in. The user will need to know the county and use the "Find Zone" application previously described (see Figure 2). The output elements from this computation will provide the GP as well as all the data elements mentioned in the SPCS conversion.

This process is strictly a conversion of mapping coordinates within a specific datum (e.g., NAD 27, NAD 83, Old Hawaiian, etc.) and does not include a datum transformation such as from NAD 27 to NAD 83. Transformations of latitude and longitude from one datum to another can be performed with the NGS-developed NADCON program, which is also available through the Geodetic Toolkit.

The subroutines GPPCGP and SPCS83 that have been integrated into this tool constitute the *de facto* standard for SPCS conversions and have been implemented into many surveying and mapping software packages by commercial developers. Users of commercially available conversion software should check with the software developer to ensure the correct programs are integrated for the appropriate applications.

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