

# VISUALIZING NATIONAL GEODETIC SURVEY CONTROL STATIONS IN GOOGLE EARTH

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**Abstract:** NGSCS, a web-based application for visualizing National Geodetic Survey (NGS) control stations in Google Earth, is presented and discussed. The program has been successfully tested on Vista, XP, Linux, and Mac machines with a variety of browsers and provides an easy-to-use, configurable framework for retrieving NGS datasheets using a Google Earth client.

## INTRODUCTION

Google Earth is rapidly becoming the land surveyor's tool-of-choice for preliminary job site reconnaissance (Leininger 2007) and survey planning. Survey projects often begin with the investigation and selection of nearby NGS marks to establish horizontal and vertical control. There are many strategies for plotting NGS control stations in Google Earth, the most flexible of which involve translating shapefiles (Zimmer 2007) or parsing datasheets, but the process is tedious, requiring server queries, file downloads, and client-side translation software, e.g. NGSREAD (Kaye 2009). Furthermore, this process must be repeated periodically because new coordinates are added to the NGS database daily (NGS 2010a). Yet another complication is that the NGS server will not return unarchived datasheets or shapefiles for more than 1100 marks per query.

Station lists are another form of data supplied by the NGS. Station list records contain less information but are much smaller and more rapidly acquired than datasheets or shapefiles and may be retrieved in far greater quantities per query. The NGS has published a Windows program, DSWorld (Archer-Shee 2010), that uses current station list data but does not support Google Earth view-based queries. Morrey (2010) offers a web application that does support view-based queries but uses data derived from archived shapefiles and datasheets.

The software presented here, NGSCS, is entirely web-based, requires no installation, and will very likely work on any Google Earth-supported platform with a modern web browser. The program provides for view-based, point of interest (POI) and area of interest (AOI) queries, and writes streaming keyhole markup language (KML) to a Google Earth client. The web application essentially acts as a front end for the NGS station list server. It submits requests to the NGS web server and translates the textual information returned by the NGS server into KML so that it can be displayed graphically by Google Earth.

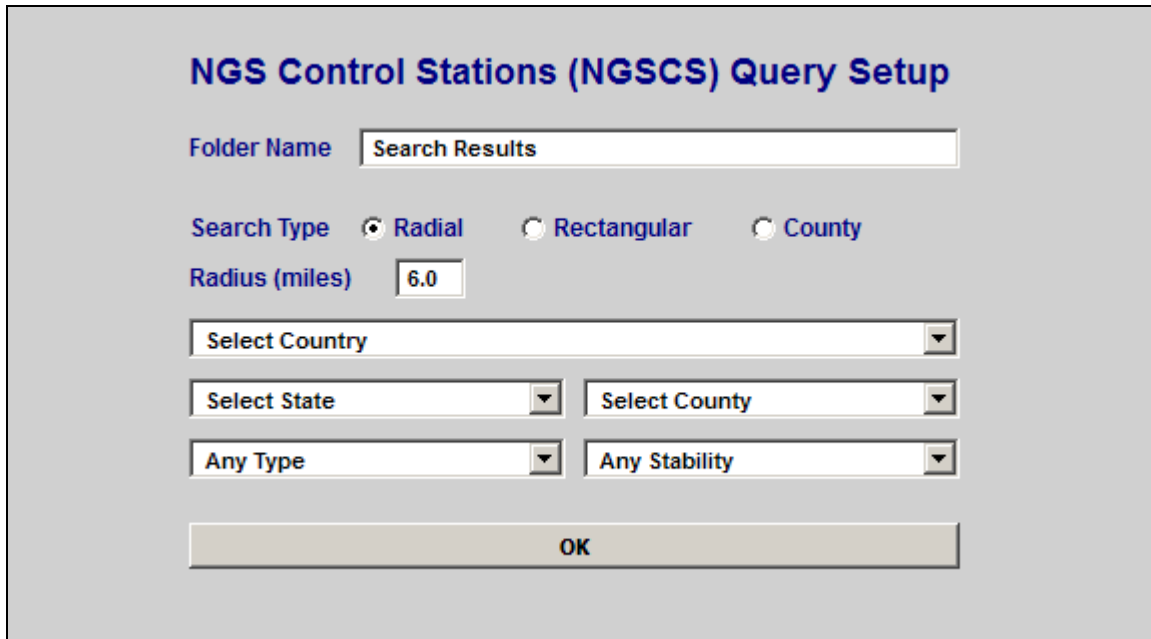
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## NGSCS

The NGSCS web page (<http://www.metzgerwillard.us/ngscs/ngscs.html>) provides brief documentation and a hyperlink to the client-side component of the NGSCS application (<http://www.metzgerwillard.us/ngscs/ngscs.kml>). When *ngscs.kml* is opened with Google Earth, the *NGS Control Stations* folder will appear in the *Places* panel, and a new search may be initiated by clicking on *Query Setup*.



**NGS Control Stations (NGSCS) Query Setup**

Folder Name

Search Type  Radial  Rectangular  County

Radius (miles)

Select Country

Select State  Select County

Any Type  Any Stability

OK

**Figure 1.** NGSCS Query Setup

The *Query Setup* form (Fig. 1), illustrated here with all form controls enabled, defines parameters that are either nongeographical or not easily related to latitude and longitude. When the *OK* button is pressed, a KML file with a Google Earth network link (Google 2010) named *Search Results* is downloaded to the client. This link contains the user's choice of 18 station types and 5 stabilities (Table 1), together with other parameters specific to the search type. Network link parameters may be inspected by examining the properties of the *Search Results* folder. Contents are added to the *Search Results* folder when the network link is activated, and replaced when the link is refreshed. All search results are collected in the *Saved Searches* folder.

All station markers are color-coded by type with mnemonic initials.

- H (orange) = Horizontal only
- V (blue) = Vertical only
- B (pink) = Both horizontal and vertical

Station types are categorized in subfolders so that visibility, icons, and labels may be customized by applying styles (color, scale, and opacity) to folders instead of individual placemarks. Each folder name includes the number of stations in parentheses.

Table 1. Station Type and Stability	
Station Type	
Any Type (default)	Destroyed Marks Only
GPS Sites Only	GPS Height Mod Station
Any Horizontal Control	Any Vertical Control
Horizontal Order-A	Vertical Order-1
Horizontal Order-B or Better (HARN)	Vertical Order-2 or Better
Horizontal Order-1 or Better	Vertical Precise GPS or better
Horizontal Order-2 or Better	Vertical Tidal Bench Mark
CORS	Wisconsin Height Mod Station
PAC and/or SAC	FBN and/or CBN
Station Stability	
Any Stability (default)	
Stability A only	Stability C or better
Stability B or better	Stability D or better

Station balloons (Fig. 2) contain all information supplied by the NGS `get_mark_list` utility (NGS 2010c).

- Station Name
- Permanent Identifier (PID)
- Distance = Distance from POI (for radial searches)
- Order H V = Horizontal and vertical orders
- V Source = Vertical source
- Approximate Latitude and Longitude
- Station Stability

Station markers are plotted at full-precision datasheet coordinates. Horizontal control stations typically have precise geodetic coordinates with five decimal digits of seconds, while vertical-only marks are usually scaled to whole seconds.

Clicking on the PID (*AA1800*) returns a current datasheet to the user's web browser. The complete output from `get_mark_list` may be inspected in the user's web browser by clicking on the *Data Source* hyperlink in the *Stations* folder balloon. The *Search Results* folder balloon contains brief instructions appropriate to the search method, and the *About* folder balloon contains copyright information and the last revision date.

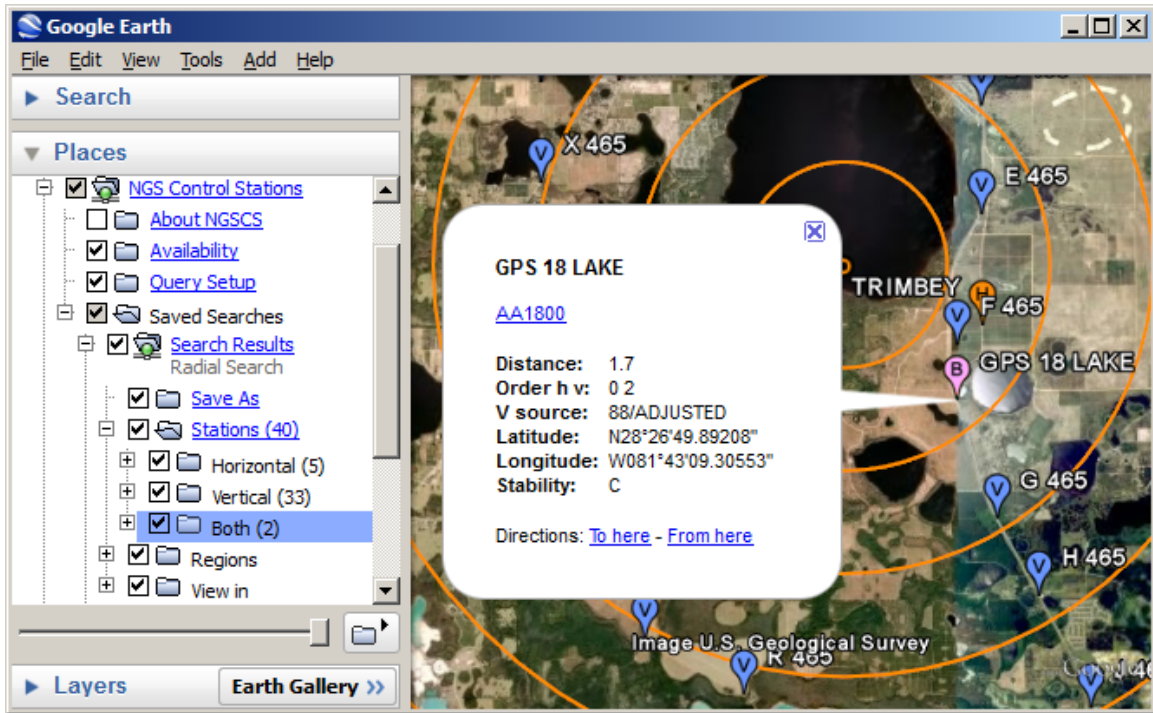


Figure 2. Station Balloon

The NGS `get_mark_list` utility will not retrieve a list with more than 3000 stations for radial and rectangular searches. If this limit is exceeded, *Search Results* will contain a folder named *NGS Server Error*. The limit for county searches is unknown. If a search finds no marks, *Search Results* will contain a folder named *No Stations Found*.

To save search results from one Google Earth session to another, open the *Search Results* folder, right-click on *Stations*, and select *Copy*; then right-click on *My Places* and select *Paste*.

Choosing *Save As* presents a hyperlink that allows the user to save unedited search results in a generic KML 2.1 document. The resulting file is suitable for viewing in NASA World Wind or ESRI ArcGIS Explorer.

Support for the *View in Google Maps* feature depends on the availability and limits of the Google Maps server. The server will not accept more than 1050 stations, and a response of "File not found" indicates a server timeout. Searches on smaller areas with fewer stations are more likely to succeed.

Support for the *View in Bing Maps* feature depends on the availability and limits of the Bing Maps server. The server will not accept more than 200 stations, and a response of "This content is not available" indicates a server timeout. Searches on smaller areas with fewer stations are more likely to succeed.

In the following sections, elements specific to radial, rectangular, and county search methods are discussed, and a software implementation summary is presented.

## Radial Search

NGSCS Radial Search (Fig. 3) creates a Google Earth network link that plots the approximate location of NGS control stations within a specified distance of the view center. The radial search method provides a graphical front end to the NGS station list server for POI queries. Unlike most network link applications, the radial search is not activated when the file is first loaded, nor is the link automatically refreshed when the view changes. Instead, the user centers the POI in the viewer and manually initiates the refresh.

1. Position the POI in the center of the view. One way to do this is to double-click an unmarked location. To precisely position the POI in the center of the view, add a placemark at the desired location; then edit the properties of that placemark and reset the view.
2. Check the box beside the *Search Results* network link. Range rings and station markers should appear within two minutes.
3. On subsequent uses, reposition the POI and ensure that the network link is checked and selected. Then choose *Refresh* from the *Edit* menu, or right-click and select *Refresh* in the context menu.

Range rings are drawn at one-mile increments from the POI and collected in the *Regions* folder. Radii up to 10 miles are permitted, but the NGS server will not retrieve a list with more than 3000 stations.

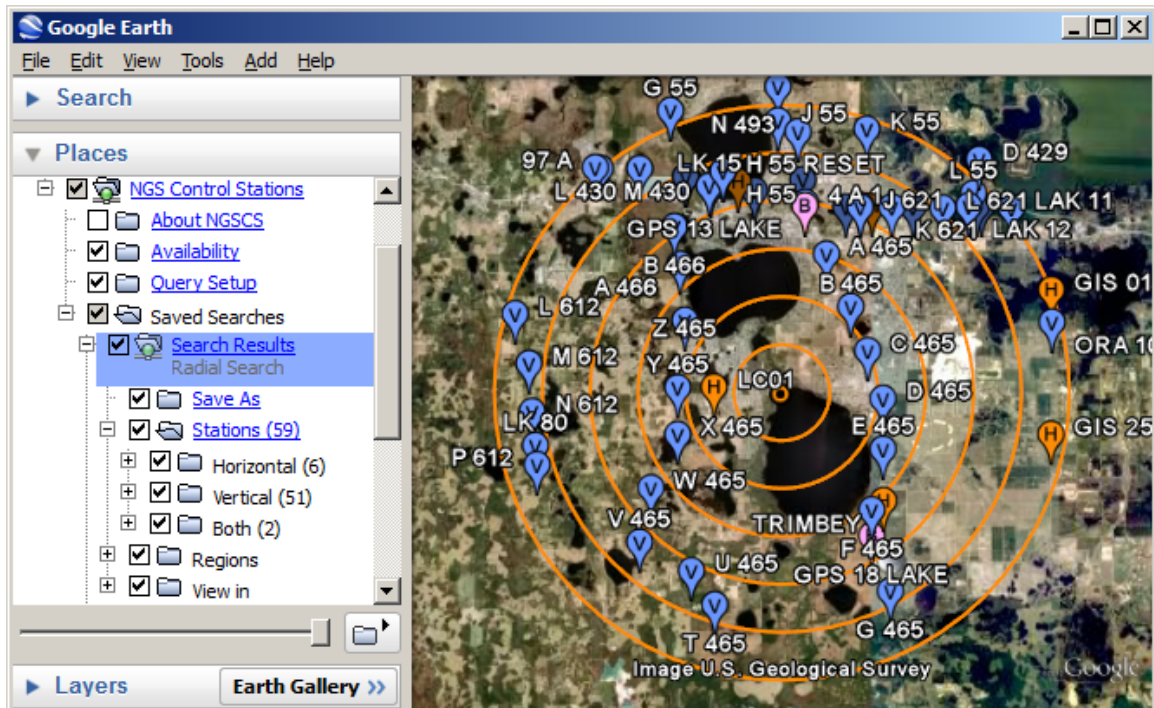


Figure 3. Radial Search

## Rectangular Search

NGSCS Rectangular Search (Fig. 4) creates a Google Earth network link that plots the approximate location of NGS control stations within the viewer bounding box. The rectangular search method provides a graphical front end to the NGS station list server for AOI queries. Unlike most network link applications, the rectangular search is not activated when the file is first loaded, nor is the link automatically refreshed when the view changes. Instead, the user positions the AOI in the viewer and manually initiates the refresh.

1. Position the AOI in the viewer.
2. Check the box beside the *Search Results* network link. Station markers and the AOI rectangle should appear within two minutes.
3. On subsequent uses, reposition the AOI and ensure that the network link is checked and selected. Then choose *Refresh* from the *Edit* menu, or right-click and select *Refresh* in the context menu.

Areas up to 20' x 20' (arc minutes) are permitted, but the NGS server will not retrieve a list with more than 3000 stations.

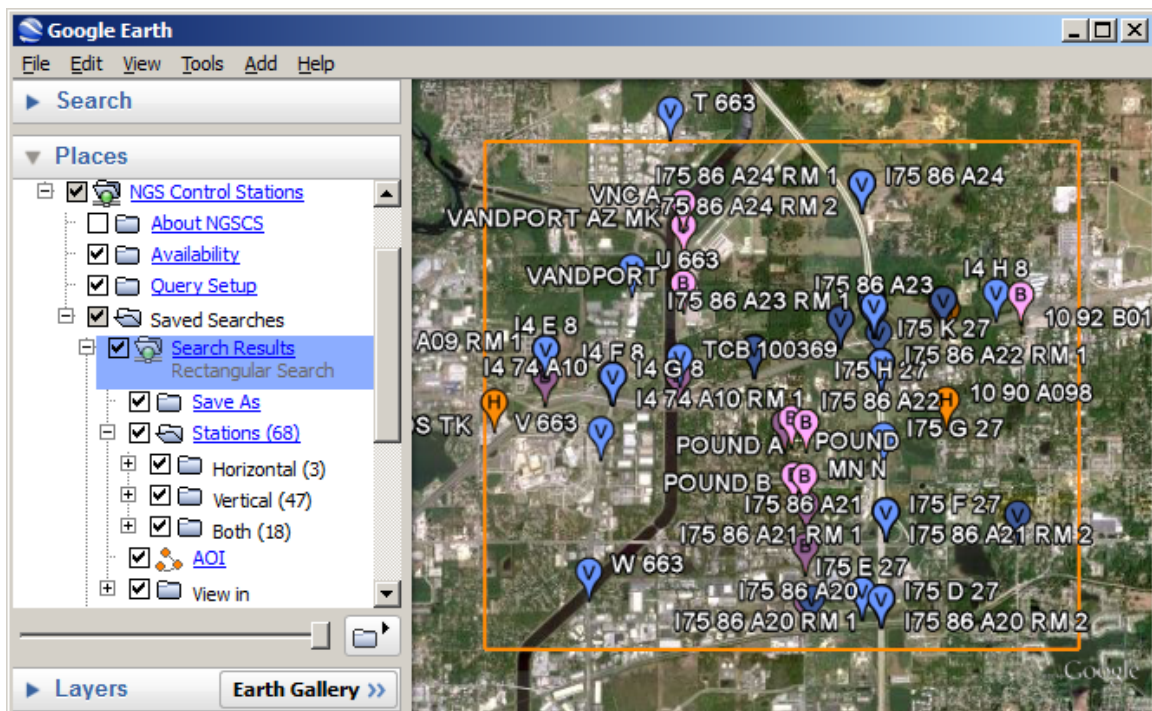


Figure 4. Rectangular Search

## County Search

NGSCS County Search (Fig. 5) creates a network link that plots the approximate location of NGS control stations within a selected county. More than 3400 Federal Information Processing Standards (FIPS) codes for counties and equivalent entities of 43 countries are supplied by the `get_country` utility (NGS 2010b).

1. The County Search network link (*Monroe, FL* folder) is activated when it is first loaded. Station markers should appear within two minutes.
2. To update the county search, ensure that the network link is checked and selected. Then choose *Refresh* from the *Edit* menu, or right-click and select *Refresh* in the context menu.

County searches do not currently recognize tanks or towers as horizontal marks. To visualize horizontal stations, plot all marks and uncheck the *Vertical* folder. Destroyed marks and marks with incomplete datasheets are not reported by county searches, nor do county searches assign vertical order to horizontal control stations with NGVD 29 heights.

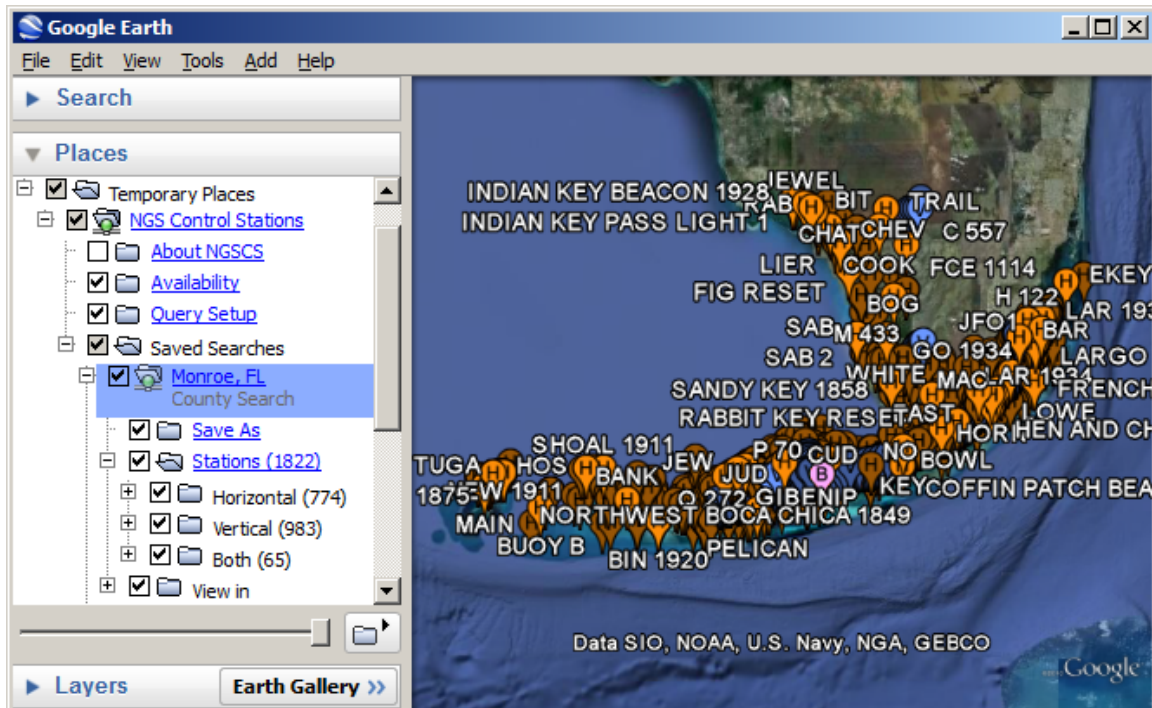


Figure 5. County Search

## IMPLEMENTATION

Google Earth permits users to add content to a display using KML, an XML-based markup language for geographic data. The content to be added can be in the form of a file retrieved from the Internet. The NGSCS web application uses this feature of Google Earth in order to graphically display control station information retrieved from the NGS.

The NGS makes control station datasheets available to the public on their web site. Anyone can visit <http://www.ngs.noaa.gov/cgi-bin/datasheet.prl> and retrieve datasheets using any of several retrieval methods, including radial search, rectangular search, and county search. The user must enter geographic search parameters (latitude and longitude) as text. Other parameters, such as desired data type and stability, are specified by selecting options from dropdown lists. The NGS web site returns a list of stations that meet the search criteria as a multiselection dropdown list. The user can then select any of those stations and retrieve the datasheets.

The NGSCS web application acts as an intermediary between its users and the NGS web site. To its users, it is simply a web application that they access using Google Earth. To the NGS web site, NGSCS appears to be a browser, which requests information and displays the results.

A user begins the process of retrieving control station data by clicking on *Query Setup*. NGSCS responds with the page shown in Fig. 1. Using this page, the user specifies the type of search and nongeographical parameters such as the station type and stability desired. When the user clicks *OK*, the browser sends the user's inputs back to NGSCS. NGSCS creates a KML file including a Google Earth network link for the search requested by the user. The network link is similar to one that could be submitted directly to the NGS, but rather than the NGS URL, it has the NGSCS URL followed by a query string consisting of the user's search parameters. In the case of a radial search or a rectangular search, the network link includes specifications for Google Earth to add latitude and longitude information to the query string based on the current display. NGSCS returns the KML file in response to the request submitted by the user. Google Earth will input the file and save the contents as a folder under *Saved Searches* as shown in the left hand panels of Figures 3, 4, and 5.

In the case of a radial search or a rectangular search, the user pans and zooms the display to the point or area of interest and then clicks on the checkbox beside the folder name. Google Earth then submits the web request in the network link. In the case of a county search, the initial display is irrelevant and Google Earth submits the request immediately.

The URL in the network link is the URL of a page in NGSCS. Server code in NGSCS is activated upon receipt of the request. Using the search parameters in the request, NGSCS creates a web request in the form expected by the NGS web site and submits the request to the NGS just as a browser would. The NGS web application performs the requested search and sets up an HTML page, intended to be displayed by a browser. The NGS server embeds the HTML in a message which it sends back in response to the request.

NGSCS receives the message returned by the NGS just as a browser would. But rather than displaying the page, NGSCS parses the message to extract the control station information. It reformats the control station information as KML and returns the KML message to the requester, Google Earth. Google Earth processes the KML and displays the control station information as shown in the right hand panels of Figures 3, 4, and 5.

*View in Google Maps* functionality is accomplished by submitting a request for the URL <http://maps.google.com/maps> followed by a query string (Mapki 2010) containing the NGSCS URL and the user's search parameters. The Google Maps server in turn submits a request to the NGSCS server, and search results are returned to Google Maps.

*View in Bing Maps* functionality is accomplished by submitting a request for the URL <http://www.bing.com/maps/> followed by a query string (Microsoft 2010) containing the NGSCS URL and the user's search parameters. The Bing Maps server in turn submits a request to the NGSCS server, and search results are returned to Bing Maps.

## **CONCLUSION**

It is likely that the NGS will someday serve KML-formatted output directly to the client (Smith and Genovese 2007). In the meantime, Metzger & Willard, Inc. is pleased to provide NGSCS to the land surveying community and others who may wish to visualize NGS control stations in Google Earth.

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## APPENDIX I. DRAWING CIRCLES IN GOOGLE EARTH

Google Earth uses geodetic coordinates (latitude  $\varphi$ , longitude  $\lambda$ ) on the World Geodetic System of 1984 (WGS84) datum. The equatorial radius or semimajor axis  $a = 6378.137$  km and inverse flattening  $1/f = 298.257223563$  are defining parameters (NIMA 2004). For the purpose of drawing range rings (Fig. 3), a spherical approximation of the ellipsoid is adequate. The arithmetic mean earth radius (Moritz 2003)  $R = (2a + b) / 3$ , where the polar radius or semiminor axis  $b = a (1 - f)$ , yielding  $R = 6371.009$  km or 3958.753 mi (1 mi = 5280 US survey ft). The semiaxes are not referenced in the sequel where, instead,  $a$  and  $b$  are redefined.

Take  $A = (\varphi_A, \lambda_A)$  = center of circle,  $B = (\varphi_B, \lambda_B)$  = point on circle, and  $C = (\pi/2, 0)$  = North Pole. Let  $a, b, c$  be the sides of a spherical triangle (Fig. 6) with corresponding opposite angles  $\alpha, \beta, \gamma$ , where each angle is subtended at corresponding points  $A, B, C$ , and each side is measured by the angle subtended at the center of the sphere with radius  $R$ .

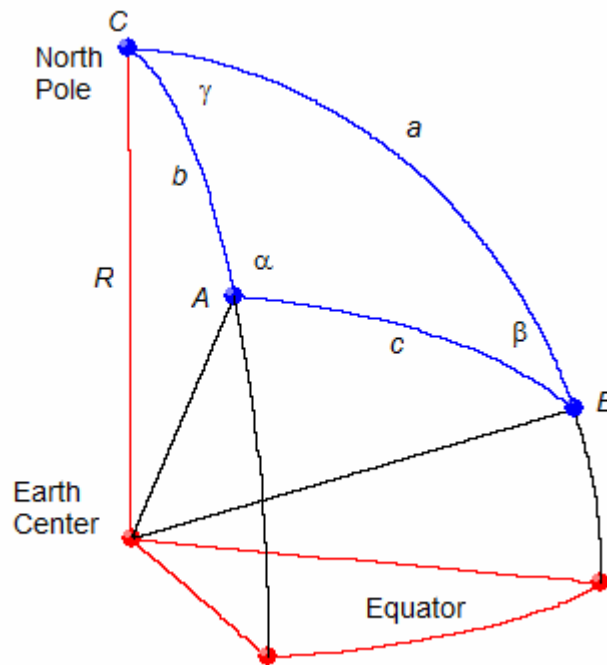


Figure 6. Spherical Triangle

Given the circle center  $(\varphi_A, \lambda_A)$ , north azimuth  $\alpha$ , and circle radius  $r = R c$ , it is required to compute the point on circle  $(\varphi_B, \lambda_B)$ .

From the law of cosines for sides (Weisstein 2010a),

$$\cos a = \cos b \cos c + \sin b \sin c \cos \alpha. \quad (1)$$

$$\cos\left(\frac{\pi}{2} - \varphi_B\right) = \cos\left(\frac{\pi}{2} - \varphi_A\right) \cos \frac{r}{R} + \sin\left(\frac{\pi}{2} - \varphi_A\right) \sin \frac{r}{R} \cos \alpha. \quad (2)$$

$$\sin \varphi_B = \sin \varphi_A \cos \frac{r}{R} + \cos \varphi_A \sin \frac{r}{R} \cos \alpha. \quad (3)$$

$$\varphi_B = \arcsin\left(\sin \varphi_A \cos \frac{r}{R} + \cos \varphi_A \sin \frac{r}{R} \cos \alpha\right). \quad (4)$$

From the law of sines (Weisstein 2010b),

$$\sin \gamma = \frac{\sin c \sin \alpha}{\sin a}. \quad (5)$$

From the law of cosines for sides,

$$\cos \gamma = \frac{\cos c - \cos a \cos b}{\sin a \sin b}. \quad (6)$$

Dividing (5) by (6),

$$\tan \gamma = \frac{\sin c \sin \alpha \sin b}{\cos c - \cos a \cos b}. \quad (7)$$

$$\tan(\lambda_B - \lambda_A) = \frac{\sin \frac{r}{R} \sin \alpha \cos \varphi_A}{\cos \frac{r}{R} - \sin \varphi_B \sin \varphi_A}. \quad (8)$$

$$\lambda_B = \lambda_A + \arctan\left(\frac{\sin \frac{r}{R} \sin \alpha \cos \varphi_A}{\cos \frac{r}{R} - \sin \varphi_B \sin \varphi_A}\right). \quad (9)$$

Using (4) and (9), the circle may be approximated by the regular  $n$ -gon with vertices  $[\varphi_B(\alpha), \lambda_B(\alpha)]$  where  $\alpha = 2k\pi/n$  for  $k \in [0, 1, \dots, n-1, n]$ . If the circle center  $A$  is a pole ( $\cos \varphi_A = 0$ ), use vertices  $[\varphi_B(\alpha), \alpha]$ .

Using a two-argument arctangent function in (9) will ensure that  $\lambda_B$  is in the correct quadrant, but the latitude must be normalized ( $-\pi \leq \lambda \leq \pi$ ) for use in Google Earth. Using the modulus operator,

$$\lambda = [(\lambda_B + 3\pi) \bmod 2\pi] - \pi. \quad (10)$$

Range rings are implemented in NGSCS as regular polygons with  $n = 64$  sides using the KML LineString tag.

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