Report on the

9th Annual CORS User Forum

Savannah, Georgia
September 22, 2009

NOAA's National Geodetic Survey (NGS)—in cooperation with the U.S. Department of Transportation and the U.S. Coast Guard—convened the 9th annual Continuously Operating Reference Station (CORS) Users Forum on September 22, 2009 in Savannah, Georgia. The Forum was an integral part of the Civil GPS Service Interface Committee (CGSIC) meeting, September 21-22, 2009. Additionally, the Institute of Navigation's Global Navigation Satellite System (GNSS) Conference convened from September 22-25, 2009 in Savannah.

The CORS network is comprised of numerous subnetworks operated by about 200 organizations. Collectively, these networks include approximately 1,370 sites—each containing a geodetic quality,

dual-frequency GPS receiver. The CORS network is growing at a rate of about 200 sites per year – many with updated GNSS capabilities, such as receiving GLONASS observables. NGS and its partners collect, process, and distribute data from the CORS sites on a continuous basis in support of numerous activities including land surveying, navigation, GIS development, remote sensing, weather forecasting, satellite tracking and geophysics.

The Forum is designed to provide users with the latest information about CORS, its partners, its tools, and its support for real-time positioning, while hearing from these users about their experiences and what NGS can do to improve its products and services.

This year's Forum featured a panel of speakers discussing the guidelines being prepared to help real-time GNSS network (RTN) operators, as well as those using RTN positioning services. A team of more than 60 people are involved in developing these guidelines, including current RTN administrators (both public and private), representatives from several GNSS manufacturers, and NGS employees. NGS plans to provide a draft of these guidelines for public review in early 2010.

Agenda

1:30   **Welcome –** Richard Snay, NOAA's National Geodetic Survey

1:35   **CORS/OPUS: Overview and Status –** Giovanni Sella, NOAA's National Geodetic Survey

1:50   **PANEL SESSION**: **Guidelines for Real-Time GNSS Networks (RTN)**

      A. **Site Considerations** - Dan Martin, NOAA's National Geodetic Survey
      B. **Planning & Design** - Gavin Schrock, Washington State Reference Network
      C. **Administration -** Gary Thompson, North Carolina Geodetic Survey
      D. **Best Methods for Users -** Bill Henning, NOAA's National Geodetic Survey

3:05   **Question & Answer Session with Speakers**

3:50   **Interactive Sessions within Small Discussion Groups**

      Group 1. CORS/OPUS

      Group 2. RTN Site Considerations and RTN Planning & Design

      Group 3. RTN Administration and RTN Best Practices for Users

5:00   **End of Forum**

PowerPoint files for the formal presentations may be viewed and/or downloaded at:

http://www.ngs.noaa.gov/CORS/CorsPP/PPT.html

Richard Snay of NGS presented the following graph during his welcoming remarks:

DIRECT BENEFITS OF CORS BY YEAR
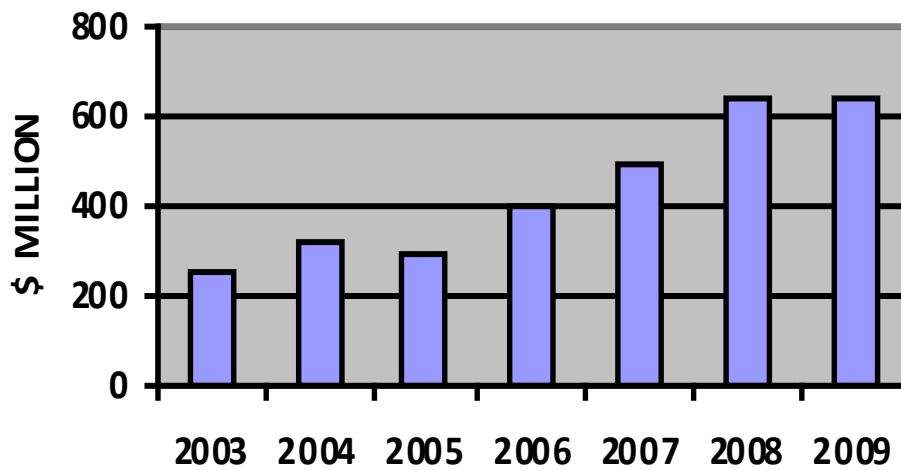
Snay also described a recent study to estimate the socio-economic benefits of both the CORS program and the Gravity for the Redefinition of the American Vertical Datum (GRAV-D) project. According to this study, conducted by Leveson Consulting of Jackson, New Jersey, the annual benefits (both direct and indirect benefits) of the CORS program equals $758 million. Details of the study are available at www.ngs.noaa.gov.

Giovanni Sella (NGS), the CORS Program Manager, reported that NGS added 180 new stations to the CORS network during the past year, including new sites in Iraq, Afghanistan and Benin. NGS also merged the National CORS network and the Cooperative CORS network into a single network in 2009. As a result of the merger, users may now obtain data from former Cooperative CORS sites in the same manner they obtain data from National CORS sites from either of the two parallel CORS data facilities—one located in Silver Spring, Maryland and the other in Boulder, Colorado. NGS, moreover, recently enhanced the OPUS utility so that its users now have the option to archive their OPUS-generated coordinates at NGS—together with such other information as a photo and a description of where the corresponding observations were collected. Thus, OPUS now allows its users to share their survey results with others. During 2010, NGS will publish positional coordinates and velocities for all CORS in the soon-to-be-released International Terrestrial Reference Frame of 2008 (ITRF2008), as well as in a new realization of the North American Datum of 1983 (NAD 83).   NGS also plans to begin distributing GLONASS data from selected CORS and to start generating precise orbits for the GLONASS satellites within the next 12 months.   NGS, moreover, is developing the OPUS-Projects utility that will rigorously process and adjust GPS data collected at multiple locations, using one or more receivers, and during one or more observing sessions.
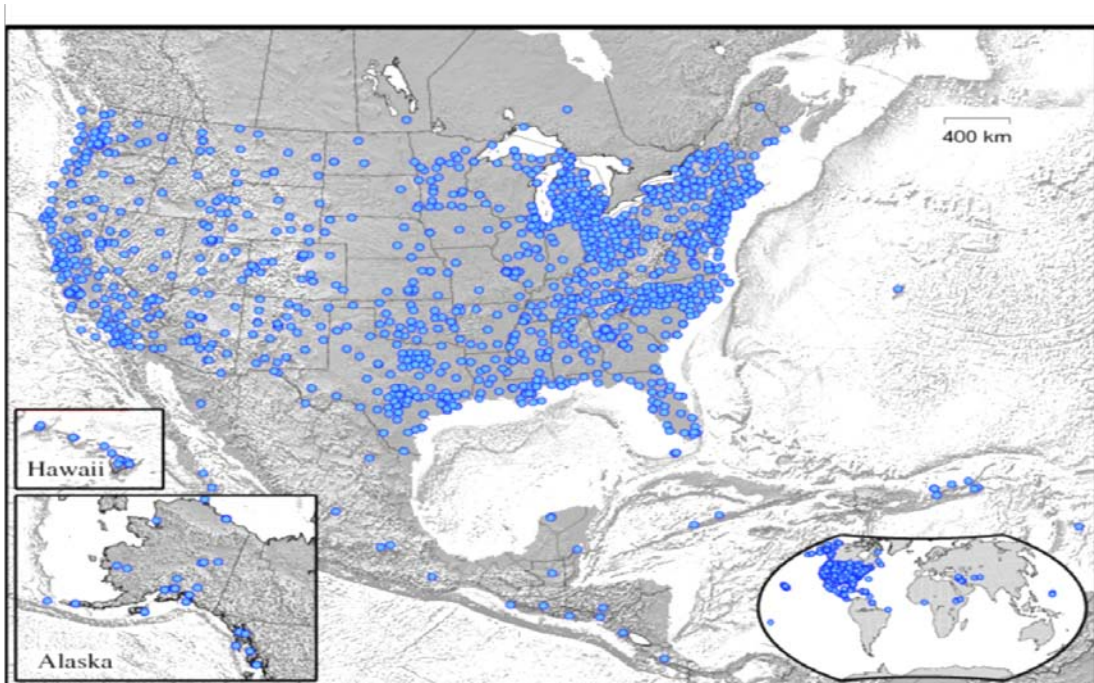
Dan Martin of NGS discussed various topics relating to the construction of RTN sites, including different options for mounting the GPS antenna. The following photo shows an antenna mounted on the corner of a building.
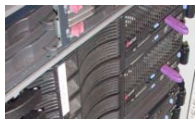
Gavin Schrock, administrator of the Washington State Reference Network, discussed various considerations involved in planning and designing a RTN.
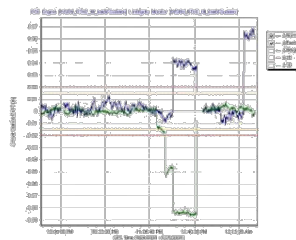
Planning & Design

- Pre-Planning
- Spacing
- Processing Center
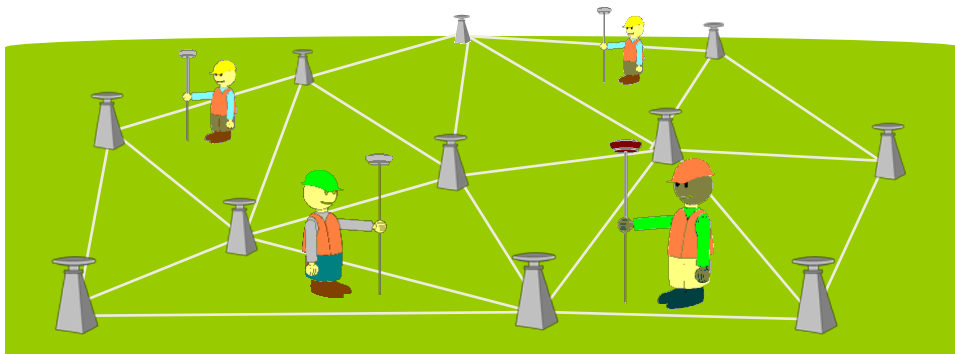
Processing Center

- Central Processing Center (CPC)
  - Host and Host Site
  - Servers and Arrays
  - Power & Environment
  - Archiving
- Communications
  - CORS to CPC
  - CPC to End-User
  - Redundancy
- Design for Operational Levels
  - Minimal (Tool Style)
  - Full (Utility Style)
- Maintenance and Support
- Network Integrity Monitoring

Gary Thompson, Director of the North Carolina Geodetic Survey, discussed the issues involved in the administration of an RTN.

RTN Administration

☐ Resources
- ■ Hardware infrastructure
- ■ Communication networks
- ■ CORS

☐ People
- ■ Users
- ■ Administration staff to provide
  - ☐ Helpful support to users
  - ☐ Partnership with IT professionals

William (Bill) Henning of NGS discussed best methods for RTN users. These methods build upon the guidelines for single-base RTK (real-time kinematic) users. These guidelines may be viewed and/or downloaded at:

http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v2.0.4.pdf

Question & Answer Session

The following notes were taken during the Question and Answer session.

Question [Irving Leveson, Leveson Consulting, New Jersey]: What happens after the Real-Time Network Guidelines come out? Will there be a push for mass education?

> William "Bill" Henning, NGS: There is no formal plan. Once the RTN guidelines are posted, we will invite public comment. NGS will be at venues such as the American Congress on Surveying and Mapping (ACSM), International Federation of Surveyors (FIG), and the Federal Geographic Data Committee's (FGDC) Federal Geodetic Control Subcommittee (FGCS) and will announce/receive questions regarding the RTN guidelines at these venues.

Question [Irv Leveson]: Will the RTN guideline have a dedicated help desk?

> Bill Henning: No, we do not have the resources. Any questions may be directed to the existing help desk.

> Richard Snay, NGS: NGS is investigating the possibility of hiring a person to assist Bill Henning.

Question [Lonnie Sears from eGPS Solutions, Georgia]: At the 2008 CORS User Forum, there was a discussion about "Interpolative Dilution of Precision" (IDOP). Has there been progress on this?

> Richard Snay: IDOP measures the geometric strength of the CORS network in a pre-specified neighborhood of a point. Charlie Schwartz, Tom Soler, and I published a scientific paper "Accuracy Assessment of the National Geodetic Survey's OPUS-RS Utility" in a recent issue of *GPS Solutions*. In the paper, we define IDOP and describe how to compute its value at a geographic location.

Question [Lonnie Sears]: Does the IDOP concept apply to RTN geometry?

> Richard Snay: Yes, the IDOP concept can be used to measure the geometric strength of the stations forming an RTN, to the extent correctors are computed via two-dimensional linear interpolation on the Earth's surface.

Question [Jim Richardson, Nebraska State Advisor]: I'm trying to convince my colleagues to install reference stations for submission and inclusion in the CORS network. I would like to be able to examine the 60-day plots for "good" sites and then search station log files for metadata, such as antenna cable lengths, antenna model, monumentation, etc., with the plan to build new, similar sites matching the target time series.

> Giovanni Sella, NGS: One challenge is that the site logs may not be complete, because data providers do not submit information. <*Note:* recall that the CORS network is 98% volunteer>. A great number of stations do not have the data you mentioned (antenna cable length, etc.). You are not alone in wanting this, but we cannot provide data if we don't receive it from the provider.

> Richard Snay: <To reiterate the question> you are trying to use the 60-day plots as an indicator of how well a site is performing? You would like to know what metadata evidences a good site, versus a bad site setup?

Question [Jim Richardson]: As the site requirements become more stringent, I'd like to know what setups have the best results.

Richard Snay: So you would like to have someone perform a study on what makes a good site.

Jim Richardson: Or a tool, say a "metadata monument tool."

Sidebar by Richard Snay: One controversial issue regarding site setups is that NGS CORS requirements prohibit installation of sites on any building with a metal roof. We realize many users have access only to facilities with metal roofs.

Question [James Stowell, Canary Inc., New Hampshire]: As a comment to Jim Richardson's request, wasn't there a study on the RMS scatter of 40-50 sites, where the sites were investigated as to how well they would track back to the "0-point" over a period of time?

Giovanni Sella: You are probably referring to the publication by Steve Hilla and Mike Cline, but that study quantified the multipath occurring at each site, not RMS scatter of daily solutions.

Richard Snay: Regarding repeatability, NGS is currently reprocessing GPS data collected as far back as 1994 for **all** CORS; a plot of the time series of weekly coordinates will be created for each CORS. It may be good to study the quality and repeatability (once the reprocessing is completed).

Question [Jim Richardson]: At this point, does NGS have vector processing software to validate the OPUS solutions—aside from using coordinates/vectors derived from other positioning services offered by other facilities (US and/or other countries)—for example, in the case of someone challenging the results output by OPUS? Will you then process the user-submitted data to a similar package, such as Bernese, Gipsy, etc., to compare with PAGES (the NGS processing software used by OPUS-S), to prove that the OPUS results are accurate?

Giovanni Sella: We are already doing that. Since NGS is an International GNSS Service (IGS) Analysis Center, we do separate processing for:

1. Rapid orbits
2. Final orbits

These are **separate** software packages. Also, during the transition of NGS becoming the IGS Analysis Center Coordinator, any issues discovered in the PAGES software were addressed at that time. In addition, NGS was the only IGS analysis center that correctly used the calibrations for GPS antennas covered by radomes. So, in answer to your question, we've compared the NGS software with Bernese, GFZ's processing software, Gipsy, GAMIT, etc., and we have addressed any discrepancies.

There are numerous online GPS processing services: JPL has "Auto-Gipsy"[1], the Australian government has "AUSPOS", the Canadian Geodetic Service has "CSRS-PPP", and SOPAC has "SCOUT."

Dan Martin, NGS: We can also compare the results using OPUS-S vs. OPUS-RS, as they are two completely separate software packages—OPUS-S uses PAGES, and OPUS-RS uses RSGPS. The metadata used are the same for both.

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[1] note: Auto-Gipsy has been replaced on Aug 15, 2009 by "Automatic Precise Positioning Service (APPS)"

Richard Snay: We continuously compare PAGES results against other software.

Giovanni Sella: There may be discrepancies if the two software packages being compared do not use the same metadata file [i.e. station log data].

Question [Lonnie Sears,]: Will the new datum include the vertical?

Giovanni Sella: The new datum will be for the three-dimensional geometric reference system where the vertical component is represented by ellipsoid height. The orthometric height update will be under NGS' Gravity for the Redefinition of the American Vertical Datum GRAV-D program.

Question [Lonnie Sears]: When will Geoid '09 be released?

Giovanni Sella: The NGS Products & Services Committee (PSC) met last Thursday (9/17/09), and Geoid '09 should be available very soon.

David Doyle, NGS: The model should be available next week (week of 9/28/09).

Author's note: GEOID09 has been released for public use.

Question [Gavin Schrock, State of Washington Reference Network]: What is the status of modernizing NAD_83 (i.e. the modernization of the 3-D geometric reference system)?

Giovanni Sella: We are moving towards a geocentric 3-D geometric reference system. The current version of NAD_83 is ~2 meters off from geocenter. With WGS84, there was a transition to the geocentric. Some people will be happy with the transition to geocentric; others will not be happy. We must agree on a compromise. [What to call the new reference system is a problem because] the term "NAD_83" is prevalent in numerous legal documents and in various published government policy. Any decisions regarding the new reference system must be made with your [the GNSS community] input.

David Doyle: This transition is documented in the NGS 10-Year Plan. We are aware that moving to the new datum is a difficult and complex process. We will be soliciting input at venues held with FGDC, ACSM, and other working groups. The NGS state geodetic advisors will be assisting in education and outreach. As expected, the transition will not be painless. There will be a new datum, but the time frame for it is undetermined.

Question [Ross McKay, Kentucky State Advisor]: This is a follow-up question to the release of the RTN guidelines. What happens after the guidelines are published?

Bill Henning: NGS will develop and present new workshops to explain the new RTN guidelines.

Richard Snay: In May of this year (2009), NGS presented three webinars[2] via our Corbin Training Center. The webinars were successful and were remotely attended by approximately 200 participants. Webinars are a beneficial tool for educating those who cannot travel out of state.

Question [Eric Gakstatter, GPS World Magazine]: Is "OPUS-International" still an active project?

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[2] http://www.ngs.noaa.gov/corbin/calendar.shtml

Giovanni Sella: Yes, the project is still active, but we have run into issues with the accuracy of the metadata at several reference stations located in other parts of the world. OPUS-International will have requirements similar to OPUS-S, but it will be globally accessible.   The user data set must span a minimum of two hours, and the computed coordinates will only be expressed relative to the International Terrestrial Reference System; that is, coordinates will not be given in any local reference frame. Precision and accuracy of certain areas, such as the high north latitudes, low south latitudes, or mid-African continent, will be problematic.

CORS/OPUS Interactive Session

The following discussion was held among the participants in the interactive session on "CORS/OPUS." The participants included:

- Gerald "Gerry" Mader, NGS Geosciences Research Division

- Giovanni Sella, NGS CORS Program Manager

- Kevin Choi, NGS Spatial Reference System Division

- Irving Leveson, Leveson Consulting, New Jersey

- Dmitry Kolosov, Director of Software Division, Topcon Positioning Systems

- DeLane Meier, North Dakota Department of Transportation

- Francine Coloma, CIRES/University of Colorado (NGS CORS-West facility data manager)

Gerry Mader is the Chief of the Geosciences Research Division at NGS. Gerry provided an update on the forthcoming Web-based utility, OPUS-Projects.

Gerry Mader: We have Mark Schenewerk making good progress on OPUS-Projects. This tool is nearing completion, and it will be capable of generating plots. OPUS-Projects has a project-scheduling engine that allows users to create a schedule and assign values, such as personnel and equipment—similar to matching a person with a particular GPS receiver/antenna to go to a site. This tool can be updated to accommodate scheduling changes, and it also has the ability to pre-populate certain fields in the metadata page. Still in the discussion phase for OPUS-Projects is how to accommodate orthometric heights. There are several internal policy issues that need to be addressed, as well.

Question [Giovanni Sella to Dmitry Kolosov]: I have noticed that Topcon regularly retrieves large quantities of CORS data. Do you (Dmitry) know for which application Topcon is using this quantity of CORS data?

Dmitry Kolosov: I do not know about the usage you mentioned. I use CORS for comparison against my solutions from the Tennessee office.

Question [Dmitry Kolosov]: How is CORS to be used for real-time network (i.e. streaming)?

Giovanni Sella: NGS is currently streaming GPS data from eight NGS-owned sites. We have 30 sites capable of streaming data, but we are limited to the eight due to communications issues. Streaming in the RTCM 2.3 and 3.x formats is being tested, because they are commonly used formats, rather than in a vendor-specific format. We are aware other organizations are interested in having NGS stream their data, but we have a policy that we will not stream data from non-federal organizations. Also, NGS will not provide correctors, only the GNSS observables.

Dmitry Kolosov: Yes, I am aware that groups, such as Japan, stream in a vendor-specific format.

Question [Gerry Mader to Dmitry Kolosov]: Dmitry, how did your comparison between your (Topcon) software and OPUS turn out?

Dmitry Kolosov: About the same. I used 6 baselines, 50 - 110 km spacing, 10 days worth of data in 3-hr increments (80 pieces of data), for 80 independent processing solutions. I held three points fixed. I saw vertical RMS differences at 16 mm, while the maximum vertical difference is 18 mm.

Question [Gerry Mader to Dmitry Kolosov]: Do you have a tropospheric adjustment?

Dmitry Kolosov: Yes

Gerry Mader: For OPUS, we want only raw data, without adjustments for troposheric refraction, in order for it to process "clean." The biggest source of error in OPUS are the CORS positions themselves, so we use IGS as a fiducial network and compare it to CORS. CORS and IGS coordinates are both accurate for an epoch date of 1997.0; however, CORS coordinates becomes progressively worse for later epoch dates because CORS velocities are not known as accurately as IGS velocities. During comparison between the use of IGS and CORS coordinates, we select the three nearest CORS versus the three nearest IGS.

Dmitry Kolosov: It's possible that, by combining CORS with RTN and running an engine for precise orbits, you may have byproducts such as an ionospheric map or tropospheric model that may work well with RTK.

Giovanni Sella: Yes, groups like NOAA's Space Weather Prediction Center (SWPC) and NOAA's Earth Science Research Laboratory (ESRL) may provide some benefits to RTN services, if they would provide ionospheric and tropospheric models sooner. SWPC produces the US-Total Electron Content product every 15 minutes, while ESRL produces its GPS-Met model every 30 minutes. Internally to NOAA, both SWPC and ESRL receive low-latency data from certain sites in the CORS network. If SWPC or ESRL would like to add other streams, they themselves would need to subscribe to those particular streams. NGS is aware of, and is sensitive to, the concerns regarding our streaming of GPS data, by commercial vendors or the private sector that charge for such service.

Dmitry Kolosov: Many RTK networks, such as the one in Tennessee, could provide you with their data stream.

Giovanni Sella: <regarding Tennessee CORS sites> It would be good to receive hourly files from Tennessee; however, we were informed it was not possible.

Dmitry Kolosov: I wrote the software, and the Tennessee network should have the capability to produce hourly files; there may be a reason this network is not set up for distributing hourly files.

Giovanni Sella: I will inquire with Jim Waters [Tennessee Dept. of Transportation Design Division] concerning whether we can receive those hourly files.

Giovanni Sella: NOAA's GPS-Met project led by Seth Gutman produces the GPS-Met product with a 30-minute latency, and this product may be useful for RTK users.

Dmitry Kolosov: During the Forum's Question and Answer session, a participant thought that, by evaluating the stability of a site's 60-day plot, a search of the stable site's station log would be beneficial for establishing the same setup at new sites. I do not think this goal is feasible in the suggested process.

Giovanni Sella: I agree, the site logs are not easily searchable.

Dmitry Kolosov: We ourselves would like to extract this information for metadata.

Giovanni Sella: Yes, but the older site logs have serious problems. Since 2006, the site logs have had valid IGS antenna and receiver names. At NGS, we have attempted to enter checks due to mismatches in equipment, but we abandoned the idea, because site operators were having difficulty inputting those values into their receivers. As a result, those records may or may not abide by the IGS naming convention.

Giovanni Sella: A substantial amount of software is required to manage a network. <For example> for firmware versions in late 2007, our software leaves whatever value the site operators input and will only overwrite the file if it is left blank. <For example> UNAVCO sets aside all data with equipment mismatches and reprocesses them later. For NGS, our automated software does not reprocess after three days.

Gerry Mader: Regarding antenna calibration, NGS' absolute antenna calibration facility is now up and running! We have a considerable backlog of antennas to be calibrated, so we will continue to do relative calibrations for overlap. In our timeline, by December 1, 2009, we will provide absolute antenna calibrations to the National Geospatial-Intelligence Agency (NGA).

Dmitry Kolosov: Topcon plans to:

1. Use NGS' antenna calibration tables. For those antennas not calibrated by NGS, we will use internal Topcon calibration values,

2. Use absolute calibration values.