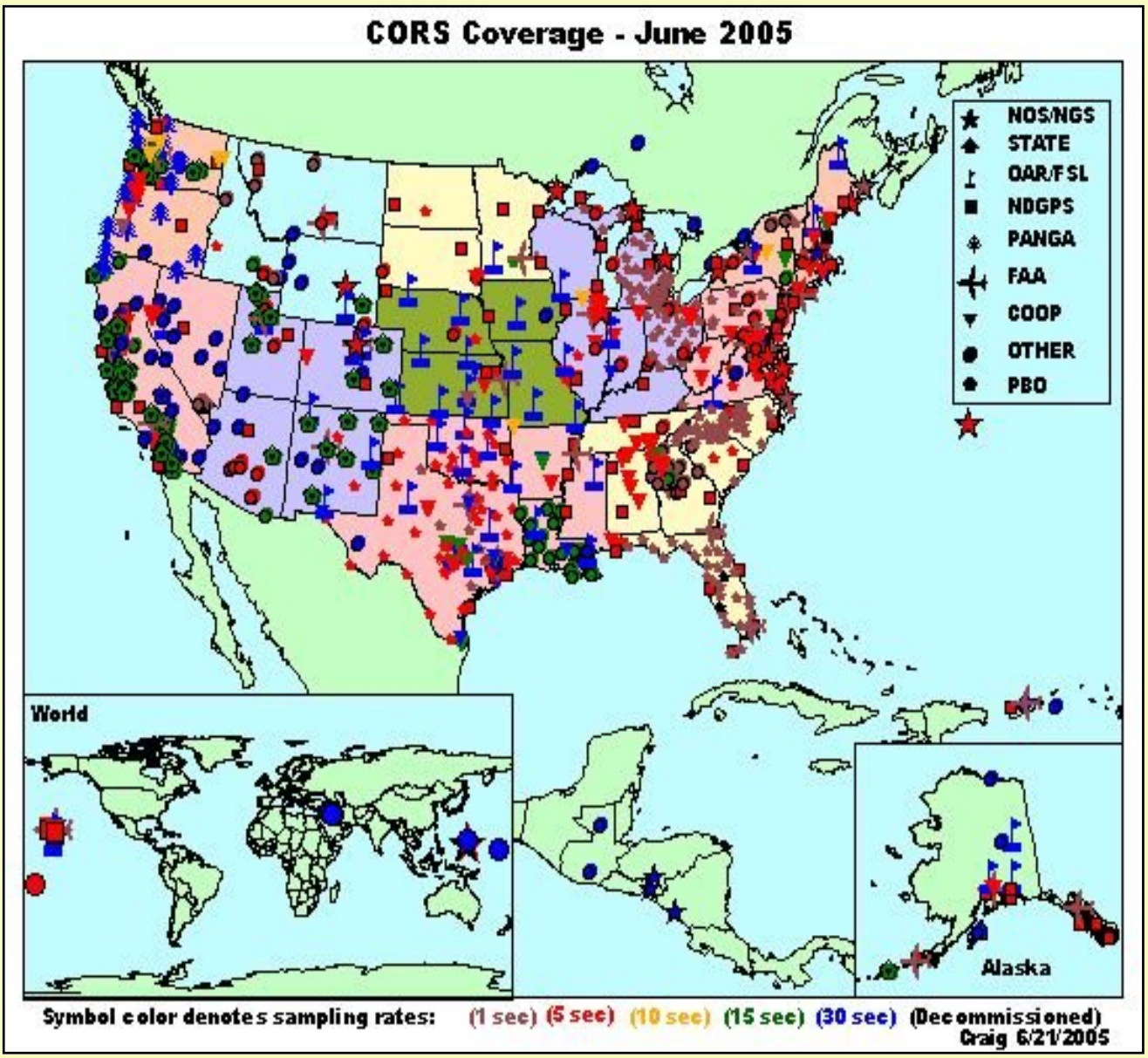
National Oceanic and Atmospheric Administration's

National Geodetic Survey

CORS User Forum

"Towards Real-Time Positioning"



September 13, 2005

Long Beach, California

Long Beach Renaissance Hotel

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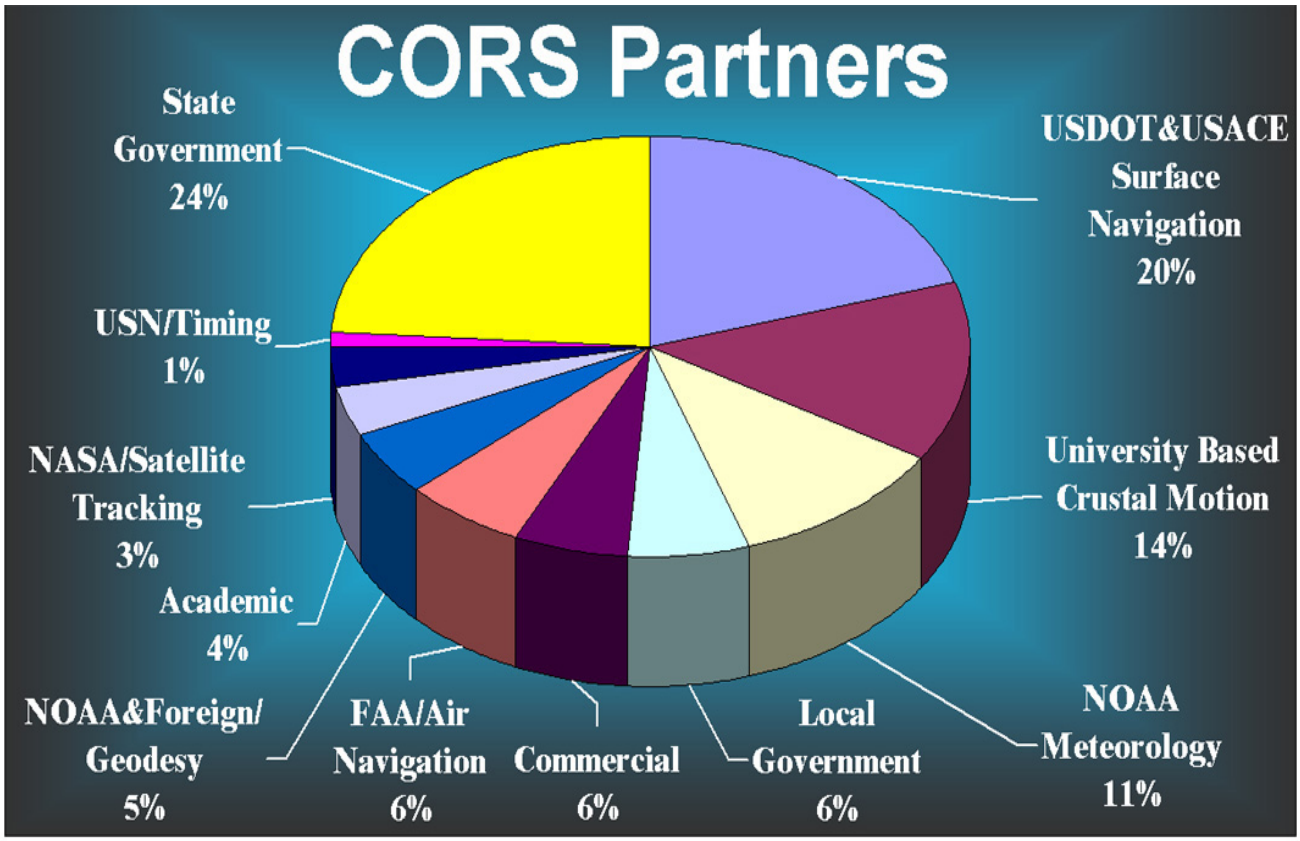
Background Information

The National Geodetic Survey (NGS) is an office of the National Oceanic and Atmospheric Administration's National Ocean Service. It coordinates a network of continuously operation reference stations (CORS) that provide Global Position System (GPS), carrier phase and code range measurements, in support of 3-dimensional positioning activities throughout the Unites States, its territories, and a few foreign countries.

Surveyors, GIS/LIS professionals, engineers, scientists, and others can utilize CORS data to position points at which GPS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters, relative to the National Spatial Reference System, both horizontally and vertically.

The CORS network consists of two sub networks, National and Cooperative CORS, operated by more than 155 organizations. Collectively, these networks include more than 1,000 sites--each containing a geodetic quality, dual-frequency GPS receiver. The CORS networks are growing at a rate of about 15 sites per month. NGS and its partners (see graph below) collect, process, and distribute data from the CORS sites, on a continuous basis, in support of numerous activities-- including land surveying, navigation, GIS/LIS development, remote sensing, weather forecasting, satellite tracking, geophysics, and time transfer.



Introduction and Summary

The fifth annual Continuously Operating Reference Station (CORS) Users Forum was held in Long Beach, CA. The forum convened in conjunction with the 45th Civil GPS Service Interface Committee (CGSIC) meeting on September 12-13, and the Institute of Navigation's GNSS Conference on September 13-16. The CORS Users Forum was organized by NOAA's National Geodetic Survey, the U.S. Department of Transportation, and the U.S. Coast Guard.

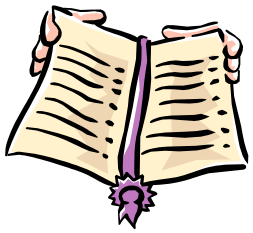
The forum began with an opening introduction and presentation by Richard Snay, of NGS. His introduction was followed by four short presentations — Greg Anderson of UNAVCO, Inc.; Georg Weber of the German Federal Agency for Cartography and Geodesy; Mark Caissy of Natural Resources Canada; and Charlie Schwarz, also of NGS. The presentations from the Users Forum are available at **http://www.ngs.noaa.gov/CORS/information5/**. Presentations from previous Users Forums (2001—2004) can also be viewed at this location.

After the presentations, there was a short question and answer session with the panel of speakers. Following a short break, there was an opportunity for participants to attend one of four interactive sessions, within small discussion groups.

More than 100 participants attended the Users Forum, with a slightly smaller crowd involved in the discussion groups. "Towards Real-Time CORS Products and Services," was the most populated discussion group. It was facilitated by Charlie Schwarz and Miranda Chin, both of NGS. The session with the second highest number of participants was "Ionospheric and Troposheric Models," facilitated by Dru Smith of NGS and Tim Fuller-Rowell of NOAA's Space Environment Center.

Participants were given a follow-up survey containing questions designed to gain users preferences regarding the streaming of CORS data, via the Internet, with the Network Transport of RTCM via Internet Protocol (NTRIP). Participants were instructed to provide answers to the survey via written answer (preferred); response at the interactive sessions; communication with a CORS team member; or in an e-mail to cors@noaa.gov, with "NTRIP" in the subject line.

Agenda



1:30	Welcome and Opening Presentation **CORS/OPUS: Status and Overview** Richard Snay, NOAA's National Geodetic Survey
1:45	**EarthScope's Plate Boundary Observatory** Greg Anderson, UNAVCO, Inc.
2:05	**Post-Processing Versus Real-Time GNSS** Georg Weber, German Federal Agency for Cartography and Geodesy
2:25	**The International GNSS Service — Progress Towards Real-Time** Mark Caissy, Natural Resources Canada
2:45	**CORS/OPUS: Future Prospects** Charles Schwarz, NOAA's National Geodetic Survey
3:00	**Question and Answer Session**
3:20	**Break**
3:35	**Interactive Sessions within Small Discussion Groups**
5:00	**End**

Interactive Sessions

A.	Towards Real-Time CORS Products and Services Moderators: Charlie Schwarz and Miranda Chin
B.	OPUS, UFCORS, and other CORS Utilities Moderators: Tom Soler, Dale Pursell, and Marti Ikehara
C.	Guidelines for Establishing CORS Sites Moderators: Giovanni Sella, Don Haw, and Julie Prusky
D.	Ionospheric and Tropospheric Models Moderators: Tim Fuller-Rowell and Dru Smith

Presentation "#1" Highlights

Richard Snay began his presentation by welcoming the forum participants. He proceeded with slides showing the forum agenda and interactive sessions. His opening slide on his topic referenced the CORS stations currently contained in the network. Here are some key points stressed during the presentation:

- CORS subnetworks are operated by more than 155 organizations; NOAA operates relatively few stations itself.
- Recently, the U.S. Army established 6 stations in Iraq which are now part of the CORS network.
- Due to Hurricane Katrina, NGS temporarily lost communications to several CORS located along a 150-km stretch of the Gulf Coast.
- CORS partners upgraded the remaining operational sites located in the Hurricane Katrina affected areas to collect 1-second GPS data to support airborne mapping performed in conjunction with post-hurricane recovery activities.
- Google Earth added a link to its web page, that leads to the NGS web site, to display the airborne imagery obtained after Hurricane Katrina.
- The combined CORS network grew by more than 240 sites during the past 12 months, including a new site at Grand Isle, LA. This site was established by Louisiana State University with assistance from UNAVCO, Inc., and it uses a satellite uplink to distribute its data.
- CORS data are being used to model precipitable water vapor over CONUS on an hourly basis; these models are now being officially incorporated into pertinent NOAA weather products.
- NOAA's Space Environment Center is using CORS data to generate models of the total electron content (TEC) for CONUS. These ionosperic models are updated every 15 minutes with a latency of 30 minutes.
- NGS expects to incorporate 15 Mexican stations into the CORS network within the next few months.
- NOAA will shortly release new guidelines for the establishment of CORS sites and the management of CORS information.
- Under these new CORS guidelines, all satellites should be tracked, regardless of their health (even data from an "unhealthy" satellite may be useful).
- Also under these guidelines, NGS is discouraging the use of radomes.
- NGS is exploring the use of NTRIP (engineered in Germany) for streaming GPS data in real-time via the Internet.
- NGS understands that this real-time data-distribution system may not possess sufficient integrity— ability to send out warnings to a user, if bad data have been detected— to support a robust navigation service.

Presentation "#2" Highlights

Dr. Greg Anderson of UNAVCO, Inc. presented information on the status of GPS activities at EarthScope's Plate Boundary Observatory (PBO) which is sponsored in large part by the National Science Foundation. He began by informing the crowd about the size of the PBO network — proposal for 875 new continuous GPS stations, currently 209 such stations have been installed, and 100 survey-mode GPS receivers. Other highlights from the presentation included:

- PBO is deploying continuous GPS stations that feature: Trimble NetRS receivers, SCIGN monuments, Solar/Wind power, and LINUX.
- PBO uses Topcon GB-1000 GPS receivers with Tech 2000 equipment for survey-mode operations.
- PBO plans to pursue the use of Real-Time GPS, through real-time kinematic feeds — landowners will have access to NetRS; third-party access will also be permitted; and there will be approximately 25 stations.
- Future plans regarding real-time GPS at PBO include: the addition of five stations in Southern California in 2005; 12 additional stations at various locations in 2006; and further expansion in 2007 and 2008.
- PBO has a Special Data Request Tool available at the following web address **http://pboweb.unavco.org/shared/scripts/datarequests**.
- Dr. Anderson presented footage from October 2004, at Mount Saint Helens (pictured below), where PBO staff participated in Volcanic Crisis Response activities — several potential GPS sites were "recon-ed" in August 2004; permission was acquired for the installation of 7 new continuous GPS stations, that called for installation beginning in Summer 2005.
- PBO's work at Mount Saint Helens conclusively found that the volcano was deflating, according to their station velocities map (based on data acquired during the October 2004 - May 2005 period).
- The final point of the presentation informed participants that PBO is the geodetic component of the EarthScope Project.

Mount Saint Helens — October 11, 2004

Presentation "#3" Highlights

Dr. Georg Weber of BKG, the German Federal Agency for Cartography and Geodesy, presented a highly informative argument for using Real-Time GNSS data as opposed to Post-Processing GNSS data. He began his presentation with a status update — the number GNSS users who post-process GNSS data has been rapidly decreasing, while at the same time, the community of real-time users has been growing dramatically. Other highlights of the presentation include:

- The question was raised as to whether NGS/CORS is running itself out of business by not supporting real time initiatives in addition to the current post-processing activities.
- NGS/CORS should consider the following: how to cope with demands for real-time processing; should NGS add new products to its portfolio, and if so, what products; what technological actions may be appropriate; and what would be an appropriate policy to follow.
- Another option was added — Networked Transport of RTCM via the Internet Protocol (NTRIP) — that is based on HTTP and GPRS/UTMS Mobile Internet.
- NTRIP became an RTCM standard in September 2004, and it is being supported by a huge selection of devices.
- Current European use of NTRIP streams includes over 500 stations, with 25 broadcasting sites.
- NTRIP is already in use in the United States. The first CORS station is located in Erlanger, KY (ERLA); which the NCAD company has operated since October 2003.
- Dr. Weber used the analogy of delivering a daily newspaper on a monthly basis, to stress the need for real-time processing, as opposed to post-processing.
- The list of products that may be generated from real-time GPS data in the future include: satellite orbits and clocks, troposphere models, ionosphere models, GPS signal interference, natural hazards, and DGPS/RTK.

Dr. Weber closed with a list of Real-Time GNSS policy recommendations: upgrade all CORS stations to real-time; pick up any stream continuously made available; support standard formats accepted by client software; disseminate high-rate data; establish a network of NTRIP broadcasters; monitor stream flow and content; assist existing real-time services; participate in global stream exchange; and begin with a pilot project and a call for participation.

Presentation "#4" Highlights

The fourth presentation, The International GNSS Service (IGS)—Progress Towards Real Time, was presented by Mark Caissy of Natural Resources Canada. His presentation was neatly organized by the following outline topics: Vision and Goal, Where We Are Today, Current Activities, Emphasis and Next Steps, and CORS - Things to Consider.

Highlights from the presentation include the following:

- IGS envisions making its data and products available in real-time via IP communication links.
- IGS would like to be able to provide real-time Precise Point Positioning on a global scale, consistently (seamlessly).
- Also, IGS envisions the prospect of multi-disc communication.
- Under IGS' plans for a Real-Time Initiative, they have the following: to develop a real-time infrastructure; to deliver real-time data to analysis centers, and to make data and products available to real-time users.
- IGS is currently in the process of developing a real-time prototype network, which currently contains 40 stations (as of July 2005); in addition to developing software tools for transmission, reception, and integration of real-time data and products.
- They have also adopted a set of defined message formats and an exchange protocol (UDP). They include an issue of data station (IODS) in order to monitor changes to stations in real-time.
- IGS monitors the performance of data flow within its network
- IGS currently has real-time stations in Mississippi (MSSC), Florida (FLIU), Washington, D.C. (NRL1, USNO), California (DHLG, WIDC) and Colorado (AMC2).
- The next steps that IGS plans to pursue are contained in a data pilot project.
- Phase one of that project calls for the following: increased reliability of data, eliminating redundancy in both real-time and near real-time data delivery; providing 100% availability for near real-time data produced at remote stations.
- Future plans also include increased characterization of network performance (Network Management), as the network grows.
- IGS made the following recommendations for CORS: provide data formats that do not limit users to a set number of observables, and manage metadata more effectively by alerting users of changes in the metadata within a few seconds.

Presentation "#5" Highlights

The final presentation was made by NGS' Charles Schwarz. The title of his presentation was "CORS/OPUS: Future Prospects". Dr. Schwarz began with an opening statement regarding real-time and OPUS research updates. The presentation highlights were as follows:

- In the near future, NGS plans to deliver portions of CORS data in near real-time, via NTRIP; re-vamp the OPUS system to allow the processing of 15-minute data sets; and pursue other OPUS projects, such as processing multiple GPS data files in network mode.
- Dr. Schwarz noted that in order for NGS to provide streaming CORS data with NTRIP, several items have been and still need to be considered — a suggested format (e.g., RINEX, RTCM, etc.); software selection; station spacing; data sampling rate; latency; amount of bandwidth; security; funding; and policy issues. The questionnaire distributed to participants was designed to address these items.
- OPUS-RS (rapid static) is now ready for alpha testing. This is the time to consider what criteria should be used to decide whether or not this software may become operational.
- It is also the time for NGS to develop guidelines for interpreting the OPUS-RS results.
- OPUS-RS uses the RSGPS software — in both network and rover modes — as its GPS processing engine, instead of PAGES, which is currently used by the regular OPUS. It also uses the P1 and P2 pseudo ranges, in addition to both the L1 and L2 carrier phase data. The system resolves all integer ambiguities with the LAMBDA algorithm, and provides geometry-free linear combinations, which are used to determine double-difference ionospheric delays.
- The technology in the RSGPS program is based on research conducted for NGS at the Satellite Positioning and Inertial Navigation group at the Ohio State University, This technology is designed to enable precise positioning with occupation times as short as 15 minutes.
- The OPUS-RS interface is identical to regular OPUS interface, except that the output report for OPUS-RS will contain quality indicators based on the W-ratio from the LAMBDA validation tests.
- No progress has been made on the research objective of computing centimeter level positions from single frequency L1 data, although this remains a desirable goal.
- Future OPUS projects include the following options: assistance to project planning/monitoring; automated file management; review of repeat measurements; network adjustment with the GPSCOM software; and publication of computed coordinates through the NGS Integrated Data Base.

Question and Answer Highlights

The short Question and Answer session opened with a series of questions, posed by Dru Smith of NGS. The following questions he raised to generated audience discussion: Why use real-time data processing? Who needs to use real-time data? How is real-time data going to be used? Has any current users stressed the need for real-time processing? There were a few responses raised in audience conversation, but none publicly addressed.

Next, Lonnie Sears, a surveyor operating a commercial RTK network in Georgia, posed the following question: Why is the government involved in providing real-time data? He had concerns that if he was a member of the CORS network, he would be creating his own competition, as a commercial provider of real-time positioning. He felt as though he was in a "catch 22" situation. His second and final question was, "What's in it for me?" Richard Snay of NGS responded by noting that NGS would mostly distribute data that are being collected with public funds. NGS would simply be making these data more accessible to the public. This agency would look to private industry to use the NGS-distributed data to provide end users with value-added services like computing positional coordinates.

A member of the Delaware Department of Transportation commented that his agency really needs real-time data processing. Another audience member (name not given) questioned whether NTRIP and UDP would eventually merge. Georg Weber responded that NTRIP 2.0 is expected to be released within less than 1 year, which will support multi-casting (NTRIP/UDP).

The third and final question asked, "Is it NGS' policy to provide a version of OPUS for processing kinematic GPS data?" Gerald Mader of NGS responded, "We would do it if we could."

Session "A" Summary

Towards Real-Time CORS Products and Services

The session began with Charles Schwarz, once again, introducing himself and making opening comments regarding the purpose and direction of the session.

Mr. Schwarz then opened the floor for introductions:

Session Attendees:
Charlie Schwarz, National Geodetic Survey
Kent Setterberg, Salt Lake County Surveyor's Office
Mike Schmidt, Geological Survey of Canada
Angelyn Moore, NASA's Jet Propulsion Laboratory
Mark Caissy, Natural Resources Canada
Robert Asher, Leica Geosystems
Georg Weber, German Fed. Agency for Cartography and Geodesy
George Lucas, Leica Geosystems
Dick Davis, California Department of Transportation
Dave Sebold, Ohio State University
Norman Beck, Natural Resources Canada
Ron Buhmann, NOAA's National Geophysical Data Center
Rene Minor, North Dakota Department of Transportation
Knute Berstis, National Geodetic Survey
Gavin Schrock, Seattle Public Utilities
Ryan Keenan, Leica Geosystems
Miranda Chin, National Geodetic Survey
DeLane Meier, North Dakota Department of Transportation
Richard Snay, National Geodetic Survey

After introductions, an audience member commented on the convenience of the NGS web site. The following questions were raised during the session: How is/will real-time CORS data be used? Who's listening to the NTRIP broadcast stations, and When and How are they listening? Since users are going to use software to process data, what is the view of manufacturers on processing real-time GPS data? If a user possessed the GPS data for a ROVER station, and used NTRIP processing, would they have a proximity issue on their hands?

There were several comments made throughout the session:
In response to the question about an NTRIP proximity issue, Robert Asher of Leica Geosystems responded that the issue would depend on the software application being used, and the intended use of the data. He also noted that users are generally more comfortable with familiar data/software, and careful consideration should be given to software choice and use of data. One final comment was that NGS needs to consider providing access to small area networks.

Richard Snay added, "at any given time, about 5% of the CORS network may be down and so numerous stations are required to provide redundancy; and to support real-time data distribution, NGS may need to become a 24-hour shop whereas NGS is a government agency that operates only for selected hours, Monday through Friday." Georg Weber responded by suggesting that the government should consider using an Internet Service Provider (ISP) to support real-time processing, which is "cheaper than manpower."

The following set of questions was provided to forum participants. Others may respond to these questions via an email to cors@noaa.gov with "NTRIP" in the subject line.

Streaming CORS Data with NTRIP

NOAA's National Geodetic Survey (NGS) is seeking information from users and constituents concerning the streaming of CORS data via the Internet with the NTRIP protocol. Specifically,:

- What format would be most useful? RTK? Raw? Rinex? Other (specify)?
- What software do you expect to be used to import and process CORS data broadcast in near real-time? Who do you expect to provide this software?
- Are there particular stations in the CORS network for which you would like to be able to receive data broadcast in near real time via NTRIP?
- Are there limitations on how close a CORS station must be to your project area for you to use broadcast data? Specify.
- What sample rate do you require?
- What latency can your processing tolerate?
- Describe a typical session during which you might ingest CORS data broadcast in near real-time. How long might a typical session last? How many CORS stations might you use?
- What value might the availability of broadcast CORS data add to your

operations? Would it add confidence to your result? Would it allow you to avoid some costs? Specify.

- Would you be satisfied with a broadcast of whatever data is produced by the GPS receiver, or would you expect NGS to perform some further quality control?

- NGS considers streaming data via NTRIP to be just another means of delivering CORS data. However, there is some concern that such a broadcast could be seen as an infringement on the activities of state, local, or private organizations. Is this a concern to you? What activities and/or areas should NGS specifically avoid?

- How many people and/or organizations do you think might answer these questions the same as you have?

Summary of Responses

NOAA's National Geodetic Survey has received about 15 responses to the above questionnaire through November 14, 2005. The following paragraphs summarize these responses.

With respect to the type of data to be delivered, most people requested real-time kinematic (RTK) data in the RTCM format. The RTCM format offers several message types from multiple satellite systems, that are easily imported into many current surveying and engineering packages. The sampling rate should set to 1 second, to accommodate most people using current real-time GPS equipment for surveying applications. The data should be available continuously (24 hours/ 7 days) from all stations in the CORS real-time network. A latency of less than 1 second is desired, but most users can handle a delay of up to 2 seconds, because most current GPS positioning software packages buffer the data before computing a position for each epoch.

Station spacing was a concern, with most people requesting a spacing of less than 100 km. Some even suggested a 40 km grid for the proposed CORS NTRIP network. No preference was given as to which CORS sites to convert to real-time, but this may change once the public accepts and becomes familiar with the CORS NTRIP grid. Almost all responders agreed that providing a raw and/or RTCM data stream would be valuable and would not infringe on private sector ventures. Many users would benefit because they would be able to forgo the expense of establishing their own GPS base stations.

Session "B" Summary
OPUS, UFCORS, and Other CORS Utilities

Session Attendees :
Barry Irwin, U.S. Geological Survey
Gerry Mader, National Geodetic Survey
Marti Ikehara, National Geodetic Survey
Dale Pursell, National Geodetic Survey y
Tom Soler, National Geodetic Survey

Barry Irwin of the U.S. Geological Survey started by saying that he uses OPUS regularly and that he is very satisfied with the results. Primarily he uses OPUS to establish base stations from where to send radio signals to determine the location of ships for bathymetric mapping. These sites are generally selected along the coast and the height of the 2 meter pole antenna is previously calibrated against the Mean Lower Low Water (MLLW) of the tidal datum. Mr. Irwin was interested in knowing the types of accuracy of the vertical component on an OPUS solution as a function of the total observation span. Because he was concerned with observations lasting more than two hours he was referred to the publications available on the OPUS Web page discussing the accuracy of GPS solutions as a function of the observing-session duration.

Another question addressed by Mr. Irwin was related to the use of OPUS in earthquake prone states such Alaska. We clarified to him that immediately after an earthquake he should select himself the sites to be fixed by OPUS, choosing stations far away from the epicenter of the earthquake and, therefore, calculating all results in the geodetic frame defined previous to the earthquake. Later, if necessary, the positions of the points could be transformed to any other frame and/or epoch.

Finally Mr. Irwin was concerned about the reliability of the peak-to-peak errors. He was informed that these statistics are the worst case scenario and that the actual standard errors attached to the horizontal and vertical components is always inferior to the published peak-to-peak errors.

Although not present at the discussions of this group, Mr. DeLane Meier (North Dakota DOT) asked Tom Soler during the celebration of the meeting when OPUS-Networks would be released to the general public. After consulting with Gerry Mader his answer was that by the middle of 2006.

Session "C" Summary

Guidelines for Establishing CORS Sites

Session Attendees:
Julie Prusky, National Geodetic Survey
Giovanni Sella, National Geodetic Survey
Don Haw, National Geodetic Survey

The NOAA office of the National Geodetic Survey has proposed an updated set of guidelines for the establishment of new, and maintenance of existing, CORS stations <www.ngs.noaa.gov/CORS/Articles/CORS_guidelines.pdf>.

The principle aim of these guidelines is to improve the overall data quality of the CORS network, and focus attention on meta-data requirements for CORS sites.

A Site Selection Team (SST) has been established to evaluate all prospective CORS sites. The SST's job is to assess the station, based on the guidelines and measure how the site will fit into the existing CORS network, with relation to geographic coverage, data quality, and data flow.

The SST meets roughly every week, decides if a proposed site should be included in the CORS network, and whether it should be a national or cooperative CORS site.

The following text presents the highlights of the new guidelines.

Monuments

It is the goal of NGS to avoid monuments which are likely to result in problems such as poor stability or relatively high multipath, e.g.:

- only masonry buildings are permitted for building-mounted antennas
- no monuments are to be placed on metal roofs
- all antennas must be properly oriented and leveled
- equal emphasis is placed on maintaining the integrity of the space around an antenna, as keeping the site operational
- for pillar-monumented equipment, the top of the pillar should be narrower than the width of the antenna, to minimize multipath

Equipment Configuration

Radomes are not recommended. **Receivers** must be configured to track all satellites (regardless of its health status) and to track all satellites down to an elevation angle of 5 degrees (0 degrees strongly preferred).

Meta-Data

Site operators must keep NGS informed of any equipment changes or site modifications so that site logs can be kept up to date. A suite of digital photographs of the site are required.

Session "D" Summary
Ionospheric and Tropospheric Models

Session Attendees:
Dru Smith, National Geodetic Survey
Joe Kunches, NOAA's Space Environment Center
Ken MacLeod, Natural Resources Canada
Steve Briggs, Topcon
Tim Fuller-Rowell, NOAA's Space Environment Center

It was reported that the ionospheric and tropospheric models are currently undergoing extensive validation to determine their utility for improving positioning accuracy. It was also reported that US-TEC (Total Electron Content) has been approved for transition into operations at NOAA's Space Environment Center (SEC) and is expected to be transitioned in the Spring 2006.

There was a requirement stated that the ionospheric model should provide the full three dimensional ionospheric structure so that the line-of-sight electron content can be determined between two arbitrary points within the domain. Currently the US-TEC product provides only the line-of-sight electron content between any point within the CONUS and the GPS satellites in view at the time. This addition can be accomplished by providing the empirical orthonormal function (EOFs) and their magnitude over the two-dimensional grid. It is then relatively easy for a user to reconstruct the full three-dimensional structure. NRCan, NGS, and SEC agreed to enter into a 3-way discussion to finalize a single agreed-upon format for distributing the 4-dimensional electron content data from the US-TEC model.

It was mentioned that the ionospheric and tropospheric models also provide value for the single frequency GPS users. The use of the models for integer ambiguity resolution in dual frequency systems has recently been assessed, and continues to undergo validation.

It was noted that data from the Canadian stations are now being streamed into NOAA's National Geophysical Data Center in Boulder from NRCan, which will augment the data currently used in US-TEC. The data will improve the accuracy of the TEC maps on the northern edge of the CONUS and will provide electron content over the Canadian mainland. Mark Caissy and Ken MacLeod expressed interest in receiving the US-TEC model output over Canada. The availability of real-time stations from Canada renders the possibility of providing a continuous TEC map over North America.

It was noted that stations in Mexico and the Caribbean are required to improve the accuracy in the southern part of the US-TEC domain. The planned Mexican stations were recognized as an important development and it was hoped the data would be available in real-time to be able to drive the ionosphere and tropospheric models.

It was reported that the NOAA Forecast Systems Laboratory (FSL) intends to transition their precipitable water vapor model to an operational NCEP model to compute the tropospheric signal delays. A transition plan is being prepared for GPS-Met into NOAA operations. FSL have expressed interest in also extending the tropospheric model to include most of North America. It was noted that gradients in the precipitable water vapor in the troposphere would be of value for estimating positioning error.

There was discussion on the possibility of extending the models to the global domain. The current limitation is the availability of sufficient global real-time stations to make the accuracy of the maps useful for the positioning community. Efforts are currently underway to extend the availability of data from the global real-time network using either NTRIP or UDP Internet protocols.

Reference Sites

1. This link points to an article in the November 2005 issue of the American Surveyor Magazine on the CORS Users Forum.
   http://www.theamericansurveyor.com/PDF/TheAmericanSurveyor_Schrock-CORSForum_November05.pdf

2. This link points to the National Geodetic Survey's CORS Web Site.
   http://www.ngs.noaa.gov/CORS/

3. This link points to EarthScope's Plate Boundary Observatory's Web Site.
   http://www.earthscope.org/pbo/index.shtml

4. This link points to the web site for the German Federal Agency for Cartography and Geodesy. **http://www.ifag.de/index_english.htm**

5. This link points to Natural Resources Canada's Web Site.
   http://www.nrcan-rncan.gc.ca/inter/index_e.html