GPS Help Line

The New GPS Operations Center for Warfighters

MAJOR VERNON (CHUCK) DANIELS II
GPS OPERATIONS CENTER, SCHRIEVER AFB

A recently upgraded GPS Operations Center has added new software tools that enable it to provide military GPS users with improved models of their equipment's functionality in operational environments. Among other benefits, this lets users anticipate their PPS and SPS positioning accuracies in real-time.

Maj. Vernon C. (Chuck) Daniels II, director of the GPS Operations Center at Schriever AFB, CO, leads one of three centers of excellence that help GPS users around the globe determine their navigational accuracy. USAF photo.

Inside the Master Control Station at the 2nd Space Operations Squadron (2SOPS), Schriever Air Force Base, Colorado, crews continuously monitor and control the GPS constellation's navigation signals. By doing so, 2SOPS keeps the GPS signal as accurate as possible, making it a phenomenally successful global utility. Yet, as GPS users know, other factors — such as differences in receivers, terrain, environment, and platforms — can affect navigational accuracy in the field.

So where do warfighters turn when they need help determining their navigation accuracy? That's where we in the GPS Operations Center (GPSOC) come in. Operated by 2SOPS, the GPSOC is one of three centers of excellence that military, civil, and commercial GPS users can turn to for navigational accuracy assistance (see sidebar "The Big Three").

The GPSOC primarily serves the needs of the Department of Defense (DoD): Military users of GPS can call us to learn what's affecting their receivers, and mission planners rely on our unit to provide specific in-field information. The GPSOC also makes routine dilution of precision (DOP) and accuracy predictions as well as past accuracy assessments for theaters requiring the information. GPSOC also provides analysis for military exercises. Through these functions, we bridge the information gap between the GPS user and GPS control segments.

Recently, the center upgraded its operational baseline of software tools to help support all GPS customers, shifting the focus from contractor-specific tools to more standardized software. Drawing on commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) capabilities, we can now tell GPS users around the world whether situational circumstances are causing disruptions in their service. This article describes how these new software resources helps GPSOC do its job better.

We've never before had an effects-based view of how the whole constellation affects a specific user's receiver performance across the globe.

Upgrading Capabilities

In January, the GPSOC installed its first COTS product, a navigation software tool. This software suite allows us to model specific GPS receivers, terrain, environmental characteristics, and land, sea, air, space, and weapon platform details, while providing receiver interference analysis to dynamically model GPS receiver performance.

The GPSOC uses the navigation software tool as its primary operations resource, but we employ additional software to complete our cadre of analysis capabilities. GOTS tools supply interference modeling and analysis and bring additional insight into constellation behavior.

As an example of how the GPSOC operates, if military mission planners using a precision guided munition need to know how well GPS will perform at a specific site over a given time, they provide us location coordinate information. We model GPS and other effects in which they may be interested. If terrain is a concern, we can also model that, but we make sure that the correct receiver model is used, because various receivers act differently in different situations.

Another layer that can be added using the navigation software tool is the effect of jamming on the receiver. To broaden the scope of understanding, the planners can also request a regional analysis. In this case, we run the same scenario over a larger grid and display the analysis on top of imagery or maps of the area, which helps the planners discern navigation accuracy over a wider location and allows them to pinpoint locations in areas of interest with specific accuracy. Static accuracy maps such as this can show the maximum error over time, or we can produce an animated map that outputs accuracy as a function of time over the region.

This level of analysis is much broader than we've ever done before. Previously, daily predictions and accuracy assessments showed the signal-in-space (SIS) accuracy of the GPS constellation and the noise behavior of a typical GPS receiver. This provided general accuracy characteristics for mission planning, but mission planners want and need more. They need to know how their GPS receivers will perform at a certain place and time, under specific conditions, so they can plan exacting, precise maneuvers.

Some of the new capabilities the GPSOC can provide using its new navigation software tool include:

- real-time situational awareness of PPS and SPS accuracy
- user-specific receiver and platform modeling for accuracy and DOP predictions
- environmental effects modeling
- interference and jamming modeling, with user-defined characteristics
- satellite outage streamlining for analysis
- parallel processing capability.

In addition to traditional SIS, the GPSOC is also exploring ways to provide GPS data via net-centric means.

Real-Time Situational Awareness

While 2SOPS has always monitored an individual satellite's accuracy, we've never before had an effects-based view of how the whole constellation affects a specific user's receiver performance across the globe. Using GPS ephemeris and clock errors produced by the Master Control Station (MCS) every 15 minutes, we can provide accurate real-time situational awareness worldwide. And, we can dynamically plot this accuracy as colored contours on a global map. See **Figure 1** for an example of an SPS accuracy map at one time step.

The MCS produces ephemeris and clock errors derived from the military's Precise Positioning Service (PPS), but

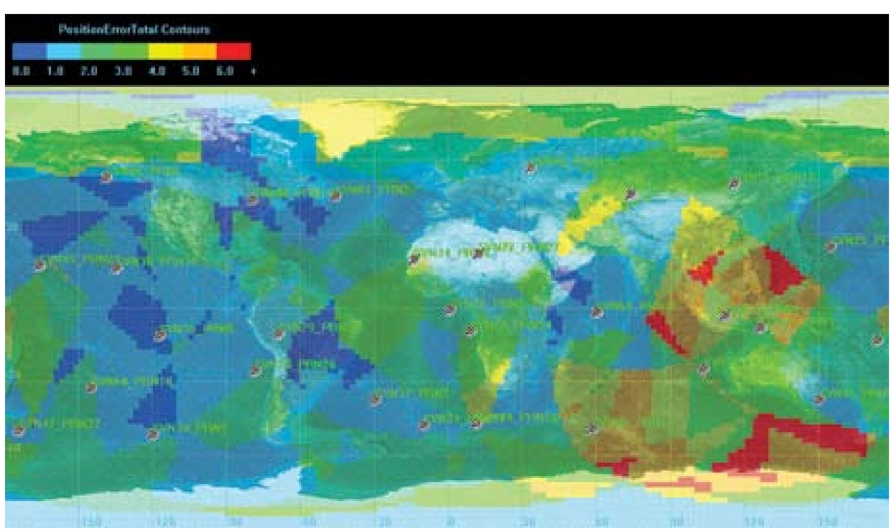


FIGURE 1 The GPSOC uses GPS ephemeris and clock errors to provide accurate real-time situational awareness that is plotted as colored contours on a global map.

real-time data also applies beyond the military into the civil sector's Standard Positioning Service (SPS). 2SOPS recently extended the navigation software tool's capabilities by subscribing to a real-time data service that allows us to generate models of GPS accuracy worldwide. With this capability, they can monitor civil GPS users' accuracy, too. Every few minutes, a new update portraying GPS accuracy across the globe is posted inside the GPSOC.

Using the navigation software tool with the real-time navigation data service, 2SOPS can now monitor both PPS and SPS signals in real time to be continually aware of how individual users are, or will become, affected by changes in the GPS constellation or signal. This allows us to begin the initial stages of achieving the long-standing goal of the DoD and the Department of Transportation (DOT): monitoring both PPS and SPS accuracy.

With new specific platform modeling, we can now closely approximate – if not exactly match – the end user's receiver and platform type.

Improved Modeling

In the past, the GPSOC's receiver modeling was rudimentary. It included the mask angle of the receiver (the angle below which satellites would not be used in a navigation solution) and a static noise value representing the receiver's noise characteristics. With new specific platform modeling, we can now closely approximate — if not exactly match — the end user's receiver and platform type. Receivers can be modeled using single-frequency or dual-frequency characteristics, figure of merit (FOM) definitions specific for each receiver, as well as dozens of engineering-level parameters.

Receivers can be used in a stand-alone fashion for infantry issues, or they can be modeled as mounted onto a platform when aircraft, ships, or satellites are involved. The platforms can match operational requirements, such as specifying GPS antenna position, platform body-masking, inertial navigation system details, and flight characteristics.

The Big Three

Before the GPS Operations Center (GPSOC) existed, a general officer was once quoted as saying he could get better GPS support by taking off his military hat, putting on his fishing hat, and calling the U.S. Coast Guard's Navigation Center (NAVCEN). At the time, the Coast Guard was the only governmental organization supporting GPS users.

Today, three centers of excellence — the GPSOC, the NAVCEN, and the FAA's National Operations Control Center (NOCC) — privately referred to as the Big Three, provide a supporting "port of entry" to any GPS user on the globe. The GPSOC primarily serves as the Department of Defense (DoD) GPS user focal point. The NAVCEN remains the primary support node to non-aviation and nonmilitary civil/commercial users with GPS issues. The NOCC handles aviation, safety of flight, and National Air Space GPS issues.

Any problem these centers receive requiring in-depth or specific knowledge are coordinated with the GPSOC for analysis. While the individual responsibilities for each GPS center seem pretty clear-cut, in reality, we find that the centers work closely together on nearly every GPS concern.

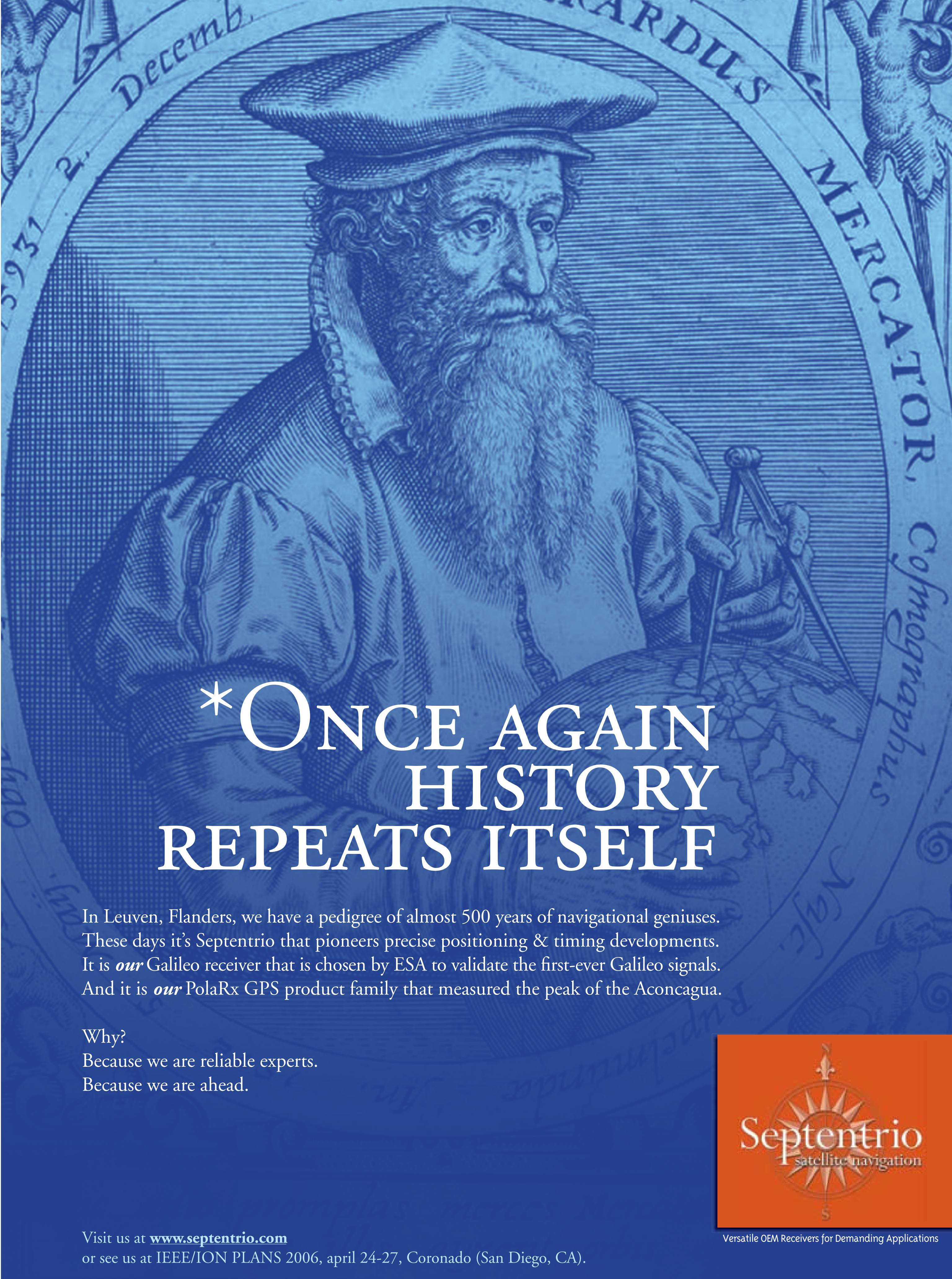
Today, three centers of excellence – the GPSOC, the NAVCEN, and the FAA's National Operations Control Center (NOCC) – privately referred to as the Big Three, provide a supporting "port of entry" to any GPS user on the globe.

How It All Began

In mid-August of 1999, the first GPS epoch rollover was about to occur. With the number of weeks the GPS navigation message could track rapidly reaching its maximum, the GPS Support Center was stood up in time to watch for receiver anomalies.

This was an important first test of the preparedness of the center — Y2K was on its way. Luckily, the epoch rollover only caused a few incidents, and they all were handled deftly by the new U.S. Commander in Chief, Space–owned GPS Support Center (GSC). The GSC was later fully absorbed by the 2nd Space Operations Squadron's GPS Operations Center (GPSOC) in Colorado Springs

As the original sponsoring organization of the GPSOC, U.S. Space Command chartered the GPSOC to provide all U.S., allied, and coalition military organizations with the GPS support they needed. The GPSOC forged operating agreements with the U.S. Coast Guard, the Joint Spectrum Center, the Federal Aviation Administration, and the civilian Federal Communications Commission. These groups continue to form an essential link to solving complex GPS problems that involve GPS outages and interference issues for civilians and the military.


MERCATOR, Cosmographus
*Once again history repeats itself
In Leuven, Flanders, we have a pedigree of almost 500 years of navigational geniuses. These days it's Septentrio that pioneers precise positioning & timing developments. It is our Galileo receiver that is chosen by ESA to validate the first-ever Galileo signals. And it is our PolaRx GPS product family that measured the peak of the Aconcagua.
Why?
Because we are reliable experts.
Because we are ahead.
Septentrio
satellite navigation
Versatile OEM Receivers for Demanding Applications
Visit us at www.septentrio.com
or see us at IEEE/ION PLANS 2006, april 24-27, Coronado (San Diego, CA).

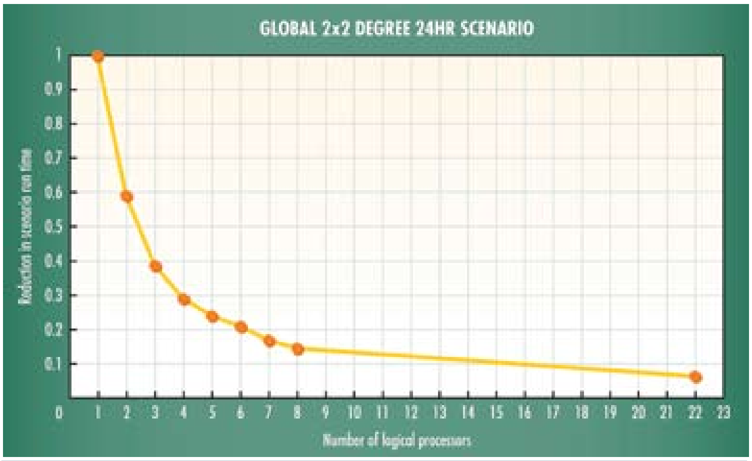


FIGURE 2 New parallel processing capabilities in the GPSOC has cut analysis run time to 1/10th of what it would be on a single processor.

Environmental Effects. Space weather is also on our general checklist. Typically, a military user will have a dual-frequency receiver allowing the subtraction of ionospheric effects from the receiver's navigation solution. In some cases, however, space weather will be bad enough to affect dual-frequency receivers. If the GPSOC must analyze a civilian issue (such as a plane crash for the Federal Aviation Administration), a single-frequency receiver model that includes ionospheric effects will most likely be used.

Landforms. Terrain is another factor that limits GPS accuracy. For instance, mountains can have a dramatic impact on the visibility of the GPS constellation, affecting DOP calculations and, ultimately, the receiver's accuracy. Now that the GPSOC can include digital terrain elevation data (DTED) in the modeling scenarios, the model can more closely match a user's physical environment.

Interference and Jamming. The new receiver models also have a full communications-link modeling capability (called the receiver front-end) so that if interference appears to be an issue, this feature can show what the user is seeing. Any GPS interference is undesirable, either friendly (such as unintentional jamming of civilian receivers due to radio frequency harmonics) or unfriendly (intentional jamming in a war zone). We've worked issues of both types at the GPSOC. The GPSOC can model emitters at GPS frequencies with varying power and spectrum characteristics to assess threatened environments and their affect on GPS accuracy.

We've learned that the cost of software development and maintenance for analysis-specific tools can be sizable and unique to a specific contractor.

Satellite Outage Analysis

Our GPSOC mission analysts carefully strive to take every detail into account — even when a problem requires accurate results within hours or minutes. One detail that has been a long-standing concern is correctly accounting for satellite outages. If a satellite is modeled as healthy and broadcasting normally, when in fact, it is unhealthy, our team may miss anomalies the user is experiencing.

Typically, the GPSOC protocol has been to review Notice Advisory to Navstar Users (NANU) messages to determine a satellite's health. This task can be cumbersome and error-prone because several types of NANUs can affect a single satellite's outage.

To reduce human error, we have implemented the use of a satellite outage file (SOF), a standard XML-formatted file containing an accurate history of GPS satellite outages since 1995. When a new NANU is generated, the SOF file updates automatically and is checked for accuracy by an analyst. GPSOC staff can then include this file type in analysis scenarios, allowing us to focus on problems, not on data collection. Reducing human error benefits the GPS customer in ways frequently only the analyst can appreciate.

Parallel Processing Capability

GPS users need high-fidelity analysis, which is computationally intensive and requires increased computer processing time. As part of our new parallel processing capabilities, we run scenarios on several computers at once. Therefore, we can do regional navigation calculations on multiple processors and collect the data at a central point for analysis and display.

This has provided a tremendous increase in analysis speed. Figure 2 shows how much faster the scenario processes based on the number of logical processors on which the scenario runs. The last data point in this graph shows the reduction in processing time on the actual GPSOC hardware configuration consisting of 22 logical processors. This speed improvement demonstrates how the GPSOC is effectively using the latest technology to meet its customers' needs efficiently.

New Role for Contractors

Mission analysis in the GPSOC is primarily performed by contractors — which is ideal for several reasons. First, it aids in long-term continuity of information, because the contractors remain in place and provide continuity, even when the military staff rotate positions.

The analysts' tools are also important: We've learned that the cost of software development and maintenance for analysis-specific tools can be sizable and unique to a specific contractor. To circumvent that problem, the GPSOC has selected COTS software as a significant part of the mission analysis and operations solution because its recurring cost tends to be less expensive than maintaining contractor-supported tools. Therefore, it frees up contractors to focus on the analysis, itself—not the maintenance of the analysis software.

Future Operations

Future GPS satellite enhancements and control-segment improvements will force the GPSOC to analyze even more challenging situations than exist today. The more data each problem requires for analysis, the more critical it will become that analysts can easily incorporate all information into scenarios. Situational awareness will involve real-time terrestrial weather data, real-time space weather data, and GPS monitoring data from the theater.

In the GPSOC, we've worked hard to lay a foundation on which others can build. I'm proud of my team and industry partners for the work we've accomplished so far, but I'll be the first to admit there is much to do. Our analysis software tools and data feeds are keys to success, both today and for the analysis requirements of the future.

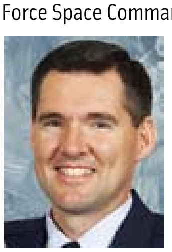
Manufacturers Credits

The GPSOC uses Navigation Tool Kit, developed by **Analytical Graphics, Inc.** (AGI), of Exton, Pennsylvania, as its primary operations tool. The GPSOC also subscribes to AGI's Real-Time Navigation Data Service.

The government off-the-shelf (GOTS) equipment acquired by GPSOC includes General Dynamics' GPS Interference And Navigation Tool (GIANT) and NASA Jet Propulsion Lab's Integrity Monitor and Generic Area Limitation Environment – Lite (GALE-LITE).

Author

Major Chuck Daniels is the director of the GPS Operations Center, 50th Space Wing, Air Force Space Command, Schriever Air Force Base, Colorado. As Director, he is responsible for ensuring all U.S. Department of Defense personnel worldwide using GPS receive accurate and current position, navigation, and timing analysis and support.



Daniels leads a contractor and military team of over 20 personnel to complete daily tasks.

Major Daniels' career includes assignments in a variety of space operations positions. Following undergraduate pilot training, he trained as a space operator at Lowry AFB, Colorado, and has served in space surveillance, missile warning, and satellite command and control. He was initial cadre with Milstar in Sunnyvale, California and served as the operations officer for development and standup of the strategic missile warning backup to Cheyenne Mountain at Offutt Air Force Base, Nebraska.

Daniels has served in staff positions at HQ Air Force and at the Air Force Command Control and Intelligence Surveillance & Reconnaissance Center at Langley AFB, Virginia. Prior to assuming his current position, he was a directorate of operations executive officer at HQ's Air Mobility Command, Scott AFB, Illinois. He has a bachelor's degree in investment finance and a master's degree in human resources management. IG