New GPS Wing Commander Col. David Madden

All Things GPS

Taking GPS modernization back to basics with a new paradigm

GLEN GIBBONS

Col. David W. Madden has taken up his post as commander of the GPS Wing, armed with a mantra, a new paradigm, and a sense of urgency about modernizing all segments — space, operational control, and military user equipment — of the Global Positioning System.

He'll need all three to help the former GPS Joint Program Office (JPO) catch up with a schedule that has moved continually to the right in recent years as delays have plagued implementation of new GPS capabilities in space and on the ground.

The mantra, "time to get back to basics," comes from Ronald Sega, undersecretary of the Air Force, by way of Air Force Lt. Gen. Michael A. Hamel, commander of the Space and Missile Systems Center (SMC) at Los Angeles Air Force Base, California, which the GPS Wing calls home.

The new paradigm has been crafted by the GPS Wing itself, which in March replaced its long-time systems engineering and technical assistance contractor (SETA), the Arinc Inc., with a systems engineering and integration (SE&I) contract worth up to $217 million for an SE&I team led by the Science Applications International Corporation (SAIC). Between SAIC, two federally funded R&D centers — Aerospace Corporation and MITRE, and civil and military government engineers at the Wing, about 300 engineers are engaged in the GPS program there.

The sense of urgency arises from a dwindling reserve of Block IIR-M satellites and delays in the yet to be proven Block IIFs now under development, with a first launch scheduled for next year. Five GPS satellites or space vehicles (SVs) now in orbit are predicted to fail or be decommissioned in the relatively near future — about the number of Block IIR-Ms remaining.

The GPS III spacecraft, for which a long-awaited request for proposals finally went out July 12, are not expected to be available for launch before 2013.

"In the past, we've milked the satellites for all they were worth," Madden says, referring to a longer-than-expected lifetime — or mean mission duration — for all of the previous generations of spacecraft. "But now we're getting to the point that they will be failing in the 2013 time frame."

"We've taken advantage of that [better than expected satellite longevity] to compensate for all of the problems that we've had in development and delivery of new capabilities."

With 29 or 30 SVs in orbit, the constellation might seem to have a cushion of well more than the 24-satellite full operational capability (FOC) for which the system was designed. However, having fewer satellites risks a lower quality of service — what some have referred to as "GPS brown-outs," and more recent analyses have suggested that 30 to 36 satellites in orbit would be optimal for GPS.

Meanwhile, the operational control segment is currently able to control only 31 satellites at a time, not enough for an expanded constellation, let alone to monitor the spacecraft of other GNSS satellites that future GPS receivers may also exploit.

Madden, in fact, warns against the tendency to get "spacecraft-centric" in thinking about GPS modernization. "We need to spend a lot more time on the user equipment segment," he says. "We can bring on a lot of capability there, too."

The need for a new SE&I contract results from increased modernization activity in virtually every element of the GPS enterprise. The GPS program office is directing major developments in the space, control, and user equipment groups.

In fact, Madden, who has an electrical engineering degree from Virginia Military Institute and an M.S. in systems management from the University of Southern California, was introduced to GPS about 10 or 12 years ago through the user equipment side. Air Force programs with which he was involved then were beginning to draw on GPS as a technology resource. In July 2001, he served at the GPS Joint Program as manager of the Combat Survivor Evader Locator program.

On June 18, Madden moved up from his position as the Wing's vice-commander, a role he'd assumed in July 2006. In a wide-ranging dialog with *Inside GNSS* editor Glen Gibbons, Madden addressed these and a wide range of topics facing the system and his command. A verbatim report of that discussion follows.

Inside GNSS: What are the top three program priorities that you have identified for your leadership of the GPS Wing and what goals, objectives, and/or outcomes have you set for addressing?

Colonel David Madden: The GPS Wing primary goals are sustaining the constellation and modernizing GPS across all segments. The Wing is making steady progress to deliver modernized satellites, ground control system, and military user equipment.

My first priority is launching the 5 remaining GPS Block IIR-M satellites; completing the development and production of the GPS Block IIF spacecraft, and awarding the GPS III spacecraft contract.

Next is the replacement of decades-old command and control systems to improve GPS operator interfaces to control the new capabilities of the modernized satellites thereby improving launch, anomaly, and disposal operations.

My third priority is to develop a new generation of military GPS user equipment to take advantage of the modernized M-code signals. The GPS Wing is currently managing three modernized user equipment (MUE) contracts to develop prototype receiver cards to process the M-code signal.

Inside GNSS: The GPS Wing has indicated its wish for a new program management paradigm or philosophy, reflected in part by its recent contract with SAIC. What specific changes are anticipated in U.S. Air Force (USAF) organizational roles/responsibilities and the GPS Wing's relationship with vendors as a result of this paradigm shift?

Col. Madden: Previously, the AF used contracts that provided systems engineering staff in a "level-of-effort" fashion to augment the government staff in accomplishing the systems integration function for the entire GPS enterprise. Under the new contract model, the AF continues to serve as "lead systems integrator," while the contractor will have specific responsibilities and deliverable products.

The government will form joint work plan assignments at the squadron level with peers from the system engineering and integration (SE&I) contractor [SAIC], Aerospace and MITRE. In turn, the program teams assign engineering resources to GPS Wing priorities using documented work plans and products. This teaming paradigm will renew the work focus to the critical path tasks with an agile systems engineering work force that actively develops and manages GPS capabilities.

In addition, this work plan with a product-orientated focus will ensure engineering process discipline, interface and configuration control, test verification rigor, and consistency across the entire GPS program and organization. Each member on the GPS engineering team will understand the GPS mission, understand their part in that mission, and will have a shared responsibility and accountability to make sure the GPS mission is successful.

The need for a new SE&I contract results from increased modernization activity in virtually every element of the GPS enterprise. The GPS program office is directing major developments in the space, control, and user equipment groups. As lead systems integrator, the Air Force retains full responsibility, authority, and accountability for the system-wide engineering and integration of the entire GPS enterprise.

This responsibility spans the GPS "system-of-systems" from the individual segments (space, control, and user) across the entire development cycle (early development, production, and fielding units). In this context, the SE&I contractor will perform as a valuable member of the government team, providing specific contract deliverables rather than level-of-effort manpower.

Furthermore, the government-led team extends to the hardware developers, which requires SE&I cross-segment integration. From the specification of requirements to the production of systems that fulfill these requirements, the government-led team will define clear roles and responsibilities to sustain and modernize the world's preeminent satellite navigation system.

Inside GNSS: Does the change from the long-standing NAVSTAR GPS Joint Program Office designation to GPS Wing primarily reflect a desire to use terminology more consistent with USAF organizational taxonomy or does it reflect more substantive underlying changes in the organic nature of the program? If the latter, what are these?

Col. Madden: The Space and Missiles Systems Center (SMC) was reorganized and renamed to mirror a more traditional Air Force structure. On 31 July 2006, SMC activated 6 subordinate Wings, 21 Groups, 12 Squadrons, 20 Divisions, 2 Systems Offices, and the 61st Air Base Wing to provide an increased effectiveness and clearer command authority to better develop, acquire and sustain military space power capabilities for the nation and improve base operating support functions. The new Wing structure provides respective commanders with strengthened authority, accountability, and responsibility.

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Inside GNSS: Given the delays in the GPS III satellite program, does it seem more appropriate to consider implementing the new SV (space vehicle) features and function on existing platforms (e.g., IIR-M, IIF) rather than attempting to create a new space segment architecture? What is the current status of the GPS space segment modernization initiative?

Col. Madden: When we began the GPS III studies, we investigated several alternatives, including upgrading the GPS Block IIR and GPS Block IIF satellites. We concluded that the magnitude of the new design work needed to upgrade those older vehicles for the new capabilities made it more practical to start with a new design that could grow to accommodate the changes.

In addition, both GPS Block IIR and GPS Block IIF vehicles have design heritages well over a decade old, so it's more than just adding on new signals - the whole vehicle would have to be updated. Similarly, we would face many of the same obsolescence issues if the GPS III satellite acquisition was curtailed to buy more GPS Block IIR-M or GPS Block IIF satellites. So, if we are to build a system that delivers required future capabilities, it must be GPS III, not more of the older vehicles.

The space segment contribution to GPS modernization is, of course, the GPS Block IIR-M, GPS Block IIF and GPS Block III programs. We have launched three of the eight GPS Block IIR-M satellites with the next launch scheduled for September 2007. The first GPS Block IIF satellite is scheduled to start environmental testing in late July 07 and be shipped to Cape Canaveral in May 2008 for further testing and integration.

The GPS Block III satellite will provide improved positioning, navigation, and timing services to military and civil users by improving accuracy, integrity, and resistance to hostile jamming. These new capabilities will be introduced incrementally in a series of 3 blocks. The first Block IIIA launch is scheduled for late 2013.

Inside GNSS: How can the GPS Wing contribute to greater assurance for industry/vendors on timely execution of GPS projects in space, ground, and user segments? What are the key factors outside the GPS Wing's control that affect this issue?

Col. Madden: We have adopted Dr. Sega's "Back to Basics" approach and applied this to all three segments of GPS. In the GPS space segment, we have taken several actions for GPS III. We separated the program into three increments, with items deferred to the later increments that have less technical maturity or have greater risks of being properly integrated.

Next, we applied the lessons that industry has learned over the past decade and reinstated both technical and management standards in many areas. These provide the basis for verifying the quality of the technical work and ensuring issues are surfaced earlier in the program.

And finally, we created a Capability Insertion Program as a key element of the GPS III program. This program is key element in maturing and integrating the deferred capabilities and assessing new requirements.

In the GPS future ground segment (OCX), we have developed an acquisition strategy that keeps two contractors on board through System Design Review (SDR). In addition, both contractors will be developing a demonstration to validate their preliminary design. The results of this demonstration will be a major part of the final contractor selection.

In the GPS User Equipment group, we are working plans to carry three contractors through prototype design. This will help ensure that not only will we have a viable design for future M-code receivers, but we will also be able to address multi-domain requirements and ensure a competitive environment.

From a systems perspective, the GPS Wing currently has a world-class configuration control and integrated master schedule process. However, to ensure success, we are revitalizing some our core GPS Wing business and systems engineering processes.

These include more comprehensive earned value management system (EVMS) analysis products, solid obligation/expenditure plans, an integrated risk and opportunity management program, a technology road map that optimizes system capability (ground, space, and user equipment), comprehensive metrics to track individual program progress, and a Wing resource-loaded schedule that focuses on critical path tasks required to keep development efforts on schedule.

The entire enterprise will be supported by a team of industry and government experts providing regular independent assessments across leadership, technical, and business processes and program execution metrics.

From a management perspective we are developing Responsibility, Accountability, and Authority (RAA) agreements with all the GPS Wing functional leadership (Systems Engineering, Contracts, & Program Control) and Groups commanders. These agreements will also identify specific goals and objectives for the upcoming year.

This strategy will enable the Wing Commander to delegate responsibility to the appropriate level and ensure Groups commanders get their critical tasks resourced. These RAAs will help enable senior leadership to better manage this complex enterprise.

Key factors outside the GPS Wing's control that impact program execution includes unexpected funding changes, user requirement modifications, movement of key individuals, and industrial base issues. To mitigate risks associated with these factors, the GPS Wing maintains an aggressive program advocacy posture with key stakeholders.

Inside GNSS: What are the current plans for the launcher for GPS III (or post-IIF) satellites? Your thoughts on the prospects/benefits/obstacles for dual-SV launch capabilities?

Col. Madden: Since the beginning of the GPS III studies, we have planned to use the medium-class Extended Expendable Launch Vehicle (EELV). Within that class, both the Boeing Delta IV and the Lockheed Martin Atlas V offer several options.

We studied whether launching two GPS III satellites on a single launch vehicle was technically feasible and affordable. This involved the weight margins available, the method for deploying the two satellites after booster separation, and the constellation management approach.

Although there may be sufficient weight margin to dual launch GPS IIIA satellites, we require high-confidence satellite designs for the subsequent GPS IIIB and GPS IIIC increments to address the feasibility and affordability concerns. So, for now, we've removed the dual-launch requirement from the baseline design and will revisit this requirement as the program develops.

Inside GNSS: What are your thoughts on multi-mission roles for GPS SVs and their potential effect on GPS Wing responsibilities in delivering new PNT capabilities in space?

Col. Madden: Many space programs face the issue of trying to integrate several missions on a satellite — it's inevitable given the high cost of deploying capabilities to space. Several times over the course of the three decades of the GPS program, senior U.S. officials have reiterated the government's commitment that the positioning, navigation, and timing (PNT) mission is premier.

Every few months, key Department of Defense and civilian agencies meet to review the health of the constellation and the upcoming plans for replenishment launches. Each participant understands that the requirement to provide safe, accurate PNT takes priority over secondary missions.

That said, GPS has flown the U.S. Nuclear detonation Detection System (USNDS) payload for over 20 years to perform the nuclear test ban treaty monitoring mission. Although important, actions taken in support of the USNDS mission must first "do no harm" to the primary PNT mission. Indeed, GPS support for USNDS has been very successful, cost effective, and without impact to providing PNT capabilities in space.

The [satellite] block strategy enables on-ramps at key decision points for each block to support and host other potential non-PNT payloads to support warfighter and civil user interests. This includes technologies with complimentary potential such as laser retro-reflectors (LRRs), the Distress Alerting Satellite System (DASS), and the Space Environmental Detection System (SEDP).

LRRs are independent ranging systems that could add accuracy to the PNT service and currently fly on two GPS SVs. DASS is a civil search and rescue (SAR) payload being developed as an enhancement for the Cospas-Sarsat system and is currently on 5 GPS SVs. SEDP will provide information on the MEO space environment.

The GPS Wing provides analysis to help the nation determine how to best support new capabilities as long as the GNSS mission is not adversely impacted. The GPS Wing's responsibility for developing and acquiring new PNT capabilities will remain steadfast as we continue to work diligently towards meeting the needs of our warfighters and the civil and commercial communities that depend on GPS to fulfill its primary PNT mission.

Inside GNSS: What does the USAF estimate the cost and timeline for implementing the new L1 civil signal (L1C) will be?
Col. Madden: The L1C signal definition was completed in April 2006. GPS Mission IIIA-1, scheduled for late 2013, will deploy the first SVs to transmit L1C. The new signal capability is expected to be completed by 2018 with the declaration of the LIC initial operational capability with four L1C (four GPS III) SVs in view at all times.

This will entail a minimum of 18 GPS III satellites on orbit with the L1C signal. Full operational capability is planned for 2021 with a minimum of 24 GPS IIIs in the constellation. Currently, the DoD is working with the Department of Transportation (DoT) to ensure adequate funding from the civil community is identified and available to support costs for L1C and civil monitoring.

Inside GNSS: At least since Desert Storm, the issue of latencies in fielding improved GPS user equipment has posed a persistent challenge to GPS program managers. What thoughts do you have about methods for accelerating GPS user equipment (UE) technology refresh and modernization?
Col. Madden: The GPS Wing is currently focused on a prototype UE card development program. We are working closely with OSD (Office of the Secretary of Defense) and the Services to better define an official program strategy aimed at fielding M-code user equipment. This requires a technology development plan, multiple domain (air/ground/space/munition) form factors, initial integration and test into lead service platforms, and the development of prototype user equipment.

These activities would be followed by Services' platform integration, hardware procurement, and sustainment programs. It is important that this strategy gets defined and budgeted before attempting to accelerate any one of the individual activities.

Inside GNSS: Given the GPS Wing's diverse customer base (and platforms) among the various DoD constituencies, is the program leadership considering a different approach to the associated processes of setting requirements, funding, contracting, certification, and fielding of GPS UE? If so, what are the most important of these?
Col. Madden: The GPS Wing recognizes the diversity of the customer base that includes Department of Defense and international coalition partners. The diverse customer base requires more than a "one size fits all" approach and the Wing actively engages in tailoring to meet individual needs.

The GPS User Equipment Group has regular meetings with each service representative and country representatives in order to better understand the individual unique requirements so that a solution can be devised to meet the warfighter's need. Flexible contracts are in place to support tailoring and certification follows tried and true processes used in previous acquisitions.

Funding is always the limiting factor and drives schedule and the ability to meet all or some of the requirements set.

Inside GNSS: What are the current plans & timeline for funding one or multiple MUE suppliers?
Col. Madden: Currently, the modernized user equipment program has three contractors (Rockwell Collins, Raytheon, and L3 Communications/IEC). Starting November 2007 the MUE program will have the funding for only one contractor. If no additional funding is added, the GPS Wing will continue the development with a single contractor.

The congressional subcommittees, House Armed Services Committee, and Senate Armed Services Committee, have added language to include a $60 million plus-up in FY08 [Fiscal Year 2008 budget] to the modernized user equipment budget. If the mark-up becomes law, the GPS Wing will continue with the multi-vendor strategy.

Inside GNSS: In the run-up to the next solar max in 2011, an increase in ionospheric scintillation and accompanying interference to GPS (and other RF) signals is anticipated as a result of solar flares. What measures is the GPS Wing considering to mitigate the effect on GPS space- and ground-based assets, including civil and military user equipment?

As we upgrade the control segment monitor receivers, the ability to track signals from other systems is being considered.

Col. Madden: GPS modernization programs in all segments are proceeding as part of the modernization program and are not motivated purely by the 2011 solar max. Recently, GPS expanded the monitor station network by integrating 11 National Geospatial-Intelligence Agency (NGA) monitor stations with the 6 AF stations. This expanded network provides more robust GPS signal monitoring with each satellite being tracked by at least two monitor stations at all times.

In addition to ground monitoring, each GPS satellite was designed to operate in an enhanced radiation region in the Van Allen radiation belt. Therefore, critical space system components are shielded, radiation hardened, and redundant. To minimize solar effects on mission success, GPS relies upon space diversity (multiple satellites) and frequency diversity (L1, L2, and eventually L5 with Block IIF).

Advanced antenna electronics will likely yield 10-20 dB of radio frequency interference (RFI) resistance with ultra-tight coupling yielding another 10-12 dB of RFI resistance. With the addition of new civil long codes (L5) and proper shielding, civil receivers may become even more RFI-resistant.

Inside GNSS: What is the GPS Wing budget for FY 2007 and projected FY 2008?
Col. Madden: The GPS Wing Budget for FY 2007 is $826.05 million, and the projected budget for FY 2008 is $1.14 billion. These funds represent the UE, Space and Control (IIF, IIR-M and OCS), and GPS III TOA [total obligational authority].

Inside GNSS: Proposals have been raised domestically and internationally for increasing operational planning and coordination among GNSS providers (i.e., GPS, GLONASS, Galileo, etc.). How might that affect the GPS Wing's responsibilities and activities?
Col. Madden: The GPS Wing leads compatibility and interoperability working groups with Europe on Galileo, Russia on GLONASS, and Japan on QZSS [Quasi-Zenith Satellite System]. Much progress has been made to assure compatibility of signals, meaning they won't significantly interfere with each other, and to enhance interoperability of signals, meaning that receivers can use signals from all sources in combination with each other. The new L1C signal is a prime example of this cooperation.

It is a bit too early to address joint operational planning and coordination, but some level of mutual awareness and cooperation between systems is very desirable and is likely to evolve. For example, as we upgrade the control segment monitor receivers, the ability to track signals from other systems is being considered. GPS will broadcast the GPS time offset to other GNSS systems in the new L1C navigation message scheduled for initial broadcast in 2013.

Inside GNSS: Other proposals have called for a separation of civil and military GPS services. What issues does this concept raise?
Col. Madden: At the very core of navigation is the geometry of the GPS satellites relative to the users, with four satellites in view to solve for latitude, longitude, altitude, and time. For this reason, the perspective on GPS constellation size has evolved over the years, from as few as 18 to recent suggestions for as many as 36, although the baseline constellation size is 24 with a current operational size of 29 satellites.

This also is why GPS welcomes other navigation satellite systems, because an improvement in geometry is valuable for all users. It would be redundant and costly for the United States to support two separate satellite constellations with the required ground support infrastructure for each. Having both military and civil signals on every GPS satellite has been determined to a more cost effective way to use scarce national resources.

For national security reasons, it is important for the military and our allies to have separate, encrypted signals for exclusive military operations. On the other hand, it is equally important for civil users to have separate signals which are unencrypted and readily available.

The U.S. Government has committed to provide GPS civilian signals free of direct user fees to all users, along with openly providing the technical information needed to develop civilian GPS receivers and PNT services based on GPS.

Since 1983, the U.S. Air Force has continually provided civilian GPS signals worldwide without interruption. This unwavering commitment and enduring record of service has been the strongest argument to maintain GPS as dual-use civil-military system. IG