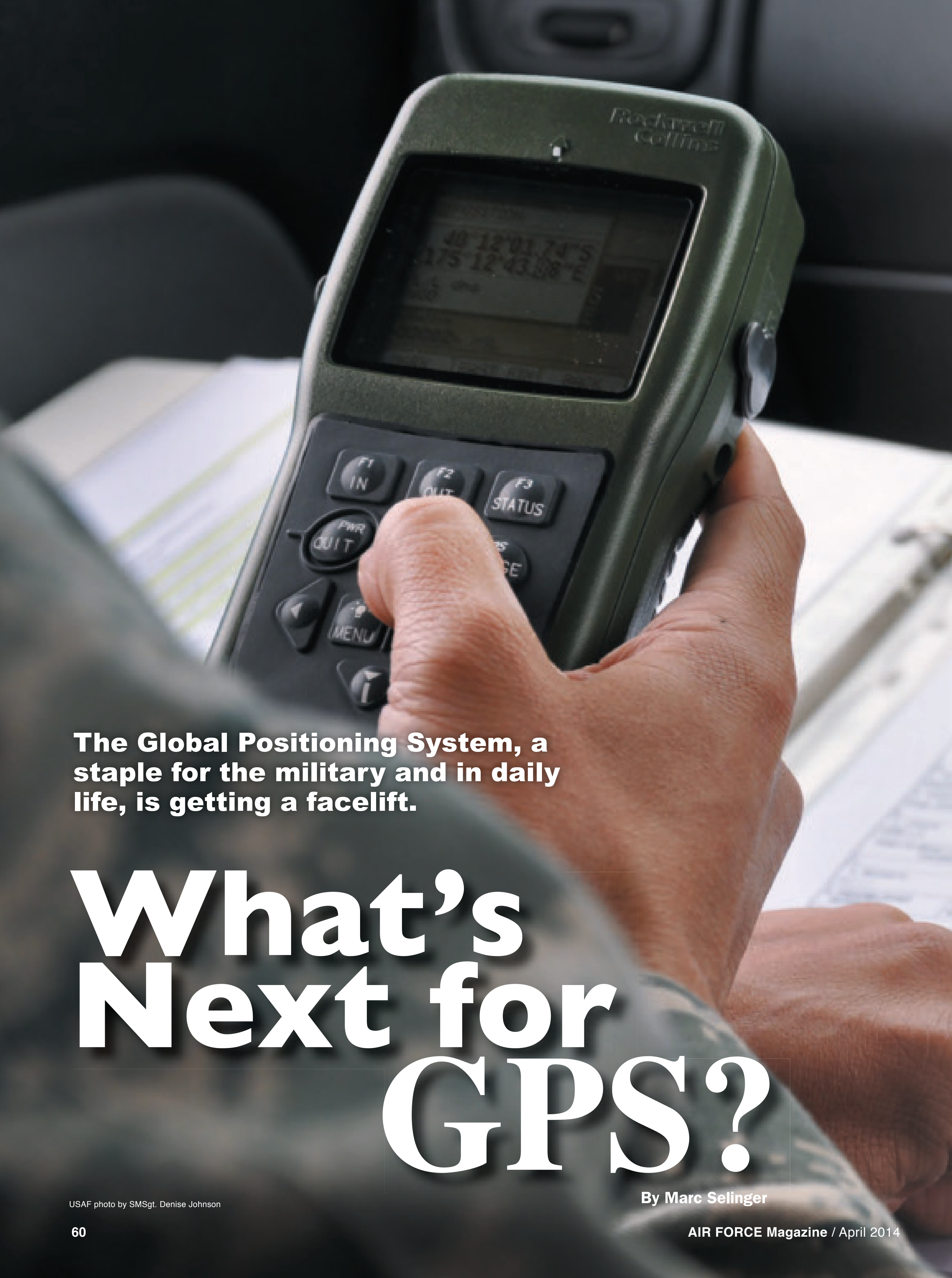

The Global Positioning System, a staple for the military and in daily life, is getting a facelift.

What's Next for GPS?

By Marc Selinger

USAF photo by SMSgt. Denise Johnson

Forty years after the US government awarded a contract to build the first Global Positioning System navigation satellite, GPS is the Department of Defense's largest satellite constellation and is as integral to modern warfare as aircraft or ships.

The heavy responsibility for keeping the system up-to-date rests with the Air Force.

This is no easy task. The ongoing modernization effort will run to billions of dollars and includes potentially dozens of new satellites, an updated ground control system, and new GPS receivers.

The large-scale, long-term modernization initiative has "a lot of moving parts," said Air Force Col. William T. "Bill" Cooley, the government's GPS program director. And there are "lots of challenges with making certain that … all of those segments are going to work together."

Key tests this spring will help determine whether GPS modernization is on the right track. But failure is not optional. GPS is vital to national security today and to the conduct of the global economy.

GPS is best known for sending out signals that help people and machines determine their location on Earth. The system was created to serve military purposes, from guiding troop movements to directing precision guided munitions. Today, the civil and commercial sector is dependent on this free service, from tracking trains to providing directions to car drivers.

Equipped with precise atomic clocks, GPS satellites also play an important "timing" role. Their signals include time data that allow communication, financial, and electric-power systems to synchronize their operations. "We're providing a global capability that not just the Air Force, not just the other services, but the entire world depends on, and it's intricately linked to the way our society functions, quite frankly," Cooley said.

The first GPS satellite, part of the Block I series built by Rockwell International, was launched in 1978. Block I was followed by five series of Block II satellites that expanded, replenished, and updated the constellation. More than 60 GPS satellites have been placed in orbit in all.

As of mid-January, a total of 36 functioning GPS satellites were in orbit about 12,500 miles above the Earth. Of those 36 spacecraft, 31 actively contribute to the constellation and the other five serve as backups. Although the minimum requirement for coverage stands at 24 satellites distributed around the Earth, the Air Force prefers to have more satellites available to provide better coverage. The larger the constellation, the more likely a GPS receiver on the ground will have a clear view of satellites.

In an April 2013 Government Accountability Office report to Congress on potential cost-saving options for GPS, the Air Force assumed a future constellation of 30 satellites.

The Air Force has exceeded its 24-satellite requirement thanks in part to spacecraft lasting much longer than planned. For example, the 19 GPS Block IIAs, developed by Rockwell and launched from 1990 to 1997, were designed to last 7.5 years and should have timed out of service by now. But as of November 2013, eight were still part of the active constellation, with the eldest now exceeding 23 years of service.

"The good news is that GPS is a robust and healthy constellation because the IIAs have lived much longer than anyone had originally projected," said Cooley, who runs the program from the Air Force's Space and Missile Systems Center at Los Angeles AFB, Calif.

Estimating how long satellites will be operational is clearly not an exact science. While designed to survive the harsh environment of medium Earth orbit, GPS satellites sometimes face unpredictable conditions, such as solar flares that can degrade electronics. But based on computer modeling and a pipeline full of new satellites, the Air Force projects it will have enough spacecraft for the foreseeable future, Cooley said.

Boeing is finishing the last of 12 new Block IIF satellites at its factory in El Segundo, Calif. On Feb. 20, the Air Force launched the fifth IIF satellite from Cape Canaveral AFS, Fla., aboard a United Launch Alliance Delta IV booster.

Assembly of the initial batch of Block IIIs is underway at a Lockheed Martin plant in Denver.

Looking Forward

Both new satellite series have had their share of glitches. The first Block IIF satellite launched in 2010, four and a half years late, due to development problems—what GAO attributed to the use of "immature technologies."

Another setback occurred when the second IIF satellite, launched in 2011, experienced a failure of its Cesium clock, one of three atomic clocks that ensure the accuracy of the spacecraft through redundancy.

The Air Force concluded the chamber surrounding the Cesium clock did not release air quickly enough once the satellite was placed in space, causing an electrical short. Satellites three through seven had the same problem, so a hole was drilled in the chamber to allow more gas to escape. The Air Force believes the issue is resolved.

"That's behind us," Cooley said.

The Block III series, which Lockheed Martin is developing under a $1.5 billion contract awarded in 2008, is supposed to deliver signals that are several times more accurate and resistant to jamming than existing GPS spacecraft. Block III satellites are also designed to last 15 years, or 25 percent longer than Block IIFs, and they will be the first GPS spacecraft with a new L1C civil signal to make them interoperable with comparable foreign systems, such as Europe's Galileo.

To help avoid the kinds of problems that plagued Block IIF, the GPS III program built the GPS III Non-Flight Satellite Testbed (GNST), a full-sized, flight-equivalent prototype of a Block III satellite, and put it through a series of exercises in the summer and fall of 2013. For a dress rehearsal, GNST was physically handled like an actual satellite, from the way it was loaded onto a C-17 aircraft in Denver to the way it was unloaded at Cape Canaveral for testing.

At the Cape, the test bed communicated successfully with the GPS program's new ground-control system and with flight-like hardware simulators for the IIR, IIR-M and IIF satellites, which make up most of the current GPS constellation. Testing also demonstrated the receiver's ability to track navigation signals transmitted by the GNST. "The efforts that we put here early on the program are going to pay off in large dividends on the production contract going forward," said Mark Stewart, Lockheed Martin's vice president of navigation systems, who earlier helped the aerospace firm build IIR and IIR-M satellites.

But in 2013 a major problem emerged in the first Block III satellite, designated Space Vehicle 01 (SV-01). In the spring and summer, the navigation payload (developed by Lockheed Martin subcontractor Exelis) experienced "signal crosstalk," or interference between signals within the payload. The problem was caused by "insufficient isolation" between signals of different frequencies and power levels and arose in the payload's mission data unit, a 167-pound box that processes signals on the payload, Stewart said.

Lockheed Martin and Exelis both expressed confidence the payload will be fixed and ready for delivery to Lockheed Martin's

United Launch Alliance photo by Ben Cooper

USAF photo by Todd Berenger

Denver facility this spring. Stewart said such hiccups are to be expected in a development phase, and the program has "a very detailed plan on hand" to resolve the matter.

Exelis spokeswoman Jane Khodos said that "significant testing with flight-like engineering units and the first GPS III satellite's flight hardware indicates that the known technical issues are being resolved, and GPS III will meet all mission and quality requirements."

While Cooley agreed that progress is being made, he won't be convinced the problem is fixed until the payload successfully completes thermal vacuum chamber testing this spring, to simulate the low and high temperatures the payload will experience on orbit.

"I applaud the optimism, but I'm not going to declare that we're out of the woods," Cooley said. SV-01 is scheduled to arrive at Cape Canaveral in 2014 for a May 2015 launch, though there were indications in March that the launch date might slip.

Exactly how many Block III satellites the Air Force will acquire is unclear. The Air Force has indicated it could buy more than 30 Block IIIs. But as of late March, it had committed funds to procure only the first six, plus long-lead items for the seventh and eighth.

"We assess the health of the constellation and the resources in the department and the needs of those things on a recurring basis to decide what makes sense," Cooley said. "So that's a decision that has yet to be made in terms of exactly how many GPS III satellites we're going to buy."

Control Issues

The GPS control segment consists of a global network of ground facilities that monitor and command GPS satellites. The Air Force and Raytheon are developing the Next Generation Operational Control System (OCX) "because the existing

Top: The GPS IIF-5 satellite atop a United Launch Alliance Delta IV rocket launches from Space Launch Complex-37 at Cape Canaveral AFS, Fla., on Feb. 20. Above: Col. William Cooley, GPS program director, says the full buy of GPS III satellites is still up in the air.

Lockheed Martin photo

A GPS III satellite prototype arrives at Cape Canaveral from Buckley AFB, Colo., aboard a C-17. The navigational satellite is scheduled for a 2015 launch.

ground control software is not compatible" with the Block III satellites, according to the GAO.

Since Raytheon was awarded the OCX contract in early 2010, the system has made "significant progress" in meeting milestones, conducting exercises, and writing software, said Matthew Gilligan, Raytheon's OCX program manager. But Cooley said a major uncertainty for OCX is not yet knowing how the system will perform until it undergoes operational-like testing scheduled for spring. "We're not going to know precisely where we are until we get through some of that testing," he said.

A major requirement for OCX is meeting Department of Defense information assurance standards. Preventing hackers from compromising the system is part of this process. The system also must be able to verify authorized operators and that they do not accidentally or deliberately cause harm.

For example, Cooley explained, "we want to make sure that there's not … a potential issue of a user clicking on the wrong button and resetting a clock on orbit." Gilligan said the OCX program has developed 1,800 individual information assurance requirements to ensure security is "baked in" throughout the system.

Yet another responsibility for Cooley's office is overseeing the development of new user equipment for DOD. GPS receivers are widely used across all services, and it falls on the Air Force to design and test chips and algorithms that receiver manufacturers can integrate into their systems.

New features include the military signal M-code, to help improve defenses against jamming. To use M-code, receivers need a new chip to process the signal. The Air Force hired three vendors—L-3, Raytheon, and Rockwell Collins—to develop M-code chips, and this effort "has gone very, very well," Cooley said.

The Air Force plans to further refine the chips and then integrate and test them on a lead platform for each military service to confirm the chips work as planned. The services will then be able to buy user equipment from the receiver manufacturer they prefer. The lead platforms chosen are the Navy Arleigh Burke-class guided-missile destroyer, the Army Raven unmanned aircraft, the Air Force's F-15E fighter, and a Marine Corps ground vehicle.

In a June 2013 test flight at Holloman Air Force Base in New Mexico, an RQ-11B Raven became the first aircraft to use M-code for navigation, according to Rockwell Collins.

The Air Force hopes to make M-code available for operations as early as 2017.

Not Immune

Like the rest of the military, the GPS program office is grappling with how to execute its mission amid belt-tightening in Washington, D.C. With defense budgets constrained and GPS III satellites projected to cost $23 billion from Fiscal 2013 through Fiscal 2030, the program could be an attractive target for budget cutters.

Several possibilities are under exploration to lower the program's price. For instance, the Air Force originally planned to buy the last 26 GPS III satellites in two increments, but it now plans to streamline this buy into one large increment to take advantage of economies of scale.

Some potential changes involve hardware. In addition to their navigation payloads, Block III satellites carry a system to detect nuclear detonations on Earth. Therefore, one option might be to leave the nuclear detection payload off some of the new satellites.

The Air Force had also been studying whether a "dual-launch capability," or launching two satellites on a single rocket, would save money.

Sorting through such intricacies does not appear to deter Cooley, who holds a doctorate in engineering physics from the Air Force Institute of Technology. Instead he welcomes the challenges ahead.

"It's an exciting time for GPS," he said. "That's what makes this job exhilarating." ■

Marc Selinger is a freelance journalist based in the Washington, D.C., area. This is his first article for Air Force Magazine.