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Feature Article

Threat to Satellite Signals Fuels Demand for Anti-Jam Products

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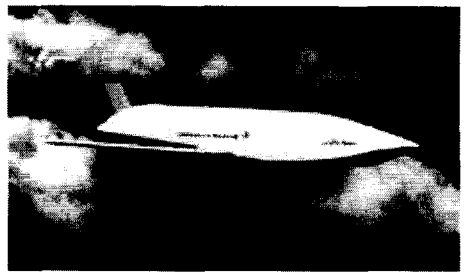

The use of satellite navigation to guide missiles to their targets has made "pinpoint accuracy" the norm in U.S. strike operations. But the growing reliance on radio signals from space-not only to direct missiles but also to locate aircraft and vehicles-has raised worries that critical military capabilities are hanging on a single constellation of satellites.

The Defense Department's constellation of global positioning system (GPS) satellites has been in orbit for about two decades now. But uses for its navigation signals have proliferated and have turned GPS into a ubiquitous military and civilian utility. Each satellite-currently there are 27 in orbit-has four atomic clocks and broadcasts time and location signals. Receivers on board missiles or aircraft, for example, compare these signals with their own clocks and then determine their location by calculating the distance between them and the satellite. By locking on to four satellites, receivers can locate their position to within meters. The satellites emit two signals, called L1 and L2. The L2 signal was encoded and encrypted for use by U.S. military forces and allies. There is one frequency available to civilian users.

Today, most modern U.S. long-range missiles are GPS guided. A missile guidance-and-control system can use GPS to determine its current position and fly toward the GPS coordinates of a designated target either directly or through a series of pre-programmed waypoints.

The guidance-and-control system typically uses position and velocity information from GPS in conjunction with an inertial navigation system (INS) to control the platform. GPS and inertial technologies are complementary.

Inertial technology provides position and velocity information during a short period, but has a tendency to drift. GPS, meanwhile, provides accurate information but may be subject to outages due to either intentional or unintentional interference or satellite blockage.

The GPS data corrects the errors from the inertial navigation solution, resulting in more accuracy. But if there is interference, the GPS receiver may not be able to operate, and the inertial navigation system will tend to drift, resulting in a navigation error.

Sources of non-deliberate interference could be harmonics from TV transmitters, FM radio stations or microwave links. Every country, including potential U.S. enemies, has access to the civilian GPS code.

Those concerns have prompted several government officials to suggest that there should be alternative precision navigation options. The fear of intentional or unintentional interference, also called jamming, has sent missile manufacturers and platform developers scrambling to equip systems with sophisticated anti-jam capabilities.

GPS signals are weak and generally susceptible to jamming. And even though there is no significant evidence of deliberate tampering of GPS signals, there is a growing consensus among military and industry experts that GPS-guided weapon systems need additional protection and could benefit from alternative technologies.

"We are concerned about the continuing reliance on GPS and difficulties that it could cause us," said Dale Uhler, the Navy's deputy assistant secretary for C4I, electronic warfare and space programs.

Uhler believes there is too much emphasis on building protection into GPS satellites and receivers and not enough attention is being devoted to developing other technologies for precision navigation. "We are putting all the eggs in one basket," he said during the recent Navy League annual convention in Washington, D.C. "We need to find some alternatives to GPS."

His office currently is working on a "navigation strategy" for the Navy, said Uhler. If the service can achieve results from a "balanced technology investment," he said, any breakthroughs would be shared with the other military services.

An "executive navigation committee" of senior Pentagon officials is expected to outline a science and technology plan by next year, said Uhler.

"It's more than just concern about GPS vulnerability," he told National Defense. "We think there are a lot of different capabilities we need in our total navigation scheme. GPS is only one part of that picture ... Until now, we've been concentrating for the most part on GPS because it is good, it is efficient."

Potential for Jamming

Rolf Johannessen, a GPS expert at Lambourne Navigation Ltd., recently wrote that he is not aware of instances of intentional interference with GPS signal reception, "except under well-controlled conditions for the purpose of obtaining scientific data." Nevertheless, he added, "we should not ignore the potential for jamming any more than we can ignore the possibility that a deranged person could transmit ... an air traffic control-like clearance that directs an aircraft to fly into a mountain."

"The vulnerability of GPS to jamming is pretty well recognized," said Rear

Adm. Robert Nutwell, deputy assistant defense secretary for C3I, reconnaissance, surveillance and space systems. "All RF [radio frequency] systems are vulnerable to some degree ... GPS probably more so because it is such a weak signal and it is not protected" as military-unique satellites, Nutwell told an industry conference in San Diego.

The race to develop powerful anti-jam capabilities in the aerospace industry has intensified in recent years. Missile manufacturers have moved to equip weapons with anti-jam systems, and the demand for this technology is expected to grow in proportion to the perception that there is a jamming threat.

Fears were fueled in recent years by the emergence of advanced commercially available jammers. During an air show in Russia in 1997, for example, a $4,000 jamming transmitter was on display and its manufacturers claimed the device foils the ability of GPS receivers to provide correct geographic coordinates.

When a GPS receiver is jammed, "it gets confused," explained James J. Kelly, director of advanced engineering at Telephonics Command Systems, an electronics firm in Farmingdale, N.Y.

A jamming signal that is tuned to a constant frequency constitutes a continuous wave jammer, said Kelly. "That is the easiest signal to defend against." It can be countered with simple mechanisms, such as a filter.

When a jammer emits energy that bounces around various frequencies often and unpredictably, it is called a broadband jammer. "It is difficult to find a mathematical algorithm that allows you to anticipate what the jammer is going to do, because it is purely random," said Kelly. "Most people are concerned about the broadband jammer. It is the most difficult to defend against ... If you were going to build a jammer, that is what you would build."

Most anti-jam devices currently in use are either "nulling" or "beamforming systems," explained Kelly.

These two technologies refer to exploit techniques that can be used to counter jamming signals. Some GPS receivers have an antenna array, with up to seven receiving elements arrayed in a geometric pattern. Upon detection of jamming interference, part of the antenna pattern can be turned down, so the noise from that particular direction does not interfere with the rest of the system.

That is called nulling the signal.

"A null means that I will not look in the direction in space that the jammer is coming from," Kelly said. The electronics protect the receiver by eliminating the interference signal. One problem with this nulling technique, however, is that "as you eliminate jammers, you eliminate your ability to receive signals from the GPS satellites," he said. "You could have a nulling system that kills off the jammers, but you no longer have enough satellites available for you to navigate."

The beamformer, meanwhile, "doesn't care where the jammers are." The beamformer selects and receives signals from at least four satellites and provides four anti-jam solutions. "The beamformer algorithm is more aggressive and you get a better result," Kelly said. Recent simulations conducted by Telephonics, he said, showed that beamformers performed better than nullers.

But these systems cannot be used with older GPS receivers. Because a beamformer produces four outputs directed at four selected satellites, it cannot interface with a standard GPS receiver that only has one input. "You need a receiver that is customized to accommodate the beamformer interface," said Kelly.

New missiles typically feature a tight package composed of an anti-jam device, antenna and GPS receiver. This makes them more adaptable for beamforming anti-jammers, Kelly asserted.

"The missile community wants anti-jam products that are small, low powered, and low cost," Kelly said. His company plans to compete in the market for GPS anti-jam products for missiles. Most recently, Telephonics lost the competition for an anti-jam system for the U.S. joint air-to-surface standoff missile (JASSM), currently in development by Lockheed Martin Missiles and Fire Control, based in Orlando, Fla.

The JASSM originally was equipped with an anti-jam product by the Raytheon Company, but after a competition, it was replaced with a new receiver called G-STAR (GPS spacial temporal anti-jam receiver), made by Lockheed Martin Federal Systems, in Owego, N.Y. and Rockwell Collins, based in Cedar Rapids, Iowa. Lockheed chose the G-STAR technology "for the long-term health of the program," said company spokeswoman Nettie Johnson.

Rockwell Collins currently has 95 percent of the military world market of GPS products, said David West, the company's manager of navigation marketing. He explained that G-STAR will allow the JASSM GPS receiver to acquire the signal and maintain it in an interference-high environment.

G-STAR also is able to employ both nulling and beamforming techniques to counter jamming, noted David Anderson, Rockwell's program manager for GPS.

The process of steering a beam away from an interfering source in order to achieve clear satellite reception in the past was based on analog technology.

But G-STAR does it digitally, said Anderson, "so it can switch modes very quickly and steer nulls when it wants to and steer beams towards the satellites when it wants to."

JASSM is a long-range missile, expected to fly out to targets about 200 nautical miles away. For that reason, it needs a robust GPS anti-jam capability, said Anderson. Cruise missiles need autonomous precision navigation capabilities that also are affordable, he said. Elaborate electro optical systems such as sea-matching or terrain contour mapping are costly, he added.

West stressed that the demand for anti-jam products is not limited to cruise missiles. The company is working on systems for manned aircraft, ships, land vehicles and command and control networks. "There are lots of dependencies on GPS for navigation and time reference," he said.

G-STAR also will incorporate the so-called selective availability and anti spoofing module (SAASM), which the Defense Department has made mandatory-beginning in October 2002-for all military GPS receivers that receive the encrypted precision satellite signal.

The SAASM module is a microelectronic device with a large number of digital components that allows an authorized user to receive the precision encrypted GPS signal.

The G-STAR receiver weighs about 25 pounds, said Jim Naylor, program manager at Lockheed Martin. He explained that the system's digital beam-forming capability means it can simultaneously point beams at the satellites, while nulling the interference. "This gives our technology an advantage over systems that just provide interference nulling because in many cases we are able to maintain track on low-elevation satellites in the presence of jamming that we would not have been able to track otherwise."

Lockheed Martin is marketing this technology for many applications, other than missiles, said Naylor. But he declined to offer details because they are competition-sensitive.

Degree of Anti-Jam

"Most current missiles don't have a high degree of anti-jam capability," said Steve Zaloga, defense industry analyst at the Teal Group, in Stamford, Conn. "The degree of anti-jam varies quite a bit from missile to missile."

When the Air Force first introduced GPS-INS, said Zaloga, "there wasn't a concern about jamming." But that changed during the past four to five years, he explained, because long-range missiles-traveling up to hundreds of miles-increasingly are being used in strike operations. The longer a missile's flight, the more likely a jammer can interfere with the GPS guidance. Shorter-range systems are less vulnerable.

"There is no concrete evidence of a threat, of anyone actually jamming GPS signals," Zaloga said, "but there are various jamming devices on the market, particularly in Russia."

The GPS-INS market is surging, he noted. "There are lots of bucks there," because the Air Force decided to discontinue purchases of laser-guided munitions and to focus on GPS guidance such as GPS-INS and GPS-terrain following radar.

The new versions of the Air Force's conventional air-launched cruise missile (CALCM), made by the Boeing Company, have a GPS-INS receiver built by Interstate Electronics Corp., Anaheim, Calif.; and a GPS anti-jam module made by Harris Government Systems, Melbourne, Fla.

Greg Martz, spokesman for Interstate Electronics, said the company provides GPS receivers for the Navy's next-generation ERGM land-attack munition and for the advanced munitions that will be used in the Army's future Crusader cannon. They will be equipped with the SAASM module, he said. He noted that adding SAASM multi-chip modules to the receivers is not a "significant cost issue."

The program manager for CALCM at Boeing, Glenn Vogel, said the decision of what anti-jam product to choose typically is based on "cost, capability and availability."

Harris' marketing manager, Sleighton Meyer, said the anti-jam product used in CALCM is a nulling system and could be adapted to other platforms. The company lost in the competition for the JASSM GPS anti-jam system.

The Navy's most capable cruise missile, the Tomahawk, has GPS guidance in its upgraded models and is equipped with anti-jam systems made by the missile prime contractor, Raytheon Missile Systems, in Tucson, Ariz. An advanced version of Tomahawk, called Block IV, will enter service in 2003 and will have a more robust anti-jam capability, said Rear Adm. John V. Cheveney, the Navy's program executive officer for cruise missiles.

The Tomahawk has a range of more than 300 miles.

Cheveney is among those who support having alternative guidance technologies to GPS for long-range missiles such as Tomahawk. For that reason, he has endorsed an emerging technology-based on terrain-mapping radar-called precision terrain aided navigation (PTAN). "It's a technology that I'm very excited about," he told a conference of the Precision Strike Association in Fort Belvoir, Va. PTAN is "autonomous, GPS independent precision navigation."

A PTAN-equipped missile would perform continuous terrain contour mapping, and match the contour with a database stored in the missile's computer. Before GPS guidance was around, terrain contour mapping was the only solution available, but Cheveney believes that it can be improved significantly and at lower cost because of the gigantic leaps achieved in computer data processing and storage. PTAN provides position updates by matching terrain profiles-measured with a radar altimeter-to digital elevation maps stored in the onboard computer.

"If we have the elevation of many places in the world, elevation data could be stored in the Tomahawk missile," he said. PTAN could be used for en-route navigation and terminal navigation, and, more importantly, it makes the missile "less dependent on GPS.

"PTAN is a concept that we think can work," Cheveney told National Defense. "We are trying to generate interest within the Defense Department in order to receive funding."

One company currently working on PTAN technology is Boeing Phantom Works, in St. Louis. According to company executive Jack Rose, PTAN is less expensive than digital terrain mapping. "It gives you precision navigation without GPS." Although the technology still remains in the laboratory, officials estimate it would cost about about $10,000 per missile.

The PTAN navigation concept is a "viable capability," said George Mavko, Tomahawk program manager at Raytheon. "We are looking at it with our Navy customer." Mavko predicted that, even if PTAN is adopted, it will be a complement to GPS, rather than a replacement. He dismissed the notion that radar signals undermine the missile's stealth. "We have a radar altimeter on Tomahawk. It allows it to fly close to the ground and follow the terrain," he said. The altimeter that will be used to measure the terrain profile for PTAN is similar.

Others are not so sure about these alternative technologies to GPS. Terry Little, Air Force program manager for JASSM, said his program is not seeking systems such as PTAN, for various reasons.

"We have confidence that GPS will be there," Little said. "Jamming can be done theoretically, but practically, it is difficult, because not only do you need the right jammer, but it has to be in the right place ... In the JASSM program, we are not interested in an alternative guidance technology to GPS. One reason is cost."