Who knew, 25 years ago, that the humble little GPS satellite would mean a revolution in accuracy?

Signal

By Peter Grier

ON Feb. 22, 1978, the first Block I Navstar Global Positioning System satellite was launched from Vandenberg AFB, Calif. The event received little notice in the press. At the time, even many Pentagon officials were not exactly sure what this unheralded new system would do. They were aware of its capability—the provision of pinpoint location information—but had little idea how that could be exploited to increase the effectiveness of United States forces.

Twenty-five years later, they have figured it out, and GPS has become one of the most successful and versatile high-technology projects of all time. Conceived as a navigational aid for ships, it is now a sort of sextant to the world, as important in its own way as the discovery, in the 18th century, of means of measuring longitude at sea. It has also turned out to be one of the most important US government investments in space, creating a $30 billion a year civilian market in GPS related devices.

For the military, GPS has been revolutionary, taking the "search" out of search and rescue, guiding troops through trackless deserts, and—perhaps most importantly—providing US airpower with the basis for unmatched all-weather Precision Guided Munitions.

For PGMs, GPS capability is as much of an advance over laser guidance as laser guidance was over "dumb" bombs, noted Air Force Gen. Richard B. Myers, Chairman of the Joint Chiefs of Staff, last year.

"When the Global Positioning Sys-

GPS offers support for a host of vital military operations. The system provides position and elevation information used by engineers building an aircraft parking ramp in the desert and data used by search and rescue personnel to name a few. Perhaps most importantly, GPS has transformed USAF munitions capabilities by providing the basis for unmatched all-weather Precision Guided Munitions, such as 2,000-pound JDAMs.

tem was being developed and "first deployed, no one was talking about using it for bombing," Myers told the Senate Armed Services Committee. "It was seen as a better navigational tool."

Beyond Navigation

"So, essentially, we've linked incremental improvements in several different technologies to achieve today our precision-strike capability, with accuracy that I believe amounts to truly transformational change."

Today's Global Positioning System is a constellation of satellites that beams navigational data to anyone in the world with the proper equipment to receive it.

The satellites travel in 12-hour circular orbits at an altitude of approximately 12,500 miles above Earth, in six different orbital planes. There are four operational satellites to a plane, spaced so that a user on the ground will typically have access to the signal from a minimum of five different "birds" at any one time.

The GPS satellites are, in essence, extremely accurate clocks in the sky. They broadcast precise time information toward the ground via coded radio transmissions, which are picked up by receivers that can range from small handheld units to the guidance systems of ballistic missiles.

The receivers calculate how long it has taken them to receive the radio pulses from different GPS satellites and use the barely perceptible differences in time to figure out a position on the face of the Earth, as well as velocity at which one is traveling.

The signals are so accurate that time can be determined within a millionth of a second and speed within a fraction of a mile per hour. Location can be pinpointed to within 33 feet.

The devices can do this, that is, if the US allows such accuracy. GPS in fact broadcasts two different kinds of signals—a Coarse/Acquisition code intended for civilian use and an encrypted Precision code for the US military. If necessary, the Pentagon can induce an error into the C/A signal, decreasing accuracy to 330 feet or so. In practice, the military has been reluctant to engage in thisditution, partly because civilian receivers have been a lifeline for individual soldiers in the past.

On May 1, 2000, President Clinton ordered that this intentional error, known as selective availability, be turned off. Turning it back on would require Presidential authorization.

The Navy Heritage

Man's desire to guide himself safely across the trackless ocean has long been an engine of scientific advance. Mariners' needs have led to everything from the development of astronomy to accurate chronometers and radio navigation. Thus, it is perhaps unsurprising that the GPS story began with a Navy program a simple, reliable system named Transit.

The first Transit satellite was launched in 1960. (A prototype was launched in 1959 but failed to reach orbit.) Developed by the Johns Hopkins University Applied Physics Laboratory, the system eventually consisted of seven low-altitude polar-orbiting satellites. Users could figure out their position on Earth by measuring the Doppler shift of the satellite's extremely stable radio transmissions.

But navigation by Transit required a long observation time, as well as correction for velocity. Coverage was limited, because the US launched only a few satellites. Position data covered only two dimensions. Overall, it was not useful for such fast-moving vehicles as aircraft.

So both the Air Force and Navy began working on more sophisticated techniques. The Navy's contribution was an experimental satellite program named Timation. The Air Force's was a design concept eventually named System 621B, which drew from pioneering work done by The Aerospace Corporation and its renowned founding president, Ivan A. Getting.

By 1970, all of the services were working on navigation systems intended to provide all-weather, around-the-clock, three-dimensional position data. Eventually, the Defense Department leadership moved to rationalize the research. In April 1973, DOD tapped the Air Force to lead a multiservice program—the Defense Navigation Satellite System.

DNSS blended the Air Force's proposed signal structure and frequency with the Navy's satellite orbits and atomic clock research. The result, whose development was approved in December 1973, is the system known today as the Navstar GPS. The Air Force launched 11 GPS development satellites, designated Block I, between 1978 and 1985. Midway through this series, designers added nuclear explosion detectors to aid in verification of treaty compliance—a subsidiary mission of GPS spacecraft that continues to this day. Eventually all Block I satellites failed as their atomic clocks or attitude control systems ceased functioning. Most, however, lasted much longer than their design life of three to five years.

Surviving Budget Cuts

GPS development was not always smooth. In 1979, the system's planned 1981 to 1986 budget was cut by 30 percent. In 1986, the loss of the space shuttle *Challenger* resulted in a 24-month delay in the launch of the first Block II operational satellite, which, like Block Is, were built by Rockwell. That convinced the GPS Joint Program Office to switch from shuttles to Delta II rockets as its primary means of access to space.

The 24th Block II was launched in March 1994, completing the GPS constellation. The Defense Department, along with the Department of Transportation (the overseer of GPS civilian use), formally declared that the system had reached Initial Operational Capability in a December 1993 announcement.

Today GPS "is able to support a wide variety of operations, including aerial rendezvous and refueling, all-weather airdrops, instrument landings, minelaying and mine sweeping, antisubmarine warfare, bombing and shelling, photomapping, range instrumentation, rescue missions, and satellite navigation," concludes an Air Force Space Command Space and Missile Systems Center history of the system. However, there is a big difference between inherent capability and translation of that capability into increased military effectiveness. US armed forces had to learn to use and appreciate GPS.

"When it first came on board, about 1991, I recall that some of the services didn't want it at the time and didn't have a use for it," said retired Gen. Donald J. Kutyna, former Commander in Chief of US Space Command. "Now the world relies entirely on GPS systems."

Two major factors hampered service assimilation of the GPS system.

One was its status as a support system, as opposed to a weapon. It did not have a history of well-defined operational concepts, noted a RAND study of GPS usage. Its value is not as obvious as that of a new tank or aircraft model.

Second was its status as a joint program. While the Global Positioning System had some eager supporters in all the services, top generals had to be sold on the need to part with scarce funds. No one wanted to shoulder the burden of paying the entire cost of something that would benefit everyone.

Thus GPS had service support difficulties, according to RAND. In budget negotiations, it was zeroed out by the services in 1980, 1981, and 1982, only to be reinstituted by the Office of the Secretary of Defense.

"It appears that OSD support contributed to the survival of the program," said the RAND report.

It was the Gulf War that really opened the eyes of the services. GPS navigation proved to be a revolutionary advance in desert warfare. Ground units found GPS extremely useful for finding their way through the featureless Gulf terrain, so much so that the GPS Program Office had to make emergency buys of small, lightweight GPS receivers. By the end of the war, GPS equipment was affixed—sometimes with tape—to the instrument panels of everything from Humvees to F-16s, KC-135s, and B-52s.

For the first time, operational US commanders were using GPS and other space systems in their daily decision-making. That led to a new appreciation of space as a factor integral to USAF operations, according to Air Force Space Command officials.

"Almost Indispensable"

A few years later, the air war over Kosovo showed in my that GPS was much more than an electronic direction finder. In the Gulf, generally clear weather and open spaces had been an optimal environment for laser-guided weapons. In the cloudy, rainy Balkans, lasers were often blocked, and GPS-guided munitions came into their own.

"It got to the point where they [GPS-guided weapons] were almost indispensable," said Gen. Lester L. Lyles, now commander of Air Force Materiel Command, not long after the war. "Everything that a warfighter, or CINC, or war planner is trying to do relative to attacking targets has become more and more dependent on precision-guided weapons. We saw the beginning of this during Desert Storm and saw it in spades over Kosovo."

Civilian use of GPS developed in a pattern similar to that of military use. Application after application was added as more and more people understood what it could do.

The first US government decision about GPS civilian use came in response to an enormity—the 1983 downing of Korean Air Lines Flight 007 by Soviet fighters after it inadvertently strayed into Soviet airspace. In response, President Reagan announced that the new Global Positioning System upon its completion would be made available for international civilian users. In 1987 the Department of Transportation set up its office for responding to civil GPS users and working with the Defense Department on GPS policy.

The first GPS civilian market, however, was not airlines but surveyors. Their need for accuracy made GPS invaluable, and surveyors' demand for receivers led to R&D and production efficiencies that lowered prices and opened up further markets.

Today, handheld GPS equipment guides hikers through the wilderness. Panel-mounted receivers guide luxury cars down streets unfamiliar to their owners. Geologists use GPS data to measure minute movements in the Earth's crust, with an eye to better understanding of the location of earthquake zones. Even farmers use GPS to help them grade their land to precise slopes and apply fertilizers and seed in patterns designed to maximize yields.

Of course, ships and airliners use GPS, too, to the point where President Clinton felt it necessary to reaffirm the US commitment to provide the signals to the international community, free of direct-user fees, in a letter to the International Civil Aviation Organization in 1995.

In the war on terrorism, GPS has been woven into operational concepts in ever more complex ways. Secure in the system's accuracy, airmen have dropped ordnance on enemy units within 75 feet of friendly positions. GPS positioning data from Predator Unmanned Aerial Vehicles, integrated with real-time video, have been data linked directly to strike aircraft, enabling them to hit targets of opportunity within minutes.

Even Greater Accuracy

Over the years, there have been advances in the system's capability. Since 1997 the system has been upgraded with Block IIR satellites, which officials say opened a new era in GPS performance.

Even after five years in orbit, the Block IIR models are maintaining a signal-in-space accuracy of better than 3.3 feet, according to US officials.

Current plans call for upgraded Block IIF satellites to be placed in orbit beginning in 2005. Per Presidential order, Block IIF will add a third civil frequency for all users. The GPS joint program office ordered its first batch of long-lead parts for Block IIF last March. Maker Boeing has a contract for six satellites, with a US option for six more.

A recent snag has affected the program. USAF wanted to move on to GPS III, the next-generation system, but plans ran afoul of budget constraints. Until recently, USAF expected a 2012 launch of GPS III, which was to feature more signal power to thwart adversary jamming. In January, according to press reports, USAF imposed a two-year delay in selecting a contractor.

The military has considered charging civilian entities for use of GPS. After all, 90 percent of users are nonmilitary. But whoever pays for it, GPS is likely to become only more important to US commanders in the years ahead.

"In spite of the fact that we are using the word 'precision' now, I think we are going to become even more precise as we get more and more refined capabilities," said Lyles. "GPS has been very helpful, but we are going to try to find ways to make that precision even tighter to accomplish the job." ★

Peter Grier, a Washington, D.C., editor for the Christian Science Monitor, is a longtime defense correspondent and a contributing editor to Air Force Magazine. His most recent article, "Desert Orb," appeared in the January issue.