Brig Gen Kenneth Newton Walker

Kenneth Walker enlisted at Denver, Colorado, on 15 December 1917. He took flying training at Mather Field, California, getting his commission and wings in November 1918.

After a tour in the Philippines, he returned to Langley Field, Virginia, in February 1925 with a subsequent assignment in December 1928 to attend the Air Corps Tactical School. Retained on the faculty as a bombardment instructor, Walker became the epitome of the strategic thinkers at the school and coined the revolutionary airpower "creed of the bomber": "A well-planned, well-organized and well-flown air force attack will constitute an offensive that cannot be stopped."

Following attendance at the Command and General Staff School at Fort Leavenworth, Kansas, in 1933 and promotion to major, he served for three years at Hamilton Field, California, and another three years at Luke Field, Ford Island, and Wheeler Field, Hawaii. Walker returned to the United States in January 1941 as assistant chief of the Plans Division for the chief of the Air Corps in Washington, DC.

He was promoted to lieutenant colonel in July 1941 and colonel in March 1942. During this time, when he worked in the Operations Division of the War Department General Staff, he coauthored the air-campaign strategy known as Air War Plans Division—Plan 1, the plan for organizing, equipping, deploying, and employing the Army Air Forces to defeat Germany and Japan should the United States become embroiled in war. The authors completed this monumental undertaking in less than one month, just before Japan attacked Pearl Harbor—and the United States was, in fact, at war.

In June 1942, he was promoted to brigadier general and assigned by Gen George Kenney as commander of Fifth Air Force's Bomber Command. In this capacity, he repeatedly accompanied his B-24 and B-17 units on bombing missions deep into enemy-held territory. Learning firsthand about combat conditions, he developed a highly efficient technique for bombing when aircraft faced opposition by enemy fighter planes and antiaircraft fire.

General Walker was killed in action on 5 January 1943 while leading a bombing mission over Rabaul, New Britain—the hottest target in the theater. He was awarded the Medal of Honor. Its citation, in part, reads, "In the face of extremely heavy anti aircraft fire and determined opposition by enemy fighters, General Walker led an effective daylight bombing attack against shipping in the harbor at Rabaul, which resulted in direct hits on nine enemy vessels. During this action, his airplane was disabled and forced down by the attack of an overwhelming number of enemy fighters. He displayed conspicuous leadership above and beyond the call of duty involving personal valor and intrepidity at an extreme hazard to life." Walker is credited with being one of the men who built an organization that became the US Air Force.

Cut along dotted line

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GPS and Galileo **Constantine**

Friendly Foes?

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GPS and Galileo

Friendly Foes?

Roftiel Constantine
Lieutenant Colonel, USAF

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Air Force Fellows

Since 1958 the Air Force has assigned a small number of carefully chosen, experienced officers to serve one-year tours at distinguished civilian institutions studying national security policy and strategy. Beginning with the 1994 academic year, these programs were accorded in-residence credit as part of professional military education at senior service schools. In 2003 these fellowships assumed senior developmental education (SDE) force-development credit for eligible officers.

The SDE-level Air Force Fellows serve as visiting military ambassadors to their centers, devoting effort to expanding their colleagues' understanding of defense matters. As such, candidates for SDE-level fellowships have a broad knowledge of key Department of Defense (DOD) and Air Force issues. SDE-level fellows perform outreach by their presence and voice in sponsoring institutions. They are expected to provide advice as well as promote and explain Air Force and DOD policies, programs, and military-doctrine strategy to nationally recognized scholars, foreign dignitaries, and leading policy analysts. The Air Force Fellows also gain valuable perspectives from the exchange of ideas with these civilian leaders. SDE-level fellows are expected to apprise appropriate Air Force agencies of significant developments and emerging views on defense as well as economic and foreign policy issues within their centers. Each fellow is expected to use the unique access she or he has as grounds for research and writing on important national security issues. The SDE Air Force Fellows include the National Defense Fellows, the RAND Fellows, the National Security Fellows, and the Secretary of Defense Corporate Fellows. In addition, the Air Force Fellows program supports a post-SDE military fellow at the Council on Foreign Relations.

On the level of intermediate developmental education, the chief of staff approved several Air Force Fellowships focused on career broadening for Air Force majors. The Air Force Legislative Fellows program was established in April 1995, with the Foreign Policy Fellowship and Defense Advanced Research Projects Agency Fellowship coming under the Air Force Fellows program in 2003. In 2004 the Air Force Fellows also assumed responsibility for the National Laboratories Technologies Fellows.

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Foreword

In *GPS and Galileo: Friendly Foes?*, Lt Col Roftiel Constantine, United States Air Force (USAF), analyzes the heated competition to provide service from high in the skies of medium earth orbit. The European Union (EU) is developing Galileo, its own global positioning and navigation satellite system, scheduled to be operational by 2010. The EU states that Galileo will provide greater precision to all users than is currently available from the United States' (US) global positioning system (GPS) through improved coverage of satellite signals at higher latitudes, and, unlike GPS, Galileo will be guaranteed to be always available—even during war or political disagreement. Regarding the enormous importance of GPS to the United States and millions of users worldwide, the prospect of a second, competing, and potentially interfering global satellite navigation system could have serious military, foreign policy, and industrial implications. The US government would benefit from the heightened awareness of the risks and opportunities Colonel Constantine presents for the United States surrounding the Galileo program.

The author recognizes the Galileo program as a watershed in EU activity; it is the largest project ever organized on a European scale, and it will be the first public infrastructure owned by the European institutions. Many see this program as a way of developing European cohesion while providing such important economic benefits as creating over 100,000 EU jobs and generating a positive revenue stream by charging fees for enhanced positioning and navigation services. In addition, Galileo can be seen as a political statement of European independence from the United States, as Galileo furthers EU sovereignty and provides an alternative to US military and political hegemony in global navigation. Galileo will assert Europe's independence by giving the EU countries guaranteed access to a critical service that the United States currently provides.

Colonel Constantine highlights the effects the emergence of the Galileo system will have on the transatlantic alliance, the North Atlantic Treaty Organization (NATO), the US dominance in defense and security of Europe, and several serious commercial and industrial concerns. In addition, he discusses China's heavy involvement in the Galileo project and the national security dilemma this presents for the United States, as Galileo technologies shared by EU nations would certainly enhance China's military modernization and intelligence programs, not to mention China's own evolving satellite navigation system.

Regarding the military and civilian communities' ever-increasing reliance on GPS signals, the United States has become heavily invested in its GPS program during the past three decades. With this backdrop, Colonel Constantine focuses on the challenges that Galileo poses to US interests and presents several distinct actions to be taken by the US government to protect its industrial, military, and national security interests, namely:

- Ensure that the EU does not impose mandatory use requirements for Galileo and that access to the Galileo hardware market remains fair and does not discriminate against non-EU companies.
- Strongly encourage US allies to adopt formally the GPS military code and equip their militaries appropriately, ensuring their ability to operate continuously with the United States during all levels of training and operations, which will not be the case if US allies equip with Galileo.
- Set the record straight. Counter EU claims to the international audience that Galileo will be available when the United States turns GPS off due to a national crisis. In all likelihood, the United States will cut off both GPS and Galileo during a national crisis to prevent hostile misuse of positioning signals, and only the encrypted GPS military code will be available. In addition, counter the EU assertion of Galileo's greater precision; publicize that by the time Galileo is operational, on-going GPS modernization will deliver precision on par with that of Galileo.
- Address China's major involvement in Galileo and the development of China's own satellite positioning and navigation system. The United States should collaborate with the EU and enter into negotiations with China, similar to the successful US-EU discussions, and address concerns in all multilateral venues.

I can recommend this paper to all who wish to learn more regarding the historical development of positioning and navigation systems, the current state of these systems' technology and capabilities, and the complex military, political, and industrial issues surrounding these vital systems as the United States looks to the future. There is no question that the Galileo system has much to offer and will be a great benefit to the global community; yet, at the same time, it presents many and varied implications. Understandably, the United States must oppose anything that would degrade the GPS's civil or military signals, diminish its ability to deny access to positioning signals to adversaries in time of crisis, or undermine NATO cohesion, the United States must continue to seek to cooperate—and not compete—with the Galileo program.

WILLIAM T. HOBBINS
General, USAF (Ret)

About the Author

Lt Col Roftiel Constantine

Lt Col Roftiel Constantine serves as chief of the Operations and Exercises Branch in the J-6 Division of North Atlantic Treaty Organization's Joint Force Command, located in Brunssum, the Netherlands. He has served as the assistant executive officer to the Air Force chief of staff, Headquarters Air Force; and as the chief of the Architecture Integration Division; secretary of the Air Force, Office of Warfighting Integration; and chief information officer at the Pentagon. He has a broad background of experience in communications and information systems and has served in a variety of leadership positions including flight commander, squadron commander, executive officer, and branch chief on two major command staffs.

Lieutenant Colonel Constantine was born in Fairfax, Virginia, in May 1967 and graduated from Fairfax High School in 1985. He received an Air Force ROTC scholarship, graduated from Georgetown University, and entered the Air Force in September 1989. Colonel Constantine holds an undergraduate degree in computer science from Georgetown University and graduate degrees in systems engineering and political science. He has served as a National Defense Fellow at the Massachusetts Institute of Technology and is currently working on a master's degree in business administration at the University of Maastricht, the Netherlands.

Abstract

The European Union's global navigation satellite system, Galileo, poses concern for the United States' global positioning system (GPS). Areas of exploration include a brief history of satellite navigation and the GPS program, an in-depth overview of the Galileo system, its multifaceted justification, expected economic benefits and revenue streams, and its four-year frequency battle with the GPS. Critical to this discussion is understanding Galileo as an expression of European sovereignty and the United States' corresponding reaction, the importance of the significant international interest in, and cooperation with Galileo, and the strategic implications of China's evolving satellite navigation system. Five distinct actions by the United States government are necessary to protect its industrial, military, and national security interests: acknowledge the existing situation; ensure fair competition for satellite navigation hardware manufacturers; compel allied militaries to adopt GPS now; drive home the fact that, counter to European claims, the availability and precision of GPS will be on par with or better than Galileo; and secure China's cooperation in satellite navigation.

Preface

The European Union (EU) is developing Galileo, its own global positioning and navigation satellite system, scheduled to be operational by 2010. The EU states that Galileo will provide greater precision to all users than is currently available from the United States' global positioning system (GPS), improve coverage of satellite signals at higher latitudes, and will be available during war or political disagreement. In light of the enormous importance of the GPS to the United States and hundreds of millions of other users worldwide, the prospect of a second competing and potentially interfering global satellite navigation system could have serious military, foreign policy, and industrial implications. The Galileo system will affect the transatlantic alliance, the North Atlantic Treaty Organization, the US dominance in defense and security of Europe, and other serious commercial and industrial concerns as well. The US government will benefit from a heightened awareness of the risks and opportunities for the United States surrounding the Galileo program.

Chapter 1

Introduction to the GPS and Galileo Programs

Competition has been shown to be useful up to a certain point and no further, but cooperation, which is the thing we must strive for today, begins where competition leaves off.

—Pres. Franklin D. Roosevelt (1882–1945)

The United States launched its original global positioning system (GPS) satellite in 1978 as the first constellation of 24 satellites that has provided the global community with increasingly accurate positioning, navigation, and timing data at no cost for nearly three decades. Now the European Union (EU) has embarked on developing and launching Galileo, its autonomous global positioning and navigation satellite system, scheduled to be operational by 2010. Galileo's constellation of 30 satellites—each flying with the most precise atomic clocks ever launched into space—is intended to provide greater precision and more reliable high-altitude coverage to its users than is currently available from GPS. In addition, the EU emphasizes that civilian control of Galileo and its commercial focus guarantee its availability during war or political disagreement.

Overview of Major Galileo Issues

The Galileo program represents a watershed in EU activity; it is the largest project ever organized on a European scale, and it will be the first public infrastructure owned by the European institutions. Many see it as a way of developing European cohesion while providing such important economic benefits as creating more than 100,000 EU jobs and generating a positive revenue stream by charging fees for enhanced positioning and navigation services. Galileo can be seen as a political statement of European independence from the United States, as Galileo furthers EU sovereignty and provides an alternative to US military and political hegemony in global navigation. Galileo will assert Europe's independence by giving the EU countries guaranteed access to a critical service that currently is provided by the United States. Similar drives for operational autonomy led to the Airbus consortium of European airplane manufacturers and the Ariane space rocket program.

In light of the enormous importance of the GPS to the United States and hundreds of millions of other users worldwide, all facets of a potentially competing, global satellite navigation system must be closely examined to uncover possible operational, industrial, military, and national security implications. China's heavy involvement in the Galileo project presents a national security dilemma for the United States, as Galileo technologies shared by the EU nations will enhance China's military modernization and intelligence programs—not to mention China's own evolving satellite navigation system.

Chapter Previews

Chapter 2 documents the evolution of satellite navigation by examining the GPS program, its augmentation systems, and modernization plans and by introducing Russia's global navigation satellite system (GLONASS) and China's Compass navigation satellite system. Chapter 3 provides an in-depth focus of the Galileo program, its multifaceted justification, Galileo's expected economic benefits and revenue streams, and the four-year frequency battle with the GPS.

Chapter 4 examines Galileo as an expression of the EU sovereignty, the corresponding US reaction, the importance of the significant international interest and cooperation with Galileo, and the strategic implications of China's Compass system. Chapter 5 presents five actions the US government could undertake to protect its industrial, military, and national security interests: acknowledge the existing situation; ensure fair competition for satellite navigation hardware manufacturers; compel allied militaries to adopt the GPS; drive home the fact that, counter to European claims, the availability and precision of the GPS will compare favorably with Galileo; and secure China's cooperation in satellite navigation.

Chapter 2

History of Satellite Navigation

Throughout time people have developed many methods to determine their position on earth and the means to navigate from one place to another. Early mariners relied on angular measurements to such celestial bodies as the sun and stars to calculate their location. The magnetic compass was invented in the early 1200s and was followed soon by the sextant, which underwent refinement over the next several centuries. Marine chronometers, developed in the late eighteenth century, provided precise timing measurements that, when coupled with sextant sightings of planets and stars, signified the only reliable means of determining a ship's position in unfamiliar waters.[1] In the 1920s, several nations constructed radio beacons along their coastlines to aid sea navigation, but the military recognized that surface-based beacons suffered at least one strategic flaw—they were vulnerable to enemy attack. The space race provided a solution to this by placing the beacons in earth-orbiting satellites. Following the 1957 launch of the Soviet Union's *Sputnik 1*, the world's first artificial satellite, a team of US scientists monitored Sputnik's radio transmissions. They discovered that, because of the Doppler effect, the frequency of the signal being transmitted by Sputnik was higher as the satellite approached, and lower as it moved away. They realized that since they knew their exact location on the globe, they could pinpoint where the satellite was along its orbit by measuring the Doppler distortion.

The first US satellite navigation system, Transit, was a constellation of five navigational satellites that was declared operational in 1964. The US Navy developed and deployed Transit to help guide its Polaris ballistic missile submarines and missiles. The system provided a two-dimensional navigational fix approximately once per hour, with a rated accuracy of 200 meters.[2] During the next 10 years, the United States experimented with several satellite navigation systems, but these were largely ineffective, as none provided dependable global coverage. In August 1974 the deputy secretary of defense declared the navigation satellite timing and ranging (NAVSTAR) GPS—a program that combined the best elements of all existing radio navigation technologies—would be a tri-service program, with the Air Force serving as the program manager.[3]

Global Positioning System

The GPS baseline constellation consists of at least 24 satellites, 21 of which perform the navigation mission and three that serve as active spares. Their orbits are arranged so that five to eight satellites are always within line of sight from almost anywhere on Earth. The launching of GPS satellites began in 1978, and the program officially reached full operational capability in April 1995. As of February 2007, there were 30 actively broadcasting satellites in the GPS constellation.[4]

The ground portion of GPS synchronizes the atomic clocks on board the satellites into a common GPS time and tracks their flight paths. It consists of the master control station at Schriever AFB, Colorado, five Air Force monitoring stations (Hawaii, Kwajalein Atoll, Ascension Island, Diego Garcia, and Colorado Springs), and three ground antennas located throughout the world (Ascension Island, Diego Garcia, and Kwajalein). A user's GPS receiver locates four or more of these satellites, calculates the distance to each, and uses these measurements to determine its location, speed, and time.[5]

GPS Services

Positioning, navigation, and timing technology is inherently dual use, and GPS is no exception. In "Space Diplomacy," the authors point out that "The precision, availability, and speed of its two service levels have made it essential to bankers, network administrators, hikers, pilots, drivers, infantry, and generals alike."[6] The standard positioning service (SPS) is available to all users on a continuous worldwide basis, is free of any direct user charge, and is broadcast on a single frequency. The more secure and survivable precise positioning service (PPS) is encrypted, incorporates antispoofing measures, and broadcasts using two frequencies; the additional frequency provides an added degree of jamming resistance. Access to the PPS is restricted to the US armed forces, US federal agencies, and selected allied armed forces and governments equipped with classified PPS receivers and a current cryptographic key.[7] To prevent an enemy from accessing the PPS through a military receiver, the cryptographic key can be erased with the flick of a switch on the receiver.[8] If a keyed military receiver is recovered by an adversary, access to the PPS will be short-lived because the crypto key must be updated frequently.

Selective Availability

J. A. Lewis argues that "Selective availability was the intentional degradation of the GPS signal that made it less precise for civilian users and was initially intended to ensure that the US military and selected allies obtained greater benefit from GPS than anyone else."[9] Foremost, GPS was designed to provide the US and allied military forces with a positioning and navigational advantage when engaged with other military forces, while still providing a reasonable positioning service to the civil community. In 1983, after Soviet interceptor aircraft shot down the civilian airliner Korean Air Lines 007 in restricted Soviet airspace (killing all 269 people on board), Pres. Ronald Reagan announced that GPS would be made available for civilian use once it was completed. During that same year, however, the Department of Defense (DOD) announced that GPS would provide no better than 100m precision to civilian users by using selective availability (SA) to degrade the signal. The DOD, in accordance with the Federal Radionavigation Plan, first activated SA in March 1990, much to the dismay of the civil GPS user community.[10]

The 1990–91 crisis in the Persian Gulf, the first major test of GPS in a combat situation, proved beyond a doubt its importance and utility, even though "the satellites available in 1991 provided . . . 16.75 hours of three-dimensional GPS service daily."[11] "Some say that GPS revolutionized combat operations on the ground and in the air during Operation Desert Storm and was, as one Allied commander noted, one of two particular pieces of equipment that were potential war winners (the other was night-vision devices)."[12] However, the shortage of military GPS receiver units and the wide availability of commercial ones among coalition forces resulted in a decision to disable SA from August 1990 through 15 November 1991. This was ironic, as SA had been introduced specifically for these situations, allowing friendly troops to use the signal for accurate navigation while denying use to the enemy. But since SA was also denying the same precision to thousands of friendly troops, turning it off presented a clear benefit. Michael Russell Rip and James M. Hasik contend that "Fortunately, Iraq did not possess a weapon system that depended on GPS for guidance."[13]

During the 1990s SA presented a problem for such US civilian agencies as the Federal Aviation Administration, the Coast Guard, and the Department of Transportation that require accurate positioning data. However, citing security concerns, the US military repeatedly rejected requests from these agencies to turn off SA. This led to the development and operation of several differential global positioning systems (DGPS) that locate ground receivers at surveyed locations, determine the GPS signal error by comparing the received GPS positioning data to the known location, and broadcast this error measurement to user receivers. Depending on the amount of data being sent in the DGPS correction signal, correcting these effects can reduce the error significantly; the best implementations offer accuracies of about 5 millimeters.[14]

To encourage greater civilian, commercial, and scientific use of GPS, Pres. Bill Clinton's March 1996 Presidential Decision Directive (PDD) on GPS stated the United States would turn off SA by 2006. Further, it promised the United States would continue to provide basic GPS signals worldwide, and these services would be free of charge to users.[15]

GPS remained a military program, and the US Air Force continued to oversee its day-to-day operations. The US Air Force had provided this global service with superb results since its inception, and no other agency was prepared to manage or to fund GPS.[16] Lewis says "The dilemma was that there was little real internal incentive for the US Air Force to optimize GPS services for civilian and commercial use. The Air Force objective was a satellite navigation system that met present and future military needs. Surprisingly, these can be less demanding than civilian applications, which often require a higher degree of reliability and redundancy."[17] Anticipating that GPS's military oversight would remain a point of contention—as GPS's commercial use outpaced its military use—President Clinton's 1996 PDD created the Interagency GPS Executive Board. This civil-military executive board (co-chaired by the DOD and the Department of Transportation) was charged with GPS oversight.[18] Pres. George W. Bush issued a policy memo in December 2004 expanding membership to include equivalent-level officials from the Departments of State, Commerce, and Homeland Security; Joint Chiefs of Staff; and National Aeronautics and Space Administration, while the chairman of the Federal Communications Commission will participate as a liaison.[19]

Discontinuation of Selective Availability

Partly in response to demands of commercial users, the precision provided by DGPS, and to the threat of the EU's Galileo and Russia's GLONASS, the White House decided in May 2000 to turn off SA—six years ahead of schedule. Lewis writes that "This decision was part of a larger effort to make GPS more responsive to civil and commercial users around the globe. Principally, the decision was driven by a fear that continuation of SA created doubts about the willingness of the United States to provide what had become a critical global infrastructure, and it had acted as an incentive for other nations to build their own satellite navigation systems."[20]

The dramatic improvement in the SPS, following the removal of SA at 0000 hours on 2 May 2000, is represented in figure 1.[21] Rip and Hasik write that the "Spherical Error Probable [SEP] is the radius of a sphere containing 50 percent of the individual fixes—somewhat analogous to the three-dimensional median location. The two-dimension equivalent of SEP is circular error probable, the radius of a circle which has a 50 percent probability of encompassing the true horizontal position."[22]

The end to SA was a significant acceptance of the needs of civilian GPS users around the world in an ever-widening set of applications, including air, road, marine and rail navigation, telecommunications, emergency response, oil exploration, and mining. It recognized GPS's dual-use nature and expressed the US government's wish to treat civilian users as much like military users as possible. As President Clinton stated in his May

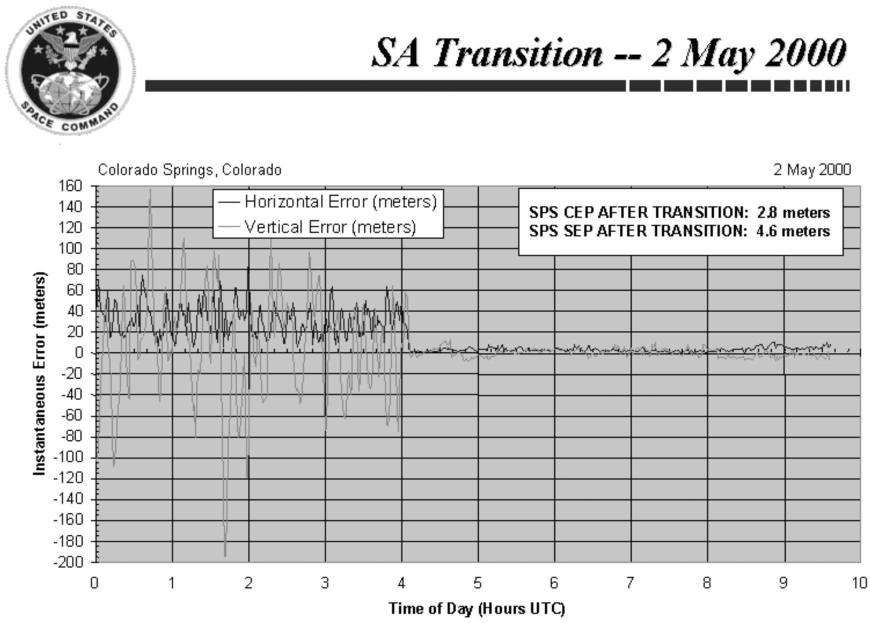

Figure 1. Transition of selective availability to zero. (Reprinted from US Air Force Space Command.)

2000 decision to stop degrading GPS precision, the improvement in precision caused by elimination of SA meant that "civilian GPS users would be able to pinpoint locations 10 times more accurately,"[23] from no less than 100-meters resolution to below 10-meters resolution. Perhaps more importantly, it removed "a significant irritant which constantly reminded users of the US military's control of GPS."[24]

While recognizing that global transportation safety, scientific, and commercial interests could best be served by discontinuation of SA, the Clinton administration reserved the right to deny civilian access to GPS in circumstances where it compromised national security. As President Clinton stated in his 1 May 2000 statement, "We have demonstrated the capability to selectively deny GPS signals on a regional basis when our national security is threatened."[25] Shortly after Operation Enduring Freedom began in early October 2001, a Schriever AFB, CA, spokesperson added that a denied GPS region could be very well defined. That would mean only military GPS receivers with a current crypto key "such as those in planes, ships and in the hands of US Special Forces operators, would work within the targeted area."[26]

GPS Modernization

Long before the European Commission (EC) was developing its initial plans for Galileo in the mid-1990s, the United States was upgrading its GPS satellites to promote further military and commercial use and to significantly improve precision, availability, and reliability. Eleven first-generation GPS satellites, known as Block I or developmental satellites, were launched between 1978 and 1985. They had neither SA capability (and were therefore fully available to civilian users) nor any anti-spoofing security features, they validated the GPS concept, and some were still functioning 10 years after launch despite their design life of five years. Twenty-eight Block II satellites (and Block IIA for advanced satellites) were launched between 1989 and 1997 and incorporated SA and anti-spoofing security features. From 1997 to 2004, the US Air Force launched 12 Block IIR (for replacement) satellites. These satellites enhanced system accuracy by using a technique of ranging and communication between the Block IIR satellites and by increasing the design life to 10 years.[27] Since 2005 three of eight planned Block IIR-M satellites have entered orbit and have broadcast the new military M-code and a second civilian SPS frequency.[28] Whereas military receivers currently require access to GPS's coarse acquisition signal to acquire the PPS, the M-code has been designed for autonomous acquisition, enabling receivers to acquire the M-code directly.[29] The M-code is backward compatible with existing military receivers, is less susceptible to jamming, and enables over-the-air rekeying of military receivers.[30]

Scheduled for launch in 2008, the fourth-generation satellite, Block IIF (for follow-on), will have many improvements over its predecessors, including a 15-year design life, advanced atomic clocks, improved reliability, increased and adjustable signal power, and the addition of a third civil signal for services where lives are at risk as in the case of commercial aviation.[31] Scheduled to begin launching in 2013, GPS Block III (commonly referred to as GPS III) satellites will be the first to be fully compatible with the Galileo satellites expected to increase signal transmitter power 500-fold, multiplying its resistance to jamming. In addition to all the features of the previous GPS satellites, GPS III will transmit a more robust signal and provide near one-meter precision, as more GPS III satellites are placed in orbit. This would improve to less than one-meter precision when augmented by signals from Galileo satellites.[32] This way, GPS III-precision could likely rival the performance of Galileo. Boeing, the prime contractor for GPS III satellites, stated in a January 2007 press release that "GPS III sets a new standard for space-based navigation. . . . GPS III will provide transformational capabilities, such as anti-jamming, to our customer and our war fighters, along with better precision and interoperability with Europe's Galileo system for our commercial and civil users."[33]

GPS Accuracy

GPS's high level of accuracy is largely due to the extremely accurate atomic clocks on board each satellite, ensuring that the pulse of each satellite is sent at precisely timed intervals. Depending on the model, a GPS satellite has either three or four clocks, yet only one clock is operational on each satellite at a time: the others are backups. During Operation Desert Storm, "most users in the Persian Gulf region obtained positional accuracies within 7.5 to 13 meters" and velocity accuracy to within 0.1 meter/second, based on 11,000 navigation solutions for the various monitoring stations and comparing them to their known locations.[34] With SA now turned off, the SPS delivers near-equivalent position accuracy as the PPS, though PPS has the advantage of dual frequency for improved ionospheric correction. This is not a significant factor in the mid-latitudes with little to no sunspot activity.[35] There will be no difference between PPS and SPS accuracy when, beginning in 2012, the 24 GPS satellites in orbit will broadcast SPS on two frequencies (a current function of the Block IIR-M).

As a part of its core mission, the Air Force Space Command's GPS Operations Center (GPSOC) monitors GPS PPS performance and periodically reports operational performance trends and characteristics. Table 1 compares GPSOC's GPS performance measurements during calendar year (CY) 2005 to the previous three years. The table shows that GPS performance followed a general trend of improvement in 2005. (The last row of table 1 combines horizontal and vertical predicted-precision values into a single three-dimensional [3D] position-error parameter.)

Table 1. GPS operational performance summary

Ops Performance Parameter	CY 2002	CY 2003	CY 2004	CY 2005
PPS 95% Horizontal Error	2.36m	2.06m	1.86m	1.78m
PPS 95% Vertical Error	4.13m	3.59m	3.22m	3.08m
PPS 95% 3D Position Error	4.77m	4.18m	3.76m	3.59m

Source: GPS Operations Center, *GPS Operational Performance Report for Calendar Year 2005*, 27 January 2006, 1.

The GPSOC stated that as older GPS satellites, which perform relatively poorly compared with current models are decommissioned and replaced by newer GPS satellites, the constellation will become more precise and thus continue the trend of increasing GPS's positioning precision.[36] Several technical improvements to the ground portion of GPS have further enhanced overall system accuracy by adding more monitoring stations, conducting more frequent atomic clock updates, and minimizing the effects of atmospheric distortions on GPS signals.

GPS and Navigation Warfare

The more the US military depends on GPS, the more it must contemplate navigation warfare against the United States and other allied forces. The objective of navigational warfare is to deny navigation capability to an enemy. Although the integrity of the GPS signal was maintained during the 2001 war with Iraq, attempts to corrupt it underscore the need to protect weapons and navigation systems that rely on GPS.

There are two kinds of GPS countermeasures. The simpler is jamming, where a noise signal covers the GPS signal and causes the receiver to break track. GPS's low-signal strength is its Achilles heel, and the graph in figure 2 shows how vulnerable the GPS signal is to jamming. Less than one watt of jamming

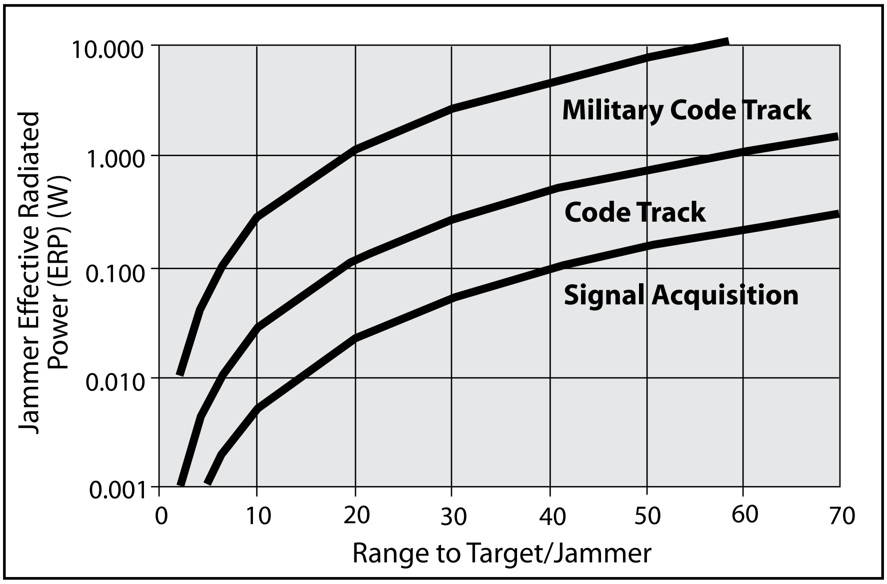

Figure 2. Effective radiated power needed to fully jam GPS signals at a given range (KM). (Reprinted from Michael Russell Rip and James M. Hasik, *Precision Revolution: GPS and the Future of Aerial Warfare* [Annapolis: Naval Institute Press, 2002, 278].)

will prevent a civil receiver from tracking GPS across a range of 25 kilometers. A one-watt jammer, antenna, and battery for 24 hours of operation will fit into a container the size of an aluminum beverage can and is relatively simple to construct. GPS jammers producing several hundred watts of effective radiated power (ERP) could be easily mounted with their power supplies in pickup trucks.[37]

The technology and capability of GPS receivers to resist jamming varies greatly. Acquiring the PPS signal (only possible with a military receiver and a current crypto key) improves jamming resistance by 10 decibels, and using a nulling antenna can boost a receiver's jamming resistance by 15 decibels.[38] While some US military anti-jam receivers lock onto eight rather than four satellites and average some of their data, others employ different techniques. US defense contractor Lockheed Martin developed an anti-jam GPS receiver in 2000 for its joint air-to-surface stand-off missile, which relies on GPS to provide guidance to a target. Lockheed's antijammer "uses digital technology to detect jamming signals and null them," and it "digitally steers the GPS receiver's antenna toward the GPS satellites and away from signals from the jammer."[39] In January 2003, the US Air Force asked Boeing to develop an anti-jam antenna for its $20,000 GPS-guided joint direct attack munitions. The new antenna—comprised of a tail kit attached to a dumb bomb including adjustable fins; a control computer; an inertial guidance system and a GPS receiver—will be able to recognize and ignore a jammer's signals.[40]

An extreme method of handling GPS jamming signals would require first localizing the jammer and second dispatching an aircraft or missile to destroy it, which could be costly if there were multiple jammers. The US military does possess such an offensive capability. For example, the Block V upgrade to the AGM-88C high-speed anti-radiation missile, fielded in 1999, was a software update that introduced a home-on-jam capability, including the option to home on high-power GPS jamming equipment.[41]

GPS's known vulnerability to jamming drove Iraq to purchase GPS jammers from Aviaconversiya Limited, a Russian company that has been promoting its GPS jamming systems at military hardware shows since 1999. Aviaconversiya claimed its products could jam GPS signals for a radius of several miles, and "the Iraqi military used at least six of these high-powered GPS jammers, which cost at least $40,000 each, during the war in 2003. All six were quickly eliminated by US forces over the course of two nights."[42] GPS jamming can be traced to its origin: "We've killed every GPS jammer that's come up—with a GPS weapon—so that hasn't worked out very well for them," said then Air Force Lt Gen Michael Moseley, commander of the United States-led coalition air forces, at a press conference in April 2003.[43]

The other GPS countermeasure is spoofing, or broadcasting a pseudo-GPS signal to confuse GPS receivers by providing false and potentially misleading positioning data to the user, especially problematic when GPS is used to compute target location coordinates based upon its position, range, and azimuth to the target. "If the GPS receiver gives the user a false reading for his location, the target location coordinates based on this false position will also be wrong by the same amount and could result in collateral damage," according to a 2005 video published by the NAVSTAR joint program office.[44] Due to the inherent anti-spoofing qualities of the PPS signal, a civilian GPS receiver using the SPS signal is much more likely to succumb to spoofing and to report a false position than a military GPS receiver using the PPS signal.[45] For this and other reasons, the DOD mandates that its combatant users acquire, train with, and use GPS systems capable of receiving the encrypted military PPS signal.[46] In addition, many missiles and aircraft employ tightly coupled inertial navigation systems and GPS receivers, making the GPS receiver not only significantly more resistant to broadband jamming but also to signal spoofing, where the inertial inputs can be used as a sanity check on the GPS receiver's data.[47]

European Geostationary Navigation Overlay Service

Recognizing the fast-growing military and economic applications of satellite navigation, the EC embarked on its first venture into satellite navigation in 1995, when it called for the development of a space-based differential GPS system. The European geostationary navigation overlay service (EGNOS), fully operational since July 2005, consists of three geostationary satellites and a network of ground stations. It uses the signals from the American GPS and Russian GLONASS satellite constellations to provide users in a geographical area covering Europe, the Atlantic Ocean, the Indian Ocean, South America, Africa, the Middle East, and Central Asia with a high-performance navigation and positioning service superior to the unaugmented GPS signal currently available in Europe.[48] The European Space Agency (ESA) believes EGNOS will provide precision of 2–4 meters vertical and 1–3 meters horizontal.[49]

The EGNOS is the first phase—global navigation satellite system (GNSS) 1—of the European Union's policy on a GNSS; the second phase, GNSS 2, calls for the launch of a second generation of systems that independently provides a full civilian satellite navigation system, which the EC later renamed as "Galileo." Experience with EGNOS helped European scientists to develop much of the required technical capability and expertise in the advanced sector of satellite radio navigation, essential to the development and fielding of Galileo.[50]

The EC highlights two significant advantages of EGNOS over GPS and GLONASS, both of which the EU will incorporate into Galileo. First, EGNOS's purpose is purely civilian, and its civilian management will guarantee reliability and availability. Second, EGNOS provides the user with information on the reliability of the system by transmitting integrity messages within six seconds whenever the quality of the signals received falls below certain thresholds. "When you get a GPS navigation signal, how do you know you can trust it? EGNOS will tell you whether you can trust the signal," said Laurent Gauthier, the EGNOS project manager at the European Space Agency.[51]

Russia's Global Navigation Satellite System

GLONASS, developed and deployed as the counterpart to the American GPS, is run for the Russian government by the Russian space forces, and its functioning is coordinated by units within Moscow's defense ministry. Like GPS, the complete nominal GLONASS constellation consists of 24 satellites; 21 broadcasting satellites, and three on-orbit spares. Also, like GPS, GLONASS was designed for partial civil use and broadcasts its civil signal on one frequency and its precision military signals are broadcast on two frequencies. GLONASS does not have an SA feature, and the Russian government has claimed that it has no plans to intentionally degrade its civil signal, and therefore, the full accuracy of GLONASS will be available to users at all times.[52]

The Soviet Union placed the first operational and test GLONASS satellites in orbit in 1982, and at peak efficiency the system offered a horizontal positioning reading accurate to within 57–70 meters. During 1995 the Russians launched nine GLONASS spacecraft, enabling completion of the GLONASS constellation with 24 primary and one spare satellite. No launches occurred for the following three years, however, and due to their relatively short three-year average lifespan, only 11 spacecraft were operational on 30 December 1998.[53]

GPS and GLONASS signals are not compatible, though a handful of companies offer combined GPS-GLONASS receivers with two sets of signal-processing hardware, principally for the surveyor market. Thus far, GLONASS has been a good GPS augmentation system, filling in during periods when not enough GPS satellites are visible for high-precision use. But that may change as more Galileo satellites broadcast their signals and GLONASS risks fading into obsolescence. The GPS-GLONASS Interoperability and Compatibility Working Group held its third meeting in December 2006 to address this issue. A statement from the meeting claimed that it "resolved many questions regarding interoperability and compatibility between GPS and GLONASS systems," but it did not indicate whether GLONASS would modify its signal, a costly endeavor, to be compatible with GPS and Galileo.[54]

In November 2006, Russian defense minister Sergei Ivanov laid out the plans for GLONASS, noting that, "Today, 14 spacecraft are in orbit," with another three satellites to be launched 25 December 2006. By the end of 2007, GLONASS is intended to cover all of Russia, which will require 18 satellites. (Three GLONASS satellites were successfully launched into orbit on 25 December 2006.)[55] He added that the planned global coverage of the system by the end of 2009 will require 24 satellites.[56] This aggressive schedule is facilitated by a Russia-India joint venture, concluded at the December 2005 summit between Indian prime minister Manmohan Singh and Russian president Vladimir Putin, in which India would launch two GLONASS-M satellites (an advanced GLONASS satellite with a seven-year lifespan) on its geosynchronous satellite launch vehicle platforms and share development costs of the next-generation K-series GLONASS satellites (several internal improvements, half the weight of the M-series spacecraft, and a 10–12 year lifespan). In addition, Russia and India will jointly develop and market GLONASS receivers for commercial use.[57] "At present India is the only country with which we want to develop all aspects of GLONASS," Defense Minister Ivanov said during the seventh Indo-Russian summit in Bangalore on 23 January 2007.[58] India's search for a GPS system had seen it engage in negotiations with the Galileo project, but the deal fell victim to security concerns. Indian negotiators were not satisfied that the information accessible on the proposed system was adequately protected against individuals and possible military users. GLONASS will attract international interest only if users can be assured that the system will meet its navigational requirements; India's satellite launch capabilities and technological expertise will help GLONASS make great strides toward establishing a record of consistent performance characteristic of a mature and reliable navigational system.

China's Compass Navigation Satellite System

On 11 April 2007 a Beidou (Big Dipper) navigation satellite was successfully launched into geostationary orbit about 22,300 miles above the earth. The Chinese previously had launched four other Beidou satellites: two in 2000, one in 2003, and one in February 2007.[59] These Beidou satellites are the first group in a series of space-based navigation platforms called the Compass navigation satellite system. According to China's state-run Xinhua news agency, the fleet should become operational in 2008 for much of China, but it could take several more years before it can be used worldwide. Xinhua further stated that China's vast size warranted a domestic system that would improve on the rough details provided by the civilian-side GPS used around the world.[60] Iain Thomson observes that "Experts said that the system is operating well and has played a significant role in cartography, telecoms, water conservation, transportation, fishery, prospecting, forest fire monitoring and national security."[61] Previous reports said Compass would provide positioning accuracy within 10 meters, velocity accuracy within 0.2 meters per second, and timing accuracy within 50 nanoseconds.[62] In general, China is substantially ramping up its space activity, and this launch came only a few weeks after China prompted expressions of concern from the United States by destroying one of its own aging meteorological satellites with a missile-launched "kinetic kill vehicle."

GPS, Galileo, and GLONASS use satellites that orbit Earth. Compass will position five of its satellites in geostationary orbit above China; they will not move relative to the earth's surface. Thirty other satellites will orbit similarly to the other three GNSS systems.[63] To date, the plans for this network have been shrouded in secrecy, with officials repeatedly declining to comment on the project. However, Xinhua lifted the veil slightly and said that there were plans to launch other navigation satellites in 2007 to create a network covering the whole of China and parts of some neighboring countries by 2008. The Compass system would then expand to offer global coverage with the creation of a constellation of 30 medium earth orbit satellites, Xinhua said, but the news agency gave no timetable for when this would be operational. John Walko recounts that "Analysts have suggested that the expanded Compass system would use the same radio frequencies as Galileo and possibly GPS, making it more difficult for adversaries to jam the network in case of war."[64]

The expansion of Compass into the civilian arena could pose a challenge to the commercial success of Galileo. Experts had believed that China planned to use its Compass system only to support its military forces, and EU backers of Galileo planned to sell receivers and commercial signal subscriptions throughout China. But in November 2006, China announced that in addition to its encrypted military service, the Compass system would begin providing an open level of service with 10-meter precision for commercial users in 2008.[65] This will likely place a large pool of potential Chinese Galileo customers in a position to take the best offer available, possibly significantly impacting Galileo's business plan. Ironically, while China's government and firms are investing 200 million euros (€) in the Galileo project with related facilities and research into commercial applications, Compass is at the same time shaping up as a potential competitor to Galileo.[66]

Notes

(All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.)

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Chapter 3

Galileo

A Program Overview

As early as June 1994, the European Commission displayed dissatisfaction with its strategic dependence on the United States' global positioning system. The EC stated that if Europe did not act promptly, it would not only remain dependent on the United States, but would also be shut out of the "huge associated market for user equipment," as the United States was setting requirement standards and certification schemes.[1]

In 1998 the EC identified several concerns with continued reliance on third countries' positioning and navigation systems, including the following:

1. A perception by the EC that European sovereignty and security would be compromised if Europe's key navigational safety systems were beyond European control;
2. The judgment by the EC that present systems could not fully meet civil users' performance requirements;
3. The desire to ensure that European users are not at risk from changes in the service or excessive future charges or fees; faced with a dominant position or virtual monopoly, it would be difficult to resist such charges and perhaps impossible to develop alternatives quickly;
4. The capacity for the European Union industry to compete in this lucrative market (predicted at the time to become a global market of €50 billion by 2005) would be seriously constrained. Europe's capacity to compete in the market for services could be undermined if it did not have equal access to the technological developments in the system itself.[2]

Galileo Takes Form

Citing several GPS shortfalls—specifically weak and intermittent GPS signal penetration, poor precision, and the ever-present risk of civil users being cut off from GPS in the event of a crisis due to the predominantly military character of GPS—the European Union's Transport Council asked the EC in July 1999 to begin the Galileo definition phase, the initial step in providing the first satellite positioning and navigation system specifically for civil purposes. The Galileo program was officially initiated at the December 2001 EC meeting at the Royal Palace of Laeken in Brussels, Belgium, when the EU—represented by the EC—and the European Space Agency (ESA)[3] committed to the development of a space-based positioning and navigation system of its own that met the criteria for precision, reliability, and security. Facilitating this decision was ESA's prediction of an associated program for equipment and services valued at around €10 billion each year and the expected creation of more than 100,000 highly skilled jobs.[4]

An obvious benefit of the Galileo program is its potential to deepen European integration and strengthen the EU's identity. With the European political identity seemingly inchoate, a unified European effort to take the technological lead in a high-profile strategic system—in keeping with the Lisbon growth strategy to make EU "the most competitive dynamic knowledge-based economy in the world" by 2010, as put forward by the EC in Lisbon in March 2000—is a strong political message, albeit an expensive one, intended to strengthen European integration by developing key strategic sectors.[5]

One of the principal strategic sectors is space, and many Europeans recognize Galileo as an optimal vehicle for pursuing development in that sector. In the summer of 2003, the EC and the ESA formally entered into the Galileo joint undertaking (GJU) to manage the developmental phase (launching the first experimental satellite, developing four more satellites, and validating the concept) of the Galileo program, to mobilize the required funds, and to manage the integration of Galileo and EGNOS. The EU's stated goal was that, when fully operational, Galileo would offer precision superior to the fielded version of GPS due to the structure of its satellite constellation and the robust ground control system. Precision of less than 1 meter has been frequently claimed by the EU and the ESA. In addition, the EC has consistently stated that Galileo will offer superior reliability because it will convey signal integrity information to the user in near real time and because it is intended to cover areas of northern Europe that GPS does not cover.[6]

Declarations of Galileo's superior precision over GPS's appear prominently in the EU's numerous Galileo marketing brochures that are designed to attract large amounts of foreign investment capital—a bold claim to make of a system that has fielded only one experimental satellite (the production satellites is yet to begin) of 30 satellites in comparison to a system that has been fully operational for more than two decades. The Galileo brochures state that, due to the geometry of Galileo's proposed satellite constellation and the modern technology of its satellites and ground stations, Galileo's signal will be more precise than that of GPS. However, the upcoming GPS III satellites will improve GPS's precision from three meters in 2007 to one meter, and GPS users could see a further improvement in precision to less than one meter when augmented by signals from Galileo's compatible satellites.[7] In this way, GPS III's precision will very likely rival that of Galileo when both systems are operational.

The core of the Galileo system will be the global constellation of 30 satellites in medium earth orbit. The mechanism for creating the constellation will be a series of rockets, each carrying multiple satellites, with a dispenser to deliver into orbit up to six spacecraft simultaneously. Galileo's ground station network will consist of sensor stations to monitor the satellites, two control centers to manage the satellites' navigational signals and monitor the system's integrity, and uplink ground stations to communicate with the satellites.[8]

Program Phases and User Services

The Galileo infrastructure is being implemented in three phases. Phase 1, the development and validation phase (2002–8), includes the launch of the first experimental satellite, development of four more satellites and ground-based components, and validation of the system in orbit. This phase's €1.1 billion cost is being shared equally by the EC and the ESA.[9]

Phase 2, the deployment phase (2009–10), will consist of construction and launch of the remaining 26 satellites and installation of the complete ground segment. A consortium of eight European aerospace and defense companies, communications device makers, and satellite manufacturing companies is expected to contribute two-thirds of the €2.3 billion needed to launch the satellites.[10] The remaining one-third of the funds will come from EU transportation funds.[11]

Phase 3, the commercial operating phase (2011 and beyond), will include routine operations and maintenance of the system for at least 20 years. The GJU will select a commercial operator, or concessionaire, to lead Galileo through this phase. The concessionaire will have to meet the annual operations, maintenance, and replenishment charges, calculated at around €220 million.[12] The ESA anticipates public funding will be required until 2015, when the revenues generated from the sale of Galileo services should exceed maintenance costs.[13]

Galileo is expected to offer several layers of service. The open service will be oriented toward mass-market applications, providing free-of-charge accessibility by any user with a receiver. It will use a combination of Galileo and GPS signals to improve performance when necessary, such as in urban areas, but will not have a service guarantee. The safety-of-life service will be as precise as the open service, but it will be optimally integrated with EGNOS to deliver a high integrity and guaranteed signal. This service will be certified and oriented toward transport applications (such as aircraft landing assistance and ship guidance through coastal waters) where human lives could be endangered if the performance of the navigation system degrades without near-real-time notice. The fee-based commercial service will add two encrypted signals to increase positioning precision and will be aimed at market applications requiring higher than open service performance, such as those that offer service guarantees or precise timing services. The search and rescue service will enable a user to send a distress signal and obtain acknowledgement of its receipt. Such civil authorities as police departments, emergency medical services, fire departments, coast guards, and customs agencies will use the encrypted and anti-jam public regulated service (PRS), and its robust signal will resist jamming and spoofing.[14]

Galileo will broadcast its signals on two frequencies, one of which is already used by GPS. Sharing this band with GPS will be on a non-interference basis to avoid affecting GPS services while offering users simultaneous access to GPS and Galileo and minimizing terminal costs and complexity.[15]

Economic Benefits

Only two independent global satellite navigation systems currently exist, and both were designed for national security needs during the Cold War: Russia's GLONASS and the United States' GPS. GLONASS is not fully operational and is plagued by low levels of precision and reliability—problems that have worsened with Russia's political and economic crisis during recent years. Although this system will likely improve with India's contribution of launch support and technical assistance to the Russian program, GLONASS cannot realistically be considered a competitive threat to European ambitions.

The ESA has argued that Galileo is not an expensive program. In 2005, the ESA estimated the development and deployment costs, including launching the 30 satellites and installing the network of ground stations, to be €3.8 billion; annual operations, maintenance, and replenishment costs were estimated at €220 million. As ESA was quick to point out, this was equivalent to the cost of building 150 kilometers of highway and was even less than the cost of the fifth terminal being built at Heathrow Airport.[16] Furthermore, the international accounting and consulting firm, PricewaterhouseCoopers, conducted an independent analysis of Galileo's proposed infrastructure and services in 2001 and concluded Galileo's cost/benefit ratio to be much higher in comparison to any other European infrastructure project thus far completed.[17]

Galileo proponents have consistently stressed the potential commercial benefits from the construction and operation of an independent European satellite-based positioning and navigation system since the EC feasibility studies in 1999. In discussing the implications of Europe's GPS dependence on its common foreign and security policy, the EC stated that "Europe is now in a position to decide whether to develop a new system. By contrast, failure to act would strengthen the present US market dominance and leave Europe entirely dependent on the US for many security-related matters."[18] The EC recognized both the economic benefits Europe would gain by developing

Galileo and the sense of security from controlling the system on which its safety critical services would depend. Accordingly, EU discussions leading up to the decision to proceed with Galileo focused on job creation, technological spillover effects, and monetary benefits—provided the EU could break into the satellite navigation market at the right time, that is, before the advanced GPS III constellation becomes fully operational and marginalizes the advantages of Galileo over GPS.

Europe's approach to Galileo is unique in its stated focus on civilian and nonmilitary applications of space research programs and the diffusion of knowledge and related advantages to the benefit of the Galileo community. In a key aspect of their 1999 argument for Galileo, the EC emphasized that the presence of European industry in this high-technology field would greatly help secure and augment employment. It estimated that putting the satellite navigation infrastructure into place would create 20,000 jobs; expected its operation would create 2,000 permanent jobs with new employment opportunities in applications (hardware and services); and anticipated that by 2008 approximately 100,000 jobs in direct, indirect, and induced employment depended on going ahead with Galileo.[19] In 2006, the EC increased its job creation estimate to 150,000, primarily in high-tech sector jobs.[20] Building Galileo's infrastructure and creating a large number of highly skilled jobs will likely have significant spillover effects on the rest of the EU economy. Galileo's high value-added manufacturing can lead to gains in the EU's innovation, productivity, rapid development of advanced products, and the accumulation of intellectual capital.[21]

Galileo's EU proponents see the potential for significant economic benefit to the Galileo operator community if they can break into the market quickly. According to the EC, European industry's share in satellite navigation markets in the late 1990s was only around 15 percent of the European market and 5 percent of the global market. The satellite industry and its EU supporters framed the need to support Galileo for ensuring a future European position in the space segment and end-user equipment markets around the world. According to the EC's estimate in 2004, the global market in products and services linked to satellite-based positioning and navigation technology was nearly €10 billion per year; growing at an annual rate of 25 percent, it was due to rise to about €300 billion in 2020. The EC estimated that some three billion receivers would be in service by 2020.[22] However, PricewaterhouseCoopers's 2001 analysis stressed that Galileo begin Phase 3 operations by 2008 to secure an increased share for Europe of the user equipment and related technologies markets. These markets would be in a rapid growth phase by then, and GPS III was expected to commence operations one or two years thereafter. According to PricewaterhouseCoopers, Galileo will become established only if it is in the market in time to gain acceptance in the launch of new equipment and services that will accompany this change. If this happens before GPS III comes on line, the 2001 PricewaterhouseCoopers's review estimated that the annual sale of Galileo receivers would increase from 100 million units in 2010 to some 875 million units by 2020, which represents market share rising from 13 per cent to 52 percent.[23] Since that 2001 estimate, the launch of the Galileo satellite constellation has slipped to 2010, but Galileo's window of opportunity is still open, as GPS III's launch has slipped to 2013.

Revenue Streams

Several potential Galileo revenue streams have been identified, some of which depend on regulatory action. The future concessionaire, leading Galileo's Phase 3 operations, would receive payment for the sale of the various services generated by the Galileo system.

One potential revenue stream would be the controlled-access services (those fee-based services controlled by way of encryption, including reliable signals for such safety-of-life applications as civil aviation and maritime transport) available to subscribers for certain fees. In some cases, such as access to infrastructure or monitoring fishing activities, freight and coach transport, and road safety services, these services might be mandatory. Insofar as Galileo allows existing ground-based air navigation facilities to be replaced and provides a better and more reliable service to airlines, it can be expected that airlines will contribute to the revenue stream.[24] There is precedent for this as the International Maritime Organization has required internationally registered ships to carry GNSS equipment since 2000, and GNSS is an integral part of the communications, navigation, surveillance/air traffic management concept adopted by the International Civil Aviation Organization.[25] However, industry officials believe that persuading airlines, shipping companies, and civil engineering groups to pay for the extra precision will be difficult. "Our position is that it is not really clear at this point that we need this paid service; we already have GPS for free, and we will have basic Galileo free of charge, and for now those are sufficient," said Vincent De Vroey, general manager for technical operations for the Association of European Airlines in Brussels, which represents more than 30 European airlines.[26] If revenue from industry does not come through, European taxpayers could end up footing the bill for the system for several years, according to Peter Marchlewski, general counselor of the GJU until December 2006.[27]

Another possible revenue source would be a tax on receivers and for satellite-based radio-navigation services. The tax would need to be introduced throughout the EU and be applicable to all receivers sold in or imported into the EU, including equipment for in-car navigation, leisure activities, and so forth. According to the EC, "This would be entirely in line with the general EC philosophy of marginal infrastructure cost charging and could be limited to very small sums."[28] Similar taxes are already used in a large number of EU member states for such products as photocopiers and video cassettes and for such services as public television and radio broadcasting.[29] A tax of €20 on each receiver would provide a revenue stream of €140–205 million annually and could go a considerable way to filling the financing gap for long-term operations and maintenance of Galileo.[30] It would also be possible to introduce, although more difficult to implement, an annual operating license fee for the reception of satellite navigation signals.

Frequencies: From Competition to Cooperation

In 2001, GPS and Galileo seemed poised to compete for the same radio frequency spectrum. Galileo planned to use a frequency for its public regulated service that would conflict with the frequency the United States would begin to use in a few years for its second military signal, the GPS M-code, which was planned to be broadcast initially from seven GPS-IIR-M satellites, three of which have been launched since September 2005.[31] The signal characteristics of GPS's M-code would enable the United States to jam its own civilian frequency in a conflict zone to prevent enemy forces from using it, without affecting the M-code's availability, thus providing the United States and its allies exclusive and uninterrupted positioning and navigation services. Likewise, the United States wanted the ability to jam Galileo without rendering ineffective the GPS M-code signals. Some US observers speculated that this signal fratricide envisioned for Galileo and the GPS military signal was intentional, designed to force the United States to jam its own signal to deny Galileo services to an opponent.[32]

In December 2001 this situation prompted US deputy secretary of defense Paul Wolfowitz to write to the ministers of defense in those EU countries that were North Atlantic Treaty Organization (NATO) members to convey US concerns over the signal competition, highlighting potential damage to future NATO operations. Wolfowitz noted that the addition of any Galileo services in the same spectrum "will significantly complicate our ability to ensure availability of critical GPS services in time of crisis or conflict and at the same time assure that adversary forces are denied similar capabilities." He added that it was in the interest of NATO "to preclude future Galileo signal development in the spectrum to be used by the GPS M-code."[33]

Galileo's potential signal interference with GPS raised much resentment in the United States and both sides entered into four years of difficult negotiations. J. A. Lewis maintains that "Success in the negotiations was not predetermined, as Galileo had become an irritant in the transatlantic relationship."[34] But, in the end, the parties agreed to make the two systems compatible and interoperable rather than competitive.

In June 2004, a cooperation agreement was signed between the EU and the United States that recognized the full autonomy of Galileo. In return for modifying Galileo's signals to protect the GPS M-code, the United States agreed to provide Europe with technical assistance in developing Galileo and to ensure that GPS III satellites would conform to Galileo's broadcast standards.[35] It would make Galileo's signal "the de facto international standard," said Charles Ries, the US State Department's principal deputy assistant secretary for Europe.[36] This cooperation would aid the interoperability of the two systems, supporting a commercial desire of both the United States and the EU to develop straightforward and fully interoperable receivers.

Out of the Gate: Early Programmatic Challenges

Despite all its promise, Galileo faces some tough challenges. Only one satellite had been launched by December 2005. The second satellite—originally scheduled for launch in April 2006, then September, and then December—was set to launch sometime in 2007, according to ESA's general director, Jean-Jacques Dordain.[37] The EU schedule still shows all 30 satellites in orbit by the end of the present decade.

The estimated cost of developing the system has soared far beyond the EC's 1999 cost estimate of between €2.2 and €2.9 billion[38] and is now projected at €3.8 billion.[39] EU officials attributed Galileo's cost overruns to increased security to prevent breakdowns, software upgrades, rising labor and marketing costs, and two additional test satellites needed to check the frequencies Galileo will use.[40] When operational, the EU expects Galileo to cost €220 million per year to operate. With fewer satellites than Galileo, the US Air Force places GPS annual operating costs at about €576 million,[41] suggesting that the EU may be underestimating Galileo's true operating costs. Recent arguments among the EU nations to acquire a portion of Galileo's operations in their territory, in addition to power struggles among the eight consortium companies, have caused significant delays in Galileo's development and deployment schedule.[42]

System Availability: GPS versus Galileo

Central to the decision to develop and operate a separate, independent GNSS service is the EU's uneasiness with continued US military control over GPS. Despite US assurances that the United States intends to make GPS available on a continuous worldwide basis for the near future, the EU has adopted the view that GNSS continuity has become too important to be left to the US military. One of Galileo's competitive advantages will be its continuous and reliable signal for all users, which will allow the wider deployment of applications, especially commercial ones. The EU and the ESA highlight Galileo's guaranteed availability as superior to GPS's availability by citing "the predominantly military character of GPS means there is always a risk of civil users being cut off in the event of a crisis."[43] According to Title 10 of the *US Code*, the DOD—as owner and controller of GPS—can interrupt reception for reasons of national security without notice.[44] However, the likelihood of GPS being turned off, even for a limited area of operations, is extremely remote. As Ralph Braibanti—director of Space and Advanced Technology for the US Department of State and head of the US delegation for GPS-Galileo consultations—stated, "The US provides the GPS civilian signal to a very high degree. The possibility of a limited shutdown is a red herring as we have never done it and do not plan to even in situations like we experienced in Kosovo and the Gulf region during Desert Storm."[45]

Further, if the United States decides to jam the GPS civilian signal due to a crisis, not only will it limit that denial to a local area of operations to minimize collateral damage, the United States will jam Galileo's positioning and navigation signals in that area also. The 2004 US-EU agreement to cooperate on frequencies separated Galileo's civilian signal from GPS's military signal, enabling the United States to jam GPS and Galileo civilian signals without harming GPS's military signal. This way, Galileo's signal will not be available when the United States decides to turn off civilian GPS. Therefore, GPS's civilian signal is just as available as is Galileo's signal. Ironically, it is not Galileo's signal that offers continuous availability, as the EU advertises heavily in its glossy Galileo brochures, but rather it is GPS's encrypted military signal.

Notes

1. "Satellite Navigation Services," 11.
2. European Commission (EC), "Towards a Trans-European Positioning and Navigation Network," 5.
3. The European Space Agency (ESA) has 15 member states: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, the Netherlands, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Canada

also takes part in some projects. Norway and Switzerland are members of ESA but not the European Union (EU).

4. ESA, “Galileo, the European Program,” 10.
5. Cheli and Darnis, “Towards a European Space Strategy?” 105–6.
6. ESA, “Galileo, the European Program,” 5–8.
7. Kim, “Global Position System,” 24.
8. Ibid., 25.
9. “Progress report on the GALILEO research programme,” 2.
10. The eight European aerospace and defense companies are Astrium, the satellite unit of European Aeronautic Defense & Space Co.; Inmarsat PLC; Thales SA; TeleOp; Finmeccanica SpA; Aena; Hispasat SA; and Alcatel-Lucent’s Alcatel Space.
11. EC, “Proposal for a Regulation.”
12. ESA, “Market Prospects and Business Opportunities.”
13. ESA, “Galileo, the European Program,” 13, 33.
14. Ibid., 22–23.
15. Ibid., 26.
16. Ibid., 11.
17. “Inception Study,” 8.
18. EC, “Galileo, Involving Europe,” 2.
19. Ibid., 4.
20. EC, COM 2006, 2.
21. Lembke, “Strategies, Politics, and High Technology in Europe,” 254.
22. “Progress report on the GALILEO research programme,” 2.
23. “Inception Study,” 4.
24. EC, “Galileo, Involving Europe,” 16.
25. Ibid.
26. Jolis, “Problems Run Rampant for Galileo Project.”
27. Ibid.
28. “Galileo, Involving Europe,” 23.
29. Ibid., 16.
30. Ibid., 17. Assuming that by 2010 around 50 percent of new cars are equipped with a GNSS-based positioning device and with around 14 million car sales in Europe annually, a levy of €20 would raise €140 million per year.
31. Navstar Global Positioning System Joint Program Office, “GPS Overview.”
32. “Progress report on the GALILEO research programme,” 12.
33. “US Warns EU About Galileo’s Possible Military Conflicts.”
34. Lewis, “Galileo and GPS: from Competition to Cooperation,” 1.
35. US Navy, “Agreement on the Promotion, Provision, and Use of Galileo,” 11.
36. Taverna, “Cross Talk,” 49.
37. “Galileo Industries Told to Put House in Order.”
38. EC, “Galileo, Involving Europe,” 5.
39. “Galileo Adrift in European Outer Space.”
40. Jolis, “Problems Run Rampant.”

41. GPS Wing Fact Sheet.
42. Marks, "Political Infighting Threatens Europe's SatNav Plans."
43. Simon, "Galileo, the European Programme," 7.
44. "Global Positioning System."
45. Warner, "EU Transport Ministries," 1.

Chapter 4

Geopolitical Perspectives

The EU's European Security and Defense Policy (ESDP) has been criticized for being more of a declaratory policy, one not translated into concrete facts. An important landmark was reached in 2003 with the publication of the European security strategy, the European counterpart to the United States' national security strategy; for the first time, the EU formulated joint guidelines for a coherent European international security strategy. Furthermore, the EU missions in the Congo (Operation Artemis) and Macedonia (Operation Concordia) were the first autonomous EU external military missions, important milestones in operationalizing ESDP. These missions, coupled with the ESDP's call for an even greater role for the EU troops in humanitarian, peacemaking, and peacekeeping activities in conflict theaters outside the EU's borders require information and data transmission on a global scale. Space technologies, especially programs like Galileo, represent the backbone of the infrastructure for future interventions in crisis theaters.[1]

Departure from US Hegemony

The general expansion of the European space sector, including the security-related aspects of European space policies affording Europe a greater role in its control of space-based information systems, also affects US-EU relations. Satellite radio navigation services supporting military and civilian applications across the EU have been provided by GPS. However, total dependence on a foreign power for a major feature of national infrastructure implies that one could never afford to upset that power to the point that it might threaten to withdraw that service. Therefore, the EU's policies would bind to some degree to those policies of the United States. Recognizing this issue in 1998, the EC highlighted serious limitations to Europe's sovereignty and security if its safety critical navigation systems remained beyond its control and suggested that this would force its continued reliance on other countries' positioning and navigation services.[2]

This concept was advanced in the EU's November 2000 European strategy for space. Still the most current European space strategy document, it highlights the strategic importance of space for economic and political growth in Europe, the global competitiveness of European industry as an industrial policy priority, and the importance of Galileo. When first written, it represented a "sharp break from the past, with space contributions to security and defense being seriously considered for the first time above the national level. The strategy calls for the EU to provide a common policy framework by integrating European space and making its history of fragmentation along national lines a thing of the past."[3] The March 2005 report of the EC's panel of experts on space and security concludes that during the Cold War, it made sense for Europe to rely on non-European (i.e., United States) space-based systems to support the EU's security, as Europe largely relied on the United States for its collective security and had no need for an organic expeditionary capability. The report goes on to note that since the end of the Cold War, Europe's security situation has been rather different, and, with the establishment of the European Defense Force, Europe and its member states are increasing their capabilities to operate outside their borders in expeditionary forces on a variety of multinational military and civil operations. This panel of experts stressed that Europe no longer could assume a fortuitous coincidence of interest with the United States.[4]

Galileo's business plan clearly has provided strong economic and commercial justification in its own right, but the Galileo program is unquestionably a political initiative as well. Underpinning the EU support for Galileo is the strong desire for political autonomy, and developing a stand-alone European satellite system is evidence of the EU's desire to free itself from its US dependency in this area. In addition, given Galileo's expected technological spillover to military and aeronautical sectors, the decision to proceed with Galileo has wider significance in terms of EU autonomy. Overall, Galileo has become a symbol of Europe's technological capabilities and its quest for further political independence. A central conclusion of the European strategy for space is that Europe should not remain dependent on foreign space infrastructure for strategic or commercial applications.[5] This followed from the belief that space was an essential national infrastructure and that it would be foolish to depend on foreign sources of supply in this vital sector. French president Jacques Chirac even went so far as to state that if Europe did not fund Galileo, Europe would become an "American vassal."[6]

US Reaction

An early US concern was that in moving forward with the Galileo program, Europe was spending funds on "a military service that was already provided by the US, funds that could be better spent addressing more pressing shortfalls in European military capabilities."[7] In relation to the United States, defense spending among US allies has been declining for the past several years. The NATO-member defense budgets have fallen from 2.49 percent of the gross domestic product (GDP) in 1993 to 1.8 percent of the GDP in 2005—compared to the 3.7 percent of GDP spent annually by the United States.[8] In fact, according to US Army general Bantz "John" Craddock, Supreme Allied Commander Europe, only six of NATO's 26 member nations meet the organization's goal of spending a minimum of 2 percent of their GDP on defense.[9] The United States, understandably, would have preferred that the EU spend its limited funds on programs that yielded a greater return in military capabilities—especially those capabilities that would enable Europe to participate more evenly in joint operations—rather than divert its funds to provide duplicate satellite navigation capabilities.[10]

However, it quickly became clear that the EU rationale for Galileo had important economic, commercial, and strategic aspects that would outweigh any US protests in European decision making. Thereafter, faced with the EU's concrete support of the program, US interests turned to ensuring the compatibility of GPS and Galileo and the capability of each to serve as a back up for the other in case of a malfunction.[11] User benefits from receiving signals from both satellite navigation constellations will include improved precision, reliability, and availability. Currently, GPS users may find their signal path to the satellite constellation significantly reduced by buildings, trees, bridges, or other obstructions. With twice as many satellites visible in the sky, the probability will be much lower that signal blockage will interfere with the delivery of the GPS and Galileo navigation solution. Applications that are currently marginal, or impossible, will become more viable and cost effective for users. Using interoperable frequencies will enable simplified receiver design (e.g., same antenna and circuitry), leading to lower costs for consumers.[12]

As warfare in the electronic arena continues to advance and the doctrine of "network-centric warfare" moves toward center stage, the use of satellite-based navigation and positioning systems has become essential for armed forces. As such, the United States would oppose anything that would diminish the ability to deny access to positioning signals to adversaries during a crisis, and how the United States would act to prevent the hostile misuse of Galileo has been considered by senior US government officials for the past several years.[13] A glimpse of a possible course of action was provided in October 2004, when US representatives at a space conference in London warned that the Pentagon could attack Galileo's satellites if the system were hijacked by a hostile power such as China.[14]

Following a Trend: Airbus and Ariane Programs

According to Braunschvig, Garwin, and Marwell, "This is not the first time that US technological superiority has prompted innovation in Europe."[15] The EU and the ESA, together with other major interested parties, view the Galileo project as equivalent in potential to other successful large-scale European efforts such as Airbus and Arianespace, both of which were developed when the United States' lead in airplane production and rocket launch sectors seemed out of reach.[16]

Airbus Industrie was set up by France, Germany, and England to offset US supremacy in the civilian airplane manufacturing industry; it now threatens Boeing for world dominance in the aircraft industry. The EU's decision to start building its own rocket launchers in the early 1970s, when the United States was aggressively lobbying the non-Soviet world to use its cheaper space shuttle for satellite launches, produced Ariane, which successfully seized a significant share of the satellite launch business when the United States terminated commercial satellite launchings by the space shuttle following the

Challenger disaster in 1986. Virtually all space launch business previously had been performed in the United States, but now Ariane has become the most widely used commercial launch system in the world.[17] As with the Airbus and the Ariane rocket programs, the expectation is that Galileo will follow suit and enable Europe to acquire some technological independence in the satellite navigation sector.

International Cooperation

Foreign participation has provided a significant portion of the funds (on the order of hundreds of millions of euros) required for Galileo's development and deployment. The involvement of foreign participants is a means to demonstrate European political leadership in space activities. Furthermore, as a global system, Galileo needs global partners to develop its full potential, so cooperating with countries beyond the EU's borders is essential. The ESA has thus been interested in involving international partners to the Galileo project.

In October 2003 China became the first country to sign an agreement with the EU when the National Remote Sensing Center of China entered in the GJU with an investment of €200 million.[18] However, "the agreement remains a shell and the ultimate role China will play in Galileo is unclear."[19] In July 2004, Israel's Matimop, the Israeli Industry Center for Research and Development—coordinator of industrial research and development cooperation between Israel and the international high-technology community—signed a membership agreement with the GJU and contributed €18 million. The agreement with Israel provided for joint work on research, satellite manufacturing, follow-up services, and marketing.[20] India agreed to participate in Galileo in September 2005 but withdrew over concerns of China's involvement and instead partnered with Russia on GLONASS. Similar agreements were contracted with Ukraine in June 2005, with Morocco in November 2005, and with South Korea in January 2006. Steps also have been taken to involve several other countries, notably Norway, Argentina, Switzerland, Brazil, Canada, Australia, Saudi Arabia, and Russia. The next step for the GJU is to determine the scope and the arrangements for cooperation with these third countries in future phases of the Galileo program.[21] "Third countries are more enthusiastic than certain European countries about Galileo," EU transport commissioner, Loyola de Palacio, said in 2003, referring ironically to wrangling in the (then) 15-member bloc about funding for the project.[22]

However, the primary reason underlying international cooperation is not the need to meet the demands of individual countries but the need to ensure interoperability with existing systems to promote European industrial and political know-how, stimulate the creation of system applications, penetrate the markets of these third countries, and install components of the terrestrial segment in certain parts of the globe. That numerous third countries are associated with the program and share the European Union's interests in promoting Galileo has helped to reduce the technical and political risks involved. These worldwide links with future users make it possible to define more precisely user requirements. Lastly, international cooperation has provided considerable funding to support the Galileo project.

Security Implications of China's Compass System

The heavy involvement of China in the Galileo program is troubling for the United States. A principal US concern with China's participation in the Galileo program is that it will allow China to transfer not only Galileo's advanced technology and knowledge to significantly enhance its Compass system but also the advanced technology of the United States. Recently, Lockheed Martin—a principal US defense contractor in the development of GPS III satellites, and Astrium, one of Europe's leading satellite systems specialists and a subsidiary of the European Aeronautic Space and Defence Company (EADS)—announced that a cooperative agreement had been signed to ensure the "interoperability, integrity, and optimization" of GPS III with the Galileo program. "This opens a new dimension of cooperation between two of the world's leading technology companies in systems that will benefit consumers for decades as the Galileo and GPS III come on line," noted Reinhold Lutz, EADS senior vice president for Earth Observation, Navigation, and Science.[23] However, because of China's significant involvement in Galileo, this agreement could benefit China by providing indirect access to advance US technologies.

A recent RAND Corporation commentary stated the following:

> China has a history of using foreign technology and assistance to improve its military. This has increased its ability to copy weapon systems, to quickly integrate advanced technology into Chinese production lines, and to raise the technical expertise of their defense production sector. Chinese participation in Galileo is part of a gradual trend in economic and defense cooperation with Europe that in recent years has seen European governments and businesses sell to China technology that could be used for military purposes. This includes British micro- and nano-satellite technology that can be used in anti-satellite weapon systems, British airborne early warning radar that can be used in military aircraft, German engines that can be used in conventional submarines, and French and Italian technology that can be used in attack helicopters.[24]

In contrast to US concerns, senior EU officials have played down concerns about China's involvement in Galileo. Hans Peter Marchlewski, general counselor of the GJU, said the agreement with Beijing ensures that it is "explicitly excluded" from confidential signals affecting Western security. EU officials say the aim is to provide Beijing with a more sophisticated satellite system limited to civilian use.[25] However, European officials admit Beijing has shown interest at the top end of Galileo, including its encrypted and jam-resistant PRS. To remove any gray zones about its use, EU ministers confirmed in December 2004 that the PRS would be available only for such military uses as pinpointing locations, not for missile technology. Heinz Hilbrecht, a director at the European Commission, insists that the PRS "will not be offered outside the EU. It is very clear that certain confidential things, for example those linked to intellectual property rights, will not be opened to the Chinese. . . . The Chinese will use Galileo for specific applications and we have no indication that they would use it for military operations."[26]

Meanwhile, China is doing little to mollify US concerns regarding its peaceful intentions. For example, a targeted attack in September 2006 on orbiting US intelligence satellites by a ground-based laser was confirmed by sensors on Kwajalein Atoll to have originated in mainland China.[27] Then, on 11 January 2007, China destroyed a defunct Chinese weather satellite by hitting it with a warhead launched on board a ballistic missile, making China only the third country after Russia and the United States to shoot down anything in space. The message China has sent through these hostile actions is quite clear, "despite the opacity of China's space and military programs and deepening suspicion over its stated commitment to the purely peaceful use of space."[28] As Vice President Dick Cheney stated in February 2007, "Last month's anti-satellite test and China's continued fast-paced military buildup are less constructive and are not consistent with China's stated goal of a peaceful rise."[29]

Notes

1. Cheli and Darnis, "Towards a European Space Strategy?" 109.
2. European Commission (EC), COM 29.
3. Gleason, "European Union Space Initiatives," 19.
4. EC, "Report of the Panel of Experts on Space and Security," 37–38.
5. Bildt, Peyrelevade, and Späth, "Towards a Space Agency."
6. Kettmann, "Europe Gives Go-ahead to Galileo."
7. Lewis, "Galileo and GPS," 7.
8. Hackett, "Military Balance 2007," 24.
9. McMichael, "US Troops in Europe Would Need Backups," 27.
10. Lewis, "Galileo and GPS," 7.
11. Cheli and Darnis, "Towards a European Space Strategy?" 110.
12. US Department of State and US Department of Commerce, "GPS-Galileo Negotiations," 10.
13. Ibid., 8.
14. "Insider Notes," *United Press International*.
15. Braunschvig, Garwin, and Marwell, "Space Diplomacy," 158.
16. ESA, "Galileo, the European Program," 10.
17. Morton, "Europe's New Air War," 8.
18. ESA, "Galileo, the European Program," 11.
19. Johnson, "China's Space Program."
20. "Israel Signs up to European Satellite Project,"*Agence France Press*.
21. EC, "Taking Stock of the GALILEO Programme," 9.
22. *AFX European Focus*. "India to Invest 300 Million Euros."
23. Stakelbeck, "Red Skies."
24. Jones and Larrabee, "Let's Avoid Another Trans-Atlantic Feud."
25. Minder, "China's Focus on Galileo," 20.
26. Ibid.
27. Stakelbeck, "Red Skies."
28. Bodeen, "China's Space Effort Seen in New Light."
29. "Cheney: China Actions Worrisome," *USA Today*, 5.

Chapter 5

Five Steps the US Government Should Undertake

The United States must undertake the following five distinct actions to protect and promote its industrial, military, and national security interests: (1) acknowledge the existing situation; (2) ensure fair competition and protect satellite navigation hardware manufacturers; (3) compel allied militaries to adopt GPS now; (4) drive home the fact that, counter to European claims, the availability and precision of GPS will be on par with or better than Galileo; and (5) secure China's cooperation in satellite navigation. The following paragraphs detail the rationale for this imperative.

Through its provision of GPS free of user fees, the United States has been able to promote its national interests by maintaining the system as an international public good. The benefits of providing such a system include international prestige, technological leadership, economic competitiveness, and the security that comes with having political control of a global resource. The United States currently plays the role of political and technological leader and as such may see Europe as beginning to challenge this status through the Galileo system.

However, the United States should not have been surprised by EU concerns over GPS in the mid-1990s; several of the EU remarks corresponded with the findings of its own review of GPS and its planned evolution. The 1994 National Defense Authorization Act called for a study to provide recommendations on the GPS program's way ahead and to ensure it continued to meet military and civilian needs, and the Global Positioning System: Charting the Future commission was convened and was led by former US Secretary of Defense James Schlesinger. The Schlesinger commission's May 1995 summary report highlighted international acceptance of GPS as central in dissuading the development of multiple competing satellite navigation systems, thereby enabling the United States to retain its leadership position in this sector. The report cautioned that the United States' approach to GPS must not appear "chauvinistic or mercantilistic" by international parties, but rather the United States should foster increasing international interest in GPS by providing other nations with a voice in the system's future.[1] The EU would do well to heed these same warnings in regard to Galileo and dispel the program's air of arrogance exhibited toward GPS.

The EU highlighted Galileo as more modern than GPS and emphasized Galileo's focus on meeting civilian and commercial, rather than GPS's military, demands. While one US argument against the Galileo program held that scheduled improvements to GPS would offset Galileo's purported technical superiority, the GPS program's susceptibility to budget-induced schedule slips made this claim implausible. The Schlesinger commission suggested that international involvement in the control of GPS and discontinuing SA might help to avoid a situation of multiple competing global navigation satellite systems. However, "US reluctance to internationalize GPS governance was matched by the EU's desire to develop and maintain an independent space capability rather than continue its dependence on the United States for access to space and space services."[2] US and EU interests, together with the realization that Europe desires autonomy in areas it considers vital to its interests, it should not be a surprise that the EU decided to proceed with its Galileo project. In the interest of promoting an improved trans-Atlantic relationship, "the US must take European initiatives in space seriously, identify the key actors, seek to understand the rationales and processes behind them, and find ways the United States can benefit from European investment."[3]

Even though Europe and the United States share numerous common values, both sides of the Atlantic have experienced strong dissonance recently; and disputes over Iraq are a symptom of larger tensions. Neither side has done a good job of managing relations, thus political relations remain strained.[4] The heavy US emphasis on homeland security has complicated matters, making it more difficult for foreign scientists to get visas. Progress requires recognition of the whole situation, including a strong acknowledgement by both sides of their real differences in interest as well as the value of their partnership, coupled with the political will in Brussels and Washington to pursue it.[5]

Protect GNSS Receiver Manufacturers

As the global economy continues to grow increasingly dependent on satellite-based positioning, navigation, and timing services, so grows the market for GNSS end-user products, and US producers of GPS products stand to lose significant market share and/or gross revenue with Galileo's implementation. The US government must prevent unfair treatment of these US producers by ensuring that a fully open and competitive market remains in place for all manufacturers of GNSS receivers and by steering the EU away from implementing mandatory use requirements and market access restrictions of GNSS receivers.

If Galileo's Phase 3 operating costs prove to be too high, or its revenue streams do not produce as expected, the Galileo concessionaire will not be able to cover its costs and will likely turn to the EU for assistance. The EU could respond with additional taxpayer financing, or it could elect to subsidize the Galileo revenue stream through mandatory regulations and standards that mandate the purchase of Galileo's services. For example, the EU may assert that since Galileo is more accurate than the current GPS civil signal, aircraft entering its airspace must use Galileo-based navigation systems to ensure flight safety. The United States must work to ensure that any new usage standards are technologically neutral, allowing civil users to choose to use GPS, Galileo, or a combination based on their needs.

An EU decision to restrict access to, or knowledge of, Galileo's signals could exclude US firms from the market for Galileo satellite navigation services and equipment, and the United States must ensure that all information needed for Galileo receiver production must be made equally available to all manufacturers. Specifically, the United States should work to ensure that the EU publishes all documentation for access to Galileo's open service, just as it is done for the GPS SPS. The EU must provide equal access to the specifications for Galileo's controlled access services to include openly publishing the encryption algorithms, ensuring the cryptographic key system does not exclude non-Europeans, and ensuring that any licensing arrangements and fees do not discriminate against non-European firms. The ESA did release the "Galileo Open Service Signal in Space Interface Control Document" in May 2006,[6] a positive step toward providing access to Galileo's technical information, but the United States must remain vigilant and ensure that this vital information continues to flow freely, equitably, and timely to US manufacturers.

The June 2004 EU-US cooperation agreement on the use of Galileo and GPS established a forum to address these two issues. The agreement states that the United States and the EU will communicate before establishing any measures that will have the effect of mandating the use of a particular system within its territory and that measures should not be used as a disguised restriction on or as an unnecessary obstacle to international trade.[7] To ensure that these critical aspects are upheld, the 2004 agreement established the trade and civil applications working group to address nondiscrimination and other trade-related issues; this group met for the first time in January 2007.[8] The United States must capitalize on this working group's operational oversight to ensure that a fair and level playing field exists for all manufacturers of civil satellite-based navigation and timing end-user equipment, regardless of nationality.

Compel Allied Militaries to Adopt GPS Now

Even though civilian GPS users today outnumber their military counterparts by at least 100 to one,[9] GPS is at its core a military system, providing a capability that has proven increasingly vital to US national security over the past three decades. GPS's encrypted precise positioning service (PPS) is designed to provide continuous positioning and navigation signals to the military community, even during periods of regional jamming of GPS's civilian signal due to national security crises. This way, GPS service will only be continuously available to users with military GPS receivers. To preserve this military competitive advantage and the force enhancement capabilities derived from direct access to the GPS encrypted military signal, the fiscal year 1994 National Defense Authorization Act prohibited procurement or modification of any DOD aircraft, ship, armored vehicle, or indirect-fire weapon system not equipped with a GPS receiver after 30 September 2000 (later slipped to 30 September 2005).[10] This measure equipped US forces with GPS capability and ensured that they would remain so equipped for the foreseeable future.

The United States does not typically train or fight alone but rather in a coalition of allied forces. To ensure that all US allies enjoy continued access to critical positioning and navigation services, the United States should compel these allied militaries to formally adopt the GPS PPS signal as their standard satellite-based positioning and timing service and then encourage them to fully and rapidly equip their military forces with GPS PPS-capable receivers. NATO recognized satellite navigation as a huge capability multiplier and has been heavily invested in GPS for several years.[11]

The addition of Galileo signals will provide greater precision in their military receivers; access to several positioning signals will benefit allied forces in future missions, especially those that take place in urban areas or under heavy foliage. Failure to adopt and equip with GPS now could lead some allied militaries to choose to adopt Galileo user equipment when it becomes available, introducing risk into any operations conducted in an area where the United States has jammed Galileo to prevent hostile misuse of its signals; Galileo will be available to neither ally nor foe.

Coupled with military exercises that clearly demonstrate the survivability of PPS over SPS, presentations to explain the theory of the advantages of the PPS signal will go a long way to compel allied militaries to adopt GPS. It is not necessary to disclose any specific US tactics or techniques; rather, the demonstration should focus simply on what is possible. For example, constellations of unmanned aerial vehicles over a battle space using special antennas and signal processors to acquire the GPS signal from satellites in spite of heavy GPS jamming and then rebroadcasting a more powerful and much closer GPS PPS signal to allied forces and weapons is one such possibility; this concept was validated by the Defense Advanced Research Projects Agency in April 2000.[12] To further drive home the point, invite the US Air Force's 26th Space Aggressor Squadron from Schriever AFB, whose mission is "to show how a space-savvy adversary could severely hinder the air and ground campaign,"[13] to participate in the multinational military exercises; the participants will quickly appreciate the value of GPS's uninterrupted PPS signal.

As more and more US allies adopt the GPS PPS signal and integrate it throughout their military forces, operational and interoperability challenges introduced by Galileo's arrival will be minimized. By compelling and enabling allied militaries to adopt, equip, train, and operate with the GPS PPS signal now, the United States will protect the future of the GPS PPS signal as the gold standard in positioning and navigation for combined military operations, maximizing the abilities of US and allied forces to conduct seamless operations with optimal effects during all phases of warfare.

Advertise GPS Availability and Precision on Par with Galileo

Since the inception of the Galileo project, the EU and the ESA have published numerous multi-page publicity brochures touting the Galileo system and all the valuable services it will provide. Key to their brochures' argument in justifying the Galileo program is Galileo's superior availability and precision in relation to GPS. In turn, to the extent that it seems almost common knowledge in the GNSS community, newspaper and magazine articles discussing Galileo and GPS frequently mention Galileo's advantages in these two areas. However, as discussed earlier, Galileo will not be more available than GPS, and the precision of the two satellite systems will likely be a lot closer than the EU and the ESA would have the readers of their brochures believe.

The EU's claims of Galileo's superiority over GPS in terms of availability and precision are somewhat understandable, as these claims are undoubtedly a significant component of the EU's ongoing campaign to attract large amounts of foreign investment. However, it is important for the US government to set the record straight by countering these claims to the international audience whenever possible and promoting the perception that GPS will continue to serve as the most trustworthy and reliable resource for the global community.

Secure China's GNSS Cooperation

The involvement of China in the Galileo program is particularly troubling for the United States. As part of a larger program of military modernization, China has sought satellite navigation services for its armed forces. While technology transfer from Europe to China and input from China into Galileo's design and operation will be limited, this cooperation will allow the Chinese to develop a more sophisticated understanding of navigational satellites. Also, China's Compass navigation satellite system, which is expected to become operational over much of China in 2008, could use the same radio frequency as Galileo and GPS, making US attempts to jam an adversary's positioning and navigational signals much more difficult during crises. Ultimately, the Compass navigation satellite system could be used worldwide to provide precise positioning data for the Chinese military similar to information already produced by GPS to support military field commanders. Thus, China's deepening space partnership with the EU could present an immediate national security dilemma for the United States, since advanced technologies shared by cooperative EU nations would almost certainly enhance China's military modernization and intelligence programs.

To mitigate this situation, the United States and the EU should enter into multilateral discussions with China to determine how best to proceed cooperatively with GPS, Galileo, and Compass, just as the United States did with the EU in 2000. The United States should discuss China's current and future participation in Galileo, starting with such questions as "What is China's role in Galileo?" "What kind of access will it have to sensitive technology?" and "What firewalls are in place to make it more difficult for China to acquire sensitive technologies through Galileo?"[14] Concurrently, the United States and the EU should capitalize on the recently formed United Nations International Committee on GNSS to address compatibility and interoperability issues among the three systems. How amenable China will be to constructive and productive discussions to achieve cooperation and avoid competition between GPS, Galileo, and Compass has yet to be seen. The US and the EU agreement took almost four years to conclude and that was between two largely cooperative entities. To sweeten the deal and entice China to the discussion table, the United States and the EU could offer such incentives as a collection of GPS and Galileo lessons learned coupled with technical assistance in developing the Compass system.

Notes

1. Schlesinger and Adams, "Global Positioning System," 7.
2. Lewis, "Galileo and GPS," 2.
3. Gleason, "European Union Space Initiatives," 37.
4. Lewis, "Galileo and GPS," 10.
5. Ibid., 11.
6. ESA/Galileo Joint Undertaking, "Galileo Open Service Signal in Space Interface Control Document."
7. US Navy, "Agreement on the Promotion, Provision and Use," articles 5 and 6.
8. US Department of Commerce, "US-European Union GPS-Galileo Working Group."
9. "GPS Overview, Fact Sheet," Navstar Global Positioning System Joint Program Office.
10. Chairman, Joint Chiefs of Staff, Instruction 6130.01B, "2000 CJCS Master Positioning, Navigation, and Timing Plan."
11. Saulay, "Satellite Navigation as Seen By NATO," 10.
12. Vizard, "Safeguarding GPS."
13. Branum, "26th SAS Trains Airmen."
14. Jones and Larrabee, "Let's Avoid Another Trans-Atlantic Feud."

Chapter 6

Conclusion

Once Galileo's 30-satellite constellation and network of ground stations is operational, Europe will become the third owner of a satellite radio navigation system, after the United States and Russia. Motivated by anticipated long-term industrial and economic benefits, the desire for sovereignty and security in an area it considers vital to its interests, the rectification of perceived shortfalls in GPS availability and precision, and the opportunity to strengthen EU integration and exert political autonomy from the United States, the EU has been a staunch supporter of its Galileo program during the past decade. In spite of these perceived benefits, the Galileo program has been dogged by nearly four years of high-pressure negotiations with the United States over broadcast frequencies and on-going funding and deployment concerns. In fielding the Galileo satellite constellation, the EU expects to reap economic, technological, security, and political benefits when Galileo, as expected, will serve as the starting point for the development of many services and applications.

Regarding the military and civilian communities' ever-increasing reliance on GPS signals, the United States has become heavily invested in its GPS program during the past three decades. Therefore, the challenges that Galileo poses to vital US industrial, military, and national security interests deserve serious attention. To protect the vast industry that has developed around GPS, the United States should ensure that the EU does not impose mandatory use requirements for Galileo and that access to the Galileo hardware market remains fair and does not discriminate against non-EU companies. Compelling US allies to formally adopt the GPS military code and equip their militaries appropriately will ensure their ability to operate continuously with the United States during all levels of training and operations; this will not be the case if our allies are equipped with Galileo. The United States must set the record straight and counter EU claims to the international audience that Galileo will be available when the United States turns GPS off due to a national crisis. In all likelihood, the United States will cut off both GPS and Galileo during a national crisis to prevent hostile misuse of positioning signals, and only the encrypted GPS military code will be available. And finally, the United States must address China's major involvement in Galileo and the development of China's own satellite positioning and navigation system. The United States should partner with the EU, enter into negotiations with China similar to the successful US-EU discussions, and address concerns in all available multilateral venues.

Without question, the Galileo system has much to offer and will be a great benefit to the global community; yet, at the same time, it poses many and varied implications. Galileo will affect the transatlantic alliance, the North Atlantic Treaty Organization, and US dominance in the defense and security of Europe; and, Galileo will present serious commercial and industrial concerns as well. While the United States must oppose anything that would degrade the GPS's civil or military signals, diminish the ability to deny access to positioning signals to adversaries during crises, or undermine NATO cohesion, the United States must continue to seek to cooperate—and not compete—with the Galileo program.

Abbreviations

AFB	Air Force base
CY	calendar year
DGPS	differential global positioning system
DOD	Department of Defense
EADS	European Aeronautic Space and Defense Company
EC	European Commission
EGNOS	European Geostationary Navigation Overlay Service
ESA	European Space Agency
ESDP	European Security and Defense Policy
EU	European Union
GJU	Galileo joint undertaking
GLONASS	global navigation satellite system (Russian)
GNSS	global navigation satellite system (Chinese)
GPS	global positioning system
GPSOC	Global Positioning System Operations Center
NATO	North Atlantic Treaty Organization
NAVSTAR	navigation satellite timing and ranging
OEF	Operation Enduring Freedom
PDD	Presidential Decision Directive
PPS	precise positioning service
PRS	public regulated service
SA	selective availability
SEP	spherical error probable
SPS	standard positioning service

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