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Commercializing the Global Positioning System

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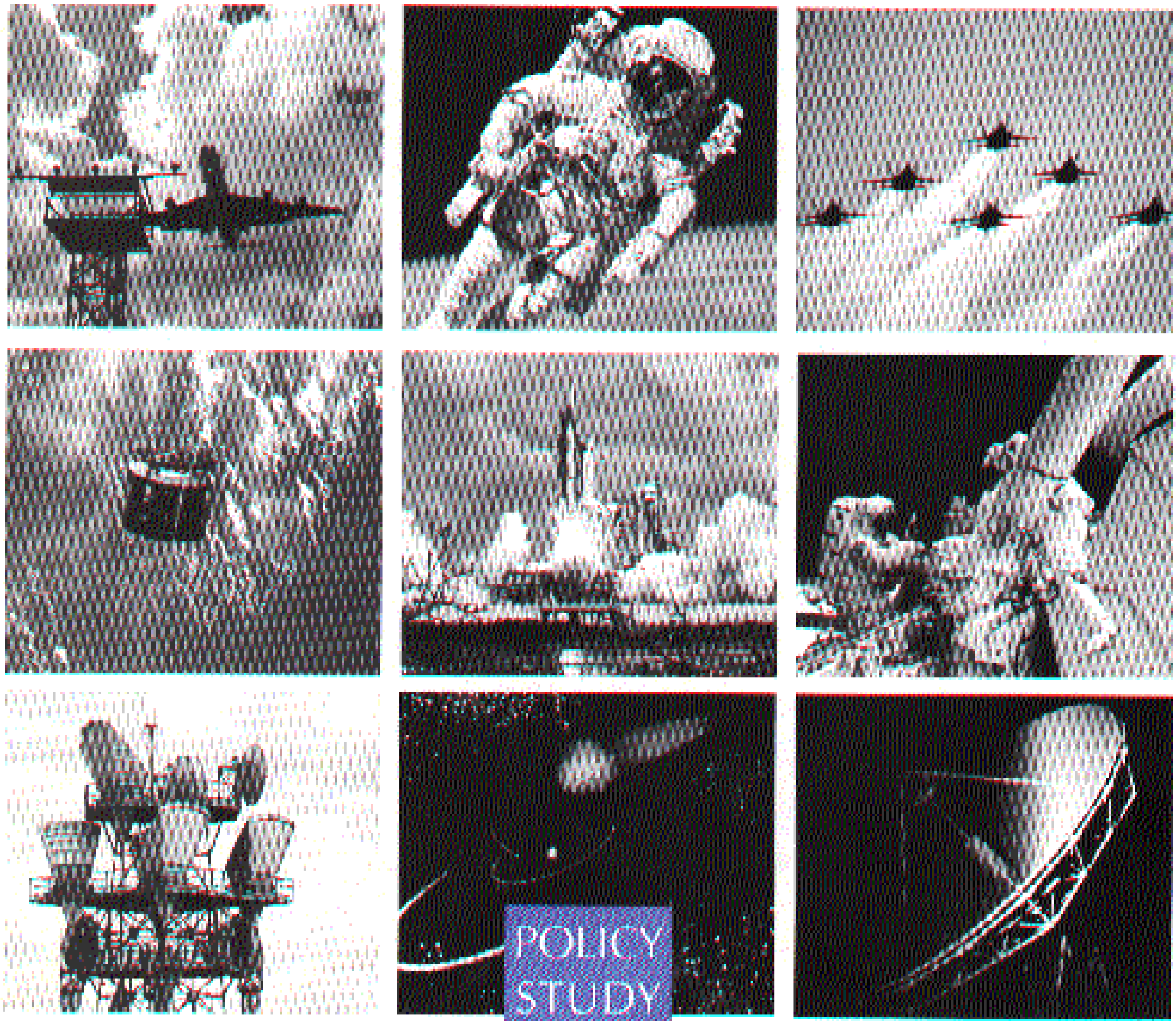

POLICY STUDY 227

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Policy Study No. 228, July 1997

Commercializing The Global Positioning System

by Albert W. Blackburn

EXECUTIVE SUMMARY

The Global Positioning System (GPS) is a 24-satellite system offering precise position location services worldwide. It was developed and is operated by the U.S. Air Force (USAF). Although GPS was developed for military purposes, its signals are widely used for civilian purposes today (e.g., air traffic control, navigation, mapping, fleet dispatching), and civilian users already greatly outnumber military users.

USAF claims it must degrade the accuracy of signals available to civilian users, but the similar Russian system, GLONASS, does not do so. Furthermore, the private market has already developed inexpensive ground-based systems to correct the accuracy of civilian GPS signals to the same levels available to military users.

The potential of GPS-like systems for civilian uses is immense. Low-cost GPS equipment can form the core of future air traffic control (ATC) systems offering greatly improved airspace utilization in developed countries and major increases in safety levels in the majority of the world which today lacks advanced ATC capabilities. Major gains are also in prospect for global shipping, land transportation (including emergency-vehicle dispatching), surveying and mapmaking, search and rescue, and numerous other uses. GPS offers major potential for saving lives. In civil aviation, about 1,000 lives are lost per year because pilots have inadequate positioning information. Even greater human losses may be avoided by greatly improved detection of highway and other transportation hazards and more certain recovery of people lost due to bad weather.

But these enormous gains are frustrated by continued military ownership and control of GPS. Constrained defense budgets and limited vision for the broadest civil uses will deny these users the ultimate performance this technology can and should provide. For these reasons, the system should be transferred to civilian control under some form of private-sector management and operation. Alternative forms of ownership include an international government consortium (modeled after Intelsat), a not-for-profit user-controlled corporation (modeled after Nav Canada), and a commercial corporation. Modest user fees or user taxes could clearly

support commercialized operations of a GPS, Inc. And the current GPS operation could be auctioned off for something close to the $7 billion it has cost taxpayers to develop.

The need for a commercial GPS-type service is so great that such a service is certain to develop, whether or not it evolves from the current USAF GPS. The choice before Congress is whether to make GPS the core of that commercial system—or to let some other (possibly non-U.S. entity) take the lead. Congress should therefore pursue a Navigation Satellite Act of 1997 that would set a date for shifting GPS to civilian control, immediately end the degradation of GPS signals for civilian users, study the best form of commercialization, and halt current government projects that undercut the commercial market for broadcasting encoded GPS correction signals.

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Part 1

Introduction

The U.S. Air Force's Navstar Global Positioning System (GPS), became fully operational in 1995. One of the truly great intellectual and technological achievements of the 20th century, the system consists of 24 satellites, orbiting the earth every 12 hours at an altitude of some 11,000 miles, and five ground stations at Colorado Springs, Hawaii, Kwajalein, Diego Garcia and Ascension Island to monitor and correct navigation signals being transmitted continuously by each of the satellites.

GPS was originally conceived three decades ago as a method to provide major improvements in the accuracy of weapons delivery and in positioning precision for all types of military units and vehicles, from the infantry rifleman to strategic bombers. Nevertheless, as the years rolled by, its creators decided to open up GPS access, not just to U.S. citizens, but to the entire civil world, albeit at a substantially lower level of accuracy, lest an enemy's forces be enabled to attack those of the United States with equal precision. To date no charge has been levied on any user, domestic or foreign, for these dramatically improved positioning services available continuously over the entire world. The total cost for the development, production, deployment and operation of GPS since its inception in 1973—over $7 billion—has been and continues to be borne by the American taxpayer.

No one could have predicted the speed and pervasive penetration that would characterize the entrance of GPS into many segments of human activity. The original goal of the system's founders was to see the price of a GPS receiver shrink to below $10,000. Already that figure is less than $200 (batteries included), and the number of civil GPS users already exceeds those in the military by more than 100 to one.

Recently, three distinguished panels have examined the future of GPS. Two of them, composed of senior government leaders, scientists, military figures and captains of industry, agreed unanimously that the intentional degradation of GPS signals by the Air Force should cease immediately.[1] The other, which was advised principally by mid-level staffers and analysts, insisted that this purposeful flummoxing of the system must continue.[2] All three panels envisioned a GPS that remains, at least for the near term, a system wholly under the control and management of the U. S. military without any user charges. The two more senior panels see the longer-term possibility of some cost sharing with international partners.

None of the panels explored possibilities for enhancing the utility, reliability, and reach of GPS for all its diverse users. None seriously examined the feasibility of operating a GPS-like service as an international

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1 Laurence J. Adams , James R. Schlesinger, et al., *The Global Positioning System, Charting the Future*, National Academy of Public Administration/National Research Council, May 1995.

2 Scott Pace, et al., *The Global Positioning System: Assessing National Policies*, Critical Technologies Institute, Rand Corp., October 1995.

utility that is fully privatized and funded through user fees to assure continued advances in technology and applicability. None examined the safety implications of continuing improvements and making the best technology available to the entire world.

This paper examines the feasibility and merits of a fully privatized and ultimately internationalized GPS, Inc. Further, it argues that early implementation of GPS as a commercial venture would save thousands of lives both in the United States and in less developed regions, by providing a precision landing approach in bad weather to airports that otherwise may never be able to offer such a capability.

Part 2

GPS Capabilities and Future Potential

A. Origins of GPS

Just a few days after the launch of the world's first satellite, Sputnik I, on October 4, 1957, British scientists at Leeds University showed how to derive highly accurate lines of position through doppler and phase-matching analyses of the radio waves transmitted by the tiny satellite speeding overhead a few hundred miles above the earth's surface. The first satellite system dedicated for navigation services was the U.S. Navy's Transit. Although the low-earth-orbit satellites of Transit still provide very accurate positioning information for surface vessels and submarines for which frequent updates are not needed, GPS makes the system redundant. For high-speed aircraft and missiles, a more dynamic capability is required.

To meet that need, the USAF started studies in 1963 that became the basis for GPS. Fifteen years later, in 1978, the first development satellites were launched. The full USAF satellite-based Global Positioning System, 30 years in gestation, achieved Initial Operational Capability (IOC) in December 1993. Full Operational Capability was officially declared in July 1995.

Almost in lock-step with the USAF, the Russians have been developing their own satellite navigation system. Known as GLONASS for GLObal NAvigation Satellite System, it is a virtual clone of GPS. Like GPS, total space vehicles in the GLONASS constellation number 24 and the operating frequencies are sufficiently close that a common receiver and antenna can be used for reception of signals from both systems. GLONASS was declared to be fully operational in December 1995.

Of special historic significance is the rapid evolution of commercial communications satellite services very soon after military spacecraft were put into orbit. Although the military's first operational units were not launched until 1962, in August of that year, Congress passed the Communications Satellite Act of 1962 which chartered the Comsat Corporation for the commercial development and operation of communications satellites. This was a clear demonstration of the strength and political clout of the U.S. communications industry. Even at that early point in satellite development, it was clear that the commercial needs for worldwide communications via space far exceeded those of the military.

It is equally obvious today that civil demand for precise positioning services greatly exceeds, by several orders of magnitude, total military requirements.

B. Current GPS Capabilities

As noted, GPS achieved full operational capability in 1995, followed by the Russian GLONASS constellation later that same year. The most serious flaw in the Russian equipment is low reliability. Two GLONASS satellites put into operation since 1989 have ceased transmitting after only seven months in service. First-generation operational satellites for GPS are designed for a service life of 7.5 years. One of the early R&D space vehicles has been working very well for 12 years. The follow-on Block IIR versions, the first of which was delivered in 1995, have a design life of 10 years.

Two levels of accuracy are offered by GPS: the Standard Positioning Service (SPS) which is generally available to everyone, and the Precise Positioning Service (PPS) available only to the military and other carefully screened applicants. Generally speaking, PPS offers positioning accuracy with errors one-fifth that to be expected with the SPS signals.

In addition, GPS features an option whereby its operator, the USAF, may further degrade the accuracy available to civil users. Called Selective Availability (SA), this feature increases positioning errors to 100 meters or more for receivers without complex military decoding devices. The Russians say that, like the USAF, they can also degrade the accuracy of their GLONASS but that they do not intend to do so. Recent comparisons of the two systems indicate that total system errors for GLONASS are approximately twice those of GPS without SA activated. With the level of SA degradation being imposed by the Air Force in 1996, GLONASS is significantly more accurate than GPS.

The Clinton administration announced in April 1996 that it intended to continue SA degradation to the accuracy of GPS for at least four more years and perhaps for as long as 10 years. Though a great deal of fanfare accompanied this announcement, it constituted nothing more than a continuation of the policy announced by the Administrator of the Federal Aviation Administration, Admiral James Busey, in 1991 and reechoed by subsequent FAA heads that for the foreseeable future, GPS will remain a U.S. military system, maintained and operated by the USAF, and provided to the world courtesy of the U.S. taxpayer.

As some clue to USAF priorities, the T-43 (Boeing 737) aircraft carrying Commerce Secretary Ron Brown and his party to their deaths in Bosnia did not have a GPS receiver installed. One was scheduled to be fitted in late 1997 if funding priorities more critical to the Air Force did not interfere. The antique nondirectional beacon (NDB) receiver on the T-43 being used for the approach to the Dubrovnik airport is known to be critically defective for flight in the presence of thunderstorms.

In most industrialized nations, civil users have invented several highly effective methods for reducing GPS positioning errors to centimeters or less, even when SA is turned on. Already, dozens of companies are supplying thousands of GPS receivers to global markets for use by ships, trucks, railroads, automobiles, aircraft, pleasure boats, farmers, surveyors, explorers, backpackers and the like. Small hand-held, battery-powered receivers with built-in antenna and an extensive data base weigh less than one pound and sell for as little as $195. Almost all of these civil units are capable of receiving corrections to the positioning signals as they are broadcast in their degraded form by the Air Force. These corrections are broadcast by commercial operators in many parts of the world for a fee. Additionally, in the United States, similar corrections are broadcast by the U.S. Coast Guard and may be available in three or four years courtesy of the FAA. With these enhancements, accuracies of a meter or less are feasible. More sophisticated GPS receivers using multiple antennas measure not only precise position in three dimensions but also calculate velocity along three axes and angular orientation about those axes to an accuracy of two-tenths of a foot per second and one-tenth of a degree, respectively.

C. Air Traffic Control Uses of Satellite Navigation

In the winter of 1984–85, with only five or six of the early GPS R&D satellites in orbit and much less than optimum coverage for only four hours in 24, F-16 fighter jets from the test group at Edwards AFB, using only the satellite signals for positioning their aircraft, flew a series of precision approaches to an unlighted landing strip in the Yuma desert at night. The results supported the proposition that GPS approach guidance would prove superior to the ground-based Instrument Landing System (ILS) now standard for safe approaches to fog-shrouded runways.[3]

Air travel is increasingly characterized by congestion and delays. The problems first afflicted major U.S. airports, but had spread to Europe by the late 1980s. North Atlantic traffic also experiences significant delays, and the impact of growing traffic over the North Pacific is beginning to be felt. In all areas, aircraft are being forced to fly less-than-optimum flight paths at large cost increases in terms of both fuel burned and added hours on expensive aircraft, not to mention time lost for the passengers.

Much of this inefficiency may be attributed to archaic route structures and to uncertainties as to the location of aircraft flying in the system. The first problem constrains aircraft to remain on narrowly defined air routes, leaving underutilized the large chunks of airspace outside the designated routes. The second means that large blocks of airspace must be reserved around an aircraft as an extra safety margin as it progresses over routes without the constant ground surveillance normally provided by radar. This latter situation occurs mostly over the oceanic routes or in the third world where surveillance equipment of any kind is virtually nonexistent.

Perhaps no potential application of GPS is quite as demanding as that in support of air traffic control (ATC). No other use requires the reliability and integrity essential for the unequivocal level of safety that the air traveler has come to take for granted. And because of the world-wide reach of air commerce, international compatibility of air traffic control systems is a growing challenge that must be met.

Thus, though air commerce may represent only 10-20 percent of the potential GPS user universe, the future directions for a GNSS (Global Navigation Satellite System—the generic name for GPS, GLONASS, and their successors) will most probably be set by the demands of aviation. This leadership will in turn provide lasting benefits to the entire transportation community as well as to all other users of such systems.

To fully appreciate the potential of a GNSS over the next two decades, we can briefly describe the improvements needed in air traffic management and the areas of technology which hold great promise for providing these improvements as the 21st century unfolds.

The problems that need fixing are:

- Intolerable delays at major hub airports and on high-density oceanic routes;
- Continued U.S. use of truly archaic, 30-year-old computer equipment with unacceptable reliability and vacuum-tube response capability for air traffic control functions;

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[3] Lynn D. Broome and Joseph E. Subczak, "F-16 GPS Evaluation, Final Report," United States Air Force (AFFTC-TR-85-15), October 1985.

- Growing intolerance for airport-area noise;
- Inefficient aircraft routing because of inflexible airways design;
- In the less-developed world, absence of even the most rudimentary elements of the ground-based systems taken for granted at major airports and along the airways of industrialized countries;
- Absence of real-time weather information in the cockpit;
- Absence of adequate information to permit safe, all-weather operations for commuter airlines, airborne firefighters, cropdusters, and other general aviation aircraft using smaller airports, both at home and abroad;
- Excessive landing intervals at large airports dictated by the danger of wake turbulence for aircraft constrained to follow a single glide slope rather than by other safety and operational considerations;
- Growing cost of mandated safety items; and
- Inability of the current system to cope safely with capacity problems and random failures in the 21st century.

What is the most promising method for solving these problems? The reality of GNSS, supported by a defined but not-yet-existing family of data link equipment and evolving data storage and processing equipment in the cockpit, permits us to describe the ultimate goal for an air traffic environment that might realistically be envisioned to be wholly in place by the year 2010. Relief from the above-noted problems would be addressed by the following enhancements to that future system:

- Order-of-magnitude increases in integrity and reliability for all elements of the system—the airborne vehicles, the ground control and management stations, and cockpit avionics;
- GNSS-equipped aircraft capable of flying an infinite variety of curved approaches and departures, and whatever glide-slope angle is deemed appropriate for the conditions of traffic and terrain; this flexibility will permit inbound and outbound routings to provide for safe separation from other traffic, avoidance of wake turbulence, and noise abatement;
- Sufficient information displayed in the cockpit for virtually all aircraft to identify nearby traffic and alert the pilot to any collision hazard posed thereby;
- Near-optimum trajectories offered to most air traffic that will allow the most efficient flight to requested destinations through the use of highly automated air traffic management systems; taking position in-trail behind another aircraft on departure, en-route and through the approach will be a common practice;
- Computer-generated displays on the windscreens of most aircraft will show terrain, landing fields, other aircraft, hazardous weather, and potential obstacles to safe flight in real-life perspective;
- A precision landing approach available for all runways throughout the world, and for emergency landing fields wherever they exist;
- Replacement of most presently mandated items such as navigation equipment, transponders, terrain proximity warning systems, etc. by much less expensive displays generated by GNSS inputs to highly sophisticated flight management systems that will be developed for all levels of flight operations;
- Replacement of many panel instruments by three-axis velocity and attitude outputs from GNSS with increased reliability and further savings in weight, space and costs;
- Roughly doubling the number of satellites in the GNSS constellation with consequent increases in the reliability and robustness of the system and in the inherent accuracy in all modes of operation, as well as alleviation of the problem of terrain (or skyscrapers) masking satellites from view.

D. Other Uses of Satellite Navigation

The USAF has created in GPS a global positioning capability which promises to become an integral element of many forms of human endeavor. Already, with Full Operational Capability recently achieved, GPS is being put to uses never contemplated by its creators. Farmers are able to make more efficient use of fertilizers and herbicides; geologists, with a little patience, measure shifts in the earth's tectonic plates to an accuracy of a few millimeters; sailors can return to a precise spot in a trackless ocean (corrected for existing currents and winds) to rescue a shipmate who fell overboard; the ubiquitous automobile is being equipped with moving map displays to show not only all the streets and highways of interest but the shortest route to the nearest gas station, the next motel, the lowest-priced pizza.

The list of users and uses is endless—autos, trucks, railroads, ships, boats, backpackers, surveyors, farmers, fishermen, and explorers already find GPS increasingly indispensable. Table 1 summarizes recent and projected sales of GPS units, demonstrating the rapid proliferation of civil applications that dwarfs military uses. Designers are now working on a GPS backpack to give synthesized voice guidance to the blind in a crowded metropolitan neighborhood.

Table 1: Worldwide GPS Sales and Projected Sales (in millions of U.S. dollars)

	1993	1994	1995	1996	1997	1998	1999	2000
Car navigation	100	180	310	600	1,100	2,000	2,500	3,000
Consumer/cellular	45	100	180	324	580	1,000	1,500	2,250
Tracking	30	75	112	170	250	375	560	850
OEM	60	110	140	180	220	275	340	425
Survey/mapping	100	145	201	280	364	455	546	630
GIS	25	35	50	90	160	270	410	650
Aviation	40	62	93	130	180	240	300	375
Marine	80	100	110	120	130	140	150	160
Military	30	60	70	80	90	100	110	130

Source: U.S. GPS Industry Council

Thanks to private industry, hundreds of innovative applications have come onto the market. Burgeoning production rates continue to drive prices down. GPS units are becoming as commonplace as the pocket calculator. Not far into the 21st century, users will number in the hundreds of millions.

In addition, thanks to GPS-type systems, the world now has the opportunity to save thousands of additional lives each year. These are the lives currently being lost because people, or the operators of the vehicles in which they are traveling, are uncertain of their position relative to nearby hazards—whether other vehicles, cloud-enshrouded mountains, precipitous terrain, rocks and shoals, or stormy weather. Incidentally, that opportunity may be accompanied by very large savings in the costs of the infrastructure once believed essential for less adequately providing such positioning information.

E. Transition to Civilian Control

The worldwide proliferation of civil uses for the USAF's GPS has already reached the point that nonmilitary applications of this highly precise positioning service far exceed use by U.S. armed forces. Ultimately, aviation applications of GPS-like services are expected to represent no more than approximately 10 percent of the total user population. Still, it is the demands of air commerce that are driving precise positioning technology toward ultimate civil and international (rather than military) operation and control.

This point was made forcefully in 1991 by the leader of U.S. civil aviation, FAA Administrator James B. Busey, when he opened the 10th Air Navigation Conference of the International Civil Aviation Organization (ICAO) in Montreal. In that historic address, Admiral Busey announced to the world aviation community, " . . . the United States government is offering its global satellite navigation system to civil aviation around the world for a minimum of 10 years, starting in 1993." Admiral Busey went on to say, "It should be clear to everyone that other systems will certainly replace GPS in the future. . . I pledge the full cooperation of the United States government to that effort."[4] Busey further observed, ". . . the world's developing nations will no longer be faced with the need to make substantial investments in the ground-based navigation equipment that is required by today's technology. That will be a terrific boon for these nations. They could save millions of dollars." (In fact, the savings will run into the billions.)

A year later, Gen. Thomas Richards, Admiral Busey's successor as FAA Administrator, reiterated and strengthened this pledge at the ICAO Triennium in Montreal in September 1992. In October 1994, FAA Administrator David Hinson further extended the U.S. commitment to provide GPS services worldwide when he publicly assured ICAO President Assad Kotaite that the 10-year guarantee should be considered an ongoing pledge until further notice.

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[4] James Busey, Remarks to the 10th Air Navigation Conference, International Civil Aviation Organization, Sept. 5, 1991.

Part 3

Could GPS Be Privatized? A Policy Challenge

The huge global demand for GNSS services is in conflict with continued ownership and control of GPS by the USAF. In the event that GPS itself is not civilianized and commercialized, it is highly probable that an international group will assume the responsibility for providing precise positioning services to the world in the 21st century. Current contenders could include (1) Inmarsat which is willing and able to put up its own GNSS, (2) a consortium built around the already fully operational GLONASS, or (3) a combination of the two. The original GPS, one of the greatest technological achievements of the 20th century, would then gradually fade away because of the inability of DoD's inner circle and U.S. policymakers to recognize the world's determination to have the very best for all. Concurrently, the United States would lose a great opportunity for creative world leadership.

It is important to note that most nations endowed with advanced technology capabilities have seen fit to commercialize their air traffic control systems.[5] This list includes, perhaps surprisingly, Russia. The most recent convert is Canada, which on November 1, 1996 sold its existing ATC system to a newly created user-controlled not-for-profit corporation called Nav Canada. Over a two-year transition period, Canada's airline ticket tax is being phased out, to be replaced by transaction-based ATC user fees paid directly to Nav Canada rather than to the Canadian government.

Furthermore, the world has already privatized most of its satellite communications operations. Most recently, the international consortium known as Intelsat has proposed that it be partially privatized, spinning off a number of its satellites into an investor-owned distributor of satellite video services, with the remainder continuing to provide basic satellite telecom services and owned by its 139 member governments or their private-sector designees (such as Comsat for the United States).[6]

A number of issues will have to be addressed in assessing the feasibility of commercializing or privatizing GPS.

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5 Robert W. Poole, Jr., "Reinventing Air Traffic Control," Policy Study No. 206, Los Angeles: Reason Foundation, May 1996.

6 Jeff Cole, "Intelsat's Privatization Beams In Rivals' Cries of Foul," *Wall Street Journal*, Oct. 17, 1996.

A. Commercial vs. Military Needs

It should be clear from the previous section, that although GPS was created by the military primarily to meet military needs, this system's vast future potential comes from ever-expanding commercial uses. At present, DoD has prevailed in insisting on retaining control of GPS and continuing to degrade the signals available to civilian users. Yet with the end of the Cold War and the huge growth in civilian uses for GPS's capabilities, it is not clear that DoD's continued dominance and control of GPS truly serves the national interest.

Moreover, DoD clearly does not have the interests of civilian users at heart. Besides degrading the accuracy of the signals offered to civilian users, USAF does not need and hence shows no interest in a larger (e.g., 40 to 50 satellite) constellation of the kind that could provide numerous benefits to civilian users. Indeed, budget pressures led to USAF dropping three GPS satellites from its proposed FY96 budget; it had many other needs that it considered to be of much higher priority.

In making its case for continued control, DoD asserts that it must maintain the ability to degrade the accuracy of signals available to civilian users, as a way to maintain a crucial military edge. Indeed, the 1995 Rand Corp. report, reflecting USAF's position, maintains that the growing number of private and civil-government augmentation systems that correct for DoD's degraded signals (e.g., the FAA's forthcoming Wide Area Augmentation System—WAAS, Europe's forthcoming EGNOS, and private systems such as that now offered by Differential Corrections Inc.) should somehow all be controlled by the U.S. defense establishment.[7]

Yet DoD's case is open to serious question. In several recent cases of serious U.S. military combat, USAF did not degrade the accuracy of its civilian signals. SA was not activated during the Gulf War (1990-91) because the U.S. armed forces had purchased for that operation a large number of civil receivers without SA decoding capability. SA was also not used during the military action in Haiti in the fall of 1994. The only situation in which it has been activated is the 1996 Bosnian operation. (This means that the U.S. soldiers who brought their own civil GPS receivers were unable to avoid with confidence the deadly mine fields in place in Bosnia.)

Second, if reserving a higher level of accuracy for the military provided a decisive advantage, why does the Russian (formerly Soviet) GLONASS not do likewise? GLONASS offers a single, uncoded level of accuracy that is available to any user who purchases a commercially available receiver.

Third, as the 1995 National Academy of Public Administration/National Research Council study pointed out, the growing worldwide availability of GPS corrections makes SA ineffective, and both panels recommended that it be discontinued. The NRC concluded that "any enemy of the United States [that is] sophisticated enough to operate GPS-guided weapons will be sophisticated enough to acquire and operate differential systems" or to use signals from GLONASS.[8]

In March 1996 the administration issued a Presidential Decision Document promising that SA would be turned off within four to 10 years. In response, defenders of DoD's GPS position claim that this has made the SA issue a "red herring." Aside from the uncertainty created by this pledge for civilian equipment producers and users, a delay of up to 10 years in making high-accuracy signals available could cost up to 10,000 lives that might otherwise have been saved worldwide.

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7 Bruce D. Nordwall, "Rand Recommends Military Control GPS," *Aviation Week & Space Technology*, Feb. 12, 1996.

8 Philip J. Klass, "GPS Plan to Add New Security Techniques," *Aviation Week & Space Technology*, April 8, 1996.

Once DoD eventually concedes that SA has been made obsolete by the advance of civilian technology, it may still argue that it must continue to own and control GPS to ensure that these vital signals will always be available, no matter what, to guide military weapons and vehicles. But if the entire world, including all air and sea-borne commerce comes to depend on accurate satellite-based navigation systems, DoD's interest in having such signals remain reliably available will be the same as everyone else's interest. DoD is also critically dependent on the continued availability of petroleum-based fuels, but since that interest is widely shared with the world's civilian commerce, DoD has not insisted on operating its own oil fields and refineries. DoD today depends on numerous goods and services supplied by the private market. The military leases hundreds of millions of dollars worth of telecommunications services (via both land-line and satellites) from commercial telephone companies each year. It pays annual fees to commercial airlines so that large numbers of airliners can be "called up" in an emergency (such as the Gulf War) to fly troops abroad under the Civil Reserve Air Fleet program; it also hires commercial charter airlines on a regular (nonemergency) basis.

Finally, DoD points out that the current USAF GPS satellites provide other functions in addition to navigation signals—such as means for detecting nuclear explosions. But these GPS satellites are not the only military satellites that provide this capability; nuclear detection is a principal responsibility of the National Reconnaissance Office, which operates numerous satellites. Under a commercialized successor to the USAF GPS, either the Air Force could contract with the GPS company to have such devices continue to piggyback on its satellites or it could add additional nuclear detection devices to some of its other early-warning or communications satellites, such as the forthcoming Space-Based Infrared System.[9]

B. Alternative Forms of Commercialization

Assuming that Congress were persuaded that the existing GPS should be civilianized and converted into a commercial provider of precise positioning information, what are the alternative forms such a provider could take? There are three possible models: an international government consortium (such as Inmarsat and Intelsat), a not-for-profit user-controlled corporation such as the recently created Nav Canada, and a fully commercial, for-profit investor-owned company. What are the pros and cons of each?

1. International Government Consortium

Thirty years ago the obvious choice would have been for governments to create and control an international consortium, funding it mostly or entirely out of tax money (as GPS has thus far been funded), with its services made available at no charge to all potential users. The argument for such an approach is that the service is in the nature of a "public good," i.e., that the signals benefit everyone in the world and that once they are broadcast, it is not feasible to charge users for them.

In addition, when Intelsat was created in 1964 (and Inmarsat 15 years later) space-borne communications services were still in their infancy, and quite costly and risky to develop. Hence, a kind of "infant industry" logic led governments to use taxpayer funds to pioneer these fields of terrestrial and maritime satellite communications. And since the services were inherently global, it was natural that such governmental ventures be carried out on an international-consortium basis.

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9 Joseph C. Anselmo, "New Sensors Drive Winning SBIRS Bid," *Aviation Week & Space Technology*, Nov. 18, 1996, p. 23.

Neither of these two rationales is very strong today. First, a number of private providers of differential corrections services already exist. They have figured out how to charge for their services by encoding their signals and charging to decode them, just as direct-broadcast satellite TV services do. Since the future market will be primarily for accurate positioning information, it seems clear that such information can be provided on a user-fee basis, negating the "not-feasible-to-charge" argument for government provision.

Second, the "infant industry" argument is belied by the $7 billion already spent by USAF in developing the current system (plus comparable sums spent by the Soviets developing GLONASS), as well as the burgeoning GNSS industry, whose annual sales of receivers and related products are expected to exceed $8 billion by the year 2000. This is clearly not an industry requiring taxpayer funding.

Moreover, the world has changed dramatically since the 1960s when international government consortia were the solution of choice. In today's global economy, it is private firms and consortia that are developing such systems as Motorola's $3.6 billion Iridium, a 66-satellite constellation that will provide direct telephone links between any two hand-held phones anywhere on the globe, and the even more ambitious $9 billion Teledesic system being developed by cellular-phone pioneer Craig McCaw and Microsoft CEO Bill Gates. Over the past 10 years, governments in nearly 100 countries have privatized over $500 billion worth of state-owned enterprises.[10] There is growing evidence that such privatized firms are significantly more efficient and productive than their state-owned predecessors.[11]

Thus, an international government consortium is not the kind of "obvious" choice that it was in the 1960s and 1970s when Intelsat and Inmarsat were created. Still, it might be selected, not from necessity, but as a deliberate choice if, for example, a strong consensus emerged that encoding and pricing GNSS signals was undesirable, or that charges to users in developing countries must be kept much lower than those to other users.

2. Not-for-Profit User-Controlled Corporation

In the early days of U.S. commercial aviation, a number of fledgling airlines recognized a common need for air-to-ground communications and rudimentary air traffic control services. To meet these needs, they created Aeronautical Radio Inc. (ARINC), a not-for-profit user-owned corporation, with airlines and other aviation firms as its sole shareholders. Although the federal government took over ATC services during the early Depression years, ARINC continued to provide a growing volume of airline communications services. In the 1940s and '50s ARINC helped set up not-for-profit, user-owned air traffic control systems in a number of other countries, including Cuba and Mexico. Today, 2100-employee ARINC is a $280 million a year global business providing not only aviation communications but also researching and developing specifications for new generations of airborne electronics (avionics) equipment. (Under an Air Force contract, ARINC provides over half the technical support staff for GPS operations at Falcon AFB in Colorado Springs.)

In 1996 a variant on the ARINC not-for-profit, user-owned model was adopted in Canada, as that country became the first in the world to fully privatize its ATC system. (Although 15 other countries—including Germany, New Zealand, and the U.K.—have commercialized their ATC systems, Canada is the first to transfer ownership to the private sector.) Nav Canada is a non-shareholder user-controlled not-for-profit corporation set up to provide ATC services in the interest of the entire aviation community in Canada. On Nov. 1, 1996 it

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[10] John O'Leary (ed.), *Privatization 1996*, Los Angeles, Reason Foundation, May 1996.

[11] See, for example, Ahmed Galal, et al., "Welfare Consequences of Selling Public Enterprises," World Bank conference, June 11-12, 1992, Washington, D.C. and the subsequent paper, William Megginson, et al., "The Privatization Dividend," *Viewpoint*, The World Bank, February 1996.

purchased the entire existing ATC system for $1.1 billion, and hired all of its employees. Its board has been carefully structured to represent the major aviation interests in Canada, and its creation (and the ATC privatization) resulted from a consensus reached among all of these interest groups (including the unions of pilots and ATC employees). Nav Canada will operate on a fully commercial basis, charging transaction-based fees for landings, en-route flights, and overflights of Canada. As a non-shareholder-based not-for-profit corporation, it is being financed 100 percent by debt; there is no equity capital.

Although Nav Canada has a statutory monopoly on providing most ATC services, it is not explicitly regulated. Since all major user groups are represented on its board, they all have input into setting the level of its user charges. And there is no question of its earning monopoly profits, since by charter any "profit" earned will either be reinvested in the business (reducing the need for borrowing) or will be reflected in reduced user-fee levels in the subsequent year.

While ARINC and Nav Canada are single-country examples, a similar user-controlled, not-for-profit, but commercially operated corporation could be applied on an international scale. Major international user groups such as those in aviation and ocean shipping would be the most likely to pursue such an approach, since they would have the most to gain from a commercialized GNSS. Other user groups—such as railroads, trucking, auto-rental firms, surveyors, hikers—would tend to be national in focus. Within a country like the United States they could be expected to assert their interest in the availability and affordability of GNSS signals, but they would have less direct interest in coordination with comparable groups in numerous other countries. Even so, with the globalization of commerce and the rapid growth in international travel and communications, some of the firms in these fields (e.g., Avis, Hertz, MCI, etc.) might also wish to participate in such a global not-for-profit corporation. Also, one can envision international associations of railroads, surveyors, motorists, explorers, etc. which would like to ensure that their special interests are defined and met as this technology continues to evolve.

3. Investor-Owned Commercial Corporation

The third alternative is an ordinary commercial corporation. As noted above, it is technically quite feasible to charge for GPS-type signals, thereby generating a commercial revenue stream. Both the massive investments now being made in satellite-based phone service and the surging demand for GPS end-user products demonstrate that commercial companies eagerly seek out opportunities to meet user demands for new services. Turning GPS over to a for-profit commercial corporation would provide strong incentives for seeking out new uses and users, so as to maximize the potential of this important technology.

Were the current GPS to be put on the auction block, there would likely be numerous high-tech bidders—aerospace firms, telecommunications firms, possibly computer or software firms. The acquiring firm (or consortium of firms) would have the kind of commercial management expertise needed to develop lower-cost (non-DoD) ways of operating, along with the marketing savvy to develop new uses for the ever-more-accurate and ever-more-instantaneously available positioning signals.

Regulation of a GPS, Inc.'s charges would become an issue if the GNSS industry evolved into a monopoly in which GPS, Inc. became the sole (or highly dominant) provider. It is not at all clear, at this juncture, that this would be the case, as discussed below.

C. Competition vs. Monopoly

Besides the Navy's soon-to-be-retired Transit satellite navigation system, there are today four competing GNSSs in various stages of development. The USAF GPS is one, and it will continue to be a player for the foreseeable future, whether or not it is commercialized. Russia's GLONASS is the second. It possesses the advantages of lower launch costs and the ability to launch three satellites at a time. To many non-U.S. users, it is more acceptable than GPS because they do not worry about its accuracy being precipitously degraded. (On the other hand, at present its spacecraft have shorter orbital lifetimes.) The third existing player is Inmarsat. Its Director-General Olof Lundberg in 1994 laid out a multi-step plan for developing a civilian GNSS that would begin as a supplement to GPS and GLONASS but that could later replace them—or compete with them.[12] The fourth potential system is the European Navigation Satellite System (ENSS) proposed by Daimler-Benz Aerospace and the German Aerospace Resource Establishment. ENSS would use a 12-satellite constellation; motivating its development is European desire for a GNSS outside military control.

If DoD prevails and GPS remains a military system, it seems highly likely that either a commercialized GLONASS and/or a commercialized Inmarsat GNSS or ENSS will emerge. If Congress decided to end DoD control and commercialize GPS, it is not likely that all four systems would develop in parallel. Some governments may resist a privatized GNSS, and they might steer Inmarsat in the direction of the traditional international government consortium approach. Inmarsat has recently reorganized to be in a position to accommodate whichever choice has the stronger political momentum.

A private purchaser of GPS might seek to integrate with GLONASS and use Russia's outstanding launch capabilities and its second ground-based master-control station. As noted in the introduction, GLONASS is a virtual clone of GPS. All 24 GLONASS space vehicles (plus a spare) of a programmed 24-satellite constellation are now in orbit. Several GPS receiver manufacturers have demonstrated the feasibility of building and are now marketing a common unit to accept positioning information from both GPS and GLONASS satellites with a relatively small increase in complexity of the receivers and a significant increase in accuracy. The Russians launch three GLONASS satellites on a single booster, which could have a significant impact on launch costs. This would be especially true if GPS units can also use the Russian rockets.

It is too early to judge whether a commercialized GNSS would evolve as a monopoly or in competition with other systems. At this juncture, the existence of several competing systems suggests that monopoly is not inherent in the provision of satellite-based positioning. What might well emerge is a world in which an international government consortium (e.g., Inmarsat) provides a basic level of positioning services while one or more privatized firms offer a variety of value-added services at various fee levels.

D. Payment Alternatives

In discussing the next generation of GNSS, *Avionics Magazine* noted that "a cost-recovery mechanism should be built into future systems, since GNSS will not be 'free' forever."[13] Among the alternatives suggested were "a levy on the price of receivers, a license, or encryption of data to limit its access." The article discussed the European Space Agency's forthcoming system to provide differential corrections to both GPS and GLONASS

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[12] Olof Lundberg, "Waypoints for Radio-navigation in the 21st Century," Keynote address, Institute of Navigation GPS-94, Salt Lake City, Sept. 20, 1994.

[13] George Marsh, "GNSS-2: The Next Generation," *Avionics Magazine*, September 1996, p. 40

signals (to be known as EGNOS) and noted that a future GNSS agency, as service provider and system operator, will have to include a "body responsible for levying and collecting charges." There are two basic alternative ways to proceed. The first is a system of government user taxes; the other is commercial charges for decidedly higher-accuracy signals.

1. Government User Taxes

Under an international government consortium approach, governments and/or international agencies could agree to a system of user taxes in each country or region, for each major segment of GNSS users. A generalized approach to such a set of user taxes is outlined in Table 2. Levels of activity for each user group within a given region could be determined annually from World Bank data. The appropriate charges could be estimated from prior-year data and finalized a month or so after year's end. Whatever formula was established for each user group, the same would be applied to each country (or regional grouping such as the European Community) as it joined the consortium. How each country actually applied or enforced the collection of the user taxes would be its own concern; it would simply be obligated to provide its share of the total estimated annual budget each year.

Table 2: Formulas For Determining GNSS User Charges

AVIATION	
• Commercial - passenger	Rev. Psgr. Mi. xA
• Commercial - freight	Rev. Ton Mi. x B
• General aviation	No. of a/c x C
• Military aviation	No. of a/c x D
MARITIME	
• Large ships (> 10,000 DWT)	DWT x E
• Other ships (> 500 DWT)	DWT x F
• All other vessels (> 8m LWL)	LWL x G
AUTOMOTIVE	
• Private	No. of veh. x H
• Rental cars	No. of veh. x I
• Large intercity trucks	Rev. Ton Mi. x J
• Intercity buses	Rev. Psgr. Mi. x K
• Other comm. veh.	No. of veh. x L
• Military vehicles	No. of veh. x M
RAILROADS	
• Passenger	Rev. Psgr. Mi. x N
• Freight	Rev. Ton Mi. x O
SURVEYORS	Revenues x P
EXPLORATION	
• Commercial	Revenues x Q
• Recreational	Units sold x R
OTHER GOVERNMENT	Units equip. x S
OTHER MISCELLANEOUS	Units sold x T

Factors "A" thru "T" are constants that may be adjusted over time.

The international government consortium approach would also facilitate a revenue scheme based on ability and willingness to pay, thereby making GNSS more accessible to developing countries. For example, the formulas could be adjusted based on some measure of national wealth such as per-capita GDP. For many potential customers, the use of GNSS would be driven by potential cost savings. Surveyors, for example, can save many man-hours using GPS. But in countries where labor costs are very low, there is less incentive for switching to GPS-like techniques. The widespread use of GNSS in a developing economy can be expected to increase its economic growth rate, increasing per-capita GDP over time, thereby bringing the levels of its user taxes up to developed-country levels.

National panels in leading nations or regions (e.g., the United States and the European Community) could develop the initial proposed user-tax formulas. An international group could then be assembled to review the formulas and the general modus operandi of the consortium, and to adopt the general schedule of charges. The consortium would probably set up geographically based regions, with two principal functions. First, they must ascertain the magnitude of the annual revenues due from their assigned jurisdictions and ensure that these funds are collected and deposited in a timely manner each year. Second, they must seek to keep satisfied all GNSS users in their assigned territories, including the identification of and advocacy for desired improvements to the system.

A GNSS consortium of this kind would draw on the examples of Intelsat and Inmarsat, as well as the worldwide satellite rescue system known as COSPAS/SARSAT coordinated by ICAO.

2. Commercial User Fees

A number of commercial firms have come into existence offering differential corrections to GPS positioning data both in North America and in Europe. For the most part, these correction signals are encoded and buried in the carrier wave of commercial FM radio stations (in a manner which does not affect the quality of the FM broadcast signal). Fees are charged on a monthly or annual basis and vary depending on the level of accuracy improvement desired by the user.

One of the leading firms in this field is Differential Corrections, Inc. DCI operates a network of fixed sites in the United States as well as Canada, Europe, Australia, Hong Kong, New Zealand, and Singapore. DCI users register their receiver number with the company and authorize their subscription service via credit card. They may choose among three levels of accuracy (basic 10-meter, intermediate five-meter, and premium one-meter), at annual fees ranging from $75 to $600. DCI's receiver unit retails for $375; established GPS receiver producers such as Trimble Navigation are incorporating DCI technology into their next-generation products.

Thus, the basis for a commercial pricing approach to GNSS has already been created by the marketplace. While currently operating essentially as an add-on to enhance the value of the free broadcasts of GPS and GLONASS signals, such pricing could become the principal funding source for a future high-accuracy commercialized GNSS.

The principal argument against such pricing is that it might work to deny the benefits of GNSS to those unable or unwilling to subscribe. Not only would this reduce the economic gains available from this remarkable technology, but it could also have adverse safety consequences. Private pilots, for example, if they chose not to pay for high-accuracy service, might endanger not only their own lives but those of others.

The counter-arguments rest on (1) low costs and (2) user self-interest. By all indications, the per-user cost of GPS-type services will continue to decrease; it appears quite likely that within a decade the on-board equipment needed to safely navigate a light aircraft via GNSS will cost a small fraction of today's on-board avionics. A requirement that all aircraft using busy air space be so equipped would not, therefore, impose a serious cost burden on anyone able to afford a plane in the first place. Second, the benefits available to users from being able to obtain precise, real-time positioning information will so clearly outweigh the likely costs that annual subscription fees of up to several hundred dollars will clearly be justified.

One other factor to keep in mind in considering the trade-off between the government consortium/user tax approach and the commercial corporation/user fee model is the potential user-responsiveness of these two alternative types of GNSS providers. Comsat CEO Bruce Crockett has pointed out how cumbersome it is for users to get what they want from Intelsat: "You cannot take the Intelsat organization, with its Board of Governors meetings, its planning committee meetings, its technical committee meetings, signatory meetings, assembly of parties meetings, global traffic meetings, and operations representatives meetings (none of which is directly focused on customer needs) with all their conflicting interests and react quickly to competitive customer requirements."[14]

One potential obstacle to the development of a commercial user-fee system based on decoding accurate signals is emerging competition from governments. As noted previously, both the U.S. Coast Guard and the FAA are developing services to provide—at no charge—differential correction services which will compete directly with the existing commercial providers. Likewise, the European Space Agency is proceeding with its similar EGNOS system, and Japan is following suit with its MT-SAT program. If governments decide that the commercial user-fee model is the best way to ensure the evolution of a robust, user-friendly GNSS for the 21st century, they will have to rethink their current plans to undercut the commercial market in this manner.

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[14] Bruce L. Crockett, "From Early Bird to the Market in International Communications and Entertainment," Washington Space Business Roundtable, April 12, 1995.

Part 4

Financial Feasibility: A Business Perspective

Regardless of how the policy issues are resolved, the inherent financial feasibility of a commercial GPS corporation can be demonstrated. This discussion assumes that the current GPS is sold to the highest qualified bidder, following an international competition, and renamed GPS, Inc. A preliminary estimate of the revenues, costs and profit potential for GPS, Inc. is depicted in the accompanying tables. One may argue some of the details of these estimates, but the reality of the indicated bottom line is not easy to refute.

A. Revenue Projections

Table 3 presents ballpark estimates of revenues based on the kinds of formulas illustrated in Table 2. While an actual commercial subscription fee schedule would probably differ considerably from this basis, the point of this exercise is simply to illustrate the revenue potential from very modest annual charges. The revenues projected in Table 3 are based on best current estimates of activity in the various operations listed. For example, the commercial aviation revenues are derived from current and projected flight activity levels as reported by the FAA and ICAO. The figure of $0.001 per revenue passenger mile as a fee for the world's commercial airlines amounts to less than eight percent of the ticket tax levied by the U.S. government to fund the FAA's ATC operations. With the advent of GNSS as a major element of the U.S. ATC system, the cost of operating that system will be dramatically reduced (by reducing its labor content), as indeed will be the case for ATC worldwide.

In the maritime market, the costs of using GPS, Inc.'s services would likely be required or encouraged (via lower premiums) by the maritime insurance industry. Several decades of fees would be less than the cost of one EXXON Valdez accident.

In the automotive market, funding might most readily come from the advertisers who would provide the frequently updated databases giving motorists the locations of various hotels, restaurants, gas stations, shops and other amenities and tourist attractions along the world's highways. This could well be a situation similar to that of the cellular phone industry which virtually gives away the mobile phone to sign up a new subscriber.

The use of GPS, Inc.'s services by railroads, surveyors and the myriad, unpredictable but burgeoning miscellaneous group are but conservative guesses. With new applications being invented each day, it is likely that these estimates are low.

Table 3: Worldwide Revenues for a Commercial GPS (All figures in millions of '95 US dollars)

	1996	2000	2010
AVIATION			
• Major airlines (0.1 cent/ rev. psgr. mi. & 1.0 cent/rev.T mi.)	1,800	2,225	3,400
• Military aircraft (\$1,000 per equip. a/c per yr.)	10	15	15
• General Aviation & Commuter Aircraft (\$150 per equip. a/c per yr.)	2	5	15
Total aviation	1,812	2,245	3,430
MARITIME			
• Large ships, more than 10,000 DWT. T. (\$1/DWT. T./equip. vessel/yr.)	300	450	600
• Smaller & special vessels, more than 500 dwt. T (\$1/dwt. T./equip. vessel/yr.)	30	45	60
• All other vessels more than 10 m. long (\$10/m./equip. boat/yr.)	10	30	60
Total maritime	340	525	720
AUTOMOTIVE (\$100/equip. vehicle/yr.)	50	500	5,000
RAILROADS (\$250/equip. train/yr.)	5	14	50
SURVEYORS (\$250/lic. GPS survey co./yr.)	2	7	20
MISCELLANEOUS (Hikers, skiers, parolees, farmers, explorers, etc.) (\$100/unit sold)	10	20	30
TOTAL REVENUES	2,219	3,311	9,250

B. Cost Projections

1. Acquisition Costs

Cost estimates for acquiring and operating the system by GPS, Inc. (Table 4) are based on the assumption that the new corporation will be able to acquire the existing USAF GPS for the \$7 billion the U.S. taxpayer has invested in the GPS constellation and its ground-based operation and control facilities. This is an approximation of the funds spent by the USAF since the system was first conceived, including R&D (but not the cost of acquiring GPS receivers for the armed forces, which costs are often lumped in with the GPS figures in budget documents to yield a total of about \$11 billion). Assuming that acquisition of the system will be by competitive bid, the ultimate price of the system could be well above or below the \$7-billion development cost, depending upon the constraints (whether competitive or regulatory) on the company's projected revenues. For example, using the revenue and expense numbers set forth in Tables 3 and 4, the net present value of that revenue stream over a 20-year period is between \$13 billion and \$29 billion (depending upon the choice of discount rate used). Either competitive forces or regulation would be likely to reduce the revenues below those projected here, which means investors would pay less to acquire the operation than the resulting \$13–\$29 billion. But this calculation does suggest that a \$7-billion valuation of the existing GPS operation is conservative.

Subsequent replacement of the Air Force system (built to rigid military specifications) could be accomplished at much lower cost as a civil system. Some current functions are simply not needed by civilian users—nuclear detection for example, which can be (and is being) provided by other military satellites. The value of the present GPS is that it exists and is well proven.

2. Interest and Amortization

Financing a \$7 billion acquisition cost at 7 percent interest will permit amortization in less than 20 years if 10 percent or \$700 million per year is set aside for both interest and amortization.

Table 4: Expenses for a Commercial GPS (All figures in millions of '95 US dollars)			
Costs	1996	2000	2010
INTEREST & AMORTIZATION	700	700	700
• (10% of initial acquisition cost/yr.)			
SATELLITE REPLACEMENT	405	405	405
• (4.5 satellites/yr. @ $90M)			
RESEARCH & DEVELOPMENT	150	250	300
SYSTEM OPERATIONS	32	35	36
• (Staff of 270 @ $120 K, fully loaded, in 1996)			
• (Staff of 235 @ $150 K, fully loaded, in 2000)			
• (Staff of 200 @ $180 K, fully loaded, in 2010)			
ADMINISTRATION & MARKETING	220	265	460
• (Initially 10% of revenues dropping to 5% by 2010)			
TOTAL COSTS	*1,507*	*1,655*	*1,901*
PRETAX NET	*709*	*1,656*	*7,349**

* Clearly before this point is reached, fees would be dramatically reduced.

3. Satellite Replacement

These costs anticipate the launching of nine new GPS space vehicles every two years. This exceeds estimated requirements for maintaining a 24-satellite constellation. In fact, present estimates indicate that for a... possible contingencies one can foresee, somewhere between 36 and 48 satellites may be needed in the constellation. This projected increase in the currently programmed launch rate will take care of this larger and more capable system. A merger of GPS operations with those of GLONASS would, over time, reduce these costs. (It is interesting to note that in the early 1980s the original system was cut back to an 18-satellite constellation by Air Force planners as an economy measure. It was believed this would meet the military needs, but FAA experts made the case for the larger system back in 1987.)

The satellite configuration assumed for these cost estimates would be the same as the Block IIR and Block IIF, which are scheduled for introduction in 1997 and 2004 respectively. With the civilianization of GPS, a considerably less complex system is possible with cost savings of 20 to 25 percent. However, it may prove advisable to retain an option to use some of the military encryption, selective availability and anti-spoof features until it is clear that fee schedules from the many user groups are readily forthcoming and that advanced-technology troublemakers are not a serious threat to system integrity. Also, a GPS, Inc. would likely consider adding an additional L-band frequency to improve the accuracy, robustness, and integrity of the system.[15]

4. Research & Development

Substantial funds are assumed for continuing R&D. The purpose would be to expand the utility and inherent accuracy of the system while seeking more efficient space vehicles and launch capabilities of greater reliability and lower cost. A principal function of the R&D staff would be to manage and provide general oversight for satellite development and production and for launch operations. In addition, R&D resources would be devoted to the development of better ancillary equipment and associated software and to the

[15] Ronald R. Hatch, "The Promise of a Third Frequency," *GPS World*, May 1996.

identification of new and unique uses for this highly precise positioning capability. This R&D will not be directed at markets that are already being well-served. GPS, Inc. is not envisioned as competing with present or future developers and builders of GPS user equipment. Nor should the company build up a large in-house R&D capability. Virtually all of the actual R&D work could be accomplished by companies with demonstrated skills in the fields of space vehicles, launch operations and related disciplines.

One of the first tasks to be taken under a civil administration for GPS would be to develop a backup operation and control facility that duplicates the present USAF installation at Falcon AFB, Colorado Springs. This is the Achilles heel of the whole system, since a successful terrorist attack on that facility could put the whole system out of business. Should a merger between GPS and GLONASS be effected, this deficiency could be rather quickly eliminated. In the absence of such a merger, the development and construction of a second master control unit must be a top priority. The R&D funding included in the pro-forma would be the source of funds for achieving this critical backup capability.

Another priority project for R&D funds would be the simplification of joint GPS/GLONASS receivers. In the event of a merger of the two systems, R&D must define the most effective and expeditious route to a common operation.

Yet another major task for the R&D function would be to devise a GPS-generated approach and runway light display for projection on the windscreen and/or the cockpit instrument panel for the purpose of replacing, over time, the approach lights on the ground at airports. These lights are the most costly elements of a precision approach installation.

5. System Operations

The projected cost of operating the system is based on hiring as many of the present staff and contractor personnel currently employed by the USAF for that purpose as may prove appropriate. The acquisition of GPS from the USAF would include the present operational facilities at Falcon Air Force Base, Colorado Springs (Master Control Station), and the Monitor Stations and Ground Antennas located at Hawaii, Cape Canaveral, Ascension Island, Diego Garcia and Kwajalein. The current level of staffing of approximately 270 individuals (of which nearly half are employees of ARINC under contract with the USAF) can over time be reduced to less than 200 while compensation is being increased by 50 percent in real terms. This staffing does not include the approximately 450 people assigned to GPS administration at Space Command Headquarters in Los Angeles. Some of these could be absorbed into the management and marketing functions of a GPS, Inc. Costs for these positions appear in Table 4 under the charges for Administration and Marketing.

6. Administration & Marketing

These costs would initially amount to 10 percent of revenues but would decrease to 5 percent as operations matured. The indicated net profits for the year 2010 are such that fees would be reduced before such levels were reached. Even so, managing the worldwide operation and keeping happy a customer base that will eventually encompass users from every nation on earth will not come without considerable cost.

Part 5

Transition Issues

Let us assume that the 10-year period of availability of GPS services promised by the United States to the world at no charge is a transition phase during which GPS (and/or conceivably GLONASS) will be put up for bid in a two-step procurement process. The first phase will be a credibility contest, in which the government issues a request for qualifications (RFQ), with bidders required to demonstrate that they have the experience and resources to operate the system and the vision and capital to improve its utility for all users. Phase two of the competition would have the qualified firms respond to a request for proposals, with selection to be based either entirely on the highest offered price or on the best overall proposal, including the price offered. This process has become relatively standard for the divestiture of major government-owned enterprises.[16]

If the present Air Force GPS were to be acquired by a private corporation, a talented cadre of operational people can be induced to join the private venture to continue the jobs they have been performing for the Air Force. Over time, their compensation would probably increase by 50 percent or more while their numbers would be approximately cut in half as good business practices take over from bureaucratic habits. This, too, is the fairly standard outcome in global privatizations.

A period of six to eight years may be required to effect the transition of GPS from ownership and management by the USAF to the full purview of a private U.S. corporation. Transitioning GPS to an international government consortium would require a longer period of time.

If the decision is made to privatize GPS via a commercialized, corporate approach (either not-for-profit or for-profit), Congress must reconsider the current plans of the Coast Guard and the FAA (via its Wide Area Augmentation System—WAAS) to provide enhanced positioning information to all potential users without charge. Not only would these services compete directly with existing private-sector providers; they would also undercut the ability of a privatized GPS, Inc. to charge user fees based on the accuracy level of the signals it provided. WAAS is a very expensive approach (well over $0.5 billion), depends on the unfailing operation of both geostationary satellites, and must still use a number of ground-based differential correction units to obtain acceptable accuracy. Given the FAA's very poor record in bringing complex systems on line on time and within budget, it might well be in the taxpayers' interest to cancel WAAS. Even a fully operational WAAS, in a GPS environment where SA remains activated, would be less attractive than a 48-satellite GNSS with no intentional degradation of its accuracy.

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[16] Henry Gibbon, "A Guide for Divesting Government Enterprises," How-to-Guide No. 15, Los Angeles: Reason Foundation, August 1996.

Part 6

Conclusions & Recommendations

The world clearly needs a global navigation satellite service (GNSS) oriented to the evolving needs of myriad civilian users, especially in transportation but also in a host of other areas, including public safety, agriculture, map-making, and recreation. Just as clearly, several such systems are under development, and one or more will reach fruition, regardless of what Congress opts to do with the existing USAF-operated GPS.

This paper has argued that there is no longer a compelling case for the military to retain control of GPS and that therefore, the $7 billion that taxpayers have invested in its development can now be recovered by selling the system. A civilian, commercial approach is far more likely to realize the full potential of this remarkable technology than is continued operation and control by the military. Moreover, privatizing GPS would save taxpayers all future costs of (1) replacing the current satellites as they reach the end of their 10-year lives ($405 million/year) and (2) the projected costs of completing the FAA's $500 million WAAS.

An international government consortium, along the lines of Intelsat, is one possible approach to civilianizing GPS, but such an approach may develop independently of the United States as Inmarsat pursues the global navigation market. One possible scenario would be to encourage Inmarsat to provide a low-cost basic level of service, targeted primarily at developing countries, while privatizing GPS as a fully commercial corporation, charging user fees for various levels of enhanced services (i.e., subscribers would pay to decode higher-accuracy signals).

In any event, Congress needs to address these issues with all deliberate speed. The European Space Agency, the Coast Guard, and the FAA are all pursuing signal-enhancement services that conflict with a commercialized, privatized GNSS. The Air Force shows no signs of willingly ceding control of GPS, and will not do so unless required to do so by Congress. Meanwhile, the needs of aviation, shipping, and numerous other users are being short-changed.

A Navigation Satellite Act of 1997, inspired by the Communications Satellite Act of 1962 (which created Comsat) should seek to resolve these issues. Such an act should:

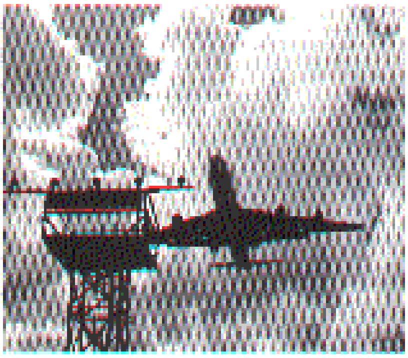
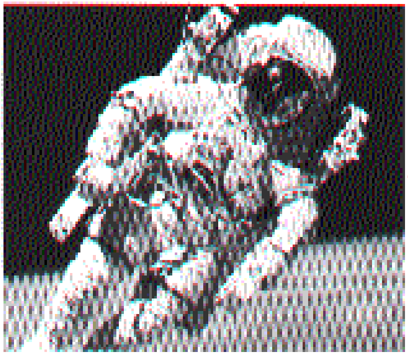
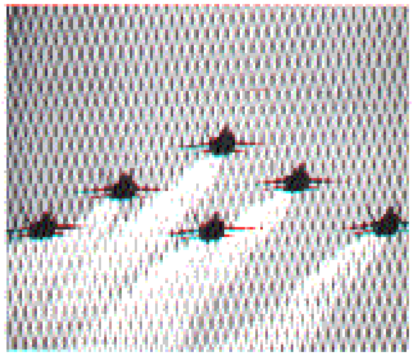
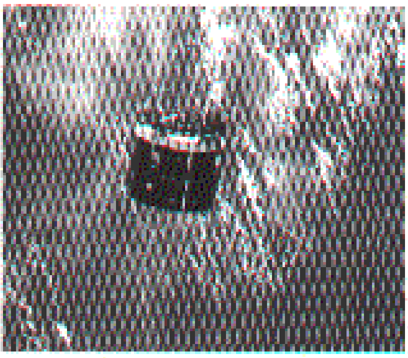
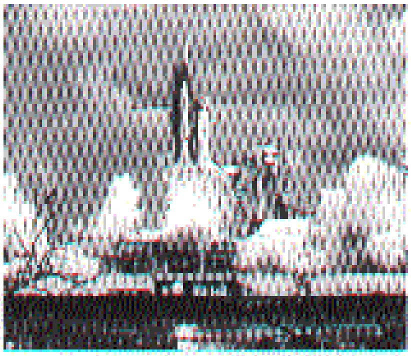
- Devise a schedule for shifting control of GPS from USAF to a civilian, user-oriented entity;
- End the current degradation of GPS's signal to civilian users;
- Authorize a detailed study of the trade-offs among an international government consortium, a not-for-profit user-controlled corporation, and a commercial corporation as the civilian GPS owner-operator; included in this study should be the pros and cons of a merger of GPS and GLONASS;

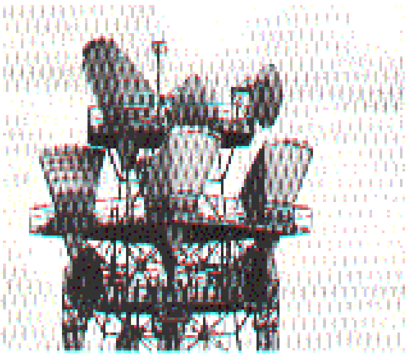
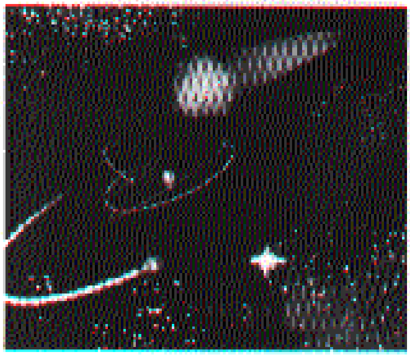
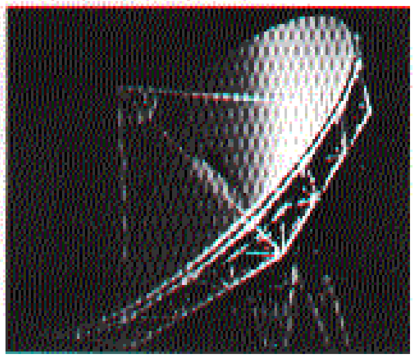
- Put on hold the development of the costly space-based differential correction system (WAAS) by the Federal Aviation Administration, pending decisions on the civilianization and commercialization of GPS.

In his recent article for *Scientific American* on GPS, MIT geophysicist Thomas Herring closes with the question, "In this rapidly changing world, one must seriously wonder: Who should control the GPS?" Forcing serious debate on and arriving at an honest answer to that question is what this paper is all about.

About the Author

Al Blackburn has more than 30 years of international aerospace experience. He graduated from the U.S. Naval Academy and received an M.S. in aeronautical engineering from MIT. In the 1950s, as a test pilot, he tested several blind-landing systems for jet fighters. As an official of the Office of Defense Research & Engineering, he prepared the study which approved the initial funding for the Navy's Transit navigation satellite program. During his two years as Associate Administrator for Policy and International Aviation at the Federal Aviation Administration (1986-88), he pressed for inclusion of GPS as an integral part of any future air traffic control system and for ATC privatization.

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