Chapter Six

CONCLUSIONS AND RECOMMENDATIONS

The four major sections of this chapter build on previous chapters to reach final recommendations. Special factors that affect decisions about GPS technology make GPS policy a unique case in many ways; however, other dual-use technologies share some of these factors. The first section discusses these special factors and how GPS may serve as a broader instructive model.

The second section summarizes the study findings on national security, commercial, and institutional and legal issues. This leads to conclusions in the third section that identify key GPS policy decisions that should be made. Additional conclusions are drawn with respect to how GPS can affect national and regional security, the role of selective availability, the importance of international acceptance, and preferred modes of governance for GPS and GPS augmentations.

Finally, the last section contains recommendations that respond to the fundamental questions being faced by national decisionmakers.

SPECIAL FACTORS AFFECTING GPS TECHNOLOGY POLICY DECISIONS

GPS is a difficult policy problem for at least three distinct reasons that are independent of particular applications and interest groups. In the first place, GPS originated as a military system, which has encouraged a risk-averse view of the technology within the U.S. government. Second, GPS is a technology that lends itself to an extremely wide range of possible applications. Third, GPS is an information technology whose impact depends not only on specific hardware and software but the exploitation of time and ephermeris information. Each of these reasons is discussed in the following section.

The Origin of GPS and Some Consequences

GPS had a military origin, and its technology arose from projects designed to support strategic nuclear and tactical military missions. The military is necessarily risk averse in its approach to technology. The collective mission is narrow; the objective is a unilateral advantage on the battlefield. The military thus tends to restrict technologies that affect operations, such as time and position data, for as long as possible to keep a unilateral military advantage for the United States.

If GPS had originated outside of the national security community and outside of the Cold War, the pressures would have been different. In that alternative world, it is likely that GPS would have been advanced as an international standard and its dissemination given a higher priority than protecting the system itself. There might have been provisions for disabling the system in wartime, but few concerns of system preemption by a potentially hostile power.

In evaluating GPS today, current and projected circumstances, rather than the heritage of the program, should be the basis for decisions. As a practical matter, this means reevaluating basic assumptions concerning the user communities, the threats posed by system preemption by adversary nations, benefits from its use in broader society, and the possibility of competing systems. Questioning some well-established assumptions is better than being artificially constrained by past history and circumstances.

GPS as an Enabling Technology

A characteristic of an enabling technology such as GPS is that a wide variety of applications can be enhanced or made possible. Good, neutral, or perhaps undesirable outcomes are now possible.

From the space segment, GPS provides precision time and ephemeris data that the end-user might apply to various applications. In the hands of a scientist, GPS provides a low-cost distributed timing system for experiments; for the entrepreneur developing network hardware, it facilitates measurement of latency in very-high-speed networks; for the civil community, it provides a precision-location service for ships and aircraft; and for the military, it allows a precision weapon to guide to its target. In the hands of the United States, GPS is a great boon, but it can also represent a hazard if it helps potentially hostile military forces find their positions or aids en route navigation of their missiles.

Tension arises between some of the civil/commercial applications and the desire to preclude an adversary's use of GPS. It is extremely difficult (technically, institutionally, politically, and economically) to combine the

nonmilitary benefits of the system that require universality of access, ease of use, and low cost with military requirements for denial of the system to adversaries. Practical considerations require civil/commercial applications to have relatively easy access.

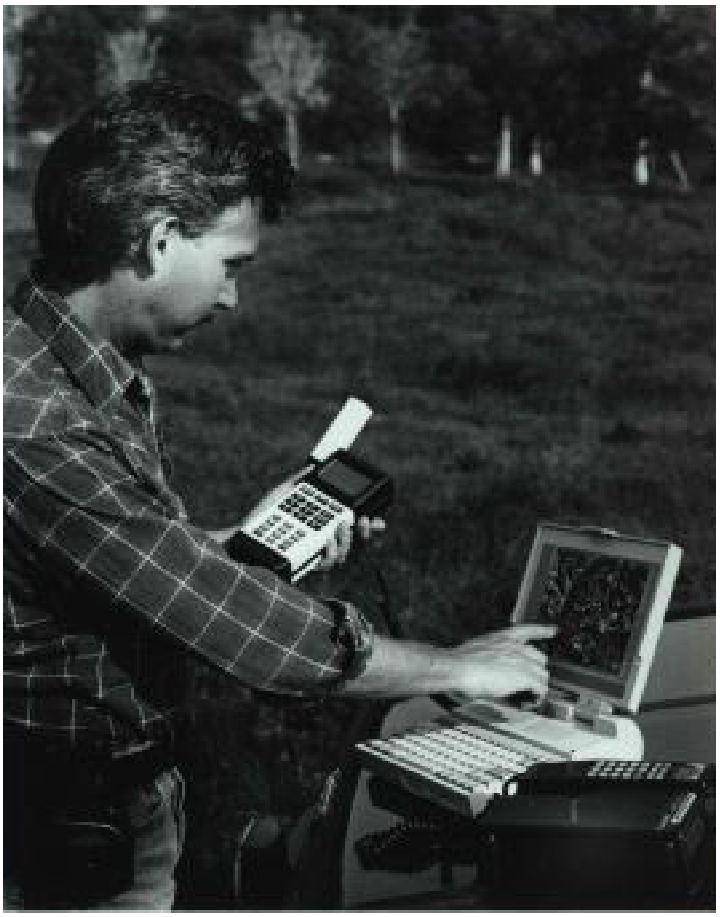
GPS as an Information Technology

GPS can be thought of as a system of hardware, software, and information (time and ephemeris) transmitted from satellites. GPS-derived information (time, position, and velocity) may be combined with other systems such as communications devices and computers (GIS systems, for example) to perform a variety of tasks. Figure 6.1 illustrates how various information technologies can be combined with GPS. The ultimate application (desirable or undesirable) of GPS's contribution to such technologies may be relatively small but is vital in the process.

Emerging information technology trends include the wide-scale use of cryptography, growing commercial use of traffic analysis techniques and database systems, powerful GIS systems and imagery workstations, and other capabilities that allow information to be combined and utilized in new ways. Like GPS, the character of these technologies is determined by how and to what end they are applied. Because these technologies are of a class that do not pose obvious, immediate dangers, it is difficult to see how controls can work or find political support. Further compounding the problem is the nonphysical nature of many of these technologies, which makes controlling them difficult.

Information technologies such as GPS represent a serious challenge to government control. In addition to the difficulties of restricting the technology, it may not serve overall U.S. interests to do so—any restriction may simply foster foreign competition and shrink U.S. advantages. In general, the United States has followed a pattern of allowing free dissemination and use of technology unless it posed an *immediate and serious* safety hazard, or a *direct* national security threat.

Decisionmakers must find an appropriate approach to handling technological issues in the information age, and address enabling technologies within a context of joint civil, commercial, and military use. If the maximum benefits of these technologies are to be realized, we must balance the benefits and risks of technologies that do not fit the mold of older physical technologies. GPS is only one information technology to hit the policy frontier. Lessons learned and policies established for GPS will likely endure in other areas.



Courtesy of Magellan Corporation.

Figure 6.1—A Combination of Information Technologies (GPS Receiver, Cell Phone, and Laptop Computer)

STUDY FINDINGS

National security, commercial, and institutional/legal issues affected by national GPS policy interact and are not cleanly separable. Nonetheless, the major findings of this report can be summarized as follows.

National Security

GPS has become an integral component of U.S. military systems, and U.S. forces are increasingly reliant on access to GPS signals. GPS provides accurate

positioning and navigation for all types of military equipment, including land vehicles, ships, aircraft, and precision-guided weapons. The DoD degrades the civilian GPS signal (through selective availability) and encrypts the military GPS signal (through anti-spoofing) to prevent potential adversaries from gaining access to high accuracies. However, the introduction of domestic and foreign local- and wide-area differential GPS systems is effectively circumventing the immediate effects of SA for most civil and commercial applications.

The wide-scale availability of highly accurate (below 15 m) positioning has many national security implications, although it is not a significant factor in nuclear threats. Potential nuclear adversaries are not likely to be capable of a strategic nuclear counterforce strike and do not need GPS-level accuracies to use nuclear weapons for lesser efforts.[1] At present, it is highly unlikely that nuclear weapons will be delivered by GPS-guided cruise missiles, although such platforms might deliver chemical and biological weapons. The situation may change if advanced cruise missiles become readily available to less-developed countries.

Second, GPS-aided conventional weapons represent an air defense challenge to the United States and its allies. Conventionally armed GPS-aided cruise missiles, in particular, may pose a significant threat to large fixed targets, although they do not threaten most mobile targets. GPS-aided weapons that evade U.S. defenses will have a greater potential for causing significant damage. The spread of low-observable technologies can increase the number of hostile aerial weapons leaking through U.S. defenses. However, the hostile use of low observable technologies is an independent concern distinct from the hostile exploitation of GPS.

Third, selective availability has little effect on the accuracy of short- and medium-range GPS-guided ballistic missiles. Third World missiles such as the Scud and No Dong 1 can improve their overall accuracy by 20–25 percent but to no appreciable affect. Missile accuracy cannot be increased simply by reducing the burnout velocity measurement errors. Vernier engines are needed to minimize cutoff control uncertainties and, more important, thrust termination control and reentry dispersion errors need to be minimized. The latter can be accomplished by spin-stabilizing the reentry vehicle or designing it to have a high ballistic coefficient, greater technical challenges than being able to access GPS signals.

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[1]Counterforce strikes have traditionally been thought of in terms of fixed installations such as airfields and ICBM silos. As SLBMs make up a greater share of the U.S. nuclear arsenal, U.S. vulnerability to a counterforce attack will diminish.

Access to GPS can allow modern ICBMs to improve their accuracies through the use of low-cost inertial instruments for initial azimuth alignment and by minimizing the effects of boost-phase inertial instrument errors. Thus there is the risk that the availability of highly accurate positioning data may provide incentives for the proliferation of ICBM-class ballistic missile technologies. Most of the advantages of GPS can be achieved with SPS-levels of accuracy, however, and DGPS is probably not required.

It is important to remember that missile proliferation—especially the spread of ballistic missiles—is (and has been) a serious problem independent of GPS.[2] There is no question that use of GPS may allow Third World nations to develop accurate cruise missiles, but GPS is a facilitator, not a driver, of missile proliferation.[3] Any potential solution to the problem of missile proliferation will require military, political, and economic components and cannot be effectively addressed by GPS policy decisions alone.

Fourth, denying access to GPS signals and GPS-related augmentations should not be done to the neglect of other countermeasures such as passive defenses, mobility, and avoidance of single-point failure modes, which can greatly reduce the effectiveness of attacks. In particular, electronic combat against GPS must be integrated into U.S. planning and routine operations. A major jamming threat arises from the proliferation of low-power, wide-band jammers, and U.S. forces must acquire P-code before entering a jamming environment. An aided military receiver can be designed to achieve a jamming resistance of about 70 dB, and special antennas can provide an additional anti-jam margin of from 10 to 30 dB. In all cases, GPS-guided weapons will require low-cost inertial navigation systems if they are to maintain high accuracies once they are jammed near a target. If the adversary employs a large jammer, it will be a ripe target for attack by precision-guided munitions such as an anti-radiation missile.

Although any threat associated with hostile use of GPS is minor at present, future threats may be greater.[4] The U.S. military must anticipate these threats and act to counter them today. To cope with the wide range of possible future threats, selective GPS denial techniques should be developed for future theaters

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[2]See, for example, Janne E. Nolan, *Trappings of Power: Ballistic Missiles in the Third World,* The Brookings Institution, Washington, D.C., 1991, and Center for International Security and Arms Control, *Assessing Ballistic Missile Proliferation and Its Control,* Center for International Security and Arms Control, Stanford, CA, 1991.

[3]See W. Seth Carus, *Cruise Missile Proliferation in the 1990s*, The Washington Papers #159, Praeger, Westport, CT, 1992; K. Scott McMahon and Dennis M. Gormley, *Controlling the Spread of Land-Attack Cruise Missiles,* American Institute for Strategic Cooperation, Marina del Rey, CA, 1995.

[4]GPS-guided cruise missiles are likely to be the most significant threat from the hostile exploitation of GPS. It is the marriage of GPS with other technologies such as low-observable materials, efficient turbofan engines, accurate inertial navigation systems, and weapons of mass destruction that poses the greatest threat to U.S. and allied forces.

of operations. In the near term, this includes DoD development of tactical jammers to deny positioning and navigation information from GPS, DGPS, GLONASS, and commercial position-location services. In addition, the United States should explore both active and passive defense programs against theater-area cruise missiles and ballistic missiles that may carry either conventional warheads or weapons of mass destruction.

Finally, the United States needs to think about how it can and should shape the international environment for space-based navigation services. For example, a stable and predictable GPS policy in the United States can promote GPS as a global standard. In the case of DGPS services that cross international boundaries, it is in the security interests of the United States to have such systems under the direct control of allies, as opposed to potential adversaries or international civil organizations. Direct control can encompass a spectrum of techniques from using encryption of the DGPS communications link to ensure access only by authorized receivers through diplomatic agreements to limit areas and times of operation when international conditions warrant.

The United States cannot count on maintaining a monopoly on precision time and location services forever. Indeed, because of the relative simplicity of GPS-like technologies, the United States must begin preparing to operate in a world where access to GPS-type and augmented GPS services are the norm. The economic and technical barriers to entry for a competing satellite navigation system are shrinking with the creation of low-earth-orbit communication satellite networks (which may lower the costs of building and launching satellites). Thus, it will become increasingly risky to assume that no other party will introduce a competing system should GPS become unavailable or unreliable.

Commercial

The availability of GPS signals to civil and commercial users has, along with supportive policy and management decisions, enabled the rapid growth of commercial applications of GPS. According to U.S. GPS Industry Council projections, sales of commercial GPS equipment alone (not including related services and multiplier effects) are expected to be about $8.5 billion in the year 2000. The important practice of providing civil GPS service free of direct or indirect user charges is a technical necessity today because enforcing payments would be virtually impossible due to the unencrypted nature of the GPS Standard Positioning Service and the large installed base of GPS equipment.

The commercial uses of GPS are diverse, with applications across many industries. Some applications are simple, such as determining a position; some are complex in combining GPS with communications and other technologies. Commercial users have varying needs for accuracy, with increasing interest in

submeter, real-time applications. GPS technology is becoming increasingly embedded in national and international infrastructures—from civil aviation and highways to telecommunications and the Internet. This is creating opportunities for improved productivity and potential vulnerabilities. The role of precision timing for mobile communications and computing will increase with the growth of global wireless applications.

The United States enjoys a leading position in the manufacture of GPS equipment and the development of new applications, particularly those requiring advanced software. Japan is the nearest competitor to the United States, followed by Europe. U.S. industry tends to see GPS technology as something that adds an "embedded capability," whereas Japanese industry tends to see GPS as another form of consumer electronics. European firms, with the exception of DGPS suppliers to the North Sea oil industry, tend to see GPS in terms of potential government contracts for improving domestic infrastructure. There is increasing interest in consumer automotive applications, however, in Europe as well as the rest of the world.

The U.S. government intends to provide wide-area augmentations of GPS accuracy for aviation and maritime navigation, which creates concerns among DGPS service providers that these government services will compete with them. The economic harm from competition may be small relative to the benefits of wide-area GPS augmentations, but U.S. government policy must balance the requirements of public safety with avoiding competition with industry. We did not reach any conclusion on whether public or private provision of GPS augmentations would be more cost-effective in meeting government requirements.

In deciding whether civil GPS accuracy augmentations should be selectively deniable, the primary concern should be to balance national security and public safety, and should include international acceptance. Commercial concerns are of lower national priority. International discussions must determine what types of selective denial would be both effective and broadly acceptable. Encryption is only one means of selective denial and need not be implemented if other means are available for national security purposes.

The ability to impose direct user fees on GPS augmentations depends on being able to selectively deny service, usually with some form of encryption. The United States could have encryption for national security reasons, but no user fees for public safety reasons. Again, while commercial concerns are important, they are secondary to those of public safety.

Although GPS accuracy, reliability, and availability are quite good, competitors to GPS could arise if the United States fails to maintain the GPS constellation, fails to provide a continuous, stable signal, or unilaterally initiates changes to

the civil signal, such as encryption or user fees. If other countries feel they cannot depend on GPS or need a complementary system, commercial interests, foreign governments, and international organizations have the resources to create alternative or complementary GPS systems.

As commercial GPS firms evaluate the various forms of risk they face—technical, market, financial, and political—they are probably confident in managing the first three. This leaves political risk. Government policy decisions can create risks to commercial GPS in many ways. New taxes and fees can be imposed, spectrum licenses may be difficult or impossible to get, international trade disputes can harm access to foreign markets, and governments may impose standards that fragment global markets into less attractive sizes. The problem of standards is particularly pervasive. Standards cut across civil, commercial, and military lines in areas such as encryption, safety certification standards, and international spectrum allocations. Rapid change in commercial GPS since the Persian Gulf War has created a strong industry interest in having a formal national GPS policy in order to provide a predictable environment for future business decisions.

Institutional and Legal

Current legal structures and historical precedents that may be applicable to GPS are more descriptive than prescriptive. There is no compelling historical or legal argument for preferring civil or military control of GPS as a navigation aid, nor is there any preference for government or private providers. The choice is essentially based on U.S. national interests; procedural disciplines to deal with emergencies (e.g., wars and crises) and user requirements; and the existence of an effective funding mechanism, whether taxes or fees. A private GPS system does not appear feasible without an enforceable funding mechanism that can deny access to non-authorized users. An internationalized GPS does not appear desirable because of potential risks to U.S. security and the lack of compensating benefits.

Future commercial growth of GPS will depend on whether it becomes an accepted global standard for position location, navigation, and precision timing. GPS is well on its way to de facto acceptance, but official acceptance depends on international decisions to use GPS in safety applications, especially civil aviation. This question can affect technical standards, spectrum allocations, export sales, and even military cooperation. At the same time, there will be multiple regional and national GPS augmentation systems. From a commercial perspective, the most important factor is that there be open, interoperable standards that allow GPS users to operate easily anywhere in the world.

International concerns over U.S. intentions with regard to GPS can be eased by U.S. policy statements, but direct discussions are likely to be more effective in addressing such specific concerns as legal liabilities and regional security. There does not appear to be any international organization that can address the full range of international security and economic concerns arising from GPS. Thus, discussions between the United States and its traditional friends and allies would likely be more effective than specialized, multilateral negotiations (e.g., in forums like ICAO) on the overall international regime for GPS. Allowing for multiple augmentation systems with common agreements on security concerns, technical standards, and spectrum usage may help international acceptance by providing a form of local control over air, sea, and land uses of GPS as well as DGPS.

CONCLUSIONS

The Global Positioning System is a simple idea that has some complex results. GPS satellites may be thought of as "clocks in space" that broadcast a uniform time. Their signals can be processed to tell a passive receiver what his location is, combined with communications to tell where someone else is, or linked into vast networks tracking the locations of physical objects or packets of data. The military applications of GPS have already been profound and promise to become more so, as both U.S. and foreign forces exploit the availability of precision time and location data. Although commercial applications were initiated many years after the first GPS satellite launch, commercial users of GPS now vastly outnumber and outspend military equipment users. Begun as a military system that allowed for civil access, GPS has become a necessity to civil, commercial, and military infrastructures around the world.

In many respects, GPS applications and their impacts have run ahead of policy. Stable, clear policy is key to the future exploitation of GPS and the development of countermeasures to the vulnerabilities and risks created by this technology. Military force structure decisions involving electronic warfare and theater air defenses are affected by GPS policy (or its lack). Similarly, industry business plans and strategies depend on U.S. and international policies involving GPS. In both cases, policy provides the framework within which military and industry leaders can plan for the future—something which they need to do irrespective of the specific policy decisions themselves.

Key GPS Policy Decisions

Key GPS policy decisions can be divided into three categories: U.S. policy decisions, foreign government decisions, and international decisions (those requiring cooperation between one or more countries). The most important

long-term policy decision is the U.S. commitment to stable funding and management for GPS to serve both national security and economic interests. In the near term, the most pressing U.S. policy decisions involve government-supported GPS augmentations such as the FAA's Wide-Area Augmentation System (WAAS) and the Coast Guard's radio beacon system. Decisions on how to proceed with these systems are significant not only for the money involved, but for what safeguards are put in place to deter hostile misuse while meeting public safety requirements. U.S. decisions on the accuracy, availability, and integrity of GPS signals and related augmentations also need to be made for the biennial Federal Radionavigation Plan (the last edition was in 1994). These decisions create expectations and political pressures in the international community as well as in private industry to maintain or perhaps increase those commitments.

The most important policy decision to be made by foreign governments is whether to accept GPS as a navigational aid within their borders. Foreign nationals have already voted for GPS with their extensive purchases, but certification of GPS for safety-of-life applications is another matter. Decisions on foreign government acceptance of GPS will be influenced by their perceptions of U.S. policy and whether the United States will be a trustworthy steward of the system, as well as their own internal political and technical assessment of alternatives to relying on GPS. In general, efforts to promote acceptance of GPS internationally are in the interests of the United States, provided appropriate protections are provided for U.S. security.

The most important international safeguards for GPS involve preventing or deterring the hostile misuse of high-accuracy GPS augmentations. With the proliferation of long-range precision strike weapons, more of our allies are facing the kind of homeland strategic threat that the United States faced for decades. The U.S. response in the case of air navigation aids was to create the SCATANA system, which provides for military control of air traffic control radars and other air navigation aids in times of war.[5] Traditional channels within NATO and the U.S.-Japan Treaty of Mutual Cooperation and Security might be used to create international SCATANA-type procedures with respect to wide-area GPS augmentations. In the event of war or a regional crisis, the operation of GPS-based navigation aids could be modified or suspended in an orderly way to mitigate the impact on commercial users.

Other international policy decisions will likely involve standards for GPS and related technologies, particularly in commercial applications. Government in-

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[5]Plan for the security control of air traffic and air navigation aids (Short title: SCATANA), 32 C.F.R. § 245, 12 p.

terventions can either help maintain an open environment for commercial development or raise protectionist barriers. Along with technical standards, the international acceptance of GPS for transportation and information applications will require agreement on allocating liability for GPS-related losses. The United States is unlikely to accept unlimited liability for all uses of GPS, but may be willing to support international integrity monitoring to provide timely warnings to aircraft and ships in event of malfunctions.

National and Regional Security

Mitigating the national security problems raised by the spread of GPS technology will require more than policy statements alone. U.S. forces are increasingly reliant on GPS and must have ensured access to the signal. The potential for hostile use of GPS against the United States and its allies is increasing with the spread of long-range, precision-strike weapons. Policy statements can provide a predictable environment for force planning decisions and can facilitate regional military cooperation, but they cannot substitute for appropriate doctrine, operational concepts, and trained, well-equipped forces.

In the immediate future, U.S. forces will likely derive more military advantages from GPS than will foreign forces—because of how U.S. forces are organized, trained, and equipped, as well as their longer operational experience with GPS. Thus, ensuring reliable access to GPS is a higher priority for the United States than preventing hostile exploitation of GPS by others. The DoD should take steps to resist enemy electronic countermeasures such as jamming and spoofing. In particular, the DoD should continue its efforts to lessen its dependence on the C/A-code to acquire PPS and should seek an operational capability to acquire the P(Y)-code directly. The DoD should also ensure that it integrates electronic warfare with (and against) GPS, GPS augmentations, and GLONASS into planning, training, and operations at varying levels of conflict. The United States needs a low-cost, effective means of selectively denying access to GPS and GPS augmentations, especially in situations where ground-based reference stations are located in nearby neutral countries. This denial could be accomplished by DoD actions as well as through positive control over access to GPS augmentations by foreign system operators.

Hostile cruise missiles and ballistic missiles may seek to exploit GPS, GPS augmentations, and GLONASS. The potential contribution of a satellite-based navigation aid to weapon effectiveness is much greater for cruise missiles than for ballistic missiles. In either case, air defense and suppression capabilities and theater missile defenses, not GPS policy, will drive force structure responses and budgets. The United States can, however, help stabilize the international environment by ensuring GPS is accepted as the primary (if not

only) satellite-based navigation aid, with GPS-related augmentations under the national control of friends and allies.

Differential GPS-based networks, some with quite broad coverage areas, have spread around the world. Many nations and regions have their own DGPS networks for civil transportation and commercial purposes. In such an environment, potentially hostile weapons systems using GPS could emerge relatively rapidly (e.g., in 12–18 months). Thus, the United States and its allies need to plan for the possible emergence of DGPS weapons, even if widely acknowledged evidence of such systems is lacking. The threat posed by accurate GPS-aided weapons—aerial weapons in particular—is most acute when the defender lacks air superiority. U.S. air power, when generated in the theater, is formidable against any foreseeable threat.[6] U.S. allies can be at greater risk than the United States itself—for example, in the opening period of conflict before U.S. air power can be brought to bear. Thus, U.S. regional allies should have greater incentives to deter or prevent the hostile exploitation of DGPS networks.

Selective Availability

We did not find a compelling economic or national security reason for keeping SA on or turning it off in peacetime. The amount of attention paid to this aspect of GPS policy seems to have obscured underlying issues that we believe are more important, such as the development of electronic countermeasures and shaping the international environment for GPS. We did conclude that SA should not be turned off without warning and a transition period, but in the future, turning SA off in peacetime could be acceptable under the right international conditions. In any event, SA should be retained as a wartime option for the United States. Since the definition of what constitutes "wartime" and "peacetime" can be debatable, we concluded that decisions about SA should remain with the National Command Authority and not lower-ranking organizations.

Selective availability is a controversial topic for some civil and commercial GPS users—who would like to see it turned off in peacetime—but the net effect of any SA decision on commercial growth and new applications is unclear. Technical alternatives in the form of DGPS and RTK techniques are increasingly available to users who need accuracies better than GPS alone can provide, even if SA were off. Although virtually all users would like better accuracy if it was costless, the commercial GPS market is driven much more strongly by declining prices.

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[6] Christopher Bowie et al., *Trends in the Global Balance of Airpower*, RAND, MR-478/1-AF, 1995.

The ability of SA to degrade the quality of civil GPS signals can be useful in wartime, assuming U.S. forces are not reliant on civilian GPS receivers. However, the military utility of leaving SA on in peacetime is not so clear.[7] The central argument for leaving SA on in peacetime is that doing so discourages foreign military exploitation of GPS by making the signal less accurate and reliable than military users would want. Also, turning SA back on would be politically difficult, even in war or crisis, because of the high degree of civil and commercial dependence accrued while it was off. However, these arguments are being overtaken by the spread of DGPS techniques that can circumvent SA, initially by the use of ground-based reference beacons and potentially over wide areas by the use of reference beacons on geosynchronous satellites.

These arguments highlight the importance of regional and international agreements on how GPS and especially GPS augmentations should be managed in times of war or crisis. The most difficult questions about whether or when to turn SA on arise in the event of attacks on allies or third party conflicts in which U.S. interests are unclear. In regional crises the United States would want a range of options, from working with allies to limit the performance of GPS augmentations, to turning SA on, to actively jamming GPS signals or attacking local DGPS ground stations. These options would be facilitated by agreements that provided a mechanism to address regional GPS security concerns and are likely to be more important than the single decision to have SA on or off in peacetime.

A related issue is whether the United States should proceed with or even encourage wide-area GPS augmentations that provide even greater accuracies than the GPS SPS signal without SA. The wide coverage of these systems and their intended usage for international air and sea transportation will make decisions to suspend operations politically even more difficult. This in turn could encourage the proliferation of GPS-aided weapons under the belief that the signals will be available even during regional conflicts. Again, the United States should be sure it has both military countermeasures and international mechanisms in place to deal with the potential misuse or hostile denial of GPS-related signals upon which civil, commercial, and possibly military users will depend. Other countries may want the United States to keep SA on to encourage use of local and regional DGPS networks that are under their own control.

Time is needed both to develop electronic countermeasures and negotiate international agreements. In 1995, for example, the U.S. Senate called for SA to be turned off in one year unless the Secretary of Defense submitted a plan for of-

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[7] A more compelling case for leaving SA on could be made if the United States faced a significant mobile strategic nuclear threat that could exploit GPS for geolocation in a first strike, as it did with Soviet SLBMs.

fensive and defensive GPS electronic countermeasures.[8] Electronic warfare is not the only consideration for SA decisions. The risk of encouraging the proliferation of GPS-aided weapons must be balanced against the benefits of GPS as a global standard for satellite-based navigation. In this balancing, a decision on SA policy must consider U.S. interests in shaping the international environment for GPS and not just individual military risks and uncertain economic benefits.

International Acceptance

The dual-use nature of GPS and its challenges to U.S. policymaking have resulted in extensive dialog among the U.S. military, civil government, and commercial communities on common policy and technical problems. In contrast, foreign discussions of GPS tend to be segregated in separate communities depending on particular applications, both because of the origins of GPS as a U.S. military system and because of domestic political constraints. For example, the Japan Defense Agency is highly constrained in its interactions with civilian ministries, and it is difficult to forge a common Japanese government approach on theregional security and economic concerns arising from the spread of DGPSnetworks, including DGPS services provided by Japanese civil government agencies. In Europe, the European Community is interested in GPS for transportation infrastructure applications, but the EC does not have jurisdiction over military matters. Similarly, NATO and the Western European Union are interested in the military benefits and risks of GPS, but have difficulty addressing civil and commercial applications in a common forum. The United States can thus have a unique role in creating and shaping an international dialog on this dual-use technology.

There is no international organization that can address all GPS-related issues at a government-to-government level. Multilateral organizations such as ICAO and IMO can address certain categories of GPS applications, but not broader international security and trade matters associated with the technology. Different regions of the world have differing interests in GPS; for example, the

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[8]U.S. Senate, *National Defense Authorization Act for Fiscal Year 1996,* S.1026, placed in the Senate July 1995. Section 1081 of the Senate bill, "GLOBAL POSITIONING SYSTEM," reads: "The Secretary of Defense shall turn off the selective availability feature of the global positioning system by May 1, 1996, unless the Secretary submits to the Committee on Armed Services of the Senate and the Committee on National Security of the House of Representatives a plan that (1) provides for development and acquisition of (A) effective capabilities to deny hostile military forces the ability to use the global positioning system without hindering the ability of United States military forces and civil users to exploit the system; and (B) global positioning system receivers and other techniques for weapons and weapon systems that provide substantially improved resistance to jamming and other forms of electronic interference or disruption; and (2) includes a specific date by which the Secretary of Defense intends to complete the acquisition of the capabilities described in paragraph (1)."

economic and security situation for Japan is quite different from that of Europe or the Middle East. In addition, a single international civil organization for GPS or GPS augmentations is unlikely to be desirable from a U.S. perspective. Such an organization may be welcomed by users who want access to high-accuracy signals at all times, but it would lead to a decline of U.S. influence in deterring the misuse of GPS in regional conflicts. The spread of GPS equipment technologies may be almost inevitable, but loss of U.S. influence and leadership is not. The United States should seek direct talks with its traditional friends and allies, especially Japan and Europe, which have economic and military importance.

Foreign government concerns with relying on the United States for GPS include public safety in air and sea transportation. Statements of U.S. intentions regarding GPS, as in the Federal Radionavigation Plan or by the FAA to ICAO, are unlikely to be sufficient, and more formal mechanism commitments are needed. Such commitments are not vital to private-sector acceptance, as demonstrated by current GPS export sales, but they can help accelerate commercial usage. International agreements other than treaties are feasible and perhaps the most effective means of overcoming foreign government objections to the official use of GPS and related augmentations.

A U.S. commitment to provide a specific level of GPS service can be verified by international integrity monitoring. Such monitoring can also limit liability for accidents because timely warnings can be considered a form of real-time notice (especially important to international civil aviation). International integrity monitoring would not appear to compromise U.S. security interests, and the United States could agree to refrain from actively interfering with such monitoring.

To help bring about international agreement, the United States might turn SA off in peacetime. On the other hand, U.S. allies may wish SA kept on so that they are able to control access to higher-accuracy signals via their own GPS augmentations. This question should be addressed in international fora; the answer is not obvious from a U.S. perspective alone.

The United States can draw on its Federal Radionavigation Plan as well as the SCATANA emergency plan in drafting clauses related to service levels, regional security measures, and third-party monitoring of GPS signal health. It should also be possible to craft, within an agreement, some quid pro quo for the provision of GPS, and the United States should carefully consider what it would want. For example, it would be unwise to require direct foreign payments for GPS because that creates a contractual relationship that would lead to an unnecessary degree of foreign influence over GPS. On the other hand, international agreements commonly seek mutual benefits without exchanges of funds,

and notional benefits to the United States could include reduced landing fees for aircraft equipped with GPS, tariff reductions, waiver of local content or offset requirements for GPS equipment, and agreement on technical standards and spectrum allocations for GPS and DGPS applications, as well as expedited foreign military sales of GPS equipment and enhanced military-to-military cooperation.

Governance of GPS and Augmentations

Given the worldwide popularity of GPS applications, the future governance of GPS is of interest to users in the United States and overseas. Aspects of governance include ownership, control, funding, and management decisionmaking. The pursuit of U.S. national security and economic interests in the use of GPS does not necessarily require U.S. control over all GPS aspects and its technologies, even if that were possible. Pursuit of such interests does, however, require the United States to make policy decisions about how it will deal with international GPS cooperation and competition.

The United States should ensure that GPS itself remains subject to its control to protect its national security interests. By GPS itself, we mean the space segment and the control segment, consisting of the satellites and the master control station, and access to overseas monitoring stations. It does not preclude larger roles for government agencies other than the Department of Defense in policymaking, management, or even funding. Nor does it preclude international agreements to which the United States becomes a party. It does say that the space and control segments should continue to be funded by the U.S. government. The user segment—and the associated burgeoning market for GPS-related equipment, applications, and services—is effectively in the hands of the private sector.

The possibility is sometimes raised of there being a competitor to GPS. This seems to be an unlikely possibility provided the United States is able to sustain key elements of current GPS practices, such as providing a reliable GPS signal with no direct user charges. The United States could create strong incentives for an alternative to GPS if it were to fail to sustain the GPS constellation (e.g., as a result of funding instability), fail to operate GPS in a competent, reliable way (which would also put U.S. forces at risk), or attempt to charge users for access to currently available signals, thus creating an economic niche for a competing system. GLONASS may be used as a supplement to GPS by some users, like other GPS augmentations, but it is unlikely to become a true alternative to GPS unless U.S. support of GPS falters.

Of greater importance than a GPS competitor is the nature of the international regime for GPS augmentations such as WAAS and local-area DGPS networks.

Local-area networks are already under the control of the private sector and national governments. The limited range, strong national interest in retaining local control, and the lack of a means for enforcing international control make such networks unlikely candidates for international control. Wide-area augmentations, particularly those using space-based reference stations, are another matter.

Wide-area augmentations to GPS can provide at least three major enhancements to GPS—improved integrity, improved availability, and improved accuracy. The public safety and commercial benefits of improved GPS integrity and availability would be of global benefit, and international, regional, or national governance would not harm U.S. security interests while enhancing international acceptance of GPS. It is likely that international organizations such as ICAO and IMO, as well as individual nations, would want independent oversight of augmentations to GPS integrity and availability, which may be accommodated in international agreements on GPS.

Accuracy augmentation governance should remain under the national control of the country providing the service. At present, the United States, Japan, Europe, and potentially Russia have the capability to provide wide-area accuracy augmentation. As argued previously, high levels of accuracy can pose risks to U.S. and regional security and require the development of military countermeasures. Wide-area accuracy augmentation should first be subject to bilateral agreements among the providers to address security and economic interests before considering multilateral agreements. Table 6.1 summarizes the various preferred forms of GPS governance.

The international environment for GPS can evolve in different directions depending on the nature of U.S. policy. If the United States makes active efforts to promote GPS as a global standard, then it will necessarily need to address the

Table 6.1

Preferred Forms of GPS Governance

Regime	International	Regional	National/ Bilateral	Local/Private
GPS segment				
Space/control			X	
User equipment				X
Wide-area GPS augmentation				
Integrity	X	X	X	
Availability	X	X	X	
Accuracy			X	
Local-area GPS augmentation			X	X

dual-use nature of the technology through international agreements. If the United States does not actively support GPS, or becomes an unreliable steward, GPS augmentations will move forward independent of U.S. interests. This will encourage the entry of foreign alternatives to GPS (e.g., GLONASS or an INMARSAT service). The United States could still have GPS for its own national security purposes, but it would risk losing the economic and diplomatic benefits from its past investments in GPS.

RECOMMENDATIONS

GPS is a unique and valuable system that enables unique military, civil, and commercial capabilities. The United States has before it an opportunity to shape the direction of GPS applications and mitigate the risks of this new technology. The window for leadership is, however, likely to be brief before foreign capabilities to field GPS augmentations and even autonomous space systems increase.

In the Introduction, we listed four major questions facing national decisionmakers with regard to GPS:

- How should the United States integrate its economic and national security objectives into GPS policy decisions?
- How should the Department of Defense respond to the existence of widely available, highly accurate time and spatial data?
- What approach should the United States take toward international cooperation and competition in global satellite navigation systems?
- How should GPS and associated augmentations be governed?

The study recommends actions that address these questions in terms of how the United States can best promote its broad interests in GPS.

Integrating Economic and National Security Objectives

- The United States should issue a statement of national policy, perhaps a Presidential Decision Directive, on the Global Positioning System to provide a more stable framework for public- and private-sector decisionmaking. This statement should identify U.S. interests and objectives with respect to GPS, address GPS management and acquisition issues, and provide guidance for the development of GPS augmentations and future international agreements.

- The United States should initiate discussions with Japan and Europe on regional security and economic issues associated with GPS that will potentially lead to international agreements. These agreements should be mutually beneficial to all parties but not involve the exchange of funds. The United States should be prepared to commit itself to providing the levels of GPS service defined in the Federal Radionavigation Plan.

Department of Defense Responses to the Availability of GPS Signals

- The DoD should reduce its reliance on civilian GPS receivers and the C/A-code for military purposes. The DoD should develop and introduce into operation, as rapidly as practicable, GPS equipment capable of rapid, direct P-code acquisition.
- The DoD should ensure that it can acquire GPS signals even in a challenged environment and should develop and field anti-jam receivers and antenna enhancements. The DoD should also ensure it has adequate electronic countermeasures to selectively deny GPS, GPS augmentations, and GLONASS signals to an adversary.
- Selective availability should be retained as a military option for the United States and not be turned off immediately ("right now"). A decision on whether to turn SA off in the future should be made by the National Command Authority after international consultations and the demonstration of appropriate GPS and GPS augmentation countermeasures.
- The United States should not preclude or deter private DGPS services except for reasons of national security or public safety. In deciding whether civil GPS accuracy augmentations should be selectively deniable, the primary concern should be to balance national security and public safety, while taking international acceptance into account. Commercial concerns are of lower national priority.

Approach to International Cooperation and Competition

- The United States should work to minimize international barriers to commercial GPS-related goods and services, such as proprietary standards and inadequate spectrum allocations.
- However, the United States should refrain, and encourage others to refrain, from providing wide-area augmentations of GPS accuracy until appropriate mechanisms (e.g., military countermeasures, diplomatic agreements) are identified to deal with the potential misuse or denial of high accuracies.

Subject to international agreements, the United States should encourage international integrity monitoring of GPS for purposes of public safety.

Governance of GPS and GPS Augmentations

- The United States government should ensure that the GPS is funded and maintained in a stable manner, free of direct user charges, to promote the adoption of GPS as a global standard for position location, navigation, and timing. The GPS space and control segments should remain under U.S. jurisdiction for the foreseeable future.
- In the case of DGPS services that cross international boundaries, it is in the security interests of the United States to have such systems under the direct national control of allies, as opposed to potential adversaries or international civil organizations.