Chapter 14:

Neither Mahan nor Mitchell: National Security Space and Spacepower, 1945-2000

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Beginning in the 1950s, the United States extended its military activities into space to provide for its defense in a global conflict with the Soviet Union. Over the next four decades, the Nation put in place an impressive array of satellites that provided remote sensing, communications, and geospatial location services. The first task for these military satellites was to obtain strategic information that neither aircraft nor human agents could access. The development of other space services (in communications and navigation) enabled a responsive global defense. Over time, the data and services provided by satellites became an integral part of U.S. military operations and of national power. The salient points of the history of this effort can be summarized as follows:

- In 1944, German scientists build and launch medium-range, suborbital missiles against Allied targets and begin to design an intercontinental missile for use against the United States. At the end of the war, the Soviets and Americans coopt scientists and seize missiles and factories and incorporate them into their own national military programs.
- In 1945, Army Air Force Commander Hap Arnold recommends to the Secretary of War that the United States pursue the development of long-range missiles and "space ships" capable of launching missiles against terrestrial targets.
- The RAND Corporation, at the request of General Curtis LeMay, issues a report in 1946 on the "Preliminary Design of an Experimental World Circling Spaceship." The Navy and Army begin programs to develop launch capabilities and satellites.
- In 1957, embarrassed by the launch of Sputnik and the shooting down of a U–2 reconnaissance aircraft over the Soviet Union, the United States manages (after 13 consecutive failures) to launch the Corona reconnaissance satellite, opening the era of spacepower as a component of strategic military power. Satellite reconnaissance solves an immediate and pressing national security problem: the U.S. inability to infiltrate the Soviet Union with agents. After a delay, Corona is followed by the first U.S. electronic intelligence satellite.
- For the next 30 years, driven by its conflict with the Soviet Union, the United States refines and expands the range of satellite services available to support national security to include military communications, navigation and timing, intelligence collection, and reconnaissance.
- Sputnik also prompts the United States to reorganize its national space effort, and the organizational steps taken between 1958 and 1962 shape how America will operate in space. The 1958 National Aeronautics and Space Act splits the U.S. space program into civil and military components and mandates that military space activities be conducted by the Department of Defense. The creation of the

National Aeronautics and Space Administration (NASA) gives space exploration a home outside of the military and diverts thousands of engineers from military programs. National space security is further divided into military and intelligence programs. The National Reconnaissance Office (NRO) is established and given oversight of classified programs. President Dwight Eisenhower's decision bifurcates the national space effort, and diffusion of responsibility for space missions becomes the norm.

- In response to a call from President Eisenhower to the United Nations, an international legal framework for space activities is created in the 1960s. This allows satellites to operate freely over other nations. There are parallels to international law as applied to the sea and to warships but also some significant differences. National sovereignty does not extend limitlessly into space, and the right of overflight is established. There is significant ambiguity over the use of weapons—nuclear weapons and other weapons of mass destruction are clearly forbidden; other classes of weapons are not.
- Secretary of Defense Robert McNamara attempts to streamline organization and budgetary oversight for national security space within the Department of Defense (DOD). He designates the Air Force as the Executive Agent for Space (the decision was rescinded in 1970 and then restored in 2003), but the other Services continue their own space programs, and early proposals to create a separate command for space fall victim to Service rivalries.
- Threats by Soviet leader Nikita Khrushchev to deploy nuclear-armed orbital bombardment systems lead in 1959 to the first U.S. antisatellite program. The Soviets begin similar programs and deploy a system in the early 1970s. U.S. efforts to develop antisatellite weapons are helped by work on missile defense and hindered by concerns over the legality of such weapons.
- McNamara cancels the Air Force X–20 space plan project in 1963, citing budgetary concerns and lack of a clear mission. This is a seminal moment for spacepower and diverts it from the vision of Arnold and other Air Force pioneers. Manned flight becomes the domain of NASA, and the United States shelves the idea of an aircraft-like manned platform capable of delivering weapons from orbit.
- The United States flirts with the idea of manned orbital military missions in the 1970s, but the Air Force's planned Manned Orbital Laboratory (conceived as a replacement to the cancelled X–20) is rapidly abandoned as impractical.
- A key development for spacepower occurs in 1976, when real-time imagery from space becomes available. Instead of dropping film canisters for aerial recovery, reconnaissance satellites convert images into electronic signals and relay them to Earth in near real time. The change ultimately allows for the creation of software to refine and better exploit imagery and creates the possibility for tactical application of dynamic (rather than stored) imagery.
- In another effort to improve coordination among Air Force, Navy, and Army space efforts, the United States establishes in 1985 a new joint command, the United States Space Command (merged into the U.S. Strategic Command in 2003). The new unified command is part of the sweeping U.S. military

reorganization aimed at improving inter-Service cooperation prompted by the Goldwater-Nichols Act Department of Defense Reorganization Act.

- In 1986, the *Challenger* shuttle explosion prompts DOD to restart its own launch programs, reversing the earlier U.S. policy to rely solely on the shuttle for access to space.[1] In 1994, the White House makes DOD the lead agency for expendable launch vehicles.
- In the 1991 Persian Gulf War, the United States discovers, almost by accident, that it has assembled a collection of space services that provide real advantages on the battlefield.The operation of space assets and the delivery of their services are poorly integrated from the combatant commander's point of view, but space provides new capabilities and improved performance. The successful use of space assets in the Gulf reflects earlier efforts to improve joint operations, such as the changes prompted by the Goldwater-Nichols Act, and to emphasize intangible factors—information superiority and coordination—in gaining military superiority over the massive forces of the Soviet Union.
- The end of the Cold War eliminates the peer competition that drove much of the change in military and intelligence activities in space. While the budget and personnel cuts that follow the end of the conflict damage U.S. space and intelligence capabilities, DOD begins to articulate a broader concept of spacepower and begins to change organizations and doctrine to take full advantage of space for national security.
- In 1995, after prompting from Congress, DOD again reorganizes to improve management and unity of effort in space. As part of this complex reorganization, it creates a Deputy Under Secretary of Defense for Space, a Joint Space Management Board, and the position of Space Architect. DOD releases the first Space Architecture, for military communications, in 1996. Perhaps the best comment on the reorganization effort is that 3 years later, Congress feels compelled to create another commission to assess and recommend changes for the management and organization of national security space.
- The United States declassifies the existence of the National Reconnaissance Office (NRO) in 1992 and releases thousands of Corona photographs. Space becomes routine rather than exotic and experimental; for example, the National Commission to Review the National Reconnaissance Office lamented in 2000 that "most unfortunately, the NRO no longer commands the personal attention of the President, the Secretary of Defense, the DCI [Director of Central Intelligence], or senior White House officials."
- In 1996, a new agency, the National Imagery and Mapping Agency (NIMA), is established. NIMA combines DOD and Central Intelligence Agency (CIA) personnel in order to better exploit and coordinate spatial intelligence. U.S. policy (in documents such as Presidential Decision Directive 23 on Remote Sensing) begins to plan for the increased use of commercial space services as a means to reinforce the services provided by government-owned satellites for national security purposes.
- Frustrated by continued duplication and slow progress in space programs, and prompted by an awareness of the increased importance of space for security, Congress uses the National Defense Authorization Act for Fiscal Year 2000 to

> create the Commission to Assess United States National Security Space Management and Organization. In its final report, the Commission concludes that "we are now on the threshold of a new era of the space age, devoted to mastering operations in Space."[2] The United States leads all other nations in the use of space for national security, but problems in organization that date back to 1958 and the acquisition of new systems threaten to erode its advantage.

This brief summary reveals several crucial trends. The first is the interconnection between larger developments in warfighting and strategy and the use of space. The second is the diffusion of control and its implications for the pursuit of unity of effort, not only among the armed Services, but also between the military and the Intelligence Community. The third is the tendency to build spacecraft for a specific function or mission rather than as part of a larger military goal (like air superiority or sea control). Finally, the refinement and elaboration of space services allow the United States to refocus military space activities from a national/strategic to an operational/tactical level, creating new combat capabilities but also creating new tensions over who controls space assets and services: Washington or the combatant commander.These trends have shaped U.S. security efforts in space.

Although the benefits of space for national security are widely celebrated, the United States has struggled from the onset with the organizational and doctrinal changes required to make full use of space for military purposes. The Nation faces three difficult problems that grow directly out of the history of its military and intelligence programs: the lack of a coherent architecture for the many independent national security space systems; changes in the acquisitions process that slow new programs; and the challenge of articulating a theory of spacepower equal to sea- or airpower when satellite systems do not deliver force or firepower from space.

This summary also suggests that while it can be useful to consider the U.S. experience in developing sea- and airpower concepts, these can be imprecise guides for spacepower. In some ways, the naval experience, with its mix of commercial and military activities and the operations of fleets on the high seas, may be the best precedent. But if Alfred Thayer Mahan is the foundation for strategic thinking on seapower, he built upon centuries of experience with naval conflict and its relations to national power, and he looked explicitly at the 300 years of fleet operations amassed by the Royal Navy. The development of airpower offers a tempting set of precedents, but there are crucial differences between airpower and spacepower: spacecraft do not fly, they do not deliver weapons onto targets, and the legal regime for offensive space operations is both markedly different from air operations and untested.

The concept of a space architecture is crucial for understanding the development of national security space systems. Architecture defines structure, equipment, and operations and can be a roadmap for investment and development. Architecture is particularly important for space, given the physics of orbital operations, which dictate static patterns for movement and position. In this sense, architecture is somewhat comparable to the

concept of order of battle.The most important point to bear in mind about a national security space architecture for the United States is that until the 1990s, there was none.

An Incremental Approach to Spacepower

In competition with the Soviet Union, the United States assembled an array of sensor-bearing, communications, and geonavigational satellites to support its ability to fight a global war.The triumvirate of spacepower—sensors, communications, and navigation—markedly increased U.S. security in the decades after Corona and ultimately provided the tools for a new approach to warfare, an approach that emphasized intangible advantage and information superiority. However, the United States undertook the construction of these space systems without a coherent vision for space and in an environment shaped by inter-Service rivalries. Services The United States built satellites because they offered a solution to a particular problem or a better way of carrying out an existing mission, not as part of some larger strategy for space operations.This fragmented approach formed the U.S. presence in space.

The absence of a larger vision meant that the development of spacepower was incremental. Satellites were useful tools or adjuncts, not the basis for an independent service. Nor was space a new arena for combat. Only after the number and kinds of satellites had reached critical mass, after U.S. organizational and strategic concepts had changed to emphasize intangible factors in military operations—coordination and information superiority—and after surprisingly quick success in a conflict against a powerful regional foe demonstrated the broader potential of space that the United States began to conceptualize the idea of spacepower.

This fragmentation is perhaps indicative of early attitudes about the military utility of space. Space was in some ways a microcosm of a larger problem. In the 1950s, when the national security space programs began, lines of responsibility and authority among the Secretary of Defense, the newly created Air Force, the other Services, and the CIA were unclear, and space projects were spread among the various agencies and Services.

The United States had learned the importance of joint operations from its experiences in World War II and had begun to reorganize military and intelligence functions to promote greater coordination.The vehicle for this reorganization was the 1947 National Security Act, which established the National Security Council, the Department of Defense, the Joint Chiefs of Staff, and the Central Intelligence Agency. The intent of Congress was to create "a comprehensive program . . . to provide for the establishment of integrated policies and procedures for the departments, agencies, and functions of the Government relating to the national security." The act envisioned "the integration of domestic, foreign, and military policies relating to the national security."It has taken years (some would say decades) to implement this vision. Military space activities began at the same moment the United States was wrestling with the larger question of how to integrate its military, intelligence, diplomatic, and economic power to achieve national security.

Yet while the Armed Forces and intelligence agencies were being subsumed within a larger integrated management structure, national security space was being fragmented. In part, this was due to the newness of the coordinating authorities of the Department of Defense.However, the fragmentation also suggests that the planners and strategists of the 1950s saw space and satellites as tools and accessories rather than as an independent military capability, somewhat akin to the way the Army saw aircraft before the First World War. An integrated vision of spacepower would advance no faster than the growth of an integrated approach to national security and military operations.

At least one service, the Navy, floated the idea of a separate command for space as early as 1958. Arleigh Burke, Chief of Naval Operations, proposed the new command, and one of his deputies, Admiral John Hayward, the Deputy Chief of Naval Operations for Development (and previously the Assistant Chief of Naval Operations for Research and Development), was "one of the strongest proponents of a unified national space program."[3] Navy's interest in space was driven by practical requirements for global communications and navigation, and the Service had begun to pursue space operations in the late 1940s.

Burke's proposal met with resistance from two quarters. The new Office of the Secretary of Defense argued that there were not enough space missions to justify an independent command.The Air Force took the position that it "should have primary responsibility for any military satellite vehicle, considering such activity to be essentially an extension of strategic air power." From the start, Air Force leaders had seen space as an extension of airpower and thus rightfully falling in their sphere of control. Efforts by the Air Force to assert dominance over space activities became one of the constants of the first 40 years of U.S. military space programs.

McNamara, as part of his larger effort to rationalize the Department of Defense and its budget processes, attempted in March 1961 to correct the fragmentation problem by making the Air Force the executive agent for military space (his decision was rescinded in 1970 and not reinstated until 2003).[4] McNamara's directive allowed the other military Services to conduct research and development but gave the Air Force oversight and lead for space. The other Services, particularly the Navy, were not overly constrained by this decision, and their independence may not have been a bad thing. The Navy initially gave a higher priority than the Air Force to developing satellite navigational aids, and its efforts led to global positioning systems (GPS) being deployed earlier than might have otherwise been the case.

The creation of NRO in 1961 was another attempt to overcome coordination problems.Eisenhower had assigned the Corona program to CIA rather than the Air Force during a time of struggle between the two agencies over control of strategic reconnaissance and over what became the U–2 and SR–71 reconnaissance aircraft. NRO was to provide a "more formalized and closer coordination" between DOD and CIA for space programs.[5] When the Eisenhower administration created NRO, vesting a secretive civilian agency with the primary responsibility for space programs made sense. There were few systems in operation, and they were highly classified. Over time, however, as

the number of unclassified military space programs grew in number and importance, the distinction between "white" and "black" programs only perpetuated the U.S. tendency toward duplication and diffusion in space programs. Efforts to align NRO and Air Force programs more closely have continued to face the problem of melding the two different cultures that grew up around national security space since 1961.

The bifurcation of national security space—as an intelligence activity and as a military support activity—has been a source of tension almost from the start of national security space activities. Initially, this tension was an outgrowth of the original discomfort of the military Services with the creation of the CIA, a civilian intelligence agency that operated independent of military command. This tension over control was also reflected in the concerns of the different Services that their missions would always receive a lower priority if a single Service was vested with control of space missions.

Control over satellite acquisitions and tasking of space assets was also a problem. While the requirements of the military and the Intelligence Community overlap to a considerable degree, there are differences. A satellite built for the Intelligence Community may not meet the needs of the military, for example; each can have different requirements for remote sensing. Efforts in the 1990s to design satellites that met all possible requirements had the unintended consequence of slowing new acquisitions and making the planned satellites more costly. Tasking and mission priority also remain a potential, albeit decreasing, friction point. The United States has put in place management structures to resolve disputes over scarce space resources and decide when a military request takes precedence over an intelligence tasking, but the dual control over national security space continues to complicate development of a unified theory of spacepower.

Space as Strategic Support

Intelligence satellites are referred to as "national technical means" of collection, reflecting the early emphasis on space as a strategic and national resource. Space activities were closely tied to strategic interests: identifying targets for strategic weapons; detecting tests, launches, and possible attacks from the Soviet Union; and providing global and survivable communications. As a counter to its lack of human resources in the Soviet bloc, the United States developed an immense technical collection infrastructure that obtained intelligence from signals and imagery. The first contribution of space to intelligence lay in photoreconnaissance. Corona provided information on Soviet strategic programs that was otherwise unavailable. Over the next two decades, the Nation developed and deployed a range of satellite collection systems for intelligence.While aerial reconnaissance and collection by numerous ground facilities reinforced space-based collection, the use of space systems for collection became a hallmark of U.S. intelligence activities.

Aerial reconnaissance began as early as the Civil War, and it was easy to think of satellites as just an extension of aerial photography into space. In addition to imagery, the United States began in the 1960s to operate satellites to collect signals intelligence, to

provide early warning of missile launches, and to monitor oceans for naval activity. Satellites obtained information that neither aircraft nor human agents could access. Over the next two decades, these satellites provided U.S. policymakers with a stream of information that few, if any, nations could match.

Gaining military and intelligence advantage from space assets depends on more than the possession of satellites. Countries seeking to use satellites for military purposes often overlook the expensive terrestrial element of spacepower. Effective use of satellite services requires the development of a support infrastructure of analysts and operators, and the ability to integrate satellite data and services into military plans and operation. The integration of space-based signals intelligence and imagery is a particularly complex task since it requires extensive changes to doctrine, expanded staffs, and increased communications capabilities. By the 1970s, the United States had developed a strong cadre of personnel, both civilian and military, who were capable of planning and carrying out operations in space to support national security objectives. Their efforts were supported by the development of new analytical tools, including software, that let them extract more value from space imagery and other data.

However, the military's struggle with jointness and integration was mirrored in the Intelligence Community. As the community grew in size, different cultures appeared in the agencies that managed each intelligence collection discipline and associated technologies. The disciplines did not integrate well with each other; the 9/11 Commission and others would later identify this failure to share intelligence as a key U.S. weakness. Only in the past few years, with the successful cooperation between the National Security Agency (NSA) and the National Geospatial-Intelligence Agency (NGA; formerly the National Imagery and Mapping Agency), have the collection disciplines undertaken a sustained effort at integration.

The prominent and foundational role of intelligence collection from space may have inadvertently hampered the development of spacepower concepts. The United States designed many of its space activities to support the highest levels of civilian and military command. In addition to this national focus and the narrow set of customers behind it, space programs were highly classified. The codeword classifications and compartmentalization covered not only the operational capabilities of the satellites, which clearly needed protection if they were not to be rendered ineffective, but also their very existence and, in many cases, the information they produced. The clandestine, compartmentalized, and restricted nature of the programs worked against unity of action or a single theory of spacepower.

The cost of access to space also hampered the development of spacepower concepts. Beyond the expense of building the satellite (and intelligence satellites were, as a rule, among the most expensive pieces of hardware the United States acquired), the cost of space launch was a serious obstacle to taking full advantage of space capabilities. The Jimmy Carter administration directed NASA to create a "National Space Transportation System" to reduce access costs by employing a reusable vehicle, the space shuttle. For the shuttle program to make economic sense, however, it would need to carry a high

number of payloads. To attain this, Carter directed that all U.S. payloads, including national security payloads, would be launched on the shuttle and, more importantly, that existing expendable launch vehicles be retired.

Carter's decision was not without precedent. Sporadic and repeated efforts by Congress, the White House, or the Secretary of Defense to eliminate duplication are a hallmark of the U.S. national space effort. As early as November 1959, the Eisenhower administration had decided that a single agency should design and build a "super booster" for the "national space program" and that this agency should be NASA. The basis for the decision was that there was no clear military requirement for super boosters. The United States took the resources and personnel for this program from the Army and the other Services.[6]

If Carter's policy on launches had worked, it would have had serious implications for spacepower; it essentially would have meant that the military would no longer control its own access to space. However, the policy foundered after the 1986 *Challenger* explosion and the launch of national security payloads for the defense community returned to the more robust expendable launch vehicles. This solved the problems of access and reliability, but not of cost. The cost of reaching orbit essentially reflects technological and scientific limitations, but the expense of putting objects into space remains a major obstacle to the further development of spacepower.

The cost of access to space shaped military thinking about spacepower. In the 1950s, consistent with the view that space was simply an extension of the atmosphere, the United States began programs to create space planes such as the X–20 DynaSoar. This was an aircraft that would have been boosted into space by a Titan launch vehicle, where it could achieve orbital speed, attack terrestrial and space targets, and then glide back to land. Cost and doubts about the X–20's mission led to the cancellation of the project after $3.7 billion (in 2007 dollars) were spent and a prototype was completed.

The U.S. decisions not to pursue spacecraft like the X–20 or its follow-on program, the Manned Orbital Laboratory, channeled spacepower away from combat and the traditional application of force. Developments in long-range missiles made some of the DynaSoar's potential missions redundant. DOD also cancelled other manned military systems, such as an orbiting military space station, as it considered them too expensive when compared with terrestrial or unmanned systems. In some ways, the expense of building a presence in space turned out to have some advantages. Space systems were too expensive to deploy except in those cases where they alone could perform a crucial task. By default, this limitation forced an answer to the question of what it is that can be done in space that cannot be done somewhere else.

The contrast with airpower can help to illuminate the nature of military and intelligence activities in space. Airpower means that a nation's forces are unhindered in their use of the airspace; airpower can support their operations, enemy air forces cannot attack them or gain advantage from the air, but the enemy's forces and homeland could be attacked. Spacepower could provide all but one of these advantages. The inability to launch attacks

from space hindered the development of spacepower theory. Sea- and airpower theorists can envision their fleets of ships or aircraft being the decisive instrument of victory. Few people imagined that for spacepower, and no one attempted to put it into practice.

The original theorists of airpower, Giulio Douhet, Hugh Trenchard, and Billy Mitchell, saw it as a new kind of conflict, one that would supplant and surpass previous forms of battle.Airpower offered the opportunity to break the stalemate of conventional warfare and defeat determined enemies without having to first vanquish their armies and fleets. Airpower could bypass trenches, fortifications, and ground forces and strike directly at an enemy's will and ability to wage war. These theories appeared in the decade after the infantry debacle of the First World War. In contrast, there were no great theorists of spacepower in the first decades of the military use of space. If the analogy holds, however, we would say that airpower theorists appeared in the decade after the first war to see the use of aircraft in combat, so if the 1990 Persian Gulf War was the first space war, we should not be surprised to see spacepower theories emerging in the 1990s.

Early proponents of spacepower saw it as an extension of airpower. This was an unworkable approach, given the difference between aircraft and spacecraft. The inability to "fly" manned weapons platforms in space closed off the easy route to the development of a theory of spacepower. Instead, the emergence of spacepower was linked to changing concepts for joint operations and the influence of intangible elements for military effectiveness and national power.

Space and New Approaches to Warfare

The military aspects of spacepower are an outgrowth of major changes in how the United States fights its wars. Defeat in Vietnam brought U.S. military forces to their nadir. From the wreckage of the mass mobilization army in the mid-1970s, new concepts of how America could apply force against its opponents emerged. The end of the draft meant the end of any serious effort to match the Soviet forces on a quantitative basis. As it contemplated how to fight outnumbered and win, the Nation would discover that space assets could provide a crucial advantage.

The new military would be smaller and professional. It would build on the scientific and technological strengths that became part of the American way of fighting in the 1940s.The incorporation of the scientific establishment into military activity during World War II provided U.S. forces with significant advantages in that conflict and the United States created a number of research institutions after the war (such as the Defense Advanced Research Projects Agency and the various Service Labs) to formalize the relationship between science and national security. The Cold War reinforced the importance of scientific research to bolster national security and provide technological solutions to military problems. The use of space and satellites was closely tied to this nexus of national security and science.

The Cold War, with its competition between two different political and economic systems, engendered a number of races to win prestige and international political support.

More importantly, as it became apparent that the United States would not be able to match the quantitative advantage the Soviet bloc had in the numbers of tanks, aircraft, missiles, and other weapons, American strategists turned to the idea of qualitative advantage as the key to defeating a conventional attack by the Soviets. The ability of the arsenal of democracy to out-manufacture the Axis powers had been one of the avenues to victory in World War II. The Soviet fixation on military production closed off this avenue by the 1970s.

Confronted by massive Soviet forces, American military thinking shifted in the 1980s to concepts where a high-tech force that obtained information and acted upon it faster than its opponents was more likely to win in combat. The emphasis on information superiority allows the most effective use of high-tech weapons, making American forces far more lethal today than their predecessors of 20 to 40 years ago and superior to any other conventional military force.

It was not until the 1980s, however, as the United States emphasized qualitative superiority in the face of unmatchable Soviet quantitative superiority, that the military began to realize that the benefits of the different space networks for collection, communications, and navigation were greater than the sum of the parts. The work of John Boyd, who emphasized the benefits of rapid decisionmaking and information superiority for military effectiveness, was influential in shaping the new approach. The elements of this new mode of warfare were information superiority, connectivity (among sensors, combatants, and commanders), and, ultimately, network-centric organization and operations.[7] The most important event for understanding this change was the first war against Iraq in the Persian Gulf. The outlines of a new mode of warfare emerged after the Gulf War. This revolution in military affairs emphasized the greater use and better communication of information among commanders, analysts, and combatants.

The Persian Gulf War, in which space-based resources played a central role in shaping both strategy and tactics for the first time, was a pivotal moment in the military use of satellites. The satellite network designed for use against the Soviet Union in a global war gave the United States a measurable advantage against a heavily armed regional competitor. Combined with airborne assets, this collection provided significant advantages to United States Central Command (USCENTCOM). Iraqi forces found it difficult to compete with an opponent well supplied with space services for navigation and remote sensing and possessing a superior communications network.

The war demonstrated the benefits for military operations of combining space-based communications, navigation, and sensor data. Remote sensing satellites provided data on the disposition and strength of Iraqi forces, supplied targeting information, and allowed coalition forces to assess battle damage. The specialized Defense Support Program (DSP) satellites were able to provide warning (albeit very little) of Iraqi Scud launches. The use of military communications satellites and rented transponders on commercial communications satellites allowed unparalleled coordination between deployed U.S. forces and Washington. Although receivers were in short supply for the campaign, GPS satellites allowed coalition forces to navigate with precision in the desert and in the air.

The combination reduced uncertainty for coalition commanders, allowing faster and more precise operations that less well-informed opponents could not match.

The most important aspect of the use of satellites in the Persian Gulf was the direction it suggested for future conventional warfare. First, the use of precision-guided weapons, combined with GPS and remote sensing data, made possible a new and more lethal method of attack. One of the early highlights of the Gulf War was General Charles Horner, the air component commander, showing the press a video of a precision-guided munition flying through an air vent into an Iraqi government building. The combination of air assets and space data required a much smaller number of aircraft, weapons, and sorties to destroy a target. Second, and perhaps more important, the integration of satellite services for communications and data collection suggested that the United States could develop an advantage in information use that would make its forces more effective in future conflicts. The integration of satellite services (communications, remote sensing, and navigation) with precision-guided munitions and command structures helped lay the groundwork for military transformation.

The successes of coordinated efforts in Operation *Desert Storm* stood in stark contrast to the operations in Grenada a decade earlier. Grenada highlighted coordination difficulties among air, naval, and ground forces that reduced the combined effectiveness of American forces. Mistakes and incompatibilities that the United States could overcome when opposed by a few hundred lightly armed Cuban soldiers might have proven fatal in any contest with Soviet forces in Central Europe. Grenada only reinforced the importance of coordination and coherence for military effectiveness.

The passage and implementation of the Goldwater-Nichols Department of Defense Reorganization Act of 1986 (PL 99–433) were crucial developments for military spacepower.Goldwater-Nichols made important improvements to the chain of command, but for space, its most important effect grew out of the new role of the combatant commanders and their new authorities over all branches of the armed Services. Goldwater-Nichols created a new set of customers—the combatant commanders—who were eager for information and impatient with the complex and slow procedures developed since the 1950s for passing information from "national" assets to the combatant.

The implications of Goldwater-Nichols for space were also significant. The new law and the Pentagon's efforts to implement it created a precedent for space operations. Instead of Army, Navy, Marine, and Air Force units or systems operating independently and reporting to different command authorities, the combatant commander had unified authority over all units and systems assigned to him. This unified, combatant-oriented approach would seep into the thinking about how to organize and use space assets.

However, Goldwater-Nichols did not extend far into space. A combatant commander exercised at best only partial control over the space assets he would use. While some assets belonged to DOD, others were controlled by the Intelligence Community. Satellites operated by civilian agencies and commercial satellites also fell outside the

combatant commander's control.This diffusion of control over assets made control over information even more important.Immediate and direct access to the information and services generated by satellites could compensate for a complicated tasking process.

Timely access did not occur automatically. Grenada and the Gulf War exposed problems in the distribution of imagery and other satellite intelligence.[8] There were long delays in relaying information to the combatant commanders, although these delays became progressively shorter during the Gulf War (daily pressure from a vociferous USCENTCOM commander helped lead to this progressive shortening). Essentially, there was a lag, usually of many hours, in getting data collected by satellites to the combatant commander and his staff. In the competition with the Soviets, when the primary targets for satellite collection were strategic—fixed missile silos, weapons plants, or airfields—this lag had not been a problem. In combat operations, however, the lag contributed to the troubling uncertainty faced by commanders. The desire of commanders for timely and full access to satellite data and services helped to move the focus of military space activities from national assets used primarily for strategic purposes to assets providing information and services for operational and tactical purposes.

This change in focus for military space helped to drive a larger shift in U.S. intelligence priorities in the 1990s. Support for combatant commanders and for the warfighter became the central mission of intelligence, particularly as the collapse of the Soviet Union left the Intelligence Community without its traditional mission focused on a major state opponent. The increased priority placed on intelligence support for the military began with *Desert Storm* and peaked during operations in Kosovo, when a large proportion of all U.S. intelligence assets (including national technical means) were used to support U.S. forces.

The Gulf War showed the shortcomings of another strategic space system designed for the static environment of the Cold War. The DSP satellites used to detect Soviet missile launches performed well in detecting Iraqi Scud launches but were inadequate for determining the position of the mobile launchers; none were found during the war.The DSP launch notification fit well with a strategy of deterrence: the Soviet Union knew that the United States would detect any launch almost immediately and could quickly retaliate against preselected strategic targets. It did not work so well in the more fluid combat environment of the Gulf War.

The Gulf War also exposed a new set of risks for the United States. The availability of commercial space services gave smaller opponents the opportunity to mimic the space capabilities of the larger powers without the expense of building and launching a large satellite fleet. During the war, the combatant commander had to consider the possibility that the Iraqis would acquire commercial imagery from a French service provider or from the Soviets. This imagery might have allowed the Iraqis to divine his intention to swing the bulk of his forces in a hook to the west. In the case of France, the provision of such imagery was blocked, but the potential of Soviet imagery being provided to the Iraqis remained a nagging concern.

This concern has only increased as commercial space services in imagery and communication have become widespread. Commercial space assets fall under a different legal regime than national assets, and by the end of the 1990s, the United States faced (and continues to face) the potential problem of how to gain space control in a conflict where an opponent uses space services provided by a neutral third party. As with the Soviets during the Gulf War, cooperation cannot always be assumed. Blocking the service or attacking the satellite that delivers it puts the United States in the awkward position of widening its campaign. The growth in the availability of commercial space services since 1990 means that space is no longer a unique source of U.S. advantage.

That said, the United States still gains more from space than its potential opponents, not only because of the size of its space fleet, but also because of the effort it has made to incorporate space services into doctrine and planning. The best example of the effect of space technologies on military operations is GPS, which in some ways helps make the dreams of the airpower theorists a reality—instead of dozens of aircraft flying hundreds of sorties to destroy a target, a single aircraft and its weapons, guided by satellite data, could be sufficient.

More importantly, and in contrast to national-level space systems, GPS provides its data directly and immediately to the combatant. The alternative, during the Gulf War and earlier, was for satellite data to stream to a facility in the United States, undergo analysis, and then make its way to the combatant. If GPS operated like other satellite services, a tank commander or platoon leader would put in a request for positional data. The request would be queued. Once acted upon, Washington would process and relay the GPS data to the combatant command headquarters. It would then work its way back to the combatant, who would know his position only a day or two after asking for it. This is how space-based imagery and signals intelligence are supplied. By providing an alternate experience of immediate access to data, from space, GPS suggested an intuitive model for thinking about how to integrate space into air and ground operations: useable data should flow from satellites directly to the combatant.

Naval operations already had incorporated space into combat planning, albeit in a less direct form. Just as GPS allowed a ship to determine its position accurately, signals intelligence and radar imagery from satellites provided the ability to locate and target enemy ships or task forces. This targeting was an outgrowth of the use of signals intelligence in the World Wars (the British and Germans began to use radio intercepts in the First World War to locate opposing warships). The lesson for air, ground, and naval operations is that spacepower may mean getting precise information to combatants more rapidly than an opponent provides military advantage.

The insights about informational advantage helped to drive much of the thinking about the future of conflict in the 1990s, and this new thinking was in turn an incentive for spacepower theory. The storyline is that the United States assembled fleets of satellites for strategic purposes and then found that they could be applied for operational advantage. The revolution in military affairs that grew out of the Gulf War showed that there had been a change in the nature of warfare brought about by the use of new

technologies, in particular space technologies. This led to changes in doctrine and organization that fundamentally alter the character and conduct of military operations.

It is no exaggeration to say that the revolution would not have been possible without satellites. Satellite communications provided new levels of coordination and the ability to transfer massive (for the time) amounts of information rapidly to commanders. Imagery and signals intelligence provided an unparalleled amount of knowledge about terrain, enemy forces, and the effect of U.S. strikes. GPS enabled precision navigation (and in later conflicts, precision-guided weapons) and helped to remove a chief cause of uncertainty from combat: the uncertainty of the location of one's own forces. Before GPS, the bulk of radio traffic in most battles revolved around the question, "Where are you?"

Uncertainty is the opposite of information superiority. Space assets provided tools and data that reduce uncertainty and allow strategists to operationalize John Boyd's ideas on how to use the decisionmaking cycle to attain superiority in combat. Space assets, in combination with new information technologies, were also an essential underpinning for jointness. Better communications, better locational data, and better intelligence increased the ability of the combatant commanders established by Goldwater-Nichols to meld the contributions of the disparate Services into a much more unified force than had been possible in previous conflicts.

The Pursuit of Coherence

Although the Gulf War showed that the United States had the most powerful conventional military in the world, the 1990s were a period of strategic confusion. The grand strategy that had guided national security since 1947 was no longer needed, but it was unclear what, if anything, should take its place, and both Republican and Democratic administrations undertook major efforts in the 1990s to define the new threats to U.S. security and formulate the appropriate response.

The effect of this strategic confusion on space programs was mixed. The United States had over 100 military or defense-related satellites in operation—roughly twice as many as all the military satellites operated by all other nations put together. These satellites provided communications, navigation, weather prediction, and intelligence and surveillance capabilities.Some programs, such as those that monitored the globe for nuclear detonations or for missile launches, remained important as nonproliferation became a new focus for strategy. Other programs seemed less relevant or were challenged by technological changes in communications, which damaged the ability to collect from space. The result was a deemphasis on spending for new space systems. The 1990s were, in many ways, a period of transition in military thinking but of stasis in space acquisitions.

The satellite network designed for use against the Soviet Union in a global war had given the United States a measurable advantage in a conflict against a heavily armed regional competitor, but the security problems these satellite networks were designed to address mapped imperfectly to the Nation's security problems once the Cold War was over. Both

requirements and targets had changed. In both past and current configurations, the United States needed to sustain a global presence, but the rationale for that presence has changed significantly.

Telecommunications provides an example of a crucial change in commercial technologies that affected an important part of the national technical collection system. The adoption of fiber optic cable as the backbone of telecommunications networks in the 1990s ended the ability to collect telecom signals from space. Fiber optics carry the bulk of traffic and use pulses of light to transmit data. Satellites cannot collect against these networks. Radio transmissions could still be collected from space, but over the course of the decade, a very expensive U.S. investment lost some of its value.

The ad hoc space architecture that emerged during the Cold War depended on a small number of large systems. This architecture is more vulnerable than an alternative that depended on a larger number of smaller (and less expensive) systems, particularly if the use of the smaller satellites did not entail a degradation of capability. At the start of the military space competition between the United States and the Soviets, both sides developed antisatellite weapons, particularly after the Soviets threatened to deliver nuclear weapons from orbiting platforms. Despite these programs, there was an understanding that neither side would interfere with the other's satellites, an understanding made possible in the context of the larger strategic contest by the need for transparency to increase superpower stability.

This rationale no longer holds. During the Cold War, a peer competitor facing a strategic nuclear exchange would want to avoid misunderstanding. New competitors do not face the same constraints. Additionally, the Persian Gulf War demonstrated the value of space assets for U.S. military performance and the dependence of the Nation on its satellite fleet. Relatively cheap attacks against U.S. satellites could have a much greater payoff in reducing U.S. military effectiveness, particularly if the opponent did not have its own fleet and did not rely on space for its military capabilities—the lack of strategic parity meant that there was no mutual exchange of hostages in space.

In the 1990s, the only potential opponent who could consider an antisatellite effort was China. The Russians had the capabilities, but relations with the United States at that time made it unlikely that their programs would be a threat. China, on the other hand, began to explore the idea of attacks on U.S. space systems as early as the mid-1990s. There was a period of debate over whether China truly had antisatellite programs and whether these systems needed to be taken seriously—a debate largely ended by the unannounced Chinese satellite test of 2007—but even before this debate concluded, the United States realized that its space assets were targets. Space has never been a sanctuary—the first programs for antisatellite weapons appeared in 1959—but in the bipolar strategic environment, it had been remarkably safe. This safety has now disappeared.

One of the key developments of the 1990s was the emergence of post–Cold War competition in space. The competition, unlike the contest with the Soviets, was asymmetric; no one tried to match the United States satellite for satellite. However, many

nations had seen the advantages space conferred on the United States in the Gulf War and have considered how to interfere with it; a handful tried to gain similar benefits from different (and smaller) space architectures.[9] One crucial difference was that these nations did not need to depend on dedicated military platforms. The emergence of a commercial space market in communications and remote imaging allowed nations to augment their military capabilities by buying commercial services. Commercial remote sensing and interpretive software provide a low-budget image intelligence capability accessible to most nations. These commercial systems do not yet provide a level of service equal to U.S. national technical means, but they offer non-spacefaring nations an immense expansion of capability for some military or intelligence tasks.

The 1990s also saw an accelerated integration of commercial space services into military operations. One reason for this was the decline in defense spending after the end of the Cold War. The United States could no longer sustain the satellite industrial base created during the Cold War at the lower levels of defense spending. This meant that some satellite manufacturers looked to take the skills and technologies they had developed for the military and commercialize them. It also meant that the military and intelligence communities would not be receiving the same flow of satellites into their inventories; this either encouraged or forced them to buy from commercial service providers.

Early debates in Congress and the executive branch in the 1960s led to the establishment of an independent military satellite communications system. This independent capability would meet national security needs, while the emerging commercial communications satellite industry would provide less sensitive services. In the mid-1970s, Congress directed DOD to increase its use of leased commercial satellite services, providing a precedent for thinking in the 1990s about commercial remote sensing.

In remote sensing, NRO encouraged some of its suppliers to undertake commercial operations. The cornerstone of the new approach, with its blending of commercial and national security activities, was the 1994 Presidential Decision Directive 23 (PDD 23). This directive was an effort by the Intelligence Community, the Defense Department, and the Department of State in 1991 to come to grips with the effect of the Persian Gulf War on demand for remote sensing and the end of Cold War expenditures for government satellite systems. The Gulf War excited foreign demand for space remote sensing capabilities at the same time that U.S. Government demand for remote sensing satellites was declining drastically. Congressional pressure to manage imagery requirements better and to support industry also shaped PDD 23 (the Land Remote Sensing Policy Act of 1992, for example, supported the development of private systems and authorized the Commerce Department to license private sector parties to operate private remote sensing space systems).

PDD 23 also provided a brief link between nonproliferation and national security space. One goal of the policy was to discourage other nations from "proliferating" dangerous remote sensing capabilities. The first Clinton administration attempted to develop a multilateral regime to control remote sensing capabilities along the lines of the Missile Technology Control Regime.Unsurprisingly, this effort was a failure; no nation was

willing to deny itself the potential for access to space remote sensing. The 1990s were thus also the decade when the United States would have to consider in its military planning the effect of ubiquitous commercial space services available to all of its potential opponents.

PDD 23, reinforced by the 1996 National Space Policy (PDD 49), did have greater success, after a rough start, in encouraging the launch of U.S. commercial remote sensing service providers.While satellites operated by NRO were more capable than those of the commercial service providers, they were not omnipresent, and the services provided by commercial operators could provide expanded coverage, fill crucial gaps in collection, and be more easily shared with allies.

Several factors shaped security space efforts in the 1990s. The first was the reconceptualization of military operations that began after the Persian Gulf War. In connection with the experience of the Gulf War, the explosive growth of information technologies and networks provided new capabilities for the information provided by space assets and a net-centric way of thinking about how to organize and use those assets.The decline of the defense market and the diffusion of advanced technology into the commercial sector led to the creation of a robust commercial space presence that created, in communications and (at the end of the decade) in remote sensing, both opportunities and challenges for national security. Finally, reorienting the massive technical collection systems away from a single, static superpower opponent to a new range of problems involving smaller, informal targets initially created serious problems for intelligence operations in space. The reorganization of U.S. imagery analytical capabilities into the National Imagery and Mapping Agency (a merger of CIA and DOD assets) and the development of close relations between NGA and NSA helped to overcome this problem by taking advantage of the new tools for analysis and blending imagery with data from other national technical collection means. This combination of commercial and government data increased the value of imagery for military purposes.

In communications, DOD would have been happier if it had its own communications satellites. However, the rapidly growing demand for data and communications engendered by the new style of warfare that began in the Persian Gulf, combined with smaller budgets, meant that DOD had no choice but to turn to commercial providers. Operations in Kosovo are reputed to have required 4 times as much communications capability as the first Persian Gulf War, and the Iraq war is reputed to require 10 times as much bandwidth. The combatant command's demand for data put immense strains on military communications and expanded the use of commercial communications satellites to support DOD.DOD purchases of satellite communications services were of considerable benefit to operators of commercial communications satellites and, in turn, gave DOD the data and communications capabilities it needed and also some flexibility in contracting for global communications services.

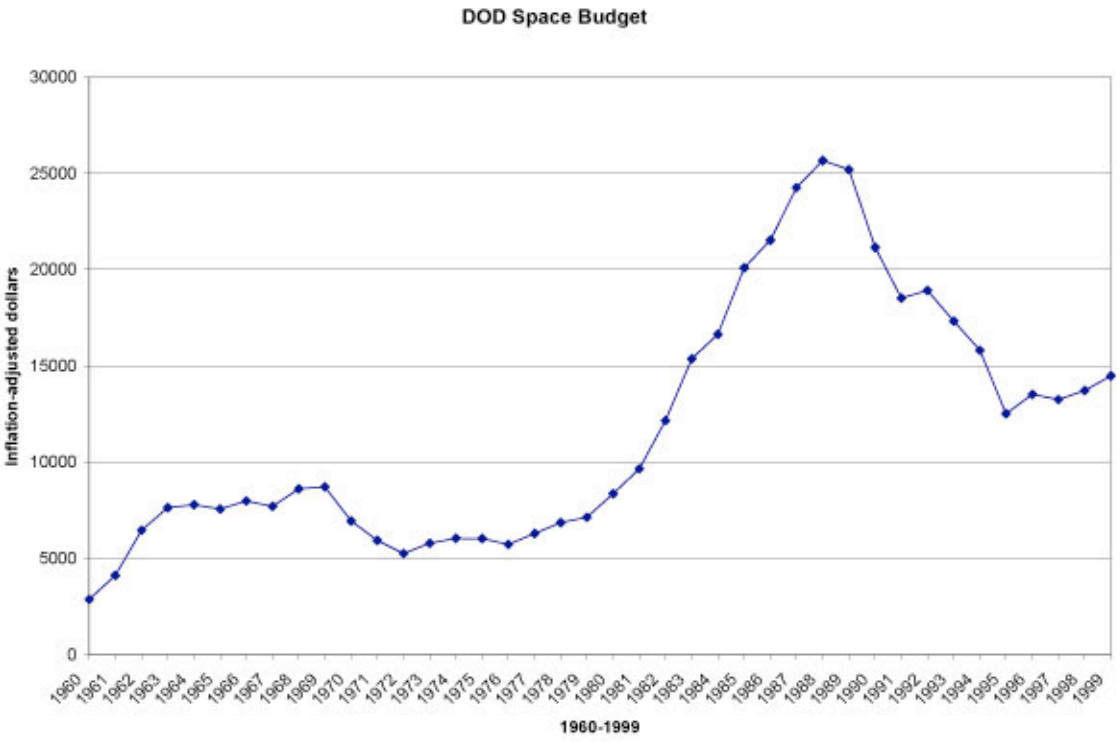
Another aspect of the new competition and the widespread awareness of U.S. capabilities in space was the routine adoption of countermeasures by a range of opponents. Adversary awareness was not new; the Soviets knew from the first that U.S. satellites were spying

on them.The Internet provided even poor and unsophisticated opponents knowledge of when U.S. satellites would be overhead, since enthusiast Web sites provide tracking data for most satellites.Potential U.S. opponents informally shared information on countermeasures. The open discussion in the United States of satellite assets and, at times, of the classified results garnered by those assets encouraged these countermeasures. During Operation *Allied Force* in 1999, the Serbs successfully used a mixture of concealment, mobility, and deception to confound U.S. technical collection. Their success has encouraged others to explore ways to counter U.S. informational advantages. Jamming, spoofing, and kinetic attack will be part of any future conflict.

The Gulf War showed that more timely, precise satellite data are the key to greater effectiveness. This revelation led to requirements and plans in the 1990s to acquire more capable military communications satellites and new kinds of sensors, including a replacement for the venerable Defense Support Program satellites. However, in the absence of the incentives for spending and innovation provided by having a competitor, U.S. space programs entered a period of decline in the 1990s.

In part, this is explained by the decline in the U.S. investment in national security space. Spending on DOD space programs declined significantly, and while figures for intelligence programs remain classified, we can assume they followed a similar trend. If the 1990s was the decade when strategists, learning from the first space war in the Persian Gulf, began to reshape doctrine and tactics to give space a central role in military power, budget figures did not reflect this. The bulk of military space spending increases occurred in the 1960s and again in the 1980s, with the high point occurring in 1988 (see figure 14–1).[10] Spending fell drastically at the end of the Cold War, bottomed in 1995, and then remained flat until the end of the century. Overall, the United States spent 12 percent less on space in the 1990s than it did in the 1980s. This produced a $20 billion shortfall that, when combined with changes in the acquisitions process, slowed the increase in U.S. military space capabilities.[11]

Figure 14–1. DOD Space Budget, 1960–1999



Changes in acquisitions regulations to tighten control over program costs slowed the ability to introduce new systems. Additionally, changes in how NRO acquired satellites, "rigid requirements" negotiated among many agencies for new systems, and an increase in congressional oversight (since the 1980s, programs had been vetted by Intelligence Committee staffs) slowed innovation. This situation could be described as the triumph of accountants over engineers.Defenders of greater oversight for space acquisitions could say that the United States tried to do too much too fast in space in the 1990s; that its programs came too close to the edge of technical feasibility; and that there had not been enough consideration of the kinds of platforms needed or the alternatives to expensive space investments. Yet acceptance of risk, and of failure, is a crucial part of innovation. Could the United States ever again have a Corona program, with its 13 consecutive failures?[12]

Conclusion

The starting point for this history is a 1945 Army Air Force Report to the Secretary of War. The end point is the 2000 Report of the Commission to Assess United States National Security Space Management and Organization. Although separated by 55 years, both reports reached the same conclusion: that U.S. national security depended on a robust presence in space.Security operations in space, however, are not the same as spacepower.

Current discussions of spacepower come at a difficult moment for American strategic thinking. The United States is in a complex transition to adjust its policies, forces, and

strategies to fit a new international security environment. This environment is not one of unalloyed peace that many had hoped for at the end of the Cold War, but a dangerous environment of uncooperative allies and asymmetric threats. Disappointment with the conflict in Iraq and disenchantment with muscular foreign policies have helped to reenergize interest in what some call *soft power*, which uses the tools of persuasion to advance national interests. Space programs are an element of soft power; they provide prestige and technological prowess that can be turned into influence and leadership on the international stage. When NASA manages to launch a shuttle, the world is reminded of America's technological prowess.

Soft power has serious limitations. It is inadequate to constrain a hostile and determined opponent. Realists might say that soft power can only be effective when it is backed by more traditional elements of power: a coherent strategy, a robust economy, a strong military, and efficient diplomatic and intelligence services—in other words, hard power. Spacepower is also a component of hard power. The information and services provided from space are a force multiplier, making for better informed strategies and more effective combatants.

In many other ways, space's unique contribution to U.S. national power is decreasing.The U.S. comparative advantage is shrinking. Commercial satellite services are readily available to anyone, anywhere, with a little money. The Mumbai terrorists used GPS and commercial imagery to plan their attacks, for example.The diffusion of technologies gives many nations an ability to build and operate satellites. More than 80 nations plan to acquire or build remote sensing satellites. Miniaturization of microelectronics, sensors, and satellites provides low-cost alternatives to U.S. behemoths. The sense that the United States spends more but gets less in civil space undercuts the history of achievements in the 1970s. Only in one area—the integrated use of national security space—does the Nation retain a comparative advantage so great that it can be termed asymmetric, an unequal lead against any potential opponent.

The basis of this predominance is the more than 100 U.S. satellites in orbit for remote collection of images and signals, communications, and navigation. The presence in space is matched by an extensive and experienced ground component to process, analyze, and disseminate information from space assets. It is reinforced by the U.S. lead in conceptualizing how best to use space assets and services for military advantage. The Cold War constellation of satellites proved invaluable in the recent wars with Iraq and the Taliban, and the U.S. lead in national security space is a core element for deterring potential opponents from challenging the United States in a conventional military conflict. Satellite services and the use of space are a critical component of U.S. national security.

The current U.S. military space system, while superior to any in the world, faces new demands and new missions for which it was not designed. For much of the preceding five decades, the space mission was targeted toward a single opponent whose threat came from large military and strategic forces. The current space mission is different; the Nation faces a range of opponents who are more diffuse, have lower profiles, and use different

technologies. The requirement for timely, continuous information on these new opponents puts increasing stress on the national security space system. Problems of cost, technological limitations, and disorganization, which have been present since the 1950s, increase this tension.

Changes in the military use of space also challenge the assets and architectures built up over 50 years. Military planning, operations, and tactics have been transformed by the use of information, sensors, space assets, and information technologies. Future missions will place intensive requirements on space-based sensors and other sensor platforms to provide persistent, real-time surveillance, intelligence, and reconnaissance over areas of interest regardless of weather conditions. Providing information superiority at the tactical level may require accelerating flows of information from sensor to weapon to provide for "instantaneous attack" over widely dispersed and separate areas. Afghanistan and Iraq show the potential benefits to be gained from the tactical exploitation of national space capabilities, but they also show the need to accelerate the use of new technologies and architectures and speed integration of information and systems into military operations.

The differences between hard and soft power are suggestive for the concept of spacepower and for reviewing military and intelligence activities in space. Spacepower remains an ambiguous concept. This ambiguity, as yet unresolved, has complicated and shaped efforts since the 1950s to develop strategic concepts for military and intelligence operations in space.Space forces, as they are now, cannot destroy an opposing force, nor are they the instrument of victory in battle. If we agree with Clausewitz that "fighting is the central military act," can spacepower be anything but soft power and a support function for national security if it does not provide for the direct application of force? The history of military and intelligence activities in space, although well known and easily summarized, does not provide a clear answer to this question.

Notes

1. The 1982 National Security Decision Directive 42 on National Space Policy designated the shuttle as the primary launch vehicle for national security payloads and instructed the Department of Defense to discontinue the use of expendable launch vehicles once the shuttle could meet all of its needs.
2. Report of the Commission to Assess United States National Security Space Management and Organization, January 2001, 10.
3. "Call for Test Pilots," *Time*, April 13, 1959, available at <www.time.com/time/magazine/article/0,9171,810946,00.html>.
4. Directive 5160.32, "Development of Space Systems," March 28, 1961. The directive gave the Air Force authority for development, acquisition, and launch of military space systems.
5. Letter, Richard M. Bissell, Jr., to Allen Dulles, August 8, 1961, available at <www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB54/st13.pdf>.
6. See <www.eisenhower.archives.gov/dl/NASA/Binder19.pdf>.
7. See chapter 10, "The Revolution in Military Affairs and Joint Vision 2010," in the Annual Report to the President and Congress, Department of Defense, 1999 at <www.defenselink.mil/execsec/adr1999/>. There is an extensive literature discussing Boyd's

theories, which appeared in his "Discourse on Winning and Losing," an unpublished set of lectures delivered at the U.S. Air Force Air University. A partial bibliography of works on Boyd can be found at <www.au.af.mil/au/aul/school/ots/boyd.htm>.

8. Admiral Wesley McDonald, CINCLANT for the Grenada operation, said afterward: "We have designed and are continuing to design systems which collect intelligence in great volume and in near real time, but I am concerned as to whether we are designing into these systems the communications capability to get that data to the tactical commander in a useable fashion and timely manner. . . . What good is sophisticated satellite imagery sitting in Washington, DC, or Norfolk, Virginia, when the field commander who needs it is on the ground in Grenada, on a ship?" Quoted in Stephen E. Anno and William E. Einspahr, "Command and Control and Communications Lessons Learned: Iranian Rescue, Falklands Conflict, Grenada Invasion, Libya Raid," Air War College Research Report, Number AU–AWC–88–043, 36–63.
9. Commission to Assess the Ballistic Missile Threat to the United States, 1998:

   A number of nations are incorporating technical features of the RMA [revolution in military affairs] into their forces. These include space-based surveillance, reconnaissance and communications by way of both space and land-based fiber-optic networks (perhaps using civilian assets), guidance from the space-based global positioning system/global navigation satellite system (GPS/GLONASS) to increase the accuracy of missiles and the computational capabilities needed to plan, organize, and conduct operations.

10. Spending as a percentage of gross domestic product correlates closely with the dollar figures.
11. NASA, "Aeronautics and Space Report of the President, Fiscal Year 2004 Activities," appendix D–1B, "Space Activities of the U.S. Government," 120.
12. The National Commission for the Review of the National Reconnaissance Office, 2000; Dennis Fitzgerald, "Commentary on 'The Decline of the National Reconnaissance Office': NRO Leadership Replies," *Studies in Intelligence* 46, no. 2, available at <https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol46no2/article12.html>.