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A Theory of Space Power: The Influence of Space Power upon the History of the Future[22]

After more than a century of research and four decades of actual practice, the notion of space flight has entered the realm of mature use. As with all successful technical novelties, this maturation process can be distilled into essentially four phases.[23]

The first phase was discovery, or the actual research that results in the fielding of a prototype that displays some heretofore unseen quality. On a space timeline, this would correspond roughly to the era beginning in the late 19th Century with Konstantin Tsiolkovsky's technical essays on artificial earth satellites, and continuing through the rocket testing of Robert Goddard in the 1920s and 1930s.

The next phase consists of sorting out various proposals in which the new technology may be applied. For our purposes, this would correspond to a period beginning in the late 1930s with the German Wehrmacht's adaptation of rockets to power V-2 missiles, and continuing through the Cold War as the two superpowers gradually concentrated on uses such as earth observation, communications, positioning, timing, as well as scientific space exploration.

The third phase of technological maturity is one of acceptance, whereby the use of a technology is no longer regarded as a novelty.

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22 Gray, Dr. Colin S. 1996. *Comparative Strategy.* Chapter 15. The inspiration for the chapter and the wording for the phrase is based upon Dr. Gray's article.

23 Sterling, Bruce. 1992. *The Hacker Crackdown.* New York, NY: Bantam Books.

This would correspond to the point at which space flight and its related activities exist today. It is no longer the exclusive domain of a pair of world superpowers. Significant strides in the realm of space have now been made by a number of countries and commercial ventures. As satellite dishes continue to appear upon rooftops to access broadcast movie channels and establish high-speed connections to the Internet, the absorption of space services as an indispensable facet of our everyday lives becomes inevitable. It is already difficult to imagine daily life without satellite-relayed pagers, precise time and location information, accurate wide area reports as the basis for weather forecasts, or communications from any location.

The final phase of technological utility—that of ubiquitous use—occurs when the technology filters down through all levels of society. Devices such as the telephone and television represent two such technologies, becoming so pervasive in today's home as to be regarded as simply another piece of furniture. Though space utility has yet to reach this final phase of maturity, it is not too difficult to envision its vague shape at some point within the next century. Space-based communications and location services are already appearing, and space mining, space tourism, space-based manufacturing, as well as the first tentative steps towards space colonization all appear to be well within the realm of possibility and probably represent conservative guesses regarding the use of space in the 21st Century.

As space activities begin to mature, a general public recognition of their increasing importance has begun. The United States and other national governments have come to view their indigenous space industries as increasingly vital economic and political assets. The international community—under UN auspices—is debating statutes and regulations which may, in turn, require enforcement. And, with the demise of the struggle for dominance between the United States and the Soviet Union, the world now perceives an opportunity to make decisions absent the rationale of a bipolar balance of power.

As a result of this increased prominence, many in the professional space community have expressed the need for a comprehensive theory of space power akin to the strategic theories expressed by Mahan, Corbett, and others for sea power, or Douhet, Mitchell, et al., pertaining to the notion of air power. These space power proponents cite the influence of the theories of Mahan as the impetus and justification for the acquisition of navies by several nations at the beginning of the 20th Century. Likewise, the reasoning of Mitchell, Trenchard, and Douhet, proved instrumental in shaping the air forces of the United States, Great Britain, Germany, Italy, and Japan in the 1920s and 1930s. At an historical crossroads, many argue that spacefaring nations find themselves in need of a similar overarching theory against which to plan their national programs and regulate their industries.

In their rush to illustrate the ascendancy of space in military and national matters, many space enthusiasts have attempted to make their point through analogy—most often to air flight. This is only natural as it represents the evolution of a facet of 20th Century national power military analysts are most familiar with. The relatively short span in which flying machines were developed, tested, and refined for increasingly sophisticated use, combined with their position in recent history, makes air flight a ready model for comparison. Furthermore, ongoing military debate regarding the optimal uses of and organizational issues pertaining to space are reminiscent of those of air power in the first half of this century.

In these arguments, today's space environment is often compared to the air environment immediately following World War I. However, this comparison fails in many regards. Unlike its air predecessor of the 1920s and 1930s, there have been no warriors in space; there have been no weapons fired from space against terrestrial targets; and, there have been no space-to-space engagements. What exists instead are numerous unmanned sensors and communications relays that have become the key to forces operating in the media of land, sea, and air. Other than the commands to keep a craft in a desirable orbit, there exists little other control over space assets by US military space organizations.

The reason for this state of affairs—though distasteful to space advocates—is simply the relative immaturity of the technology, systems, and concepts of employment. Rather than comparing space to the post-World War I state of air warfare, a better analogy would move the timeline back approximately 30 to 40 years—to an era prior to powered flight when balloons served as the sole method of air transport. Though quite limited when compared to powered flight, ballooning did, in fact, find some limited military utility during the 19th Century in the American Civil War[24] and Franco-Prussian War.

This analogy, too, is lacking in some regards, but does hold up in several important areas of comparison. Not unlike today's satellites, balloons served as a very constricted model of the utility of an emerging medium. For instance, balloons exhibited a limited ability to maneuver, being always at the mercy of wind and weather. Speed and direction changes could only be affected by a skilled balloonist altering his altitude, thereby making use of varying wind currents. Satellites also are at the mercy of the elements—namely the Earth's gravity and solar weather. Only skilled operators who make use of orbital mechanics to change position and speed achieve limited maneuvering of present day satellites.

Well before the invention of powered, maneuverable aircraft, science fiction writers, scientists, and engineers of the 19th Century ventured predictions of the future of aviation operations, often with remarkable foresight. Jules Verne and Otto Lilienthal both projected the use of powered air vehicles for commerce and war, though neither was ever to see such an aircraft.[25] Current science fiction writers, scientists, and engineers also envision maneuverable craft enabled with the power to free themselves from the constraints of the gravitational fields of Earth, and the physical effects of solar weather.

But, how far removed are they from such spacecraft? And, how close are their predictions to the actual employment of future spacecraft? Is it worthwhile to hazard such forward looking guesses at this point in history? Or is the attempt likely to serve as an amusing historical anecdote? These questions are obviously unanswerable at present, but they may explain the reluctance of many to attempt a comprehensive, strategic theory of space power.

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24 Professor Thaddeus Lowe, an advocate for the use of tethered balloons to conduct military reconnaissance, was placed in charge of a newly authorized US Army Balloon Corps in 1862, after demonstrating their utility to President Lincoln.

25 Though Lilienthal's hang gliders were a major design source for early Wright brothers' models, he died in 1896 after stalling and crashing to the ground while gliding. Some speculate that, had Lilienthal avoided this accident, he might very well have succeeded in becoming the first person to demonstrate powered flight.

An oft-stated view within the US military—most prominently within the Air Force—holds that the Persian Gulf War represents the first space war. Others, less numerous, contend this distinction belongs to the Cold War. But both claims are dubious. Though replete with examples of space support for terrestrial forces, these conflicts were devoid of confrontation in space. It is doubtful that history will remember either as space wars. This distinction likely awaits a clash between roughly equal competitors, one of whom suffers from a decided disadvantage in space support. Such a lopsided advantage may tempt the disadvantaged side to take the offensive in space. Or, quite possibly, the world may begin to learn the tenets of space power as a result of a nihilistic attack on all its low earth orbiting assets by a desperate state or group. Whatever the case, past space operations are unlikely to serve as a future model.

Further caution is advisable. Given the relative infancy of military space systems and the pitfalls of projecting current capabilities into the future, we must also take care to remember that the study of war is not an empirical science and that no single warfare theory—whether it focuses on land, sea, or air—can stand as an enduring truth. Rather, it is like all hypotheses: attempting to explain circumstances based upon observations at given moments in time. And, though many warfare theories contain fragments that continue to prove worthwhile, the body of work invariably loses relevance as it is removed from its historical context. What this says, then, is that the utility of any warfare theory is mostly confined to a near-term future. It is then subsumed by other, more currently relevant hypotheses that retain the applicable pieces of the predecessor, while discarding the others that have outlived their usefulness.

Nevertheless, it is worth a try. Just because current space operations and the tenets derived from them are too limited to be of much use to space warriors 50 to 100 years from now is no reason that we should fail to try to derive near-term benefits over the next 10 to 20. In other words, the fear of appearing historically naive is not a valid reason for refraining from development of a space power theory. The previous 40 years of space experience, along with near-term technological and political trends, can and should serve as a basis for the advancement of a strategic theory. The impact of our national space program, both civil and military, has after all, been immense. The personal computer, live television, worldwide 24-hour news, precision weapons, and hurricane warning are just a very few of the estimated 307,000 secondary applications from space systems development and use.[26] Warfare has been changed (as has espionage) through information gathered and transmitted by space systems, which has profoundly impacted matters both military and diplomatic. Hence, a strategic theory on space power, as it relates to national security at the dawn of the 21st Century, is clearly not only achievable, but highly desirable.

Truths and Beliefs

The primary attribute of current space systems lies in their extensive view of the Earth. Ability to service large areas from a distance of less than a thousand kilometers for most low-earth systems is the key ingredient for stationing the vast majority of systems in space. It is difficult to identify a unique space-based application, since almost all could be and have been accomplished either terrestrially or within the confines of Earth's atmosphere (counterexamples include geodetic measurements of Earth's gravity anomalies, and platforms needing constant sunlight). Communications, navigation, and surveillance are all functions whose origins are earthbound, and are only projected into space because it is more efficient or cost effective to do so. It is this extended area—virtually global in nature—that not only represents space power's most valuable asset, but also sets it apart from all other forms of power. While all other forms of power are effectively regional, space power allows worldwide access in time spans measured in minutes as opposed to hours and days.

A corollary to this attribute is that a space vehicle is in sight of vast areas of Earth's surface. This means that electromagnetic radiation—signals, beacons, or high-energy beamed attacks)—can access the vehicle. The vehicle can also be observed and its orbit measured for future applications of this knowledge.

26 National Aeronautics and Space Administration, NASA Facts, August 1995, document FS-JSC-95(08)-004.

The most exploitable aspect of this worldwide view is that of information transfer, and to a lesser extent, information gathering. As with many other aspects of the information revolution, space enterprises will lead to national power in ways otherwise impossible to obtain. These include the benefits of space activities that we now engage in, those that we can reasonably predict, and many, many others that we cannot fathom. Among the benefits to citizens of the future, the greatest may lie in the prospect that our knowledge and the rate at which we assimilate that knowledge will continue to increase: knowledge of our planet, knowledge of our solar system, knowledge of our origins, and that of the universe. Information and knowledge derived from information can and will prove vital to improving our lives and our national stature.

The emergence of a commercial space industry that owns and operates a growing majority of space systems signals a maturity in space power previously lacking. As opposed to the days of the Cold War, space power now includes all aspects of commercial, civil, and military activities. In this regard, it has come to resemble its predecessors of land, sea, and air power. Like the other mediums of national power, military and civil craft are greatly outnumbered by commercial vehicles—many of indeterminate national allegiance—although each has a "flag" denoting some legal responsibility. Together they contribute to national power just as commercial, civil, and military aviation constitutes the sum of a nation's air power.

For this reason, any useful theory of space power must take this commercial aspect into account. A national power theory based solely upon military-exclusive generalities and tenets would be foolish in any case and especially inappropriate in the emerging space operations cast of characters. Although the military establishment continues to exert a significant influence over the nation's space policy, space remains unarmed. And, irrespective of any change in this state of affairs, military systems are likely to constitute only a fraction of future space activity. It will be the commercial manufacturers, owners, operators, and users who will contribute the larger, if less clearly perceptible, aspects of space power.

Specific steps can be taken to enhance survivability of commercial systems upon which military forces may rely in a confrontation (the harder a target is to attack successfully, the less the temptation to attack it). Nuclear hardening of a subset of commercial satellites, perhaps funded by the military, would be similar in principle to previous arrangements with merchant shipping and commercial airlines. Emergency access to a subset of commercial space services might also be worth arranging and paying for. At the very least, coordination and consultations must be widespread to avoid further widening of cultural gaps between the commercial and military cultures of space power.

Commercial industry's influence on space power further complicates the already formidable task of deriving a formula for national space power—particularly regarding US space power. As the mantle of space power provider is passed to commercial entities, it appears likely that the owners, manufacturers, and users are all likely to be increasingly internationalized. Some argue that this will elevate such consortia beyond the power of sovereign governments; others contend it will result in global influence akin to that of traditional nation states. Since commercial space services and products can be purchased by anyone, it is likely that a common level of space support will soon be available to the citizens of all nations, including their armies. The United States could thus find itself engaged in a confrontation or even a conflict without its traditional advantage in space support, unless it had prepared innovative ways to perform selective denial functions on these assets.

Space exists as a distinct medium. This notion, at first glance, might seem to be intuitive or of little import. However, operational concepts derived over the last forty years have served to obscure and hinder this concept. Specifically, attempts to combine space and air operations—the aerospace philosophy—have served to retard development of space doctrine. We are coming to realize that space operations require a radically different application of the laws of physics as are commonly understood on Earth, and are at times counter-intuitive to our notions of motion and speed. An unshakable insistence on envisioning spacecraft as little more than rocket propelled aircraft is testimony to our inability to divorce space from Earth.

Access to the medium of space has already changed the conventional terrestrial concepts of area, volume, and time. This fact will only become more pronounced as humans and their instrumentalities venture farther into space. The unique attributes of space operations clearly differentiate space power from other mediums of national power, but can only do so if we cease clinging to notions influenced by earthbound prejudices. Until then, space power will continue to be hamstrung by doctrine that owes more to US military organizational maneuvering than rational formulation. The basis of space power is an understanding and use of astrophysics, not aeronautics. For the near term, this will require a sound usage and further understanding of orbital mechanics. For the longer term, it may require complete severance from even this vestige of Earth's influence.

Space power, alone, is insufficient to control the outcome of terrestrial conflict or ensure the attainment of terrestrial political objectives. For the next several decades, the control of space, or even war in space, is important only in that it is important to terrestrial events. Space power must be combined with its emerging sibling, information power, and the older, purely terrestrial, expressions of national power such as air, sea, and land power to successfully influence the actions of competing nations. By recognizing this limitation at the outset, space power can avoid many of the difficulties confronted by those who embraced the early claims of sea and air power theories. They believed that single-minded pursuit of a specific arm of national power could overcome other deficiencies if only properly understood—a belief that some air power proponents continue to espouse even today. Through recognition of national power as the synergistic sum of all its components, a space power theory can avoid overstatement and overconfidence, both of which can prove costly in confrontations. A theory that begins with erroneous premises, will lead to faulty doctrine, which may result in failure in the battlespace and on the battlefields of the future. A theory with a lack of respect for other forms of national power can lead to a misdirection of national assets that can prove disastrous.

Space power has developed, for the most part, without human presence in space, making it unique among other forms of national power. Humans have been physically distant from the vast majority of space operations, including almost all military missions. Technology (both artificial intelligence and teleoperations) has substituted for a human crew in space, providing instead, a virtual presence through a connection to terrestrial control sites.

This physical absence may, in fact, help to explain a general reluctance to lend credence to notions such as space doctrine, space forces, or space power itself. Without the presence of humans in space, the tendency is to view space capabilities as essentially terrestrial with a small, albeit critical, adjunct in orbit. It is difficult to envision sailors who do not sail, and airmen who do not fly. It is equally difficult to attribute the term “spacemen” to those who never set foot in space—perhaps a better term for space operations people is “orbiters,” since that is what their systems do most. And yet humans ARE present “in spirit” aboard their remote emissaries in terms of the attributes most vital to successful space operations: observation and recognition, evaluation and decision, flexibility and innovation.

As with sea and air power, several tenets of space power may be gleaned in forming the basis of an overall theory. Though, here too, we have to make a disclaimer of “from our vantage point in history,” for certainly future circumstances can overcome what today seems intuitive. These tenets are, in fact, derivatives of the attributes of space power listed above and are, therefore, as susceptible to the mutations of time as have been their precursors. Nevertheless, they do provide a foundation from which we may build an outline of the attributes a nation must possess in order to capitalize on space systems as a form of national power.

Technological competence is required to become a space power, and conversely, technological benefits are derived from being a space power. In practicable terms, a strong space industry and a strong educational and laboratory system is required to form a vanguard civil space program and powerful military space capability. As a result, a properly organized and efficiently aimed space industry enhances national wealth. A belief in space technology as a catalyst for overall technological growth—and therefore wealth—is, in fact, often cited as a rationale for many national space programs. Though it does appear that competence in space technology is reflected in overall technological ability, this is a classical “chicken or the egg?” paradox. Technological competence is certainly a prerequisite for beginning a national space program. However, a continuing space program (as long as it is properly designed since some space activities are far more efficient in generating wealth than others) also generates many technology "spin-offs" that lead to general technology improvement. Thus, it would seem that, to the degree that one leads in wise use of space technology, one tends to lead in other technologies. This is not to rule out the need to keep close track of other national space technologies both as a means of assessing their long-range intentions and as a source of additional good ideas for domestic application.

As with earthbound media, the weaponization of space is inevitable, though the manner and timing are not at all predictable. In the near term, US policy will strive to keep space a weapons-free sanctuary, as the United States is the primary beneficiary of such a condition. And, should the United States find it necessary to arm itself in space, it will require some time to untangle itself from the self-imposed constraints erected during the Cold War. At some point in the future, however, the international system of sovereign states and the nature of mankind will combine to cause a state to put a weapon into orbit. The key event may be a perceived need to deploy a defense against ballistic missiles. Other reasoning, based upon a different set of cultural biases, may also lead to the deployment of space weapons. One can imagine that some reasons can be developed for deploying weapons systems beyond the Moon. For example, Dr. Sullivan believed that the development of antimatter for weapons, or for other uses, would have to be kept far from the Earth, perhaps beyond Mars. When warfare moves to space, many orbital locations will prove to be advantageous, including some that use the Moon's gravitational field.

At some time in the future, the physical presence of humans in space will be necessary to provide greater situational awareness. Humans have and will continue to possess a keener ability to sense, evaluate, and adapt to unexpected phenomena than machinery. This is an important attribute in any case, but especially so as spacecraft begin to venture farther from Earth where electromagnetic signal round-trip times stretch from seconds to minutes to even hours. Because of the relative narrow view of sensors that are, of necessity, specialized in their functions, unmanned missions must be pre-programmed to search for and categorize what their programmers have determined to be the likely events they will encounter. Anything outside this realm could be missed, ignored, misinterpreted, or cause for system shutdown due to undefined variables. Also, humans are uniquely able to provide the flexible prioritization in decision making necessary to best manage any situation, whether that job is tasking sensors or maneuvering the spacecraft.

Situational awareness in space is a key to successful application of space power. This means knowing not just where everything is in space and where they are going, but also knowing where they could go if desired, what they are doing, what they are seeing, and what they are relaying to their operators. The United States should enhance its own level of space situational awareness, while taking measures to reduce the situational awareness of potential adversaries so that the United States can exploit that uncertainty and ignorance. The latter principle involves both keeping accurate information away from those who might use it against us, but also camouflaging and masquerading information. To the extent that the level of detailed technical and operational knowledge of the public is degraded by this policy, this may be regrettable but culturally it has proven acceptable.

Control of space is the linchpin upon which a nation's space power depends. As the portion of space containing useful earth orbits becomes predominantly populated with commercial space assets, the country with the largest capital base for such commercial endeavors will, by default, assume a proportionally dominant share of the power accrued from such enterprises. In the near-term, the only individual nation with such an extensive capital base will continue to be the United States. Assured access to space, space-based services, and space-derived products will become of critical import to the US public and policy makers. Control of space and access to space, as a result, will be a non-negotiable issue.

Space operations have been and continue to be extremely capital intensive. Exploration of our planet, the land, the sea, and aerial flight, was often conducted within the means of individual or group wealth, with occasional appeals to royal or republican treasuries. Space has required the wealth of nations—and large nations with large budgets, at that. Only recently have corporations formed consortia to reap potential profits by investing their combined wealth. There is speculation that technologies to more efficiently access space may yet reduce the high cost of doing business there in the near future. It may not.

Scientific research and exploration pays off. Far from being an expression of idle curiosity, exploration and research have proven themselves to be the engine of technological advances, even breakthroughs. They enhance both national industrial capabilities and cultural attitudes toward space. The NASA program on "Origins," seeking data on the origin of life and the possibility of life on other worlds, may look useless in military terms, but that's like the infamous quotation, "How many divisions does the Pope have?" Such research has both the moral authority to create power, and also has a track record of providing the eventual means of generating such power.

There will be wild cards. The British physicist Haldane wrote in the 1930s, "I suspect that the universe is not only queerer than we imagine, it is queerer than we CAN imagine." For space power more than any other current aspect of human activities, the unexpected must be expected. Administrative structures must be in place, and minds must be sufficiently flexible, to detect, recognize, and move quickly to exploit or counteract these surprises. We're talking here about "blue sky" and beyond eventualities, low probability but high impact developments—perhaps development of anti-gravity or inertia-less propulsion, perhaps the capability to easily see neutrinos (and hence to be able to locate every nuclear device on our planet), perhaps energy-sinks and "force fields" which would open physical access to the interiors of planets and even stars, perhaps detection of traces or extraterrestrial civilizations, or contact with representatives of them. Since by definition those with the greatest impact may be those which catch us most by surprise, the best prediction is that these wild cards will be "none of the above," but wilder. The only recipe for Haldane's warning is to stretch our imaginations now and every day of our lives.

Attributes of a Spacefaring Nation

Several basic traits are shared by most spacefaring nations: geographical size and location, national wealth, an extensive and well-educated population, existing national power, a popular appetite for technology, and political will. Of these, it's hard, and perhaps impossible, to determine which is most important—except that at the most basic level, space power can be conceived as a combination of all the quantitative factors multiplied by the qualitative factor of will.

Exceptions to all these traits can be found among today's spacefaring nations, and what appears to have proven most important in one case can be found wanting in another. Japan and France, two countries that occupy the second tier of the world's space powers, are both moderately sized in geographic area, though both rank among the world's wealthiest. Other countries with large populations and landmass, such as India and Brazil, have achieved space programs that are best described as nascent. Israel, which has neither large land area, population, nor GDP, has nevertheless succeeded in becoming a modest spacefaring nation.

The difficulty would appear to lie in the fact that each of these attributes does not exist in isolation from the others. Various traits are inextricably tied together so that no single one can be said to be an overriding factor. For instance, the geographical size and natural resources of the United States have provided an excellent foundation for the creation of the wealth of this nation. Its wealth, population, and geographical isolation enabled the country to emerge from World War II as one of two preeminent world powers. And, as such, the United States had an existing infrastructure and political impetus to commit to an undertaking of great magnitude as was the space race with its Soviet nemesis. The current result of all these intertwined factors is unquestionable space hegemony.

Certainly large countries—as measured by area and population—have an advantage in attaining space powers status. Of the world's largest and most populous countries, Russia and the United States are preeminent space powers with a third and fourth, China and the European Union, potentially emerging as others sometime early in the 21st Century.

As with other forms of national power, space operations are facilitated by national territory. At the dawn of the 20th Century, Mahan[27] specified the extent of a nation's territory as a necessary

27 Mahan, Alfred Thayer. 1890. *The Influence of Sea Power Upon History, 1660–1783.* Boston, MA: Little, Brown & Co.

attribute for maintaining status as a sea power. In his view, Great Britain was an adequate territorial base, while Venice—despite a glorious history of naval success and a culture attuned to the sea—was not. Similarly, countries that occupy large terrestrial territories have an advantage in that they can site their space launch ranges and satellite control nodes within their national territories. Countries with overseas possessions have an equivalent capability, if the possessions are scattered about the globe.

Another geographical attribute of space powers—taking into account current launch technology—is the presence of a coastal or sparsely populated area, such as forest, steppe, or desert. This enables launch sites to be situated so that debris and failed launches avoid densely populated areas. In addition, a spaceport must not only afford an area to accommodate downrange dangers, but ideally, one in an optimal launch direction. Satellites are often launched towards the East to take advantage of the speed of the Earth's eastward rotation. Thus, a launch site whose safety zone lies in this direction may accommodate heavier payloads than one whose does not.

There are other advantages among spaceports. For instance, a nation with territory that straddles the equator or near to it, has a decided edge in launches to geostationary orbits. Not only is the Earth's rotational speed greater at the equator, but less rocket fuel is used since the expensive out-of-plane maneuver to reach an equatorial orbit is greatly reduced, even eliminated. For example, a Zenit booster launched from the equator can place twice as much payload into geostationary orbit as one launched from Baykonur. Sites such as Alcantara in Brazil, the European launch site at Kourou, French Guinea, and the Indian launch sites all benefit greatly from their equatorial geography. Current consideration of Cape York, Australia, as a prospective launch site is based upon its near equatorial location. Other proposals for utilizing the benefits of equatorial launches include mobile sea launch operations.

Some projects seek to circumvent this dilemma altogether by substituting large low earth orbiting constellations (requiring near-polar orbits for full coverage) in lieu of geosynchronous satellites. As other methods of launch become practicable, it is likely spaceports closer to payload construction plants or return payload processing sites will become the most advantageous. However, as long as weight continues to equate to tens of thousands of dollars per kilogram, equatorial launch sites will retain their advantage.

Large countries are also likely to have large populations, and within that population, a large number of highly educated people able to perform the technical work necessary for space systems development. Whether by free choice or through selection, engineering schools as well as mathematics, physics, chemistry, metallurgy, and computer science programs must be sufficiently robust to support a national space program. The dream of space is rooted in educated minds, and space programs are the provinces of the technologically educated. Perhaps more importantly, however, there must be others whose motivation lies solely with attaining knowledge of space and space systems. It is these individuals who are invariably the catalyst for a successful program. They are the visionaries whose single-minded drive allows them to overcome bureaucratic inertia, apathy, and the waxing and waning of support any national program must endure.

Wealthy countries also attract skilled immigrants, many of whom seek out the most challenging professions, including space technology. Five to ten percent of civilian space workers, including astronauts, are foreign born, and their contribution in both technical and cultural terms is spectacular.

As with any great national endeavor, in the end it is the role of the state that is of paramount importance. A national culture must be flexible enough in political, economic, and religious values to permit—if not promote—the challenging of science and engineering standards. In such a national culture, educational institutions must strive to encourage innovation and irreverent attitudes towards the perceived scientific and engineering truths of the past. Information must flow swiftly and widely. In the large, well-funded, national laboratories of a space power, subordinates must be allowed to freely state new scientific truths as they are discovered. Management must not be allowed to reshape fact. There are lessons from history about the consequences of ignoring this principle. In the former Soviet Union, the national space program was greatly burdened by additional costs incurred as a result of excessive secrecy, paranoid compartmentalization and a bureaucratic penchant for substituting political edit for truth.

And we need the “fringe,” those at or beyond the boundaries of accepted thinking. Space power, like air and sea power before it, cannot grow without the input of those who challenge the assumptions of the culture and its leaders. Bright minds, free to explore and learn, are a prerequisite—including those considered eccentric, even crackpot. Space power cannot advance merely from classic cookbook applications of current engineering knowledge. As with any innovative endeavor, many of those who served as pioneers in the development of space systems were dismissed as “weird” in their thinking. The culture of a nation must be able to accommodate many different intellectual approaches to the challenge of defining space power and exploring the means to exercise and retain space power. Those cultures and nations that have not understood this necessity for the free exchange of information and the challenging of known facts, have now fallen behind. As a consequence, we can expect the cultures of successful space powers of the 21st Century to be relatively open by today’s standards.

Large populations can also be beneficial in that they tend to generate large national revenues—an attribute that may be as important a factor as geographical size and population. Provided that a certain portion of these revenues are discretionary and can be freed from other governmental expenditures, a wealthy nation will be able to afford the large development costs of a space program. As with many governmental programs, a national space effort seeks, at least in part, to justify such expenditures, not only as the necessary cost of national power, but as an economical investment in the future. Such claims appear to rest upon safe ground; few analysts doubt that space enterprises will bring great wealth. Given this foresight, those countries that invest the most can expect to reap the most. To this end, the United States should feel fairly secure in that its investment in space is already huge. Others, though making similar investments in terms of percentage of their annual expenditures, pale in comparison in absolute terms.

Large populations also provide a potential market for space-related services and products. This market potential can stimulate commercial investment in space technology, as is now the case within the United States, and in limited form elsewhere in the world. The benefits of direct economic advantage and spin-offs that will, in turn, revolutionize other fields of economic growth will enrich spacefaring nations. This belief is so widely held that the United Nations Committee on the Peaceful Uses of Outer Space annually discusses how to ensure that others benefit from the growing treasure chest of space results.

What are we then left with, in our examination of these necessary attributes of a spacefaring nation? Certainly size—both geographic and in populace—are important though not critical, if the case of Israel is considered. A well-educated population is also needed, however, the Chinese, who have yet to produce a Nobel laureate, are nevertheless well on their way to becoming a future space power. Wealth must necessarily be considered. But, in terms of absolute wealth, the Soviets lagged far behind the United States and still managed to field a comparable space program. Also, though the Indian and Chinese states are not usually considered to be among the world's wealthiest, they have afforded entry into the space community. What then, if anything, can we say that could qualify as a maxim in a state's drive to attain space power? Probably, only that: a state's drive to attain space power.

When all layers are peeled away, what is left is a state's political will. In the absence of absolute wealth, as well as bureaucratic and technical inefficiencies, it was the political will of the Soviet Union to commit a disproportionate share of their national resources that enabled them to keep pace with the United States. It is also the policy in China, which views itself as the once and future "Middle Kingdom," where national will is responsible for an ascending space program in the midst of a myriad of competing national interests. And, most tellingly, it is the political backing of Israel's space program that has enabled that country to overcome the apparent obstacles to becoming a full-fledged member of the space community.

Interestingly it is this very attribute—political will—that makes the European space endeavor so enigmatic. In combination, Europe has population, education, wealth, size, and suitable launch sites. And, it appears, only in combination does it have a future as a space power.

However, it is questionable whether a combined political will can be found to drive the machinery of a space program comparable to that of the United States and the erstwhile Soviet Union. France, Britain, and Italy, all had ambitious national space programs in the early 1960s; however, only France has carried that impetus through to the present—maintaining an aggressive space program both within the European Space Agency and nationally. Every other European national space program has essentially become a supporting player to ESA and, in essence, to France. Furthermore, having recently experienced national budgetary constraints due to the rising costs of social programs and labor, there are serious doubts that the French can continue to finance their space program at present levels. Future plans for a European military space program, centered about an already under-funded French program, are equally uncertain.

An outgrowth of national will is the development of a cohesive space development strategy that avoids the worst features of endless bureaucratic infighting and freebooting commercial bloodletting. Centralized control is not desirable, but some sort of coherent entity must operate to resolve disputes, set policy, break ties, and act as an advocate for space power in the halls of government. Whether this is a "National Space Council" or an activist department elsewhere in the Executive Branch, experience has shown there is a beneficial role for such a player.

The Exercise of Space Power for National Security

The history of mankind has proven time and again that anything which enhances the power of an individual or group—be it political, economic, or military strength—will be coveted by others. It follows then, that any prudent consideration of national power must include the resources to protect it from those who would seek to turn it to their own advantage. If the United States, or any other spacefaring nation, wishes to retain its national space power, it must necessarily protect its interests in space. The term most commonly used for expressing this need is space control, derived from Mahan's notion of sea power and sea control. This notion—no matter its designation—is the primary principle of the exercise of space power.

A basic tenet of space control is a requirement that all elements of space power, whether orbital or terrestrial, be protected. Also, should confrontation become inevitable, then it is vital to be able to disrupt or deny some elements of opposing space power. This does not imply that third party states or groups will be barred from space activities, nor will they be required to obtain the permission or acquiescence of the spacefaring nation exercising space control. Space control is, rather, akin to concepts for air and sea control. It is exercised less by the active use of military forces than subtle pressures, including the possibility of military action.

Space control, as practiced during the Cold War, was defined as the use of space by one's self and friends, combined with planning for terrestrial actions to deny a potential adversary the exploitation of space systems. This view of space control will likely change with the events and politics of the 21st Century as coalition forces become the rule and international commercial consortia come to dominate many of the space services once the province of militaries.

As mentioned, the protection required and provided by the concept of space control must be applied to all space assets upon which a spacefaring nation relies. Due to the ascendancy of commercial enterprises in space, this will come to include a large number of commercial orbital and terrestrial assets as well as the assets owned by our international friends and allies. Protection will remain primarily a passive function as the threat of hostile actions against spacecraft and terrestrial facilities itself remains passive.

Additionally, a spacefaring nation must become adept in the related concept of information control. The most feasible threat against space power will likely continue to be the blocking of, or introduction of error into, the information streams from and through space, including those necessary to conduct space operations.[28]

As an adjunct to protection, survivability must also be integrated into the elements of space power, whether by protection or through redundancy. Physical security of terrestrial facilities, while not

28 See *Space Control Issues in the Post-Cold-War Era* (Bruce Wald, Gary A. Federici, Linton Brooks, Center for Naval Analysis, Research Memorandum CRM 96-83, November 1996) for a more detailed analysis concerning the most likely threats to space systems.

unimportant, can often be accomplished by auspicious siting within the boundaries of the spacefaring nation. For instance, as launch sites are nearly always located within national territory, physical access to space can be assured, barring terrorist attack or invasion. Tracking stations and certain control nodes are often not, however, providing an adversary with a potential point of disruption. Advances in satellite control and tracking through the use of satellite cross-linking may circumvent this deficiency by redirecting a constellation's signaling over national territory. Such a mechanism is hardly foolproof, though, as the accessing of information to and from space is more easily tampered with by reason of its route through the Earth's atmosphere.

For the most part, survivability of orbital spacecraft continues to be based largely upon a consideration of odds. Though satellites may be protected against radiation associated with a nuclear detonation at a relatively small increase in component cost and weight, near earth satellite owners have been loath to accommodate even this small increase due to the additional costs of launch and the negligible chance of nuclear hazard during the life of the satellite. Should near-earth radiation levels change, this additional protection would, no doubt, be added very quickly.

The ease by which satellites in low earth orbit have been tracked by many groups of interested amateurs, illustrates a different problem concerning the certainty of orbital periods. Easily tracked satellites are, by default, easily targeted. This state of affairs will be mitigated somewhat by the advent of large, commercial, low earth orbiting systems that will complicate satellite tracking by increasing the number of objects in view at any given moment. Another mitigating factor is the current discussion of replacing larger satellites with smaller, more numerous "microsats." Given the increased number of satellites near the Earth, survivability could be further enhanced through the ability to freely maneuver, hiding in the vastness of space and among other objects in earth orbit.[29] Such maneuverability would greatly complicate the calculations of those who would wish to track a particular satellite. To counter satellite maneuverability, an

29 Though almost all satellites today possess some such ability (for most, a minimal capability), large or numerous changes are too expensive in terms of satellite lifetime.

adversary would be required to develop a very robust, widely situated, and very precise space surveillance system to successfully attack a particular satellite, or type of satellite.

This leads to another vital component of space control: the ability to gain visibility over operations in space. As with any attempt at management, particularly as it pertains to the military concept of the battlefield, knowledge of all applicable variables is absolutely vital. It follows then that no nation, or group of nations, can hope to achieve space control without knowledge of the environment. If one can't see other spacecraft, man-made debris, or pieces of the cosmos hurtling by, one can't assess, warn, dodge, protect, or attack.

Thus, surveillance of space emerges as the key element of space control, enabling the other facets of protection and denial. This is, in actuality, a declaration that controlling one's destiny in space hinges upon an ability to detect what is happening in real time, as it happens. Until the point when we can truly watch over satellites, we must place our faith in the good intentions of others.

Though precise, real-time knowledge of a satellite's position could prove to be a daunting task should someone truly wish to hide in space, everyday space control could be more easily effected simply by patterning it after aspects of air traffic control. Both surveillance and survivability could be greatly enhanced by requiring satellites to report their own position as do aircraft.[30] However, given such an analogy to air, the problem arises: who then assumes the mantle of space traffic control? Would it default to the United States by virtue of its standing as owner of the world's most extensive existing surveillance network? Or would there be objections to hegemony over such a vital function? Would there be a competition? Or, more likely, would such an executive agency fall under the auspices of the United Nations in the same fashion that flight beyond national airspace does under the International Civil Aviation Organization (ICAO)?

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30 Unlike aircraft, however, which cease to fly when they malfunction, spacecraft remain aloft (albeit in a gradually decaying orbit), presenting an uncontrollable hazard to the remaining space traffic.

As the space environment matures and corresponding doctrine evolves, space control will necessarily become a facet of any spacefaring nation's space policy, particularly as space becomes important to the economy and national security of those nations. However, like any effort to exert a nation's will, space control will be most effective when all avenues of influence are employed.

The exercise of space control is more than the muscle and bulk of a dominant spacefaring nation. It will require diplomacy as well as a believable, coercive capability. It will require national autonomy, as well as economic cooperation and true partnerships. Effective space control must provide the freedom to allow consortia to lead the way, the freedom to allow others to develop different methods and approaches, and the freedom to accept new ideas. Space control accepts the presence of others, while reserving the ability to checkmate threats.

And in the end, history teaches that the fullest exploitation of space power, as with other forms of national power, ultimately rests on the willingness to use force. That is a topic for its own chapter.