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The Nature of Space Power

"Les Yankees, ces premiers mecaniciens du monde, sont ingenieurs, comme les Italiens sont musiciens et les Allemands metaphysiciens,—de naissance." (The Yankees, the best mechanics in the world, are engineers, as the Italians are musicians and the Germans are metaphysicians, by birth.)—Jules Verne, *From the Earth to the Moon*, 1865.

The enviable position of the United States as the leading player in space activities at the end of the 20th Century is the culmination of many factors of "space power," some of them involving foresight and hard work, and some of them involving luck and circumstances. Consequently, any strategy to exploit and expand this position must pay attention to these different types of factors and how they can be encouraged. First are the resources to be applied to the task. Secondly is the wisdom and vision to choose among an infinity of alternative strategies. Lastly is the flexibility to anticipate, respond to, and benefit from random, opportunities which cannot cease to occur.

"Space power" is a phrase that evokes parallels with historical concepts of "sea power" and "air power." Useful parallels can be drawn. But without an appreciation for how different space is from air, sea, or land (chapter 1), false analogies and resulting erroneous decisions are possible, even likely. And without some familiarity with how "space power" has already been applied, sometimes well and sometimes poorly, at other times and in other places, insights and lessons may be lost. The purpose of this chapter is to provide that familiarity.

The elements of "space power" range from the obvious hardware—space vehicles, launch and control sites—to the often overlooked human element: people whose intelligence and dedication drives the innovation, and a parent society which understands and values "space" activities, and considers the payoff worth the major effort. The more of these elements that are possessed by a user, the more flexible, reliable, and robust the applications will be.

Elements of Space Power

Elements within a nation that make it capable of wielding "space power" are outlined below. While these are the individual elements of space power, to achieve a leading or even dominant space role, a nation must also develop the attendant national and military strategies and the policies that enable it to exercise and exploit space power.

Any explicit list of elements of "space power" will probably be incomplete, and often, weaknesses in one area can be overcome by strengths elsewhere. The following elements are neither mutually exclusive nor necessarily complete.

Facilities: A user must have the obvious elements of hardware with which to conduct space operations: manufacturing facilities, launch facilities, and command and control facilities. Ideally the user owns these, although exploitation of another owner's facilities is often feasible.

Technology: Laboratories (primarily but not exclusively government-funded) must develop basic and applied research programs relevant to the full spectrum of capabilities related to desired space operations. These programs must compete favorably with defense, energy, transportation, and medical programs for funding. National and private laboratories should ideally work in cooperation with universities and develop programs that encourage students to enter the field. Access to the technology of other users—both for direct transfer and for assessment of capabilities and intentions—can often provide crucial guidance in the development of both short-term responses and long-term strategies.

Industry: Private industry must vigorously pursue space technology and applications for "business and profit" and fund their own in-house basic and applied research to maintain a competitive edge in the designing, manufacturing, deploying, and operating of space systems. This includes the innovation of modern and efficient production facilities for producing large numbers of satellites (buses and payloads) rapidly and at very competitive costs, the ability to operate space systems economically but safely, and the strategy to leverage other technologies into space-related applications.

Hardware and Other Products: The actual space vehicles (e.g., the payloads and the boosters) and the material required to operate them (e.g., fuel, power, and other utilities) are the result of industrial and financial capabilities, modulated by utilization strategies. Their quality, cost, lifetime, and other characteristics reflect original strategic intent and determine actual operational capabilities. The level of spare parts and of reserves (providing a rapid replacement of losses, or a "surge" to deploy more-numerous-than-normal assets) depends on strategies and constraints, but is an often-overlooked element of "space power" that can mitigate weaknesses in other areas.

Economy: A strong economy makes it easier to fund a strong space program, both government and commercial programs. But a weak economy should not be allowed to lead or to terminate space activities. Because space expenditures often tend to be long-term payoff investments, nations and corporations undergoing financial crises often are tempted to reduce space spending, especially since such reductions give little short-term indications of damage. But space systems currently available often depend on decisions made ten or fifteen years in the past, so short-term cutbacks often require downstream overspending, often at multiple levels of the original shortsighted savings. Space activities often require substantial new investments, with government instigation and subsidies to pioneer some technologies, and more prosperous times may allow government and private funding of a wider range of investments. But even in temporary hard times, wise users strive to protect space-related investments in future space power.

Populace: The citizenry must be well educated with sufficient numbers of engineering specialists and theoretical scientists. Because space spending is so sensitive to initial investments and to personal innovation, a high ethical level—especially in economic and legal terms—is also a benefit for minimizing losses due to administrative overhead and financial corruption. In terms of citizenship, the taxpayers need to understand the importance of government expenditures on developing space technology. Just as importantly, the populace must be comprised, in part, of an influential group of technology proponents. This will make the market for new technologies culturally important. Also, since popular culture is influenced more by noise than by opinion polls, it's important that there NOT be vociferous and energetic opponents of specific space policies since they tend to have social influence disproportionate to their absolute numbers.

Education: There must be access to a sufficient number of universities (either domestic or foreign) offering relevant engineering and science courses from undergraduate through doctorate-level, in order to generate the knowledge and talent pool required to support and grow a vibrant and vigorous space industry. In addition, domestic universities, in cooperation with the government and other institutions, must conduct research programs to keep the nation on the leading edge of space-related technology.

Tradition & Intellectual Climate: A nation's space activities require broad popular appreciation and support in order to have the endurance to tolerate both long-term economic and political variations as well as short-term setbacks. This appreciation is both for practical applications and as inspiration and affirmation of national consciousness. Public enthusiasm for space activities translates directly into a pool of candidate professional space workers and a constant source of ideas and inspiration for space policy makers (as in Verne's prescient quotation at the head of this chapter).

Visionary leadership is needed from decision makers and decision shapers in government, in commercial companies, in academia, in the news media, and at large—they must all have basic understandings of real versus unreal space possibilities. Public respect for and trust of national space organizations is also highly important and any domestic intellectual climate that hinders that relationship will diminish the national capability to develop and wield space power. The intellectual climate must include widespread popular interest in the acquisition of knowledge. New discoveries, even if not immediately applicable, must be seen as eventually providing to the general knowledge base from which practical applications will come. Academia should be excited about new discoveries and infuse students with that excitement. It is also important that the agencies responsible for exercising space power generally be respected and trusted, to avoid developing a "garrison mentality" on one side and a mistrust and aversion on the other.

Geography: The free exercise of space operations requires a launch site with ample downrange safety zones (in the multi-stage expendable booster environment) and usually a far-flung string of communications sites. This favors geographically large nations or those with good diplomatic relations with potential host nations.

Exclusivity of Capabilities/Knowledge: The most volatile aspect of power in general is related to features which one owner alone possesses, or one owner alone understands the capabilities of. Since experience demonstrates that any such benefits are bound to be short-lived, efforts to protect these features must be matched by efforts to develop replacement features.

Uses of Space Power

As users possess various elements of "space power" to varying degrees, they can exploit them in a number of specific ways. The effects of "space power" can be categorized as economic, cultural, diplomatic, and military (next chapter). Another way of looking at space power is to delineate the different ways it can be applied.

First, it can be applied as a direct benefit to the owner, through pursuit of diplomatic, civil and military applications. More and more such applications are becoming cost-effective even on their own merits alone.

Secondly, space power can be used to encourage and reward other global players. The opportunity to piggyback one player's space efforts onto existing and easily shared/transferred capabilities of another has measurable economic value.

Thirdly, space power can be used to dissuade targeted players. Discouraged and unwanted behavior can result in termination of valuable joint activities, withholding of accustomed information and other services, or isolation from the international space community.

Fourthly, space power can be utilized to avoid punishment from other players aimed at the owner of the space power elements. Each user seeks as great an immunity as it can obtain from dependence on other nations for key space power elements, but only those with the broadest infrastructure can achieve this and exploit the freedom of action it provides.

Fifthly, space power can be used to project national influence, both through the cultivation of dependency among other global players and through control of the agenda of international discussions of cooperative projects, and treaties. One nation's space power can also significantly influence the internal space policies (and other policies as well) of another player by forcing symmetric developments or by discouraging ambitions for competition or confrontation.

Lastly, space power can be used to apply force, both in space, from space, or through space, and to resist the use of force against oneself.

The United States and Space Power

US space power owes a debt for the pace of its development to the Soviet Union and its military ballistic missile program, the base of the early Soviet space program. The United States would have ventured into space activities anyway as a result of internal intellectual energy and scientific curiosity. As evidence, the US Government had announced its intention to launch a satellite into low earth orbit during the International Geophysical Year (IGY) in 1958. The advantages of geosynchronous satellite communications relay were apparent to Arthur C. Clark and his readers years before the space race. Communications relay through LEO would have been attempted and been found to be very useful in the decade following the IGY. It is likely that the space-based communications industry would have grown up without the Soviet Union. However, the public relations triumph of Sputnik forced the United States to attempt to match the Soviet space program as soon as possible. President Kennedy's commitment to put a "man on the Moon, and return him safely to Earth" in the decade preceding 1970, caused the expansion of space technology into many unimagined capabilities, in addition to manned space flight. Likewise, the need for information about Soviet military capability was the rationale for the development of space-based information sources. The requirement to support worldwide military options against possible Soviet initiatives hastened space-based weather and communications technologies.

The successful applications of "space power" by the United States have already filled many, many books. With an annual NASA budget of about $13 billion and a larger military space budget, of which the published portion is a similar size, the United States holds a dominant lead in Earth's space activities. It has deployed and is operating the most capable earth observation systems, the most flexible orbital launch and retrieval system, the most advanced constellations of Earth-orbiting space vehicles, and the most far-flung fleet of interplanetary space probes in the history of the space age.

In the commercial space sector, US commercial advantages are equally strong. According to John Logsdon,[10] "US industry has a wide lead in all markets other than space launch." Even here, writes Logsdon, "the European lead is fragile." New US launcher projects include Sea Launch, new versions of the Atlas and Delta vehicles (including the use of Russian designs for rocket engines), and a possible commercial version of the DoD-sponsored Evolved Expendable Launch Vehicle. The US space industry also has probably the largest variety of innovative advanced concepts for smaller launchers. All of these potential launch systems point to significant near-future gains in this arena.

Logsdon quotes the Teal Group[11] as forecasting that US firms will be prime contractors for almost 75% of the various types of information transfer satellites over the next decade. "The United States is in this position because it adapted more rapidly than Europe and Japan to a changing economic and political climate," Logsdon wrote. His use of the singular pronoun implies a centralized, monolithic management which in fact does not exist; more accurately, he should have worded it that "US industries are in this position

10 Logsdon, Dr. John, Director, Center for Space and Policy, George Washington University, Washington, DC. "The United States, the Only Space Superpower." Space Policy. Nov. 1997, Vol. 13, No. 4, pp. 273–279.

11 Teal Group Corporation publishes the World Space Systems Briefing, a monthly information service that reports the status and outlook of the world's space systems, spaceports, and markets.

because THEY adapted...” which underscores the classic advantages of distributed decision making in a highly dynamic environment.

Russia and Space Power

Besides the United States, many nations have exercised all or many of the elements of space power. A review of these other approaches to space power will show alternative strategies, which may provide new ideas for US space power, or may highlight challenges to US space power. Since it is very human to not be good at self analysis, we often learn the most from looking at others. An analytical approach to looking at someone else’s strengths and weaknesses may give us a better picture of our failings and our virtues.

Union of Soviet Socialist Republics (1957–1991): The Soviet space program has been, apart from the US program, the only other space program in the world to conduct a full range of space activities—scientific, manned, commercial and military. The Soviets possessed all elements which made up “space power.” They exercised these elements, and then they lost these elements. As a case study, the Soviet/Russian space program deserves some in-depth description, but readers may skip to the “Other Nations” section if they desire.

From the viewpoint of official Soviet culture, it was natural for the USSR to lead the world into space. Lenin himself had realized the value of embracing such space visionaries as Konstantin Tsiolkovskiy. This was useful both as a symbol of futuristic, idealized communism as the supposedly most advanced social organization on Earth, and as a distraction from harsh everyday realities. Like the United States, tsarist Russia too had a recent geographical expansion—a “Wild, Wild East” scenario where Cossacks had advanced into Siberia for centuries.

Thanks to a series of highly popular books as early as the 1920s, an entire generation of Soviet engineers and scientists were inspired to see themselves as space pioneers. As it turned out, few of them survived the Stalin purges and World War II. But by 1947, the Soviet government turned to the survivors—Sergey Korolyov, Valentin Glushko, and others—to lead a major push in rocketry that soon expanded into ground-breaking space accomplishments.

For most of its history, the Soviet space program was carried on by a collection of distinct, often mutually antagonistic entities with an ad hoc pattern of shifting alliances and animosities. Centralized decisions were often made and unmade by whim, by personal influences, or by misreading external factors. Organizational relationships were often determined by factors as arbitrarily Byzantine as hiring or marrying the children of Kremlin officials. This confusing, unstable, and inefficient system was, in the beginning, fairly effectively concealed behind the public facade of a monolithic, coordinated program.

Rocket (and nuclear weapons) development was coordinated by the deceptively-named "Ministry of Medium Machine-Building," usually referred to in its Russian abbreviation of MinObMash or "MoM." It financed a suite of specialized civilian institutes and manufacturing facilities led by brilliant but often highly-competitive "General Directors" and "Chief Designers." The Soviet armed forces (the Air Force, the Strategic Rocket Forces, and a specialized ministry-level independent unit called the "Space Forces") supported space operations by running the launch sites and tracking stations, and by training the cosmonauts. The prestigious and well-funded Academy of Sciences, especially in the early years, had significant input on programmatic decisions, although later its branches, such as the Institute for Space Research (which usually billed itself deceptively as "the Russian NASA") and the Institute of Biological and Medical Problems, shrank in significance and staffing. Later, various specialized bureaucracies such as "Interkosmos" and "Glavkosmos" were established as "fronts" for international cooperative projects.

Since the entire Soviet space program was presented to the world as "entirely peaceful," there was no need to split and duplicate facilities between a NASA-like civilian organization and a parallel military organization. Nevertheless, massive duplication and overlap existed between competing bureaus and military units.

Within a short time of the Sputnik launch (October 4, 1957), Soviet leaders quickly realized the most important result of their space activities. These "space spectaculars" convinced the West (and the Soviet public themselves) that the USSR possessed highly advanced space and missile capabilities. This high level of perceived status—scientific, technological, and military—proved to be the main (some would say only) benefit of Soviet space activities. It would be simplistic to say that the program was only funded primarily for prestige; rather, the program proved its worth when Western attitudes shaped by the public perception of the program could be exploited diplomatically and commercially.

From a very long historical standpoint, the greatest contribution to humanity from the Soviet space program may turn out to be that it energized a vigorous US response at a scale that otherwise was inconceivable. Without Sputnik, Vostok, Lunik, and other challenges to America's political ego, it is questionable if there ever would have been an Apollo, or Viking, or Skylab. This international dynamic underscores the theme that Earth's space activities are more than the sum of each nation's individual programs, and shows that there is a powerful feedback mechanism among them. Decisions in one country often depend profoundly on decisions made in other countries; they also depend on perceptions and often misperceptions of other national programs.

Meanwhile, inside the real Soviet space program, the military application of all space projects was paramount from the beginning. The Vostok manned spacecraft of the 1960–1963 era was quickly adapted to serving as a photo reconnaissance vehicle. The first orbital antisatellite weapon tests in 1963–1964 were deceptively called "Polyot" missions allegedly aimed at "perfecting space technology for peaceful purposes." Systems for placing nuclear warheads in orbit were tested as early as 1966, with false cover stories about "scientific exploration missions"—after Moscow had signed an international treaty outlawing the placement of nuclear weapons in orbit. Manned spacecraft were developed in the mid-1960s for satellite interception roles, and like designs for manned military reconnaissance platforms in the 1970s, they were to carry a space-to-space cannon (these plans were never carried out). In the 1970s, spacecraft design bureaus drew up plans for space systems to conduct Earth surface bombardment; the USSR launched several manned Salyut stations devoted to military reconnaissance and developed plans for even larger ones with better sensors. As late as 1987, on the first flight of the "Energiya" super-booster, the hundred-ton Polyus-Skif payload carried prototype space-to-space laser weapons and a collection of tracking targets.

By late 1998, enough hearsay evidence had been gathered to convince some space historians that the Soviets installed a defensive cannon on one of their early space stations, the Salyut-3 military reconnaissance vehicle, launched in 1974.[12] According to published accounts, reportedly confirmed by the spacecraft commander, Pavel Popovich, the station carried a modified Soviet jet interceptor cannon. It was a Nudelman-Rikhter "Vulkan" gun, similar to models installed on the Mig-19, Mig-21, and the Sukhoi-7.

The Soviet weapon was installed to defend against manned or unmanned American interceptor spacecraft approaching Salyut 3. The gun was fixed along the station's long axis and aimed by turning the station, guided by a sighting screen at the station control post. At ranges of less than a kilometer it could have been highly effective, as long as it was not fired crosswise to the station's orbital motion, in which case orbital mechanics would have brought the bullets back to the station within one orbit!

Specifications for the 30 mm version of this cannon are a length of about 2 meters, weight of 66.5 kg, 900 rounds per minute rate of fire, developing a muzzle velocity of 780 m / sec for a projectile mass of 410 grams. There is also a 23 mm version weighing about 40 kg. It is not clear which of the two was on the Salyut 3 space station, but in the late 1960s the Soviets did design (but never built) an "attack Soyuz" manned spacecraft carrying the 23 mm gun. Several sources confirm that after the last crew left the Salyut-3 station, the cannon was test fired to depletion via remote control.

This space cannon would have been operational in the same period that Soviet leaders such as Yuri Andropov were piously proclaiming that the USSR would "never be the first to deploy weapons in space." This defensive weapon and the public policy statements may be evidence of Soviet fear of US space capabilities or another example of Soviet duplicity, or both.

A wide range of other Soviet military space programs provided both "force enhancement" and special unique capabilities. Both

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12 The US civil space program was nearing the end of the Apollo series of flights (the Apollo-Soyuz linkup was just months away) and design of the reusable American "spaceplane" was being publicly debated.

anti-missile and antisatellite units were established within a few years of Sputnik. Reconnaissance satellites, both visual and electronic and even active radar, soon appeared. Military communications, navigation, and weather systems were developed, along with space-based missile launch warning systems. A special reconnaissance system was developed to spy on the Soviet Union itself to determine what corresponding US assets might be able to observe.

Civil applications also were developed, usually as adjuncts to military systems. Civilian communications and weather satellites began operations in the mid-1960s, at first from low and medium orbits and only much later from the 24-hour geosynchronous orbits.

Exploratory programs were also funded generously, at least at first. These included probes to the Moon, Mars, and Venus, plus a number of scientific research satellites. The pinnacle of this program occurred in 1985–1986 when two Soviet probes flew past Venus and then Halley's Comet, carrying an impressive suite of domestic and foreign scientific instruments.

Partly due to traditional Russian culture, but largely due to the overwhelmingly military nature of the infrastructure, the Soviets shrouded their space activities inside the deepest secrecy. Failures were concealed, to convey falsely inflated impressions of relative status with Western programs. Most activities were totally hidden and lied about. Massive propaganda efforts—ranging from cosmonauts lying at press conferences, to forgeries of photographs, to vicious attacks on American space efforts—drove home the messages which Moscow wanted to be received.

As an aside, it should be pointed out that although it comforted many Americans to think of Soviet space equipment as crude and clumsy, and in the darkest days of the space race to console themselves with rumors of a legion of secret Soviet cosmonaut fatalities, these too were dangerous delusions. The Soviets were capable of making world-class space systems—boosters, payloads, and manned vehicles—and Western estimates based on understating their capabilities frequently led to unpleasant surprises.

Technology aside, however, the Soviets did suffer from one long-term weakness. This was the failure of the Soviet economy to ever harvest the technological advances made inside their space industry.

So compartmentalized and restricted was Soviet space technology, that other components of Soviet industry—even other components of the Soviet aerospace industry—never even began to benefit from the "spin-offs" so characteristic of Western programs. Nor did scientific and technical research aboard Soviet manned space stations ever seem to result in any commercially available products or any world-class scientific breakthroughs. For decades, cosmonauts tinkered with materials processing experiments for a series of Soviet orbital laboratories and uncovered many interesting phenomena which were published in scientific journals. There was considerable Western anxiety that Soviet industry would be able to exploit these opportunities and make major gains in capabilities.

But aside from a few instruments handcrafted for their own use, the Soviets never came up with any detectable practical space-related benefit to the USSR's industrial base. The failure here was not within the space program itself but in the centrally planned structure of Soviet industry, which was hostile to innovation and unresponsive to "market forces" which make Western private industry much more sensitive to anticipating future customer needs. This failure to exploit industrial opportunities opened by research aboard the Salyut and Mir space stations and elsewhere was ultimately a significant factor in the economic decay of the Soviet Union.

The Soviet approach to space engineering relied on existing Soviet industrial strengths and tried to work around enduring weaknesses. With few ground test facilities (including large computers), the Soviets preferred flying prototypes as soon as possible in order to perform testing and verification in flight. This approach ensured a long series of unsuccessful early missions but it led to operational status about as quickly as would the other approach of extensive ground testing and flight testing only after verification. Although Soviet rockets were never as elegant as Western counterparts—for example, they needed twice the liftoff thrust to place equivalent weight into orbit—the hardware (especially their rocket engines) was highly efficient where it had to be, and "good enough" where that level was good enough. As a result of these approaches, their space hardware, both in absolute and relative terms, was cheaper than American hardware with no noticeable diminution in reliability.

Where the lifetime of flight avionics was limited, the Soviets chose to fly more short missions, an approach which also happened to have significant military advantages since their replacement and surge capacity was supported by a very heavily populated pipeline.

This philosophy worked adequately for routine near-Earth missions. But the limitations of this approach began to be felt in the late 1960s, as space missions became more ambitious and complex, and the inherent Soviet weakness in ground verification became critical.

The first major Soviet space setback was the loss of the moon race. Soviet space officials were caught by surprise by President Kennedy's 1961 challenge to "land a man on the moon before the decade is out and return him safely to Earth." They wasted several years in internecine bureaucratic struggles over what strategy to pursue and which specific institutes and bureaus would have leading roles. But by the late 1960s, they were deeply engaged in expensive programs to develop a super rocket (the "N-1") and to develop and fly a two-man spacecraft around the moon (the "Zond"). After that, they had plans to develop a larger Zond-class vehicle for lunar orbit flight (the "L-1"), and to develop an actual lunar lander vehicle (the "L-3").

Due to crippling organizational and leadership inadequacies, these programs all failed. Booster engine development was crippled by the refusal of one passed-over institute to allow another institute to use its engine static test stands. Consistent management was stymied by power shifts within the Kremlin and the deaths of several key personalities. When flight failures began to accumulate in 1968–1969, bitter infighting and recriminations crippled recovery efforts. With the project in ruins, the responsible institutes were suddenly subjected to a "hostile takeover" by the leadership of competing institutes. Billions of dollars and a decade of work by a hundred thousand engineers were wasted. Through careful manipulation of known Western political biases, Soviet propagandists successfully convinced many leading foreign opinion makers that the Soviet man-to-the-moon program had never actually existed and the Apollo program's victory was hollow.

By the mid-1980s, flight hardware capabilities constraints became the main limiting factor of Soviet space missions, both scientific and applications. For example, until near the very end, the Soviets never attempted deep-space missions more than a year in duration, limiting their range to 5 to 6-month voyages to Venus (where they had notable successes). They never quite managed to reliably master the 8 to 10-month voyages to Mars (where they endured a nearly unbroken sequence of dispiriting setbacks). Their geosynchronous relay satellites were limited to 4 to 6 television channels and 4 to 5-year lifetimes while corresponding Western payloads had hundreds of channels and 10 year (or more) lifetimes.

The longest-lasting Soviet space vehicles were their manned space stations in the Salyut and (since 1986) Mir programs. With remarkable tenacity, they overcame early setbacks (including the death of the first Salyut 3-man crew) and gradually extended their flight duration to a year or more. By the mid-1980s, they repeatedly demonstrated the previously absent ability to respond effectively to in-flight anomalies and breakdowns with bold, innovative repairs.

Ironically, the zenith of Soviet space technology came in a project which graphically illustrated the weaknesses of their space doctrine, the Buran space shuttle. The project appears to have been conceived as a reaction to a misperceived military threat from the corresponding NASA program. Through a research program that involved both the work of domestic laboratories and an aggressive, coordinated espionage effort, Soviet space engineers built an entirely new heavy booster—called "Energiya"—and a reusable shuttle vehicle to ride it into orbit. A single, unmanned flight occurred successfully late in 1988, without crew systems or an operational electrical power system. Completing and operating the system proved to be so expensive that the Soviet government, already teetering on bankruptcy, simply let the impressive technology wither away and die.

At the end of its life, the Soviet space program had made substantial recent technological advances to new levels of spaceflight capabilities, threatening many specialties where the United States had been dominant since the 1960s. But due to bad national leadership, much, even most of its activities had been frittered away on projects that contributed neither to national applications needs or even to useful technology development and their high cost hastened the ultimate collapse of the Soviet regime. The space program that had been a diplomatic triumph in the late 1950s, a bargain in the 1960s, an embarrassment in the 1970s, but a promising rebirth in the 1980s, became, in the end, another nail in the USSR's coffin.

Russian Federation (1992–present): Following the collapse of the USSR in December 1991, there was a short-lived attempt to maintain a looser alliance called the Commonwealth of Independent States (CIS). The former Soviet space apparatus tried to continue as a slightly modified "CIS Space Program." But within a short period, the programs of other Former Soviet Union (FSU) states (particularly Ukraine) went their own way, leaving Russia to manage its own space efforts alone.

The Russians managed to secure 75%–90% of the program's facilities or components. This included control of Baykonur, the main launch site in Kazakhstan. The greatest Russian losses were the rocket assembly plants and avionics suppliers in Ukraine, and the deep space tracking site at Yevpatoriya in Crimea. In Moscow, the MoM was preserved as a unitary administrative entity and transferred to the new Ministry of Industries. But national economic collapse and lack of funding and orders has caused MoM personnel strength to decrease to a fraction of its pre-1991 numbers. In 1992, the Russian government organized the "Russian Space Agency," modeled after the American NASA, to gradually take control of the remnants of the disintegrating space infrastructure.

Because any financial payoff from space exploration is usually long term, and because Soviet space activities turned out to have no measurable economic benefit, the new Russian government gave a very low priority to space budgets. It was no longer competing internationally for prestige vis-a-vis the United States. Even in the area of military applications, the real-dollar expenditures dropped by as much as a factor of six between 1989 and 1994.

For several years, the effects of this financial starvation were disguised by the infrastructure's ability to consume existing stockpiles of rockets, space vehicles, and other consumables, and by the lingering loyalty of the personnel (primarily the generation of workers hired young at the dawn of the space age and now nearing retirement). Routine space missions continued, at a lower rate but almost as effectively as in Soviet times. By continuing on momentum while "eating the seed corn," the cumulative debilitating effects of the neglect could be ignored.

But by 1996–1997, the serious collapse of Russian "space power" was evident all across the board. Russia's promised contributions to the International Space Station were delayed again and again. The ambitious Mars-96 mission ended in failure, the craft's plutonium "batteries" scattered across the Andes Mountains. Quality control lapses led to the losses of formerly reliable boosters. Near-fatal crises engulfed the crews on board the Mir space station. High-level arrests and accusations of corruption shook the space industry. Nine-tenths of the specialists in space-related academic institutions left to seek employment elsewhere. Non-payment of the promised lease on the Baykonur launch center led to customs hassles and the interruption of power and water supplies. After a generation of under-recruiting, a demographic crisis faced the Russian space workforce as the backbone of the space teams succumbed to old age (by 1998, 50% of the remaining space workers were over 55 years of age, in a country where the male life expectancy had dropped to 58). Aging applications satellites, long past their design lifetimes, began failing at a rate far exceeding the Russian ability to replace them. Each of these factors can be compared to the description at the beginning of this chapter of the elements of space power. The Russian space program, which once was a source of domestic pride and international prestige, was fast becoming an embarrassment and a widely-perceived waste of meager budgetary resources.

As a stopgap financial solution, Russian space firms have been taking in growing amounts of Western money. They have offered launch services (by both regular space boosters and converted strategic missiles) and space technology (such as nuclear power plants and rocket engines) for support of specific science missions. In addition, they have received some funding as a result of grants from NASA in support of International Space Station hardware and of Russian space science research in general. By 1998, the Western funding of Russian space services was approaching US$800 million per year, twice as much as Russia itself allocated to its civilian space activities (a similar amount is budgeted for military space activities).

This allowed long-overdue upgrades to facilities at the Baykonur launch site and elsewhere.

Nevertheless, such short-term prosperity and the official government commitment to the International Space Station remain very shaky foundations for the revival of the Russian space industry in the next decade or two.

Other Selected Nations and Space Power

Europe: Despite a GDP roughly equal to that of the United States, a larger but equally well-educated population and an enormously powerful technological-industrial base, Europe's space efforts generally are tightly focused and marginally financed. European nations spend about US$3 billion annually through the 14-nation European Space Agency (ESA) and a similar amount for individual national programs. With the growing administrative cohesiveness of the European Union (EU), a trend toward more unified space activities—commercial, scientific, and military—can be expected. More ambitious European space activities have been retarded by weak economies and a lack of space-mindedness among the peoples of the EU.

The Europeans are well aware of the need to further consolidate national space programs, if only to enjoy economies of scale. They know, however, that this can only be a slow process subsumed within the greater European efforts at political unity. Still, there seems little doubt that a European Confederation of fifty years hence could be a great space power, possibly even the equal of the United States.

Given the similarities between European and North American cultural, political and economic institutions, as well as the influence of joint programs such as the International Space Station, European and US space programs are likely to evolve in roughly the same directions. However, since "statism" (state dominance of national activities) remains a strong component of European life, it seems very likely that European space technology firms will operate under stricter government control than is or will be the case in the United States. For example, telecommunications are state monopolies in all European countries. Although laws governing such activities are being liberalized to allow for greater competition among European manufacturers bidding for contracts, the Europeans intend to replace national control of space-based communications and broadcasting with EU supervision.

French Space Power:[13] The lingering influence of Gaullism on French thinking, the fact that France is the leading EU state in developing strategic weapons and military space projects, and the French belief that the EU should evolve into a unified European superpower combine to give French notions about space power a special significance, separate from that of their neighbors.

Paris is subjected to enormous strain in meeting its US$800 million annual funding obligation to ESA and in maintaining national space budgets at their present US$1.5 billion level. Left unmentioned is the fact that the French-built Syracuse and Helios, as well as the proposed Horus/Osiris and Cerise future intelligence satellite projects have been partially funded by Italy and Spain since the early 1980s. There is good reason to suspect that Germany also has been quietly subsidizing these programs, as well as other French civil and military space projects.

Dr. Brian Sullivan believes that within the French national security community, opinion is sharply divided over the importance of the "American Revolution in Military Affairs (RMA)" and its relevance to possible future space warfare. For over a decade, dominant thinkers inside the French military and defense ministry have viewed war in space as virtually inevitable. After a period of hesitation, this same group has accepted the notion that information and information-based technologies will enjoy the major role in such warfare. But applying such conclusions has proved extremely difficult. Some argue that while the United States can afford to spend billions investigating such systems, France cannot and should await the outcome of American research. Others insist that France will inevitably sink to lesser-power status if it does not immediately move to develop such technologies. Otherwise, this group believes, France will fall into a position of such dependency on the United States that it will never

13 Sullivan, Dr. Brian R., *Tomorrow the Stars.* (Working title of a draft for US Space Command.) March 1998. The entire section on French Space Power is an adaptation of Dr. Sullivan's argument.

recover. After all, the need for the French military to rely on American satellite communications 20 years ago during its intervention in the Congo motivated the development of the original French communications satellite (Syracuse I) in the first place.

The result of many combined influences has been to push the French toward finding a way to join its European allies in creating a multi-national military space program. They also seem to believe that similar scientific, technological, and commercial endeavors must be expanded under ESA auspices. The logic of these conclusions is powerful, but emotional resistance to accepting them remains strong.

Japan: Strategic space doctrine in Japan has been to build on acquired technology. Once a technology has been mastered, specialized lines of development are pursued for those technologies which promise significant industrial capabilities enhancements, as well as immediate practical applications. The most important of these developmental technologies are those that allow domestic production to replace reliance on overseas purchases of space hardware and services. With an annual budget of about US$2 billion, Japan has focused activities on specific projects, but has recently been encountering an across-the-board array of technical problems which will take more time and more money to overcome.

John Logsdon, Director of the Space Policy Institute at The George Washington University in Washington, DC, recently described a key problem with Japan's space doctrine. "The National Space Development Agency (NASDA) has a reputation for developing advanced technologies with little or no input from potential users; no NASDA-developed technology has been adopted by the Japanese space industry." He asserts that Japan's strategy is widely seen as a failure "in terms of producing adequate benefits for the Japanese government, industry, and society."[14]

As an example of US dominance, Logsdon noted that "all communications satellites currently over Japan are US manufactured . . . Attempts by NASDA to develop a domestic

14 Logsdon, Dr. John, Director, Center for Space and Policy, George Washington University, Washington, DC. "The United States, the Only Space Superpower." *Space Policy.* Nov. 1997, Vol. 13, No. 4, pp. 273–279.

communications satellite industry were halted in 1990 by a threatened US trade action."

Logsdon has noted irreconcilable conflicts between the Japanese drive toward space hardware autonomy and the desire for commercializing launch services. The advanced H-2 booster (10,000 kg in LEO) is far too expensive for successful foreign sales, and the only solution appears to be the acceptance of less expensive non-Japanese components in its manufacture.

Japan has cooperated deeply with NASA's space shuttle program and has sponsored one entire Spacelab mission and several partial missions; several Japanese astronauts have flown in space aboard shuttles. It also has signed on as a major partner in the International Space Station, and is developing a special add-on research module, the JEM (Japanese Experiment Module) which has suffered repeated delays and cost overruns.

Japan possesses many of the factors of space power, such as an educated, industrious population, a highly capable industrial technology, and a philosophy of long-term investment. However, other factors, such as government policies to preserve a strong economy, remain elusive. Even its launching sites suffer from long periods of inactivity imposed by restrictions from the fishing industry, signifying where national priorities and political power reside.

On specific projects, the Japanese space program continues to demonstrate the highest levels of competence. They are the third nation to have engaged in interplanetary probes, and they recently demonstrated an extremely impressive automated space docking system.

Yet despite high hopes and ambitions, and substantial investments of money and personnel, Japan has yet to significantly benefit from its space activities. However, the long-range determination to achieve specialized technological superiority (such as in their world-class earth observation satellites) and autonomy for critical applications appears to be undiminished.

China: Proving their claim to status, the Chinese government has obviously selected space operations as an area to prove their status as a modern great power. Space technology and intercontinental ballistic missile technologies share enough to allow the Chinese space program to leverage the military missile program. Similar technologies included guidance, range control and microelectronics. Space policy in China seems to be to get as much commercial benefit as possible from the space program and apply what is learned back into the military missile program.

A rough estimate of China's annual space budget is over US$400 million, but not exceeding US$1 billion. With the announcement of a Chinese manned space program, it is likely that the real figure is very near the high end of the estimate. In fact, Yuri Koptev of the Russian Space Agency, estimated the total Chinese space expenditure at US$1.7 billion.[15] For purposes of comparison, China's annual defense budget is estimated to be approximately US$10 billion (not including supplemental funding from commercial enterprises, purposeful deflation of funding and hidden funding of related budget items). A more useful comparison is NASA's current budget of US$13.3 billion.

China has not been exceptionally successful in garnering commercial funding of its space program. China did not announce how much they charged per launch of Iridium, Chinastar-1 and Sinosat-1 satellites launched recently. Strictly speaking, only Iridium was a foreign customer, since the others were for Chinese domestic use. A reasonable estimate for a CZ-3B launch is about US$50 million-US$60 million. Since China conducted four commercial launches in 1998, two CZ-3Bs and two 2C/SDs, China could have earned US$150 million–US$240 million to reimburse a portion of their space program. This constitutes a relatively large percentage but a relatively small total funding source.

A strong Chinese economy remains elusive. Well-publicized rocket failures make marketing of its commercial launch capability difficult. The Chinese have the ability to overcome their technical difficulties, but economics will limit China as a space power until the domestic economy can provide greater levels of government and commercial funding.

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15 Press briefing on results of government meeting (Boris Kondrashov and Yuri Koptev) provided by Federal Transcript Service, Washington, DC. (Russian Federation Government House, Nov. 12, 1998.)

Canada: While modest (US$200 million annual budget), Canada's space program demonstrates the value of highly efficient alliances with other larger programs, mainly that of the United States. By concentrating on specific technologies (such as the robot arm installed on Space Shuttles and a larger version for the International Space Station), Canada achieves world leadership status in an area of advanced robotics technology with promising terrestrial applications. It also conducts specialized applications developments, such as deploying communications and advanced earth observation systems (specifically their extremely impressive RADARSAT system).

India: For India, the primary feature of space power is autonomy and self-reliance. The modest Indian space budget (estimated at US$300 million) goes half toward booster development and most of the rest towards applications in communications and earth observation. For the time being, some payloads are launched on Russian, American, and ESA boosters pending completion of domestic booster development. Attempts to acquire advanced propulsion technology, especially cryogenic upper stage manufacturing capability, from Russia have created serious diplomatic conflicts with the United States.

Nth Country: As space technology advances in capability, minimum capabilities decline in price. Probably two dozen nations today have access to the level of space and missile technology wielded by the United States and USSR forty years ago, including medium range missiles, guidance systems, and command and control systems. Even modest surface-to-surface missiles can project force out into space to the altitudes of low earth orbit satellites, and the addition of upper stages can send lightweight packages much farther into space or even into orbit. The potential for even low-reliability Nth country antisatellite attempts, especially at in-space components where legal constraints are most nebulous, must be considered more and more likely in coming years. The lack of sophistication of such systems implies enhanced likelihood of collateral damage to non-targeted assets as well.

Non-state Organizations: Space power is no longer exercised only by nation-states. In recent years, the space arena has seen a major increase in activity of commercial organizations, both within nations, and multinational. We have seen corporations making commercial arrangements for desired satellite launching services with various branches of governments (including the United States) and with other corporations.

There has been a growing interest from other undesirable non-government entities, such as drug cartels and revolutionary/terrorist groups. It is possible some of the latter may be allowed the use of space-based services by consortia made up of friendly governments, and near-future application of US "space power" in the denial mode is becoming a more and more plausible option.