STRATEGIC STUDIES QUARTERLY

The Changing Dynamics of Twenty-First-Century Space Power

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Abstract

Many recent assessments of space power have posited a US decline and predicted a gloomy future in comparison to China and Russia. However, such analyses—based almost exclusively on state-run activities—present only part of the picture. In the twenty-first century, a new form of bottom-up, net-centric, commercially led space innovation is emerging that promises cheaper and more timely technological developments to those nations that can effectively tap into them, thus reshaping traditional definitions of space power. This study first sets a baseline by focusing on Cold War space power determinants, next analyzes recent changes among the three leading spacefaring nations, and then looks into the future, factoring in the expanded role of commercial space start-ups and military space alliances. The article concludes that new forms of networked space power could put the United States in a more favorable position than countries relying on state-controlled innovation and development.

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Traditional measures of space power have focused on the activities of a nation's military and civil space programs. This common emphasis comes from the Cold War when the United States and the Soviet Union created well-funded, government-run, and largely military-led (and sometimes secret) space programs to "show the flag," support their operational forces and intelligence needs, and prevent surprise nuclear attacks. Since

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the early 2000s, China has entered this club with a large-scale space program run by its military while also conducting civil human spaceflight and a range of scientific and quasi-commercial activities. After a decade of severe decline in the 1990s, Russia's space program has rebounded under President Vladimir Putin and, according to some accounts, is set to surpass Soviet achievements, especially regarding new military capabilities, including counterspace.[2]

According to some popular and expert reports, the United States is falling behind in comparison to these rising and revanchist space powers.[3] As Vice President Michael Pence stated at the first meeting of the newly revived National Space Council in the fall of 2017: "America seems to have lost our edge in space."[4]

US military leaders are legitimately concerned. US intelligence officials recently released an assessment stating that Russia will likely deploy new antisatellite weapons within the next few years for use against US space assets.[5] US Strategic Command's Gen John Hyten also stated recently, "From a defense perspective, the isolation [as a result of Western sanctions] has not slowed the Russian modernization program . . . on the space side."**6** Russia also remains the only country currently delivering US astronauts to the *International Space Station* and continues to produce the main engine used in the United States' Atlas V rocket, setting up uncomfortable dependencies for the United States.

Regarding China, Air Force Lt Gen Steven Kwast has argued that Beijing has a relative advantage in its preparedness for space conflict, stating, "In my best military judgment, China is on a 10-year journey to operationalize space. We're on a 50-year journey."[7] In civil space, a major US news magazine recently concluded that, in contrast to currently vague US goals, "China is boldly moving ahead with its own space exploration efforts, and with little ambiguity about its mission,"[8] given its continuing manned spaceflights, new Hainan Island launch site, and plans for larger boosters.

Finally, military analyst Brian Chow says that the United States is facing "a new game-changing threat under development in China and Russia" in the form of spacecraft with robotic arms that might quickly disable US military satellites in a conflict.[9] Such negative assessments of US space power are based on traditional determinants, which presume that capabilities emerge almost exclusively from top-down, government funded, and largely military-led efforts, where centralization, national

autonomy, and secrecy play key roles. Aspects of these trends are indeed worrisome. However, do they tell the whole story? Or are there other factors that need to be considered in evaluating comparative twenty-first-century space power?

Traditional, state-run approaches to space security have led authors to three assumptions: (1) that war in space is inevitable, (2) that nations will have to rely exclusively on their assets for fighting in space, and (3) that space wars will be dominated by offensive strategies, as opposed to space-based defensive or deterrent approaches. One of the leading realist scholars on space power, Everett Dolman, makes this case, "if some state or organization should desire to contest or control space, denying the fruits thereof to another state, there is simply no defense against such action—there is only deterrence through the threat of asymmetric, Earth-centered retaliation."[10]

However, new conditions may facilitate other options, such as space-based deterrence by denial. A state may, over time, create a resilient constellation of hundreds of networked satellites (national, commercial, and allied) that may be able to convince an adversary that its forces will not be able to accomplish their objective of denying space-derived information. In 2016, Deputy Assistant Secretary of Defense Douglas Loverro stated in congressional testimony, "we must remove the likelihood that attacks in space will succeed. Strangely enough, there are those who believe that we cannot do this… That conclusion would be untrue."[11]

In the modern world, technological, economic, social, scientific, and even military dimensions of power have begun to shift from the national to the international context. This point suggests that space power will also be affected by globalization and interdependence, where networks and success in innovation are becoming at least as important as national government capabilities in creating power and influence. Indeed, the highly nationalistic and state-focused strategies of Russia and China may in the future represent anachronisms rather than cutting-edge approaches to space security. At the same time, new forms of networked space power could offer the United States a distinct advantage. If this is true, then assessments of comparative future power in space must be reexamined and, possibly, recalculated based on new measures. As Loverro argues regarding the proper response to the threats posed by Russia and China in space, "the US response is clear—we must leverage our two natural and sustained space advantages: the US commercial/

entrepreneurial space sector, and our ability to form coalitions with our space-faring allies."[12]

If such comparative advantages can be exploited to supplement national assets and eventually transform narrow, national defensive capabilities into more robust architectures, then the autonomous, highly centralized, military-led, nationalistic, and secretive space programs that dominated the Cold War period could face new challenges of their own against more resilient, networked space coalitions. A key variable affecting these trends is the future nature of space innovation. Will traditional state-run programs lead it or instead will it be led by commercial actors, who may move more quickly in responding to market conditions and in developing new technologies? These dynamics merit particular attention, as effective innovation will be the main driver of future space transformation and, consequently, changes in space power.

This article first presents a brief history of the Cold War and the "technocratic" approach to space power. It then assesses how the United States—after riding high in the 1990s—suffered relative declines in the military and civil space sectors after 2000 compared to Russia and China. Next, it reconsiders emerging trends in space activity and the increasing (and often discounted) role of the commercial space sector, especially start-up innovators. It also considers the potential contributions of military space allies, proposing a new concept for space power via networked capabilities. Finally, the article assesses future US, Chinese, and Russian prospects in space. It concludes that the United States—thanks to its vibrant commercial space sector and its emerging partnerships with space-proficient allies—has greater potential than its rivals to retain (and even expand) its future space power and influence. However, this will require continued US national commitment to space and favorable policies in regard to the commercial sector and US allies.

A Brief History of Cold War Space Power

Looking back at Cold War trends in space power assessments, the popular metrics for success were the number and size of launches, accomplishments by astronauts (first in orbit, first spacewalk, and first on the moon), the fielding of military support technologies, and discoveries in space science. These areas depended almost completely on state-run and state-funded programs throughout the Cold War. It was a period dominated by the two superpowers who together conducted well over

95 percent of space launches up through 1991.[13] As historian Walter McDougall argued in his 1985 Pulitzer prize-winning book, space activity embodied the post–World War II concept of "technocracy," which he defined as "the institutionalization of technological change for state purposes, that is, the state-funded and -managed R&D explosion of our time."[14] Without state sponsorship and military interest, McDougall observed, the US-Soviet "space race" and its many technological developments would not have taken place.

In building space power, the Soviet Union benefited from its larger rockets and ability to put significant payloads—instruments, canines, and humans—into space. With the Soviet Union's accomplishments piling up, from *Sputnik I*'s launch in 1957 through Yuri Gagarin's spaceflight in 1961 and then other flashy Soviet "firsts" (two people in space, then three, and then a spacewalk), the United States was seen as woefully lagging behind Moscow in perceived space power. However, public perception was only part of the story. In the secretive world of national security space, the Soviet Union knew the United States was creating advantages. The first reconnaissance satellites (*Grab* and *Corona*) achieved success in 1961, years before their Soviet counterparts, but the Eisenhower and Kennedy administrations chose to keep their existence secret. During the 1960s, US technological advantages in reliable electronics, computers, and miniaturization combined to move the United States even further ahead in national security space. Furthermore, it helped to facilitate the highly successful and well-publicized Mercury, Gemini, and Apollo programs, which culminated in the 1969 moon landing. This event finally ended the notion of the Soviets leading the way in space power, at least until the late 1970s.[15]

Meanwhile, China lagged even further behind, conducting its first space launch in 1970. The influence of Communist Party politics plagued China's space program—and overall "technocratic" power—during the 1960s and 1970s. This came as a result of the anti-Western Cultural Revolution (which sent thousands of engineers into the countryside for reeducation) and an unlucky association with General Lin Biao, whose alleged coup attempt against Mao Zedong in 1971 and subsequent death in a suspicious airplane crash in Mongolia set back the space program for nearly a decade.[16] Only in the 1980s did China begin to emerge as a fledgling space power under Deng Xiaoping, by building a space launch infrastructure and a cadre of space-trained personnel.[17]

The failure of the United States to launch any astronauts during the Carter administration in the late 1970s began to raise concerns of a US space power decline. Critics of the US program began pointing to Soviet long-duration flights on a series of *Salyut* stations and to counterspace capabilities from the resumption of Soviet antisatellite testing. Popular fears of a relative US nuclear and space power "gap" helped elect Ronald Reagan.[18] The *Challenger* disaster in 1986 and coincidental problems with the US Air Force's satellite launch program led to renewed assessments—including the cover story of *Time* magazine in October 1987—of a dangerous advance in Soviet space capabilities.[19] However, the United States again resumed its stature as the leader in space with a series of successful shuttle flights and new constellations of military satellites, including the groundbreaking capabilities introduced by the Global Positioning System (GPS). The Soviet Union's collapse led to the selling off of many Russian space technologies, which later contributed to China's emergence in space.

Space Power Dynamics in the 1990s: US Hegemony

The early post–Cold War period was characterized by US technocratic dominance in space. US space accomplishments included the successful operation of the space shuttle, leadership in organizing the construction of the *International Space Station* (*ISS*), commercialization of the military GPS system (a vast windfall for US companies), and the reestablishment of military space launch reliability under the Evolved Expendable Launch Vehicle program.

Meanwhile, Russia experienced its sharpest decline in space power—in both relative and absolute terms—since 1957. Although a legacy fleet of launchers allowed it to maintain a significant role in the newly internationalized, post–Cold War commercial launch sector, its constellations deteriorated significantly, its spending on civil space dropped precipitously, and its military space program developed wide gaps in capability, suffering dangerous "blackout" periods in space-based reconnaissance and early warning. With post-Soviet Russia on the brink of economic collapse, NASA opted to extend a helping hand to the Russian Space Agency in the form of contracts for astronaut flights to the Russian *Mir* station and cooperative work on the *ISS.* US goals in this cooperative effort included lowering overall costs for the station and

preventing former Soviet missile scientists from taking jobs in countries of proliferation concern.[20]

Nevertheless, Russian space employment dropped precipitously due to long periods of unpaid wages, as the Yeltsin government struggled financially. By 1996, the Russian Space Agency's budget had declined to a mere $700 million.[21] As Brian Harvey describes, despite efforts by the Energiya enterprise to keep up with its commitments to the *ISS* in the late 1990s in the face of on-again, off-again support from the Yeltsin administration, "new [state] funding turned out to be a complex set of bank loans rather than on-the-spot cash. Dates again slipped and slipped. The situation worsened with inflation and the slide of the ruble on foreign exchanges."[22] US funding helped salvage some of the work, and the Russians met their commitments, albeit late. The de-orbiting of Russia's *Mir* space station in early 2000, due to lack of funding, marked the symbolic end to this humiliating period of relative decline for Russia. The subsequent launch of the *Zvezda* module for the *ISS* marked a new start, as did Russia's success in marketing the Proton booster, which had 17 commercial launches by the end of the decade.[23]

China in the 1990s was still emerging slowly as a "technocratic" space power. It began pursuing a state-led, import substitution strategy by acquiring foreign technology and learning to build copies. With Russian enterprises struggling to survive, China benefited greatly from fire-sale prices for major space technologies, especially for its own future human spaceflight operations. The Chinese government also invested heavily in the development of space manufacturing infrastructure and personnel, making only small advances in near-term capability but setting the foundation for later growth. In the commercial sector, it benefited in part from the Reagan administration's cooperative agreements, which eventually allowed 26 US commercial satellites to be launched on Chinese Long March boosters by the end of the next decade. However, this program—under the state-created Great Wall Industry Corporation—came to a halt in 1999 after the House report, *U.S. National Security and Military/Commercial Concerns with the People's Republic of China* ("Cox Report"), alleged the transfer of sensitive information by two US space companies during investigations after failed Chinese launches.[24] The cessation of this cooperation cut Chinese commercial space revenues dramatically in the initial years of US sanctions and heightened export controls.[25]

In the military sector, this period saw significant Chinese investments in research and development, but few tests. Little hint of the military direction of China's space program in the coming decade would be found at the time. However, China had witnessed the United States' use of space-supported warfare in the Persian Gulf in 1991 and the Balkans in the late 1990s. This convinced Beijing of its dangerous inferiority and the need to be prepared to challenge and defeat US space assets in a crisis. The Chinese military's new goal of being able to fight "local wars under modern, high-tech conditions" meant that disruption of US space-supported command, control, communications, and intelligence would take on a new level of importance in the future.[26]

Shifts in Space Power from 2000 to 2017: Russia's Resurgence, China's Rise

The twenty-first century began with an all-consuming terrorist strike against the US homeland in the form of the 9/11 attacks. In this environment, space became a secondary priority for Washington, and the two main elements of US space power—civil and military space—both struggled, allowing China and Russia to make relative gains. The United States remained the world leader in civil and military space, but its reigning position diminished. The commercial sector continued to grow steadily but did not yield revolutionary, sector-changing products in launch, communications, human spaceflight, space manufacturing, or imagery. Relative US space power suffered under both the Bush and Obama administrations, which witnessed tight budgets and the untimely cancellation of the US space shuttle program without a replacement.

NASA faced considerable problems in the early 2000s, beginning with the 2003 *Columbia* disaster, which killed all the astronauts aboard during a breakup as the shuttle reentered the atmosphere. The standdown of shuttle operations forced the United States to rely on Russia for access to the *ISS*. This was the first such period of dependency, but not the last. Pres. George W. Bush's Vision for Space Exploration speech in 2004 attempted to rally NASA for a cooperative return to the moon as a jumping-off point to Mars.[27] However, in the midst of the wars in Afghanistan and Iraq, the US administration could not offer any real funding. President Obama's attempt to continue elements of that program with the Asteroid Redirect Mission failed to garner either congressional or public support. With the end of shuttle flights in 2011, NASA

entered into its second and longest period of dependence on Russia for human spaceflight. While the completion and operation of the *ISS* marked major accomplishments and the Mars Rover program captured the public's attention, an inherited budget deficit forced the Obama administration to cut NASA's budget and its planned return to the moon. US civil space leadership suffered globally as a result.[28]

In the face of rising threats to US space assets, however, the Obama administration developed new concepts in its 2010 US National Space Policy and the 2011 National Security Space Strategy. These documents set a course away from traditional US nationalism in space toward international engagement, including operational cooperation with allies. By 2016, the United States had signed over a dozen space situational awareness sharing agreements with foreign countries and 50 companies and commercial organizations.[29] Also, in 2015, the US military began work toward a Joint Interagency Combined Space Operations Center (JICSpOC) to begin the process of operationalizing space cooperation with allies and the commercial sector. Secretary of Defense Ash Carter established the Defense Innovation Unit Experimental (DIUx) in Mountain View, California. The goal was to increase the pace of adopting innovations from Silicon Valley's commercial start-up companies into the realm of military deployment to boost effectiveness and save money. However, this effort had limited initial results and had to be reorganized. The JICSpOC also failed to achieve its intended mission. In the face of emerging Russian and Chinese threats, the outgoing Obama administration approved funding for $5 billion aimed at increasing "space protection" capabilities. Overall, however, under both Bush and Obama, the United States failed to address a series of problems in civil and military space enterprises in a context where promising commercial technologies had not yet yielded significant security benefits.

Meanwhile, Russia under Vladimir Putin took a very different activist course to reconstitute its space program in the early 2000s. Recognizing the military vulnerability Russia faced and the fact that the nation's space program represented one of the few remaining elements of Russia's international prestige, he pursued several actions. Putin plugged the gaps in his military constellations, restored the Russian GLONASS GPS system, and upgraded the military launch site at Plesetsk. Most worrisome, Putin restarted work on several counterspace programs, dormant since the Cold War, citing new threats from US missile defenses

and the X-37B experimental space plane. Russia began testing its Nudol direct-ascent antisatellite system and undertook a series of on-orbit experiments in proximity operations, including near some Western communications satellites in geostationary orbit.[30]

Drawing on revenues from newly renationalized oil and gas companies, Putin also restored the civil space budget. Due to Russia's average annual economic growth of 7 percent from 2003 to 2007, the Russian space program underwent a remarkable "resurgence," in the words of French space expert Bertrand de Montluc.[31] He specifically cited Russia's leadership in commercial space launch. But Montluc cautioned that Russia's long-term strategy remained unclear, noting, "Reusable launchers will not be on the cards for another 30 years."[32] Nevertheless, Russia's possession of the Soyuz launcher eventually made it the sole point of access to the *ISS*, putting it into a de facto leadership role. Not surprisingly, President Putin used his leverage to increase the price for foreign astronauts of a round-trip ride to the *ISS* to $70 million. Under President Dmitri Medvedev (2008–12), Russia also began an effort to stimulate a start-up sector by creating the Skolkovo Innovation Center near Moscow. With state funding and a favorable "incubator" environment, several small firms emerged, mostly in the launch components sector.[33] However, their activities remained minor, due in part to opposition from the state sector, indicating a Russian preference for traditional technocracy.

Efforts to reconstitute Russia's former space science glory proved unsuccessful. The much-ballyhooed flight of the *Phobos-Grunt* spacecraft to a moon of Mars in November 2011 (with a range of Russian and foreign, including Chinese, scientific payloads) ended in a disastrous failure. When faulty computer chips caused the spacecraft to become unresponsive shortly after launch, it became stranded in a low, uncontrolled orbit around Earth. The reentry and breakup of this expensive and much-anticipated mission in early 2012 met with finger-pointing about failures of quality control within Roscosmos and political pressures to launch. However, flush with cash, the Russian government doubled down on a major plan for lunar and planetary exploration. The development of a series of new launchers, plus the construction of a major new launch site in the Russian Far East (Vostochny) was intended to remove Russia's dependence on—and $115 million in yearly rent payments for—the former Soviet launch facility at Baikonur in Kazakhstan.

Russia's space resurgence reached a high-water mark in 2014 when Roscosmos's annual budget totaled a healthy $4.2 billion, and Russia conducted 35 successful launches, far surpassing both the United States and China.[34] However, the combined effects of corruption, Western sanctions after Russia's seizure of Crimea and intervention in eastern Ukraine, and falling state oil and gas revenues eventually began to put pressure on Roscosmos. President Putin's prized project—the Vostochny Far Eastern launch site—failed to meet its operational goal of a 2015 launch due to rampant corruption, which resulted in politically embarrassing hunger strikes by unpaid workers, the loss of hundreds of millions of dollars, and the firing of two successive managers.[35] Putin eventually took the unusual step of putting the project directly under the control of Deputy Prime Minister Dmitri Rogozin. In late 2015, to eradicate corruption and raise quality control after a series of Roscosmos launch failures, President Putin abolished the space agency altogether and established the eponymous "State Space Corporation Roscosmos" in early 2016. It was described as a commercial unit of the Russian government intended to reduce corruption and run the consolidated space industry according to best business practices. However, Roscosmos remained much more like a state enterprise than a commercial one. Vostochny finally conducted its first launch in April 2016. However, after a failed launch in November 2017, even Russian analysts began to downplay previously rosy prospects for the facility, discounting the possibility of any near-term cosmonaut launches.

Meanwhile, China's major state-led investments in space advancement began to bear fruit in the early 2000s. Fearful of US military space advantages, eager to rally public support for the communist leadership through high prestige space missions, and hopeful of spurring developments in high technology to benefit the Chinese economy, Beijing began to make deliberate efforts to advance its place in the space community. After several unmanned tests, the Chinese military launched *Shenzhou V* with its first *taikonaut* (Chinese astronaut) aboard in October 2003, shocking the world by becoming the third country to launch and return a human from Earth orbit. A slow but steady series of successes in human spaceflight, including a small station (*Tiangong 1*) visited by taikonauts in 2012 put other countries on alert that China was making a long-term commitment to civil space activity, even if it was managed by the military. With an unmanned mission to the lunar surface with

its *Jade Rabbit* rover, the establishment of a substantial space science program, and cosponsorship (with Russia) of a UN initiative to prevent the weaponization of space, China sought to burnish its credentials as a responsible space player. In 2008, China attempted to establish itself as an international space leader by founding the Asia Pacific Space Cooperation Organization (APSCO). The Beijing-based APSCO was modeled on the European Space Agency, but the limited space capability of its other members—including Iran, Mongolia, Pakistan, and Peru—reduced the likelihood of any real technological synergies emerging from this cooperation.

China's kinetic antisatellite test in January 2007 showed another, more troubling side of its military-led space program. By flaunting international norms on debris mitigation and then continuing to develop a range of counterspace capabilities over the next decade, China showed a commitment to developing an offensive military space capability aimed at possible use against the United States in a future regional conflict. From being a virtually nonexistent military actor in 2000, China emerged by 2017 as a potent military competitor, albeit one with considerably less operational experience.

Only in the commercial sector did China's space capabilities seem to lag behind world space leaders. While China's Great Wall Industry Corporation expanded its sales of on-orbit satellites and low-cost launches—to countries such as Nigeria, Venezuela, Bolivia, and Laos—the highly subsidized nature of most of these deals suggested that the criteria for sales were based more on politics than economics. In the launch sector, after its loss of launch rights for satellites with any US components after 1999, China slowly gained a niche commercial market thanks to European efforts in developing satellites without US components. However, this market remained modest.

More significantly, China successfully bypassed its former European partners in the Galileo GPS network by developing and launching its own system called BeiDou.[36] With 23 satellites by 2016, the constellation entered into regional operation, with additional satellites and global functionality promised by 2020. China began to force domestic enterprises to purchase BeiDou receivers while enticing foreign countries to buy into the network on favorable terms. Overall, Chinese developments during the 2000 to 2017 period marked major accomplishments relative to both Russia and the United States, although the US space program continued to lead the world in terms of its absolute space capabilities.

Emerging Changes in Space Power Dynamics

Until recently, the source of space power has relied heavily on state funding and innovation. However, over the past several years, the increasing share of commercial space in the total arena of space activity merits reevaluating traditional measures. Christopher Kirchhoff, a former official at DIUx, observes that "most innovation today—unlike that of two generations ago—takes place in the commercial sector, not government labs."[37] Accordingly, where state spending dominated space revenues well into the 2000s, today the commercial sector accounts for over three-quarters of the $323 billion spent yearly across the globe on space activity.[38] These new trends in space spending, activity, and the nexus of innovation suggest the need to consider a revised model of space power as we look toward the future. While the earlier space race period could be accurately characterized as dominated by rival, state-led "technocracies," a more flexible, disaggregated, and resilient "netocracy" is now emerging as a rival model of space organization (see Fig. 1.) It may soon prove to be a superior model for the challenges facing countries in establishing twenty-first-century space power. We can define space-related *netocracy* as a new form of organization based on public-private partnerships, distributed architectures, rapid innovation, and the use of multiple commercial and allied partnerships.

Cold War Space Power Model ("Technocracy")	21st Century Space Power Model ("Netocracy")
• National	• International
• Secret	• Transparent
• Military-led	• Commercially led
• Independent	• Networked
• Few, large platforms (vulnerable)	• Many, small platforms (resilient)
• Slow, top-down innovation	• Rapid, bottom-up innovation

Fig. 1. Comparison of space power models

Conditions for the creation of net-centric space power are emerging from the so-called "NewSpace" revolution, where venture capital, dynamic entrepreneurs, scientific innovators, and a supportive political and legal infrastructure are combining to bring a whole range of new space technologies to the marketplace. Critical in this process is an environment that supports the free flow of ideas and people and protects intellectual property. Otherwise, innovators may develop to a certain stage and then move elsewhere for a more favorable business climate. Notably, such innovation "hubs" are present in some areas of the United States, due to a combination of technological factors, human capital, and political/legal mechanisms that have made rapid start-up formation possible and have assured investors that successful companies will be allowed to keep profits and expand their businesses. Such conditions do not exist in Russia today and are only partly present in China, creating significant potential advantages for the United States.

Another set of changing factors relates to the role of international cooperation in military space. In the past, the disparities in capabilities between the superpowers and other spacefaring countries were so stark that neither the United States nor the Soviet Union would have derived any substantive benefits from sharing constellations and engaging in extensive data-sharing or operational cooperation with allies.[39] Until 2010, US National Space Policy had not made any mention of possible benefits to the United States from integrating aspects of the US military space program with those of its allies. However, those conditions have changed as a number of US friends and allies have now developed sophisticated space capabilities—including India, Israel, Italy, France, Germany, Japan, and the United Kingdom. Moreover, a number of these countries in Europe and Asia have the financial capability to contribute to advanced military space architectures, some of which are too expensive for even the United States to field alone. These space capabilities have raised the attractiveness of military space alliances for those countries that are willing to engage foreign space powers.

In light of these new dynamics, how are the three leading space powers likely to fare going forward? Are the gloomy assessments of certain US experts and officials merited?

US Trends

The United States has begun to address its relative decline in space, although only in part due to government efforts. NASA's budget remains flat, and the Department of Defense projects aimed at addressing the resilience of space assets are largely continuations of policies begun late in the Obama administration. However, these projects are now coming to fruition. General Hyten's focus on space as a war-fighting realm has brought a new tone of seriousness to the US approach to military space protection, as has the standing up of the National Space Defense Center at Schriever Air Force Base, Colorado. The reestablishment of the National Space Council has raised the importance of space activity within the national defense enterprise, while also highlighting the importance of public-private partnerships. Former Defense Secretary James Mattis's decision to reform and reinvigorate the DIUx organization set up by his predecessor (and change the name to the Defense Innovation Unit-DIU), by increasing funding and expanding its reach, marked another positive sign. DIU can now fund projects directly and operates in Mountain View, Boston, Austin, and Washington, DC.[40]

However, the most dynamic recent change in US space capabilities is coming from the commercial sector itself, especially among start-ups. Already, the space marketplace is being flooded with new products and services from these emerging US space ventures. These include revolutionary, low-cost services now being offered by US companies in the fields of Earth observation, space situational awareness, satellite tracking, space launch, and space manufacturing. After many years of promising change, NewSpace companies are now bringing revolutionary products to the marketplace, which is shifting space power leadership back toward the United States.[41]

In Earth observation, the San Francisco-based company Planet now operates 150 satellites, the largest constellation of satellites ever launched by a private company or a government, providing daily revisits of all areas of the globe.[42] In the field of space situational awareness, Menlo Park, California–based start-up LeoLabs is operating its own phased-array radar (constructed in Texas) and developing the largest catalog of low Earth orbital objects outside the US government.[43] It plans to expand this network with three additional radars, supported by a growing commercial and governmental client base. In space manufacturing, another Mountain View-based start-up, Made in Space, now operates

the only 3-D printer on the *ISS* and is working toward the capability to build and robotically assemble large structures in orbit, thus drastically reducing construction costs.[44] Each of these companies is helping the United States build new elements for future space power and resilience.

In the launch field, 2017 marked the first time the United States has led global launches since 2003, with 29 successful orbital missions, compared to 20 for Russia and 16 for China.[45] Even more remarkable is the fact that Elon Musk's Space Exploration Technologies (SpaceX) company conducted 18 successful launches. SpaceX has the prospect to launch more in the future if the company can perfect its ability to return boosters to the ground and reuse them safely. SpaceX's Falcon 9 rocket also surpassed Russia's Soyuz as the most successful launcher for the first time. Other US companies, including the United Launch Alliance and Orbital ATK, add to the US tally, while start-ups like Blue Origin and Rocket Lab provide further capability to the US launch stable. Indeed, the commercial launch sector seems to be entering a period of United States dominance.

In the intelligence area, the National Reconnaissance Office (NRO) and the National Geospatial-Intelligence Agency are aggressively pursuing benefits from the commercial sector, including from start-ups with small satellites. Growing capabilities and the availability of persistent observation of points of interest have changed the previously skeptical attitude of US intelligence providers regarding the commercial sector. As NRO director Betty Sapp said recently about the US government's former development of its own buses and systems, "Those days are long gone."[46] Today, with purchases from companies like Planet, DigitalGlobe, and others, the real problem facing the US intelligence community is how to handle the vastly increased flow of data. The NRO, according to Sapp, is using this commercial bonanza to plan for a future involving "integrated architectures that meet user needs with far more affordability, resiliency, and tolerance for failure."[47]

Another area where the United States has begun to show leadership is in the area of military space alliances. The underlying concept of military space cooperation begun during the Obama years has continued thus far under the Trump administration, providing benefits in terms of reduced cost, increased deterrence, and expanded resiliency, despite the recent emergence of new counterspace threats. Again, the prospects for space cooperation are greater for countries with existing military

alliances, such as the United States. For the first time, the concept of a military space "network" is realistic. The Wideband Global SATCOM system now funded by the United States and eight of its close allies, who receive bandwidth in return for their financial contributions to this constellation of communications satellites, demonstrates this concept.

In the area of space situational awareness agreements, US Strategic Command has now established 83 international data-sharing agreements to expand its network of satellite and debris information to improve space safety and the effectiveness of US operations.[48] Also, the Air Force announced the opening of the Combined Space Operations Center in the summer of 2018 at Vandenberg Air Force Base, California, completing a multiyear process of consultations and exercises that eventually led to the center. [49] The initial foreign military partners will include Australia, Canada, and the United Kingdom. The point of this effort is to allow more rapid sharing of information among countries and the actual conduct of joint missions involving the commercial sector and the intelligence community. A supporting process—the Multinational Space Collaboration (MSC) initiative—is working with additional countries toward future cooperation in space situational awareness and operations, including Germany and France, with future participation expected from Italy, Japan, New Zealand, South Korea, and Spain.[50] Another example of emerging military space cooperation is the Enhanced Polar System recapitalization, in which US military communications payloads are being hosted on Norwegian polar-orbiting satellites, saving the United States some $900 million.[51] US military space war games now also regularly include US allies. Notably, such military space partnerships have not yet emerged in either Russian or Chinese space policies or architectures. Neither country has significant military allies that are space-capable, and the two sides, despite other forms of military cooperation, have thus far exhibited inadequate trust for real cooperation in military space.

The one area of space power where the United States' commitment and plans remain somewhat vague is in civil space. Although President Trump's one-page Space Policy Directive of December 2017 outlined a general goal of returning to the moon and moving on to Mars, it did not offer details on how to organize or fund such missions.[52] The administration's second directive on space in March 2018 provided more information on commercial and military space but almost nothing about NASA.[53] The currently flat NASA budget does not seem to offer enough

flexibility to support major manned missions—absent new funding—and more recent discussion of trying to free up funds by privatizing the *ISS* do not seem realistic. The absence of a NASA administrator or a White House science advisor for over a year set back the organization's planning process. It remains to be seen if the Trump administration will be able to make up for lost time in getting NASA back on track as a global civil space leader, as the commercial sector cannot be expected to carry out US scientific missions.

Russian Trends

Russia's course under Putin regarding space organizations and innovation has followed political dictates rather than global economic best practices. The Putin administration has steadily reversed the significant integration of the Russian space sector into the international marketplace, with mixed (and sometimes negative) results. In sharp contrast to US and other Western trends—where small start-ups are driving a continuous process of innovation—the Russian situation has moved toward extreme centralization. Since forming the State Space Corporation Roscosmos, President Putin fired director Igor Komarov, who had come out of the commercial sector, and instead appointed his former deputy prime minister Rogozin to take over the agency in May 2018, suggesting the primacy of political loyalty over business experience.

The problems Roscosmos faces today have much to do with the disconnect between its nationalist agenda and its growing isolation from the rest of the space community. Ironically, the very success of the Russian space industry in integrating into global supply chains in the 1990s has now made it dependent on foreign components for construction of satellites. A recent study indicated that up to 75 percent of electronic parts on certain current-generation satellites come from the United States.[54] With the advent of Western sanctions after Russia's 2014 seizure of Crimea and intervention in eastern Ukraine, Russia has been forced to substitute substandard and often ill-fitting Russian or other foreign components from countries that do not adhere to UN sanctions. Russia may develop renewed capabilities, but it will take time and steady budgetary support for such efforts to succeed.

A second problem facing Roscosmos relates to changes in the international marketplace. In the 1990s, Russia was able to enter into the commercial marketplace successfully due to a combination of factors

including low costs, avid buyers (from the West and China), and the existence of large stockpiles of "legacy" Soviet space products, especially launchers. However, as that legacy of rockets and other technology has gradually dwindled and Russian manufacturers have been spoiled by two decades of high Western prices for space products, the NewSpace revolution in the United States has created serious new challenges. Put simply, prices are dropping, especially in the launch sector, and a variety of new products are now available from commercial start-ups that Roscosmos cannot produce or cannot offer with comparable quality and price. Russia had only one commercial launch in 2017; the rest were paid for by the state. Similarly, there is not a market for Russian communications satellites. As one recent Russian article observed regarding the quality of satellites produced under Roscosmos, "a significant portion of its satellites lack commercial potential" compared to their foreign, especially US, counterparts.[55] The main niche Roscosmos fills today is human spaceflight—it is the only provider for astronaut transportation to and from the *ISS*. However, when NASA's commercial crew program begins service (now planned for 2019), Russia will lose much of that business and the associated income.

Russia's uncertain and highly oil-dependent state budget is another problem facing the now re-centralized space industry. The long-term Russian space budget for the 2016 to 2025 period, originally planned for $70 billion, has now been reduced drastically to $20 billion.[56] Looking ahead, Russia's decision to put the bulk of its space investments into the military sector over the past few years has created a serious decline of planned state investments in civil and commercial space. One of the main enterprises within Roscosmos, the Khrunichev State Research and Production Space Center—builder of the workhorse Proton booster and new Angara rocket—has had to resort to selling some of its property and buildings to recoup costs not covered by existing funds from Roscosmos.[57] The problem stems, in part, from a drop in state orders from seven rockets to only three.[58] This overall situation poses a serious threat to the long-term competitiveness of the Russian space industry. State orders are falling, and Russia does not have marketable products for the increasingly competitive and innovation-driven commercial market.

Regarding innovation, Russia has become one of the least friendly countries for start-ups since the business-friendly Medvedev finished his one-term presidency in 2012. According to a recent report by experts at

the Moscow-based Center for Strategic Assessments and Forecasts, the business and legal environments for space start-ups in Russia today are highly unfavorable.[59] One Russian analyst describes a series of structural problems that have reduced its ability to organize itself for modern space operations (compared to during the Cold War), such that its share of the international space market has now declined to between 1 and 3 percent.[60] Despite its declining budget, or perhaps because of it, Roscosmos itself has worked actively to block the emergence of commercial start-ups, supported by Russian regulators who have made it extremely difficult for entrepreneurs to obtain licenses to operate private space companies. As the Center for Strategic Assessments and Forecasts notes, even the list of requirements for establishing a space start-up is "classified," adding that "to access it you need the permission of the FSB (Federal Security Service)."[61] Despite these obstacles, several Russian start-ups do exist, some from Medvedev's Skolkovo initiative. In the launch sector, for example, a small number of fledgling rocket builders have been able to find sponsors among Russia's oligarchs and state-favored businesses. Nevertheless, the hurdles facing Russian space start-ups are formidable, making the kind of commercial space "innovation hubs" present in the United States unlikely to be developed or duplicated any time soon.

Chinese Trends

China has risen the fastest and farthest among major spacefaring countries over the past two decades and seems likely to continue on this trajectory. However, despite recent Chinese efforts to stimulate technology incubators with government-provided seed money, the bulk of Chinese space activities continue to be state-run and militarily controlled. As one Russian space analyst observed recently, "The Chinese model is really the Soviet model."[62] The point here is that state direction and state funding have gotten China to where it is today in space, an impressive accomplishment. However, defense analyst Richard Bitzinger notes that "critical weaknesses remain" within China's military industry and that it has played the role of a "fast-follower" rather than that of an innovator.[63] The question is, can this path continue?

Tai Ming Cheung from the University of California–San Diego has studied China's military-industrial complex for more than two decades. He has documented China's keen ability to acquire and reverse-engineer foreign technologies in the service of state programs, especially in the

defense sector. However, he raises doubts about whether China can take the next step into innovation. Given the structure of Chinese industry, he observes, "Having the state define and pick winners and losers is not how long-term sustainable innovation happens."[64] He notes the increasing pressure on Chinese companies to comply with government directions and controls, thus slowing innovation.

China's typical processes over the past few decades of developing new military technologies, as described by Cheung, "range from spending heavily on importing large amounts of [foreign] technology and engaging in collaboration to the use of more nefarious means, such as industrial and cyber espionage."[65] The question going forward is whether China can develop its own pathways to sustainable innovation rather than copying existing technologies. In a startling realization after the Chinese company Zhongxing Telecommunication Equipment faced sanctions from the United States in the spring of 2018, Chinese leaders had to admit that the country still has a 90 percent dependence on foreign (mainly US) components for its semiconductor products.[66] Regarding space launch, a recent article in the state-run newspaper *Global Times* lamented SpaceX's accomplishments, "we are almost 10 years behind; more importantly, what our country has to desperately catch up with is actually a private US enterprise."[67]

Reforms, however, are being attempted. The problem, as Cheung notes, is that "the People's Liberation Army and defense industrial regulatory authorities are seeking to replace this outdated top-down administrative management model with a more competitive and indirect regulatory regime, but there are strong vested interests that do not want to see any major changes."[68] Nevertheless, in 2014 China instituted new laws lowering financial thresholds and bureaucratic red tape in the establishment of private businesses. China hoped to stimulate the employment of new college graduates, spur the slowing economy, and accelerate technological innovation. It followed with more specific actions in 2015 aimed at fostering space start-ups.[69] Overall, these actions succeeded in boosting the number of technology start-up companies in China, many facilitated by the establishment of government-funded start-up "incubators" located around major universities, such as Beijing's Tsinghua. Thus far, some 60 fledgling space companies have been registered, but the results have been somewhat disappointing.[70] OneSpace Technologies conducted China's first private launch in May 2018, but it is a solid-fuel

rocket that only reached an altitude of 25 miles and lacked orbital velocity, thus putting it behind German rockets of the 1940s, which used more sophisticated and scalable liquid-fuel technology. Shanghai-based SpaceOK plans to build a constellation of 40 satellites aimed at supporting the government's "One Belt, One Road" investment initiative across Asia.[71] LandSpace hopes to begin solid-fuel rocket tests in 2018 using former military rockets, while ExPace will use former military air defense missiles to attempt to enter the launch market.[72] These dynamics, thus far, suggest that conditions mirroring those in the US marketplace are still lacking in China and may require more political reforms to stimulate truly bottom-up innovation.

Despite the existence of obstacles to innovation, China will continue to advance rapidly in space capability. Through its state institutions and its military, China is moving to fulfill ambitious plans to establish a presence on the moon, launch a large space station, develop space-based solar power, and harness the ability to mine asteroids.[73] It will also seek to improve upon its already significant counterspace capabilities. However, if China's economy wavers, that raises questions related to the pace and the sustainability of these efforts and leads to doubts about this state-led path in space. Thus far, there are few signs that game-changing commercial technologies will be developed in China. Moreover, if US commercial companies and allies can render attacks on US national space assets more of an inconvenience than an existential threat, China's heavy investments into military space may simply be wasted. Former Deputy Assistant Secretary of Defense Loverro noted in 2016 that US reconnaissance satellite cooperation involved "nearly 200 satellites and likely 20 ground infrastructures" and that the number of networked satellites would rise to "over 600" by 2020.[74] As he concluded, "Using this lever to increase assurance of US imaging capacity presents an extremely complex problem to our adversaries, with little increase in our own costs."[75]

Conclusion

The future of space power may not look like the past if current trends in the commercial space sector continue. As US Space Command's Gen Howell Estes predicted in 1997 as he looked ahead in terms of space power, "It is not the future of military space that is critical to the United States—it is the continued commercial development of space that will provide continued strength for our great country in the decades ahead."[76]

Similarly, trying to determine the likely relationship between the US military and commercial space sector back in 2002, Lt Col Peter Hays commented, "It is currently unclear that military means are the best way to protect commercial satellites or that the military will be called upon to build a more robust space infrastructure based on perceived threats to commercial systems."[77] Since Hays wrote that passage, the Cold War assumption that US military assets would be needed to "protect" commercial assets in space has been challenged even more, to the extent that it is now more common to discuss the concept of using commercial infrastructure or allied assets to provide resilience to what are seen as more vulnerable US military assets. If this trend continues, it may well be that commercial capabilities and allies will prove to be essential to sustainable space power by providing the mission assurance needed in various areas of space activity necessary for effective deterrence.

Just because the United States has a vibrant, emerging commercial space start-up sector and strong friends and allies, however, does not mean it can assume future US power relative to its adversaries. As Gen Jay Raymond stated recently, "Space superiority is not a birthright; it must be earned."[78] Indeed, a lack of investment in either dimension of national space capability (civil or military) or ineffective policies to engage (and draw upon) the commercial sector and allies could cause overall US space power to fail to reach its potential. However, unlike some of the gloomy assessments of relative power trends frequently heard today within the US space community, there are also considerable grounds for believing that the United States has comparative advantages over Russia and even China thanks to emerging innovation in the commercial space start-up sector and the presence of increasingly space-capable allies. The problem facing both Russia and China in the twenty-first century is that their model for space development posits a dominant role for their governments, thanks in part to their leaderships' insistence on absolute political control over the process and results of innovation. Reforming their state-centric model to favor start-ups and bottom-up innovation or sharing of assets with foreign governments would require loosening political controls. Such actions are feared by current Russian and Chinese leaders, making them unlikely to occur. State control over investment can successfully develop national space activities in periods of strong budgetary support and under conditions where technological innovation need only occur slowly. It is a less effective organizing principle in

a fast-growing, globalized, information-based economy where market-based solutions can respond more quickly than state-led initiatives and where private capital is more readily available than government sources. Under these conditions, state-led strategies are more likely to fail.

These points, however, should not make US policymakers overly confident. Continued slowness in US military acquisition and in establishing more resilient constellations, challenges posed by excessive government secrecy and export controls, and recent underfunding of space science and civil space could all cause the United States to miss the benefits from these favorable trends. To ensure that the US advantage in NewSpace comes to fruition regarding future space power, the US government and the US military must develop and follow through on initiatives aimed at institutionalizing strong US public-private and allied links in space. Also, the US should focus on moving from Cold War "technocracy" to twenty-first-century "netocracy." Some of these actions items should include:

- continuing to create favorable rules for the US commercial space sector that emphasize responsible behavior but allow for entrepreneurship;
- fostering international discussions and interpretations of the Outer Space Treaty that support commercial outcomes with proper national licensing procedures;
- engaging in sensible export control policies, allowing sharing of technologies that are already widely available from other foreign suppliers but preventing the export of cutting-edge technologies and purchases of US commercial space companies by non-allies;
- shaping the space security environment by building more binding international norms and rules against the creation of orbital debris (to include kinetic weapons testing) and interference with satellites, while emphasizing the rights of companies to prosecute foreign violators through existing international liability law;
- developing public-private partnerships to support US civil space activity, and continuing to invest in a robust space science and exploration agenda to build US leadership;
- supporting military space resilience and sustainability, as well as enhancing the military's ability to work with the commercial sector,

especially start-ups, through expanded use of rapid acquisitions under "other transactional authorities" allowed under US law; and

- promoting policies that institutionalize cooperation with US allies in space, including joint space training, exercises, and operations.

Overall, the United States remains the world's leading space power and has the tools—national, commercial, and allied—to retain its comparative advantage in space. The challenge will be how to create flexible yet effective mechanisms to build a new, "netocracy" framework for US space power. Given emerging threats, this effort should focus on creating a shared deterrent posture based on resilience, superior numbers, continuous innovation, and cooperative resolve to deny adversaries any belief that they will benefit from starting a future conflict in space. In this way, the United States should be able to develop a robust commercial infrastructure and sustainable defenses to continue US space power under changing twenty-first-century conditions. SSQ

Notes

1. The author thanks an anonymous reviewer for providing a useful set of points to consider. The views in this article are those of the author alone and do not represent statements of the official policy of the US Navy or the US Department of Defense. It draws upon interviews conducted by the author at commercial space start-up companies in Silicon Valley, southern California, Seattle, and Denver from May to September 2017. The author is grateful to Dan Rasky, Bruce Pittman, and Tina Panontin of the NASA Ames Research Center for their advice and assistance during this process.

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