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Low-Cost Access to Space: Military Opportunities and Challenges

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About the Authors

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Key Points

- In support of the Air University "Fast Space" study, the National Defense University collaborated with Johns Hopkins University, eight think tanks, and subject matter experts to analyze the utility of ultra-low-cost access to space (ULCATS) for the U.S. military.
- Contributors identified disruptors that could achieve ULCATS and Fast Space as well as space architectures and capabilities that could reduce the cost of access to space. They also offered recommendations for legal, policy, regulatory, authority, and oversight adjustments that could facilitate cost reductions.
- The combination of a greater number of innovative commercial space actors, industry advocacy for licensing reform, and optimism regarding reusable launch vehicles will eventually change the ways the United States operates in space.
- As the economic landscape of space activities evolves, some missions in low earth orbit may be turned over to commercial sector operation, but the next 3 to 5 years might not be revolutionary for government use of space capabilities.

Space activity is critical to the American way of war. The commercialization of space has potentially radical implications for U.S. national security through its impact on a range of military and intelligence functions and on the ability of the nation to effectively project power around the globe.

Historically, U.S. space access has been under government control. In recent years, the increasing congestion of space with the rise of commercial space systems has been fundamentally changing the traditional government-centered calculus. The reality of modern space activity is that both the commercial and civil space sectors are vital for achieving national security objectives and enhancing American spacepower.[1] Burgeoning commercial space activities are leveraging technologies from the information technology sector to enable ultra-low-cost access to space (ULCATS). Air University likens these developments to the early history of aviation whereby the improved affordability of access to space has the potential for breakthroughs in national security and the space industry with global ramifications.[2]

In 2016–2017, Air University conducted a "Fast Space" study on how this evolution will present opportunities and challenges to the security of the United States. In support of Air University, National Defense University (NDU) collaborated with Johns Hopkins University, eight think tanks, and multiple subject matter experts to analyze the utility of ULCATS for the U.S. military. Each of these organizations contributed one or more reports for the Fast Space study.

For this study, the authors have adopted the Center for Strategic and International Studies (CSIS) definition of *cost of access to space* as the cost of placing and maintaining capabilities in space. This definition encompasses launch costs as well as the costs associated with "launch infrastructure, launch operations, and the size and number of payloads required to operate a capability in space." On this basis, CSIS defined *ULCATS* as a reduction by an order of magnitude (factor of 10 or more) in the total cost per pound delivered to orbit.[3]

ULCATS is a subset of the term *Fast Space*, which Air University defines as:

> *an ecosystem of concepts, capabilities, and industrial partnerships that makes speed the defining attribute of advantage in space. In this approach, speed describes both the supply and demand sides of the space market. On the supply side, Fast Space envisions sortie-on-demand launch capability, made possible through economically viable business cases, high launch rates, sustainably lower costs, rapid turn-around, and higher reliability from emerging approaches that industry is experimenting with. On the demand side, Fast Space enables users of all levels of conflict, from tactical to strategic, to harvest new advantages in and through space. These advantages include persistent command and control, ubiquitous communications, on-demand Intelligence, Surveillance, and Reconnaissance (ISR), and new axes for kinetic effects.*[4]

The goals of this paper—using reports from the Fast Space study and a concurrent report by Air University—are to identify disruptors that could achieve ULCATS and Fast Space; explore new space architectures and capabilities that could be undertaken due to an order of magnitude reduction in cost of access to space; and make recommendations for legal, policy, regulatory, authority, and oversight adjustments that need to be addressed to encourage innovation in the commercial space sector and to facilitate reductions in the cost of access to space and Fast Space.

The following is a list of the think tanks that participated in the Fast Space study and contributed reports:

- Center for Strategic and International Studies[5]
- Center for a New American Security[6]
- Wikistrat, Inc.[7]
- Telemus Group[8]
- Special Aerospace Services[9]
- BMNT Partners LLC[10]
- Interstellar Technologies LLC and Onyx Aerospace Incorporated.[11]

Air University envisions a three-phase maturation process in forging a Fast Space environment. The first phase—industry—is already present and is changing the U.S. Government-centered calculus on space. In this initial phase of 1 to 3 years, industry will lay the crucial groundwork for Fast Space by developing large constellations of small satellites. In the second phase of 3 to 10 years, Fast Space will emerge, providing the U.S. military with greater command and control; ISR; and positioning, navigation, and timing capabilities. It will also provide a "civil reserve space fleet" due to commercial reusable launch vehicles bringing threefold reductions in cost of access to space. In the final phase of more than 10 years, Fast Space will be fully obtained as a result of achieving ULCATS.[12] Aviation-like sortie access to space, reusable launch vehicles, resilient communications and ISR systems, tailored space applications, and rapidly deployable launch-on-demand systems will shape a new ULCATS-enabled, Fast Space environment.

Reducing Cost of Access to Space

Several contributors to the Fast Space study sought to identify and assess the viability of disruptive breakthroughs that have the potential to significantly reduce the cost of access to space. These potential disruptors include economies of scale and learning efficiencies, fixed and variable costs, future technologies, reusable launch vehicles, and virtuous cycles.

Economies of Scale, Learning Efficiencies, and Fixed and Variable Costs. Building more launch vehicles would enable economies of scale and learning efficiencies that could reduce manufacturing costs. A higher launch vehicle production rate could enable changes in the manufacturing process and procurement of inputs, such as the adoption of automated processes and assembly systems, that could drive down unit costs. Learning efficiencies could occur in parallel with economies of scale and repetition of the same process, reducing required labor.[13] More launch vehicles, particularly reusable ones with a higher launch frequency, could increase labor efficiencies and the rate of lessons learned.[14]

An increased frequency of launches from a given site has multiple advantages. One is a decrease in fixed cost per launch. With increased launch frequency, fixed costs such as upkeep and maintenance of launch infrastructure could be spread out. Additionally, variable launch costs would be affected. Those costs associated with the integration of payloads with their respective launcher and the operation of pads during launch could be reduced as personnel grow more efficient with practice.

Procedural changes would also evolve with increased launch frequency. For example, alterations to preflight testing regimes and payload integration processes could lead to more substantial reductions in the cost of launch operations, as follows. Before being fueled and encapsulated within the payload faring, satellites arrive a month or more in advance of launch and undergo expensive preflight checks in costly cleanroom environments. This is followed by additional tests on the pad before launch. One study notes that advanced reusable vehicles could eventually lead to tests being reduced to something like a walk-around inspection on the pad and that payload integration in an open-air environment could significantly reduce the duration and cost of launch operations. According to the study, this would begin to fit an aircraft model of reusability.[15]

It is not likely that economies of scale and learning efficiencies alone could result in ULCATS. Achieving economies of scale in launch activities and systems is unlikely without much higher levels of demand. Furthermore, achieving the necessary demand requires substantial reductions in launch costs, which is also unlikely at this time. Even if yearly launches quadrupled from their present numbers, launch operations costs could not achieve an order of magnitude reduction.

Future Technologies. Several new technologies—such as novel propulsion systems, on-orbit servicing, and on-orbit mining and manufacturing—were considered for their potential in generating ULCATS. On-orbit servicing could be used to reposition satellites so they would no longer need to expend their own propellant for station-keeping maneuvers, upgrade satellites in orbit by replacing sensors with new ones, and repair mechanical issues in situ. These disruptors would extend the life of satellites, as well as reducing launch costs because less mass would be launched. On-orbit mining and manufacturing would similarly reduce the mass needed to be launched, although not by the magnitude associated with ULCATS. As of 2017, no novel propulsion technologies are poised to provide a breakthrough that would lower launch costs in the foreseeable future.[16] NASA's renewed interest in nuclear thermal propulsion is focused on increasing speed, not necessarily reducing costs.

Reusability. Reusable launch vehicles are perhaps the most promising means of reducing launch costs. While companies like SpaceX and Blue Origin have demonstrated competencies in this area with their reusable first-stage boosters, maturation of reusability is a core requirement in Air University's Fast Space ecosystem. With continuing reductions in cost a result of reusable features, current and future national security payloads could be launched more economically and more frequently, enabling greater operational agility.[17] While the U.S. Government is currently dependent on costly and infrequent launches with long lead times, these qualities could assure the U.S. military's access to space.

Primary barriers to developing reusable launch vehicles include commercial business cases. Current market demand is not sufficient to justify the high-risk private investment. SpaceX has invested $1 billion or more in research and development costs on the Falcon 9 reusable first stage. European government and industry officials claim that to close the business case for reusable launch vehicles, ensure a return on investment, and make reusable launch vehicles economically feasible, flight rates of at least 35–40 per vehicle per year are needed.[18] Reliability and the associated risk of launch systems following repeated launches and refurbishment are concerns for both investors and customers.[19] Additionally, reusability without market competition could result in negligible cost reductions as the launch provider would only pass on significant cost reductions if forced by competition.[20]

If reusability is to play a role in supporting ULCATS and bolstering Fast Space, iterative refurbishment time and associated cost will need to be minimized. If each launch requires lengthy inspections, followed by repairs to damage suffered on the previous launch, then the process would not be consistent with the aircraft-like reusability model needed for routine, reliable access to space. SpaceX spends months evaluating, refurbishing, and testing the first stage of their Falcon 9 launch vehicles prior to reuse. They intend to reduce this timeframe to the same day and reuse other components such as second-stage rockets. If this could be achieved, launch cycles could begin to fit an aircraft-like reusability model.

While some claim that expendable launch vehicles could be developed to achieve higher frequency of launch and similarly achieve ULCATS, the Air University study does not agree. The authors argue that, based on this logic, expendable airplanes, flown once and then thrown away, would be employed.[21] While they note that launch vehicles—like airplanes—are complex systems, not mass-manufactured commodities, airplanes do not undergo the stresses of atmospheric re-entry with each flight. The proposed cost reductions are enticing, but it has yet to be proved that launch vehicles could routinely return and rapidly relaunch with minimal risk and without costly refurbishment. Operational costs for the National Aeronautics and Space Administration (NASA) Space Shuttle Program turned out to be 20 times higher than projected, and never achieved the anticipated 160-hour turnaround time or launch frequency.[22]

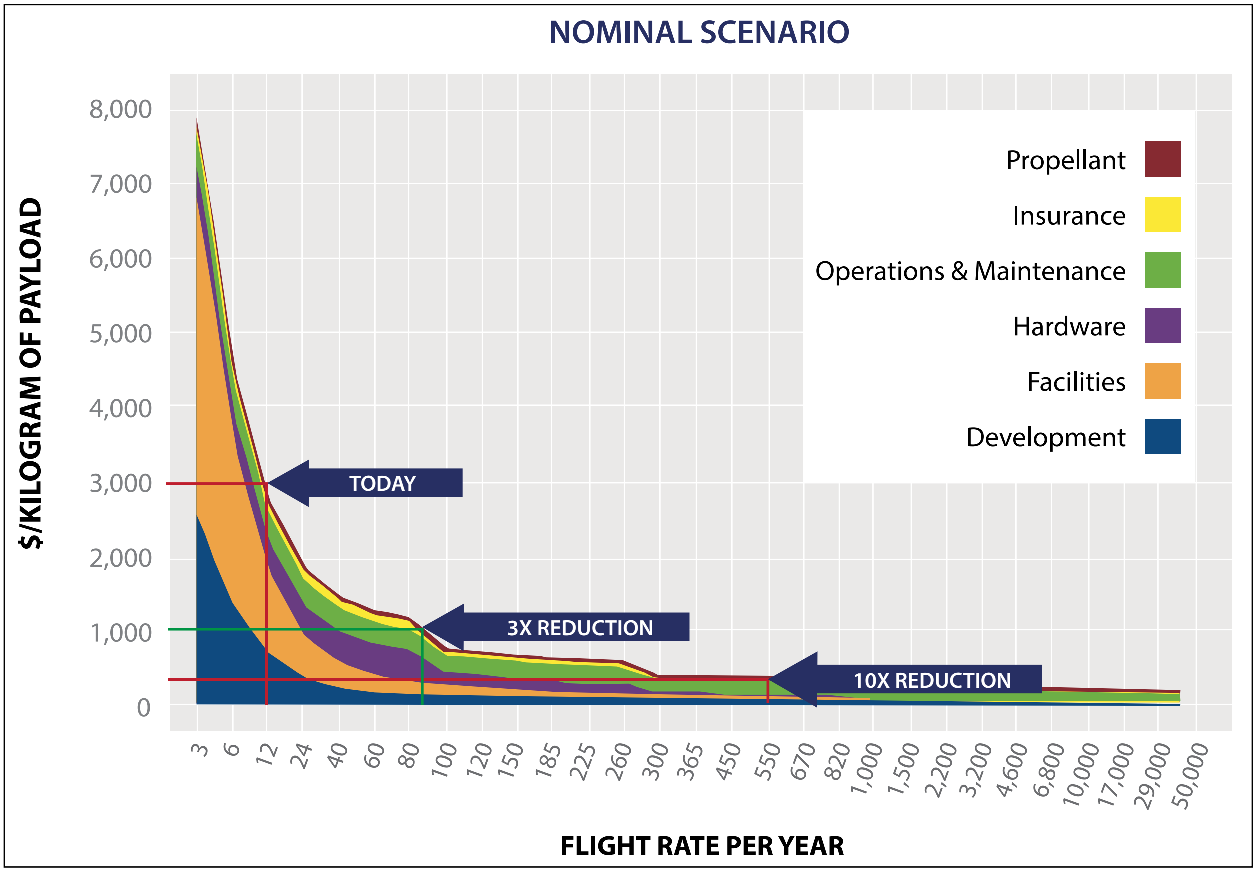
The Virtuous Cycle of Launch Frequency. Many of the contributing studies recognized that launch frequency is crucial in achieving reduced cost of access to space. Figure 1 illustrates launch cost per kilogram (kg) of payload given flight rate per year. While launch costs can vary dramatically, the graph nominally shows that increasing the flight rate per year by nine times would result in a threefold reduction in cost per kg of payload. Furthermore, a tenfold reduction in cost per kg of payload would require an almost fiftyfold increase in the number of launches. This observation raises the question of what comes first: ULCATS that would enable a robust space market, or a thriving market that requires ULCATS. One study referred to this question as a chicken-and-egg problem and remarked that it remains unclear which will initially need to occur to produce a Fast Space environment.[23]

Air University proposed that if some of the disrupters discussed above succeed in reducing initial costs of access to space, then a virtuous cycle could be jump-started, eventually leading to tenfold cost reductions in access to space. Figure 2 depicts the reinforcing cycle of costs declining, leading to increased investment and innovation that enables more efficient and frequent space activity, resulting in costs iteratively declining.[24] The virtuous cycle of new markets, higher flight rates, and more investment (leading to development of advanced technologies) would lead to reductions in labor intensity. In turn, this could enable achievement of ULCATS.[25] The space industry assumes a cyclical nature where an increased customer base fuels a larger, innovative launch industry. Industry could charge less per launch, encouraging the development and expansion of more satellite companies. This cycle could create wealth for the United States and deliver additional space-based capabilities for the military.[26]

Space Architectures and Military Capabilities

From space-based missile defense to persistent ISR capabilities, contributors contemplated the viability of

Figure 1. Launch Cost per Kilogram



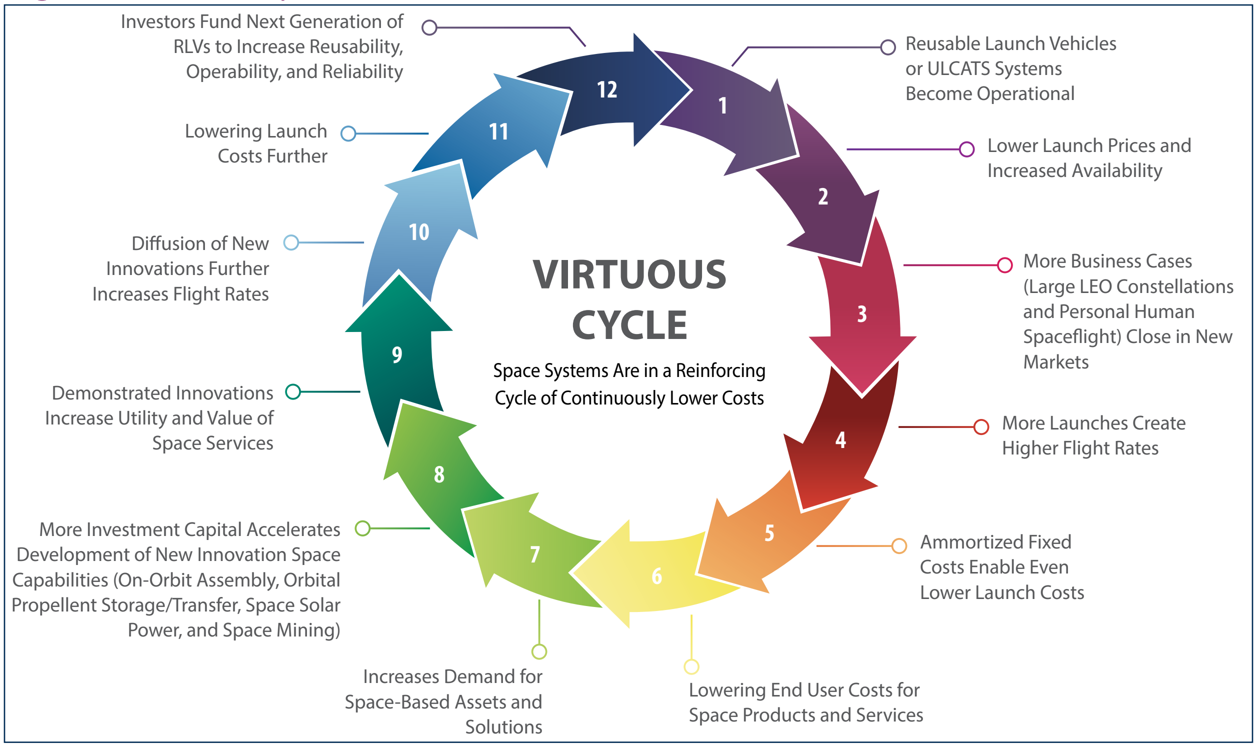
technologies and architectures that could be supported in a fast space environment by ULCATS, as follows.

Launch Cost vs. Total Cost. Recognizing how ULCATS and, specifically, reduced launch costs impact a mission's total cost is vital to understanding which missions could be considered in a Fast Space environment. Variables include the size and weight of a payload, altitude and inclination of planned orbit, type of launch vehicle used, utilization of vessel capacity, and urgency of placing a payload into orbit. Costs vary widely according to these variables. One study tested how various sized payloads, with different total system acquisition, development, and procurement costs, would be affected by ULCATS.[27]

For existing types of military satellite systems, the systems themselves are so expensive that even a tenfold reduction in launch costs due to ULCATS would have a negligible effect on the overall costs of the projects. Space-Based Infrared System Early Warning satellites have a unit acquisition (development plus procurement) cost of $3.1 billion and a unit procurement cost of $1.5 billion.[28] The new Advanced Extremely High Frequency Commercial satellites and the Mobile User Objective System both have similar high acquisition costs. For payloads with very high acquisition costs, launch costs are a much smaller percentage of total costs. ULCATS would contribute a negligible improvement to the cost effectiveness of these systems.

Navigation satellite systems are likely to benefit from ULCATS. NAVSTAR GPS and GPS III have relatively low unit acquisition and procurement costs, resulting in a larger proportion of total lifecycle costs being attributed to launch costs. Nonetheless, unit acquisition and unit procurement costs are still far in excess of launch costs.[29] Unless future capabilities can be developed and procured

Figure 2. Virtuous Cycle



at less expense than launch costs, ULCATS would likely have a modest or negligible impact on lifecycle costs.

Space-Based Weapons and Orbiting Ballistic Missile Interceptors. Space-based weapons for kinetic ground attack were considered for their viability in a Fast Space environment. One study noted how 48 weapons, each with a mass of 750 kg, would need to be placed in 16 orbital planes to provide the continuous ability to strike within 45 minutes. Using this capability, hardened or buried targets could be penetrated. Sixteen launches, each carrying three weapons, would be used to reach all 16 orbital planes. Even if not used, the capability would need to be replaced every 10 years due to orbital decay and degradation of components within the satellite. Over 30 years, this would require 48 launches and 144 weapons. With a unit cost of $10 million, and $50 million per launch vehicle, over 30 years the total procurement cost would be $3.8 billion (not taking into account development costs). If ULCATS could be achieved, procurement cost could drop by half. However, a decision to place weapons in orbit would have extraordinary policy implications and would be much more expensive than a terrestrial capability.[30] The impact of ULCATS may not be significant enough to make such a mission more cost effective than terrestrial alternatives.[31]

A space-based missile defense system could be enabled by ULCATS. In Wikistrat's crowdsourced simulation, the majority of experts recognized such a capability occurring 10-plus years after achieving ULCATS. An orbiting missile defense capability could deter adversaries by denying them the confidence of a ballistic missile attack. In a Fast Space environment, costs of deploying a system could be reduced and greater operational flexibility could be achieved, relieving pressure on theater missile and ground-based midcourse defense systems. An orbiting missile defense capability would engage inbound threats early in their trajectories and reduce the effectiveness of multiple independently targetable reentry vehicles, decoys, and countermeasures. Finally, an orbiting system could reduce the political and logistical issues of forward-basing missile defense technologies.[32]

A space-based missile defense architecture would have low unit acquisition costs but a large mass. This combination means that launch costs could represent a considerable portion of total costs. A 2004 Congressional Budget Office study contemplated a constellation of 156 to 368 space-based interceptors in low Earth orbit. Production costs for each interceptor would be around $35 million, with each having a mass of 442–847 kg and an operational lifetime of 7 years. Launch costs would amount to approximately 40 percent of a system's lifecycle costs. With this high proportion of launch costs relative to lifecycle costs, a reduction in launch costs could improve the cost effectiveness of such a system. While a space-based missile defense system could benefit from ULCATS, such a system could remain impractical or inferior to terrestrial-based alternatives.[33] Similar to deploying space-based weapons, an orbiting missile defense capability would have dramatic policy consequences. It would be viewed as reversing decades of American space policy, likely normalizing the placement of weapons in orbit, and would be unlikely to gain the acceptance of commercial space actors who would view it as a destabilizing threat to the space industry.

Small Satellites. The U.S. military's current space architecture is defined by small constellations of highly aggregated, expensive satellites. High launch costs have influenced these architectural choices. A majority of Wikistrat's expert analysts expect that within 5 years of ULCATS, space architectures could change to large constellations of small satellites.[34] The current situation of a small number of launch vehicles with individual flights taking weeks to prepare is feasible in peacetime but will be a vulnerability in times of conflict as reconstitution of assets in space could take years.[35] Currently and historically, access to space has been expensive, incentivizing highly complex payloads for few launch opportunities. ULCATS could enable the fielding of smaller, less costly satellites.[36]

An alternative architecture consisting of a large number of small satellites with disaggregated functions, reserve satellites for replenishment, and a launch infrastructure capable of repopulating constellations could better serve the U.S. military in situations where conflicts could extend into space. Lower cost and shorter on-orbit life expectancy of small satellites could allow for more consistent replacement and replenishment, allowing technology to be refreshed more frequently and reducing the need to incorporate the latest expensive and often risky technology.[37] A constellation of small satellites would increase the redundancy, modularity, and dispersion of space assets,[38] thereby increasing the resiliency of American satellite constellations. It would enhance deterrence by eroding an adversary's confidence in its ability to gain a first-strike advantage through a critical blow against the United States' on-orbit space infrastructure.

For small satellites, launch costs represent a much higher percentage of system lifecycle expense. OneWeb, a company planning to provide global internet broadband through a large constellation of small satellites, aims to manufacture 840 small spacecraft for $500,000 each with 32–36 spacecraft launching on a Russian *Soyuz* launch vehicle. Under the assumption of a $50 million cost per launch, each spacecraft would cost roughly $1.5 million per launch, and subsequently the ratio of launch costs to production costs would be 3 to 1.[39]

OneWeb and other small satellite producers could benefit from ULCATS, but the cost reductions would only occur because OneWeb's planned constellation is large enough and will deploy many satellites with similar orbital characteristics, allowing it to take advantage of medium-launch vehicles. Small satellite operators planning on launching smaller constellations using satellites with differing orbital characteristics would not be suitable for launching large batches on medium-launch vehicles. BlackSky Global, a startup satellite imaging service, plans to operate a 60-satellite constellation that will become operational in phases and will therefore be unable to launch in large batches. Small satellite operators like BlackSky currently rideshare as secondary payloads, incurring indirect costs that could inhibit the greater adoption of small satellites. Further, small satellite operators have limited control over the timing of launch or the precise orbital parameters.[40] Small satellites within the constellations would need to be replenished much more frequently than those in the current architecture, but they would not be able to take advantage of launching in large batches like OneWeb's planned initial deployment.

Replenishment missions, and missions needing to deploy fewer small satellites relative to OneWeb, would require the use of a small-launch vehicle. The current U.S. domestic launch base will be unable to handle any future demand for launching small satellites.[41] Current small-launch vehicles are inefficient and expensive. The Minotaur IV small-launch vehicle has a cost of $29,000 per kg of payload, compared to SpaceX's Falcon 9 medium-launch vehicle that costs $6,000 per kg of payload.[42] If ULCATS could enable the production of efficient small-launch vehicles capable of launching on demand, small satellite constellations could be utilized and reconstituted in civil, commercial, and military applications.

ULCATS-enabled small-launch vehicles capable of launching on demand and low-cost small satellites could enable a new architecture of reserve satellites that are "ready to launch" to reconstitute national security capabilities. Such a capability would improve the resiliency of U.S. space-based assets. If adversaries calculated that American satellites could be reconstituted quickly, then a shift to a ready-to-launch architecture could reduce the incentive for a preemptive attack. However, a movement toward low-cost satellites, stockpiled and ready to launch on demand, would require major changes in the space industrial base.[43]

A Fast Space architecture of large constellations of small satellites could enable persistent ISR. By fielding large constellations of remote-sensing satellites, the United States could, among many other applications, increase situational awareness, expand maritime domain awareness, reduce the risk of inadvertent escalation, and illuminate the credibility of threats. Large constellations of ISR satellites could increase warning times and enhance transparency in an adversary's military actions while allowing for replenishment of degraded assets.[44]

In strategic terms, it is unclear whether persistent ISR based on constellations of small satellites will be effective in future conflicts. Adversaries are aware of U.S. reliance on informational advantage and understand that future conflicts will have a great emphasis on information dominance. Adversaries are developing more robust, asymmetric antisatellite technologies to thwart the many benefits the United States could derive from large constellations of ISR satellites. Other more cost-effective intelligence resources, such as the exploitation of the Internet of Things, could be fielded, rendering investments in large constellations of satellites impractical, even in an ULCATS scenario.[45]

One contributing study contemplated the ULCATS-enabled capacity for combatant commanders to have dedicated satellite communications and ISR constellations to deploy in support of mission requirements. Command, control, communications, and ISR capabilities could be disaggregated, allowing for more responsiveness to the needs of the specific mission at hand. However, if implemented, the space operating environment would be made much more complex. Furthermore, the recruitment and training of so many personnel to operate these satellite communications and ISR assets could be impractical.[46]

Some challenges arise in the shift toward a new architecture of large constellations of small satellites. It would generate a significantly greater number of objects requiring management, operation, tracking, and monitoring. Orbital debris could become a greater issue, especially if new space actors neglect to deorbit their assets within the 25-year international guideline. Large numbers of satellites could overwhelm situational awareness of the space domain. Confusion could arise regarding the escalatory steps of targeting and destroying a small satellite. While a physical attack on one of the highly aggregated satellites currently in orbit would likely be an indicator of hostile intent, the destruction of a redundant, disaggregated small satellite would be more opaque and could allow adversaries to act nefariously without being held accountable.[47] Even with the development of ULCATS, it is not assured that a space launch infrastructure allowing for the on-demand deployment of small satellites into orbit would be developed.[48]

Finally, such an architecture would not be possible for all U.S. missions. While the Department of Defense (DOD) would appreciate the higher revisit rates provided by small satellites, the Intelligence Community would need the higher resolution provided by large, expensive assets like those currently in orbit.[49] Space-based radars require high levels of power while observation systems require large apertures for high resolution and/or sensitivity. The technology to distribute these functions across a large constellation of satellites is not currently available.[50]

A "Megasatellite" Architecture. Along with disaggregation, some studies envisioned the aggregation of capabilities into massive satellites. Through ULCATS and the development of on-orbit servicing, military and commercial firms could develop large space station-sized modular satellite busses that would aggregate many payloads together.[51] Instead of maximizing performance per pound, features could be optimized without regard for minimizing their mass.[52] These megasatellites could be built to host a wide variety of interchangeable payloads. Although megasatellites would be enticing targets for adversaries, they could also aid in creating "red lines" in space, potentially dissuading adversaries from targeting American space assets.[53]

Strategic Deterrence, Conventional Deterrence, and Management of the Strategic Environment. The adoption of some of the architectural changes and capabilities mentioned in this paper, and others changes, would allow the United States to derive advantages from the space environment. Air University noted that the benefits derived from a highly reliable launch infrastructure with high sortie rates, industry participation, entrepreneurial ventures, and new sources of commerce and economic growth would advance strategic stability by improving strategic deterrence, conventional deterrence, and management of the strategic environment.[54]

In a Fast Space scenario, strategic warning assets could be disaggregated from tactical and operational capabilities, further enabled by the ability to reconstitute such assets. These capabilities would strengthen the nation's nuclear deterrent by establishing clear red lines for U.S. strategic assets. As adversaries field greater anti-access/area-denial capabilities, American conventional military power and deterrence have declined in relative terms. Fast Space capabilities could provide a new paradigm for power projection, allowing the United States to reduce its reliance on forward bases while fielding a renewed command and control construct and allowing for highly synchronized multi-domain operations and multi-axis approaches. The United States could shape the strategic environment through its global role in military, commercial, and civil space, all enabled by a Fast Space architecture and a strong industrial base.[55]

The Government Role in Commercial Space

Governments are key contributors to the commercial space industry through investments in technologies that do not have an immediate market but can evolve into beneficial capabilities. In this way, government programs can create new opportunities for commercial technologies by reducing the risk for early commercial entrants.

Government demand for space-based capabilities serves to enlarge the market for many commercial capabilities and applications. Better coordination and cooperation in this area will deliver mutual benefit. For example, geospatial data overlap between the commercial development community and the national security community is successful and constantly improving. Similarly, to prevent famine and mitigate food insecurity, programs like the Famine Early Warning Systems Network depend on NASA, National Oceanic and Atmospheric Administration (NOAA), Department of Agriculture, and U.S. Geological Survey to provide decision-makers with accurate, credible, timely, and actionable information.[56] Commercial enterprises such as Planet and SpaceX augment their commercial client base by providing a range of services to defense, intelligence, and interagency organizations, thus creating economies of scale.

Recommendations

Many laws, policies, and regulations could be revisited to encourage innovation and development in the commercial space sector. Areas for consideration include increased use of commercial space launch contracts, more flexible approaches to risk mitigation and mission assurance, increased development of common design standards, investment in dual-use technologies and launch infrastructure, sophisticated implementation of International Traffic in Arms Regulations (ITAR), and streamlined Federal Aviation Administration (FAA) launch licensing.

To achieve the benefits of ULCATS and Fast Space, the United States will need to adjust its policies, organization, and organizational culture so it can leverage and respond to disruptive technologies, enable innovation, and advance American interests.[57] By not actively encouraging innovation and partnering with the commercial sector, industry could develop systems that have less than optimal value to the warfighter. As a result, revolutionary systems could take longer to develop, and other countries could benefit from engaging with their respective industries, surpassing some American capabilities.[58]

The following recommendations have been selected from the contributing studies.

Following current trends such as NASA's Commercial Crew and Cargo Program and the Air Force's steadily increasing use of SpaceX Falcon 9 launches—to include a future launch of the X-37B space plane—CSIS recommends the Air Force and other U.S. Government agencies should use commercial space launch contracts for regularly scheduled launches to the maximum extent possible in order to build the government's expertise in buying these services.[59]

CSIS recommends the U.S. Government should be an early investor in cutting-edge space technology that is likely to have future applications in both military and commercial space, such as the development of systems and software for the exploitation of large satellite constellations.[60]

Addressing government influence in supporting the commercial space market, CSIS recommends the government should leverage its purchasing power to create a baseload demand for emerging services.[61] This could help commercial actors to close their business cases and would enable commercial space actors to overcome cost barriers to entry by granting reliable long-term revenue streams and helping foster a commercial environment capable of producing transformative technologies.[62]

To engage with the private sector, Air University recommends the use of Other Transaction Authorities (OTA) as a proven, effective vehicle for public-private partnership capable of reducing costs. Companies are investing their own capital into innovative ways to reduce launch costs. By partnering with government investments via an OTA, industry would gain access to unburdened capital, technical expertise, and unique infrastructure while government could leverage private business models and innovative cultures where failure is more accepted. Air University asserts that OTAs could be fundamental to initiating a virtuous cycle.[63]

Existing technology transfer programs are beneficial to several of the large successful members of the commercial space industry. Such transfers are critical to the commercialization of high-risk, high-value concepts. BMNT recommends government agencies should provide frameworks for the adoption and transition of commercial systems, derived from technology transfer, to incentivize companies to consider government-use cases from the start.[64]

To encourage shifts in current U.S. space architectures away from small constellations of aggregated satellites, the Telemus Group recommends government support for the development of small satellites. The group proposes the DOD and Air Force should consider funding for small satellites as these constellations could prove more survivable and reconstitutable, even if this change results in reduced funding for traditional satellite programs. Further, the government should support the development of efficient small-launch vehicles to launch thousands of small satellites. Perhaps the best way to encourage the development of efficient small-launch vehicles is for the U.S. military to begin developing, producing, and deploying more small satellites.[65]

Currently, American launch providers conduct missions from 10 active and approved launch sites within the United States. With the current launch cadence, this number of sites is appropriate, but a much larger number of launch sites and launch pads will be needed if launch frequency increases to the levels predicted by Air University. CSIS recommends the government should invest in improving current launch infrastructure and be willing to collaborate with industry and state and local governments on future designs that could be capable of higher operational tempos.[66]

The Telemus Group notes a need to rapidly reconstitute critical satellite constellations in a Fast Space environment and recommends the U.S. military should encourage development of launch vehicles deployable in sufficient numbers to enable an effective reconstitution capability.[67]

One of the most important actions for the United States to enable a future ULCATS environment is to assume a leading role in establishing norms and guidelines for actors' behavior in space.[68] CSIS recommends the United States should establish national space governance procedures and advance approaches for the development of similar international standards.[69] Setting the framework for conduct of actors in space would provide clarity as new opportunities and services in space unfold.[70]

Recommendations for Federal Policy and Regulation Reform

Clear policy guidance and standards for commercial space activities are needed for a thriving commercial space industry.[71] Guidance currently provided by the U.S. Government inhibits commercial space activity through a lack of transparency, clarity, and predictability.[72] Specifically, industry lacks appropriate Federal regulations and licensing that could bring confidence to the market. Regulatory systems are failing to keep up with rapid expansion and innovation from the commercial space industry, and this will be exacerbated by ULCATS.[73]

Regulations for space-related missions are spread across several agencies, making licensing processes overly complicated and unintuitive. Firms dealing with emerging technologies face regulatory processes that are not comprehensive and, at times, nonexistent. Without proper regulations and licensing processes, commercial companies find it difficult to receive adequate investments and insurance.[74] The following are recommendations for Federal policy and regulation reform.

CSIS recommends that mechanisms be developed and personnel should be put in place at various levels in government to review space-related licensure. Agencies such as NOAA, the Federal Communications Commission, and the FAA should cooperate to enhance the capacity for licensing new and existing commercial space actors and activities. Further, licensing agencies should clearly communicate with industry on issues likely to lead to license denial, perhaps by granting security clearances to a limited number of company personnel in order to discuss reasons behind license denial.[75]

Unclear regulatory structures and dispersed responsibility within the regulatory environment inhibit the growth of the commercial space sector. BMNT recommends that if the United States seeks to maintain its leadership in space technology development, it must pursue a more efficient and centralized method of regulating space activities. BMNT cautioned against enforcing regulations that stifle innovation.[76]

Several contributors commented on the government's expensive test requirements and high mission assurance costs. Air Force mission assurance is 30 to 50 percent of launch costs.[77] High mission assurance standards are driven by the high acquisition costs of U.S. military satellites and the extent to which the military is dependent on a small number of assets in orbit for most of its missions.[78] Some contributors suggested that if the Air Force could increase its tolerance of risk and mission failure, it could achieve lower launch costs and higher launch rates, possibly contributing to the virtuous cycle. CSIS recommends that the Air Force continue to review ways the launch certification process could be simplified so that launch services could be purchased in the same way as commercial customers purchase them.[79] Air University recommends replacing this system with a one-time testing process to verify reliability before fielding operational service.[80] CSIS notes a transition to a system of regulating payloads by exception—with only specific items unable to launch until criteria are met—may be necessary, especially if ULCATS was to enable a launch frequency of over 100 per year.[81]

There are a greater number of actors in the space domain than ever before and this trend will continue, especially if ULCATS is achieved. Concerns have arisen about whether existing sources of space situational awareness data and analytical tools are sufficient to handle the proliferation of access to space. Both space situational awareness and space traffic control will be vital with the numerous capabilities, missions, and markets that will be enabled by ULCATS.[82] CSIS recommends creating a clear set of standards and processes to check orbits for collision risks, ensuring that there are plans for debris mitigation and safe re-entry disposal and implementing an effective, but minimally burdensome, space traffic management system.[83]

Strict ITAR rulings have been criticized by commercial actors for stifling the U.S. commercial space industry. Such restrictions are necessary for national security, but ITAR's stringent export controls have made some companies decide to avoid exporting space-related products because of the complexity of the regulations and the fear of penalties. These regulations have caused some foreign organizations to produce "ITAR Free" space products to ease acquisition. While President Barack Obama initiated an Export Control Reform initiative, many in the industry hope for greater clarification and relaxation in the export control of space products. CSIS recommends that the United States approach export controls with the understanding that American spacepower grows when its firms are industry leaders in the global space market.[84]

Public vs. Private Sector

While the above policy and regulation reform recommendations seek to bolster the commercial space industry, encourage ULCATS, and anticipate a Fast Space environment, they do not seek an unconditional switch to assets provided exclusively by the private sector. Such a recommendation is made by Robert Zimmerman from the Center for a New American Security (CNAS). He recommends that a complete shift in power and regulatory authority be made away from the Federal Government to commercial industry and that commercial entities be given unprecedented freedom to act in response to the demands of the market.[85] His study includes comparisons between launch and development costs of various spacecraft associated with the private sector and those associated with the government.[86] It supposes a binary relationship between the public and private sector, leading to the conclusion that free enterprise should be the victor.[87]

Zimmerman claims that commercial markets exist for public goods. He does not consider the absence of a commercial market, where governments must provide public goods that make no commercial sense like science, exploration, and security.[88] Specifically, he compares costs between the U.S. Government's Space Launch System (SLS) and commercial launch providers like SpaceX and Orbital ATK. He notes commercial satellite companies cannot afford a launch on the SLS, but he does not mention that SLS is a vehicle designed for deep space exploration. It was not developed by the government to perform a service provided by private-sector actors.[89] In an ULCATS scenario, the Federal Government will purchase many launch capabilities, data, information, and space assets from the private sector. At the same time, it will need to provide public goods that cannot be addressed through the market. The recommendations in the previous section, unlike Zimmerman's recommendations, do not consider the movement toward greater partnering with the private sector as a zero sum choice toward free enterprise.

In purely financial terms, Zimmerman is correct. More than $15 billion has been spent on SLS development and it has still not been launched. The SLS will cost about $1 billion per launch. Falcon Heavy is now a proven launch system, priced at about $90 million per launch, with potential to support science, exploration, and security missions.

Déjà Vu?

The assertion that ULCATS and Fast Space bring the promise of cost-reducing reusable launch vehicles causes many in the space industry to recall previous hopes and plans. The Dyna-Soar/X-20, Space Shuttle, National Aerospace Plane, Military Spaceplane, and X-33/Venturestar were programs that failed to achieve routine access to space and expected cost reductions. Other ambitious plans from the commercial space industry in the 1990s never materialized, leading to numerous bankruptcies. Although many predictions for the development of commercial space have been premature, the push toward commercial space is a constant trend.[90]

According to Air University's study, several hurdles prevented past attempts at achieving ULCATS. The study identifies the perceived lack of a compelling military need, high costs of development and acquisition, technical infeasibility of reusable launch vehicles, and a requirements-driven acquisition process that was not structured for paradigm-breaking capabilities, all inhibited reusability and ULCATS from succeeding. It asserts that emerging national security threats, advancements in technology capable of delivering the benefits of reusable launch vehicles, wealthy entrepreneurs willing to invest their own capital into space assets, increasing engagement with the private sector, and the benefits of OTA agreements in creating partnerships with commercial firms all make reusability, ULCATS, and Fast Space an attractive possibility.[91]

Congress is ready and willing to aid in the formation of a prosperous space sector, and it is aware of the regulatory gaps and struggles that exist for commercial space actors. With the U.S. Commercial Space Launch Competitiveness Act of 2015, Congress recognized the need for a regulatory regime to provide stability for the commercial space industry, particularly to actors interested in harvesting resources in space. The House Committee on Science, Space, and Technology approved the American Space Commerce Free Enterprise Act, which seeks to establish "a legal and policy environment intended to unleash American free enterprise and business, assure conformity with Outer Space Treaty obligations, and ensure that the United States will lead the world in commercial space activities throughout the 21st century."[92] Notably, the bill reforms the licensing system for commercial remote-sensing satellites, which has come under fire from industry representatives for impeding growth. In the National Defense Authorization Act for Fiscal Year 2018, the House Armed Services Committee (HASC) adopted an amendment instructing the Secretary of Defense to brief the HASC on the DOD "plan to evaluate the risks, benefits, costs, and potential cost-savings of the use of reusable launch vehicles" for national security missions.[93] This amendment encourages the Air Force to rethink its policies regarding reusable launch vehicles. As Congress increasingly addresses matters affecting the commercial space industry, it could play a vital role in facilitating ULCATS.

Conclusion

The ongoing commercialization of space activities is enabling increased privatization of government tasks.[94] Government remains the critical player and anchor customer in the industry. Only when there is a large influx of non-government customers into the market, so that fixed costs can be spread over a larger number of players, can access to space become a viable commercial enterprise. SpaceX's introduction of greater price competition into the international launch market has not yet resulted in new demand for launch services, but it has caused a reallocation of market share among international launch providers. The Air University study anticipates a virtuous cycle leading to even greater ULCATS, aligning with past studies that predicted new sources of demand when launch prices are below $1,000 per pound.[95]

There is no guarantee that ULCATS will occur. If it does, it could play out differently than recent scholarship has envisioned. Trends and technological advances in a number of areas suggest that ULCATS is a possibility.[96] The growing number of commercial space actors advocating for licensing and regulation reform could succeed in lowering the cost of access to space for U.S. entities. Cost reductions from commercial reusable launch vehicles, even if not achieving ULCATS or Fast Space, will change the ways the United States operates in space.

The emergence of low-cost access to space is prompting debate on the challenges and opportunities presented by "old space vs. new space" and "government vs. commercial" space-related activities. As the economic landscape of space activities evolves and business cases become viable, it may be logical for some missions in low Earth orbit to eventually be turned over to commercial sector operation. But the next 3 to 5 years of technological development might not be revolutionary as the industry adjusts to new risk factors.[97]

Many of the studies encouraged the U.S. military to enable—and capitalize on—developments within the private sector. The military may not be moving quite as fast as these studies would prefer. General John Raymond of the U. S. Space Command noted that the Air Force is monitoring commercial launch developments but that the Service's goals of gaining assured access to space, competition, and ending reliance on the Russian RD-180 engine would take priority.[98] Air Force Major General Roger Teague, when speaking on Air Force acquisition, mentioned that the Air Force would continue to follow the Evolved Expendable Launch Vehicle strategy, viewing reusability as a feature, not a requirement.[99] Congress and the National Space Council could serve a vital role in directing and implementing the reforms and recommendations outlined by the contributing studies.

The Trump administration's early emphasis on job creation and expansion of domestic industry appears to make Fast Space a strong candidate for investment opportunities. A flourishing commercial space industry has the potential to create high-paying and stable jobs in engineering, manufacturing, communications, and other fields. NASA and Air Force centers that contribute to space operations are located in most regions of the country, and the commercial space industry has potential for creating jobs across the nation. However, this growth in opportunity does not come without cost. Expansion of the commercial space industry and the evolution of Fast Space will require an increased supply of space-related professionals and significant investment by government in required human capital.

Several contributors to this study note that ULCATS would not be just an American phenomenon. If the United States achieves ULCATS, the ability to attain reductions in cost of access to space would spread to other state and nonstate actors. CSIS notes how ULCATS could enable proliferation of long-range missiles as well as adoption of space-based anti-satellite systems. Wikistrat notes how American supremacy in ISR could be threatened.[100] CNAS mentions how adversaries could end reliance on the U.S. Global Positioning Satellites and exploit their own global navigation satellite systems for precision strike capabilities.[101]

Spacepower is proliferating among a variety of state and nonstate actors. Understanding how the U.S. military can achieve ULCATS and operate in a ULCATS environment is fundamental to national security.

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