OUTPACING THE THREAT WITH AN AGILE DEFENSE SPACE ENTERPRISE

**THE PROJECT THOR TEAM
THE AEROSPACE CORPORATION**

AEROSPACE

WHY WE WROTE THIS REPORT

While the DOD adapts to a new national security space paradigm, The Aerospace Corporation, as operator of the only federally funded research and development center (FFRDC) dedicated to the space enterprise, is working aggressively to address all aspects of this critical challenge. As a trusted advisor and liaison among DOD, intelligence, civil, and commercial space, Aerospace offers an informed perspective, which we holistically call Project Thor, on the changing landscape and necessary course of action. Decades of experience working with government customers and industry partners, coupled with technical depth and domain breadth, uniquely provide Aerospace with the insight needed to help the government make this crucial transformation.

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Summary

This is a critical moment for the United States in space. Potential adversaries are developing and fielding anti-satellite weapons and more effective military satellites. Meanwhile, the commercial market offers promising new possibilities for space, such as cheaper launch, large constellations, and miniaturization. But U.S. national security has traditionally relied on space systems developed over long timelines to provide extraordinary capabilities and avoid losing satellites to a hostile environment with little room for error. The United States can rise to the challenge of the threat and harness the power of the commercial market with a focus on quickly developing and fielding its space systems. To envision an architecture in which this rapid deployment enables the United States to outpace threats in space, The Aerospace Corporation created Project Thor, which recommends:

♦ Realigning space acquisition for agility and resilience through increased production, a modular and open architecture and contracting approach, and greater competition.

♦ Using modern systems engineering to create a single, agile space enterprise.

♦ Accelerating advancement with meaningful prototyping and stronger partnerships.

♦ Streamlining decisionmaking for requirements, resources, and acquisition.

This paper is the first in a series that will explore these recommendations in greater depth and variety.

Introduction

Unfettered access and freedom to operate in space is of vital interest to the United States.[1] With the emergence of new entrants, new business models, and new technology, the Department of Defense (DOD) space enterprise is poised for unprecedented transformation. Development and proliferation of advanced space systems across the commercial, civil, and military sectors and aro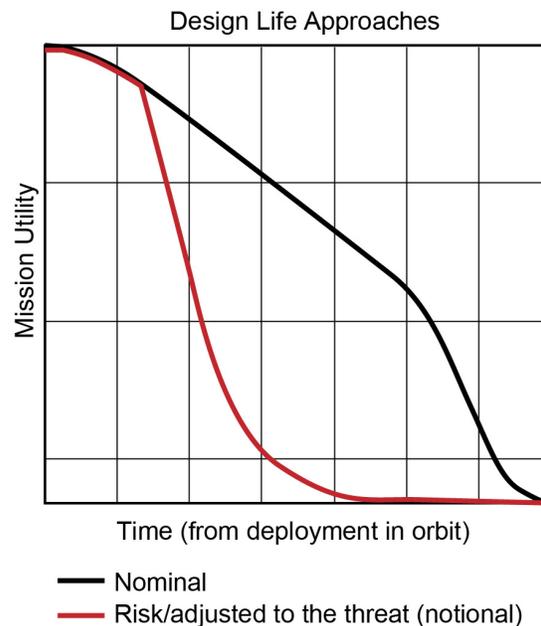und the globe has made the space domain more crowded and contested. U.S. adversaries have developed anti-satellite and other counter-space capabilities that threaten U.S. interests. The number of foreign reconnaissance and remote sensing satellites has tripled from 100 to 300 in the last 10 years, with China comprising almost 40% of the foreign remote sensing total. In areas where the U.S. has a lead, China and Russia are gaining; in some cases, the U.S. intelligence community assesses that these

potential adversaries are deploying unprecedented technologies.[2] China and Russia are aggressively pursuing new electronic warfare technology, directed energy and kinetic weapons, and cyberattacks. These circumstances present both threats and opportunities.

We must transform our national security space enterprise into an architecture that can continuously outpace the adversary threat. Under the current approach, it can take more than 10 years to develop, build, and launch highly complex space systems, which means that some of the technology is already obsolete when launched. These complex space systems are the fundamental backbone supporting U.S. military operations as well as U.S. economic interests. Relying on undefended, exquisite systems worked while space was a sanctuary, but potential adversaries have come to recognize our dependence on these high value assets and are actively seeking to deny our access, transforming space into a warfighting domain.

A new paradigm is needed. In some mission areas, this means developing dramatically new concepts. In others, it means making changes to existing systems and processes. The DOD must field architectures that are resilient, responsive, scalable, and affordable. To do so, we must transform our space enterprise by removing roadblocks, modernizing antiquated processes, and thinking differently about how we develop new capabilities. Our adversaries will seek to be unpredictable and develop new threats inside our decision cycle; they have already demonstrated this behavior. Responsiveness and agility must be defining characteristics of our architectures as well as our acquisition, development, and production processes.

Satellite replacement should be based on adversary timelines, not design life.

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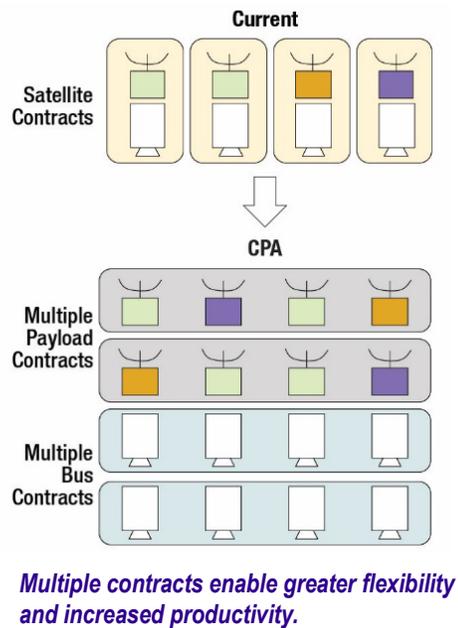
A Strategy to Outpace the Threat

In March 2018, the Deputy Secretary of Defense asked Aerospace for recommendations on how to outpace the threat in space and align to the new National Defense Strategy. To ensure consideration of diverse and innovative options, Aerospace created a Project Thor research team of personnel who support the intelligence community, Missile Defense Agency (MDA), National Aeronautics and Space Administration (NASA), and commercial

companies, as well as those with program experience in the Pentagon, U.S. Strategic Command (USSTRATCOM), Air Force Space Command (AFSPC), and Space and Missile Systems Center (SMC). Based on the team's work, Project Thor recommended three technical lines of effort as well as institutional reforms:

1. Moving space to an agile, higher-volume-production footing, modifying current acquisition plans to adopt a concept Project Thor refers to as *Continuous Production Agility* (CPA). CPA calls for a modular bus design to increase opportunities to transition innovations into compatible payloads—enabled by interoperability standards and open architecture. This approach combines modular bus contracts across DOD space acquisition programs to quickly adopt and deploy new technologies and capabilities, and to achieve production efficiencies.

2. Integrating national security space architectural elements to function as an agile enterprise, using modern enterprise systems engineering, digital engineering, DevOps[3], and cybersecurity methodologies across the space, launch, ground, and user equipment areas. Replacement of aging user equipment that has prevented full use of on-orbit capabilities and constrained space development is another key enabler but will require coordinated effort across organizations.

3. Advancing the architecture through meaningful prototyping for rapid technology development and insertion, combined with eliminating barriers to deeper, interdependent partnerships with allies and commercial providers.

4. Additionally, Project Thor concluded that streamlined decisionmaking on requirements, resources, and acquisition is needed to achieve the aggressive speed targets identified by the Deputy Secretary. This could entail simplifying

the top-level requirements documents for the space enterprise, consolidating delegated decision authority in the hands of a key accountable official across both space operations and acquisition, and potentially simplifying the programming and appropriations structure for space.

Multiple contracts enable greater flexibility and increased productivity.

Implementing CPA

Project Thor's CPA strategy realigns space acquisition for speed, adaptability, and resilience using increased production, a modular open systems architecture and contracting approach, and enhanced competition. The current slow pace of constellation refresh, which produces only enough for replacement of long-life spacecraft and which adjusts schedules as spacecraft outlive initial projections, limits opportunities for technology insertion, disincentivizes investment in long-term production efficiencies, and fails to account for the inevitable attrition that would occur during an active conflict. To break out of this model, Project Thor recommends an agile, higher-volume space production concept that delivers bus and payload capabilities in a modular fashion. The fundamental

insight behind the CPA approach is that resiliency does not come from picking one optimal future architecture now. Instead, it comes from the ability to adapt the architecture and scale to future needs in an affordable way.

Maintain Production Cadence. CPA changes how we replace satellites in constellations. Currently, major programs build long-life satellites in small quantities sufficient to maintain a small constellation with purchase timelines based on projections of functional availability. For high profile mission areas like protected communications and missile warning, this strategy, coupled with fiscal constraints, results in satellite production rates of just 4 or 5 units every 15 to 20 years. It reinforces the high-reliability, low-risk mindset that discourages change, avoids risk-taking, and stifles innovation.

In contrast, CPA focuses on delivering an *entire constellation* over a short period (e.g., five years) and immediately beginning the replenishment process on a schedule-certain basis. The additional quantity of satellites drives a predictable manufacturing cadence and incentivizes industry to invest for efficiency and speed. Producing and launching satellites on regular, frequent intervals (also known as launch-on-schedule) is critical in the CPA strategy. Increased spacecraft production diminishes dependence on individual satellite reliability. Constellations are more robust against threats and single-point failures. Shorter design lives enable simpler designs with less redundancy, reducing per-unit costs and partially offsetting the increased costs from production and launch quantities. Aerospace studies show that approximately 90% of satellites meet or exceed their design life, even for higher risk, shorter life missions, so over time this approach will also create reserve capacity on orbit to hedge against anticipated wartime attrition.[4]
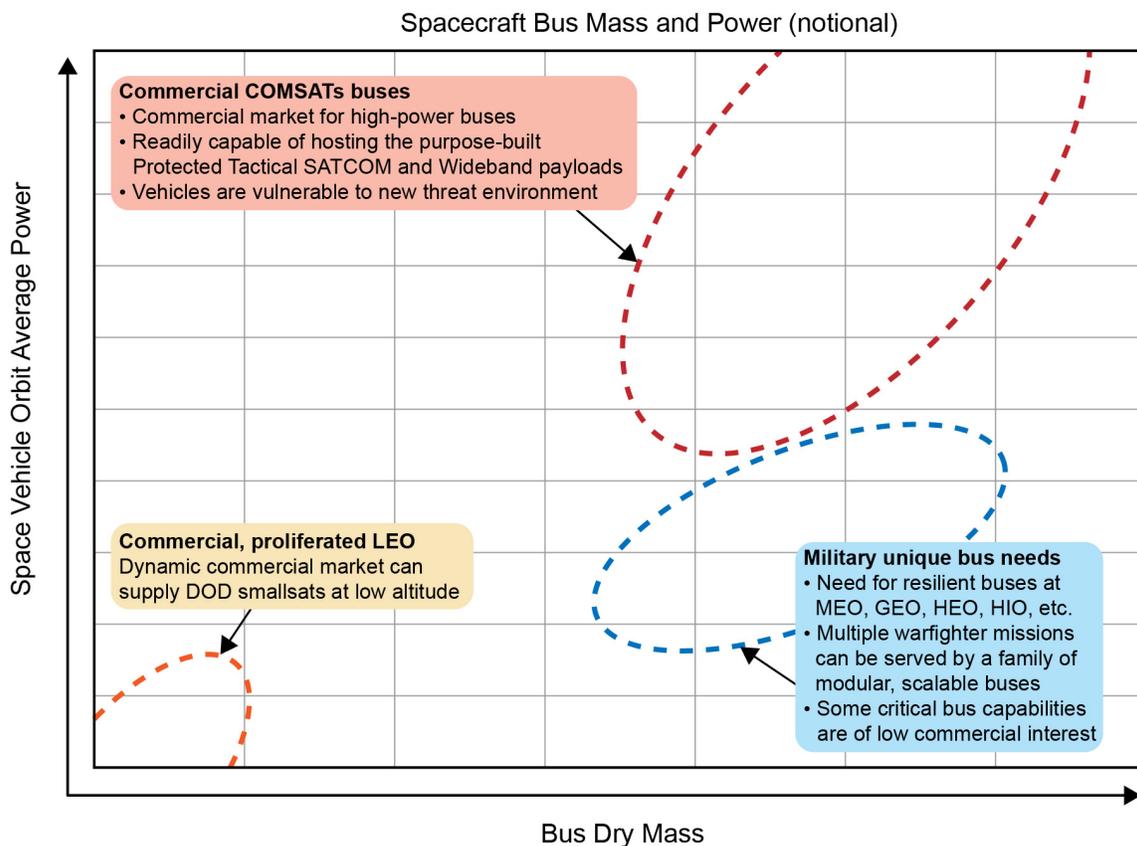
Adopt Competitive Modularity to Motivate Industry and Innovation. CPA also applies a different acquisition strategy, focusing on the acquisition of modular elements rather than buying whole satellites or systems. In this approach, the U.S. government contracts with multiple providers for satellite buses and peripherals in support of multiple programs. Modular, nonproprietary interfaces, defined in consultation with industry but controlled by the government with FFRDC support, will allow rapid integration of these elements while enabling each element to develop at an appropriate pace, as the threat dictates. Where appropriate, the government will contract for multiple payload providers as well. To encourage innovation, competition, and schedule confidence, multiple parallel contracts can be established where economically viable, with each delivering a portion of the needed units. This allows major components to be competed throughout the program's life, giving the industrial base multiple opportunities to participate. A key first step will be the development of a modular bus and its incorporation in future programs.

Allowing commercial proprietary technology into the CPA ecosystem is critical because it motivates the commercial sector to introduce new innovations into the space system. Our recent discussions with industry indicate support of the modular approach, though industry partners warn that standardization below the level of bus or payload interfaces is best handled by contractors to allow maintenance of proprietary technology and incentives. The government and industry must work together to ensure that proprietary technology maintains interoperability and meets performance and reliability requirements for the space enterprise. Such technology must also be reasonable and nondiscriminatory to avoid innovation "lock out" of competing potential technologies.

A regular cadence enables manufacturers to keep their supply chains healthy and their workforce trained, and it reduces time from decision to delivery. Increased volume improves engineering and manufacturing efficiency across multiple design variants, reduces cost and schedule risk during production, and possibly reduces unit cost. The benefits of CPA can also extend to mission partners, other U.S. government agencies, and allied nations that share the same contractors, production lines, and designs. Overall, the anticipated result is more capability buying power per dollar. While it will take increased investment, increased frequency and number of space vehicles provide more opportunities to innovate, respond to the threat, and address warfighter needs.

CPA offers important opportunities but also requires some challenging changes to the status quo. It will require DOD and congressional support for increased budgets and adjustment of expectations. The transition of acquisitions to the CPA strategy will also disrupt some existing acquisition plans. As change within the space enterprise is enabled by CPA, proper alignment of all other architectural elements requires acceleration of critical components, such as user equipment and ground systems. Integration of modules onto space vehicles requires increased government responsibility across the interfaces, which will require careful selection and training of the government workforce. This can be accomplished by a combination of government workforce, integration contractors, and FFRDC expertise. Despite these challenges and the practical limits on instantaneous implementation, the CPA strategy positions the industrial base to build the architectures of the future.

Spacecraft Bus Mass and Power (notional)

Commercial COMSATs buses
• Commercial market for high-power buses
• Readily capable of hosting the purpose-built Protected Tactical SATCOM and Wideband payloads
• Vehicles are vulnerable to new threat environment

Commercial, proliferated LEO
Dynamic commercial market can supply DOD smallsats at low altitude

Military unique bus needs
• Need for resilient buses at MEO, GEO, HEO, HIO, etc.
• Multiple warfighter missions can be served by a family of modular, scalable buses
• Some critical bus capabilities are of low commercial interest

Space Vehicle Orbit Average Power (vertical axis)

Bus Dry Mass (horizontal axis)

Leveraging defense and commercial capabilities across orbits in a common architecture enhances agility and resilience.

Enterprise Alignment and Governance

To increase the pace of change in defense space, Project Thor recognized that the space enterprise needs to be aligned as an integrated whole across multiple segments, rather than as stovepiped programs. These segments include space, ground, transmit/receive layer, user equipment, launch, and cyber.

Within the space segment, use of quick-turn, high-volume, and independent production lines for spacecraft platforms, payloads, and peripherals allows each to proceed at a cadence appropriate for the technologies involved, the evolution of warfighter needs, and the rapidly changing threat landscape.

The ground segment, including battle management, command and control (BMC2), must be fielded at a more rapid pace to remain in synchronization with the enterprise and stay ahead of the threat. This can be accomplished using commercially based approaches, fielding incremental solutions of increasing capability using DevOps strategies, and potentially adopting commercial systems outright where feasible.

The transmit/receive layer requires substantial enhancement to achieve the required capacity, diversity, and responsiveness. To allow for rapid response and coordinated action, the United States must field a ubiquitous, survivable communications layer for near-realtime C2 and for limited mission data dissemination. This can be achieved via upgrades to the Air Force Satellite Control Network (AFSCN), other upgrades and architectural additions, and by use of commercial and allied gateways.

User equipment for communications must be fundamentally re-architected to keep pace with a changing on-orbit baseline. This requires the phase-out and replacement of significant portions of the installed equipment base to enable in-situ upgrades via software upload and line-replaceable modular elements.

New launch service procurement processes currently being implemented address many of the challenges associated with fielding a cost-effective, responsive, launch-on-schedule paradigm. However, additional steps may be required after contract award to ensure standardized integration interfaces facilitate a flexible and rapid multi-mission launch-manifesting capability. This requires deliberate action to be broadly compatible by both spacecraft and launch vehicle programs.

Finally, cybersecurity must be designed into the entire enterprise, not merely overlaid as has been the case with legacy systems. Defense-in-depth strategies, employing nearly continuous penetration testing, are necessary to protect against the pervasive threat. The development must also consider concepts of operation where regular component and system failures are anticipated and exercised.

Advance the Architecture Through Prototyping and Partnerships

To achieve continual advancements in technology and capability, Project Thor recommends greater reliance on prototyping and partnerships. With the desire for continual and frequent upgrades and with the continual evolution of the threat, developers in collaboration with operators must adopt a tailored DevOps culture to rapidly deliver greater resilience. Prototyping allows for experimentation and demonstration prior to installation across constellations, which allows technology to advance when it is ready, rather than when it is time to refresh a constellation. Acquisition practices such as other transaction authorities can allow for faster development of that technology than traditional Federal Acquisition Regulation (FAR)-based approaches.

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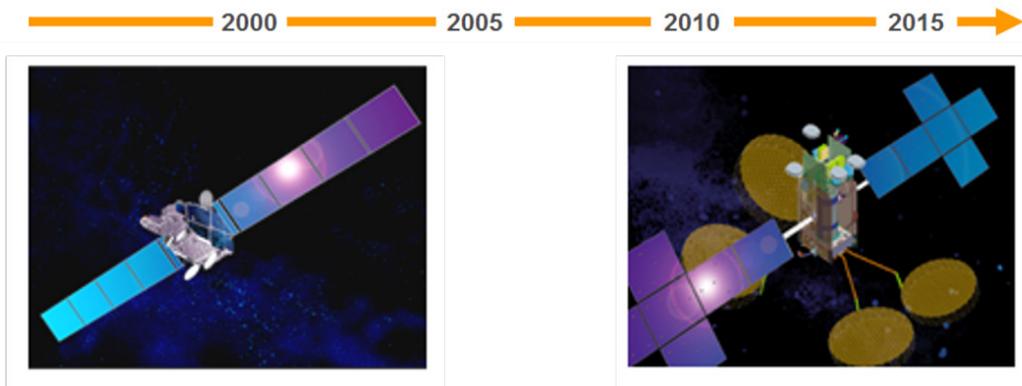
Strong inter-agency, international, and commercial partnerships significantly increase opportunities, economies of scale, and innovation. Properly architected partnerships allow the enterprise to decrease time for technology insertion while increasing resilience at minimal risk. Opportunities include partnering with international allies for hosted payloads and shared missions, sharing technologies between national laboratories and government agencies, and partnering with transmit/receive ground stations for satellite communications. New commercial ventures, such as the planned low Earth orbit communication constellations, offer the potential for directly procuring services and for new architectural

strategies based on large numbers of hosted payloads and employment of their communication infrastructure. Aerospace is partnering with companies to advance their technology and enable them to get their assets on orbit faster; e.g., helping them navigate through autonomous flight safety system certification, tailored safety requirements, and payload integration standards.

The value proposition must be mutually beneficial between the government and commercial industry. This requires government to think like commercial industry, especially about factors that drive corporate financial health. Furthermore, aspects of the policy and regulatory environment such as the International Traffic in Arms Regulations (ITAR), commercial remote sensing licensing restrictions, and traditional applications of the FAR limit potentially beneficial partnerships.

Streamline Decisionmaking

Project Thor identified speed and agility in decisionmaking as essential elements of fast acquisitions. The current space acquisition system lacks agility in requirements, resources, and acquisition decisions. The requirements process often results in over-specificity that stifles innovation and the processes for validation/update are often measured in years. During execution, program leaders make undesirable cost and schedule

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Significant increases in commercial satellite power and capacity illustrate the value of steady, incremental innovation.

trades in attempts to satisfy warfighter requirements, which are perceived as inflexible because it would take too long to update them to broaden the tradespace.

At the time Aerospace made its recommendations to the Deputy Secretary of Defense, Project Thor identified the opportunity to accelerate space decisionmaking through delegation of detailed implementation of requirements, resources, and acquisition decisions to a single lower-level authority that was more tightly connected to operational risks, such as AFSPC/CC in the Joint Force Space Component Commander role. Project Thor recommended streamlining Joint Requirements Oversight Council (JROC) requirements validation using service level agreements to capture warfighter essential requirements, which would expand tradespace during development. Project Thor also recommended that DOD and Congress simplify the Major Force Program 12 (MFP-12) account structure to improve resource flexibility and that the service acquisition executive delegate key oversight between major milestone decisions to improve decision speed. Similar to some Intelligence Community management approaches, these recommended changes target increased speed and relevance of the requirements, resource, and acquisition decisions. Since Aerospace offered its recommendations, the Space Development Agency has been created, U.S. Space Command has been activated, and Congress is considering the administration's proposal to create a U.S. Space Force.

Conclusion

Project Thor showed that DOD can implement a space portfolio plan that is affordable, lethal, resilient, and capable of outpacing the threat per the National Defense Strategy. To achieve this, Project Thor recommended that the Department of Defense:

- Endorse the CPA approach and transition plan to build a strong, stable industrial base.

- Require phased upgrades of user equipment for extensibility and future capability.

- Require use of DevOps practices across the space enterprise.

- Implement architectural advancements for lethality and enhanced resilience.

- Enhance opportunities and remove barriers to partnerships with industry and allies.

- Delegate to the lowest possible level and move toward a single authority accountable for space operations, acquisition, resources, and requirements.

- Request a plan to change the current requirements process to focus on warfighter essential requirements.

- Simplify MFP-12 account structure and request a single color of money to facilitate more rapid development and fielding of capability.

This paper provides an overview of the recommendations Project Thor offered in 2018. Additional papers in the forthcoming "Outpacing the Threat" series will further explore and update these findings. Aerospace remains committed to applying its technical depth and domain breadth to help lead the transformation into this new paradigm, applying unique tools and deep expertise to the evaluation of the space enterprise against an evolving threat—both today and into the future.

Aerospace is itself piloting new processes, prototyping advanced technology, and working closely with government and industry to establish new and innovative approaches to speed production while also working to integrate and empower efforts across our government customers adapt to and lead in the contested space domain.

References

[1] White House, "National Security Strategy of the United States of America," December 2017.

[2] National Air and Space Intelligence Center (NASIC); "Competing in Space"; December 2018.

[3] In its "Ten Commandments of Software," (2018), the Defense Innovation Board defines DevOps as "the integration of software development and software operations, along with the tools and culture that support rapid prototyping and deployment, early engagement with the end user, and automation and monitoring of software." This approach also can be applied to the incremental and iterative development and deployment of space systems.

[4] N. Brown, et. al, Spacecraft Lifetime Study, TOR-2010(8582)-3. *Space Development and Test Wing Aerospace Mission Assurance Processes for Small Satellite Programs*, L. Berenberg, Aerospace TOR-2010(1531)-1.