MONOGRAPH

Future Military Space

From Procurement to the Tactical Fight

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General Issue

Current space acquisition, vehicle processing, and operations are too cumbersome and expensive to meet future emerging war fighter needs. The cost associated with placing assets into orbit has been the greatest problem to the United States (US) fully recognizing its potential in space. With the emergence of commercially available reusable launch vehicles, the military must consider the possibility of building an internal space lift capability as a core competency. Also, the military must develop and integrate new capabilities from space that will enable strategic capabilities, down to tactical war fighter implementation.

Launch costs currently represent a third to half the cost of fielding a space system.[1] Additionally, the current bureaucratic model for the Department of Defense (DOD) space architecture does not enable a rapid approach to space for the US to gain space supremacy and prevent further loss of space superiority. Key hurdles must be removed and new methods utilized to accomplish this goal. This process requires a change in acquisitions, operations, doctrine, and organizational structure.

Requirements for space systems are developed on a five to ten-year time horizon, which does not allow the development of systems that can be utilized on demand in an area of responsibility (AOR). New systems must be developed that can be deployed on demand to AORs and utilized by ground, sea, air, cyber, and space forces.

Problem Statement

Space access and capabilities are rapidly evolving, and the US military must posture itself to utilize these capabilities to protect and defend US national security.

Research Objectives

This research seeks an end-to-end approach for developing new space capabilities, fielding the capability on demand, and utilizing that capability across all domains (land, sea, air, cyber, and space) of military power. To meet the objective of a new end-to-end approach for space, a new methodology will be developed in five parts. The first part is to develop and analyze the current state of acquisitions, launch, and payload operations, and how space capabilities are utilized today. This part will set the baseline from which to build a future end-to-end approach for future space mission sets.

The second objective of this research will utilize various approaches to develop a desired future state of space. This objective will include developing a new end-to-end architectural view that incorporates requirements development, acquisitions, launch operations, payload command and control, and tactical war fighter implementation of space capabilities.

The third objective will utilize this new architecture and contrast it against the current conditions of space to find gaps in military capabilities, processes, and doctrine. This objective includes looking at how space supports terrestrial domains and how space will be required to defend itself and project offensive capabilities in the future.

The fourth and final objective will recommend new processes, organizations, and capabilities. These processes, organizations, and capabilities will be in the form of recommended technological investment, changes to processes, changes to organizations, and updates to doctrine and tactical war-fighting approaches.

Methodology

The primary methodology for this research is to research best practice systems and processes and overlay them into a new approach for rapid space acquisition, fielding, and operations. Figure 1 provides an outline of how the research will flow into the future desired end state.

The top row of figure 1 lays out the building blocks for this research that include: defining user and system requirements process; acquisition approaches; satellite processing, launch, and checkout; and on-orbit operations and end-user interaction. The literature review in chapter 2 looks at analogous systems and processes that apply to the research building blocks. The literature review focuses on best and worse practices, a technology that has been demonstrated, and planned future technology. From the literature review, the desired end state is derived in chapter 3. Finally, utilizing the current state and the desired state, this research

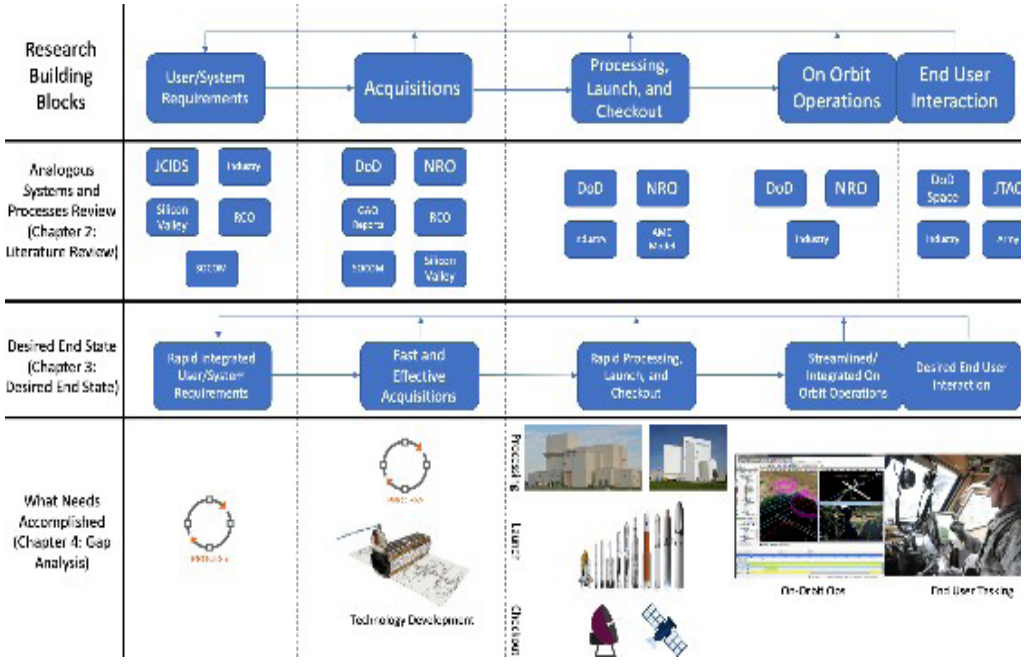


Figure 1. Research methodology road map

discusses the gaps in chapter 4 that need to be filled both in processing, technologies, and war-fighter integration that need to be filled.

Research Focus

This research will focus on developing and generating a new end-to-end approach for space capability implementation. In general, this research will:

- Define in general terms the current state of how space approaches end-to-end capability.
- Develop a new architecture for end-to-end capability implementation.
- Analyze future space technologies and capabilities for future war fighters in all domains of operation.
- Develop a concept of operations (CONOPS) for the new end-to-end space approach.
- Analyze technological, process, and doctrine gaps that must be addressed to enable this new architecture and CONOPS.

Investigative Questions

To meet the research objectives, the following questions will be answered to help build a new end-to-end approach for space operations.

- What is the current landscape for end-to-end space operations?
- What should the future architecture for an end-to-end approach for space operations be?
- What gaps will the US military need to fill to enable this new architecture?
- How should the US military organize to enable this new architecture?
- What technology should the US military invest in to enable this new architecture?
- What new military doctrine should be created to allow the implementation of this new architecture and CONOPS?

Assumptions and Limitations

This research paper is written in the context of developing a new end-to-end architecture for space. The following forms the key assumptions and limitations of this research:

- A time horizon of 2030 for this new architecture to be in place.
- The cost will not be factored into this effort.
- This article will assume that capabilities discussed (launch, satellite and ground processing) will mature at a rate that will enable this future architecture.

Implications

This research defines future end-to-end architecture for space capabilities. It has the potential to improve the responsiveness of space to better support terrestrial users, as well as provide a means for space to defend space, and project offensive capabilities.

Document Overview

This thesis is organized into six chapters. Chapter 1 provides a general overview of the research and problem set. Chapter 2 provides a foundation of literature reviewed and a summary of that literature, setting the baseline for the current state of space.

Chapter 3 provides a desired end state architecture for a future end-to-end space capability. Chapter 4 will describe gaps in technology, processes, and doctrine that must be overcome to enable this new end state. Chapter 5 develops key recommendations to include recommended requirements, changes to organizations, new processes, and key investment areas. Finally, Chapter 6 provides conclusions and areas for further research.

Background and Literature Review

Chapter Overview

The literature review covers the topics that are the foundation for this research. Each topic provides key insight into a specific area essential to the development of this research. The first key area will be a review of the state of space acquisitions. Next will be a review of space vehicle processing and launch operations. The third area reviewed is end-to-end on-orbit satellite operations, which includes a discussion on Kestrel Eye.

Kestrel Eye is an Army program that demonstrated end-to-end imagery collection to real-time downlinking of those images to troops on the ground. Following this, a review of potential analogues models that could be used in the future for space operations will be revised. Next is a general review of how government satellites are tasked for use.

Finally, a comprehensive review of current space technology and technology that is likely to be available by 2030.

Space Requirements Development

Joint Capabilities Integration and Development System (JCIDS)

The JCIDS process in the formal DOD process to define requirements for acquisition programs. JCIDS' main purpose is to enable the JROC to execute its statutory duties to access joint military capabilities and identify, approve, and prioritize gaps in these capabilities.[2] The JCIDS process starts with a robust assessment of missions, functions, and tasks in the context of threat and environment to identify and quantify capability requirements.[3] These capability requirements are service, solution, and cost-agnostic. Therefore, these requirements are thought of as "what needs to be done and to what level" without taking into account cost or schedule. The process then further flows by assessing these requirements against current capabilities across the force. After a capability gap is identified an Analysis of Alternatives (AoA) is performed to assess options for filling the gap. The AoA is then utilized to make decisions on the best path forward for a capability solution, including capability requirements, measures of performance, and required resourcing to develop the proposed capability solution.[4]JCIDS is a very deliberate process that was developed to integrate the requirements process of all four branches of the military. The intent was this process would be informed by

combatant commanders to procure capabilities required to fight ongoing contingency operations, anticipated contingency operations, and further out operations.

Figure 2 provides a depiction from JCIDS on how these needs correlate to timelines and what documents are created.

JCIDS Lanes	Operational Timeline	JCIDS Documents	JCIDS Staffing Timeline
Ongoing Contingency Lane	Urgent Need (<2 Years)	JUON	15 days
Anticipated Contingency Lane	Emergent Need (<2 Years)	JEON	31 days
Deliberate Lane	Future Need (>2 Years)	ICD, CDD	97 days, 103 days

Figure 2. JCIDS process lanes
Source: JCS, JCIDS, B-A-2

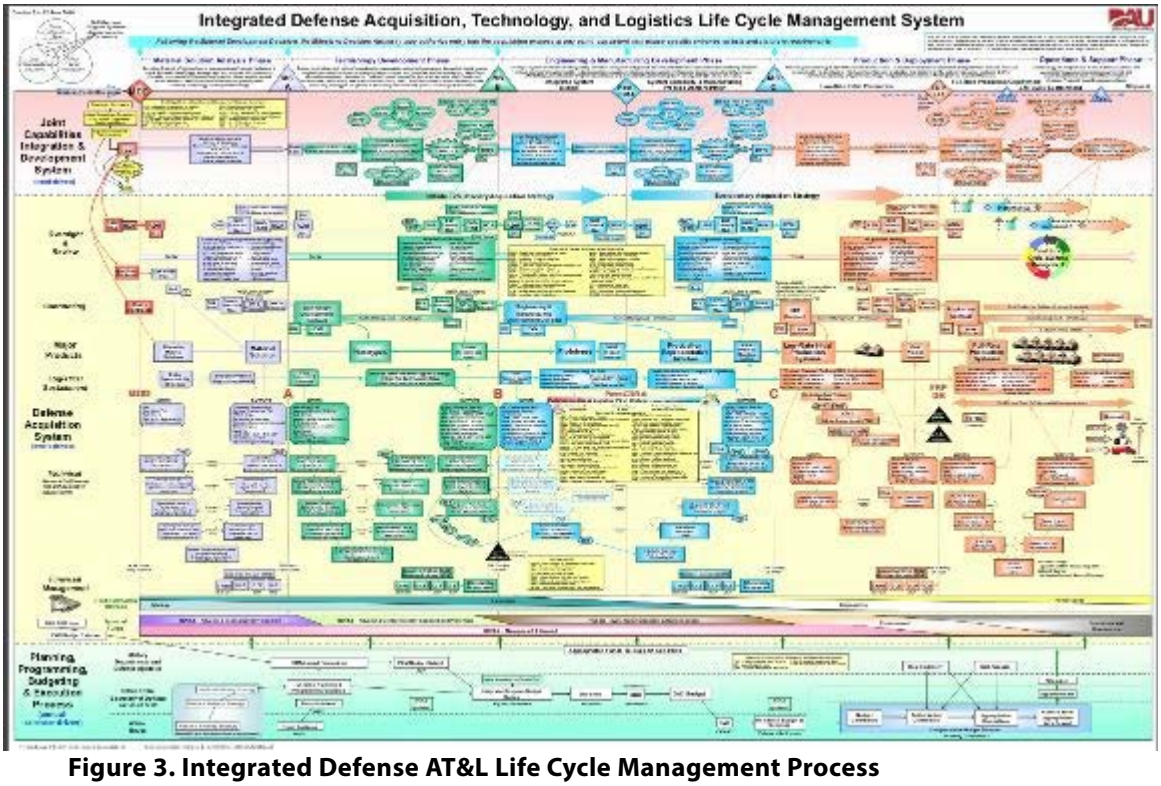


Figure 3. Integrated Defense AT&L Life Cycle Management Process

The overall JCIDS process flows in parallel with the standard DOD acquisition process. Figure 3 shows how the two processes flow and are interconnected. On the top is JCIDS, in the middle is the Defense Acquisition System (DAS) and the bottom of the chart depicts the Planning, Programming, Budgeting and Execution process.

From figure 3, it is easy to see how complex the process for requirements, acquisition, and budgeting is within the DOD. The complexity of JCIDS and DAS typically leads to long acquisition timelines for large programs. The benefits are that all services have a chance to provide input into the requirements to these systems.

Air Force Rapid Capability Office (RCO)

The Air Force RCO was formed in 2003 to expedite important, often classified programs while keeping them on budget.[5] The RCO has a streamlined flat structure that is seen as critical to its success, as is the office's ability to keep requirements stable and work alongside operators.[6] This organization reports directly to a board of directors with members that include the Secretary of the Air Force, Air Force chief of staff, and the assistant secretary of the Air Force for acquisition. The office directly responds to Combat Air Force and combatant command requirements.[7]

Commercial Industry

Commercial industry approaches requirements different than a typical government satellite acquisition. After the JCIDS process, an initial capability document (ICD) is developed which contain the high-level production requirements. This document is then further refined into multiple system level specific documents and further refined into subsystem specification documents in a Systems Program Office. On the other hand, the commercial company procuring a system typically keeps requirements at a higher level and allows the satellite vendor to distill the requirements to more effectively make trades.[8] These trades include balance cost, schedule, and satellite performance more effectively against a risk tolerance level. At the same time, the commercial company procuring the satellite loses insight into the program progress and mission assurance associated with the build. Additionally, commercial companies rely on mature technologies to be inserted on satellites, whereas the DOD will take the additional risk for less mature capabilities that potentially will bring greater user capability.

One example of commercial vendor procurement is IntelSat. IntelSat succinctly notes this and states:

> Intelsat must assess and predict future customer and market demands and pursue rapid capability evolution in our satellite systems and networks to meet those demands and stay ahead of our competitors. We enable rapid system development through streamlined organizations and processes. We also rely on mature technologies, when possible, to reduce risks and to increase the speed to market. When necessary, we use market leverage to drive technology innovation through our manufacturing base, in order to bring transformational capabilities to bear against new market opportunities.[9]

This example from IntelSat shows the flexibility of commercial companies to procure satellites fast to meet customer requirements. To do this IntelSat relies on procuring proven technologies to reduce risk to the program. As discussed before the DOD typically takes on greater developmental risk versus commercial companies to bring on new capabilities for the war fighter. Each approach has pros and cons that must be weighed during an acquisition program.

Space Acquisitions

General

Over the past 20 years, multiple reports, publications, and recommendations have been generated related to the issues within space acquisitions. Over this course of time, a few major organizational and process changes occurred in space acquisitions.

The first change came on 1 October 2001 when space acquisition authority was transferred from Air Force Materiel Command to Air Force Space Command. The goal was to provide "cradle-to-grave" management from concept through development, acquisition, sustainment, and final disposal of space systems."[10] The next major change was the guidance for DOD Space Systems Acquisitions, which was implemented on 27 December 2004. The goal of the National Security Space (NSS) acquisition process was to emphasize the decision needs for "high-tech" small quantity NSS programs, versus the DOD 5000 model, which focused on making the best large quantity production decision.[11] In 2009, the decision was made to move space acquisitions back under the standard DOD 5000 instruction for all acquisition's programs.

A RAND Study from 2015 listed the key factors contributing to space acquisition difficulties as space programs implementing a high-risk acquisition approach contributing to difficulties and inefficiencies in space acquisition programs.[12]

These reports continue to be generated, and the DOD recently stood up two organizations to address rapidly developing future space capability. The first was

directed by Congress and is the 2018 National Defense Authorization Act (NDAA). The NDAA directed the DOD to develop a Space Rapid Capabilities Office (RCO). In response, the Air Force is transitioning the Operationally Responsive Space Office into a new Space RCO. In testimony to Congress in 2018, General Raymond (AFSPC/CC) discussed the new Space RCO by stating,

> The SRCO must have the same rapid acquisition capabilities as the existing Air Force RCO. We are working hard on an implementation plan that will expand the former ORS office portfolio to include highly-classified, hand-picked, game-changing, space programs, that will move at an accelerated pace while not losing the demonstration, experimentation, warfighter-focus and Joint Capabilities Integration and Development System (JCIDS) exemptions covered in ORS statutory guidance. This will not be just a name change, AFSPC will look to broaden the scope and scale of this office to deliver real results.[13]

The second organization that was formally designated by the DOD in April 2019 is the Space Development Agency (SDA). In a presentation to the Space Symposium, the new director of SDA, Fred Kennedy, briefed that the new organization will: "Do business in a way that is radically different from the way the military currently develops and acquires space systems."[14] Director Kennedy also believes that disruption is long overdue, and will be drafting an architecture that leverages commercial capabilities coming online to churn out hundreds and thousands of satellites such as OneWeb and SpaceX that will begin deployment in low-Earth orbit (LEO).[15] SDA has plans to leverage these commercial companies to develop an accelerated acquisition cycle that will develop hundreds of satellites for DOD use in a streamlined manner to meet new emerging operational needs.

Finally, the main acquisition of the DOD space enterprise remains the Space and Missile Systems Center (SMC). The SMC has long been criticized due to the slowness and cost overruns associated with acquisitions of major DOD satellite systems, including GPS, the Space-Based Infrared System (SBIRS), Advanced Extremely High Frequency (AEHF), and other satellite programs. In response, the SMC begins an overhaul of the organization in 2017 under the leadership of Lt Gen John F. Thompson. This overhaul is known as SMC 2.0. Recent reports have noted that SMC 2.0 will work to acquire future capabilities in a more streamlined manner. The plan is to turn vertical stovepipe focused mission areas into horizontal "enterprise" mission areas.[16] As reported by *SpaceNews*, these new four horizontal organizations will be a Development Corps (for innovation and prototyping), a Production Corps (for system procurement), an Enterprise Corps (for product support and launch services), and finally an Atlas Corps (for workforce talent and culture management.)[17]

Constellation Design Overview

Satellites come in various sizes, depending on mission requirements and mission design. For example, satellites placed in medium-Earth orbit (MEO) at 20,200 kilometers (km) provide an orbital period of 12 hours. This provides the benefit of a longer dwell over a point on the ground when compared to LEO systems. But this longer dwell comes at the expense of larger aperture requirements for transmitting or receiving signals. Also, MEO satellites at 20,200 km operate in the Van Allen Belt, which requires additional shielding to protect key components, thus adding weight to the vehicle. This example showcases various trades that need to occur between mission requirements, mission design, and size, weight, and power (SWaP) of the satellite. Figure 4 provides a depiction of the orbital period versus satellite altitude.

Satellites in LEO operate with an orbital period of approximately two hours or less. This period means a satellite will orbit the same spot on the earth 12 or more times per day. In contrast, a satellite operating in GEO dwells on a single location for the life of the satellite by having an orbital period equal to the rotation of the earth. (Note: Geosynchronous satellites can have various inclinations and will appear to make a figure eight pattern over a location but still has constant dwell.)

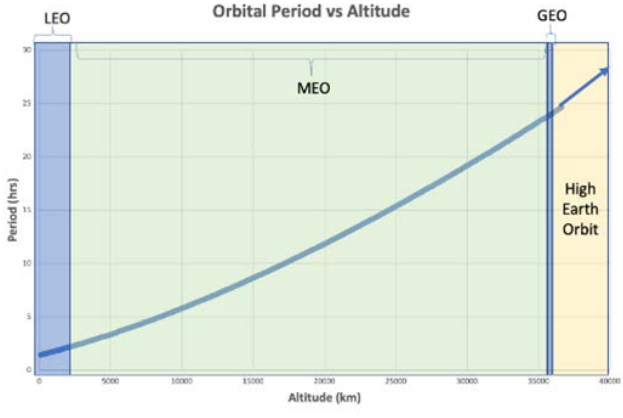


Figure 4. Orbital Period vs Altitude (km) (See Appendix A for derivation)

Additionally, when considering mission requirements and design for a constellation, desired intended effects must be taken into consideration. For instance, if the desired effect is to provide constant imagery to a ground user, the trade between resolution required, size of the satellite, and the required orbit must be considered. This trade is where requirements become of vital importance to the design of a system. For example, if the requirement is to provide a signal strength

on the ground of - 125 dBm, it is possible to analyze how this might impact a satellite constellation design. Table 1 provides the required effective isotropic radiated power (EIRP) from a satellite at various orbits (assumes signal of 2000 MHz and free space propagation loss modeling). Therefore, a satellite in LEO would need to produce an EIRP of 9 watts, in MEO, 900 watts, and in GEO, 2,900 watts. Logically one would want to choose the LEO satellite the requires far less power, but if a secondary requirement exists to dwell over a target for long periods of time, LEO may not be a feasible choice.

Table 1. EIRP for desired signal strength on ground (See Appendix B)

Satellite Altitdte (km)	EIRP at Satellite to Achieve -125 dBm on Ground (W)
2000	9
20000	900
36000	2900

From the discussion above, it is easy to see many trades must occur when designing a constellation of satellites to perform the desired task. SWaP and orbit determination are key factors that help determine how a mission is designed. Other factors that are considered include design life, launch vehicle selection, on-orbit maneuver requirements, point accuracy, and more.

The above analysis shows that solution sets have multiple variables when it comes to satellite constellation design. Therefore, it is not as simple as dictating solutions to constellation designs. Careful trades between cost, schedule, performance, risk, and mission design should occur to ensure the correct satellite constellation is developed to meet end-user requirements. Therefore, well-defined requirements up-front are essential in enabling a program to best meet end-user needs.

Launch Vehicles

The launch market is rapidly evolving. In the past, one of the greatest expenses in placing a satellite in orbit was launch. Today, the commercialization of launch is creating new competition that is reducing the cost of placing payloads on orbit. In the past launch, vehicles were full expendable, which means the launch vehicle was lost after every mission. This loss is extremely costly and requires the constant production of new launch vehicles. The Fast Space Report discusses leveraging Ultra Low-Cost Access to Space (ULCATS), as a means to bolster strategic stability is space.[18] The report notes the benefits of rocket reusability and increasing launch rate to reduce the cost of launch from more than $7000 per kilogram to

less than $1000 per kilogram (fig. 5).[19] Reductions in the cost of launch of this magnitude are significant and will bring new space vehicle companies and technology into the space market, creating new opportunities for satellite companies.

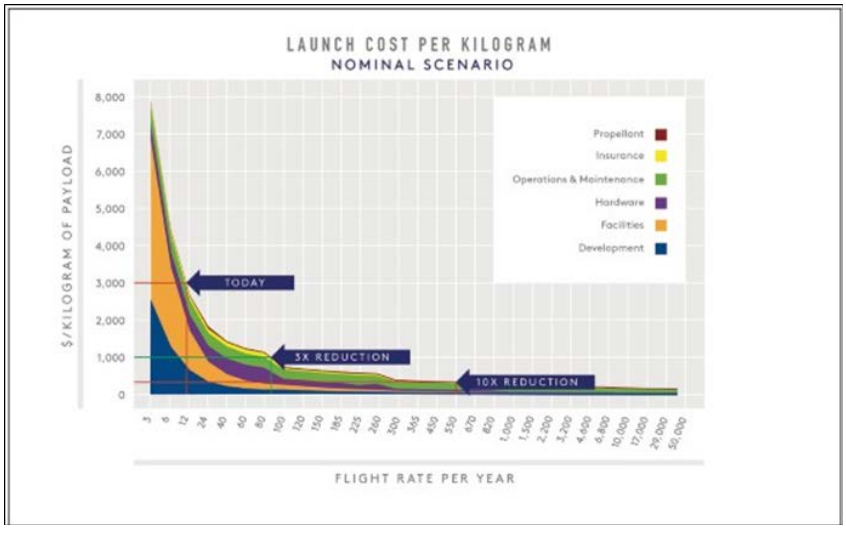


Figure 5. Launch cost per kilogram

In the case of spacelift, the US currently has the capability to launch 14,500 lbs of mass directly into a geostationary orbit with the Delta IV Heavy launch vehicle. A significant issue with this capability is cost, which by some accounts is estimated to be around $400M (~$60,000 per kilogram to directly injected GEO orbit).[20] The result is the cost of "heavy" launch is nearly unaffordable and deprives budgets from focusing on actual space capability. Therefore, the current gap in technology is not due entirely to technology not being able to meet requirements; but rather, technologies costing too much to reasonably meet requirements.

Based on the Fast acquisition report, company plans from SpaceX, Blue Origin, and ULA are continuing to seed the commercial market to develop new and innovate spacelift capabilities. Currently, SpaceX plans to develop a rocket known as the Big Falcon Rocket capable of launching 150,000 kilograms into LEO in a 9 meter fairing.[21] Blue Origin plans to develop the capability to lift almost 45,000 kilograms into LEO in a 7 meter fairing.[22] The SMC recently awarded other transaction authority (OTAs) to ULA, Blue Origin, and Northrup Grumman to support these development activities in December 2018.[23]

The launch vehicle is also moving toward an "aircraft" model, where launch vehicles are launched, landed, refueled, and reused. This capability has been demonstrated by both Blue Origin and SpaceX who have both successfully landed launch vehicles. The FAST Space study notes that the reuse of launch vehicles has the potential to increase access to space, reduce the cost of launch significantly, and allow rapid deployment of systems.[24]

Timeline for Developing and Launching Government Satellites

The perception is that it takes almost 10 years to develop and launch a government satellite system. This perception is due in part to the government acquisition process, which includes a lengthy pre-Milestone A and B phase to develop and mature the concept and requirements, as well as achieve funding and advocacy for a new system.[25] Research shows that it takes roughly seven and a half years to develop and launch a first article space vehicle, but that subsequent vehicles take approximately three years to assemble and launch.[26] This is comparable to the two to three-year duration for typical commercial satellite development. Figure 6 provides the typical satellite production time for commercial and DOD systems by minimum, average, and maximum time. From figure 6, we can see that satellite development time is comparable between commercial and DOD launches for non-first article vehicles.

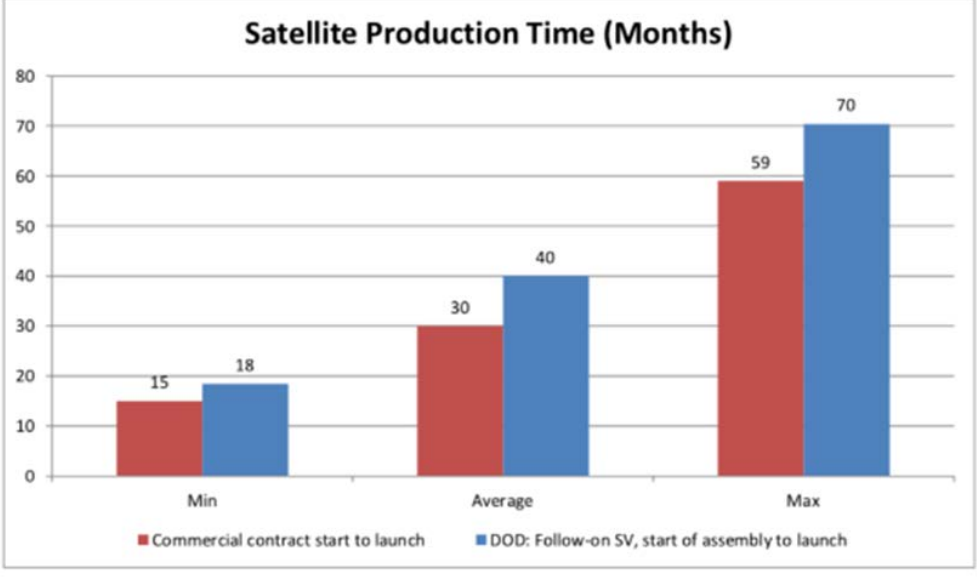


Figure 6. Satellite production time

Source: Lorrie A. Davis and Lucien Filip, "How Long Does it Take to Develop and Launch Government Satellite Systems," The Aerospace Corporation, 12 March 2015, 1.

Figure 6 may seem counterintuitive to many who believe that DOD acquisitions take far longer than commercial acquisitions, but the data shows that similar scale commercial acquisitions take only slightly longer for the DOD. Therefore, it is feasible that procuring smaller commercial satellites in the DOD would be relatively fast as is seen in the commercial industry.

Space Vehicle Processing and Launch Operations

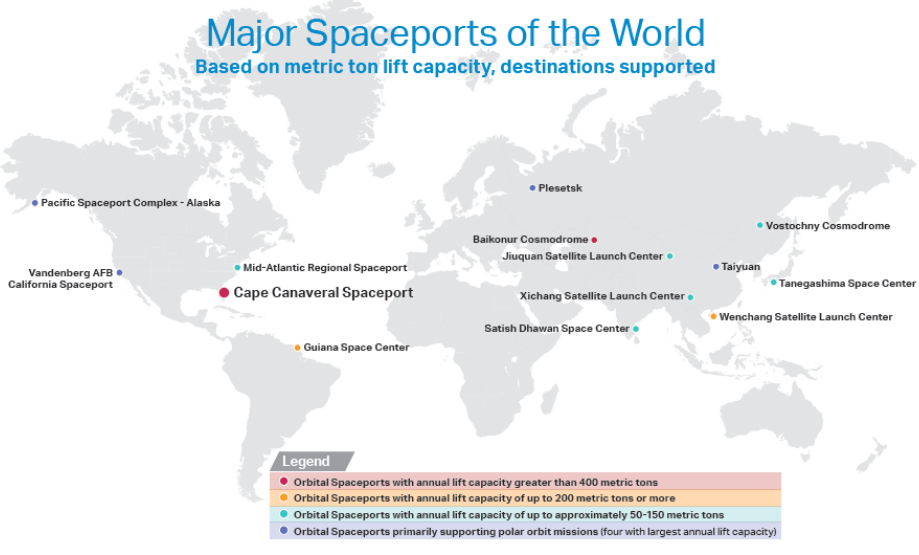
Air Mobility Command Space Concepts

Air Mobility Command's (AMC) mission is to provide rapid, global mobility, and sustainment of American's armed forces. They also provide humanitarian support around the globe. AMC utilizes a mix of intrinsic military capabilities such as the C-5, C-17, and C-130 aircraft. In addition to military capability, the US Transportation Command aircraft supports airlift requirements and transports military forces and material in times of crisis.[27]

(Source: Space Florida)

Figure 7. US spaceport locations

With the recent launch of reusable launch vehicles by commercial companies, AMC has begun to discuss the feasibility of utilizing these systems to transport military equipment and personnel.[28] The capabilities of future rockets such as the Big Falcon Rocket could potentially launch 150 metric tons in 30 minutes or less to any point on the globe and at a cost less than that of a C-5.[29] Additionally, these future reusable launch systems have the potential to place supplies on orbit, that could be rapidly deployed to AORs; as well as, rapidly transport US forces to a battlefield.



(Source: Space Florida)

Figure 8. Major world space ports

Spaceports

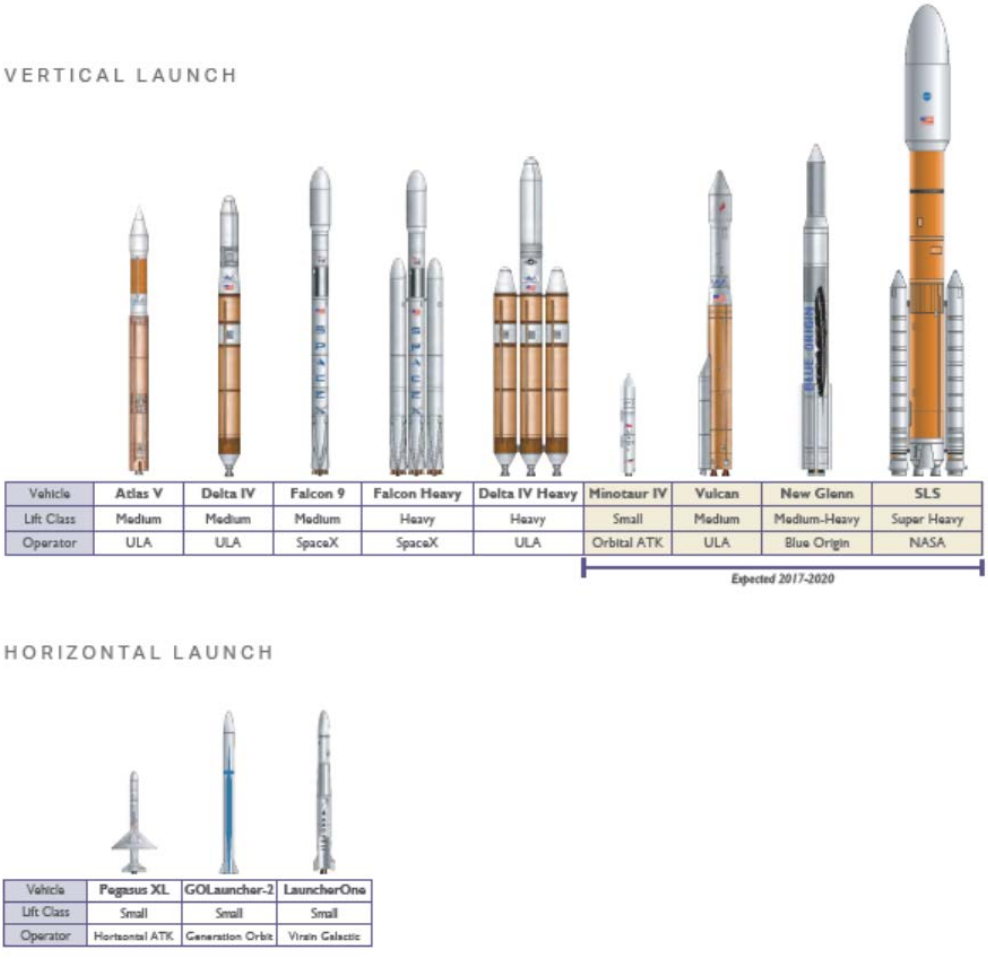
All end-user markets for space-based products and services depend on the availability of reliable and affordable access to space.[30] Additionally, they require a higher level of responsive to meet the needs of customers. Figure 7 showcases the United States' Federal Aviation Administration's current inventory of spaceports includes 19 active launch sites. Ten are licensed sites that are operated by state established entities and local airport authorities. Eight are US government operated sites, and some of these are available for commercial operations.[31]

Figure 8 shows the major spaceports of the world.[32] From a DOD standpoint, the more launch sites, the better as this provides additional access points to space outside of Vandenberg Air Force Base and Cape Canaveral Air Force Station

(AFS), Florida. Additionally, such disaggregation prevents adversaries from only having to target two locations to impact American access to space.

Launch and Space Vehicle Processing

The process of preparing both launch and satellite vehicles for their mission is crucial to mission success but is often overlooked in the overall process of getting a satellite into orbit. Payload processing facilities are an essential component of a spaceport system.[33] Payload processing may happen at facilities on-site at spaceports like Cape Canaveral AFS or a separate location.[34] Processing timelines and requirements may vary considerably depending on the type of payload, launch



(Source: Space Florida)

Figure 9. US launch vehicles

vehicle and mission. Figure 9 shows the current launch vehicles utilized within the US,[35] each of which may have unique mission requirements to add to the vehicle processing process. The significance is that current infrastructure must be in place to meet the unique mission requirements of each launch vehicle.

As seen in figure 10, there are numerous moving parts and this only accounts for launching a United Launch Alliance (ULA) Atlas-V rocket. The process will vary between launch vehicles. The illustration below demonstrates all that goes into bringing all to bear for mission success. First, the launch vehicle and satellite vehicle should be transported to the launch facility. In most cases, ULA will transport both their centaur (upper stage rocket) and its lower stage rocket body and engines by the sea in the Mariner. It will transport the vehicles from Decatur, Alabama to Cape Canaveral AFS that can take 7–10 days to travel the 2,100 miles. Next, the vehicles will be offloaded and sent to a processing facility to prepare them for launch and then brought to the vertical integration facility where it will wait to be mated with the spacecraft/satellite.

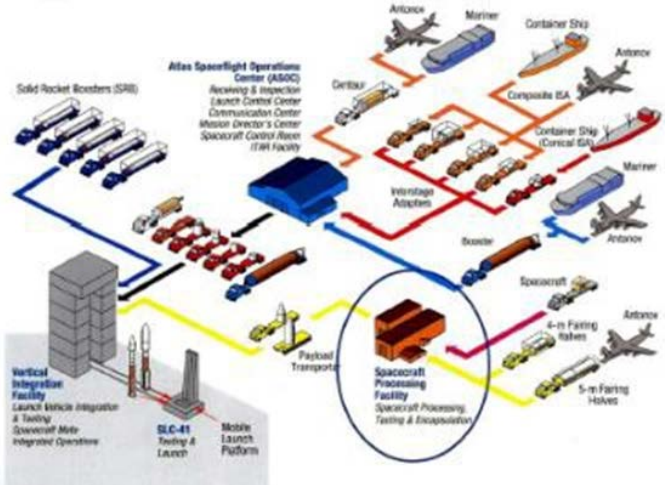


Figure 10. "Typical" mission processing flow

The spacecraft will also be shipped from its factory that can come from a variety of locations within the US and depends on where the manufacturer is located. Often the spacecraft is transported by air because there are significant limitations to traveling with spacecraft over the road, such as speed limitations to ensure spacecraft safety and environmental conditions. Additionally, over-the-road travel requires coordination with all local authorities and government bodies to ensure roadways are cleared and obstacles are removed. Once the spacecraft arrives at Cape Canaveral AFS, it will be brought into a spacecraft processing facility to

prepare it for launch. Nominally, this is a 60–90-day process. That process will encompass testing and integration of its electrical and mechanical parts, ground station compatibility testing, fueling, encapsulation, transport, and mate to the booster. It will then be transported to the launch site where it will be mated atop the launch vehicle and ready for launch.

The National Reconnaissance Office (NRO) utilizes its own designated processing facility called the Eastern Processing Facility (EPF). The EPF is a state-of-the-art processing facility and enables the NRO to process its dedicated satellites and not have to rely on contracting out to privately owned processing facility like Astrotech. The EPF is unique in the capabilities it provides. It has four processing bays, two transfer aisles, an equipment air lock (area designated for equipment to be cleaned before going into the clean rooms), and each bay is a designated clean room. The EPF is also protected against hurricanes that can generate 155 mph winds. It demonstrated the level of its hurricane protection during Hurricanes Michael and Irma in 2016 and 2017.

The typical process for satellite processing for the NRO at the EPF starts with the spacecraft arriving at the EAL where its shipping container will be cleaned. Next, the satellite will be removed from its shipping container within one of the transfer aisles and floated into its appropriate processing bay. At this point, work can begin on the satellite to prepare it for launch. Satellite checkout will include mechanical inspections, electrical testing, propellent load, and encapsulation. All these steps are significant, but the most dangerous to the vehicle and personnel is propellent loading. Most satellites utilize hydrazine as a propellent, and it is deadly to breathe in.

Therefore, the EPF provides trained personnel to conduct the fueling while in full protective equipment that resembles hazardous materials and astronaut suits. Additionally, safety personnel monitor the 8- to 12-hour fueling operation from a safe location to ensure procedures are adhered too and respond to any anomalous conditions. Upon the completion of fueling, the satellite is ready for encapsulation and transport to the launch site.

What the illustration and NRO process above does not show is how painstakingly long operations surrounding the launch and satellite vehicles can be. For example, while transporting the prepared spacecraft to the launch site to mate with the launch vehicle the allowed speed limit is 5 miles per hour and is conducted during the night, which typically lasts several hours. Additionally, removing a spacecraft from the transport aircraft it arrived on typically takes three to five hours and requires a large footprint of support personnel to get the spacecraft off the plane. Due to the fact, that moving the spacecraft off the aircraft is going an inch at a time. Additionally, fueling operations can take 8–12 hours and last for

up to three days. Air Force missions typically take one day to run through the procedure, another day to load oxidizer if necessary, and a final day to load propellant.

For the US to become more responsive in space, it must begin looking into process improvements to reduce the burdensome processes in place.

However, that is significantly easier said than done. Most spacecraft contain sensitive instruments that can be easily damaged and thus require gentle handling.

Therefore, for processes to improve, spacecraft may need to be more robust and be required to handle harsher conditions. The need for clean rooms is often due to the sensitivities of optical components. Obstruction of said components will decrease signal throughput and can scatter the signal beyond the diffraction design and thus decrease the performance of an optical satellite.[36] Additionally, on thermal control surfaces alteration of absorptance and emittance ratios can change thermal balances. Finally, contamination or foreign object debris can decrease power output on solar arrays and mechanical failure on moving parts. Therefore, the current construction of satellites requires the need for clean rooms.

Currently, Cape Canaveral AFS has the following payload processing facilities:

Armstrong Operations and Checkout (O&C) Building, Orbiter Processing Facility 1 and 2, Commercial Crew and Cargo Processing Facility, Multi-Payload Processing Facility, Orbiter Processing Facilities (OPF), Payload Hazardous Servicing Facility, Space Station Processing Facility, SpaceX Payload Encapsulation and Integration Facility, Large Processing Facility, Eastern Processing Facility (EPF), CCAFS Satellite Processing and Storage Area, and Space Life Sciences Laboratory.[37]

The O&C building was originally used for the integration of the Apollo spacecraft. In 2005, it began building renovations to receive and assemble the Orion Spacecraft.[38] The MPPF is being utilized for processing several payloads at once within a clean room environment and has also been renovated to accommodate Orion processing.[39] The OPF is home to the Boeing Starliner program, but OPF 1 and 2 have been utilized to support the processing of the Air Force's X-37B program.[40] The Payload Hazardous Servicing Facility is used for the integration of payloads with solid motors and liquid fueling. It is used for processing National Aeronautics and Space Administration (NASA) payloads.[41] The large processing facility was built in 1964 for the Air Force to assemble solid motor sections of DOD military rockets and is currently licensed to SpaceX and is used for large payload processing.[42] The EPF is a recently completed NRO facility that is utilized to prepare its satellites for launch. Finally, the Space Life Sciences Laboratory is the primary gateway for life science payloads bound for the International

Space Station, and it will enable testing and development of small payloads for launch on all Cape Canaveral-based launch vehicles.[43]

The significance in listing all these facilities out is to showcase that there are currently 12 processing facilities on Cape Canaveral AFS and not a single one is dedicated to the Air Force or the DOD. With the exception of a few select mission areas that the NRO has allowed to be processed at the EPF and the OPF, all Air Force and DOD mission process through the Astrotechs Space Operations facility. It is the only major processing company in Florida that is not located on Cape Canaveral.[44] In comparison to the EPF, it does not offer the same level of capabilities and is much more cramped as it was not designed to accommodate all DOD missions, unlike the EPF which was designed with NRO current and future mission needs in mind.

On-Orbit Satellite Operations

Spacecraft Checkout

On-orbit checkout and verification of the satellite occurs after launch and deployment of a satellite. The process for checkout is a deliberate process that takes anywhere from days to months. The checkout process and timeline are dependent on the complexity of the payload, characterization of sensors, testing of onboard systems, and exercising flight software. First of a kind satellites can take upward of six months to fully check out and characterize. Similar payloads can be checked out and verified in less a week. Continued reduction of on-orbit checkout times is a priority of both commercial and military providers; due to the fact, shorter timelines enable the payload to be placed into operations sooner, and extend the usable life of satellites.

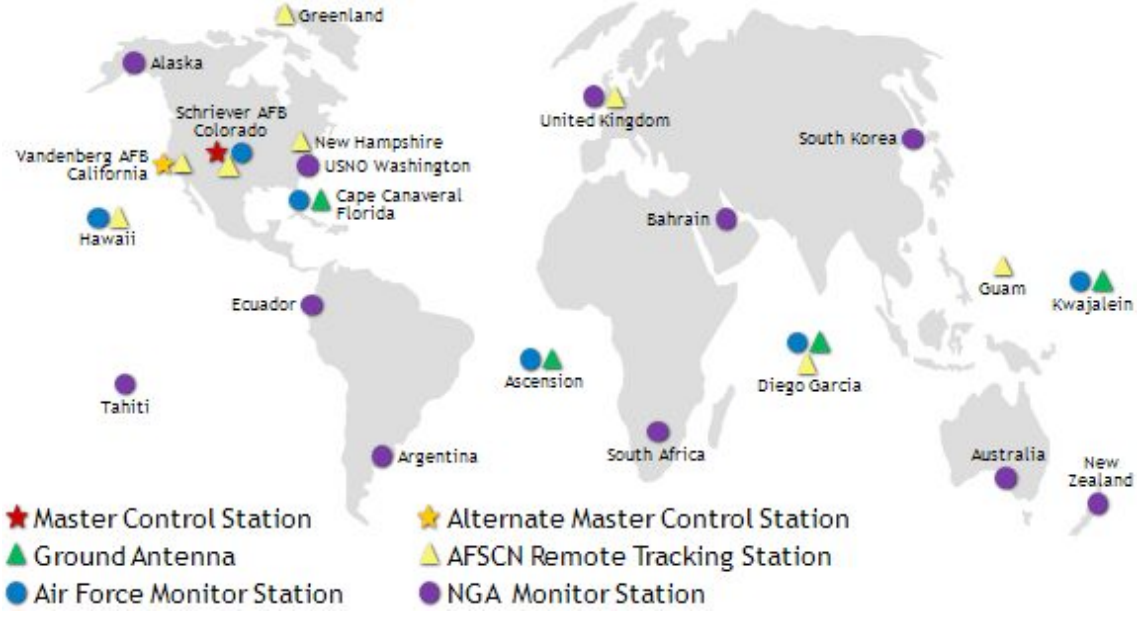
A study by the Joint Airpower Competence Center (JAPCC) notes that the idea of short notice, especially for military reasons or requirements, is to react quickly to developing situations. Process-wise, classical Space launch campaigns last from several weeks to even months, and conclude with the on-orbit checkout phase of the satellite, which satellite operators also must reduce significantly. A responsive launch capability requires already produced and preassembled Space Launch Vehicles, either produced or at least in assembly sets, and preproduced satellites, all kept in stock and ready to deploy. If a critical satellite is disabled, either due to technical reasons or due to an opponent's counterspace activities, it provides a quick way to react to restore the mission.[45]

In other words, the system should be able to be deployed and checked out quickly to respond quickly to user requirements.

Spacecraft Operations

Spacecraft operations consists of commanding and controlling satellites to perform station-keeping operations, checking the status of health, operating payload operations, and managing the day-to-day operations of the system. In the Air Force, most satellites are operated at Schriever Air Force Base (AFB) outside of Colorado Springs. To accomplish on-orbit operations, the satellite operator first must connect to the satellite.

The majority of Air Force satellites connect through the Air Force Satellite Control Network (AFSCN). Other satellites, such as GPS, utilize AFSCN and system dedicated ground sites.



(National Coordination Office image)

Figure 11. GPS control segment

Figure 11 provides an overview of the GPS control segment. To have worldwide coverage and access to the on-orbit operational constellation of 31 satellites (currently), GPS utilizes a mixture of the seven AFSCN and four dedicated ground antennas for commanding and controlling the constellation. Also, sites around the global constantly monitor signals from the GPS satellites that are relayed back to the Master Control Segment at Schriever AFB. This monitoring

allows the operators to know if any issues are occurring even when the satellite is on the other side of the earth.

After a satellite operator connects to a satellite via AFSCN or other dedicated ground antennas, they can then command the satellite. These commands can vary from repositioning the satellite, performing software updates, turning on or off payload functions, and more. The operator utilizes ground-based software to accomplish these tasks at Schriever AFB. DOD space operations continue to evolve in tactics and techniques. Space was once a sanctuary where the US was free to deliver effects to the war fighter without worrying about the actions of advisories. China recognized the US success in leveraging the space domain and has taken steps to remove the US advantage in space. In 2007 the Chinese launched a ballistic missile with a direct ascent antisatellite (kinetic kill vehicle, destroying a defunct Chinese weather satellite.[46] This test illustrated that space was no longer a benign domain where the US is free to operate without the intervention of foreign advisories. Space has now become a new war-fighting domain with a unique character. This new domain has created a situation where space operators must learn to react in real time to preserve on-orbit capability.

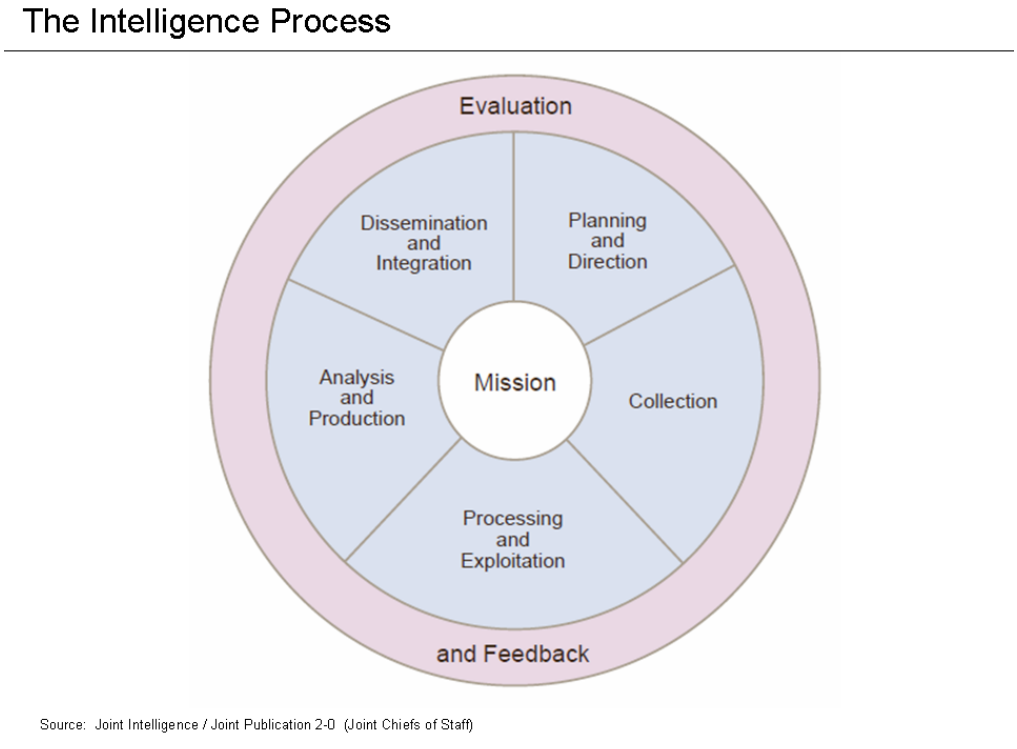


Figure 12. Task, collect, process, exploit, demonstrate (TCPED) process

Spacecraft Tasking

One example of space tasking is the intelligence model. Figure 12 provides the process as depicted by Joint Publication 2-0 (JP 2-0). This process starts at the top right where planning and direction is provided by an end-user to collect on the desired target. Next, the asset is prioritized to collect against the desired target.

Prioritization is predefined by standard operating procedures and may or may not elevate a user's requirement to the collection deck depending on sensor requirements. After collection of the data, the collection agency processes and exploits the received data. The functional manager of the data will then analyze the exploited data and process products for the user. This data is finally disseminated to the user for use in operations.

The TCPED process is further explained by JP 2-0 in Figure 13 by explaining how the operational environment filtered through a lens down to data, further refined into information, then finally into end-user intelligence.

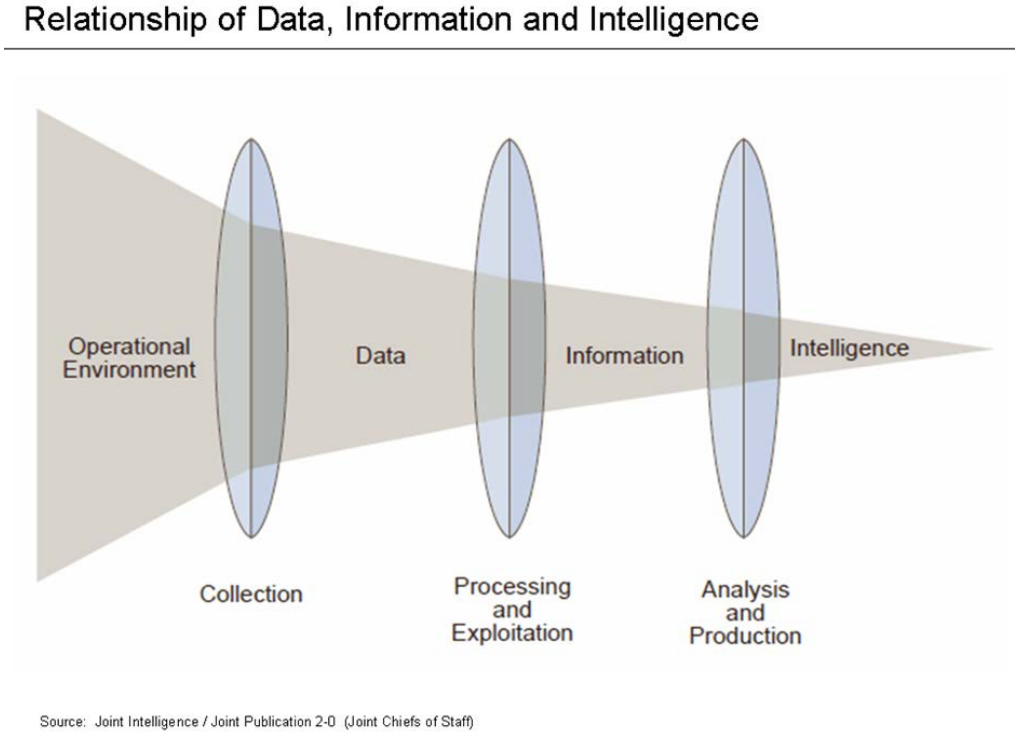
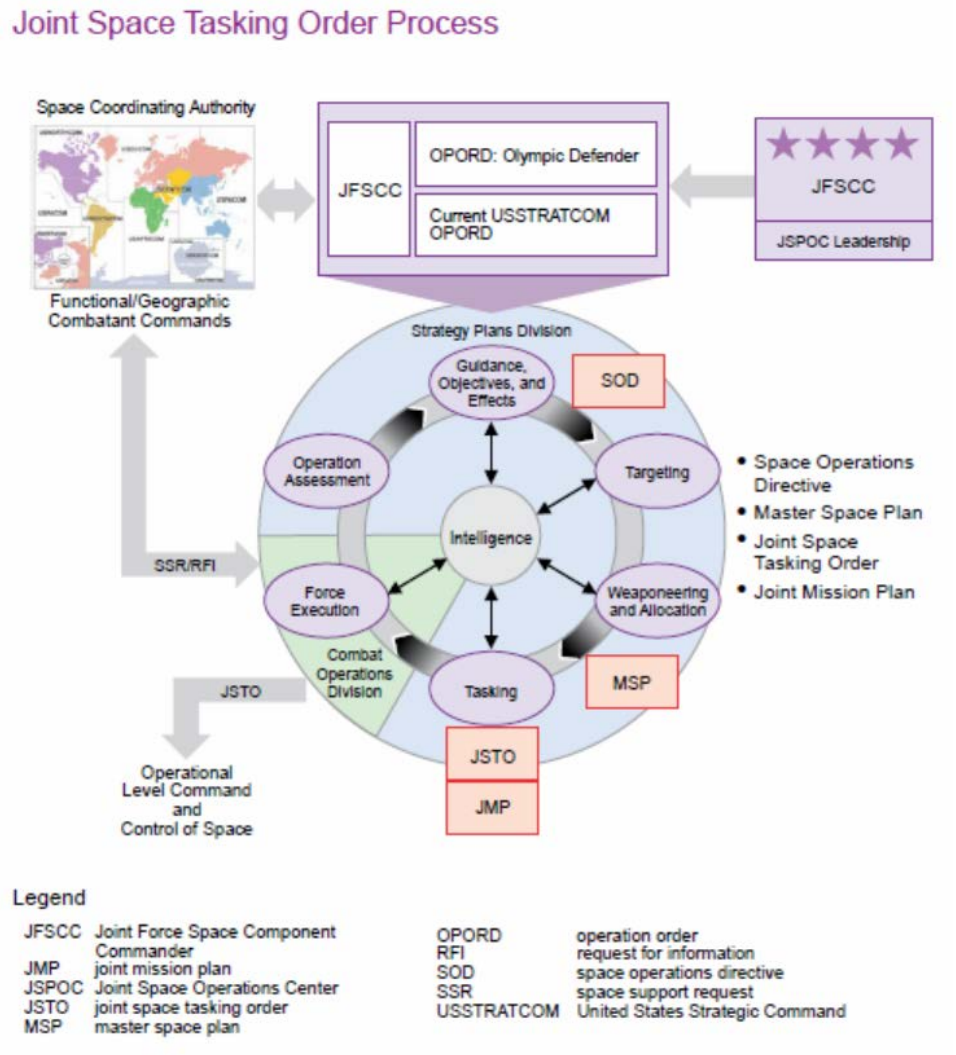


Figure 13. Data refinement process

The data refinement process is one example of how on-orbit assets are tasked by an end user in the field to receive final intelligence. While tried and true, this

process lacks the immediate raw intelligence some users require to accomplish missions at the speed of relevance.

The second example of current DOD space vehicle tasking is the Joint Space Tasking Order (JSTO) process defined in JP 3-14, and figure 14 provides a pictorial representation of how the JSTO process is accomplished to meet requirements for the JFSCC and functional and geographic commands.



(Source: JP 3-14: Space Operations)

Figure 14. JSTO Process

JP 3-14 discusses the JSTO process transmits the JFSCC's guidance and priorities for a timeframe, assigns tasks to meet operational objectives, and, when required, synchronizes and integrates JFSCC activities with other combatant command elements. The JSTO process can be sped up or slowed down, depending on the urgency of the requested space effect.

Future End-User Interaction

Typical User Interaction with Satellites

Interaction between end users (i.e., combatant commanders down to theater units) is typically a passive experience. For instance, a GPS user simply turns on a device, and the signal from several overhead GPS satellites is received, correlated to, and a position is calculated and displayed on the user's device. Similarly, satellite communication occurs in much the same way. A user transmits or receives data to or from a satellite that is then received and processed. Additionally, COCOMs are typically not presented space assets as forces to be utilized in the planning and execution of theater operations. Space assets reside under the commander of Strategic Command and effects are produced through the JSTO process.

Army Program Kestrel Eye Program

The Kestrel Eye program was an Army initiative to prove a small, low-cost, visible-imagery satellite capable of providing images rapidly to the tactical-level ground war fighter.[47] Kestrel Eye was a prime example of how within a future space architecture, ground users will be able to receive tactically relevant data nearly real time. Kestrel Eye was a microsatellite with a weight of only 50 kg. The small size provides the advantage of being more affordable than larger satellites and therefore the ability to propagate a larger number of these satellites on orbit for better persistence of presence. The program manager noted:

> The chief item we learned from Kestrel Eye is that the concept to provide the Warfighter with rapid situational awareness at a reasonable cost has validity. Heeding lessons learned from the Kestrel Eye demonstrator will enable other SMDC small-satellite science and technology efforts to have an increased chance of success. The demonstrator has been a trailblazer for Army imaging from a microsatellite. It has shown beneficial tactical capabilities from space, which could represent a new tool for the tactical commander.[48]

The Kestrel Eye program is an emerging example of how future satellites may be tasked directly by ground users in the theater. This program has the possibility of pushing the use of satellites from the strategic level down to the operational and tactical level. Once this occurs, new doctrine, tactics, and procedure will rapidly evolve to deal with these changes.

Space Capabilities

Current Space Capabilities and Architectures

The current US space architecture includes capabilities across the DOD, intelligence community (IC), NASA, National Oceanic and Atmospheric Administration (NOAA), and commercial entities. Within the DOD, Air Force Space Command (AFSPC) provides the vast majority of current space capability. DOD capabilities include global positioning and timing, space-based communications, space-based infrared, space-based weather systems, and space-based surveillance systems. Inside the IC, the NRO provides the vast majority of capability, which includes signals intelligence, geospatial intelligence, and special communications. NASA is the focal point for US civilian space activities and conducts various space exploration missions, deep space imaging, and international space station occupation. NOAA operates geostationary operational environmental satellites. Also, US commercial entities operate various communications, imagery, and remote sensing satellites.

To implement the capabilities discussed above these organizations typically utilize a three-segment architecture approach. The first segment is the space segment and consists of a satellite on-orbit that contains mission payloads, hosted payloads, TT&C systems, station-keeping systems, flight software, and power systems. This segment requires launch vehicles to lift the satellite into specific orbits to meet mission requirements.

The second segment is the ground segment. This segment is responsible for the commanding and controlling of the satellite. In recent years, the ground segments have become extremely complex and one area of constant concern. As an example, in the Air Force, the Next Generation Operational Control Segment (OCX) for GPS has been under development since 2010 and has still not been fielded for operations. OCX has also faced numerous program breaches for both cost and schedule.[49] Issues and delays in field ground segment capabilities directly impact both the satellite and user segments. Since satellites are designed to last 10–15 years, capabilities are developed in the space segment and launched awaiting the ground segment to catch up with the proper software to command and control

the new capabilities. In the case of GPS, OCX will bring on capabilities for a new military code (M-Code), as well as deliver the capability to turn on a signal that is compatible with allied Global Navigation Satellite System known as Galileo.

Ground systems are also responsible for receiving, processing, and, in many cases disseminating data, to users. Processing data in space is a costly task due to the required computing power required to convert data output from a sensor into the desired end product. For this reason, satellites typically transmit raw data down to the ground segment to be processed by server farms on the ground.

The final segment is the user segment. This is the segment that utilizes the on-orbit capability for the desired effect. In the case of communications satellites, the user segment could be a satellite phone; for GPS, it could be a smartphone; for weather satellites, it might be a military weather officer. The user segment must have the requisite equipment capable of receiving and processing the signal.

Capabilities on the Horizon

Multiple capabilities are on the horizon that is already beginning to revolutionize the space domain. First is the reduced cost to access space through the reduction in the cost of space launch. The decreased cost to orbit is leading companies to development proliferated constellations of small satellites. Next, is the development of extremely large launch vehicles capable of moving more mass to orbit in a single launch. Finally, artificial intelligence and machine learning will quickly revolutionize both space and ground segments.

The reduced cost to access space has been discussed earlier. Reducing access costs is rapidly changing the space marketplace from one where only large wealthy companies and countries have access to space, to a market where college students now have the ability to launch satellites into orbit. The reduction in cost to orbit has created a market for new technological solutions that include developing smaller proliferated architectures, that can rapidly be developed and launched.

The first example of a proliferated constellation design is OneWeb and Starlink.

OneWeb plans to build a constellation of 650 satellites in LEO to provide high-speed space-based internet.[50] Similarly, Starlink plans to develop a constellation in LEO of 4,425 satellites to provide broadband services.[51] Assuming one of these two companies comes to fruition, vast manufacturing lines of satellites will be developed that can be leveraged by both commercial and military markets.

Currently, SpaceX plans to develop a rocket known as the Big Falcon Rocket capable of launching 150,000 kg into LEO in a 9 meter fairing, and Blue Origin plans to develop the capability to lift nearly 45,000 kg into LEO in a 7 meter fairing. Additionally, the SMC plans to award other transaction authority to some

of these companies to support these development activities in September 2018.[52] Future fairing of 9–11 meters will open up the engineering trade space in the design. Providing engineering flexibility to payload size will allow rapid development of technology that vastly increases performance and capability. For instance, larger payloads will be able to carry larger apertures into orbit. Larger apertures will enable new capabilities due to the fact they can collect more light and RF signals. This will increase the ability to accomplish both space intelligence, surveillance, and reconnaissance (ISR), communications, and situational awareness missions. In addition to receiving more and lower power signals, larger apertures allow energy to be transmitted more effectively. Therefore, large rockets have the potential to expand space capabilities tremendously.

Finally, artificial intelligence and machine learning are technologies on the horizon that will change space in the future. Artificial intelligence has the potential to change the space ISR enterprise by finding and tracking targets from satellites without user intervention. Also, as satellites architectures become more complex, satellites will utilize machine learning to fly without space operator intervention. These technologies are being researched by research institutes within the DOD and IC. IARPA discusses one program known as the Space-based Machine Automated Recognition Technique (SMART) that has the objective to develop tools and techniques to automatically and dynamically execute a broad-area search over the diverse environment to detect construction and other anthropogenic activities using time-series spectral imagery.[53]

Current Command Support Relationships to Combatant Commands

This section provides the background of space operations command support relationships to COCOMs. This background is important to understand to develop new command support relationships in the future.

Currently, space operations and the associated units deployed (either in-place or forward deployed) to a combatant command (COCOM) have clearly defined command and support relationships. Daily operations and the various staffs that work within the COCOM often misinterpret these command and support relationships. The common misunderstanding results in frustration and leads to discounting the integration of space effects that support the COCOM's theater campaign plan.

Joint doctrine and associated authorities place the command authority of all DOD space personnel, assets, and capabilities with the commander, United States Strategic Command (CDR USSTRATCOM).[54] When the US Strategic

Command (USSTRATCOM) presents these space units to a COCOM, the CDR USSTRATCOM delegates tactical control (TACON) of these space units to the Joint Force space component commander (JFSCC) who is dual-hatted as the commander. Ultimately, the JFSCC "coordinates, plans, integrates, synchronizes, executes, and assesses space operations, as directed by CDR USSTRATCOM, and facilitates unified action for joint space operations."[55]

Critical in maintaining the ability to command and control, synchronize multidomain effects, execute, and assess space operations is having a staff of professionals that maintains the technical, tactical, operational, and strategic understanding of the operating environment. The operation center that exercises TACON of STMF units and is responsible for command and control theater space operations is the Combined Space Operations Center (CSpOC). The CSpOC has various functions, but when the CDR USSTRATCOM presents forces to a COCOM, the CSpOC provides "reach back to facilitate coordination and support to theater SCAs."[56]

A restructuring and force structure review could occur for an organization like the CSpOC to address the monumental task of taking in requirements from the COCOMs and prioritizing their effects for execution. The missions assigned to the CSpOC may be attainable in peacetime or gray zone conflict but will eventually overwhelm the current structure of the CSpOC when engaging in near-peer conflict. During a force structure review, the CSpOC should address doctrine, organization, training, material, leadership, personnel, and facilities solutions to the required mission sets assigned to the CSpOC. There are numerous solutions that could be pursued that include a proposed change to the command and support relationships for SMTF units assigned to COCOMs.

Space forces, when deployed under the SMTF, should have the ability to conduct their mission with a clear and concise set of mission orders and tasks. Their operational support to COCOMs may take place in their home-station locations or in a forward deployed capacity physically located within a COCOM. However, a specific COCOM may use these space forces in a manner of their choosing to accomplish the COCOMs mission.[57] Under the current command and support relationships, space forces that are forward deployed must maintain numerous command and support relationships from USSTRATCOM to the operational unit they may be supporting. These relationships become complex when dealing with the ground, link, and space segments that include potential operations and impacts spanning multiple COCOMs.

COCOMs should request space forces within the SMTF for a period that they assess is required to meet the end state. Furthermore, these forces may be required for a JTF within a COCOM which adds another layer of complexity to

the organizational chart, command and support relationships, and execution authorities. If a JFC requests TACON or operational control (OPCON) of space forces in their AOR, this process will be denied under the current construct because those authorities are held at USSTRATCOM. However, if requested OPCON or TACON of SMTF units can be coordinated by the CDR USSTRATCOM and the JFC with final approval usually from the secretary of defense.[58]

When considering how to integrate SMTF units and effects into the COCOM theater campaign plans or contingency plans, command and support relationships that reduce redundant staffing and coordination should be paramount. Joint Publication 3-09 dictates that units conducting joint fire support, whether lethal or nonlethal must be coordinated with adjacent units. This requirement to coordinate joint fires implies a level of coordination between the Joint Staff, COCOMs, service components, and operational units. Additionally, this reduction in staffing efforts and focused operational support to the COCOMs will be essential to consider and require coordination to procure, request, launch, checkout, and operational support to provide an economy of force and concentrate efforts within the SMTF.

To enable this coordination, the space coordinating authority (SCA) is a special type of authority that gives a specific individual the ability to coordinate space functions, missions, effects, and activities. This authority can be delegated to any individual from the CDR USSTRATCOM, but historically has been delegated to the air component commander (ACC).[59] This authority should not be confused with TACON or OPCON authorities but rather specific coordination between joint space forces within a specific ACC in the COCOM. Historically, SCA has been delegated to the director of space forces (DS4). The DS4, exercising SCA should integrate multidomain effects and ensure the proper level of coordination required for joint fire support for specific COCOM missions. The individual with SCA uses the staff functions to plan and present space effects based on the objectives of the operation for the joint force.[60] The DS4 does not have any authority to employ or direct space forces, but rather coordinate their requested effects from the COCOM to USSTRATCOM and JFSCC. This becomes complex when dealing with multiple requests from subordinate units within the COCOM that may be located in different areas of responsibility or regions throughout the COCOM.

Summary

Chapter 2 provides an overview of current requirements processes, acquisitions processes and organization, launch market summary, satellite tasking process, satellite operations, and current and future capabilities on the horizon. Understanding

each of these elements is essential to have an informed conversation about where space will be moving in the 2030 timeframe. The next chapter will look at the desired end states for space architectures in the future.

Desired End-to-End Space Architecture

Chapter Overview

The primary goal of this research is to provide a future space architecture, that can be used as a vision to align priorities. Building on the literature review conducted in Chapter 2, Chapter 3 creates a future end-to-end architecture for space in 2030. The ultimate desired end state is a rapid process for developing space capability, processing the satellite, launching the satellite, and providing effects to the end user.

Architecture

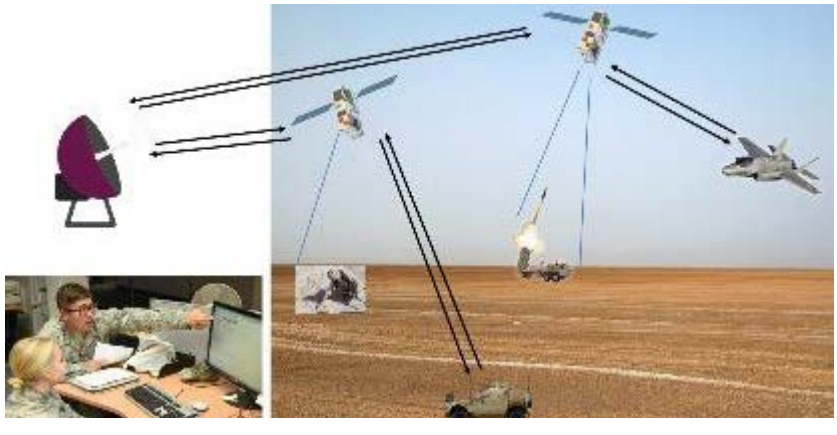


Figure 15. High-level operational concept graphic

Figure 15 provides a high-level operation concept for the desired system. The first step is to develop systems that end users can utilize for operational and tactical fights. Most satellites today are strategic assets utilized for strategic missions, and data produced from these systems is flowed slowly down to the operational and tactical levels. The architecture depicted in figure 15 will allow end users (i.e., forces on the ground, planes in the air, or ships at sea) to utilize satellites real-time to provide intelligence, reconnaissance, and surveillance (ISR) data real-time from rapidly deployable space-based assets. Additionally, data received from on-orbit sensors will be able to fuse data real-time with end users platforms to generate a

synergy of effects from those platforms to target adversary forces. Day-to-day operations of the satellites, to include station keeping, the status of health checks will occur by space operators at CONUS or OCONUS locations.

To enable this future space capability for operational and tactical users, multiple items should be accomplished. First, requirements for systems that need to be designed. Next, the systems must be designed, built, and fielded. Fielding requires rapidly processing, launching, and certifying the system as ready for operations. Finally, the satellites will have to be command and controlled. This command and control will first occur between satellite operators who will provide satellite check-out, the status of health, and daily maintenance. The second type of command and control will occur between the operational and tactical user and the satellite.

Future Space CONOPS

Requirements and Acquisitions

It is envisioned that forces on the ground will require immediate tactical and operational space assets upon entering a theater of operations. To accomplish this task, these new systems must be ready to be deployed before entering a campaign. This preparation will require changes to the requirements and acquisition process. These processes must move to rapidly acquire systems capable of accomplishing the desired function of providing tactical and operational level ISR from space and fuse that data with end-user systems.

First, the requirements process must be set up in such a way that users provide direct input into the development of requirements. Similar to JCIDS, the end user would define capabilities required to enhance mission effectiveness. In parallel, a Joint Systems Program Office (JSPO) would be established. This office will analyze what is in the realm of the possible through a technology maturation office that will conduct market surveys, broad-area announcements, and fund basic research. The technology maturation office will be responsible for accessing options that meet end-user requirements, as well as determining areas for investment to bring new technologies required online. The JSPO will also have a systems office, required for procuring space and ground system to meet end-user requirements. This entire JSPO and requirements process will be overseen by a relatively small board of directors. This board will be responsible for making decisions on which requirements to fund and guiding the JSPO through acquisition decisions.

As requirements are developed, the program office will work to rapidly procure technology demonstration satellites to test requirements and determine updates

to requirements required for seamless end-user interaction with the satellite systems. This will involve taking high-level capability requirements and distilling them into system level requirements for both satellite vehicles and ground software. To streamline this approach, it is recommended that the acquisition office be flat, similar to the RCO or NRO acquisition offices. This means that one program executive officer (PEO) is over the office with the authority to make acquisition decisions. This PEO will report to a board of directors, who will also have oversight of the requirements process. This board will comprise of five executives representing the four branches and US Space Command. Figure 16 provides a recommended PEO structure for decision-making for high-level requirements and program decisions.

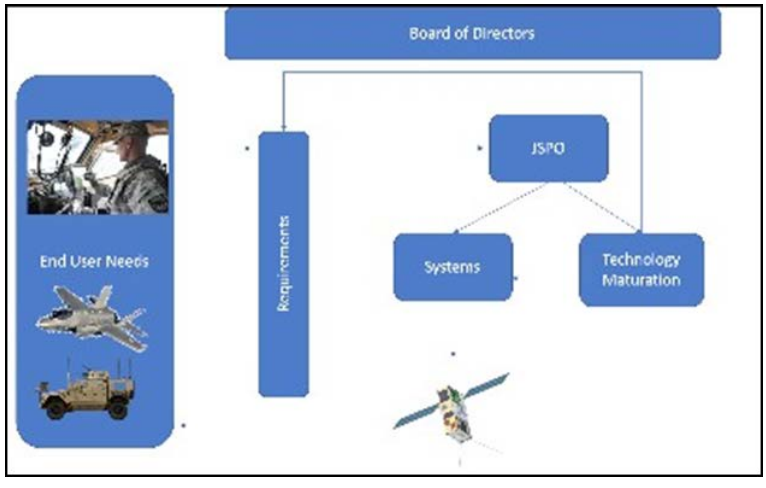


Figure 16. Streamlined requirements definition process

Processing Operations

With a renewed commercial interest in the launch mission, the DOD should begin seeking to benefit from achievements made by commercial parties. The US government should begin building partnerships with US commercial firms to pursue ultra-low-cost access to space.[61] Figure 17 demonstrates how the market has grown and should further motivate the DOD to begin developing partnerships.[62]

Additionally, the introduction of reusable launch vehicles (RLV) will likely generate a significant increase in the number of suborbital and orbital launches as it has the potential to significantly reduce the cost of gaining access to space.[63] For example, RLVs typically have a smaller footprint, require less infrastructure, and

	TOTAL NUMBER OF NON-COMMERCIAL ORBITAL LAUNCHES CONDUCTED FROM 2006-2015	TOTAL NUMBER OF COMMERCIAL ORBITAL LAUNCHES CONDUCTED FROM 2006-2015
Russia	225	93
USA	208	151
China	198	14
Europe	55	64
Japan	39	2
India	41	4
Iran	8	0
Israel	4	0
South Korea	4	0
North Korea	4	0
Multinational	0	23
Argentina	0	3
Canada	2	2
Singapore	5	1
Indonesia	2	0
Philippines	1	0
TOTAL	800	357

Source: FAA, Commercial Space Transportation Year In Review (2006 to 2017); AECOM compilation

Figure 17. Total launches by country (2006–17)

can often utilize the mobile infrastructure.[64] Figure 18 shows the percent of sub-orbital RLV launches which are currently being dominated by the commercial human space flight market.[65] This is yet again another opportunity for the DOD to benefit from the commercial sector.

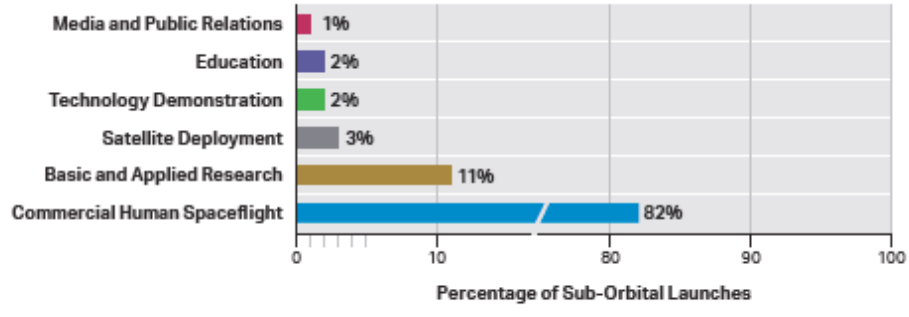


Figure 3.1e: 10-year RLV demand forecast
Data Source: The Tauri Group
Note: Total exceeds 100 percent due to rounding

Figure 18. 10-year launch vehicle demand

Future demands from the commercial sector will likely drive the requirement for future processing centers similar to Astrotech. Additionally, commercial operators processing smaller satellites and cube satellites will likely be only willing to pay smaller fees to process through a facility.[66] Both large and small satellites will require clean rooms, thermal vacuums, vibration tables, acoustic chambers, radio frequency chambers, and an electronic bench.[67] The difference will be the size and scale.

Smaller satellites will likely be able to utilize mobile processing centers which will reduce the needed infrastructure that larger satellites require.[68] Therefore, the US government, specifically, the DOD should begin investing in infrastructure that provides processing capabilities for DOD specific satellite mission areas. The construction of a processing facility along the lines of the EPF but dedicated to the Air Force and the DOD could eliminate processing timelines and reduce the potential bottlenecks if the DOD begins realizing the capability of launching on demand. As stated earlier, Astrotech is not located on Cape Canaveral AFS, and thus transportation timelines are longer for DOD satellites. Additionally, the transportation infrastructure can pose issues as their bridges and roadways that fall on local government to maintain and thus put the DOD mission at risk if local governments do not deem infrastructure maintenance as a priority. Finally, a DOD-dedicated facility allows for more flexible and responsive access to space as it eliminates reliance on commercial entities, can ensure for future growth, and provide for storage of satellites. This final point provides for the storage of satellites and will be a requirement for the US to enable rapid constellation replenishment and enable rocket initial supply or resupply downrange into the theater.

Launch Operations

In the desired future, architecture launch operations should be seamless and rapid. With the advent of reusable launch vehicles that act similar to aircraft, with the capability to transport payloads to a desired orbital location, it is envisioned the future of space launch will evolve into an Air Mobility Command model. A future Space Mobility Command would be responsible for rapid deployment of forces and material to a battlefield. In the future, battlefields will also include space orbits; therefore, a Space Mobility Command would assume responsibility for launching and deploying satellites on-orbit.

Similar to AMC, who has in-house capability and utilizes commercial services, a future Space Mobility Command would have both intrinsic capabilities and the capability to procure commercial launch services.

Proposed Command Support Relationships to COCOMs

Concepts put forward in this article require an assessment of current command support relationships when requesting space assets as needed within a COCOM. Historically, the space assets have been organized, trained, and equipped within the joint services and presented to USSTRATCOM as the COCOM authority. USSTRATCOM has retained COCOM authorities and OPCON of space assets within the space operations squadrons and TACON within the JFSCC at the CSpOC. Also, the Air Component Command within a geographical COCOM has been delegated SCA from CDR USSTRATCOM and generally further delegates this authority to their director of space forces (DS4). The current command and support relationships as outlined above will be challenging to manage with the standard ATO and JSTO cycles when presented with robust capabilities from a proliferated LEO constellation and the evolution of complex threats.

In the proposed solution to the current command and support relationship, COCOMs can identify gaps or requirements that are not fulfilled to achieve their theater campaign plans or during times of crisis. The COCOMs must have the ability to request, task, and integrate space effects that can create redundancy and resiliency within all war-fighting domains within their COCOM. This process could begin with a formal request from the COCOM to the CDR USSTRATCOM for a specific effect or unit.

Furthermore, assuming concepts such as a proliferated LEO constellation as outlined in this article come to fruition, the COCOM could request space assets from USSTRATCOM for use to mitigate risks from identifying gaps. For example, if United States Africa Command (AFRICOM) has identified a gap in their ISR collection plan due to higher level national priorities and their inability to collect with organic means, they could request in-theater ISR augmentation to enable their collection plan and support preplanned or ongoing operations. The CDR USSTRATCOM at that time could allocate space-based assets within a proliferated LEO constellation, SMTF units or elements, and delegate authorities to AFRICOM. Once the CDR USSTRATCOM concurs with the request from the COCOM, multiple authorities could be delegated to streamline the ATO/JSTO process within the COCOM resulting in the delivery of space effects for the COCOM's subordinate units.

First, space crew units that are trained, certified, and assigned to the SMTF fall under the OPCON authorities of USSTRATCOM. Their daily operations are to ensure the health and safety of the satellite (bus) and payload (sensor). These SMTF space operating squadrons that operate the bus and payload are currently

under OPCON of USSTRATCOM even though their satellites may be supporting various COCOMs.

Currently, their daily tasking and operations are dictated and prioritized by the CSpOC based off requirements and requests from the COCOMs through the JSTO process.

If USSTRATCOM were to delegate OPCON to a requesting COCOM, the subordinate units could leverage proliferated LEO constellations in a more dynamic and rapid tasking methodology. Under this restructuring, OPCON of the SMTF space operating squadrons that ensures the health and safety of the bus will more than likely not need to forward deploy from the ground site previously used for operations under USSTRATCOM. As an example, AFRICOM may not require the SMTF unit to physically be within the COCOM to conduct operations to ensure the health and safety of the bus but still retain OPCON of the space operating squadron that USSTRACOM delegated OPCON to the COCOM.

Second, OPCON of the sensor operators assigned to the SMTF space operating squadrons may or may not be required to forward deploy to the COCOM. If required to colocate within the COCOM, the SMTF would have the ability to dynamically task dedicated space assets during operations without delaying operations due to the ATO/JSTO cycles. For instance, AFRICOM may request a deployable space crew sensor operators from the SMTF space operating squadrons home station to colocate within COCOM C2 nodes to enable operations. If required to be an expeditionary unit within the SMTF, they must maintain a trained and ready force capable of providing space effects to the requested COCOM and their subordinate units. The ability of an expeditionary SMTF element to forward deploy and integrate space effects will be a requirement within the next decade.

Third, SCA should continue to be delegated to the COCOM as this delegation has been historically exercised in COCOMs. However, SCA may require further delegation to ensure the requirements and effects when conducting operations in, from, and through the space domain. This will ensure that multidomain effects are synchronized from the tactical level to the COCOM. There are various units that are in existence today from the Army and Air Force to provide such integration at the tactical to operational levels such as Army space coordination elements and Air Force weapons officers. However, SCA has not traditionally been delegated below the DS4 who has traditionally integrated and working within the Combined Air Operation Center on behalf of the ACC.

Additionally, if the SMTF establishes an expeditionary element within the unit, they could be delegated SCA for their specific mission set forward deployed

in the COCOM. As outlined in this article, this individual could be trained, certified, and placed on the SMTF as a space master gunner. As an example, SCA may be delegated from USSTRATCOM to AFRICOM, who further delegates SCA to the ACC/DS4. If and when mission requirements or COCOM request is submitted, SCA may be further delegated to a designated SMTF space crew servicemember that is deeply familiar with the satellite capabilities and architecture. More importantly, this individual must maintain a high level of operational planning and understanding of the operating environment to support the overall ground scheme of maneuver. This individual can be the liaison on behalf of all space entities, understand multidomain integrations points, and provide the best military advice to multiple echelons of commanders within the COCOM. They can also remain synchronized with the DS4 and their home-station SMTF unit conducting the bus and payload operations that enable COCOM mission success.

Gap Analysis

Chapter Overview

To reach the desired architecture, multiple items need to be accomplished. These include developing and integrating new technologies, streamlining processes for both requirements and acquisitions, and finally taking a fresh look at military doctrine on how to incorporate the new capabilities.

Technology

Multiple technologic gaps exist to achieve the capability to operate extremely large constellations of satellites and nearly instantaneously provide that data to ground users within the theater. First, satellites must be able to be produced at large scale. Also, it will be required to rapidly deploy these satellites on a large scale. Next, it must be possible to command and control large constellations of satellites. Finally, data must be processed on board the satellite and downlinked to end users with extremely low latency to ensure the data is timely and accurate.

Satellite Production

Currently, satellites are produced in very small numbers. Within the DOD, the largest current manufacturing line for satellites is the GPS III and IIIF production line in Waterton, Colorado operated by Lockheed Martin. This production line is projected to produce a total of 32 satellites, with production starting in 2012 and anticipated to complete in 2036.[69] This is approximately 1.5 satellites

produced per year. In the future, it is anticipated that the DOD will have constellations of hundreds of satellites operating in various orbits. To produce hundreds of satellites on a rapid timeline will require rethinking how satellites are developed and built.

Additionally, it is envisioned proliferated constellations will provide numerous capabilities. These capabilities include localized PNT, GEOINT, SIGINT, communications, space situation awareness, and space-based offensive and defensive services. Therefore, to effectively leverage large-scale production lines, flexible payload integration options must also be produced. This will require the development of standard satellite bus to payload interfaces. These interfaces will allow payloads to be developed that can simply plug into satellite buses. A standard interface will provide the flexibility to develop specific payloads required for specific tasks and allow for rapid integration of these payloads to buses in large-scale production.

Large-Scale Rapid Satellite Deployment

Currently, there is no existing infrastructure to process or store DOD assets at a launch site. The launch on-demand capability will drive increased processing needs in addition to clean room storage. If the DOD is to recognize a more agile launch capability for its existing satellite assets large dedicated infrastructures will need to be created.

One significant issue currently facing spaceports is the ability to store spacecraft before launch. Storability allows for increased launch opportunities and launch on demand.[70] There is currently no location at Cape Canaveral AFS to store satellites outside their launch processing window. This is due to the current acquisition process for satellites that launches on order not on demand. Space domain capabilities can be further expanded through smaller launch on-demand systems when rapid and responsive effects are necessary.[71] Currently, as showcased above such capabilities do not exist for the DOD. The current American space launch system is based on a policy that is focused on launching on schedule, not on demand.[72] Operationally responsive launch is one vital component of an operationally responsive space architecture.[73] It will require acquisition and production capabilities that allow for rapid satellite and launch vehicle procurement.[74] Additionally, it will require streamlined processing procedures and satellites that utilize components that are the same to reduce the need for unique mission requirements.

However, a lack of processing facilities may result in spaceports like Cape Canaveral AFS acting as chokepoints to space mission areas. Therefore, the Air Force and the DOD as a whole must work to adapt to the changing marketplace and

begin seeking opportunities to better support more capable ranges, mobile clean rooms, flexible satellite transportation, and spacecraft processing infrastructure.[75] Such a process should focus on incorporating lessons learned from NASA and other space organizations transportation operations to improve existing transportation concept of operations and inventory.[76]

Key Recommendations

Chapter Overview

This chapter provides the key recommendations derived from the research of a future end-to-end vision for the future of DOD space. These include recommendations in the areas of requirements development, organizational constructs and relationships, processes, and finally technology.

Requirements

It is recommended that the US streamline future requirements processes and provide more crosstalk between the user and acquisition organizations for systems that can be utilized by theater commanders. Experienced acquisition professionals should be embedded in COCOMs to a greater level and act as direct liaisons to space program offices. This will enable SDA, Space RCO, SMC, and the Air Force Research Lab to conduct more focused research through broad-area announcements, small business innovate requirements, and studies with vendors to rapidly mature technologies that meet end-user needs. Also, the requirements process should be flattened to enable disruptive space technology to deploy at a more rapid rate.

In addition, it is recommended current global and strategic systems such as GPS remain on the deliberate requirements approach defined in JCIDS, with appropriate oversight. The importance of specific DOD strategic systems requires deliberate development and mission assurance that results in longer requirements cycles.

Organizations

As discussed in Chapter 2, the DOD is moving forward with three key organizational changes in space acquisitions. These are the development of the SDA, Space RCO, and a redefined SMC. Effectively integrating and deconflicting the roles and responsibilities of these organizations will be essential to developing a streamline and coherent space acquisition capability within the DOD. This will

require deconflicting roles and responsibilities, effectively integrating the acquisitions into a coherent enterprise, and leveraging developments across the organizations.

The second organizational recommendation is to further research the development of a SMC. The benefits of having an intrinsic military capability, manned by members of the military to process, launch, and deploy military forces, military and capability in the future cannot be underestimated. In conflict commercial entities may not be able to take the same risk as the military concerning reusable launch vehicles. Therefore, the military must consider possessing its capability through the procurement of launch vehicles, and development of military launch organizations that own reusable launch vehicles and launch those vehicles.

The final organizational recommendation is to rethink how some satellite constellations are utilized to present forces to a COCOM. With the vision of future satellite proliferation, it is feasible that capabilities could be presented to a COCOM when assets are above the theater. These assets could be tasked by the COCOM to meet theater level requirements, without the approval or coordination with STRATCOM or a future USSPACECOM.

Infrastructure

As stated above the US must begin developing infrastructure that supports the growing commercial space capabilities. Specifically, the DOD should move away from the current model that focuses solely on commercial provided space craft processing.

The ability to launch on-demand as opposed to on-schedule will require space craft to be stored and at the ready with its required flight hardware. The current infrastructure in use is not sufficient.

Technology

It is recommended that the DOD begin to invest in companies planning to do large-scale satellite development. These companies need to mature the capability of producing satellites at scale. In addition, these companies will need to develop methods for controlling large constellations of hundreds of satellites. By leveraging the work of these commercial companies, the DOD can save significantly on research and development costs, while bringing significant capability to the fight.

Conclusion

Conclusions of Research

This research provides a concept for future end-to-end space architecture for US national security space. It looks at requirement, acquisitions, processing and launching space vehicles, on-orbit operations, and constructs for how these future forces could be employed by COCOMs. This research concludes that by 2030, new capabilities will be readily available that allow larger proliferated architectures to conduct numerous theater activities from space. Moving forward it will be important to develop requirements proliferated satellite systems. Also, it will be important to rethink how satellite processing and operations occur. Currently, our ground infrastructure to processing and launching satellites is vastly inadequate to meet emerging capabilities brought along with proliferated architectures.

Finally, this research recognizes the benefits of proliferated architectures, but still recognizes the importance of maintaining current capability with smaller constellations of large satellites that provide PNT, ISR, early missile warning, and communications. A proliferated architecture should be built in parallel to maintaining and modernizing existing capabilities.

Investigative Questions Answered

The following section answers the investigative questions presented in Chapter 1 of this article.

What is the current landscape for end-to-end space operations?

The current landscape is two parts. First, the DOD and IC must maintain current strategic assets held. These assets must continue to be procured and fielded to meet strategic needs. Second, the landscape is changing to include constellations of hundreds of satellites.

What should the future architecture for an end-to-end approach for space operations?

The future architecture should include a mixture of both proliferated satellite constellations and modernized legacy constellations. This end-to-end approach should maintain maintenance and status of health monitoring of satellites in CONUS, but also be able to present these satellites as in theater forces to COCOMs

when the satellites are available in the AOR. Modernized legacy constellations will remain national assets with authority for tasking out of USSTRATCOM (or a future USSPACECOM).

What gaps will the US military need to fill to enable this new architecture?

The major gaps the US military needs to fill are both technological and bureaucratic. The technological gaps include determining how to procure, build, and operate extremely large constellations of satellites. Also, the DOD must fill the gap of processing and launching large constellations. This will involve developing new processing facilities, and potentially an intrinsic military capability for space mobility, such as an SMC.

Finally, multiple bureaucratic challenges need to be overcome organizationally. These include flattening the requirements and acquisitions process, developing a new space tasking concept that includes presenting space forces to COCOM.

How should the US military organize to enable this new architecture?

The US military is already moving forward with a USSPACECOM that will be in charge of DOD strategic space assets. In addition to USSPACECOM, the organizational methodology should be worked out so that COCOMs are presented assets for in-theater use. Satellites presented to COCOMs would fly over multiple commands in a single orbit, and therefore deconfliction, handing over assets between commands needs to be addressed organizationally.

What technology should the US military invest in to enable this new architecture?

The US military should invest in three key technologies to enable this future architecture. The first key technology includes methods to reduce the cost of placing satellites to orbit. Today, multiple companies are pursuing reusable launch vehicles as a means to reduce cost to orbit. In addition to the reusable launch, the US military should continue to search for other means of placing satellites in orbit at a low cost.

Next, the US military needs to invest in satellite processing and launch infrastructure. Today, only two sites exist for processing and launching satellites. These are at Cape Canaveral AFS and Vandenberg AFB. Limiting launch to these locations will limit the ability to meet the flexibility and rapidness of launch. Finally, the DOD should invest in companies who plan to mass produce satellites for commercial proliferated constellations.

What new military doctrine should be created to allow the implementation of this new architecture and CONOPs?

Doctrine should be reviewed and updated to work through tasking and presenting space forces to COCOMs. This update would likely be provided in JP 3-14 *Space Operations*. Also, manning should be reviewed to determine how to staff future organizations that are envisioned. These organizations include launch squadrons that can process and launch satellites; organizations within COCOMs who take control over satellite tasking while specific assets are in theater; and finally, how to embed acquisitions with COCOMs to produce better requirements. Finally, this research looked at one methodology based on the Army Master Gunner Concept for Space. Proposed doctrine language to leverage is located in Appendix B.

Recommendations for Future Research

This article identified a few areas for recommended future research. These include the following:

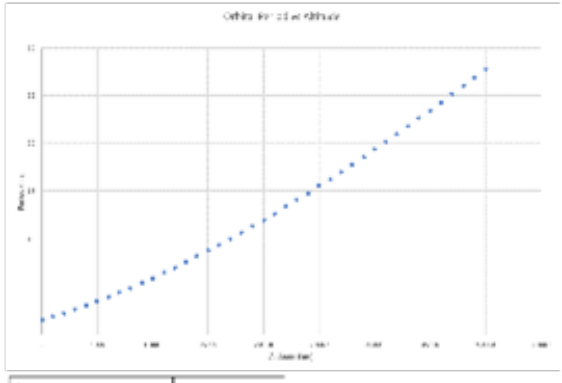
- How should space acquisition offices (i.e., SMC, Space RCO, and SDA) be organized, and what should each organization's roles and responsibilities be within the space enterprise?
- What would a detailed construct for a SMC? What infrastructure (launch and processing) will be required for rapid replenishment and launch on demand?
- How will assets in future proliferated LEO constellations be utilized by COCOMs, including how will these assets be transitioned as they fly through various COCOMs?

Appendix A: Orbital Period vs Altitude Derivation

Equation for Orbital Period (P_o)

$$P_o = 2\pi\left(\sqrt{\frac{a^3}{GM}}\right)$$

Altitude (km)	Semi Major Axis (km)	Period (seconds)	Period (Hrs)
100	6480	5191.266962	1.4420186
1100	7480	6438.182024	1.7883839
2100	8480	7771.496088	2.15874891
3100	9480	9185.934838	2.55164857
4100	10480	10677.08692	2.96585748
5100	11480	12241.19134	3.40033093
6100	12480	13874.99171	3.85416436
7100	13480	15575.63254	4.32656459
8100	14480	17340.5831	4.81682864
9100	15480	19167.58019	5.32432783
10100	16480	21054.58402	5.84849556
11100	17480	22999.74372	6.3888177
12100	18480	25001.36985	6.94482496
13100	19480	27057.9122	7.51608672
14100	20480	29167.94167	8.10220602
15100	21480	31330.13526	8.70281535
16100	22480	33543.26357	9.31757321
17100	23480	35806.18022	9.94616117
18100	24480	38117.81295	10.5882814
19100	25480	40477.15593	11.2436544
20100	26480	42883.26319	11.9120176
21100	27480	45335.2429	12.593123
22100	28480	47832.25237	13.2867368
23100	29480	50373.49374	13.9926371
24100	30480	52958.21011	14.7106139
25100	31480	55585.68217	15.4404673
26100	32480	58255.22516	16.182007
27100	33480	60966.18622	16.9350517
28100	34480	63717.94197	17.6994283
29100	35480	66509.89636	18.4749712
30100	36480	69341.47872	19.2615219
31100	37480	72212.14203	20.0589283
32100	38480	75121.36131	20.8670448
33100	39480	78068.63219	21.6857312
34100	40480	81053.46959	22.5148527
35100	41480	84075.40653	23.3542796
36100	42480	87133.993	24.2038869
37100	43480	90228.79501	25.0635542
38100	44480	93359.39361	25.9331649
39100	45480	96525.38408	26.8126067
40100	46480	99726.37511	27.7017709



Constants	
GM (m^3*s^-2)	3.986E+14
Earth Radius (km)	6380

Appendix B: Space Master Gunner Concept

The US Army's Master Gunner's primary duty description is to be the subject matter expert for their assigned weapon system and to assist the commander in the planning, development, execution, and evaluation of all individual, crew, and collective combat training.[77]

The United States Army establishes 11 principles of unit training listed in figure 19.[78] For the purposes of this article, we will analyze principles of unit training and their application to either individual training, collective training, or ongoing during the unit training cycle.

- Commanders and other leaders are responsible for training.
- Noncommissioned officers train individuals, crews, and small teams.
- Train to standard.
- Train as you will fight.
- Train while operating.
- Train fundamentals first.
- Train to develop adaptability.
- Understand the operational environment.
- Train to sustain.
- Train to maintain.
- Conduct multiechelon and concurrent training.

Figure 19. US Army 11 principles of training

With the lack of established and fundamental doctrine, the US Air Force must look to other organizations to establish doctrinal principles to enable the space master gunner to develop, plan, execute, and assess training for space crews. Furthermore, these principles could provide rough guidelines and priorities for unit commanders, leaders, and master gunners to emphasize during individual and collective training events. The 11 principles discussed in Chapter 2, figure 4 can be used within the individual and collective training phases of the space crew certification before their assignment to the SMTF. For this article, we will analyze principles of unit training and their application to either individual training, collective training, or ongoing during the unit training cycle. It is imperative that the commander, unit leadership, and the proposed space master gunner(s) take an active role and are invested in the unit training pipeline.

The unit commander is ultimately responsible for their space crews mission execution; they must delegate authorities within the unit, understand the all facets of the unit training, they themselves must observe training management processes, and develop leaders that are capable of executing decentralized operations if required.[79] Furthermore, these standards and space crew certifications are certified by the command authority for the unit. To enable organic training and evaluation opportunities, the space master gunner, on behalf of the unit commander, can oversee and evaluate the certification training events for the unit.

During this process, the space master gunner should implement training that is sustainable within the available time and resources allocated to the unit during the training cycle. The space master gunner, with the execution and oversight authority

from the unit commander, incorporates training that takes into consideration unit maintenance for space systems and their requisite equipment. Space crew operators must understand their equipment and reinforce fundamentals at all levels of training proficiency. This understanding also must be clearly and deliberately outlined in the unit training plan. All these training principles are primarily ongoing throughout the unit training cycle and varying levels of attention and application will occur during unit training.

Individual training must incorporate initial entry training and unit level training opportunities that ultimately provide trained and ready space crews. When understanding the fundamentals of training, "Units proficient in fundamentals are more capable of accomplishing a higher level, more complex collective tasks that support the unit's mission-essential task list—the fundamental, doctrinal tasks that units should be prepared to execute during any assigned mission."[80] In the current USAF Squadron construct, it is difficult to grasp and understand the big picture and support to multidomain operations without working on the staff before gaining operational experience on a space crew.

The USAF must utilize its noncommissioned officers to provide training oversight on behalf of the commander and train and develop junior leaders in the unit. In the US Army, noncommissioned officers (NCO) train subordinates within the direction and guidance of the commanders unit training plan.[81] Ideally, in our proposed space master gunner concept, the unit training would be led by them with overall direction and guidance from the commander.

It is important to stress the importance that as the space master gunner, this must be their only job within the unit. Pending recent developments at the Space Weapons School, NCOs may indeed be able to execute this concept. This would require a culture shift within the USAF to utilize their NCOs differently than historically used. But if the culture change is overcome, it may enable the assignment of space master gunners at all flight levels due to availability of personnel trained as space master gunners. The shift from individual to collective training requires that all space crew members be proficient in their individual tasks. Space crews must train as a crew and is introduced to the ever-changing operational environment and changing variables dictated by the unit commander and space master gunner. These inputs and variables are chosen from space crews that are operational under the SMTF, captured through formal and informal feedback mechanisms. Enabling the communication and training objectives proposed by

SMTF space crews helps collective training objects they would see in the operating environment.

Space crews must be presented with realistic and demanding training during the collective training phase. To enable realistic and demanding training, space crews must train as they fight, or they must "establish in training what the unit can expect during operations to include the culture of an operational environment."[82] Collective training that forces space crews to react to varying scenarios that required adaptability as they would as a member of the SMTF. This training can also help the space crews understand important reporting requirements that are often time-sensitive and complex authorities to execute and report.

Space crews must train in multiechelon and multidomain operating environments for their final space crew certification. Space crews could "train to improve performance and address changes in tactics, techniques, and procedures that affect the operation."[83] This final step must be the commander's certification of the crews before their transition to operational space crews as part of the SMTF. This final certification would exercise the request process for space support and effects through multiple commands, certify approval authorities at varying echelons of command, and display the ability of a space crew to transition custody of the spacecraft from a launch squadron to a command and control squadron.

Upon completion and certification of the training requirements under the RSP or modified concept stated above, the space crew will become a certified crew available for operations in the Space Mission Task Force (SMTF). Once designated certified for operational use, the space crew is part of the SMTF that allocates personnel, equipment, and capabilities to a variety of commands and applications either within a garrison or in a forward deployed capacity.[84] If able to streamline SMF concepts, unit training management, and implement principles of training, the space crews that are operational as part of the SMTF will be more prepared to operate in a complex and changing environment that can provide support and effects to the Joint Force in support of the multidomain operation.

To effectively take custody of a launched vehicle under the current SMF construct, organizational structure and training oversight must ensure readiness for the space crew to take an on-orbit spacecraft through checkout, operations, and taskable support to the Joint Force. First, the organiza-

tional structure must adopt a subject matter expert into organizations that bring effectiveness to the command and the Joint Force.

Second, training must be managed by these subject matter experts at all unit levels from crew to squadron to ensure operational readiness and effectiveness for the SMF. In the following paragraphs, we will use the US Army's master gunner concept as an example of how the SMF could provide the impacts as outlined at conception, referred to as the space master gunner.

Gen John E. Hyten's vision in 2016 for the SMF highlighted the need for a cultural transformation that would emphasize the need for a "force capable of achieving space superiority" and one that could "provide vital space capabilities for the Joint Force now and in the future.[85]" To produce a force that is capable of achieving space superiority to the greater Joint Force, effective training becomes paramount to operational readiness. To establish a culture that supports General Hyten's vision, space crews must be exposed to varying complexities during individual and collective training events. For the SMF to be successful, the training, evaluation, and certification process must impart specific lessons learned from the operating environment today and those perceived threats in the future.

Commanders of operational units within SMF can leverage the concept of a space master gunner and bring an expert into their organizations that have the technical and tactical knowledge to maintain high levels of readiness to the Joint Force. It is important to identify a potential master gunner as one of the most competent individuals from the unit, send them to training and retain them within the master gunner billet to ensure continuity within the unit. This may require the US Air Force to extend or curtail assignments based on high-demand skillsets within the force

The space master gunner could have several responsibilities for the operational units, but, most importantly, they must be used primarily in the capacity for what they are intended. First, the master gunner at any level should be the subject matter expert for the assigned weapon system. These weapon systems will vary depending on the mission area, but they should understand the complexities of the system, subsystems, sensors, architecture, and capabilities of the weapon system large. Second, the squadron master gunner in conjunction with the flight master gunners should manage individual, crew, and collective training events. As subject matter experts, they understand the

doctrinal application of the weapons systems and therefore are most qualified to train individuals and crews. Lastly, the master gunner, at all levels, should coordinate and forecast changes in crew decertification for various reasons. Actively managing this process results in a streamlined process to ensure onboarding of new crews in the most efficient manner and redundancy for unforecasted decertification.

Training, evaluation, and certification are important for the US Air Force if its space crews pursue a role in the acquisition, launch, and operational control of a spacecraft that supports the overall Joint Force. The Ready Spacecrew Program (RSP) is the name of the training mechanism that was identified in SMF that would manage individual and collective training requirements of crews and would require commander certification before assuming operations.[86] The RSP is the umbrella program of different mission areas within the space domain. This program should not only focus on the training, evaluation, and certifications of space crews but also stress the importance of retaining certified crews and personnel within operational units as part of the SMF.

Vital to the success of the RSP is the execution of individual and collective training that represents the rapid evolution in the space operating environment.

Underpinning this training as an operational unit is continuation training that maintains space crew proficiency as well as the advanced training required for space crews that focus the advancement of the space crew in an observed and projected contested domain environment.[87] As a crew transitions out of the Space Mission Task Force (SMTF) as an operational unit and into a period of reset, continuation training could be utilized to maintain the certification for various reasons. The space crew can maintain its cohesion and effectiveness, springboarding them into the next SMTF operational cycle as the crew that can mentor newly formed space crews or maintain certification to reduce risk and supplement operations in times of extremes due to unforeseen circumstances.

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