CENTER FOR SPACE POLICY AND STRATEGY

SEPTEMBER 2021

DESIGNING FOR PRINCIPLES: IMPLEMENTATION STEPS FOR THE UNITED STATES SPACE FORCE

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Summary

United States national security is highly dependent on Department of Defense (DOD) space capabilities, which provide unique force-multiplying options to the joint warfighter, exclusive intelligence to national leadership, and potent economic benefits to all citizens. However, as remarkable and critical as these space capabilities may be, they exist within an inherently fragile and stovepiped architecture. Outdated capability development strategies have conspired with the complacent inertia of historical assumptions regarding the "sanctuary" nature of space to render the DOD space architecture vulnerable to a rapidly expanding arsenal of adversary threats. The result is that U.S. space capabilities—long a bastion of strength—have become an Achilles' heel to America's national security. This is a major reason why the United States Space Force (USSF) was established.

Now the fledgling service faces a daunting task: It must not only organize, train, and equip space forces to deliver a host of critical capabilities to the warfighter and the nation, it must ensure those capabilities endure in an environment increasingly characterized by extreme complexity and uncertainty. In other words, the USSF must develop a more survivable, flexible, and interoperable space architecture. And it must do so quickly; potential adversaries are moving apace, determined to eclipse U.S. dominance of the space domain. Given the scope and nature of the challenge, it's fair to question whether traditional DOD development and design methodologies are up to the task. What is desperately needed is a more nimble capability development methodology.

As noted in a previous paper by the author, the basis of such a nimble methodology may already exist. It is called *Designing for Principles* (DfP), and its name is derived from the fact that it emphasizes broad architectural principles of design—like survivability and flexibility—over traditional performance requirements. Furthermore, DfP thrives on uncertainty, favors strategic thinking, and prioritizes responsive speed above almost all else. It is perhaps an ideal match for the USSF to overcome its daunting task and exploit the opportunities unique to this moment. Whereas the previous paper described the general DfP approach to capability development, this paper provides specific recommendations on how the USSF can actually begin implementing DfP across the space enterprise.

You take the blue pill—the story ends; you wake up in your bed and believe whatever you want to believe. You take the red pill—you stay in Wonderland, and I show you how deep the rabbit hole goes.

—Morpheus, The Matrix

Introduction

The space domain isn't what it used to be. The days of it being a virtual sanctuary ceased long ago, even if broader recognition of this fact lagged. The days of it being a realm of undisputed U.S. dominance are also coming to an end—if they haven't already. For many space-related capabilities, potential rivals are not just nearing parity, they have already surpassed the U.S. or are on pace to do so. Given the critical role space capabilities play in U.S. national security, this rapidly changing landscape is of tremendous concern to national leadership and was a key driver for the standup of the United States Space Force (USSF).

The establishment of the USSF was just a first step; the real challenge starts now. The USSF must completely flip the script on how it supports the joint warfighter. Instead of developing stovepiped and fragile *systems*, the service will need to provide enterprise *capabilities* that can survive across the spectrum of conflict. And it will need to act with unprecedented velocity, fundamentally revectoring its current capability development trajectory. Potential space adversaries are not only moving more quickly than the U.S.—they appear to be moving more quickly than the nation is even *capable* of.[1,2] The traditional DOD systems engineering (SE) approach to capability development may have served the national space community well for decades, but it is increasingly clear it is unsuited to the challenge at hand.

> ***"Let me be clear—if we do not adapt to outpace aggressive competitors, we will likely lose our peacetime and warfighting advantage in space."***
>
> —General Raymond
> Chief of Space Operations (CSO)[3]

There is another option for the USSF—a strikingly different approach to capability development called Designing for Principles (DfP). This alternative is addressed in a previous CSPS paper titled "Principled Design vs. Designing for Principles: Rethinking Capability Development for the Space Domain." That paper describes what DfP is and argues that it is generally a superior capability development strategy for the current space environment than the classic SE (i.e., Principled Design) methodology as applied by the DOD. This paper is essentially part two of that paper, explaining how to implement DfP for the space enterprise, providing a series of specific, actionable steps for vastly improving capability development outcomes across the USSF.

It is assumed readers of this paper are familiar with the predecessor paper. Whether that's the case or not, a quick review may be warranted. Therefore, this paper begins with a short synopsis of DfP, including a recap of the three pillars that capture the essence of the approach: (1) *Don't Be Obsessed with Requirements*, (2) *Keep the Big Picture in Mind*, and (3) *Embrace and Understand Uncertainty*. To this list, however, an additional "paramount" pillar is added that captures perhaps the most central theme of DfP: *Go Fast*. The remainder of the paper is organized around this framework, with one major section corresponding to each of the four pillars. For each section, a series of implementation recommendations are identified, explained, and justified, culminating in a six-element reference table that summarizes the key recommendations related to each pillar, to include basic rationale and suggested actionees.

The intended audience for both DfP papers is primarily enterprise architects and systems-of-systems thinkers in the USSF. However, the implications of what is being proposed here are broad and deep, affecting everything from how space capabilities are acquired to how planning and programming is executed to how the USSF itself is structured. As such, if DfP is pursued, it will have significant ramifications across the entire capability development tradespace and is bound to impact development contractors, government program office personnel, USSF headquarters staff, and senior decisionmakers across the DOD space community.

Synopsis of Designing for Principles (DfP)

As noted in the introduction, this paper assumes readers are already familiar with the DfP concept. For those to which this assumption does not apply—or for those who simply would appreciate a refresher—this section provides a quick overview.

The proposed DfP methodology is premised on the notion that, in environments characterized by high uncertainty, the right capability development approach is not to focus on one optimal future design now; rather, it comes from the ability to continually adapt designs to a range of future needs and threats that cannot possibly be known and/or characterized today. Unlike traditional DOD implementation of SE, which is generally requirement-based, system-centric, and driven primarily by technical mission performance, DfP is *objective*-based, *capability*-centric, and driven primarily by *design principles* and *speed*.

Ultimately, embracing DfP concepts can achieve levels of architectural resilience and capability survivability that are simply not feasible using traditional DOD SE approaches.

These core ideas of DfP are captured via four, interrelated pillars:

1. **Don't Be Obsessed with Requirements.** Reduce total number of requirements, use objectives in lieu of requirements, and prioritize non-functional requirements (NFRs) over functional requirements.

2. **Keep the Big Picture in Mind.** Emphasize the broader perspective of capabilities over systems and extend this thinking to all facets of development, including performance, resilience, and risk.

3. **Embrace and Understand Uncertainty.** Uncertainty is not to be feared; recognize that nothing is as certain as we think it is and that to pretend otherwise is myopic and counter-productive.

4. **Go Fast (paramount pillar).** Prioritize speed of capability development to supplant the pernicious "stagnation" cycle with a self-reinforcing "celerity" cycle that embodies and enables agility.

One of the important takeaways from the first paper is that DfP is *not* intended to be a wholesale replacement for systems engineering. Traditional SE practices will continue to play a key role in capability development regardless. The argument, however, is that this role should be diminished, especially at the higher levels of architecture, requirements, and resourcing. Adopting or emphasizing a DfP approach as the overriding paradigm (with SE sprinkled in where appropriate) has the potential to fundamentally transform capability development across the space enterprise. It can expedite the fielding of systems and make the contributions of those systems both more immediately relevant and relevant for longer periods of time. Ultimately, embracing DfP concepts can achieve levels of architectural resilience and capability survivability that are simply not feasible using traditional DOD SE approaches.

Don't Be Obsessed with Requirements (DfP Pillar 1)

The DOD acquisition system is broken. Acquisition costs are not just through the roof; they are almost always higher than advertised. Same thing goes for schedule; not just lengthy, but longer than anticipated.

This is not exactly breaking news. And it's certainly not something that hasn't already been investigated ad nauseam. Consider, for example, that between 1945 and 2009, there were over 130 separate studies and commissions focused on defense acquisition.[4] Reams of findings have been published. Hundreds of rules and regulations have been enacted to "reform" the process. The result? Study after study shows these reforms have resulted in little, if any, improvement in acquisition outcomes.[5,6,7] This observation is not meant to disparage the various well-intentioned reform efforts and the dedicated professionals that create and implement them; the point is, rather, that the desired improvements are seldom, if ever, realized.

> ***Insanity is doing the same thing over and over again and expecting a different result.***
>
> —Unknown (though almost certainly not Albert Einstein, as commonly believed)

We need to face reality. It simply doesn't matter how many phases there are in the acquisition process, or what we name them, or what entrance/exit criteria are required at what development milestone, or who approves the requirements, or when we hold a design review, or what type of contract type we favor, or how training is revamped, or how the bureaucracy is re-organized. At best, these changes are just nibbling at the edges of the problem. The actual problem is more fundamental, and it's really an acquisition "overhaul" that is needed, as opposed to another "reform."

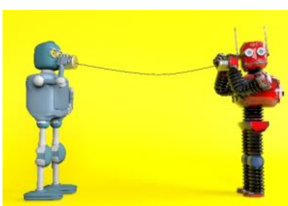
And the primary target of that overhaul should be *requirements*. The DOD is obsessed with them. The general approach is often, "The more requirements, the better." As noted in the previous paper, current SE-driven thinking regarding requirements can be summarized as "Do we have everything we need?" DfP inverts this question to, "Do we need everything we have?" DfP essentially argues that, for many types of capability development efforts, the requirements are simply too numerous and/or of the wrong type. In circumstances characterized by high levels of uncertainty, we would be better off using objectives in lieu of requirements and elevating the priority of non-functional requirements such as changeability, flexibility, and survivability. The question is, how exactly do we do this?

Objectively Speaking

Ultimately, are we okay writing things in pencil in [the Pentagon], or do we want that tablet of stone? If the answer is that tablet of stone, then we're going to continue communicating the way the Flintstones did.

—Dr. Will Roper
Air Force Assistant Secretary for
Acquisition, Technology, and Logistics[8]

Let's start with the idea of using objectives in lieu of requirements. The explanation of—and argument for—this approach was spelled out in the previous paper; now we want to identify what needs to happen for this idea to be executable. For an objective-based capability development approach to work in the world of defense acquisition, it will need to be coupled with three other important changes: "Continual User Engagement," "Rapid Development," and "Pervasive Competition."



Continual User Engagement. The first step to implementing an objectives-based capability development approach is to formally enact and enforce a different user collaboration strategy (the term "user" is intended in the broadest sense, applying to anyone expected to use some portion of the developed capability, including operators, maintainers, and joint warfighters). We must first recognize that having a formal written statement of what the end user wants can't be used as an excuse not to talk to one other. Today, it's not unusual for a program to receive user requirements early on and then spend a decade or more in a figurative corner developing a system to meet those requirements without any further conversation with the user. One day — usually a long time later — the developer shows up and asks the user to come test (or even use) the system that has been developed, tacitly assuming the user's needs have not changed in the intervening time. This isn't a good practice in general and would likely be fatal for an objectives-based approach. Instead, there should be extensive and ongoing engagement between user and developer to ensure the developer remains focused on what users care about.

Another benefit of continual user engagement is that it enables the developer to stay abreast of changes to user values and priorities. Not only can the user's objective legitimately fluctuate (recall the American Ninja Warrior example from the previous paper), but changing circumstances may alter user perspectives and priorities. Staying apprised of the user's value model allows the developer to remain focused on the right objective and to make better-informed trades between performance and schedule. This last point will be addressed in detail as part of "Embrace and Understand Uncertainty (Pillar 3)," where it is argued we need to fundamentally rethink the concept of risk.

Rapid Incremental Development. So what are the chances the Pentagon would give a large sum of money to a program office with few (or no) top-level performance requirements and simply say, "I completely trust you—go do good things and come talk to us again in a decade when you're done." The answer, of course, is slim to none.

But what if we change "a decade" to "a year" in this rhetorical statement? Suddenly, this notion doesn't seem so implausible. This suggests that one of the best ways to make objective-based development viable is to ensure we have more frequent and explicit technical accountability. Without the use of hard requirements to help provide that accountability, there are just two realistic options. Either programs furnish even more detailed status more often through the defense acquisition chain or programs deliver frequent, incremental operational capabilities to the user as a structured value proposition.

Hopefully, it's apparent why the first option is all sorts of *awful*. More stringent oversight is generally a reactionary response to problems, which often creates unintended—and sometimes ironic—consequences.

On the other hand, the second option is all sorts of *great*. For starters, delivering ongoing, incremental capabilities ostensibly gives the user something of value much sooner. It may be a car that lacks upholstery, windows, and a radio, but it at least gets the user from point A to point B much faster than walking. Secondly, it allows the user something tangible to evaluate. "Continual User Engagement" is good, per se, but having something to test drive (literally or figuratively) allows the user the opportunity to provide much more substantive feedback, thereby establishing an invaluable "vector check" for the developer. The final, and most compelling, benefit of "Rapid Incremental Development" is that obtaining relevant feedback directly from the user is a far more effective method of program accountability than any bureaucratic review process could ever be. Ultimately, this recommendation provides recurring validation throughout development as opposed to waiting until the end. (Of note, delivering capabilities more quickly is more fully addressed as part of the "Go Fast" paramount pillar near the end of this paper.)

Pervasive Competition. The third recommendation to realize objective-based development involves fully unleashing the power of competition.*

Recalling the weight loss example from the previous paper, imagine how much more effective the person would likely be if they were competing with someone else to see who could lose more weight more quickly. The USSF should generally apply this same catalyzing force wherever possible, but it's particularly important for objective-based acquisition where we lack some of the innate impetus of formal requirements Leveraging competition can offset that risk and help ensure participants remain focused on the objectives and achieve good outcomes even without the riding crop of formal requirements.

It isn't controversial to state that competition should apply to DOD development contractors. This principle is already enshrined in law (e.g., the Competition in Contracting Act[9] and the Weapon Systems Acquisition Reform Act [WSARA][10]). WSARA, for example, explicitly requires competition for both prime contractors and subcontractors, and includes mandatory provisions for dual sourcing and competitive prototyping prior to Milestone B for all Major Defense Acquisition Programs (MDAPs). Available evidence strongly suggests that competition, under the right circumstances, fosters new solutions, curtails overall risk, and significantly reduces cost and schedule.[11,12,13]

When we create and maintain a competitive environment, we are able to spur innovation, improve quality and performance, and lower costs for the supplies and services we acquire.

—Frank Kendall
Under Secretary of Defense for
Acquisition, Technology, and Logistics[14]

* See "Freedom's Forge," by A. Herman for an illustration of the transformative power of competition during World War II.

The point of the "Pervasive Competition" recommendation is to take advantage of these competitive pressures much more deliberately and much more often. This includes extending competitive prototyping to include more than just MDAPs. Smaller space programs are likely to benefit from early competition as well, and they should be encouraged—and enabled—to realize that goal. It also includes discouraging waivers for MDAPs unless the case is extremely compelling. Too often programs are deterred by the high up-front cost of competition without fully considering the longer-term benefits.[15]

The USSF should also look to prolong competition *past* Milestone B. The conventional thinking is that it simply isn't cost-effective to dual source into the later acquisition phases involving manufacturing and production. This view is generally premised on the notion that, given the much larger proportion of money involved, it doesn't make sense to "carry" two vendors. But this argument is specious. If we truly believe in the power of competition and its ability to drive down cost in the long run, then, logically, the greater the costs involved, the greater the opportunity for cost-savings.

In many circumstances, it can make sense—both economically and strategically—to carry multiple contractors into these later acquisition phases, and even indefinitely into sustainment and beyond. Consider, for instance, the fact that a publicly premeditated strategy to limit competition to the early phases of acquisition (i.e., Materiel Solution Analysis and Technology Maturation and Risk Reduction) has the potential to create perverse incentives for development contractors to misalign or misrepresent long-term costs, schedule, and/or risks in order to ensure they secure sole award of more lucrative production contracts. And although splitting production between two vendors can result in some reduction in learning curve efficiencies and increased per-unit costs, this isn't necessarily the case; moreover, these cost increases typically pale in comparison to the cost savings realized by competitive pressures.[16] Finally, carrying multiple vendors offers various strategic benefits, including strengthened industrial base, greater solution flexibility, and elimination of "vendor lock" for additional rounds of competition in the future.

Of course, if planned production quantities are below a certain level, then it simply isn't viable to carry two development contractors into the later acquisition phases. And since unit quantities for the space domain are, historically, extremely low, this would seem to present a significant obstacle to the notion of extending competition across the full lifecycle of space systems. The reason why this isn't the case is because of that qualifier of "historically." Small production quantities are, arguably, *not* the future of space. As legacy architectures of few, exquisite systems give way to distributed, proliferated architectures, the case for "Pervasive Competition" in the space domain becomes increasingly compelling.

Finally, and perhaps most controversially, the USSF should consider opportunities for healthy competition between its component organizations. If done on a selective basis with precautions to avoid unnecessary duplication of efforts, this could also yield competitive efficiencies. In an effort to cost-effectively achieve some core objective, for instance, the USSF could simultaneously solicit solutions from the Space Development Agency (SDA), the Space Rapid Capabilities Office (SpRCO), and the Space and Missile Systems Center (SMC). Notably, such an idea was recently proposed by senior USSF leadership.[17]

(Non-)Functionally Equivalent

The second strategy that supports the pillar of not being obsessed with requirements is prioritizing non-functional requirements (NFRs). As articulated in the previous paper, a fundamental challenge the DOD faces is this notion that only functional requirements matter. To address this challenge, it's necessary to appreciate *why* NFRs tend to be regarded as an afterthought. There would appear to be three principal reasons: "Lack of Sex Appeal," "Quantification Issues," and "Implementation Challenges." Each of these reasons is discussed below, in turn, along with recommendations on how the USSF can shift the balance.

Lack of Sex Appeal. The first reason NFRs tend to be neglected is the relative attractiveness of the two types of requirements. Functional requirements can be likened to Neo, the handsome protagonist of *The Matrix*, whereas NFRs are more akin to the aesthetically-challenged Cypher. Neo is easy on the eyes and what we naturally fixate on. Examples of Neo-like requirements include sensor resolution, satellite revisit rates, and reporting latency. These are the "sexy" requirements. We are typically much less concerned with things like modularity, extensibility, and flexibility. These are the dull, Cypher-like attributes. To some extent, this can be traced back to warfighter priorities, which also tend to be much more focused on how lethal, or fast, or strong something is, as opposed to how readily it can adapt to a new threat.

In order to resolve the sex appeal discrepancy, the key is packaging; we need to make Cypher look a lot nicer. We know pursuing Cypher NFRs incurs additional costs or requires technical performance tradeoffs[18] and, at present, there is little incentive for programs to make these investments or trades. To alter the decision calculus, the USSF will need to make it evident that NFRs are at least as vital as the functional requirements, and that can be acceptable—even preferred—to sacrifice some technical performance to achieve that aim. This will require a clear mandate coupled with an accountability mechanism.

A straightforward way to accomplish this would be to specify a comprehensive list of NFR-derived requirements (or better yet, objectives!) that are treated with the same importance as traditional technical performance requirements. They would explicitly address "-ilities" (like survivability, flexibility, and interoperability) by mandating, for instance, common interfaces, modularity approaches, and self-protection tactics. Because NFRs, by their nature, would not be mission-specific (like performance requirements tend to be), there would only need to be a single compilation of NFRs for the entire space enterprise. Thus, the consolidated listing of "enterprise requirements" would then be applicable, by default, to every development activity. In terms of making programs accountable, program "success" would need to be judged not just on whether technical, system-specific performance requirements are met, but also whether enterprise requirements are met.

Quantification Issues. A second reason that NFRs are treated with little regard is that they are generally perceived as being much harder to quantify. There is some truth to this. For instance, resilience (at least in the context of space architectures) has yet to be quantified or even credibly defined.[19] This is also the case for changeability, adaptability, and extensibility. However, measures *do* exist for many other NFRs, to include modularity,[20,21] flexibility,[22,23] and elements of system survivability,[24] so the notion that NFRs are not quantifiable is not fully accurate.

Addressing the difficulty of NFR quantification is easy in principle, but admittedly harder in practice. For cases where metrics exist, the USSF will need to document and promulgate them; an obvious method would be as part of the enterprise requirements. For cases in which metrics do not exist, the USSF will need to establish them, or identify acceptable proxies. At the end of the day, if we can't define and quantify "resilience," we can't assess our progress toward achieving it. Furthermore, and perhaps even more importantly, the USSF will need to formally account for NFRs in its value models (ideally in tandem with the traditional functional requirements) in a way that enables us to make smart, enterprise-driven trades between functional and non-functional requirements.

Implementation Challenges. The third reason that NFRs are largely ignored is because of how hard they can be to implement, especially from the perspective of an individual program. Even assuming we can effectively quantify resilience, how does a single program achieve it? It is an inherently *architectural* attribute involving a collection of different systems.[25,26] Success hinges on detailed, strategic planning and integration activities involving a multitude of separate systems over many years. This would include flexibility (e.g., common satellite bus attachments), deployability (e.g., agile launch), sustainability (e.g., on-orbit servicing), defendability (e.g., defense force packages), and interoperability (e.g., propagation of community standards) and many others, all of which must come together to achieve resilience of the overall capability. Implementing NFRs is just plain hard, often requiring coordination across disparate activities, which makes ignoring it very tempting.

The solution here becomes clear once we recognize that some NFRs require an integrated, enterprise-wide solution. Because of this, the USSF will need to rely not on individual programs to deliver NFRs, but rather capture these as part of "enterprise requirements" and push overall responsibility for satisfaction of NFRs upwards. Explaining how this would work in practice is addressed in the next section regarding Pillar 2.

Summary of DfP Pillar 1 Recommendations

This paper is the follow-on to the first paper on DfP. Whereas that paper was primarily intended to convey an understanding of what DfP is as capability development methodology, the purpose of this paper is to provide specific recommendations regarding how to implement it. To make that goal easier, the below table summarizes the key recommendations related to the first pillar (similar tables will be found at the end of each pillar discussion). Furthermore, to make this more executable, one or more primary actionees is specified in each case, as follows:

- **SP/SPO.** Refers to acquisition "solution providers" (e.g., SMC, SDA, SpRCO) and/or associated System Program Offices. Because this category of actionee is relatively low level, these types of recommendations tend to be the most straightforward and easiest to implement.

- **OSD/HQ USSF.** These recommendations require action from the Office of the Secretary of Defense and/or Headquarters, United States Space Force. Due to the higher level of coordination and/or approval involved, these types of recommendations will likely be more challenging to enact.

- **COCOM.** Some recommendations will require involvement from the Combatant Command (or similar end user). These types of recommendations aren't necessarily harder, but the involvement of a different or broader constituency could complicate the implementation.

- **Congress.** These types of recommendations will almost certainly be the most difficult to implement. Fortunately, there are only two recommendations (across all four pillars) that list Congress as an actionee; however, they are both critical to fully realizing the power of DfP.

Table 1: Implementation Recommendations for DfP Pillar 1		
Recommended Action	**Principal Actionee(s)**	**Notes/Rationale**
Objective-Based Capability Development Use objectives in lieu of requirements for higher level needs; minimize total number of top-level requirements regardless.	☐ Congress ☒ **COCOM** ☒ **OSD/HQ USSF** ☐ SP/SPO	Reduces decomposition errors and likelihood of requirements creep; enables speed, broadens design tradespace, and improves solution flexibility and validity.
Continuous User Engagement Formally establish extensive, ongoing dialog between developers and customers to ensure continued validity of objectives.	☐ Congress ☒ **COCOM** ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Developer remains apprised of warfighter priorities, and warfighter is informed of system status; ensures development objectives remain relevant and operationally focused.
Rapid Incremental Development Ensure that developers frequently deliver beneficial capability increments.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Provides frequent, direct validation and enables more responsive re-vectoring; establishes tangible benefits to operator sooner. Supports "celerity cycle."
Pervasive Competition Extend formalized competition between development contractors to more program types and more program phases and perhaps even govt organizations.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Leverage power of competition in more ways to reduce cost/schedule and increase innovation; strengthens industrial base, mitigates "vendor lock," and supports vision of more proliferated architectures.
Enterprise Requirements Establish common, mandatory set of non-functional requirements applicable to every system in the enterprise.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Elevates importance of "-ilities" (like flexibility, interoperability, and capability survivability); inherent in this approach is willingness to sacrifice some system-specific performance for benefit of the enterprise.
Non-Functional Requirements Define every NFR and establish corresponding method of quantification, to include associated metrics for inclusion in enterprise value models.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Without clear definitions and metrics for each NFR, there can be neither an analytical underpinning to justify necessary trades with traditional performance requirements nor a viable means to monitor progress.

Keep the Big Picture in Mind (DfP Pillar 2)

Perhaps we are asking the wrong question.

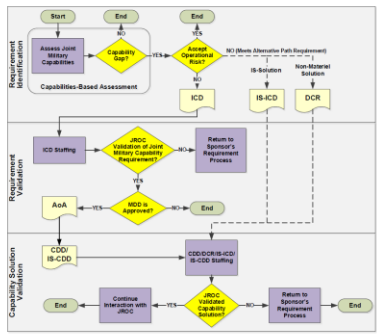
—Agent Brown, *The Matrix*

As discussed in the previous paper, the central thrust of the second DfP pillar is ensuring that top-level requirements are conveyed at the capability level, not the system level. The purpose of this is, in part, to sidestep intrinsic problems with decomposition in complex systems. But the more compelling reason not to convey requirements at the system level is to minimize stovepiped solutions and to broaden the design tradespace. This promotes the possibility of a given system simultaneously supporting multiple space mission capability areas (e.g., Missile Warning and Space Domain Awareness) as well as accounting for—and better integrating—various enabling "foundational capabilities," which can be better provided as enterprise *services* across the entire enterprise.

This idea represents a transformative shift in architectural strategy. To successfully implement it will require significant companion changes in other aspects of capability development, including how requirements and resources are established and allocated (see next two sections: "Rethinking Requirements" and "The Smart Money") as well as how to effectively synthesize the requirements and resources into integrated capabilities across the entire USSF (see "Digitized Enterprise").

Rethinking Requirements

We've already discussed a couple key aspects of how to fix the requirements: We should pursue objective-based capability development and elevate the priority of non-functional requirements by establishing enterprise requirements. In tandem with these changes, however, we will also need to address the most foundational requirements problem of all—how requirements are initially formulated, validated, and conveyed to the armed services. This is, of course, the ponderous Joint Capabilities Integration and Development System (JCIDS) process (which is not for the faint of heart, nor the acronym averse).



As a quick overview for the uninitiated, the first step in the deliberate JCIDS process is to conduct a Capabilities-Based Assessment (CBA), which typically leads to an Initial Capabilities Document (ICD). The ICD captures the joint capability requirements and associated capability gaps that will need to be addressed by materiel and/or non-materiel approaches. Once an ICD is validated, an Analysis of Alternatives (AoA) is conducted for potential materiel solutions, which culminates in one or more Capability Development Documents (CDDs). The CDD generally describes a system-specific solution along with a corresponding set of approved performance attributes (e.g., Key Performance Parameters, Key System Attributes) as well as any relevant Doctrine, Organization, Training, materiel, Leadership and Education, Personnel, Facilities, and Policy (DOTmLPF-P) considerations.[27]

The official procedural guidance for executing the JCIDS process is "conveniently" described in a 341-page manual, so summarizing it in a few sentences requires some significant simplifications. But here's the key takeaway: A whole lot of decisions are made—and a whole lot of tradespace is consumed—prior to the point where a service is allocated the responsibility to deliver the validated capability. In one sense, this is perfectly reasonable since the expressed purpose of the JCIDS process is "to assess joint military capabilities, and identify, approve, and prioritize gaps in these capabilities."[28] Logically, to enhance collaboration across the DOD and facilitate joint warfighting solutions, JCIDS must restrict the solution space to some degree. However, the current state of the practice has become overly prescriptive, smothering flexible and agile solutions and precluding DOD components like the USSF from devising agile enterprise solutions.

Without question, the JCIDS process plays a critical role in the nation's ability to identify and prioritize military capability gaps as well as ensuring that potential solutions are risk-informed, cost-informed, and ultimately combat-effective and interoperable across the joint force. This role must continue. What needs to change is the level and degree of solution specification that is provided to the Services. The JCIDS process needs to remain focused on the question of *what* is needed and stay as far away as possible from the question of *how* it will be done. By making preliminary assumptions about materiel versus non-materiel options and by stipulating system-specific solutions (as is usually the case for CDDs), JCIDS is overly constraining the solution space before the internal service-based processes can even commence.

In line with the first pillar of DfP (i.e., "Don't Be Obsessed with Requirements"), a far better option would be to capture and validate the capability need (i.e., the objective) and determine which Services will contribute which capability increments along with their respective interoperability responsibilities. Then, in accordance with the recommendation for "Continual User Engagement," the Joint Requirements Oversight Council (JROC) would step back and let each service pursue its assigned capability increments—and work together as necessary with each other and the warfighter—to deliver them. Arguably, this is not even a change in the purpose of JCIDS; rather, it is more a restoration of its original mandate.

Consider a recently released JROC memo, which states, "The JROC will validate requirements in a top-down, broad and strategic manner to provide Services clarity on Joint Force capability needs while allowing flexibility on how to deliver those capabilities for the Joint Force."[29] This is precisely the right sentiment, but additional implementing details are needed. For starters, the JROC must stop issuing system-centric CDDs to the services, effectively enshrining a cloistered mentality from the start and handcuffing integrated solutions among the entities charged with capability development. Consistent with the premise of capturing the "what" versus the "how," the JCIDS process should allocate capability increments of the ICD—not the CDD—to certain services and allow them to create CDD-equivalent guidance across their respective enterprises as part of a set of integrated materiel and non-materiel solutions.

Here's how this could work in practice. Suppose that following a CBA, an ICD is established that documents the joint requirement (and existing gap) for providing the warfighter with rapid, reliable, secure communications anywhere on earth. Performance attributes are established (e.g., bandwidth, latency, survivability), but they are high-level and are system-agnostic. And instead of a lengthy (i.e., yearlong) AoA, there is rapid assessment and interchange with each of the services to determine who is best-suited to contribute to addressing this gap. For this hypothetical scenario, the result is that the responsibility for the predominance of the capability increment is allocated to the USSF as part of a SATCOM (satellite communication) solution with an additional augmenting increment allocated to the Air Force as part of a persistent airborne solution. Of course, the JCIDS process would continue to include the mechanisms to identify and enforce interoperability between the two services as well as the combatant commands.

The problem is that America is playing a losing game. Over many decades we have built our military around small numbers of large, expensive, exquisite, heavily manned and hard-to-replace platforms that struggle to close the kill chain as one battle network.

—Christian Brose
The Kill Chain[30]

Extending this scenario, the USSF would know it cannot consider this ICD in isolation; its internal DfP-based approach to capability development would seek synchronized, enterprise-level solutions with other ICDs allocated to the USSF (e.g., Missile Warning, Positioning, Navigation, and Timing, and Space-Based Environmental Monitoring ICDs). As such, the USSF would pursue an integrated combination of materiel and non-materiel solutions that collectively and symbiotically contribute to a mutually reinforcing lattice of kill chain capabilities that span *all* relevant ICDs. Furthermore, as the USSF devised the SATCOM solution, they would seek a hybrid approach involving a family of space systems in different orbital regimes across an architecturally diverse constituency, to include not just sister services, but also other national agencies, international partners, and commercial services.

This last point about the inclusion of non-DOD entities is crucial. Involving additional stakeholders outside the DOD can confer significant tactical and strategic benefits, ranging from the inclusion of unique capabilities, to enhanced adversary deterrence, to increased affordability. Yet this is decidedly not the historical purview of JCIDS. As broadly intentioned and big-picture-focused as JCIDS aspires to be, it is only scoped to address efficiency and interoperability across the U.S. military services. And, to be clear, this is not to suggest that that JCIDS scope should be expanded (imagine how unwieldy it would be to have to reconcile multiple JCIDS-equivalent processes across multiple nations); in general, the services are best suited to identify and forge these partnership opportunities, and a truly enterprise process should foster that.

The driving force behind this approach is the DfP pillar of "Keep the Big Picture in Mind," which compels us to optimize across the enterprise even at the (marginal) cost of component segments and programs. This likely means that the most affordable, flexible, and survivable way to meet *all* joint warfighter requirements will call for some performance and risk offsets at lower levels. In other words, a relatively minor sacrifice involving a couple of systems could easily result in asymmetric benefits to the enterprise.

The consummate example of this dynamic are the cross-cutting, foundational capabilities that permeate all space mission areas (e.g., data management, data transport, logistics, command and control [C2]). Within the current JCIDS process that provides largely siloed CDDs, programs of record are necessarily predisposed toward developing custom solutions for each of these functions, such that the enterprise is burdened with an increasingly unwieldy patchwork of mission-unique architecture enclaves. The USSF has processing and storage facilities that can only handle one particular type of mission data; the USSF deploys C2 software that only works with one set (and specific number!) of satellites; the USSF builds satellites that are incompatible with standard launch interfaces. And on and on and on…

You've felt it your entire life, that there's something wrong with the world. You don't know what it is, but it's there, like a splinter in your mind, driving you mad.

—Morpheus, *The Matrix*

The solution to this dilemma—and what a recalibrated JCIDS process described here could enable—is to *"bake-in" enterprise perspectives from the outset*. For the USSF, this means establishing the set of force-multiplying functions that every mission needs and provide these as common enterprise services to all missions. This notion is revolutionary, as it flips the focus from a disconnected set of stovepiped missions to an integrated set of "capability utilities" that provide a singular foundation that each mission can "plug into" or "subscribe to." This notion of the *architecture-as-a-service* — and ensuring conformance to it — is not only more cost-effective and combat effective in the aggregate, it is the only feasible way to develop an integrated enterprise. Linking this back to the JCIDS process, clearly the best way to determine the necessary overall service provisioning levels is to consider all of the ICDs in concert.

An additional advantage of the architecture-as-a-service approach is that the USSF gains inherent mission flexibility and fungibility. In an uncertain and dynamic environment, the USSF should not constrain its architecture to current conceptions of what space missions can or should be. In the not-too-distant future, the USSF may be asked to support or lead missions currently accomplished elsewhere in the DOD (e.g., global transport) or to adopt new missions no one is doing (e.g., asteroid interdiction). An architecture that is built around enterprise services can much more readily accommodate the addition of a thin layer of mission-unique capability overlaid on increased service capacity or easily exchange one mission for another.

At the end of the day, the JROC should serve as the clearinghouse of joint capabilities across the services, ideally remaining focused on capability gaps (i.e., the "what") and service interoperability concerns so each branch can determine the right combination of common services, programs, and DOTmLPF-P solutions (i.e., the "how") that will deliver those capabilities. Although this revision to the JCIDS process described in this section would arguably benefit the entire DOD, it does admittedly represent a massive paradigm shift. To help reduce the perceived risk and gain buy-in, it could be instituted on a trial basis within the service that is the newest, smallest, and most keen to break the mold on how agile a military service can be (yes, USSF, this is you).

The Smart Money

Establishing top-level requirements that enable development of enterprise solutions is a necessary step in realizing the second pillar of DfP; however, it's not a sufficient condition, per se. Without the same strategic flexibility for the resources to accompany those solutions, the process is unlikely to be executable. In other words, if requirements are capability-focused and enterprise-based, but resource planning and funding remains system-centric and tactical, then we still fail.

For some perspective, consider how the analogous process works in China. First, they establish a long-term plan. Second, they stick to it. Third, they fund it in a logical, deliberate fashion. Readers are likely aware that China is in the midst of a century-long, coordinated investment effort to become the world hegemon,[31] which necessarily requires immense strategic patience and consistency. To achieve its long-term goals, the Chinese government establishes ongoing, structured resource plans integrating social, economic, and defense initiatives that span five years.

Contrast this with how things work in the United States, where enduring strategic thinking is practically unheard of. Although long-term strategies are occasionally developed in certain factions of the U.S. government, they are certainly not integrated across the federal government, let alone national defense. Can you imagine the DOD consistently pursuing a 100-year investment strategy or even establishing one in the first place? Of course not—that's crazy talk.

The result is that, with respect to resourcing decisions, Chinese *tactical* timelines are on the order of American *strategic* timelines. Whereas China invests in a series of five-year plans in the context of a much larger strategy, the U.S. commits resources once a year in support of a five-year strategy (via the Future Years Defense Program, an annual, obligatory report to Congress). And even this annual funding line is perennially unstable due to self-imposed wounds like delayed authorizations, budget sequestrations, debt ceiling fights, continuing resolutions, and government shutdowns. And that's just the beginning. When funds do become available, they include significant constraints on how they are used, and this effectively thwarts any possibility to "Keep the Big Picture in Mind."

When it comes to national budgeting strategy, the U.S. is its own worst enemy. So what can be done?

Some of this may simply not be fixable because it is indelibly linked to American history and culture and is now fully imbued in our way of governance. The notion that the allocation of resources to the DOD could be stable and synchronized with a long-term, integrated strategy across the whole of government would likely take a miracle of major proportions. There is just too much pervasive dysfunction in the nation's contemporary political environment to resolve that anytime soon. But with the establishment of the Space Force, there is a generational opportunity to fix the next level down. And this, perhaps, would only require a *minor* miracle.

Of course, we need to be clear about what is wrong with that "next level down." We know that the statutory responsibility of the USSF is to organize, train, and equip (OT&E) space forces in support of joint warfighting capabilities. This is obviously a wicked management challenge involving an extraordinary number of interrelated and continually changing factors. To have any chance of being successful, one logically needs the ability to rapidly move resources where needed. The Chief of Space Operations (CSO)—as the head of the USSF—is the individual who has this OT&E responsibility; however, the CSO lacks the basic budgetary flexibility necessary to do the job.

The first problem is the rigid and exclusive establishment of appropriation categories (so-called "colors of money") whereby funding earmarked for one category may not be used for any other. Even if operations (using the Operations & Maintenance (O&M) appropriation) have come to a standstill waiting for a new facility to be constructed (using the Military Construction (MILCON) appropriation), no operations funds may be used to accelerate completion of that facility. Similarly, if a new class of threat were to emerge during the production of a particular satellite system (using the Procurement appropriation), none of those production funds could be used toward devising a new way to counter that threat (they instead would have to come from the Research, Development, Test and Evaluation (RDT&E) appropriation).

The way that the Air Force and now Space Force put their budget submissions into Congress, it puts all of the programs into individual program elements, and that's like locking [each] program into a little financial prison.

— Dr. Will Roper
Air Force Assistant Secretary for Acquisition, Technology, and Logistics[32]

The second problem is the overly specific funding lines based on established *programs of record*. Congress currently allocates DOD funding largely on a program-by-program basis, and this funding cannot be used for any other purpose. Even within the same capability area (e.g., in support of a single ICD), this is not allowed, such that the CSO is barred from reallocating funding from a missile warning program running ahead of schedule to one running behind schedule[†] even if there are crucial interdependencies between them. And certainly no portion of the funding that has been appropriated for the procurement of that missile warning system may be used to accelerate the procurement of a C2 system, even if that C2 system is critical to the functionality of many other systems, including said missile warning system.

The third problem is the stringent rules regarding the timing of expenditures, which tends to promote gross spending inefficiencies and discourage long-term planning. Because the funds for each appropriation category are only valid for a limited time (ranging from one year for O&M to five years for MILCON), there is often a "use it or lose it" mentality that prevails. Based on market conditions or threat environment, it might be preferable to delay production of a particular system or put on hold a certain RDT&E activity, but doing so under current rules means a high likelihood of receiving less funding in the future or losing funds entirely. Conversely, there may be a powerful opportunity to reduce lifecycle costs with a one-time investment right now, but unless the funding required is very small, this is prohibited as well.

The upshot of all of this is that, although the CSO does approve the top-level USSF annual budget request, he or she has extremely limited authority to adjust those resources during the execution phase. For the most part, funds may not be moved between appropriation categories, may not be moved between efforts, and may not be advanced or delayed. We have to ask the obvious question: Does it make sense to hold someone accountable for the OT&E of an entire service, but hamstring that person from making even the most basic decisions in how the financial resources are executed to achieve those objectives?

And while it's certainly appropriate for Congress to exercise its constitutional right to appropriate public funds on behalf of the federal government, there is little rational justification for this level of constraint and micromanagement. Allocating funding based on strict, stovepiped categories for very short durations and providing detailed budget edicts and onerous oversight down to the individual program level actively undermines the DfP principle of "Keep the Big Picture in Mind" (not to mention basic management principles). The bottom line is that the USSF cannot possibly develop and field broad, flexible capabilities if the accompanying resourcing structure is egregiously narrow and inflexible.

Fundamentally, the USSF needs to empower senior leaders with budget authority that is commensurate with their command authorities. These leaders are the people who possess the necessary expertise on what needs to be done to accomplish the mission; let's give them the tools to do their job and hold them accountable. Relative to the USSF, this means enacting the following changes:

- **Service-wide Resource Authority**. Grant a single person (presumably the CSO[‡]) multi-year (at least five) total obligatory authority (TOA)

[†] Technically, under certain limited circumstances, a relatively small amount of money (on the order of $10 to $20 million) may be "reprogrammed" within a particular appropriation category in a particular year.

[‡] An argument could also be made to combine these authorities within a different position such as the Secretary of the Air Force or the Service Acquisition Executive; regardless, the key point is that authorities and accountability must be better aligned.

for all of the funding associated with "National Security Space" (i.e., Major Force Program (MFP) 12). The TOA should be an amount established and approved for a rolling five-year period, which is to be allocated within the USSF as determined by the CSO. The funding should not be broken out by appropriation nor earmarked for specific activities (i.e., no designated program elements). Congress should authorize and allocate a single funding amount to MFP-12 to be used as the CSO deems appropriate.

- **Accountability by Capability**. Granting the CSO flexible spending authority is not free license to sidestep oversight nor an excuse to forego sound accounting practices, which are critical to assessing return on investment. So while the CSO should certainly maintain a financial management structure that supports tracking where and how money is spent, the emphasis of that structure needs to change. Since the purpose of the USSF is to deliver *capabilities*, not *programs*, the accounting—and associated accountability—should be configured accordingly. Therefore, instead of the world revolving around a cadre of program managers, the USSF should establish and empower a smaller, select group of "capability managers" who would be responsible for delivering capabilities and managing resources to satisfy ICDs. Although the use of program elements and the existence of program managers would likely persist for the purpose of internal accounting granularity and transparency, the new central focus must be on capability managers who would oversee a corresponding "capability element" line item consisting of a non-exclusive portfolio of programs.

- **Prioritize the Foundational Capabilities**. That leaves the question of what the capability categories should be as well as their relative importance. Generally speaking, there are really just two categories of capabilities. The first is the warfighter-focused, ICD-driven capabilities; these could be broken out according to traditional space mission areas (e.g., Missile Warning, Positioning, Navigation, and Timing) or aligned to broader considerations of warfighter effects, such as "space superiority," "multi-domain awareness," or "spectrum dominance." The second category is the foundational capabilities (e.g., data transport, data management, etc.), and these are the ones that must be the strategic resourcing priority for the USSF if it wants to establish an agile and integrated enterprise that can readily accommodate changes to the first category of capabilities. Over time, under the DfP vision of architecture-as-a-service, the predominance of the resources should eventually go to the enabling "capability utilities," thereby allowing mission-unique elements to be quickly and efficiently modified as circumstances warrant.

[T]he purpose of the USSF is to deliver capabilities, not programs.

Of all the recommendations in this paper, these three may be the most critical. However, they may also be the most difficult to implement because they will require (literally) an act of Congress. And Congress is notoriously disinclined to relinquish any of its appropriation authority. Yet there is reason for hope. Decades of growing frustration with DOD acquisition outcomes may have primed Congress to be willing to pursue a bolder solution, especially if it can be pursued on a relatively limited, low-risk basis. Once again, this is where the Space Force may be uniquely situated to capitalize on this moment. Like the novel requirements recommendations above, these proposed changes to the money side of the equation could be enacted on a limited or trial basis for the service whose funding line represents a tiny fraction of the annual defense budget[33] and is eager to prove—given the right tools and authorities—exactly how nimble it can be.

Digitized Enterprise

Keeping the big picture in mind is easier said than done. Every level we move up in the capability development tradespace, the more that needs to come together. We have to account for more stakeholders, more relationships, more integration challenges, and more interoperability considerations. As spelled out in the previous paper, the notion of c*omplicated* quickly gives way to *complex*. With respect to the myriad requirement and budget considerations discussed above, the USSF needs a mechanism to manage and synchronize all of the dizzyingly intricate interdependencies across every aspect of design, development, fielding, and operations (some communities are referring to this as "Mission Integration Management"[§]).

The answer is to go digital, as in *digital* engineering (DE). The DOD defines DE as "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."[34] To manage the enormous complexity of capability development across the space domain, the USSF should make extensive use of DE.

The full implications of what it could mean to implement DE across all aspects of the capability development are still being determined within the community, but they are potentially game-changing. Although much of what we do today is "digital" in the sense that it involves computers, models, and software, we've only scratched the surface of what's possible to achieve within a fully integrated digital ecosystem. Imagine if everyone in the USSF could instantly access the most current "authoritative source of truth" regarding any aspect of their job. Imagine no more reports or briefings, but instead direct exchanges of data and information to inform all levels of decisionmaking. Imagine a seamless virtual thread that binds together the lifecycle of a capability, dismantling the artificial barrier between acquisition and operations.

Sound like science fiction? Not at all. This ambitious vision will take some time to achieve, certainly, but the journey is already underway. DOD leadership clearly recognizes the power of DE. Dr. Roper (whose comments have been featured a couple of times already) recently authored a "thought piece" publication meant to disrupt the thinking within the acquisition community. In "There Is No Spoon," he asserts that "the digital world is now a primal acquisition battlefield where future wars will be won or lost. Seeing how deep this rabbit hole goes could not be more imperative."[35] He lays out numerous ideas for investing in DE across the defense acquisition community and some specific actions, some of which can serve as implementation recommendations for the USSF "Digitized Enterprise."

Moreover, the USSF recognizes the extraordinary opportunity here and has begun enacting the first

[§] Mission Integration Management is "the synchronization, management, and coordination of concepts, activities, technologies, requirements, programs, and budget plans to guide key decisions focused on the end-to-end mission" [61].

steps toward becoming a fully digital Service. "Create a Digital Service to Accelerate Innovation" is one of five priorities articulated by the CSO in his recently released planning guidance, which states that the USSF will "lead efforts to implement Digital Engineering standards for Space Force acquisition programs."[3] The CSO has also published his Vision for a Digital Service[36] and formally established a headquarters office (i.e., the Technology and Innovation Office) to oversee the transformation of the USSF to a digital service.[3] Meanwhile, Space and Missile Systems Center (SMC) has embarked on an effort to establish the necessary infrastructure to bolster DE, to include adoption of shared repositories (e.g., Cloud One) and shared software factories (e.g., Platform One).[37] Further, individual space programs have already made significant gains toward virtual threads by leveraging "digital twins" of systems to accelerate development and fielding.[38]

To these efforts already underway, there are a few other recommendations that should also be considered. One, the notion of an "authoritative source of truth" can be an immensely powerful enabler for speed and efficiency, but it also represents an inherent vulnerability. The USSF will need to establish the right balance between broad, collaborative access and the need to safeguard the "keys to the kingdom." Two, the USSF should ensure that it establishes the right incentive structures (e.g. funding) to encourage programs to embrace DE; there is an "activation energy" associated with adoption of DE that must be overcome. Three, and on a related note, the USSF needs to recognize that the transformation to DE will be at least as much cultural as it is technical. There will need to be significant attention on outreach activities to the workforce and ensuring all personnel are equipped with the right digital skillsets, and *mindsets*, to succeed in a DE environment.

To be clear, the rationale for a digital transformation in the USSF is, in no way, exclusive to DfP. DE is a powerful enabler for whatever capability methodology is used in a complex domain, and should be pursued regardless. But whereas SE is merely strengthened by DE, DfP is far more dependent on it. Pillar 1 (i.e., "Don't Be Obsessed with Requirements") and Pillar 2 (i.e., "Keep the Big Picture in Mind") both rely heavily on the ability to manage colossal complexity as well as a willingness to "Embrace and Understand Uncertainty" (the third pillar discussed next). Further, DE enables and propels the kind of speed and agility that is the most central feature of DfP that will be addressed in the final section, "Go Fast." In other words, DE is foundational to achieving DfP in a multitude of ways, and this paper highly encourages the USSF to continue investing in it.

Summary of DfP Pillar 2 Recommendations

The table below summarizes the key recommendations related to the second pillar using the same structure as the previous recommendation table.

Table 2: Implementation Recommendations for DfP Pillar 2		
Recommended Action	**Principal Actionee(s)**	**Notes/Rationale**
JROC Strategic Focus Validate the joint capability need only and allocate capability increments to services along with appropriate interoperability requirements.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☐ SP/SPO	Validate Initial Capabilities Documents (ICDs) and delegate responsibility to satisfy portions of ICD to services; broaden tradespace by allowing services to determine optimal balance between types of solutions.
Architecture-as-a-Service Establish the set of force-multiplying functions that every USSF mission needs and provide these as common enterprise services.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Shifts focus from disjointed set of stovepiped missions to integrated "capability utilities" that each mission plugs into; more cost-effective and flexible, and only feasible way to develop an integrated enterprise.
Service-wide Resource Authority Grant CSO multi-year, comprehensive total obligation authority for all funding associated with Major Force Program 12, commensurate with command authority.	☒ **Congress** ☐ COCOM ☒ **OSD/HQ USSF** ☐ SP/SPO	One person must be able to apply funding where and when needed to fulfill organize, train, and equip role; must be able to rephase funding and shift between appropriation categories and programs to optimize the enterprise.
Accountability by Capability Realign central focus of management accountability away from programs to broader portfolios of capabilities.	☒ **Congress** ☐ COCOM ☒ **OSD/HQ USSF** ☐ **SP/SPO**	The purpose of the USSF is to deliver capabilities, not programs; capability managers would be responsible for delivering capabilities and managing resources to satisfy ICDs.
Prioritize the Foundational Capabilities To realize Architecture-as-a-Service, the strategic resourcing priority must pivot to the enabling infrastructure.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Enables an agile and integrated enterprise whereby mission-unique elements can be quickly and efficiently modified as circumstances warrant.
Digital Service Seize the generational opportunity to leverage digital approaches for more agile capability development, particularly with respect to implementation of Digital Engineering (DE).	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Only viable approach to manage this level of complexity; ensure sustainability through right governance structure, the supporting information technology infrastructure, the necessary security, and appropriate incentives/training.

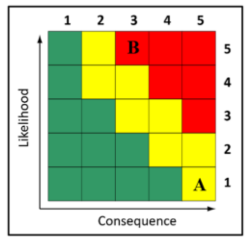
Embrace and Understand Uncertainty (DfP Pillar 3)

With respect to the treatment of uncertainty, the prior paper lays out the stark differences between traditional DOD SE and DfP. To summarize these differences—

- SE seeks to suppress uncertainty, ignoring it or "mitigating" it wherever possible; DfP embraces it knowing every source of uncertainty serves as additional justification for investing in the "-ilities."
- SE tends to consider only the downsides of uncertainty (i.e., risks); DfP considers uncertainty more holistically, to include the upsides (i.e., opportunities).
- SE risk management is inherently tactical, largely focused on individual programs; DfP is strategic, considering uncertainty at the enterprise level and in the larger context of operational capabilities.
- The way that SE treats uncertainty is generally overly simplistic and mathematically invalid; DfP seeks to characterize the full spectrum of uncertainty in a manner that is more mathematically sound.

In sum, DfP, in contrast to traditional SE practiced in the DOD, recognizes that uncertainty is a fact of life that can be understood—and sometimes exploited—as long as we are willing to confront it in a robust way. In terms of changes to current risk management processes, the "Stop the Stoplight" section will provide recommendations related to the first three items listed above. The fourth item will be addressed in the subsequent section, titled "Strategic Uncertainty Management," which illustrates the need to reconceptualize risk in the context of a use case familiar to many in the space community. Finally, we address the cultural implications of this new approach to uncertainty in "Incentivizing Innovation."

Stop the Stoplight



Anyone who has spent any time in or around a DOD program office has probably seen some version of the (in)famous risk "stoplight" (or "heat map") chart. There are a number of versions in use, but the most common variant is almost certainly the 5x5 matrix, which is consecrated in DOD guidance.[39] This guidance specifies that the probability of some event occurring should be shown on the vertical axis as five discrete levels of increasing *likelihood*, and the significance, should that event occur, will be captured on the horizontal axis as five discrete levels of increasing severity of *consequence*. Thus, every risk has some estimated likelihood and consequence, the pairing of which places it in one of the 25 cells of the risk matrix. Each cell is pre-assigned one of three colors (i.e., green, yellow, or red) that corresponds to a particular level of risk (i.e., low, moderate, or high).

Let's first explore all of the good things about the risk stoplight chart. First, it's highly intuitive—easy to create and easy to understand. Second… well, there is no second. There are really no other merits to the risk matrix. Like *functional availability* discussed in the previous paper, the core concept is deeply flawed, both logically and mathematically. Yet we continue to use it because it simplifies decisionmaking, packaging complex concepts into an easy-to-understand, pretty little package. The fact is, however, we are deluding ourselves, and the structure and application of the stoplight chart is a hot mess. Let's talk about why. (Warning: There's a little bit of math in the upcoming discussion.)

The flaws with the risk matrix approach are extensive and well documented; some of the more significant and obvious are as follows:[40,41,42]

- **Coarse Resolution**. Based on predefined criteria, specific levels of likelihood or consequence have to be binned into one of just a few levels. These levels are an ordinal level of measurement, which means they are merely qualitative, ordered ranks rather than having a strict numerical relationship. The conversion from a higher level of measurement (e.g., from a specific probability on a 0–100 percent ratio scale) to a lower level of measurement necessary creates data loss and distortions. Using the standard DOD criteria for likelihood levels,[39] this gross discretization of a natural continuum gives rise to situations where one pair of events binned into levels one and five could reflect a mere fourfold difference in likelihood (i.e., 80 percent versus 20 percent), but another pair of events binned into the same two levels could have a likelihood difference of almost two full orders of magnitude (i.e., 99 percent versus 1 percent).

- **Range Compression**. Another implication of discrete categorization is that it results in the assignment of identical ratings to what are quantitatively very different risks. This phenomenon can manifest itself at any categorical level but is most pronounced at the highest and lowest levels where orders of magnitude differences are necessarily compressed. Again using the typical criteria for DOD programs, an event that has a one percent chance of causing a 10 percent cost increase over the baseline would be captured in the same cell in the risk matrix as an event that has a 20 percent chance of resulting in a 100 percent cost increase (they would both be in the cell marked with an "A" in the graphic above). Furthermore, Range Compression combined with Coarse Resolution clearly invalidates the whole notion—applied by many programs—of establishing a single risk score based on the product of the likelihood and the consequence levels.

- **Rank Reversals**. Of greater concern than the loss of key information to inform risk analysis is having the resulting risk rating be blatantly wrong. This includes cases where risks that are quantitatively greater are assigned a qualitatively lower level of risk, which happens far too readily in the standard risk matrix. Take the second scenario identified in the Range Compression discussion in which risk "A" reflects a 20 percent chance of a 100 percent cost increase. For a program with a $1 billion cost baseline, this would translate to an expected value (or "expected loss") of $200 million (i.e., $1 billion x 100% x 20%). Compare this to a separate risk which is deemed to have an 80 percent chance of experiencing a 2 percent cost increase above baseline (shown as risk "B" in the graphic). The expected loss for risk "B" would be $16 million (i.e., $1 billion x 2% x 80%). Even though the quantitative level of risk for risk "B" is over 12 times less than that of risk "A," the former is designated as a high risk whereas the latter is only a moderate risk.

To this list, we could add a multitude of other problems:

- **Presumption of Independence**. The isolated treatment of one risk at a time assumes that risks are independent of one another. But in many cases—such as common failure modes—there are inescapable correlations that invalidate this approach, especially with respect to consequence, which includes the always intertwined parameters of cost, schedule, and performance.

- **Bias Toward Negative Outcomes**. Risk matrices, by definition, only consider the downsides of uncertainty while ignoring opportunities. Although the DOD risk management guidance makes mention of opportunities, it is a brief discussion (i.e., just five pages out of a 96-page document), with little explanation on how to implement and no guidance on how to integrate with risks.

- **False Equivalence**. The risk matrix methodology necessarily equates low-consequence, high-probability risks with high-consequence, low probability risks. Whether or not this is warranted is highly situationally dependent. Some efforts and some decisionmakers are inherently more risk-averse than others, and these parameters will likely change over time.

- **Temporal Invariance**. Speaking of time, risk matrices have no mechanism to capture temporal variation to account for the reality that assessments of likelihoods and consequences can change quickly. In fact, there is no organic time component at all — probability and consequence are not qualified in this manner even though probability and consequence can be drastically different depending on whether the time horizon is one week or one year.

Given the extensive gamut of glaring problems with the stoplight chart, it's a wonder that it's so widely used. Truthfully, it's a preposterously simplistic methodology for managing uncertainty in major defense programs. It has the barest veneer of rigor that probably couldn't withstand the scrutiny of a middle-school-level math student. And that's before we even consider the more fundamental problems of DOD risk analysis: The underlying math is invalid, and its inherent value is questionable.

The entire DOD risk analysis framework requires an abdication of the basic tenets of probabilistic analysis. Only the most trivial sources of uncertainty can be accurately captured by a point estimate or via an extremely narrow range of values that conforms to a single discrete category. The vast majority of sources of uncertainty in the real world can only reasonably be characterized with a probability distribution that necessarily spans multiple categories both in terms of likelihood and consequence. But the risk matrix is entirely incapable of incorporating any of these nuances.

The entire DOD risk analysis framework requires an abdication of the basic tenets of probabilistic analysis.

On top of all of this, it's far from clear that risk matrices are even useful. There appears to be no empirical evidence or published scientific studies showing whether outcomes are improved as a result of their use; in fact, there is legitimate concern that they actually lead to *worse than random* decisions. As observed by Thomas, et al., "if risk assessment is a failure, then the best case is that the risk management effort is simply a waste of time and money because decisions are ultimately unimproved. In the worst case, the erroneous conclusions lead the organization down a more dangerous path."[43]

As part of a DfP-driven approach, here are several straightforward steps the USSF can enact to address these problems:

- **Murder the Matrix**. The preceding discussion makes it clear the entire risk matrix concept is so fundamentally flawed it cannot be salvaged through some degree of tweaking. Risk matrices mask complexity and distort reality in dangerous ways. Therefore, our only option is to completely kill them. Let's give our leaders—who tend to be technically savvy—some credit that they can handle a more sophisticated treatment of uncertainty (the next two bullets describe how this would work).

- **Merge Risks and Opportunities**. Risk is generally regarded as the *downside* of uncertainty with opportunities being the *upside* of uncertainty.[**] This can be a useful distinction in some cases, but is often too simplistic and potentially counterproductive. For the most part, there isn't risk management and opportunity management; there is only *uncertainty management* (UM). Both risks and opportunities (along with related scenarios, probabilities, and consequences) must be simultaneously accounted for in any robust valuation of tradespace. It is often unclear whether a source of uncertainty is simply "good" or "bad," and whether it should be considered a risk or an opportunity often varies based on perspective and time. Resources should be used where they provide the greatest return on investment, whether it is mitigating a risk or exploiting an opportunity.

- **Treat Uncertainty as Uncertain**. Other than the most trivial examples (e.g., whether a single coin flip will come up "heads"), uncertainty is not a discrete event. It is a range of possible values with (typically) varying probabilities that must be modeled as a statistical distribution. Moreover, uncertainty should be treated as a *vector* quantity that simultaneously accounts for both likelihood and consequence. For example, simply stipulating there is a 20 percent probability of a $1 million cost impact is borderline nonsense. Although both numerical values might represent *expected* values, the reality is there is likely to be a range of probabilities corresponding to a range of costs. This means we need to develop and maintain joint probability distributions—most likely as part of Bayesian networks—for relevant sources of uncertainty and, crucially, we must explicitly incorporate some degree of temporal phasing.

- **Don't Discard Information**. Ultimately, we must recognize that while UM is a crucial focus area, it is necessarily subordinate to decision analysis (i.e., the process by which leaders make effective, data-driven decisions). As part of our effort to smartly incorporate uncertainty analysis into overall decision analysis, it's perfectly reasonable to seek to simplify complexity. However, the drive toward clarity and understandability cannot reduce content to the point of invalidation. Any translations into stoplight matrices or heat map visualizations should only be done as the *end product* of a stochastic uncertainty analysis methodology, not as a lossy conversion where information is distorted to the point of being "worse than useless."[41]

We also must keep in mind the limits of UM. When executed properly, it can be a powerful tool for coping with "known-unknowns," but only if we have some reasonable means of efficiently and accurately estimating those unknowns. There are two abiding challenges. First, it is neither practical nor cost-effective to identify and characterize all sources of uncertainty. The USSF UM process should focus on areas of uncertainty that promise the best return on investment based on established strategic priorities, value models, and empirics. Second, standard methods of probabilistic modeling are ill-equipped to handle unknowns that are truly, well, *unknown*; some events may be predictable in the sense we have some notion they could happen, but the range of outcomes is inscrutable, and/or the probabilities defy reliable quantification. The previous paper discusses this concept of "deep

[**] This is the prevailing approach in most communities of practice including operational research, decision science, and the majority of engineering domains. There is, however, an alternate view among some in the program management community that risk, per se, includes all types of outcomes whether positive or negative.[40]

uncertainty" in some detail and introduces the practice of Robust Decision Making (RDM). RDM techniques should be formally instilled into all USSF uncertainty management—it is far better suited to deal with "uncertainty about uncertainty" as it rejects single probability distributions in favor of sets of probability distributions, emphasizes robustness over optimization, and provides a more explicit tie to foundational assumptions to improve decisionmaking.[44]

[T]he real power of DfP…is that through its emphasis on non-functional requirements like flexibility and adaptability, it is inherently better postured to effectively respond to the specter of unknown unknowns.

The real quandary are the "unknown unknowns." UM—and traditional SE techniques in general—are wholly unsuited to this category of uncertainty. No matter how thorough or rigorous our analysis may be, these types of events cannot be "managed" by virtue of the simple fact they cannot be foreseen. And this is enormously concerning as this is where the greatest potential for disruption exists. The events that cannot be predicted—or events that are deemed so unlikely they are ignored—are exactly the kinds of events that tend to be catastrophically bad or game-changingly good. This is the premise behind claims like less than 0.1% of adverse events will cause at least half your losses (on the risk side) or less than 0.1% of drugs generate more than half of the pharmaceutical industry's sales (on the opportunity side).[45] The only way to have any reasonable chance of coping with unknown-unknowns is through the intrinsic nature of our architecture so that we're poised to accommodate massive, unpredictable change.

Which is precisely the strength of DfP. Yes, the DfP methodology can be useful for the many instances where we elected not to quantify the uncertainty. Yes, it can fill in the gaps in those cases in which we can't sufficiently quantify the uncertainty. But the *real* power of DfP—what it can do the SE generally cannot—is that through its emphasis on non-functional requirements like flexibility and adaptability, it is inherently better postured to effectively respond to the specter of unknown unknowns. This is what it means to embrace uncertainty—not just that we understand it and will treat it in a more mathematically rigorous way, but that we don't fear it because we prioritize design principles that are inherently better at accommodating it.

Strategic Uncertainty Management

The Evolved Expendable Launch Vehicle (EELV) program commenced in 1995. It led directly to the development of two space launch vehicles: The Delta IV and the Atlas V. As of October 2020, there were 125 satellite launches involving these rockets, and all but one has been successful. The one exception was an EELV demonstration flight that occurred very early in the program.[††] Of note, the failure was not catastrophic; the payload simply did not reach the correct orbit. Even so, these two launch vehicles still have performed satisfactorily 124 out of 125 attempts, which translates to an astounding overall mission success rate of 99.2 percent.

That is a truly impressive track record, especially when one considers how complicated space launch vehicles are (it literally *is* rocket science). The EELV program is a compelling testament to what is

[††] In one other case, the EELV failed to inject an operational satellite into the intended orbit, but the error was recoverable, and the customer deemed the launch a success.

possible with the SE methodology: to date, every launch of an operational system has succeeded. But that's precisely the problem, at least from the perspective of DfP thinking. In traditional SE, achieving a system reliability of nearly 100 percent would be worthy of unqualified commendation. The DfP viewpoint, however, is that this ridiculously high mission success rate is actually indicative of a dangerously insular treatment of risk (and uncertainty).

Consider what tradeoffs were necessary to achieve this feat. Significantly more investment was required—in terms of both time and money—to realize this level of performance (versus, say, a 90 percent reliability). This is likely a significant contributor to the fact that the EELV program did not achieve Initial Operational Capability (IOC) until 10 years after it was initiated, including a 15-month delay in the planned launch of the first EELV and a 52-month delay in the launch of the first heavy-lift EELV.[46,47,48] In addition, the cost of the program has skyrocketed (pun *is* intended), incurring multiple critical cost breaches along the way, such that development costs were 130 percent higher than expected, and unit procurement costs are currently 223 percent higher than originally estimated.[49]

The delay in the EELV IOC wreaked havoc across the space community. Enormous ad hoc investments were needed to extend the life of the previous launch system (i.e., Titan IV) in a desperate effort to get at least some critical satellites into space. Countless warfighters and intelligence professionals incurred adverse impacts because satellite capabilities they were counting on were either stretched thin or simply unavailable. U.S. national security was almost certainly diminished as a result. And, of course, there was a significant opportunity cost; the billions of dollars in overruns to achieve the exquisite reliability for EELV could have been used in any number of other ways to better enhance operational capabilities and/or advance national security.

[A]n entire reconception of risk…is needed—one based on operational capabilities instead of programmatics.

The intent of citing EELV as an example is not to disparage another struggling space program exhibiting cost and schedule overruns. Honestly, that would be like shooting fish in a barrel. The point is to note how traditional treatment of risk often leads to ironic effects. Certain measures of success at the program level (e.g., extraordinary technical performance) can easily have unintentional strategic impacts. This is a natural consequence of failing to "Keep the Big Picture in Mind" in that the traditional conception of risk focuses on minimizing the *development* risk associated with *individual* platform failure. Programs are understandably consumed by eventualities that can jeopardize their established cost, schedule, and/or technical baseline. These are important considerations to be sure, but what actually matters is that the joint warfighter is provided with the right capability at the right time.

As mentioned in the previous paper, an entire reconception of risk (though the lens of uncertainty) is needed—one based on *operational capabilities* instead of *programmatics*. This paradigm shift has two clear repercussions: one for *how* we do uncertainty management, one for *where* we do uncertainty management. For the first, existing uncertainty categories for consequence need to be expanded to explicitly include the current desires of the end user. Acquisition programs are increasingly unresponsive to the rapidly changing space environment, taking an inordinately long time to deliver exquisite capabilities. However, given the dynamic nature of the threats, the operational community would often prefer to have some increment of capability today vs. the “perfect” capability tomorrow. Therefore, just as requirements should be validated by the user, uncertainty assessments should also be validated by the user, but throughout development and not just near the end. And the way to do this is through the “Continual User Engagement” recommendation in the “Objectively Speaking” section (not to mention a healthy sprinkling of “Digitized Enterprise”).

For the second repercussion (i.e., the question of *where*), UM should continue at the program level, but it needs to be augmented with higher-level, integrated assessments. Programs do not exist in isolation. Just as uncertainty is often correlated within a given program, it is also frequently correlated *between* programs. Common failure modes can cascade across multiple programs, exacerbating risks; investment opportunities beyond the reach for any single program can become feasible by pooling resources. Meanwhile, interdependencies permeate the enterprise such that decisions in one program can have unexpected or unintended ripple effects across the larger portfolio. For all of these reasons, uncertainty needs to be managed at least at the capability level, with the ideal candidates being the capability managers identified in “The Smart Money" section. This broader consideration of uncertainty is really the only viable approach to realize the provocative scenario described in the first paper in which we could intentionally initiate four high-risk programs all independently pursuing the same capability and yet still deem the risk of successful capability delivery as sufficiently low.

Eventually, the USSF will need to integrate UM across the entire enterprise, extending well beyond acquisition. Understanding uncertainty is foundational to decision analysis and should be used to inform decisionmaking at every level. In time, and with increasing maturity of a “Digitized Enterprise,” the USSF can incorporate virtually all elements of the decision space, to include architecting, budgeting, intelligence, training, and wargaming.

Incentivizing Innovation

The USSF could create and implement the ideal supporting frameworks for truly embracing uncertainty. Similarly, the USSF could establish the most integrated, broad-based, and mathematically sound treatment of uncertainty imaginable. But none of that will matter much if it doesn’t also address the people side of the equation. The USSF must pair these technical enhancements regarding UM with the right business processes and professional incentives to ensure that the workforce is primed to take advantage of the service’s new perspective on risk.

> ***Failure is an option here. If you are not failing, you are not innovating enough.***
>
> —Elon Musk[50]

Under a DfP approach, failures are acceptable—even desired to some extent. The USSF cannot possibly innovate from a “no-risk” posture. Failures help us learn, and they help us push the boundaries of what is possible; they can even help us go faster if we can “fail smart.” Moreover, with distributed and modularized developmental activities, the failure of one *subsystem* does not necessarily mean the full *system* won’t be successful. Likewise, failure of one *system* does not necessarily mean the *capability* won’t be successful. Bold approaches propelled by strategic considerations of risk are the best way to innovate quickly across the USSF enterprise.

I expect commanders and program managers to accept moderate risk associated with innovation and experimentation to build an agile force that better ensures our long-term competitive advantage in space. Failing to accept the risk that accompanies innovation and experimentation will slow capability development and ultimately transfer risk to Joint warfighters.

—General Raymond
Chief of Space Operations[3]

The problem, however, is that these strategic measures of "success" generally do not translate well to humans. Given traditional assessments of individual performance, it is perfectly reasonable for a person to prefer to avoid assignment to—or responsibility for—a high-risk activity that is, axiomatically, less likely to succeed. Association with a failed endeavor is likely to be perceived as a surefire way to blunt one's prospects for career advancement. For similar reasons, individuals will tend to eschew proposing or actively supporting bold solutions that might be game-changing, but could easily result in a high-profile failure. And forget the idea of prioritizing the enterprise over one's parochial perspectives; under the current system, it's not reasonable to expect someone to accept additional risk on their program to reduce risk for other programs or the warfighter.

Clearly, if the USSF is to have any chance of getting everyone to embrace strategic UM, *individual* conceptions of success will need to be realigned to *enterprise* conceptions of success. Rather than superficially considering outcomes only, leaders will need to look more closely at how those outcomes were achieved. Which members are routinely able to think critically about the status quo and gravitate toward innovative endeavors? Which leaders cultivate an environment that encourages this type of thinking and emboldens members to take smart risks and pursue innovative solutions? Who is adept at recognizing how they fit into the bigger picture and can self-organize to work across functional boundaries to foment success at larger levels? These are the kinds of qualities that should be incentivized in every space professional at every level of the USSF.

The USSF will need to revamp personnel appraisal methodologies. For standard supervisor-based assessments, new rubrics will need to be incorporated that account for the member's demonstrated ability and perceived aptitude to function effectively in a dynamic, fast-paced environment. Other appraisal methodologies should also be considered, to include psychometric-style tests to assess potential for innovation and 360-degree feedback to better capture the member's ability to think more broadly. Similar incentive structures should apply to every component of the Space Force, to include supporting contractors; thus analogous modifications will be needed for applicable contract provisions and, as applicable, award fee criteria. Of course, humans are fallible, and people will still make flagrant mistakes that result in unfavorable outcomes. And these should be treated accordingly; the restructuring of individual performance assessments and contractor assessments to not focus solely on outcomes is not an excuse to abdicate performance accountability. It will be incumbent upon seasoned leaders to be able to discern the difference.

New approaches to recognition will also be warranted. Awards and accolades will necessitate greater consideration to more clearly set the right expectations. It can't be a simple formula of, "well the launch was successful, so everybody on the launch team deserves recognition." If the launch team did everything the same way they always have, and/or the resulting launch was postponed to ensure a "fourth nine" of reliability, that isn't praiseworthy in a DfP climate. The team that aggressively sought to accelerate a launch with a brilliant new approach to payload integration may be the one more deserving of acclaim, even if the first attempt ended in failure.

In a DfP environment where everything is moving much faster (see next section, "Go Fast"), opportunities for growth will be greater, and accountability should be more straightforward than ever before. Delivery of a capability will no longer be a monolithic activity that takes a decade (or two), effectively diffusing responsibility across multiple generations of program managers. Instead, capability development will be both rapid and diversified with far greater continuity. With many concurrent efforts, more individuals will be empowered with opportunities to gain experience and demonstrate proficiency in higher accountability positions. And with shorter timelines associated with each effort, it will be far easier for individuals to remain in place for the full duration of the effort. This nourishes more intense investment in the program from all participants, spurs greater continuity of effort, and reduces ambiguity about who is responsible.

Summary of DfP Pillar 3 Recommendations

The table below summarizes the key recommendations related to the third pillar.

Table 3: Implementation Recommendations for DfP Pillar 3		
Recommended Action	**Principal Actionee(s)**	**Notes/Rationale**
Holistic Uncertainty Conduct comprehensive uncertainty management (UM) that simultaneously accounts for both risks and opportunities in integrated fashion.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Risks and opportunities are not binary and tend to be intertwined; resources should be used where they provide the greatest return on investment.
Uncertainty Is Uncertain Use joint probability distributions for relevant sources of uncertainty and incorporate temporal phasing.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Uncertainty is not discrete; it is a range of possible values with varying probabilities that must be modeled as a time-based statistical distribution with vector components.
Informed Decisionmaking Ensure process supports decision analysis through valid, data-driven techniques that can cope with all types of uncertainty without distortions.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Need for clarity is not an excuse for negligent or lazy analysis that risks worse-than-useless outcomes; confront specter of "unknown unknowns" with screening techniques paired with suitable methodologies like RDM.
Operational Risk/Uncertainty Expand consequence considerations beyond programmatics to explicitly incorporate user preferences and threat pacing issues.	☐ Congress ☒ **COCOM** ☒ **OSD/HQ USSF** ☒ **SP/SPO**	UM should be validated with user via continual user engagement in order to inform tradespace; longer development schedules may reduce technical risk, but often increase operational risk.
Capability-level Uncertainty Management Take more strategic approach to UM by having capability managers look across portfolios of programs.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☐ SP/SPO	Programs do not exist in isolation, and uncertainty is often correlated between programs; use DE to understand and manage enterprise interdependencies.
Personnel Incentive Structure Align individual conceptions of success to enterprise conceptions of success to promote innovation and smart risk-taking.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Instead of considering outcomes only, leaders will need to examine how outcomes were achieved; requires changes to contracts, personnel appraisal approaches, and awards and recognition.

Go Fast (DfP Pillar 4)

MDAPs not only tend to take a long time, but durations are trending worse. As part of the Pentagon's own assessment, it was acknowledged (without a hint of shame) that weapon system cycle times "have increased only from about 5 years to 7 years since the 1980s."[51] That "only" translates to a 40 percent average delay in delivery of critical capabilities to the warfighter. And that's "only" considering the point from program initiation to IOC. The length of time from identification of need to fully addressing that need (i.e., Full Operational Capability, or FOC) is generally twice as long, at least. Relative to the scope of this paper, it should be noted that when development cycle times were analyzed for each type of commodity (e.g., aircraft, ground vehicles, munitions, ships, etc.), satellite programs were easily the longest (with EELV classified separately as its own problem child). Cue the sad trombone.

So, yes, today's major space systems take a very long time to develop, easily seven to 15 years, depending on the particular system and the specific start and stop points we want to use. There's no need to quibble about the endpoints because the duration of most space programs is perhaps an *order of magnitude* too long regardless. Waiting over half a decade for the first increment of capability and over a decade for the full capability is not okay. In reality, it should never have been acceptable, but it's certainly not in today's rapidly changing, complex, and threat-laden space domain.

The problem, in a nutshell, is we are stuck in a cycle of self-reinforcing stagnation (i.e., the "vicious circle of space acquisition"[52]). The longer it takes to build a satellite system, the more we become invested in its success, and the more reliable and exquisite these satellites must be to justify the investment. This translates to even larger satellites with longer service lives, which, in turn, tends to drive even higher levels of reliability and even more performance enhancements, all to the point of increasingly diminishing returns along every dimension and extending development timelines even further. Worse, the stagnation cycle isn't confined to one system—it infects the entire enterprise. Due to the massive investment cost of the exquisite satellite system, risk of loss becomes so unpalatable that innovation is stifled across the board, and virtually all reasonable risk trades are squashed. Ultimately, we are compelled to also spend exorbitant time and money on infallible launch vehicles and elaborate protection schemes to pair with our exquisite satellites. And with each circuit of the stagnation cycle, we increase the fragility of our overall space architecture.

Meanwhile, the longer it takes to build a system, the more likely it is that the requirements will change before we're done, either because the additional time results in more opportunities for requirements "creep" or because the program becomes a "requirement magnet" for other needed capabilities. This latter eventuality is particularly pernicious as it can cripple whole families of programs and potential programs. When a program achieves a certain size, it's like a black hole for any and all requirements and technology opportunities for no other reason than it's the only game in town and will remain so for the foreseeable future, so everyone else gets sucked in. This predicament is summarized in the aphorism regarding fitting "ten pounds [of requirements] into a five-pound sack"[53] and is exactly how the Bradley troop transport ended up as an amphibious, reconnaissance, fighting vehicle.[‡‡]

The key to fixing this is inverting the stagnation cycle. By infusing the right developmental priorities, we can create an alternate, constructive cycle that feeds on itself to go increasingly faster,

‡‡ If you haven't read or seen *The Pentagon Wars*, you need to remedy that immediately. Seriously, stop reading and go do it now.

stoke innovation, and infuse the principles of DfP across every corner of the enterprise. Below, we'll explore the idea of a positive feedback loop in "The Celerity Cycle" and then illustrate how it can be put into practice using a satellite production example in the "Exquisite vs. Rapid Scenario" section. We'll conclude with a series of specific techniques that can enable the USSF to accelerate and sustain celerity in "The Speed of Agile."

The Celerity Cycle

> ***You're faster than this.***
> ***Don't think you are; know you are.***
> —Morpheus, *The Matrix*

In the acquisition world, there is a concept known as the "Iron Triangle" (sometimes called the "Project Management Triangle"). The vertices of the triangle correspond to the three basic constraints (and risk elements) of a development activity: cost, schedule, and technical performance. The triangle is generally depicted as equilateral to reflect the equal proportional tension between each element such that you cannot adjust one without affecting the others. The *theory* of the Iron Triangle is that all three constraints are of equal importance. In practice, technical performance is almost always dominant.

To some extent, this makes perfect sense. After all, delivering warfighting capability is a service's *raison d'être*, and system technical performance is the most direct proxy for that. But schedule and cost considerations provide crucial constraints on how that performance is delivered; the warfighter often has a capability gap now and can't wait 20 years to have it addressed, and the service has to balance many competing performance requirements and can only allocate finite budget to any particular solution.

But because of the stagnation cycle, everything is out of balance. The obsession with requirements extends to the technical performance they represent such that programs will typically spend whatever time and money is needed to chase exquisite levels of performance, even if it adversely impacts other portions of the enterprise. This is one of the reasons why cost and schedule breaches in defense programs are so much more prevalent than performance breaches (for all DOD MDAPs from 1987-2010, there were 102 total schedule breaches, 60 cost breaches, and only 23 performance breaches[18]). Thus, instead of an Iron Triangle, we create a black hole of performance requirements around which cost and schedule are trapped in orbit.

Even root problem assessments and proposed solutions tend to revolve around the performance requirements. Based on numerous studies and meta-studies, one of the most commonly cited causes for prolonged schedules or schedule growth are issues related to "requirements development, generation, and management."[7,54,55] These studies almost always note that "fast" programs need to have *stable requirements*. The rationale is that requirements creep is the source of all evil; if we can just prevent requirements from changing (i.e., keep pesky operators and the real world from intruding), then programs won't experience delays. These studies are right to identify a correlation between speed and requirements, but, unfortunately, they almost certainly have the direction of causality backward.

The fallacy here is the notion that requirement stability is an input that can be directly controlled. In truth, no matter how committed we may be to keeping requirements stable, there's a litany of things beyond our control that can, and will, wreak havoc on performance requirements. New technologies emerge, unexpected threats arise, markets crash, international relationships realign, operational prerogatives evolve, and so on. Unless we choose to ignore these external factors—and thus risk system obsolescence—it is clear that requirement stability cannot possibly be an *input* to the capability development process.

But requirement stability is still a worthy goal and is something we can drastically increase the likelihood of through one of two inputs we *can* control. One option is to minimize the number of requirements that are subject to change in the first place; this was a key takeaway of the "Objectively Speaking" section. The second option is to reduce the amount of time we are exposed to the hazard of requirement volatility; in other words, we can make *schedule* the dominant vertex of the Iron Triangle.

This makes *schedule* an input, which is a parameter we actually can control if we are sufficiently motivated to do so. Under this conception, the causality is as follows: The shorter you make the program (or, more accurately, the less time there is between capability increments), the more likely it is that the requirements will be stable, and, thus, the more likely we are to be successful. Once we invert our thinking to recognize this, everything else falls into place. A compressed schedule means having fewer requirements (recall "Objectively Speaking") but is predicated upon the ability to rapidly adjust requirements (recall "Rethinking Requirements") and resources (recall "The Smart Money") as circumstances warrant. A shorter timeline also reduces operational risk (recall "Strategic Uncertainty Management") and incubates boldness and accountability for the condensed life of the program (recall "Incentivizing Innovation").

By prioritizing schedule, we work until time expires, and we deliver whatever performance we have at that time (though we can, and generally should, iterate). This breaks the mold. Rather than a pernicious "stagnation cycle," we create a virtuous "celerity cycle." Less time developing the system translates to less cost. The reduced investment in time and money means that failures are not as critical because we can quickly learn and try again, or we can turn to parallel development paths, which are suddenly commonplace because budget is not being sucked into a programmatic black hole. In fact, rapid, incremental development efforts (i.e., prototypes, pathfinders, etc.) create an ecosystem where companion rapid, incremental developments can simultaneously thrive, further reducing the impact of a failure. Stakeholders become more willing to wait until the next capability increment instead of forcing everything into the current one because they know there is a multitude of speedboats to catch rather than having to hitch a ride on the Titanic. And because increments come more quickly, there is little justification to expend so many resources on system longevity, thereby allowing us to go even faster.

Fundamentally, rapid development sparks flexibility and agility better than any other single technique. It allows us to better incorporate new technologies and account for new threats at the speed of need. It is truly the paramount pillar of DfP because it is intertwined with all of the other pillars, simultaneously enabling each while also being enabled by them. Going faster is the stand-alone meta recommendation that permeates all DfP thinking and is precisely how we supplant the stagnation cycle with the celerity cycle.

Exquisite vs. Rapid Scenario

I won't support the development any further of large, big, fat, juicy targets.

—General John Hyten
Commander, U.S. Strategic Command[56]

Let's illustrate the power of the celerity cycle via a scenario that directly compares the performance-centric, exquisite approach to the schedule-centric DfP approach. The general premise of this scenario is that the USSF needs to acquire a particular space mission capability, and there must be at least a 90 percent likelihood we will attain FOC for at least six consecutive years. For simplicity, we will consider only the space segment.

One option to achieve this mission capability is by procuring a traditional constellation of exquisite satellites. Here are the characteristics of that option, which we'll refer to as the *Exquisite System*:

- A total of four satellites will be acquired, three of which will need to be simultaneously operational to achieve FOC

- Each satellite will have an expected 10-year operational service life

- It will take seven years to build, launch, and activate the first satellite and an additional three years to activate each subsequent satellite

- There is a 98 percent chance of platform success, which is defined as the satellite successfully reaching the intended orbit and working correctly (i.e., meeting its performance specifications)

The other option is to achieve the same capability via smaller satellites that are individually less capable and less reliable but can be acquired more quickly. Here are the characteristics of the *Rapid System*:

- A total of 20 satellites will be acquired by two different developers (per the "Pervasive Competition" recommendations in Pillar 1). Each developer will procure 10 satellites, and 6 satellites from either provider will need to be simultaneously operational to achieve FOC (it takes two rapid satellites to equal the capability of one exquisite satellite)

- Each satellite will have an expected five-year operational service life

- It will take three years to build, launch, and activate the first satellite (for each acquirer) and an additional year to activate each subsequent satellite

- There is a 75 percent chance of platform success, which is defined as the satellite successfully reaching the intended orbit and working correctly (i.e., meeting its performance specifications)

Figure 1 compares the characteristics of both options in schedule form. The filled-in isosceles triangles (orange for the Exquisite System, blue for the Rapid System) represent satellite activations. Notice the first satellite of the Exquisite System is activated in the seventh year (the dashed triangle marked "Dev" denotes development time) with the other three satellites following in three-year increments per the schedule specified above. Meanwhile, the alternate development strategy employed by the Rapid System expects to activate its first two satellites in the third year (one from each developer) with two more satellites coming online every year after that. The shaded bars that extend to the right of each triangle represent the operational service life of that satellite, (i.e., 10 years for each of the satellites in the Exquisite System, 5 years for the satellites in the Rapid System).

The other key thing to note in this figure is the multi-colored horizontal "CAPABILITY" block shown at the bottom of each option. This is a representation of the expected level of operational capability for that option over the life of the constellation. As annotated in the figure, gray means zero capability, pink means one-third capability (i.e., at least one Exquisite satellite or two Rapid satellites), yellow

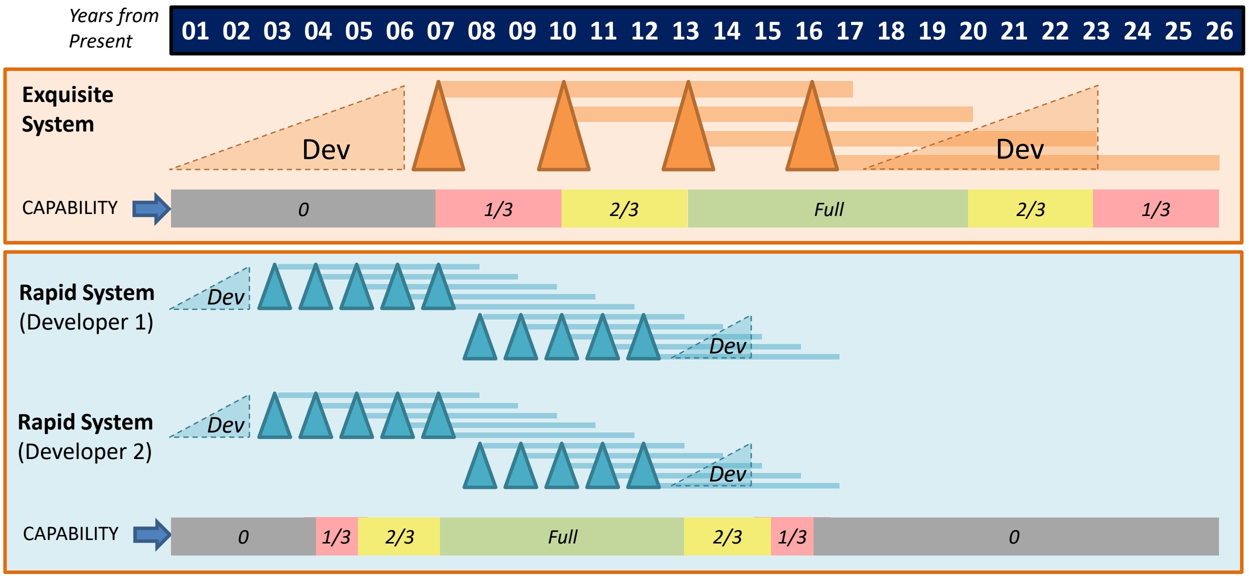


Figure 1: Comparison of Exquisite System versus Rapid System.

means two-thirds capability (i.e., at least two Exquisite satellites or four Rapid satellites), and green means full capability (i.e., at least three Exquisite satellites or six Rapid satellites). All of these capability levels were calculated via Monte Carlo analysis based on the stated platform success rates and would have at least a 92 percent chance of achieving the overarching FOC requirement.[§§]

Given all of this, let's compare the performance of the two options. To achieve the same level of capability (i.e., one-third, two-thirds, full), the Rapid System must successfully deploy twice as many satellites as the Exquisite System. Furthermore, each satellite in the Rapid System must contend with a failure rate of 25 percent, which is 12.5 times higher than the unit failure rate of the Exquisite System (i.e., 2 percent). But because the Rapid System is, well, so darn *rapid*, it can deliver every increment of capability much sooner. Specifically, the Rapid System is expected to achieve one-third capability three years sooner than the Exquisite System, two-thirds capability five years sooner, and full capability six years sooner.

So even though each individual platform of the Rapid System is half as capable as the Exquisite System and an order of magnitude more likely to fail, the Rapid System is expected to deliver more capability to the warfighter much sooner. This illustrates the merits of the celerity cycle; it greatly reduces operational risk not just in the short-term, but also the long-term. Deploying larger numbers of smaller satellites instead of a few large ones is at the heart of powerful architectural strategies like node proliferation and capability diversification, which greatly complicate adversary targeting and decision calculus. These strategies are crucial in allowing us to minimize "juicy targets."

It is also true, however, that the Exquisite System promises an extra year at full capability (i.e., 7 vs.

[§§] For the Monte Carlo nerds among you, 20,000 iterations were used in a simulation executed by the Microsoft Excel plug-in, "RiskAMP." Several simplifying assumptions were used, including all failures being independent, all failures being binary (i.e., complete mission success or failure), no uncertainty in the operational service life, and no consideration of orbital phasing. Granted, these assumptions greatly reduce the realism of this scenario; however, the essential point remains.

6) and seven more years (i.e., 19 vs. 12) with at least partial capability. At first glance, these might seem like points in favor of the Exquisite System. But that's outmoded thinking. In an uncertain, rapidly changing environment like today's space domain, these are actually additional *liabilities* of the Exquisite System. With a larger number of smaller platforms deployed that are replaced more quickly, the Rapid System inherently affords more opportunities for technology insertion and strategic pivoting in response to uncertainty. Not only do we have more platforms available (i.e., 20 vs. 4) at more frequent intervals (annually vs. three years), but a new development cycle can start at least eight years sooner, thereby allowing us to field more cutting-edge capabilities and more effectively outpace emerging threats.

The last potentially cogent argument in favor of the Exquisite System is that the total lifecycle cost may be lower. One might be tempted to contend that four Exquisite satellites are likely to cost less than 20 (and probably even more in order to compare equivalent time scales) Rapid satellites. However, there are many reasons to believe the Rapid System would likely be the overall cheaper option. For starters, the fact that there are two competing acquisition entities will tend to create downward cost pressure. In addition, the fact that each entity is producing over twice as many articles (i.e., 10 vs. 4) provides improved economies of scale. Most important of all, the reduced reliability and longevity requirements put the satellites in the realm of commoditization, which is certain to simplify the designs—and reduce associated cost—tremendously. This also serves to lower the launch costs associated with payload integration and mission assurance activities. In the final analysis, the Rapid Option is not only more strategically flexible, more tactically agile, and more operationally responsive, but it is probably less expensive as well.

One last note. The entire "Exquisite vs. Rapid" scenario exemplifies the power of a concept known as "continuous production agility," which will be discussed in more detail in the hardware portion of the next section.

The Speed of Agile

Success does not go to the country that develops a new technology first, but rather, to the one that better integrates it and more swiftly adapts its way of fighting. Our response will be to prioritize speed of delivery, continuous adaptation, and frequent upgrades.

—James Mattis
Secretary of Defense[57]

So all that remains is identifying some specific recommendations to enable going faster in the space domain. With that goal in mind, below is a list of techniques to more rapidly deliver capabilities within the context of *software*, *hardware*, and the *acquisition process* itself. Most of these ideas pertain to agile development practices and will likely sound familiar to most readers, as they generally have some proven track record in other domains or applications. The trick is to adapt them to the USSF. For the most part, it isn't a question of *whether* we should do these things—it's a question of exerting the will to do so.

Software. The first step in being more agile (lowercase) is doing Agile (uppercase). *Agile* is the term used to describe "an approach to software development under which requirements and solutions evolve through the collaborative effort of self-organizing and cross-functional teams and their customer(s)/end user(s)."[58] At its heart, Agile software development prioritizes rapidly fielding capability increments that can respond to change versus following a plan and having comprehensive documentation. It is the opposite of the "waterfall approach" employed so often in SE where development moves slowly and steadily toward a final requirement-driven objective that was established at the outset. This is antithetical to Agile, which generally rejects the very notion of a finished product.

Agile proponents have established a famous "manifesto," which codifies a series of principles that include the following:[59]

- First and foremost, satisfy the customer through early and continuous delivery of valuable software
- Welcome changing requirements, even late in development
- Working software is the primary measure of progress and should be delivered frequently
- Simplicity—the art of maximizing the amount of work not done—is essential

The goals and principles of Agile should seem very familiar. To a large extent, Agile is the software embodiment of DfP.

Of note, Agile software methodology is closely related to the concept of development operations (DevOps), whereby there is formalized collaboration between the software developers and operators. (Recently, the importance of considering cybersecurity as part of an integrated software development strategy is being more broadly recognized such that the term "DevSecOps" is becoming increasingly prevalent, but here we use the DevOps term to be inclusive of both.) DevOps is all about shorter development cycles and increased deployment frequency with more incremental changes and, thus, is a perfect fit for Agile methods. Not surprisingly, then, there is a growing movement in the software community to couple DevOps with Agile. For instance, both Agile and DevOps are widely employed in the commercial sector and have been successfully merged and achieved at scale. Companies like Amazon, Google, Spotify, Walmart, Target, and Netflix have instilled close linkages between users and developers and are routinely deploying new software to users—often millions of users—on a daily basis. In some cases, updates are occurring just a few times per day; in other cases, updates are happening hundreds of times each day.[60,61]

Some space programs have already begun adopting Agile practices and pursuing aspects of DevOps, but this is more the exception than the rule. In addition, the maturity of implementation has a long way to go. In virtually all cases, programs do not fully commit to crazy ideas like prioritizing working code over hard requirements nor do they welcome requirement changes to better meet user needs. Furthermore, metrics for software development continue to be legacy measures such as the total number of requirements satisfied or the lines of code produced. And the notion of delivering new code multiple times a day is beyond the pale for government programs. Delivering software updates a few times a year to a relatively small community of users is considered impressive for current space programs.

DfP requires that the USSF more fully commit to the core principles of Agile and pick up its game immensely. Note that this doesn't have to be an all-or-nothing thing. The USSF can fully commit to an Agile approach for certain programs, certain functions, or for certain locations—but it must make that commitment and break the mold on how software development can be done across the service. As observed in the *Harvard Business Review*: "Even the most advanced agile enterprises—Amazon, Spotify, Google, Netflix, Bosch, Saab, SAP, Salesforce, Riot Games, Tesla, and SpaceX, to name a few—operate with a mix of agile teams and traditional structures."[62]

Hardware. Even if we can transform space program acquisition strategies to begin developing software that epitomizes "rapid and flexible response to change," that still leaves the problem of hardware. Nearly all space capabilities consist of both hardware and software components, so having agile software capabilities without accompanying agile hardware is an incomplete solution to going faster. Fielding new software every day does us little good if it takes years to produce or procure the hardware that hosts the software and/or is controlled by the software. And certain types of space hardware systems, especially those designed for use on satellites, do have notoriously long build times. These systems tend to be highly robust (e.g., radiation-hardened) to survive the brutal environment of space, extremely specialized to provide exquisite performance, and produced in limited quantities because we have historically preferred small numbers of large, expensive satellites.

There are still several ways to significantly reduce "lead times" for the production of hardware. One proven method is to commit to Modular Open Systems Approach (MOSA). MOSA is a type of design strategy that has many manifestations but always espouses at least two core tenets. One is, as the name implies, an emphasis on the design and implementation of modular components. The other is a commitment to comply with consensus-based (i.e., "open") standards for all key interfaces. These two MOSA tenets alone can serve as powerful enablers of rapid and agile capability development, even for hardware. MOSA facilitates interoperability, thus greatly reducing integration time or eliminating it altogether. It also enhances commonality among systems and enables component reuse, thereby obviating the need to build new hardware at all in some instances. MOSA also increases the likelihood of being compatible with commercial systems, thereby opening the door for off-the-shelf solutions. The fastest way to build something is to not have to build it in the first place.

Another strategy is to apply Agile principles directly to hardware development and manufacturing. This might seem far-fetched, but it can be feasible with some adaptations, even for space systems.[63,64] It certainly isn't appropriate for all aspects of hardware systems; for instance, the Agile notion of continuous deployment is largely a non-starter for hardware. However, some Agile practices and principles translate well. This includes frequent customer interaction, acceptance of requirement changes, and delivery of working hardware early and often. For this last item, a key tactic is the extensive use of mock-ups or prototypes to obtain user feedback or demonstrate incremental capability sooner. Providing at least partially working increments of hardware is certainly far more agile than the conventional "big bang" approach and can be especially effective when paired with Agile software practices. Further, MOSA practices enable hardware agility as they allow for the development and maturation of different components at different rates, which can then be incrementally deployed. And while there are some valid arguments for stipulating that "satellites are just different," it's worth remembering that the majority of space enterprise hardware is actually *not in space*.

Another way to expedite the hardware side of the equation is by employing many of the recommendations already discussed. Moving away from formal requirements, prioritizing schedule over technical performance, and employing greater numbers of smaller systems all inherently allow hardware procurement to proceed more quickly. Smaller systems that have more modest technical objectives can be delivered more reliably and quickly using already available tooling and standard manufacturing practices, and yet still not preclude opportunities for innovation and tech insertion through the use of open, modular interface standards implemented via common satellite buses and hosted payloads. Meanwhile, larger quantities allow for increased production efficiencies, greater opportunities for competition, and greatly reduced lag time between each completed article, further enhancing ability to adapt to new technologies and threats.

The culmination of these principles is captured in a concept known as *Continuous Production Agility* (CPA). CPA was developed by The Aerospace Corporation in 2018 and is essentially the synthesis of MOSA with the Exquisite vs. Rapid scenario above; it is intended to deliver satellite constellations much more quickly and then continuously replenish those satellites on an incremental, schedule-driven basis. As such, CPA "realigns space acquisition for speed, adaptability, and resilience using increased production, a modular open systems architecture design and contracting approach, and enhanced competition."[65,66] Critically, when viewed through the lens of "Keep the Big Picture in Mind," CPA becomes even more game-changing. If applied across many satellite programs, it cultivates an entire ecosystem for faster hardware production. Multiple programs committed to CPA can stabilize industrial throughput for satellite bus manufacturers to increase the pace of production learning for everyone, and to drive satellite price points down across the board. This, in turn, can open up further opportunities for commercial investors and mission partners, both in the U.S. and abroad.

Acquisition. Last, but not least, we have to address the (DOD) 5000-lb elephant in the room: How do we actually speed up the mechanics of the acquisition process? If every other aspect of capability development is primed to go quickly, but key aspects of the Defense Acquisition System lag, we again fail. This is yet another area that can benefit from a "Digitized Enterprise." The more we can translate acquisition processes—from JCIDS to programs to development contractors—into the data space, the more quickly we can go. Bureaucratic processes can be streamlined and automated, information exchange can be dynamic and efficient, modeled data can be rapidly reused and shared among stakeholders to accelerate all aspects of capability development.

Programs should have to get a waiver* not *to be an MTA.

It can be argued, however, that there is only so much to be done within an inherently rigid and cumbersome acquisition process. One hypothetical, but extremely appealing, option would be to allow acquisition programs to completely bypass the onerous bureaucracy of the Defense Acquisition System. But, of course, that's sheer madness—that would never happen.

Except that it did. It turns out that Congress passed legislation a few years back (in the National Defense Authorization Act for Fiscal Year 2016) that authorizes—even encourages—certain types of acquisition activities to forego JCIDS and DoDD 5000.01. The term used to describe the approach is Middle Tier Acquisition (MTA) (or sometimes "Section 804 acquisition" for the portion of the bill where it is described). MTA consists of two discrete pathways, both aimed at expediting the delivery of capabilities to the warfighter within two to five years. The first pathway is "Rapid Prototyping," which seizes on innovative technologies to ensure we address emerging warfighter needs and leave behind a minimum viable operational capability. The second pathway is "Rapid Fielding," which applies to more mature acquisitions, relying on proven technologies to fully field an operational capability. As of 2019, only a few dozen DOD programs (out of hundreds) have been designated as MTAs.[67]

MTA represents an extraordinary opportunity for the USSF. Here we have a rare instance in which Congress has authorized reduced oversight with the expressed intent to streamline acquisition—it would be asinine not to take advantage. So instead of regarding MTA as the exception, it needs to become the rule. By default, every USSF acquisition program should either be designated as a Rapid Prototyping or Rapid Fielding MTA. Programs should have to get a waiver *not* to be an MTA. And this really isn't asking a lot. If the USSF can't deliver a prototype capability in five years for new technology or a full capability in five years for a mature technology, then it might as well cede the high ground now.

Summary of DfP Pillar 4 (i.e., the "Paramount" Pillar) Recommendations

The table below summarizes the key recommendations related to the fourth pillar.

Table 4: Implementation Recommendations for DfP Pillar 4		
Recommended Action	**Principal Actionee(s)**	**Notes/Rationale**
Schedule Precedence Break out of the current stagnation cycle by prioritizing schedule over technical performance.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	The best way to achieve requirement stability is by focusing on fewer requirements and purposely reducing total duration of programs or the time between capability increments.
The Celerity Cycle Embrace the positive cycle that feeds on itself to go increasingly faster, stoke innovation, and infuse the principles of DfP across every corner of the enterprise.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Reduced investment in time and money means failures are not as critical and more parallel paths are available; rapid, incremental development efforts create a thriving ecosystem of innovation and speed, which promotes boldness and accountability.
Exquisite Avoidance Prioritize larger numbers of smaller platforms and recognize that extremely high system reliability and longevity are not desirable features.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Excessive system reliability/longevity consumes precious resources and creates "juicy targets;" proliferation provides comparable performance, but enables better tech refresh, threat response, and strategic pivoting.
Agile Software Institute Agile software methodology and DevOps to rapidly field capability increments and maintain tight linkage between development and operations.	☐ Congress ☐ COCOM ☐ OSD/HQ USSF ☒ **SP/SPO**	Consistent with Agile principles, program should prioritize working code over hard requirements and welcome requirement changes to better meet user needs; strive to deliver software enhancements continuously.
Agile Hardware Adopt Modular Open Systems Approach (MOSA)and apply Agile principles to hardware and associated development and manufacturing to keep pace with software.	☐ Congress ☐ COCOM ☐ OSD / HQ USSF ☒ **SP/SPO**	MOSA facilitates interoperability, enables component reuse, and opens up possibility of commercial solutions; deliver increments of hardware where possible and use schedule-driven continuous production agility approach regardless.
Rapid Acquisition Use authority granted by Congress to go faster and have every program, by default, be designated as a Rapid Prototyping or Rapid Fielding Middle Tier Acquisition.	☐ Congress ☐ COCOM ☒ **OSD/HQ USSF** ☒ **SP/SPO**	Don't let the acquisition process slow us down; take advantage of mechanism that bypasses JCIDS and DOD 5000.01 to deliver minimum viable capabilities or fully fielded capabilities in two to five years.

Review of Recommendations

As noted at the outset, the scope of the DfP implementation recommendations is far-reaching. They touch on not just systems engineering, but also the broader acquisition, requirements, and resourcing environment. To truly achieve agile, rapid capability development will require meaningful change to processes that extend well beyond the traditional role of SE. And though many of these recommendations can be wholly instituted within existing USSF authorities, a few will require broader coordination with OSD or even Congress, thus posing a significant challenge to enact.

Further, considering all of the recommended actions in aggregate, one thing clearly stands out: they are highly interrelated. Although they are listed discretely across four different tables in four different sections, there are many obvious interdependencies. In fact, few of these actions are likely to be fully effective in isolation—they really ought to be implemented as part of a structured, unified strategy.

For instance, prioritizing schedule ahead of technical performance will not work if we don't reduce the number of technical requirements and accept more risk. Nor does it make sense to accept more risk if we don't do it smartly as part of a strategic uncertainty strategy that is coupled with the right personnel incentives. An ability and a willingness to embrace uncertainty and treat requirements more like objectives is also necessary if we are going to meaningfully commit to Agile software development. And Agile software development can be valuable, per se, but it needs to be paired with concepts like continuous production agility to be fully effective. Greater technical risk at the system level may be daunting, but it can be effectively managed by broadening our perspective of risk to encompass the operational perspective and span an entire capability portfolio. And managing risk and requirements across an integrated enterprise of capabilities is only feasible if we have the ability to allocate funding when and where we need it. To effectively manage all of this complexity also requires that we implement digital engineering. And so on.

Despite all of the interdependencies, though, enactment of the DfP recommendations doesn't have to be an "all or nothing" proposition across the entire space enterprise. Some agencies—or just select programs within agencies—can employ a coherent set of these recommendations. SpRCO could fully adopt DfP while SMC retains more of the traditional SE approach. Agile software and hardware methodologies could be applied for select programs. Enterprise requirements could be established immediately and incorporated into technical baselines for all new programs without the JCIDS changes. The digital model of the enterprise architecture could evolve gradually, folding in different elements of the enterprise as they are ready. Ultimately, the DOD space enterprise could incrementally enact many of these changes in targeted ways and monitor the results before progressing further. In fact, this sort of phased approach to deploying new methods of capability development is fully consistent with the DfP approach to capability development!

Summary

***The Architect:** You played a very dangerous game.*

***The Oracle:** Change always is.*

—The Matrix Revolutions

We are in a new era. The space domain has fundamentally transformed, and the establishment of the USSF is a testament to that. Potential U.S. adversaries are actively developing and deploying hostile space capabilities at an alarming pace, directly challenging America's historical advantage in space and jeopardizing joint warfighting capability and overall national security. Space is now a dynamic and volatile warfighting domain, and the USSF must figure out how to regain the moxie from America's early successes in space to counter the growing threats.

Another critical element of this new era that the merely *complicated* has given way to the truly *complex*—and all of the uncertainty and unpredictability that entails. Systems engineering has an impressive track record going back to the mid-20th century in effectively managing development of complicated capabilities, but it is increasingly ill-suited to the challenges of today. A new approach is needed that doesn't rely on stability of requirements, predictability of the future operating environment, nor inherently reductionist approaches to problem solving. It's extremely likely that DfP—as currently envisioned—is not the perfect or complete answer to this dilemma. Whether or not all of the proposed recommendations can or will be implemented, the essential pillars of DfP represent a compelling framework for thinking about the problem, informing solutions, and serving as a font for future ideas as well. In fact, simply recognizing the hard truth that a new methodology is needed to rise to the challenge of this moment would represent a consequential step forward.

Against this backdrop, the newly commissioned Space Force is confronted with a critical choice. It must determine how to best forge a *complex* set of space capabilities into an integrated enterprise architecture that will assure space warfighting capabilities across the spectrum of conflict. The Space Force has two options: it can either play it safe and employ the DOD's traditional SE capability development methodology that tends to be requirement-based, system-centric, and driven primarily by technical mission performance or it can seize a generational opportunity to pursue Designing for Principles, a capability development framework that is objective-based, capability-centric, and motivated chiefly by design principles and speed. This paper argues that the choice is clear. DfP is tailor-made for a small, bold service that prioritizes innovation and is committed to more quickly develop and field agile capabilities in an uncertain environment.

Acknowledgments

I would like to acknowledge Dan Ward whose previous publications and thought pieces were influential in the development of the DfP concept. I also wish to thank the following colleagues for their thoughtful and valuable contributions to this paper: Ryan Noguchi, Allison Taylor, Albert Hoheb, and Angie Bukley. And a special shout-out to Robin Dickey for her creative brilliance in helping develop the cover art for both DfP papers and Mary Mills for her fantastic editing skills!

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