# From Innovation to Deployment: Addressing Testing Gaps in USSF, NASA, and Commercial Space Ventures


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# Introduction

The United States Space Force (USSF) budget request of $29.4 billion[1] surpassed NASA's annual budget of $25.4 billion[2] for the fiscal year 2025. A key focus of the USSF Commercial Space Strategy, "the USSF will leverage the commercial sector's innovative capabilities, scalable production, and rapid technology refresh rates to enhance the resilience of national security space architectures, strengthen deterrence, and support Combatant Commander objectives"[3]. A key distinction being that a capability can be described as a system of systems composed of multiple technologies that come together to achieve a certain result.

The commercial space industry is experiencing continued growth with projections exceeding $1 trillion by 2030[4]. Fueling this growth is a combination of private and public investments. Since 2015, there has been over $47 billion in private investment in space capabilities[5]. These investments resulted in the development of hundreds of innovative commercial space capabilities across the space enterprise.

Given the increased supply of innovative commercial space capabilities, coupled with expectations for all government space-faring organizations to use "commercial first" outlined in the National Space Policy, along with DoD and USSF Commercial Space Strategies[3], conditions exist for significant expansion. Comparing the breadth and scope of space capabilities developed over the past 5 years with the number of capabilities with the number of capabilities deployed in the same period indicates only a small percentage have made the leap from developed to deployed (D2D). For an emerging area of the space market, of 400 companies developing in-space servicing, assembly, and manufacturing (ISAM) capabilities, an assessment indicates that only 7 have been deployed through August 2024.

This gap drives an assessment of constraints for the efficient flow from the stockpile of developed space capabilities to the deployed capabilities in space-expanding LEO ecosystems and beyond. Fig. 1 below outlines the mentioned flow including the different stages and entities involved in the process.

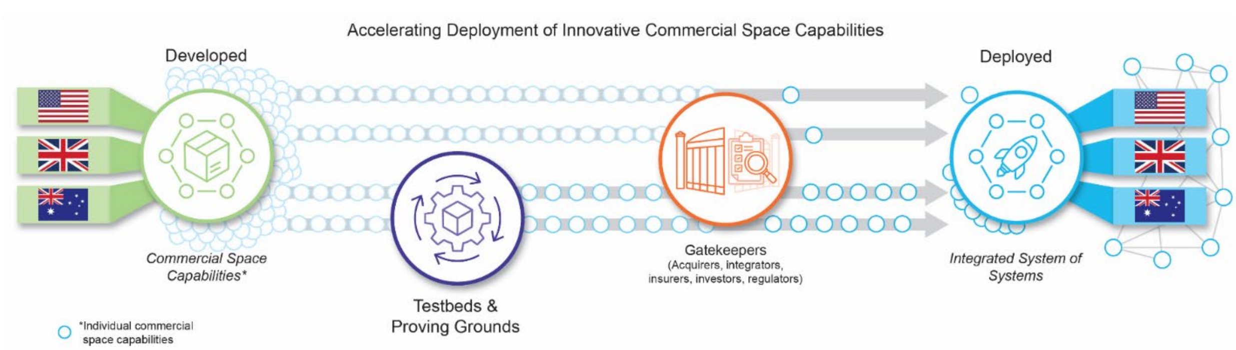


**Fig 1: Accelerating Deployment of Innovative Commerical Space Capabilities**

The USSF Space Enterprise Test Vision[6] calls for a robust digital engineering infrastructure for testing and training to build confidence in deploying innovative space capabilities. While this vision is aspirational, it sets out a target for expanding the use of testbed and proving ground infrastructure to advance US space capabilities in the national interest. For the purpose of this paper, collectively and individually, TB&PGs are physical and/or digital facilities used to test and evaluate performance of space capabilities to facilitate orderly transition of innovative capabilities to operational implementation. TB&PGs can include physical and/or digital representations of operating environments.

The process of advancing innovative commercial capabilities to get to space involves a series of decision gates. Decision gates include investment, insurance, regulation, acquisition, and integration. The people and organizations that make these decisions can be collectively thought of as "gatekeepers". Gatekeepers benefit from information to assess risk as an integral part of their decision calculus. They generally look to manage risk through flight proven capabilities. The substantial stockpile of innovative commercial capabilities presents a challenge in terms of realizing flight-proven as there aren't sufficient opportunities in terms of launch capacity or funding for launching everything twice, once to prove and subsequently to deploy. An alternative is to leverage existing and developing testbeds and proving grounds to conduct and achieve "flight proven equivalent" to build confidence in specific of space capabilities in the U.S. and with Allies.

## Success Landscape

Expectations for deploying innovative commercial space capabilities drive needs for an organized approach to build confidence in capabilities developed but not flown in space. One example of this is shown from the backlog of developed space capabilities that have not yet been deployed for operations in national critical missions. SpaceWERX, the innovation arm of the USSF, has awarded 124 Orbital Prime contracts[7] the majority of which will require some level of testing and proving for program managers and acquisition officials to integrate into their space architectures. This example represents only one portion of required aerospace industry testing.

Payloads that have been able to fly have seen a mix of success and failure. According to NASA's "Small-Satellite Mission Failure Rates" report[8], the study found that 41.3% of small satellites launched between the years 2000 and 2016 failed or partially failed. This report considered a total of 522 small satellites. Common systems resulting in failure include but are not limited to communication, battery, on-board computer, thruster, reaction wheels, gyroscope, and temperature control.

In 2022 the Orion Spacecraft was able to perform an uncrewed lunar orbit and return[9]. A success setting up the return to the Moon with the Artemis missions. SpaceX has also been successful with its Falcon 9 rocket. Although recently going through their first in-flight failure since 2015[10], they have still achieved >95% success rate with the vehicle and were able to return to flight in weeks. A major factor enabling this return and success is flight rate, having completed over 300 flights. The large amount of data they have produced allows for quicker turnover. They hope to do the same with Starship which has currently conducted its 4th test flight. The company is a prime example in deploying the necessary resources into testing and risk mitigation to accomplish their intended objectives.

Other private companies have not been as fortunate with development. Not having enough resources for multiple test launches. This has caused failures through the private industry. Recent examples are Astrobotic's Peregine lander suffering from a propellant leak just hours after liftoff[11]. Or the recent Intuitive Machines lunar lander which, although successfully being able to land on the Moon, suffered from an unstable landing which tipped the lander on its side hindering it from conducting its desired activities[12]. This is attributed to factors including engineering needs, lack or insufficient operation systems and protocols, and the high cost of launches to achieve flight-proven qualification.

There are more than 100 test beds and proving grounds, as captured in an inventory compiled by The Aerospace Corporation. These include both physical and digital TB&PGs, that can be used for testing both on the ground and in space, including Low Earth Orbit. Getting access to these platforms is currently limited to knowledge of the existence and availability. Companies may not know what is available or when or how to benefit from each and several TB&PGs for advancing their plans to deploy innovative, as yet unproven, capabilities. This limits space enterprise efficiency to benefit from TB&PG capabilities to decrease risk of mission failures and informed decisions by acquirers, investors, insurers, integrators, and regulators, to move forward with actions resulting in deploying more capabilities sooner.

## Prospective Solution

NASA shared a compilation of 50 available facilities in their ISAM State-of-Play report[13]. NASA organizes and tracks space developers, facilities, and capabilities to help mission designers create the starting point to plan and roadmap a path to deploying capabilities.

A good start to the process, but still missing critical steps in advancing commercial capabilities into deployment. The following is an effective method of advancing infrastructure to build trust and confidence in innovative solution through a structured three-step process.

1. Establish a federated approach to recognize available and accessible test beds and proving grounds for an inventory aligned with capabilities across multiple space domains.
2. Harmonize a governance model for using federated TB&PGs that includes the basis of credentials and recognition from running a system through the TB&PG to assess performance and ability/capacity to operate in the intended deployed environment.
    a. Facility must be recognized and trusted.
    b. Access to facilities must be equitable.
    c. Output of the TB&PGs must be recognized as valid to its intended purpose.

3. Shared cognizance by the gatekeeper community these facilities exist and are available to provide information needed to make decisions to move forward, coupled with the trust of the commercial provider community and the owners and operators of the testbeds and proving grounds, and the end user space infrastructure community assimilating the innovative commercial capabilities into space ecosystems.

Fig. 2 below provides an outline of the proposed solution. In order for this to become a successful model of accelerating deployment, collaboration between the different entities involved is crucial. Government officials must organize the existing infrastructure of TB&PGs and make them accessible to commercial engineers. Private companies should then be able to use the existing infrastructure to achieve "flight proven equivalent" status. Gatekeepers must recognize this status to mark systems ready for deployment.

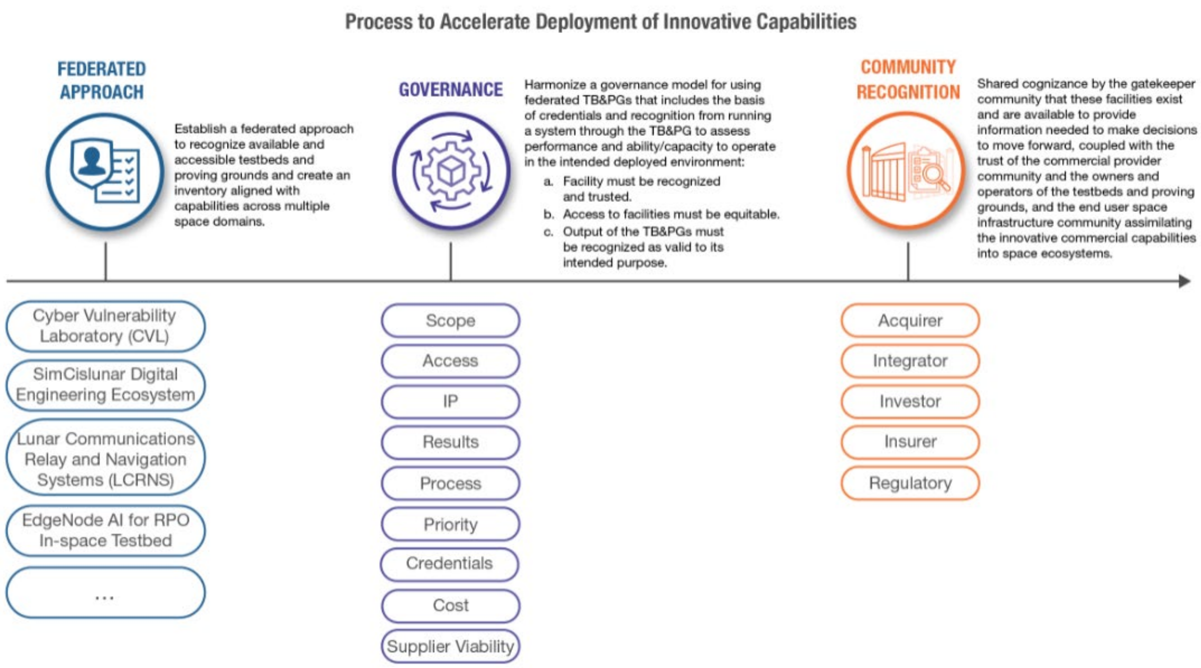


**Fig 2: Process to Accelerate Deployment of Innovative Capabilities**

# Expected Outcome

An organized approach to use a federated set of TB&PG will indeed foster more confident systems, which is crucial for the rapid deployment and operation by gatekeepers, owners, operators, and engineers. This confidence stems from a structured methodology that ensures reliability and predictability in system performance. As a result, these stakeholders can expedite their processes, leading to a quicker expansion of infrastructure within the space environment.

The expansion of infrastructure is a critical step in supporting the burgeoning space industry. With more historical data and operating systems available, the industry can leverage these resources to develop more complex and advanced systems. This progression not only enhances the capabilities of existing systems but also paves the way for innovation and the creation of new technologies.

By accelerating the industry, the U.S. continues to advance its space capabilities, which is in the national interest. The joint effort and trust between the government and the private space sector is pivotal in achieving space dominance for the U.S. and its allies.

## Synopsis

The rapid pace of development in the space sector has highlighted significant gaps in the efficient transition to deploy capabilities to meet USSF and other national needs. The USSF call to action emphasizes the strategic importance of leveraging commercial innovations to enhance national security and operational readiness. The backlog stockpile of undeployed space capabilities indicates a gap worthy of closing. Robust testbed and proving grounds, and associated governance frameworks, can enable progress in closing these gaps.

Implementing a federated approach to recognize and utilize existing test beds and proving grounds is a way to increase the throughput advancing space capabilities from the stockpile of developed to the ecosystem of deployed. Establishing a governance model for facility usage, establishing credentials for the facilities, and ensuring that TB&PG outputs are recognized and trusted by stakeholders all contribute to intended goal of "accelerating deployment of innovative commercial space capabilities in the national interest." This will enable ability to significantly manage risks, building confidence to enable a smoother transition between development and deployment.

Addressing the testing and validation challenges for commercial capabilities to be assimilated into hybrid architectures for national security can increase mission success and accelerate the commercialization and operational readiness of US space economy and ecosystems. This strategic approach will support the USSF objectives of space domain superiority and drive sustained growth and innovation in the broader space community.

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