National Aeronautics and
Space Administration

STMD-STRAT-FY2026

RELEASE DATE: MAY 14, 2026

TECHNOLOGY INFUSION GUIDE

Signature Page

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REVISION AND HISTORY PAGE

Revision No.	Description	Release Date
Baseline	Initial Baseline	

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1.0 INTRODUCTION

1.1 Purpose

This document aims to provide a helpful framework, with potential suggestions for moving technologies (both hardware and software) from the research and development (R&D) stage to successful integration in operational missions. It is not intended to impose requirements on a technology or mission/user teams, but rather it identifies best practices for infusion by examining infusion paths and existing mechanisms and makes recommendations for areas of improvement. It does not direct changes to existing governance.

Technology infusion inherently involves some degree of uncertainty and risk, particularly when introducing maturing capabilities into mission-critical systems. Aligned with NASA's established Risk-Informed Decision-Making approach, this guide strives to provide a balanced approach that encourages deliberate, evidence-based acceptance of appropriate uncertainty where it furthers mission objectives, while providing flexibility to adapt choices to the specific context, priorities, and phase of each mission. It provides a framework that allows teams to become fully informed about those risks, evaluate them thoughtfully in context, and make confident, evidence-based decisions that balance potential benefits against the full spectrum of programmatic considerations spanning technical, cost, schedule, safety, and mission-opportunity considerations ultimately increasing the likelihood of successful adoption and mission achievement.

The Technology Infusion Guide, as the name implies, is a guide only. It is intended primarily for members of the NASA Space Technology Mission Directorate (STMD) community and its partners who play key roles in advancing and adopting new technologies for space missions. It is intended for technology developers and researchers (from NASA centers, academia, industry, and other government agencies) who mature innovations and seek pathways to operational use. Program and portfolio managers within STMD who align investments with strategic needs; and other stakeholders such as risk managers, technical review panels, and procurement teams involved in decision-making around technology readiness, maturation, and infusion can benefit from content within this document. By providing these best practices, the guide equips these groups to collaboratively bridge the gap between technology development and mission application - fostering smarter risk-informed strategies that enhance mission success while promoting effective adoption of innovative capabilities across NASA's diverse portfolio of exploration, science, and aeronautics endeavors.

1.2 Change Responsibility

This document was coordinated and developed with input from STMD technologists and members of the Technology Coordination and Integration Group (TCIG). While primarily representative of STMD, it is the first step in providing insight and best practices at the Agency level. Once other Mission Directorates have identified their technology infusion mechanisms and best practices, further coordination with the TCIG could be taken to broaden this document for the Agency.

The NASA office responsible for updates to this document is the STMD Strategy and Performance Office (SPO).

1.3 Definitions

For the purposes of this document the following definitions will be used.

<u>Pull Technology</u>: Technology which has an identified market need, directly addressing a customer problem or user demand.

Push Technology: Technology that creates solutions for problems that customers may not yet realize they have or even inventing entirely new needs.

Translational Technology: Technology that has use cases identified but lack stakeholder “pull”.

Technology Demonstration: The act of showing or validating the technology’s performance and capability in a relevant environment or operational setting to reduce risk, prove feasibility, and build confidence for further development or deployment. It begins with research and development of technology with laboratory demonstrations of critical component and subsystem technologies, then moves up the chain to a component or subsystem demonstration where prototypes are rigorously tested and validated in relevant or operational environments (typically reaching Technology Readiness Levels 5-7) to prove feasibility, gather performance data, and reduce technical risks. Technology demonstrations can occur in a lab, testbed, on a flight mission, payload or ground system, but are not performing a mission critical function or considered necessary for mission/system success. Technology demonstrations reduce risks before full integration or deployment into a system.

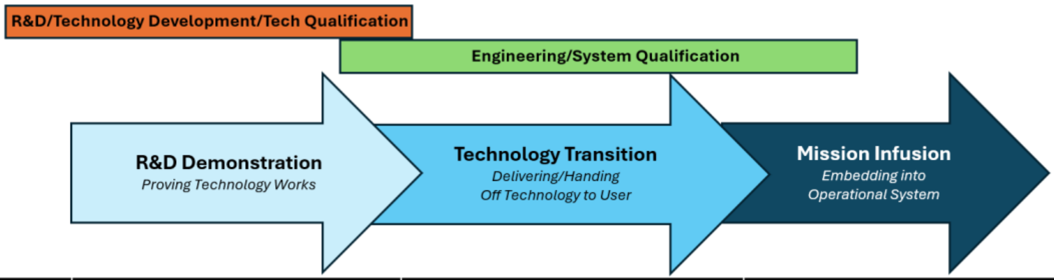
Technology Transition: The stage in the process that moves a technology from the R&D phase of development to another mission/user organization in preparation for later mission infusion (operational use)– shifting authority from technology R&D to user. Focuses on bridging between further technology maturation through a hand-off or transfer of technology to the mission/user organization to be adapted to the specific use case and fielded. Technology moves from the R&D organization to the operational program to make any engineering changes or advancements beyond the initial technology feasibility demonstrations. The operational program customizes the technology for specific use and certifies it for operational use as part of a larger system. This could be a transition within NASA (internal), between NASA and another government agency (external) or between NASA and academia/industry (external), etc.

Infusion: The integration or incorporation of a new or emerging technology into an existing system or a system under design to enhance the system’s performance, add new capabilities or improve how the system operates. Infusion emphasizes embedding a technology into the host system generally in its “matured” end state enabling improved performance, new functionalities, or logistical efficiencies for permanent, long-term operations that directly support the mission objectives (becomes part of its core design or operations). This includes the first time a technology is selected for use on a proposed flight mission, payload or ground system. Typically, infusion of new technology into flight missions or architectural elements is accomplished by maturation to TRL 6 as part of the technology development process. Second or subsequent uses of the technology in that specific environment are considered heritage use.

Technology Readiness Level (TRL): standardized **1–9 scale** used to assess the maturity of a technology. See Appendix E in NPR 7123.1 for further information.

Valley of Death: The critical gap where promising technologies don’t transition from research and development to market-ready or operational use due to funding, technical, and organizational challenges.

Figure 1 below illustrates the technology lifecycle phases describing the focus of each phase, generally the maturity level of the technology, the activity associated with that phase and its desired outcome. The table also addresses the risks mitigated for each phase along the maturity path.



	R&D Demonstration	Technology Transition	Mission Infusion
Focus	• Proving or showing the technology works in relevant or operational settings via prototypes and/or tests. • Mid-stage: Validation & risk reduction (often TRL 5–7).	• Moving/handing off matured technology from R&D to user organization. • Bridge from technology R&D and demonstration to user engineering and system qualification.	• Deep embedding/integration into an existing system/product. • Operational Use/Deployed System
Activity	Build and test prototypes and models in realistic conditions.	Secure funding, agreements, requirements match; cross "valley of death".	Incorporate and utilize technology deeply within host system.
Outcome	Demonstrated technology confirming feasibility	Qualified technology for integration into mission.	Enhanced mission capability.
Risks Addressed	Technical feasibility and performance uncertainty.	Programmatic and operational mismatch.	Technical performance and reliability.

Figure 1. Technology Infusion Lifecycle

Not all technologies advance through the entire lifecycle from early research to transition and eventual infusion into operational programs or missions. Some innovations progress more slowly, encounter maturation challenges, or do not move into long-term use, even when they show initial promise. Section 4.1 provides additional discussion of the factors that influence these outcomes.

Table 1 below provides some example technologies and their progression along the technology lifecycle.

Table 1. Example Technology Progression

Technology	R&D Demonstration	Technology Transition	Mission Infusion
Thrusters for the Advancement of Low-Temperature Operations in Space (TALOS)	STMD/GCD funded technology development and ground demonstrations	Astrobotic adopted TALOS and further developed thrusters to use on Peregrine lunar lander.	Astrobotic infused in Peregrine lunar lander that launched January 2024.
Roll-Out Solar Arrays (ROSA)	STMD/SBIR funded technology development and ground demonstrations. (SBIR III contracts)	RedWire/Air Force partnership for flight demonstration on the International Space Station (ISS) in 2017.	ROSA as the primary power source for the Double Asteroid Redirection Test (DART) spacecraft that successfully launched in 2021, and ROSA upgrades were sequentially installed on top of legacy solar array wings starting in 2021 as ISS supplemental power.
Deep Space Optical Communications (DSOC)	STMD/GCD funded initial technology development and transitioned to TDM for further maturation and ground demonstrations. (MOA between STMD and HEOMD for cost sharing and SMD commitment to fund integration with Psyche)	STMD partnered with SMD to include DSOC on Psyche mission as a Payload Element. Launched with the Psyche mission in 2023 and successfully demonstrated 10–100x faster data rates than traditional radio systems.	None yet.
Solar Electric Propulsion (SEP)/Advanced Electric Propulsion System (AEPS)	STMD/GCD funded initial technology development and transitioned to STMD/TDM for further maturation and environmental qualification testing.	STMD/TDM delivered three flight-qualified 12 kW-class Hall thrusters to the PPE for integration to the vehicle for flight demonstration.	SEP Project delivered three AEPS flight thrusters to the Power and Propulsion Element (PPE).
Cryogenic Thermal Coating (aka "Solar White")	Initiated as STMD NIAC project, transitioned to GCD and TDM for technology maturation. 2018, Cryogenic thermal coating tested in low Earth orbit on ISS under the Materials International Space Station Experiment (MISSE).		DN-2485: AZ Technologies – Nonexclusive DN-2484: T.G.V. Rockets, Inc – Evaluation DN-2650: AZ Technology, Inc - Evaluation

2.0 TECHNOLOGY INFUSION PATHWAYS

A technology infusion pathway is the approach or route through which the technology matures starting with technology demonstrations to technology transitions to a user organization where they perform engineering for their specific use case prior to adoption for operational use. The pathways vary by mission type, funding source, risk tolerance and whether the infusion is into NASA-led, competed or commercial efforts.

Technology maturation can and commonly does take a combination of pathways within NASA's technology development ecosystem. Technologies often follow hybrid or multi-path trajectories where they intersect to maximize impact, reduce risks, and achieve both agency mission goals, and broader societal benefits.

For instance, technology might start with competitive selection through open solicitations for early maturation and proving its value in relevant environments. Once the technology feasibility is confirmed, it can undergo internal transition to a NASA mission directorate for baseline planning or direct infusion into a flagship program (e.g., becoming government-furnished equipment in an Artemis-related architecture). Simultaneously or subsequently, the same technology could pursue external transition to industry partners or other government agencies while pursuing commercialization through NASA's Technology Transfer Program - licensing IP to private companies, enabling spinoffs, startups, or market products.

Many technology development efforts explicitly combine pathways by matching, for example, SBIR/STTR investments with NASA/internal and external/non-NASA funds to accelerate both infusion into NASA missions/applications and commercialization in private markets. This hybrid approach reflects the reality that successful technologies rarely follow a single linear path - instead, they branch and converge to deliver maximum value to meet stakeholder needs.

2.1 Infusion through Advocacy

This pathway relies on active promotion, education, and championing to build awareness, enthusiasm, and organizational buy-in for technology. The process emphasizes collaboration between the technology developer and the receiving mission team. It involves “champions” (e.g., technical leads, executives, or subject matter experts) highlighting benefits, sharing success stories, presenting them at forums, or incorporating the tech into strategic roadmaps/plans. Advocacy often precedes or complements other methods by reducing resistance and aligning stakeholders. Example: A principal investigator or program manager advocating for a new sensor in mission concept reviews to prioritize its adoption in upcoming spacecraft.

2.2 Infusion through Incentivization

This approach uses tangible rewards, funding, policy incentives, or performance-based motivators to encourage adoption and integration. It lowers barriers (e.g., cost, risk, or effort) for users or programs to incorporate technology into their missions. Common tools include grants, matching funds, priority access to resources, or risk-sharing mechanisms. Example: Offering SBIR/STTR follow-on funding or internal innovation prizes to teams that successfully infuse technology into their mission.

2.3 Internal Transition

Internal technology transition refers to the agency-internal process covering the handoff and maturation of a technology within the same organization (e.g., intra-directorate) or closely affiliated entities (e.g., inter-directorate such as from R&D lab to mission/operational program). It focuses on bridging development to implementation through internal processes like technology readiness level (TRL) advancement, technology demonstration, integration testing, requirements alignment, and program baselining. When this transition occurs across Mission Directorates, agreements are often documented via a Memorandum of Agreement (MOA), to ensure the technology meets operational needs, integrates effectively, and supports mission success and may require the accepting government party (user/program) to implement the technology transition via contract mods between any industry partner. Example: Moving a propulsion prototype from a NASA center's advanced concepts group to a flagship mission's baseline design via internal maturation efforts and risk-reduction testing.

2.4 External Transition

External technology transition involves the deliberate transfer of a matured technology from an internal NASA research and development organization to an external entity (e.g., other agencies, industry, or nonaffiliated organizations) without necessarily pursuing full market entry. This process typically follows successful technology demonstration (around TRL 6 or higher) and serves as a steppingstone to broader adoption, commercialization, or dual-use applications beyond NASA's direct missions. Example: Sharing a NASA-developed composite material process with a Department of War (DoW) contractor for adaptation in a national security mission via agreements or joint testing. For government-to-government transitions, generally the mechanism is an Interagency Agreement (IAA) when there is a transfer of funds, and/or a Memorandum of Understanding (MOU) when no transfer of funds is required. External technology transitions with industry require navigating licensing agreements, technology transfer offices (e.g., via NASA's Technology Transfer Program[1]), patent considerations, Space Act Agreements, and/or competitive procurements to facilitate the hand-off.

2.5 Directed Technology Demonstrations

Directed Technology Demonstrations are purposefully funded, structured demonstrations to validate technology performance in relevant or operational environments, often to de-risk infusion or prove readiness for a specific mission need. They are typically directed for inclusion by programs (e.g., via dedicated missions) to target specific gaps, accelerate TRL progression, or provide evidence for decision-makers. Example: STMD's Radio Frequency Mass Gauge (RFMG) flying a new propulsion system sensor in space to demonstrate viability for future missions.

2.6 Public-Private Partnerships (PPPs)

This collaborative model brings together government entities, industry, and sometimes academia/non-profits to co-develop, co-fund, demonstrate, or infuse technologies. It leverages shared resources, expertise, and risk to achieve mutual goals (e.g., mission success plus commercial potential).

2.7 Commercialization

Commercialization at NASA refers to the process of transitioning agency-developed technologies - often through patents, software releases, or subject matter expertise - into the private sector to provide commercial products, services, or businesses that benefit the public, economy, and U.S. industry.

SBIR/STTR exists to foster commercialization and funds small business technology development through a phased approach to enable commercial success. NASA's Technology Transfer Program (under STMD) emphasizes licensing inventions to private companies (via mechanisms such as Standard Commercial Licenses, Startup Licenses with no upfront fees for new ventures, or Evaluation Licenses for testing viability) and open-source software distribution also to support commercial development of NASA technology.

The goal is to maximize societal return on taxpayer-funded R&D by enabling broad adoption outside government use, generating economic growth, jobs, and innovations in diverse sectors (e.g., healthcare, materials, consumer goods), with royalties feeding back to support the inventors rather than prioritizing revenue. Table 2 below provides example technologies and their transition approach.

[1] https://technology.nasa.gov/blog-top-licensing-questions-answered

Table 2: Example Technologies for Each Infusion Pathway

Technology	Demonstration/ Infusion Destination	Transition Approach
Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)	Mars 2020	**Directed Technology Demonstration with Internal Transition** Selected from 58 instrument proposals submitted by research teams around the world for a demonstration on Perseverance. The Announcement of Opportunity (AO) was released by the Science Mission Directorate (SMD) for the Mars 202 mission. NASA selected MOXIE based on its potential to address the agency's high priority "Strategic Knowledge Gaps" for human exploration. HEO and STMD funded the development of MOXIE while SMD managed the rover development.
Terrain Relative Navigation (TRN)	Mars 2020	**Infusion through Advocacy: Mission Adoption** The M2020 project adopted TRN to enable the selection of Jezero crater as the landing site for Mars 2020. Initially, the project did not baseline TRN because M2020 was sold without the TRN capability. As a result, the project did not want to take on the additional implementation risk of paying for the required technology maturation. However, the Chief Engineer for the Enhanced Lander Vision System and the science team were persistent advocates for maturation of TRN technology because some of the most desirable science sites (like Jezero crater) could not be safely accessed without TRN. Once TRN achieved TRL 6 though a successful helicopter and close-loop pin-point landing demo, the technologists, engineers, scientists, and project worked with STMD and others to secure additional funding for the flight implementation of TRN. Co-funding in hand, the project agreed that any additional risk to the project was acceptable and baselined the implementation work associated with accommodating TRN. This allowed the science team to select Jezero Crater as the M2020 landing site. Transfer codified via MOA between STMD and SMD.
Deep Space Optical Communications (DSOC)	Psyche – Ride Share	**Directed Technology Demonstration with Internal Transition (STMD to SMD)** DSOC was a directed tech demo, which was also an internal transition. DSOC was a ride along do-no-harm payload with the DSOC development team operated the demonstration the entire time.
Solar Electric Propulsion (SEP)/Advanced Electric Propulsion System (AEPS)	Power and Propulsion Element (PPE)	**Government Furnished Equipment (GFE) with External Transition to Industry** SEP/AEPS was provided as GFE (originally as GFI, then GFE) to the contractor developing the PPE
Radio Frequency Mass Gauge (RFMG)	Intuitive Machines (IM) Nova-C Lander	**Directed Technology Demonstration with External Transition (NASA to IM)** RFMG was a directed tech demo.
Hypersonic Inflatable Aerodynamic Decelerator (HIAD) technology demonstration on Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)	JPSS-2 Spacecraft – Ride Share	**Public Private Partnership Technology Demonstration** NASA STMD/LOFTID Project and ULA entered into a public-private partnership through the ACO/TP acquisition to demonstrate an orbital entry of a HIAD. SMD and STMD entered into an agreement via MOA to fly LOFTID in a ride-share configuration with the JPSS-2 spacecraft.
Roll-Out Solar Arrays (ROSA)	Double Asteroid Redirection Test (DART)	**External Transition from AFRL/DSS to NASA** Air Force Research Laboratory (AFRL) provided initial funding for ROSA via SBIRs to Deployable Space Systems (DSS). After technology maturation, ROSA continued as a 2017 demonstration on the International Space Station - an AFRL-led experiment conducted in partnership with NASA and DSS.

		Once demonstrated, ROSA became a successful technology infusion, selected by the mission, for DART.

3.0 TECHNOLOGY ON-RAMP ACQUISITION AND AGREEMENT MECHANISMS

NASA's mechanisms for solicitations, partnerships, funding, and agreements for technology maturation and infusion can be grouped into several logical categories based on their primary purpose, legal basis, level of competition, degree of NASA involvement, and nature of the relationship (e.g., competitive research funding vs. flexible partnerships).

For those wanting to learn more about the available acquisition mechanisms for on-ramping technologies, refer to Appendix A.

4.0 KEY OBSERVATIONS

4.1 Challenges to Technology Infusion in NASA's Ecosystem

Technology infusion faces numerous hurdles that can impede or derail the process, even after successful technology demonstration and transition phases. These challenges are multifaceted, spanning technical, programmatic, financial, and organizational dimensions, and often result in only a fraction of promising technologies achieving sustained operational use. Below are some challenges drawn from qualitative observations collected via email and phone interviews with NASA Principal Technologists and the Chief Technologists of Science Mission Directorate (SMD) and STMD and highlight why infusion requires targeted strategies to overcome barriers. These challenges are interconnected and can be grouped into four primary categories to better illustrate their interdependence and systemic nature. Addressing them holistically rather than in isolation enables more effective risk-informed strategies and higher infusion success. Sections 4.2 and 5 discuss mitigation approaches and recommendations relevant to the challenges below.

1. **Maturation and Transition Gaps (The "Valley of Death" and Related Funding Issues)**
    - "Valley of Death" - Graduating between the two valleys (1) basic R&D (TRL 1-4) to technology maturation (TRL 6), and (2) technology demonstration (TRL 7-9) and operation: The "Valley of Death" is defined as the funding and transition gap between technology development (e.g., prototypes from science and technology efforts) and production or integration into programs of record. Technologies often face challenges at these cliff edges due to insufficient bridging mechanisms, where basic R&D funding ends prior to a technology maturation organization adopting the effort, and technology maturation budget is expended but mission-specific budgets are not yet allocated. This results in technology sufficiently matured for transition but not funded for adoption. This further results in delayed or abandoned infusion, as seen in cases where technologies from STMD demonstrations are unable to secure follow-on support from mission directorates, exacerbating the disconnect between innovative concepts and conservative operational requirements.
    - Funding and Resource Constraints**:** Infusion demands significant investment for integration, testing, and adaptation, but competing priorities often divert budgets. NASA's cost-capped missions prioritize low-risk heritage technologies to stay within tight cost and schedule requirements, sidelining novel ones that could offer breakthroughs but require extra funding

for risk reduction. Additionally, fluctuating budgets or program reallocations can orphan technologies mid-transition, leaving them without sustained resources. A detailed example is the underfunding of maturation efforts post-technology demonstration, where initial investments cover prototypes but not the funding needed for further maturation beyond TRL 6 and system-level integration and testing, leading to sub-optimal infusion rates.

- Interdependencies: These two are tightly linked - insufficient sustained funding directly widens the Valleys of Death, while the gap discourages further investment.

2. Risk Aversion and Cultural/Organizational Barriers

- "Heritage Bias" - Risk Aversion in Mission Programs: NASA's "failure is not an option" culture fosters conservatism, where program managers avoid unproven technologies to minimize schedule slips or failures in high-stakes missions. Failure is frequently due to inadequate testing or characterization of performance limits, potential faults and failures and risks. Lack of flight or operational heritage leads to "heritage bias" as a distinct barrier where there is systematic penalization of new technologies in mission selection, risk assessments, and board reviews. For instance, a demonstrated prototype may lack the flight heritage needed for spaceflight, leading to high residual risks that mission managers deem unacceptable. Even mature technologies may face scrutiny if they introduce perceived uncertainties, such as compatibility issues with legacy systems. Managers might default on safer alternatives, disincentivizing innovation and perpetuating reliance on lower risk technologies. Some mission organizations take informed risks in infusing technologies if it leads to a significant improvement (will not consider infusion for marginal improvements) towards the overall mission objectives.
- Organizational Resistance to External Technologies: Mission teams often favor conducting their own technology R&D efforts because this approach enables deeper technical understanding of the technology, greater control over its maturation timeline, seamless integration with mission-specific requirements, and more effective management of flight engineering processes. This reluctance to adopt externally developed ("not invented here") solutions creates a protective boundary around missions, limiting the incorporation of innovative technologies from outside sources and contributing to slower overall infusion rates despite investments in broader technology programs.
- Workforce and Institutional Knowledge: Erosion of NASA's core technical competencies and the lack of robust succession planning to preserve and transfer institutional knowledge manifests in several ways relevant to infusion. These include a reduced capacity for independent, critical assessment of maturing technologies' readiness, benefits, risks, and applicability to specific mission contexts or limited advocacy and technical leadership during mission formulation, proposal development, or review processes, where deep domain knowledge is needed to champion innovative options.
- Interdependencies**:** Heritage bias is amplified by cultural silos and risk-averse norms; limited cross-directorate collaboration hinders early alignment.

3. Awareness, Communication, and Alignment Issues

- Limited Awareness of Maturing and Available Technologies: A persistent barrier to effective technology infusion is the limited awareness among mission planners, proposal teams, and project stakeholders of emerging or maturing technologies that could enhance mission capabilities. Mission formulation often occurs within tight timelines driven by competitive mission opportunities, strategic priorities, and proposal deadlines. Proposals must be submitted with well-defined concepts, budgets, risks, and Technology Readiness Levels (TRLs). If a promising technology is still in development (e.g., TRL 3–6) or its benefits/performance aren't widely communicated when mission teams are forming their concepts and writing proposals, planners often default to heritage (proven) approaches to minimize risk. This creates a "timing mismatch".

- Requirements Mismatch and Integration Difficulties**:** Technologies developed in isolation often find themselves misaligned with evolving mission needs, leading to costly redesigns. For example, a sensor demonstrated in a lab may not integrate seamlessly into a spacecraft's power, thermal, or data systems, requiring extensive modifications that inflate costs and timelines. This challenge is compounded by poor communication between R&D teams and mission offices, where initial specifications drift, resulting in "requirements creep".
- Interdependencies**:** Awareness gaps cause teams to miss opportunities for early alignment, leading to mismatches and costly redesigns; poor communication between technology development teams and mission teams perpetuate both.

4. **External and Strategic Factors**
   - Commercial Service Acquisition Barriers: Infusing new technologies into systems acquired by NASA as a service - such as Commercial Lunar Payload Services (CLPS) and Human Landing System (HLS) models or other emerging systems - presents unique challenges. In these arrangements, NASA purchases end-to-end services from commercial providers who own, design, build, operate, and maintain the systems with limited direct NASA oversight or control. Service providers, like the HLS prime contractors, who are under extreme schedule pressure, or international partners (IP) who are delivering an element under an agreement - while they sometimes need NASA technologies, there are a lot of concerns about potentially putting a NASA technology development organization in the critical path of an IP or Service Provider's success. This highlights the tension between NASA's push for transformative capabilities and the commercial model's emphasis on efficiency, ownership, and profitability.
   - Intellectual Property and Partnership Hurdles**:** For external or commercial infusion pathways (e.g., via CLPS), IP rights, licensing complexities, or mismatched incentives with industry partners can delay adoption. Companies may hesitate if NASA's technology requires heavy adaptation for market viability, or if data-sharing agreements are overly restrictive. This is evident in commercialization efforts where spinoffs succeed only after navigating patent negotiations, but many technologies remain unused due to perceived low commercial potential, or that were initiated without a clear understanding of market needs.
   - Strategic and Priority Shifts**:** Shifts in agency objectives can limit the relevance of previously developed technologies before they are fully infused. Updates to Decadal Survey priorities or changes in political direction may also reduce emphasis on certain areas, affecting ongoing investments. Technologies initiated to meet earlier policy priorities, such as the On-Orbit Servicing, Assembly, and Manufacturing Mission 1 (OSAM-1), may face challenges adapting to new strategic directions, which can result in reduced applicability and unrealized benefits.
   - Interdependencies: Strategic shifts can orphan partnerships or create IP barriers when priorities change mid-development; external hurdles worsen when internal alignment is weak.

Addressing these challenges requires robust strategies like enhanced transition agreements, dedicated infusion funding, better TRL assessments, and cross-directorate collaboration. By explicitly tackling these challenges, NASA can improve infusion rates, ensuring more innovations contribute to exploration and science objectives.

4.2 Potential Mitigation Strategies to Overcome the Infusion Challenges

Successful technology development infusions result from a blend of many factors: effective communication between developers and customers, effective identification and ranking of customer needs, effective research and identification of technologies to satisfy customer needs, thoughtful development plans with key performance parameters, identification of on and off ramps, realistic development schedules and budgets, stable funding, and successful development execution. Table 3 below provides examples of potential mitigation approaches for each challenge listed above.

Table 3. Mitigation Strategies

Category	Sub-Challenge	Description	Key Mitigations
Challenge #1. **Maturation and Transition Gaps**	Valley of Death (TRL 1-3 to TRL 4-6 gap) (TRL 6-8 to TRL 9 gap)	Technologies are shelved after demonstration due to lack of bridging mechanisms, and continued maturation funding; results in delayed/ abandoned infusion.	• Active participation of Capability SMEs across STMD portfolio • Cross-directorate coordination (TCIG) for follow-on support • Joint working groups and technology exchange forums • Innovation challenges, awareness campaigns, leadership endorsements • Standardized communication protocols across directorates • Include technology SMEs into early mission planning • Early Technology Infusion Plans (TIPs) highlighting transition targets with transition milestones • Technology reviews tracking development and infusion planning progress
	Funding and Resource Constraints	High integration/testing costs compete with tight budgets; cost-capped missions favor heritage; fluctuating budgets orphan mid-transition tech (e.g., only ~3% STMD infusion in FY21).	• Bridge funding to cover integration costs • Diversified funding (industry co-investments, Congressional supplements) • Multi-year commitments and contingency planning in roadmaps • Metrics tracking to justify resource advocacy
Challenge #2. **Risk Aversion and Cultural/ Organizational Barriers**	Heritage Bias / Risk Aversion	"Failure is not an option" culture leads to systematic preference for proven tech; new tech penalized in reviews/ proposals even if mature. Some missions accept informed risk for significant gains.	• SMEs highlight value propositions of technology and potential mitigation plans in evaluations • Adopt RIDM processes with quantitative risk tools • Infusion incentives & training to reframe risk as essential
	Organizational Resistance to External Technologies	Reluctance to adopt externally developed solutions creates a protective boundary around	• Foster Early and Ongoing Collaboration Between Technologists and Mission Teams

Category	Sub-Challenge	Description	Key Mitigations
		missions limiting the incorporation of innovative technologies from outside sources	• Incentivize Adoption of External Technologies in Proposal and Review Processes
	Workforce and Institutional Knowledge	Erosion of core competencies; lack of succession planning reduces capacity for critical assessment, advocacy, and oversight of new tech.	• Knowledge capture tools (wikis, mentorship, repositories) • Targeted training, retention, and cross-training rotations • "Technology champions" roles drawing on preserved expertise
Challenge #3. **Awareness, Communication, and Alignment Issues**	Limited Awareness of Maturing Technologies	Timing mismatches & poor dissemination during tight proposal cycles lead to default to heritage approaches.	• Centralized visibility (TechPort, webinars hosted by technology SMEs, showcases) • Pre-proposal workshops and "matchmaking" events linking supply and demand • Technology forecasts in roadmaps
	Requirements Mismatch and Integration Difficulties	Isolation in development causes misalignment, integration hurdles, and requirements creep.	• Co-development and iterative requirements definition • Early system-level studies/simulations • Dedicated liaisons and joint reviews for immediate feedback loops
Challenge #4. **External and Strategic Factors**	Commercial Service Acquisition Barriers	Space systems acquisitions as commercial services, limits NASA control or insight.	• Early and Continuous Collaboration/Engagement • Flexible Contracting and Partnership Mechanisms • Incentive Alignment in Contracts to reward infusion-friendly behaviors
	Intellectual Property and Partnership Hurdles	IP/licensing complexities, mismatched incentives delay commercial/external adoption.	• Streamlined IP management and licensing templates (Tech Transfer Program) • Market-aware partnerships and early viability assessments • Royalty-free options and negotiated agreements for spinoffs
	Strategic and Priority Shifts	Evolving goals (e.g., Artemis pivots, decadal changes) render tech obsolete or misaligned.	• Regular portfolio reviews & scenario planning • Strategic alignment forums (TCIG) to prioritize resilient technology

5.0 RECOMMENDATIONS

It must be acknowledged that technology development and the required activities that support it cannot be prescriptive. Technology development is a winding path of challenges, setbacks and innovation. Thus, the following recommendations are made as a rough framework that can be further defined and tailored to meet the needs of projects and provides activities to help improve the successful infusion of NASA technology into NASA missions. The recommendations below are not requirements – only potential solutions or suggestions to overcome the technology infusion barriers outlined above. The following section will discuss each recommendation.

5.1 Prioritize Early and Continuous Engagement Between Technologists and Users/Missions

Successful technology infusion is more about trust and relationships than processes. Infusion often hinges more on human elements - particularly trust in the technology and the relationships surrounding its implementation - than on processes and procedures alone. The first recommendation suggests prioritizing early and continuous engagement of technology experts with stakeholders and user missions to mitigate the gap between technology demonstration and operations. Successful technology infusion into missions, systems, or operational environments depends on alignment between the technology solution and the real-world needs, constraints, and priorities of the end-user (e.g., mission programs, payload teams, ground systems, or operational organizations). Early and constant engagement of technology experts (developers, principal investigators, systems engineers) with stakeholders and user missions is critical to:

- Validate the technology addresses genuine capability gaps or mission requirements (for "pull", "push", and “translational” technologies).
- Obtain stakeholder advocacy.
- Identify integration challenges, interface mismatches, performance shortfalls, or operational constraints before significant investment is locked in.
- Build trust, awareness, and buy-in across technology development organization and mission/program communities.
- Establish an objective technology readiness assessment and system integration assessment as a critical part of the mission pre-formulation process.
- Enable collaborative refinement of key performance parameters (KPPs), infusion targets, and gap closure assessments.
- Reduce downstream risks of schedule delays, cost overruns, redesigns, or failure to infuse.
- Increase the probability of successful handoff and adoption.

Table 4 below illustrates a suggested engagement approach at the various TRL levels with best practice techniques along the TRL maturation.

Table 4: Stakeholder Engagement Approach

Tech TRL	Engagement Approach	Technology Provider Engagement Focus
LOW (TRL 1-3)	**Broad, Exploratory Engagement**	Early socialization is internal or community-wide (e.g., workshops, communities of interest) to validate gaps and potential pull.
		Socialize the concept broadly to confirm customer interest, needs alignment, and initial buy-in before formal start.
		Initiate direct conversations with candidate missions/programs to identify applicability and document initial KPPs collaboratively.
MID (TRL 4-6)	**Targeted, collaborative engagement with potential or selected Program/Mission**	Share assessments and plans; secure approval on infusion goals and decide on continuation.
		Shift to active, ongoing coordination with selected mission/program office; assign infusion POC for advocacy.
		Regular technical and schedule updates; embed infusion activities and communicate risks directly.
High (TRL 7-9)	**Formal, contractual engagement with Program/Mission owners**	Integrate into formal mission reviews; assess and identify funding for Pre-Phase A and integration.
		Secure commitments (funding, contracts, formal agreements) to enable transfer.

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Tech TRL	Engagement Approach	Technology Provider Engagement Focus
		Side by side collaboration with Stakeholder/Program who will take technology to flight.
		Formal transfer of responsibility; document successful infusion and conclude dedicated activities.

5.1.1.1 Tactics

Initiate Early and Continuous Technologist-Stakeholder Engagement: Establish dedicated "bridging" initiatives where early engagement by technologists with stakeholders and potential customers allows the technologist to better understand the needs of the missions and share with mission designers the available technology solutions that will be mature enough to support their mission requirements on the schedule required by the mission. Begin technologist involvement with mission stakeholders, potential customers, and end-users during Pre-Phase A / Phase A mission engineering (technology discovery and gap assessment phases). To address defined mission gaps properly, technology development must be targeted at a specific need from a mission or customer. Creating a joint team comprised of both mission designers and technology development members during early mission planning, enables technologists to understand mission needs and constraints while simultaneously informing mission designers of maturing technology solutions that can meet requirements within mission timelines. Also, conducting technology readiness assessment jointly can guide technologies through development and qualification.

Establish Transition Points of Contact (POC): Establish "infusion champions" in both the mission program offices and the technology development organization to foster a "risk-informed" culture and overcome risk aversion in mission programs. The infusion champions would advocate for novel technologies in hopes to encourage the project manager to accept some risk and adopt the technology and/or help inform the mission planning community of new technologies. This can be done by promoting cross-directorate collaborations with formal agreements.

Form Joint Mission-Technology Teams During Early Mission Planning: Create integrated teams comprising mission planners, systems engineers, end-users, and technology developers during pre-Phase A or earlier to mitigate any requirements mismatch during mission development. For example, the technologists would directly support mission system engineering efforts working as "embedded technology champions". Joint teams build mutual awareness of mission requirements before critical design decisions are locked in, guide technology maturation and qualification through collaborative readiness assessments, and align development with mission needs.

- Jointly develop requirements and conduct early technology compatibility assessments.
- Ensure that the technology testing is performed in an environment like the operational infusion target to prevent the need for re-testing prior to integration.
- Determine if the use case for the technology is broad or narrow early in its development. For broadly applicable technologies, avoiding the development of a mission tailored, niche product can bolster wide adoption across many missions and can be a more effective approach. Alternatively, if the technology supports a narrow use case, creating a broad technology first and tailoring it later may result in a failed infusion due to lack of further development funding.

Define Targeted Mission On-Ramp Timelines: Define the timeline for each applicable on-ramp mechanism and avoid changes to prevent contractual churn and delays. It is recommended mission teams define when the on-ramp mechanism needs to be in place and executed to support the mission schedule. This will help determine which on-ramp mechanism is the most appropriate. If applicable, identify if there are opportunities for infusion to second deliveries of an element should the technology's readiness not meet the original timeline for delivery.

For external transitions and technologies targeted at commercialization, ensuring marketability of the technology can assist in commercial willingness to partner. If the partner's development schedule does not match the mission schedule this needs to be understood early on. Consider that commercial partners may be required to use company IRAD funding which can add unplanned schedule delays.

5.2 Link Pull Investments to Gaps with Infusion Plans

This recommendation proposes to establish an infusion plan for each "push", "translational", and/or "pull" investment to have a direct linkage to a shortfall or capability gap. The infusion plan should outline the pathway from maturation to operational embedding.

Infusion plans will evolve and become more detailed as the technology matures towards infusion and should be regularly reviewed and updated throughout the technology maturation to ensure the project is on track and challenges are addressed. The following information is recommended to be included in an infusion plan at the time when the information is known:

- Infusion targets (e.g., end user)
- Shortfalls or capability goals addressed by the technology
- Infusion mechanism (e.g., contract, MOU, etc.)
- Current TRL and estimate of TRL progression by year
- Estimated probability of technology maturing to TRL 6 on the timeline needed to meet end user's schedule
- Estimated cost to reach TRL 6 (phased by year)
- Estimated cost for integration/infusion
- Transition Point of Contact – the person responsible for tracking and reporting infusion activities, engaging with stakeholders and advocating for the technology

5.3 Measure technology infusion readiness during normal project management reviews.

The final recommendation suggests augmenting the current entrance and exit criteria in NASA Procedural Requirement (*NPR) 7120.8, NASA Research and Technology Program and Project Management Requirements*[2], to include intentional discussion on infusion readiness beyond just technical performance of the technology project using a Technology Infusion Confidence Level (ICL). As required by NPR 7120.8, Authority to Proceed (ATP) seeks to understand the needs of the stakeholders and any high-level threshold requirements, as well as the expected end-state of the project and its deliverables. NPR 7120.8 also requires Continuation Assessments (CA) on a recurring basis to understand the technical progress summary, cost/schedule summary, top risks, relevancy to stakeholders, and continued suitability of the project end-state is determined.

Evaluating technology infusion readiness during normal project management reviews is good project management behavior. It involves systematically assessing how mature and prepared a new or emerging technology is for successful integration into operational systems, missions, or programs as part of routine

[2] https://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_7120_008A_&page_name=main

oversight checkpoints (such as milestone reviews, gate reviews, or periodic status meetings). This practice ensures that technologies are not prematurely advanced or integrated, reducing risks like cost overruns, schedule delays, performance shortfalls, or mission failures. Teams typically use an established maturity framework - most commonly TRLs - to gauge progress, often supplemented by related metrics like integration readiness.

During these reviews, it is recommended that project managers, technical experts, and stakeholders examine evidence such as test results, demonstration data, risk assessments, and maturation plans to determine if the technology meets predefined thresholds (e.g., TRL 6 or higher before major commitments like preliminary design review). This evaluation identifies gaps, validates assumptions about benefits and costs in the target context, updates risk registers, and informs decisions on resource allocation, contingency planning, or alternative paths.

Appendix B provides a specific example as a suggestion of a structured framework that could be used, or modified, to evaluate the technical progress aspect of technologies at a Continuation Assessment. NPR 7120.8 only provides “Expected Input and Outcomes” and does not prescribe approaches for executing a CA. The example in Appendix B is for illustration purposes only and not a requirement. The Continuation Assessment should be scaled and scoped appropriately for the nature and size of the project.

As a complementary evaluation to the technical progress, establishing a qualitative Technology Infusion Confidence level (ICL) metric helps decision-makers track a technology project's development progress toward successful adoption (infusion) into missions or systems and goes beyond just tracking technical maturity (measured by TRL). While complementary to TRL maturity, it focuses on the non-technical aspects of transition success such as stakeholder engagement, gap closure validation, funding security, agreements, and handoff. Tracking these metrics reveals which key activities have been completed and whether the project remains on track for eventual infusion, making infusion progress measurable, and actionable.

Appendix C illustrates a suggested approach for evaluating ICL for each phase with a brief description of the activities performed at that stage of the technology maturation followed by the exit criteria for evaluation.

6.0 CONCLUSION

The observation and recommendations presented in this document highlights a suggested structured yet complex nature of NASA's technology infusion ecosystem. From initial R&D demonstrations through embedding into operational missions, the lifecycle demands careful navigation of technical maturation, organizational hand-offs, and programmatic alignment. NASA's primary infusion offer flexible routes tailored to mission needs, risk profiles, and stakeholder involvement, often in hybrid forms that maximize reach and impact. These pathways are supported by a diverse set of on-ramp mechanisms, enabling efficient maturation and transfer.

Despite these established frameworks, persistent challenges - focusing solely on processes rather than relationships, funding discontinuities, risk aversion in mission programs, requirements mismatches, IP complexities, and shifting priorities - limit the success rate of technology infusion. Many promising innovations don’t realize their potential despite strong early technology demonstrations, underscoring the need for deliberate, proactive strategies to bridge gaps between development and operational adoption.

The suggested mitigation strategies provide a practical, high-level framework to enhance technology infusion outcomes without prescribing rigid processes that could stifle the inherently iterative and unpredictable nature of technology advancement. Implementing the intent of these observations and recommendations - tailored as needed to specific projects, directorates, and contexts - can foster a more risk-informed culture, strengthen collaboration between technology developers and potential end-users, secure sustained resources for bridging phases, and increase the fraction of demonstrated technologies that achieve lasting operational impact. By systematically addressing barriers while preserving flexibility and innovation, NASA can better ensure that its investments in space technology translate into transformative capabilities for exploration, science, and broader national benefits.

7.0 APPENDIX A: ACQUISITION AND AGREEMENT MECHANISM

ACO (Announcement for Collaborative Opportunities): A standing or topic-specific solicitation from STMD inviting industry proposals for non-reimbursable partnerships. It enables collaboration (e.g., NASA providing expertise, facilities, or testing) to mature commercial space technologies without direct funding exchange, benefiting both commercial and government applications.

AO (Announcement of Opportunity): A competitive solicitation for high-cost, PI-led science investigations or missions (e.g., Explorers, New Frontiers, Discovery programs). It invites proposals for spaceflight hardware, instruments, or full missions, often with cost caps, leading to selections for development phases; emphasizes scientific merit and alignment with Decadal Surveys.

CAN (Cooperative Agreement Notice): A solicitation specifically for cooperative agreements, emphasizing substantial NASA involvement in the project (e.g., for technology development, institutes, or partnerships like EPSCoR). It invites proposals where collaboration is key, often for ground-based or enabling activities, and results in awards with shared responsibilities.

Cooperative Agreements: Grants that involve substantial partnership with the NASA workforce.

CRADA (Cooperative Research and Development Agreement): A formal agreement under the Federal Technology Transfer Act allowing NASA (or federal labs) to collaborate with non-federal entities (e.g., industry, universities) on R&D. NASA provides personnel, facilities, or expertise (often without funds to the partner), while the partner contributes resources; it supports technology transfer, with provisions for IP protection and commercialization.

Government Licensing: The NASA Technology Transfer Program evaluates, patents, and then licenses out new NASA-developed technologies that have potential to benefit the country through commercialization. In cases where a licensee will require more hands-on support or collaboration from inventors or perhaps needs to leverage NASA capabilities as part of their work, NASA would typically need to pair a license with a Space Act Agreement (SAA).

> **Exclusive:** When NASA grants an exclusive license, it means that it agrees not to issue any other licenses with the same rights that fall within the same field of use. In other words, NASA may grant other licenses for the same technology, but not in the same field of use. Oftentimes, an exclusive license will also allow the licensee to sublicense the technology to others, thus generating additional revenue streams.
>
> **Non-exclusive:** NASA can grant a license agreement to any other company with the same rights and field of use if they meet all the criteria for a non-exclusive license agreement. This means a company's competitor may be granted the same rights to NASA technology.[3]

Grants: Financial assistance awards from NASA to support research or projects that advance public purposes aligned with NASA's mission (e.g., via ROSES or other solicitations). They involve minimal NASA involvement beyond funding, with recipients (often academia or non-profits) bearing primary responsibility; governed by federal regulations like 2 CFR 200 and NASA's Grant and Cooperative Agreement Manual.

Interagency Agreements: Formal arrangements (often reimbursable or non-reimbursable) between NASA and other U.S. federal agencies (or sometimes state/local governments) to share resources,

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[3] https://technology.nasa.gov/when-an-exclusive-license-might-be-right-for-your-company

expertise, or funds for mutual goals. They enable collaboration on missions, research, or operations (e.g., with DoD, NOAA, or NSF) under authorities like the NASA Space Act.

MOAs (Memoranda of Agreement): Often legally binding (enforceable as a contract), especially when it includes commitments of resources, specific actions, or conditional agreements (e.g., transfer of funds/services). It can create enforceable obligations if the language shows intent to be bound. Details specific responsibilities, actions, obligations, roles, timelines, and sometimes resource commitments (e.g., conditional funding, services, or tasks) to achieve defined objectives and provides more concrete and operational details (e.g., who does what, how, when, and under what conditions).

MOUs (Memoranda of Understanding): Non-binding agreements outlining intent for cooperation between NASA and partners (e.g., other agencies, international entities like UNOOSA, or private organizations). Outlines broad concepts, mutual goals, intentions, shared objectives, and general frameworks for cooperation. It expresses a convergence of will or "agreement to agree" on high-level principles. It signals good-faith commitment but lacks the elements required for a full contract (e.g., no detailed obligations, consideration, or penalties for non-performance).

NRA (NASA Research Announcement): A broad solicitation mechanism announcing NASA's research interests in specific areas (e.g., ROSES as an omnibus NRA). It invites proposals for research, often resulting in grants, cooperative agreements, or contracts after peer review; used across directorates for basic/applied work.

Prizes, Challenges and Crowdsourcing (PCC): STMD program that taps into the creativity and ingenuity of the public, industry, universities, and independent innovators. The program uses open innovation methods — such as incentive prize competitions and crowdsourcing — to solve tough technology problems that support NASA's space exploration goals. There are two key components of PCC:

- **Centennial Challenges**: NASA's flagship prize competition program offers monetary prizes for revolutionary solutions and prototype demonstrations in areas like space robotics, food production for deep space, waste recycling, and other critical technology gaps.
- **Center of Excellence for Collaborative Innovation (CoECI):** Handles broader crowdsourcing efforts, including the NASA Tournament Lab, internal idea challenges, and freelance-style tasking to gather ideas and solutions from global communities.

ROSES (Research Opportunities in Space and Earth Sciences): NASA's primary annual omnibus solicitation (a type of NASA Research Announcement or NRA) from the Science Mission Directorate (SMD). It invites proposals for basic and applied research across Earth and space sciences through numerous program elements with varying due dates, often resulting in grants or cooperative agreements. Proposals are submitted via NSPIRES and evaluated through peer review.

Space Act Agreements: SAAs are a flexible, NASA-specific partnership tool authorized under the National Aeronautics and Space Act of 1958 (as amended), specifically NASA's "Other Transactions Authority" (51 U.S.C. § 20113(e)). They enable collaborations with domestic or international entities (industry, academia, other governments) to advance NASA's missions, including technology development, demonstration, commercial space use, and exploration goals like Artemis. Unlike traditional contracts or grants, SAAs are not bound by Federal Acquisition Regulations (FAR), offering greater flexibility in terms, IP rights, and structure. They are often used for public-private partnerships where standard mechanisms are insufficient. Key types include:

> **Non-reimbursable SAAs**: Mutually beneficial activities where each party funds its own participation (no funds exchanged); common for joint R&D, testing, or demonstration that furthers NASA's objectives and the partner's goals.

Reimbursable SAAs: Primarily benefit the partner; NASA provides goods, services, facilities, or expertise (often underutilized), with the partner reimbursing NASA's costs (in full or part) on a non-interference basis.

Funded SAAs: NASA provides funds to the partner to achieve agency objectives (e.g., stimulating commercial capabilities like crew/cargo transport or commercial space stations); used sparingly when contracts, grants, or cooperative agreements can't meet needs, often after competition (e.g., in programs like COTS, CCDev, or recent Commercial Low Earth Orbit Destination efforts, STMD's Tipping Point).

Unfunded SAAs: Unfunded agreements are agreements in which the Agency provides goods, services, facilities, or equipment on a no-exchange-of-funds basis to a domestic partner to accomplish an Agency objective where there is no direct benefit to NASA. NASA will enter into Unfunded agreements only after full and open competition.

The STMD Announcement of Collaboration Opportunity (ACO) program is an example of a solicitation process that utilizes unfunded space act agreements. Through this program NASA helps reduce the development cost of space technologies and accelerate the infusion of emerging commercial capabilities into future missions. NASA centers partner with selected companies to provide expertise, facilities, hardware and software at no cost. STMD has historically utilized a two-year cadence for awarding ACOs to commercial partners**.**

International SAAs: Similar to domestic but with additional considerations (e.g., governed by international law for non-reimbursable or U.S. federal law for reimbursable).

Tipping Point: A competitive solicitation from NASA's Space Technology Mission Directorate (STMD) for public-private partnerships. It funds industry-led development of "tipping point" technologies (mature enough that investment pushes them toward commercial viability and NASA infusion), typically via firm-fixed-price contracts with milestone payments, focusing on Moon/Mars-relevant advancements.

The STMD Tipping Point program is an example of a solicitation process that utilizes funded space act agreements. Through the Tipping Point Announcement for Partnership proposals, NASA seeks industry-developed space technologies that can foster the development of commercial space capabilities and benefit future NASA missions. Technology is considered at a tipping point if an investment in a demonstration will significantly mature the technology, increase the likelihood of infusion into a commercial space application, and bring the technology to market for both government and commercial applications. The partnerships established through Tipping Point selections combine NASA resources with an industry contribution of at least 25% of the total project resources (10% minimum for companies with 500 or fewer employees), shepherding the development of critical space technologies/capabilities to stimulate commercial space economy while also saving the agency, and American taxpayers, money. STMD has historically utilized a roughly two-year cadence for awarding Tipping Points to commercial partners.

SBIR/STTR: The NASA Small Business Innovation Research / Small Business Technology Transfer (SBIR/STTR) program is part of America's Seed Fund, the nation's largest source of early-stage non-dilutive funding for innovative technologies. Through this program, entrepreneurs, startups, and small businesses with less than 500 employees can receive funding and non-monetary support to build, mature, and commercialize their technologies, advancing NASA missions and helping solve important problems facing our country. [4] Not all SBIR awards directly support infusion. The subset listed below are specifically designated to enable near term infusion.

[4] https://www.nasa.gov/sbir_sttr/

Civilian Commercialization Readiness Pilot Program (CCRPP): The purpose of CCRPP awards is to enable near-term infusion and/or commercialization of SBIR/STTR-developed technologies. CCRPPs are not designed for the incremental changes of earlier phases of development. Rather, these heavyweight technologies are running an accelerated path into transitioning to NASA missions and applications as well as commercial markets.

To support these impacts, CCRPP funding combines additional SBIR/STTR program investment with NASA or non-NASA entity investment.

Technology maturation without infusion and/or commercialization will not be accepted for CCRPP. The resulting technology should have a strong relevance to NASA's missions, as well as a strong potential near-term use by NASA and/or markets outside of NASA beyond the CCRPP investment.

SBIR Phase II Sequential Purpose: Phase II Sequential awards are available to Phase II awardees in agency-specified topics to continue the work of an initial Phase II award. A Phase II awardee may receive only one additional Phase II Sequential award.[5] The purpose of Phase II Sequential awards is to enable near-term infusion of SBIR/STTR-developed technologies into NASA missions. The submission period opens on an annual basis.

SBIR Phase III Purpose: Phase III is the commercialization of innovative technologies, products, and services resulting from either a Phase I or Phase II contract. This includes further development of technologies for transition into NASA programs, other Government agencies, or the private sector. Phase III contracts are funded from sources other than the SBIR and STTR programs and may be awarded without further competition.[6] A Phase III award can be awarded at any time.[7]

[5] https://www.nasa.gov/sbir_sttr/phase-ii-sequential/
[6] https://www.nasa.gov/sbir_sttr/phase-iii/
[7] https://www.nasa.gov/sbir_sttr/post-phase-ii/

8.0 APPENDIX B: TECHNOLOGY DEVELOPMENT ASSESSMENT CRITERIA EXAMPLE

As required by *NPR 7120.8, NASA Research and Technology Program and Project Management Requirements*[8], Continuation Assessments (CA) are required to understand the technical progress summary, cost/schedule summary, top risks, relevancy to stakeholder, and continued suitability of the project end-state is determined. Table 4-5 provides specific Continuation Assessment Expected Inputs and Outputs. This document recommends establishing a structured framework for the CAs where technology development organizations hold formal checkpoints on a recurring basis (e.g. annually), where a panel of Subject Matter Experts (SMEs) evaluates the portfolio of technologies against predefined and potentially weighted criteria to make objective go/no-go decisions on progression toward infusion. The ultimate outcome of the Continuation Assessment is to arrive at one of four decisions for each investment in the portfolio: Continue, Redirect/Rescope Hold, or Terminate. Below is a specific example of a structured framework to evaluate technologies at a Continuation Assessment. NPR 7120.8 only provides “Expected Input and Outcomes” and does not prescribe approaches for executing a CA. The example below is for illustration purposes only and not a requirement. The Continuation Assessment should be scaled and scoped appropriately for the nature and size of the project.

Drawing from models like NASA's Dust Management Project (DMP) Decision Gate Process and adapting to meet the current needs, portfolio reviews should occur annually, assessing each investment in the portfolio against categories such as technical maturity, risk reduction, programmatic alignment, and resource readiness[9]. Criteria weights would evolve with TRL of each investment, with a higher early emphasis on resources and development effort (e.g., weights of 0.6–0.7), shifting to integration, safety/reliability, and applicability (e.g., weights of 0.3–0.4) at later gates, to reflect decreasing uncertainty. The Continuation Assessment is comprised of assessments with cross-functional teams, to identify early off-ramps for underperforming investments, resource reallocation, and stakeholder confidence, improving infusion success through transparent, data-driven governance.

The Decision Gate Review evaluates “push”, “translational” and “pull” technologies. Even though “push” and “translational” technologies do not require an infusion plan, any “push” investment with a duration of greater than two years should undergo a formal review and re-assessment of its value to the agency.

Modeled after the DMP Decision Gate Process, the review consists of a panel of SMEs evaluating each investment against criteria followed by answering the three fundamental questions below:

1. Is the project sufficiently performing to expectations?
2. Is all required programmatic (technical, cost, schedule, risks) information available?
3. Is technology still aligned to an Agency priority?

The project must initially pass Question 1 to continue towards the remaining 2 of the 3 fundamental questions. Otherwise, the project fails the gate review and is terminated. At the second fundamental question stage, the panel can either recommend continuing to the next question or redirect the project to be evaluated again later. For Question 3, if the priority of the investment is identified as high, the technology is supported, and the project is continued. For a low priority verdict, there likely is a higher priority project that should be invested instead, and the technology is placed on hold while another technology is evaluated for maturation. If the project passes all three elements, it also passes the decision gate being evaluated.

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[8] https://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_7120_008A_&page_name=main

[9] R. Kohli, J. L. Fishman, M. J. Hyatt, “Decision Gate Process for Assessment of a Technology Development Portfolio”

Leveraging the DMP Decision Gate Criteria, below are recommended predefined criteria to evaluate a technology's progression along the maturation lifecycle towards infusion into a stakeholder's mission/system. Each criterion is weighted and rated by each SME on the panel as High, Medium, and Low. Refer to Appendix B for the Technology Development Criteria Matrix.

- Needs addressed: (e.g., Number – multiple, single; type – near-term or far-term)
- Technology Readiness Level (TRL): (e.g., Current state)
- Technology Impact Level: (Low, Medium or High)
- Development effort to achieve next TRL level: (e.g., Required or not required; Degree of difficulty; Probability of success)
- Resources: (e.g., Cost - personnel, capital, materials, infrastructure, travel)
- Performance improvement (e.g., Improvement (or contributes to improvement) over current state-of-the-art (SOA) current SOA
- Technical experience of Project Team: (e.g., Team composition, technical background and skills)
- Project Management: (e.g., Prior experience of the organization and the management and technical team; Controls (budget and schedule, milestones, decision gates and deliverable products)
- Mission applicability: (e.g., Types of missions (Transit, Lunar sortie, Lunar outpost); versatility)
- Benefit from other similar technology development programs (e.g., leverage NASA or non-NASA programs)

After evaluating each investment in the portfolio, the SME panel assesses the portfolio based on thought provoking questions to provide their overall thoughts on the health of the portfolio and suggestions for future investment strategy. The panel composed of program and SMEs (to include SME center representation based on Center) systematically consider the thought-provoking questions:

- Is the overall technology R&D portfolio on track to meet its capability goals? If not, what is hindering progress? Are we overinvested or underinvested in any areas?
- What are the highest priority investments to 'keep doing'?
- What are the highest priority stakeholders' needs to tackle next?
- Are there any projects in need of deliberate transition/infusion attention
- How much risk is there of not achieving the deliverables?
- Is there any apparent imbalance in funding, either over or under the need?

Table B-1 below provides an example of a scoring sheet that can be used and/or tailored for Continuation Assessment reviews.

Table B-1: Example Technology Readiness Criteria Scoring Sheet

No.	Criteria	Rating			Rank	Weighting Factor
		High Score: 67-100	Moderate Score: 34-66	Low Score: 0-33		
1	**Needs addressed** a. Number b. Type	a. Multiple needs addressed or full intent of single need addressed b. Short-term and long-term	a. Few needs addressed b. Mainly short term	a. Single need addressed b. Mainly short term	1	1.000
2	**Technology Readiness Level (TRL)**	TRL: 6 and higher	TRL: 3 to 5	TRL: below 3	2	0.9000
3	**Technology Impact Level**	a. Technology/ research required to meet mission/ system objectives b. Technology/ research has major impact on meeting mission/ system objectives.	Technology/research has a minor impact on meeting mission/ system objectives.	Technology/research has a minor impact on meeting mission/ system objectives.	3	0.8000
4	**Development effort to achieve next TRL level** a. Required or not required b. Degree of difficulty	a. Minimal or no development b. Very low degree of difficulty anticipated to meet end objectives. Probability of success ≥ 99%.	a. Moderate development effort required b. High degree of difficulty anticipated to meet end objectives. Probability of success from 50 to 98%.	a. Intensive development effort required b. Very high degree of difficulty anticipated to meet end objectives. Probability of success < 50%.	4	0.7000
5	**Resources** a. Cost (personnel, capital, materials, infrastructure, travel) b. Availability and allocation	a. Low b. High (limited interference with other projects)	a. Moderate b. Moderate (some interference with other projects)	a. High b. Low (significant interference with other projects)	5	0.6000
6	**Performance improvement** a. Improvement (or contributes to improvement) over current state-of-the-art (SOA) based on applicable figures of merit (FOM), such as reduction in percentage of crew time, up mass (weight /volume), power requirements b. FOM app	a. Significant improvement versus current SOA b. High FOM	a. Some improvement versus current SOA b. Moderate FOM	a. Minor improvement versus current SOA b. Low FOM	6	0.5000
7	**Technical experience** a. Team composition, technical background and skills	a. High	a. Moderate	a. Low	7	0.4000
8	**Project Management (PM)** a. Prior experience of the organization and the management and technical team	a. Extensive PM experience b. Well defined project controls	a. Moderate PM experience b. Limited project controls	a. Limited or no formal PM experience b. Minimal project controls	8	0.3000

No.	Criteria	Rating			Rank	Weighting Factor
		High Score: 67-100	Moderate Score: 34-66	Low Score: 0-33		
	b. Controls (budget and schedule, milestones, decision gates and deliverable products)					
9	**Mission applicability** a. Types of missions (Transit, Lunar sortie, Lunar outpost) b. Versatility for a specific mission	a. Meets multiple missions b. Versatility for multiple aspects of a single mission or applicable to multiple missions	a. Meets multiple missions b. Versatility for multiple aspects of a single mission or applicable to multiple missions	a. Meets one type of mission only b. No versatility	9	0.2000
10	**Benefit from other similar technology development programs** a. NASA b. Non-NASA	a. Significant leverage off NASA programs; or not required b. Significant leverage off non-NASA programs; or not required	a. Some leverage off NASA programs b. Minimal leverage off non-NASA programs	a. Minimal leverage off NASA programs b. Minimal leverage off non-NASA programs	10	0.1000

9.0 APPENDIX C: EXAMPLE OF TECHNOLOGY INFUSION CONFIDENCE LEVEL CRITERIA

These metrics are intended to be informational, not decisional and complementary to the technology maturation assessment performed during a Continuation Assessment per NPR 7120.8. Although the activities are presented roughly sequentially, they can occur in parallel or out of order, depending on the project's specific nature and context. ICL, as presented, is framed as a tool to assist evaluating pull technologies, but it could be leveraged to track push technologies with strong use cases and identified gaps as well. The example below is for illustration purposes only and not a requirement. The ICL assessment performed during a Continuation Assessment should be scaled and scoped appropriately for the nature and size of the project.

Infusion Confidence Level	Description	Evidence of CL Status
CL1 Technology Discovery	• **Gap Assessment & Technology Discovery**: Involves strategic planning activities, such as identifying technology gaps, determining required timelines to address them, categorizing existing technologies, and pinpointing low- to mid-TRL technologies suitable for maturation. It also evaluates whether closing the gap requires new technology development or an engineering solution. • **Project Identification & Gap Mapping**: Identifies candidate technology projects aligned to specific gaps, along with preliminary assessments of feasibility, challenges, potential benefits, off-ramps, funding sources, and estimated development duration. Projects are classified as technology push, translational, or pull.	• A potential project has been clearly mapped to mission, capability, or agency-defined gaps and validated as a "pull" technology (i.e., driven by end-user needs).
CL2 Technology Project Initiation	• **Early Stakeholder Engagement:** Technologists promote the proposed project through forums like working groups, communities of interest, industry days, and discussions with potential mission partners to build awareness, confirm alignment with stakeholder/customer needs. • **Project Initiation**: Follows confirmation of potential users; the project is formally selected, funded, and begins active development.	• Key stakeholders are identified, buy-in is secured (including confidence in a viable path to infusion), and development has commenced.
CL3 Infusion Target Identification	• **Establishment of Technical Goals:** Project plans are written which document the technology's key performance parameters (KPPs). • **Infusion Target Identification:** Identifies candidate missions, payloads, or provider systems where the technology could apply, informing the infusion strategy and fostering early relationships with receiving programs. This is done collaboratively to ensure mutual awareness.	• Key performance parameters are documented; specific missions, payloads, or ground systems that stand to benefit are identified; and initial discussions with relevant mission planners have begun.
CL4 Initial Infusion Planning	• **Infusion Goals Approved:** Approved goals include a planned infusion/transition schedule, agreed-upon technical performance requirements, and a gap closure assessment. The assessment evaluates the project's expected end-state TRL, performance parameters, and timeline to determine how effectively and timely it will close the targeted gap. Results are shared with infusion targets and roadmapping/gap assessment teams. • Gap closure categories include: ○ Enhances: Improves another technology's ability to close a gap.	• A gap closure assessment is complete; if investment continues, a detailed infusion plan exists.

Infusion Confidence Level	Description	Evidence of CL Status
	○ Partially enables: Delivers some but not all required capability/performance. ○ Fully enables: Provides full capability with performance parameters sufficient to close the gap. • **Invest or Divest Decision:** If no credible infusion targets emerge or the gap assessment shows insufficient maturity/timeliness for gap closure, decide whether to continue or divest resources. • **Infusion Plan:** For continuing projects, develop a formal infusion plan (standalone or integrated into the project plan) to guide and track progress toward infusion objectives.	
CL5 Target Coordination	• **Infusion Targets Named:** Active, ongoing coordination begins with named infusion targets, including regular status updates to recipients. • **Infusion Point of Contact:** Assign a dedicated POC (for direct infusion, internal transition, or external transition pathways) to maintain/update infusion plans, communicate status, and advocate for the technology.	• Regular coordination with intended recipients is underway, and a responsible individual is assigned for infusion-related activities.
CL6 Infusion Planning Maturation	• **Technical Infusion Planning:** Conducts assessments of technical progress and validates that the project will meet required infusion parameters (may include supplemental mission analysis, test environment validation, etc.). • **Infusion Schedule Planning:** Reviews project schedule, incorporates infusion/transition activities, communicates the integrated schedule to recipients, and tracks/monitors infusion schedule risks.	• Any additional infusion-supporting work is identified; infusion activities are embedded in the project schedule; technical progress and risks impacting infusion are regularly communicated to targets.
CL7 Integration Strategy	• **Technology Transition at User Mission DDT&E Milestone:** Conduct assessments to validate technology is at least at a TRL 6 maturity to pass successfully. If not, user organizations must accept mission risk. • **Cost Estimates Performed:** Assess costs for continued development through Phase A and any transition-related expenses if management shifts to a new program. • **Funding Identified:** Secure sources for further development, integration, and testing.	• Technology maturation is at TRL 6 or higher; technology transition funding needs are assessed; and funding sources are identified.
CL8 Funding and Contracts	• **Bridge or Integration Funding Secured:** Obtain necessary funding for internal transition/continued development or direct mission integration. • **Agreements Signed:** Finalize any required agreements, contracts, or MOUs that formalize the technology's readiness and transfer to the mission, payload, or ground system.	• Transition funding is secured, and all necessary contracts/agreements are signed.
CL9 Mission Acceptance	• **Mission Acceptance:** Contracts are awarded; management responsibility transfers to the receiving mission/program, concluding dedicated infusion activities.	• Technology is formally handed off to the recipient, with documentation confirming successful infusion.