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Access to Space for NASA Missions: Current and Future Needs

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ABSTRACT

Small spacecraft technology advancements have fundamentally shifted how NASA's Science Mission Directorate (SMD) executes science investigations. To support this approach, the SMD Rideshare Office (SRO) was established in 2020 to lead the definition and implementation of a directorate-wide rideshare strategy. Serving as the central point of contact for coordinating compatible NASA payloads with launch opportunities, the SRO maximizes science, exploration, and technology return on investment by enabling rideshare or other access to space opportunities for small spacecraft on SMD primary mission launches, Venture Class Acquisition of Dedicated and Rideshare (VADR) contract commercial launch procurements, and other government agency launch opportunities. As NASA seeks to reduce costs and increase the rate of discovery, small satellites and multi manifest access to space have become integral to achieving the agency's strategic vision.

While NASA has created the above-mentioned mechanisms to expand access to space and achieve lower launch costs for its small satellites, many factors have limited full exploit of the opportunity these mechanisms can bring. NASA continues to evolve its mission cultures and technical requirements to adapt and take advantage of burgeoning commercial launch and rideshare advancements. To do so NASA requires collaboration with small satellite manufacturers, principal investigators, and commercial industry partners. Current needs include technical development and design of structurally robust spacecraft buses capable of withstanding varied launch loads, which will increase rideshare interchangeability and versatility. Further, instrument and spacecraft designs must also evolve to handle diverse launch environments and loads factors, while reducing reliance on complex purge and cleanliness constraints, sensitivities to silicones and hydrocarbons, and magnetic requirements. Continued maturation of small and medium launch providers in the near-term is also essential to drive down costs through competition.

The current mission selection cadence often complicates the ability to synchronize multiple missions on a single launch. Future needs can include affordable space maneuverability options such as enhanced spacecraft propulsion systems and unique orbital maneuvering capabilities for our individual smallsats or constellations. These emerging capabilities offer a path to unique science orbits for NASA small satellites, but only under the condition that their cost remains affordable and competitive to accommodate inherently smaller mission budgets. Additionally, the projected surge of multiple SMD small satellites launching simultaneously and to unique deep space science orbits necessitates evaluation of expanding deep space communications capabilities. This presentation provides a comprehensive overview of NASA SMD's access to space landscape and offers further unique insights and discussion, backed by NASA rideshare experiences and lessons learned, on the current and future developments required to unleash the full potential of rideshare opportunities.

INTRODUCTION

NASA's Science Mission Directorate (SMD) has continued to strategically embrace rideshare capabilities, significantly maximizing scientific return on investment by reducing launch costs, fostering industry and government collaboration, and opening access to unique orbital destinations for our small satellite missions. As the Agency seeks to reduce costs and increase the rate of discovery, small satellites and multi manifest access to space have become integral to achieving its strategic vision. While NASA has successfully established mechanisms and processes to embrace rideshare and lower initial launch costs, achieving this vision requires evolution across the broader small satellite ecosystem. True optimization of multi-manifest access to space relies on versatile spacecraft buses designed to internally shield sensitive instrumentation from diverse launch environments, complemented by commercial small dedicated launch options and in-space mobility providers offering affordable, shared capacity that considers the inherently constrained budgets of small satellites. Informed by NASA's rideshare experiences and lessons learned, this paper outlines the current and future paradigm shifts needed to reduce integration challenges and fully unleash the potential of rideshare.

NASA'S ACCESS TO SPACE LANDSCAPE

Context: NASA SMD Rideshare Policy and SRO

NASA's rideshare philosophy is straightforward: utilize the lift capability of an available space transportation service to the maximum extent practicable (as defined by NASA Policy Directive (NPD) 8610.12H). To implement this agency-wide philosophy, SMD established SMD Policy Directive 32 (SPD-32) in 2018, formalizing the integration of secondary payloads onto secondary payload adapters. Although the rideshare landscape has evolved since then, the tenets of the policy have allowed the agency to adapt swiftly to rapid innovations from the commercial sector.

The SMD Rideshare Office (SRO) implements the policy and serves as a central hub for access to space. The SRO is charged with defining the process and documentation needed to implement rideshare and to serve as the single point of contact for tracking launch opportunities and coordinating integration activities among primary missions, secondary payloads, commercial vendors, and other government agencies. Additionally, the office standardizes these processes across SMD's divisions and NASA's centers and guides Principal Investigators and program managers navigating rideshare.

NASA implements rideshare through use of a specific set of launch contract types and agency partnerships. Each contract option offers different levels of risk tolerance, budget, and mission assurance to match a given mission's risk posture. Before we can isolate the limiting factors slowing down rideshare today, we first need to look at what these existing contract options are, and how they function to enable access to space.

NLS-II

The initial implementation of SPD-32 focused on the process of adding rideshare on NASA Launch Service Contract II (NLS-II) contracted launches for SMD primary missions. Under NLS-II, NASA purchases the total performance capability of a launch vehicle. Once a primary mission is selected and its launch requirements are identified, the Launch Services Program (LSP) identifies any excess capacity. If excess performance is available, SMD will use this capacity to launch SMD-sponsored secondary payloads. If performance remains after accommodating SMD-sponsored payloads, the capacity can be offered to other NASA mission directorates, other U.S. Government Agencies (OGAs), or international space agency partners, consistent with international agreements for collaborative science, technology and exploration efforts.

As an NLS-II rideshare, secondary payloads benefit from full LSP technical oversight. This path is ideally suited for NASA ESPA-class small satellites, but it requires secondary payloads to conform to the NASA primary missions' interface and mission assurance requirements. Rideshare payloads on NLS-II launches are completely tied to the primary mission's analyses and launch schedule.

A guiding principle for SMD's rideshare process is the "Do No Harm" (DNH) philosophy. Every secondary payload on a shared launch must prove that its design, materials, and electronics present zero risk to the primary spacecraft or launch vehicle. Under the NLS-II framework, the primary mission remains the absolute priority. The SMD Associate Administrator (AA) has the final authority on all matters of spacecraft payload compatibility and DNH compliance.

VADR

NASA's policy foundation enables SMD to adapt to the dynamic launch and rideshare market. This evolution is evident in the development of the Venture-Class Acquisition of Dedicated and Rideshare (VADR) contract. VADR was created by LSP to fulfill NASA's need for lower cost launch services for higher risk tolerant missions. VADR incorporates lessons learned from previous LSP contracts such as NASA Launch Service (NLS), Venture Class Launch Service (VCLS), CAPSTONE, TROPICS, and various CubeSat contracts, as well as feedback received from commercial partners.

The VADR contract provides a Federal Aviation Administration (FAA) licensed launch service for payloads with a risk tolerance of Class D (per NPR 8705.4, Risk Classification for NASA Payloads), or lower. VADR is not applicable for Class A, B, C, and some D payloads who require a higher level of mission assurance and oversight. The launch services contracted under VADR are intended to align with standard commercial practices while still retaining an appropriate level of Government oversight commensurate with a Class D mission and a FAA licensed launch. To encourage commercial innovation and lower costs, launch providers are permitted to propose rocket configurations with little to no flight history, allowing NASA to utilize emerging commercial capabilities without forcing providers through extensive certification requirements.

The VADR contract has Standard Launch Services (CLIN 1) and Streamlined CubeSat Launch Services (CLIN 2) which include dedicated launch vehicles, primary (or anchor) payload on rideshare launches, or traditional rideshare launch options.

The VADR contract allows SMD to procure dedicated or rideshare opportunities on commercial launches where NASA does not own the excess performance. This reduces NASAs launch costs by allowing the launch vehicle providers to sell any additional capacity to their customers.

Other Government Agency Launch Opportunities

NASA maintains interagency agreements with other U.S. government agencies (OGAs), such as the National Oceanic and Atmospheric Administration (NOAA) and the United States Space Force (USSF), allowing NASA and its partners to fly secondary payloads on each other's launches. Because different government agencies have different interests in space, and thus different destination orbits, and operate under different selection timelines, integration schedules, and funding cycles, matching a NASA payload to an OGA launch window or launch orbit can be challenging.

Due to these differing integration processes, this path is best for payloads that have very few unique requirements, and utilize more standard, containerized deployment systems that simplify mechanical integration. It is possible for larger Class D SMD missions to be placed on an OGA launch, provided their development schedules align with the host agency's schedule, launch parameters, and environmental requirements. When NASA payloads are rideshares on an OGA launch, they are entirely subject to the host agency's schedule and must satisfy DNH requirements dictated by that agency's specific mission assurance standards.

Summary

Despite having multiple launch options, the Agency still struggles to utilize rideshare routinely. This challenge is not rooted in a lack of access to rideshare opportunities, rather it is driven by spacecraft requirements, and schedule and orbit alignment challenges.

RIDESHARE CHALLENGES: ADDRESSING CURRENT AND FUTURE NEEDS

Science vs. Spacecraft Design

An inherent tension exists when asking the scientific community to adopt flexibility and standardized commercial spacecraft. Historically, NASA's pioneering science has been synonymous with bespoke instruments, highly tailored engineering, and unique orbits. Because of this history, discussions regarding rideshare spacecraft and orbit design often trigger concerns that interchangeability, enveloped constraints, or orbit flexibility equate to a compromise in scientific capability.

However, advocating for increased flexibility and interchangeability does not mean compromising on science discovery. The instrument can, and often must, remain a bespoke, sensitive, state-of-the-art payload. The distinction lies in separating the instrument from the bus. The space vehicle that hosts, powers, and points the instrument can evolve to protect that sensitive payload internally through higher structural stiffness and environmental sensitivity mitigations.

A spacecraft bus should act as a protection mechanism, shielding the science instruments sensitivities from the launch vehicle's environments. Ultimately, designing a structurally stiff or absorbent bus with less interface requirements does not limit the science. Instead, it protects the science by ensuring the mission can survive extreme rocket environments, thereby enhancing the likelihood of securing a timely, affordable launch across a wide variety of available options.

Self-contained environmental protections and enhanced structural integrity implies an increase in mission mass, presenting a conflicting design paradox for mass-constrained small satellites. However, this conflict only exists under the legacy paradigm of extreme mass-optimization. Since launch capacity and increased vehicle performance has become routinely available, the small satellite community must shift from optimizing for minimum mass to optimizing mass resources for mission resiliency. Reducing mass for the sake of low mass is no longer valuable. Trading a few kilograms of structural mass margin saves months of expensive, customized integration engineering, ultimately driving down the total mission lifecycle cost.

Coupled Loads Analysis & Structural Stiffness

The Challenge - A persistent challenge for NASA's small spacecraft and their rideshare missions is the potential for dynamic coupling between rideshare payloads, primary spacecraft, and the launch vehicle. This coupling can significantly increase loads on the primary mission, potentially violating "do no harm" requirements. This risk is elevated when primary and secondary payloads are similar in size or mass. Evaluating this coupling requires multiple rounds of Coupled Loads Analysis (CLA), which impacts integration timelines and lifecycle costs for the entire launch.

Because NASA's unique science and technology payloads often have fundamental frequencies in the 0-100 Hz band, they are more susceptible to coupling with rideshares and launch vehicles. The launch vehicle's most strenuous launch events occur within this same range.

To encourage launch vehicle agnosticism, NASA has defined conservative maximum predicted environments that encompass all potential launch vehicles on contract within the Rideshare Users Guide (RUG) for missions to implement into their design. However, meeting these enveloped requirements necessitates significant structural stiffening. Traditionally, the onus of mitigating these loads issues has been placed on the launch provider through requested customized isolation systems or other design modifications. This approach results in multiple time consuming CLA cycles that create cost and schedule management struggles and uncertainty in the launch manifest, ultimately limiting routine rideshare usage.

New Paradigm - Shifting stiffening and isolation strategies to the spacecraft could offer a practical solution. While NASA science instruments are inherently sensitive, having the spacecraft itself handle the task of protecting them from launch loads could greatly ease the rideshare integration process. This proactive design approach would reduce the risk of low-frequency coupling between rideshares, the primary spacecraft, and the launch vehicle, ultimately ensuring mission compatibility and success, and enable NASA to regularly utilize rideshare effectively.

Payload Sensitivities

The Challenge - Beyond loads, other stringent interface sensitivities of NASA science instruments introduce further operational complexity, limiting routine rideshare. Due to their state-of-the-art designs, these instruments often require mission specific requirements, including complex instrument purges, strict cleanliness levels, hydrocarbon and silicone sensitivities, or magnetic cleanliness accommodations. These requirements consistently conflict with the needs of the primary payload or other manifested rideshare payloads.

In practice, accommodating these requirements complicates launch site operations and strains the integration schedule. When a rideshare payload levies requirements such as post-encapsulation battery charging, frequent contamination sampling, or dedicated purge lines at the launch pad, the operational burden is traditionally imposed on the launch vehicle provider. If implementable, managing these unique requirements extends schedule timelines and drives up launch integration costs, increasing the launch service price and minimizing the cost saving effect that rideshare is intended to provide. Stringent needs can render rideshare payloads technically and programmatically infeasible for addition to SMD primary launch services or to any other rideshare option including VADR and OGA rideshares. These requirements may also be prohibitively costly for dedicated launch options on VADR.

Over-tailoring requirements can result in restricting the mission into a specific spacecraft design that is only compatible with a single launch environment. If that specific launch service delays, or the opportunity falls through, the secondary payload may not be able to easily move to a different launch vehicle or fly under a different primary mission, resulting in further cost and schedule impacts.

New Paradigm - To overcome this limiting factor, small satellite missions could benefit from designing their spacecraft for maximum independence and flexibility with minimal mission unique interface requirements. To increase launch options, and ease integration, minimizing reliance on launch site resources is highly recommended. Spacecraft providers could engineer spacecraft to require minimal battery charging, lessen magnetic constraints at the launch site, and evaluate strategies or implement covers that could be used to minimize cleanliness and contamination issues. Designing small satellites to isolate their sensitive instruments from the inherent launch environments reduces schedule conflicts, avoids costly launch service modifications, and preserves the flexibility needed to pivot across multiple launch options.

Orbit Incompatibility

The Challenge - NASA's rideshare approach cannot entirely mimic commercial practices and approaches to rideshare (e.g. SpaceX Transporter missions). NASA science missions are designed for specific measurements, that target unique orbital destinations that frequently differ from the typical targets of commercial launches.

Orbit incompatibility and inflexibility present significant hurdles when trying to manifest rideshare payloads across various NASA, commercial VADR, and OGA launches. It is common to find multiple NASA payloads headed for "similar" destinations, yet their trajectories or launch readiness dates vary drastically. Orbital inclination changes by the launch vehicle are typically unachievable due to the immense performance required to execute the maneuvers. For small satellites, the on-board propulsion needed to bridge these inclination gaps is often cost constrained and structurally complex. While modern launch vehicle performance surpluses mean that total launch mass is less constrained, packing heavy dedicated propulsion systems into a small satellite bus introduces cost and design impacts and complexities. Additionally, they lack the financial budget for an Orbital Transfer Vehicle (OTV). Carrying the extra propellant required to correct spacecrafts orbit often negates the initial cost savings of the rideshare slot.

Long Term Paradigm Shift - NASA science payloads will continue to require unique inclinations and special trajectories to achieve their cutting-edge objectives. Accomplishing routine rideshare for these unique trajectories requires a potential change in approach or culture. Science missions that have greater flexibility regarding their acceptable orbital insertion parameters will inherently match easier with other missions. Others may need a dedicated launch vehicle, or onboard propulsion systems to succeed. An additional solution that maintains the ability for unique trajectories is the evolution of the OTV marketplace. NASA's larger ESPA-Class science missions would benefit from affordable and reliable rideshare opportunities on OTVs, without having to procure the whole vehicle or system. Addressing these orbital limiting factors would vastly improve NASA's ability to maximize fairing capacity and increase the scientific return on investment per launch, while still enabling small satellite access to unique orbits.

THE PAYOFF

NASA has embraced rideshare and has proven it is one of the most apparent ways that SMD can maximize delivery of science to space, demonstrate cost savings, and increase the Agency's rate of discovery. NASA has enabled various launch options for access to space for small satellites. We've experienced and demonstrated the benefits of rideshare through our large IMAP and SPHEREx rideshare launches, and multiple VADR and OGA launch efforts.

Rideshare is a tool in NASA's arsenal that needs to be nurtured and maintained. Manifest optimization and integration of rideshare missions could be improved through evolved approaches to spacecraft designs that can internally protect their own sensitive instruments and incorporate effective onboard propulsion capabilities. Our missions additionally need accessibility to affordable in-space mobility providers or small and medium launchers that can get spacecraft to their required destination.

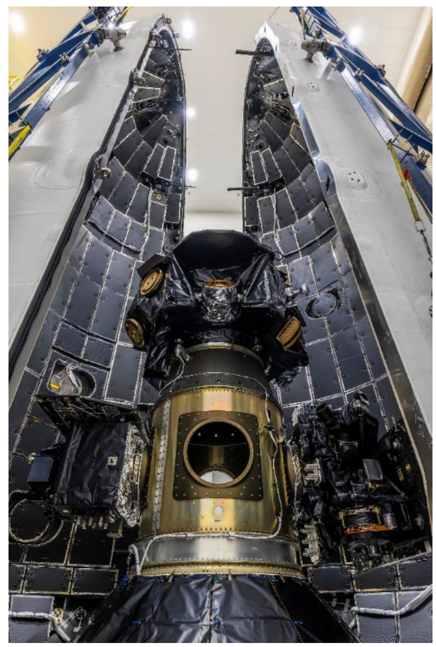

Figure 1: IMAP, SWFO-L1, and Carruthers Geocorona Observatory enclosed in a payload fairing prior to launch
NASA/SpaceX

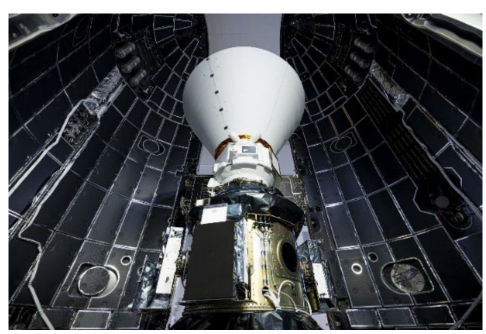

Figure 2: SPHEREx and PUNCH enclosed in a payload fairing at Vandenberg Space Force Base
NASA/BAE Systems/Benjamin Fry