



NASA SBIR 2021 Phase I Solicitation

S4.03 Spacecraft Technology for Sample Return Missions

Lead Center: JPL

Participating Center(s): GRC, GSFC

Scope Title:

Critical Technologies for Sample-Return Missions

Scope Description:

This Subtopic focuses on robotic sample-return (SR) missions that require landing on large bodies (e.g., Luna, Mars Sample Return (MSR)), as opposed to particulate-class SR missions (e.g., Genesis, Hayabusa) or touch-and-go (TAG) missions to relatively small asteroids or comets (e.g., OSIRIS-Rex, Hayabusa2). The mission destinations envisioned are dwarf planets (e.g., Vesta, Ceres) and planet or planet moons (e.g., Phobos, Europa). These are the most challenging missions in NASA's portfolio but also the most scientifically promising, given the vast array of instruments available on Earth to study the retrieved samples. The challenges associated with these SR missions may be grouped into four categories: (1) Mass-efficient spacecraft architectures (e.g., efficient propulsion or materials that significantly reduce the mass of the launch payload required), (2) Sample handling (e.g., subsurface acquisition mechanisms), (3) Sample integrity (e.g., surviving reentry), and (4) Planetary protection/contamination control (PP/CC) (e.g., preventing leakage into the orbital sample (OS) canister). This Subtopic seeks potential solutions to areas (1), (3), and (4), considering it best that technologies associated with (2), sample handling, be directed to Subtopic S4.02. The intent is to have this Subtopic S4.03 manage only those technologies in areas (1), (3), and (4) that are specifically related to SR missions; technology solutions related to other classes of missions should instead be directed to Subtopics S4.04 (Extreme Environments) and S4.05 (Contamination Control and Planetary Protection).

The heightened need for mass-efficient solutions in these SR missions stems from their extreme payload mass "gear ratio." For example, the entire MSR campaign will require three heavy launch vehicle launches with rough spacecraft mass of 5,000 kg each in order to bring back multiple samples with an estimated total mass of 0.5 kg. Clearly, any mass savings in the ascent vehicle's gross liftoff mass (GLOM) or in the lander mass, for example, would yield many times more savings in the launch payload mass, enhancing the feasibility of these missions.

Once acquired, samples must be structurally and thermally preserved through safe landing and transport to Johnson Space Center (JSC) for analyses. Sample integrity technology solutions that address the long, high-radiation return trip, as well as the dynamic and high-temperature environment of reentry, are sought. Potential solutions include near isotropic and crushable high-strength energy-absorbent materials that can withstand the ballistic impact landing. Materials that offer thermal isolation in addition to energy absorption are highly desirable

given the reentry environment. In the case of cryogenically preserved samples, the technical challenge includes development of thermal control systems to ensure volatiles are conserved.

Finally, acquired samples must be chemically and biologically preserved in their original condition. Examples of PP/CC technology solutions sought include:

- **Materials selection:** selection of metallic materials (non-organic) for the interior of the OS capsule as well as materials that allow preferable surface treatments and bake-out sterilization approaches.
- **Surface science topics:** Adsorber coatings/materials for contaminant adsorption (getter-type materials, such as aluminum oxide, porous polymer resin) and/or low-surface-energy materials to minimize contaminant deposition.
- **Characterization of contamination sources** on lander, rover, capsule, ascent vehicle, and orbiter, for design of adequate mitigation measures.

Expected TRL or TRL Range at completion of the Project: 3 to 6

Primary Technology Taxonomy:

Level 1: TX 04 Robotics Systems

Level 2: TX 04.3 Manipulation

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype

Desired Deliverables Description:

A Phase I deliverable would be a final report that describes the requisite research and detailed design accomplished under the project.

A Phase II deliverable would be successful demonstration of an appropriate-TRL performance test, such as at representative scale and environment, along with all the supporting analyses, design, and hardware specifications.

State of the Art and Critical Gaps:

The kind of SR missions targeted in this solicitation are those that require landing on an extraterrestrial body. This most challenging kind of SR mission has only been successfully done in the Soviet Luna program that returned 326 g of Moon samples in three missions—out of eleven attempts—in the early 1970s. Hayabusa2 and OSIRIS-Rex are TAG SR missions that are expected to return samples in December 2020 from asteroid Ryugu and in September 2023 from asteroid Bennu, respectively. The first segment of NASA's MSR mission is the sample collection rover Perseverance, launch of which took place in July 2020. The MSR sample retrieval segment (lander, fetch rover, Mars Ascent Vehicle) is scheduled to begin Phase A development in October 2020 for a 2026 launch. The third MSR segment will be ESA's Earth return vehicle (ERV).

The content and breath of this Solicitation is informed by lessons learned in MSR over the Pre-Phase A years. Future SR missions are in need of technology improvements in each of the critical areas targeted: mass efficiency, sample acquisition, sample integrity, and planetary protection.

This solicitation seeks proposals that have the potential to increase the Technology Readiness Level from 3 or 4 to 6 within 5 years, and within the cost constraints of the Phases I, II, and III of this SBIR Program. Such progress would allow full flight qualification of the resulting hardware within 5 to 10 years.

Relevance / Science Traceability:

Medium- and large-class SR missions address fundamental science questions such as whether there is evidence of ancient life or prebiotic chemistry in the sampled body.

Table S.1 of *Vision and Voyages for Planetary Science in the Decade 2013-2022 (2011)* correlates ten "Priority Questions" drawn from three Crosscutting Science Themes, with "Missions in the Recommended Plan that Address Them". SR missions are shown to address eight out of the ten questions and cover every crosscutting theme, including Building New Worlds, Planetary Habitats, and Workings of Solar Systems.

References:

Vision and Voyages for Planetary Science in the Decade 2013-2022, <http://nap.edu/13117>

Visions into Voyages for Planetary Science in the Decade 2013-2022: A Midterm Review (2018), <http://nap.edu/25186>

Mars Sample Return (MSR), <https://www.jpl.nasa.gov/missions/mars-sample-return-msr/>

Comet Nucleus Sample Return (CNSR), <https://ntrs.nasa.gov/search.jsp?R=20180002990>