NASA SBIR 2022 Phase I Solicitation

S13.02 Spacecraft Technology for Sample Return Missions

Lead Center: JPL

Participating Center(s): GRC, GSFC, LaRC, MSFC

Scope Title

Critical Technologies for Sample-Return Missions

Scope Description

This subtopic focuses on technologies for robotic sample-return (SR) missions that require landing on large bodies (e.g., the Moon, Mars, Vesta, Ceres, Phobos, Europa), 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. Specifically, technologies are sought to address the following challenges associated with these SR missions: (1) Mass-efficient spacecraft architectures (e.g., efficient propulsion or materials that significantly reduce the mass of the launch payload required), (2) Sample integrity (e.g., surviving reentry), and (3) Planetary protection/contamination control (PP/CC) (e.g., preventing leakage into the Mars Sample Return (MSR) mission's orbital sample (OS) canister).

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 probably require four 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 mass of either the lander or the Earth Return Orbiter, for example, would yield many times more savings in the launch payload mass, enhancing the feasibility of these missions. Examples of propulsion technologies that may reduce overall mass include the development of lightweight, restartable ignition techniques for hybrid and solid rocket motors, lightweight spin motors, lightweight vectoring systems, lightweight insulation materials, and lightweight expandable nozzle designs to increase nozzle area ratios.

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 canister 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 analysis, 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. The former returned asteroid Ryugu samples to Earth in December 2020; the latter is expected to follow suit in September 2023 from asteroid Bennu. The first segment of NASA's MSR mission is the sample-collection rover Perseverance, which landed on Mars in February 2021. The MSR sample retrieval segment (lander, fetch rover, Mars Ascent Vehicle) is currently in Phase A development and expected to launch in 2028.

The content and breadth 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 integrity, and planetary protection.

This solicitation seeks proposals that have the potential to increase the TRL from 3 or 4 to 6 within 5 years and are 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 10 "Priority Questions" drawn from three Crosscutting Science Themes, with "Missions in the Recommended Plan that Address Them." SR missions are shown to address 8 out of the 10 questions and cover every crosscutting theme, including Building New Worlds, Planetary Habitats, and Workings of Solar Systems.

References

- Comet Nucleus Sample Return (CNSR): [https://ntrs.nasa.gov/search.jsp?R=20180002990](https://ntrs.nasa.gov/search.jsp?R=20180002990)