SAMPLE RETURN ENABLED BY A CREWED PRESENCE IN CISLUNAR OR CISMARTIAN SPACE: FARTHER REACH, BETTER SCIENCE. R. Lewis[1], P. Niles[2], M. Fries[3], F. McCubbin[4], D. Archer[5], J. Bleacher[6], J. Boyce[7], B. Cohen[8], C. Evans[9], T. Graff[10], J. Gruener[11], S. Lawrence[12], M. Lupisella[13], D. Ming[14], D. Needham[15], K. Young[16], [1,6,13]NASA Goddard Space Flight Center, Greenbelt, MD, 20771 (ruthan.lewis@nasa.gov, jacob.e.bleacher@nasa.gov, mark.l.lupisella@nasa.gov), [2,3,4,5,7,9,11,12,14]NASA, Johnson Space Center, Houston, TX 77058 (paul.b.niles@nasa.gov, marc.d.fries@nasa.gov, francis.m.mccubbin@nasa.gov, doug.archer@nasa.gov, jeremy.w.boyce@nasa.gov, cindy.evans-1@nasa.gov, john.e.gruener@nasa.gov, samuel.j.lawrence@nasa.gov, douglas.w.ming@nasa.gov,), [8,15]NASA Marshall Space Flight Center, AL 35812 (barbara.a.cohen@nasa.gov, debra.m.hurwitz@nasa.gov), [10]Jacobs Technology, Inc., Houston, TX 77058 (trevor.g.graff@nasa.gov), [16]University of Texas, El Paso / Jacobs Technology, Inc., Houston, TX 77058 (kelsey.e.young@nasa.gov).

Introduction: Sample return (SR) from Solar System bodies is a proven and powerful method for answering fundamental questions about the history and evolution of the Solar System, and has been recognized as a high priority as documented in the 2013-2022 National Aeronautics and Space Administration (NASA) planetary science decadal survey. Although there are many options for accomplishing sample return from Solar System bodies using robotic mission concepts, the human presence in cislunar and cismartian space, and on lunar and martian and/or martian moon surfaces, provides a unique opportunity to take advantage of both robust spacecraft infrastructure as well as the capabilities of humans (e.g. decreased time delays, greater situational awareness of site context, finer control over robotic and sampling assets, etc.) and human-piloted spacecraft to fundamentally improve SR well beyond current capabilities, and enable SR missions of greater range, mission duration, and potentially returned volume and mass.

Description: As mission options are under study, accompanying alternatives of potential methodologies for surface and on-orbit collection, preservation, analysis, curation, and return of samples compose a multivariate trade space for human and robotic interaction and collection/analysis services and accommodations.

Human assisted sample return in combination with robotic sample return missions provide several advantages in nearly every mission architecture:

1) *Transit of samples to Earth using a robust and reliable human capsule/spacecraft can reduce the need for investment in and mass penalties of a singular, customized SR craft.* Less mass is required to support equipment for a) protection from thermal alteration than a SR spacecraft, which is especially true for SR missions with requirements for maintaining cold/cyrogenic conditions for samples during passage through Earth's atmosphere, b) maintaining the need to carry Earth atmosphere transit hardware throughout the entire SR mission, and c) maintain the high "gear-ratio" of SR systems.
2) *The robustness of the human spacecraft allow for more complex sample handling protocols including any repackaging operations to break the sample chain to satisfy Planetary Protection requirements as well as potential intermediate analysis.* While this can also be done robotically, the adaptability of humans substantially improves the potential reliability of these operations and expands the range of possible solutions to these problems.
3) *Robotic sample return missions are excellent precursors for future human exploratio*n. They provide a means for testing human-scale equipment while simultaneously characterizing the materials likely to be encountered by the astronauts. This was seen in the Apollo missions to the Moon, which were preceeded by fifteen successful Ranger, Surveyor, and Lunar Orbiter missions that provided information critical to Apollo's successes. Experience dictates that robotic missions can be an integral part of future human exploration architecture.
4) *Sample return spacecraft could be refitted and refueled to increase the diversity of sampled bodies in the Solar System, and to better utilize NASA spacecraft investment.* Rendezvous between the robotic sample return spacecraft and a human spacecraft could allow for repair and refueling operations that enable SR spacecraft reusability. Thus a robust robotic sample return cycler could operate continuously to multiple targets in the inner solar system. This concept was partially proven with the Stardust-NEXT extended mission, wherein the Stardust SR spacecraft visited and imaged comet Tempel-1 after completing its primary mission of returning samples of comet Wild-2 to Earth. SR spacecraft are physically capable

of visiting multiple bodies but can currently perform SR from only a single body.

Implications: The development of human assisted sample return capability provides strong programattic and scientific benefits. Future human with robotic exploration on the surface of Mars and the Moon will provide a unique opportunity for ground truth discovery and collection of samples. Sample analysis capabilities on the surface are likely to be limited, therefore many of these samples will be returned to Earth for further comprehensive analysis and essential curation and preservation. To maximize science return and value, it is necessary to develop candidate scenarios that help determine the most effective methodologies, potential technology identification, surface analysis accommodations, operational handling and manipulation processes, containment devices, surface and on-orbit exchange, etc.

The “trade space” of sample return contains many different options with important differences. Taking advantage of human missions of opportunity with accommodating on-surface and on-orbit infrastructure in tandem with robotic missions will provide greatest exploration and discovery value.