

DEVELOPING GEOLOGY SAMPLING TOOLS FOR THE ARTEMIS PROGRAM. A. J. Naid¹, H. R. Bergman¹, A. D. Hood¹, M. L. Walker¹, H. P. Newton¹, T. G. Graff², K. E. Young³, J. L. Mitchell¹, ¹NASA Johnson Space Center, 2101 NASA Pkwy, Houston, TX, 77058 (corresponding author email: adam.j.naids@nasa.gov), ²Jacobs at NASA JSC, 2101 NASA Pkwy, Houston, TX, 77058, ³NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD, 20771.

Introduction: Humans are set to return to the Moon for the first time since 1972 with the National Aeronautics and Space Administration's (NASA) Artemis Program. One of the primary objectives will be the collection and return of lunar samples. To support this objective, the Extravehicular Activity (EVA) Tools Team at the Johnson Space Center (JSC) has started developing the next generation of lunar geology sampling tools. The EVA Tools Team are experts in the hardware certification process for space hardware and have been working on planetary surface tools for nearly a decade. Funded by the EVA Office at JSC, the Artemis tools project began on October 1, 2019 with an initial set of eight tools. That initial set of tools was brought to a Preliminary Design Review (PDR) on October 30, 2020. An additional 17 tools have been proposed to support geology sampling operations, with the development of a subset of that list beginning on October 1, 2020. Additional tools may also be considered in the future should the science requirements drive this need. This abstract describes how this project is defining requirements, what tools are being developed, and the schedule for this work.

Science Requirements: The team is working to an aggressive schedule of performing the first human lunar landing of the Artemis Program in 2024. The EVA community understands that geologic sampling and return will be a major part of this exploration program; therefore, the work has started as early as possible on sample tool development. The team has been working with the Astromaterials Research and Exploration Science (ARES) Division at JSC to ensure these tools are designed to meet anticipated lunar science community objectives. Now, with the release of the Artemis III Science Definition Team (SDT) Report on December 7, 2020, the EVA Tools Team and ARES will ensure any assumptions made prior to this report line up with the SDT's priorities. Additional integration with the Artemis SDT or whatever comes after it will also take place to ensure compliance of the tools with all science requirements.

The Tools: The focus of this work is to develop a suite of geology sampling and support tools, building on the lessons of Apollo and new experiences working in analog environments (such as the Neutral Buoyancy Laboratory and the JSC rock yard). The team has researched the Apollo missions to understand what

designs were used on the lunar surface, why they were used, what designs weren't used, what worked well, and what designs changed throughout the mission profiles and why.

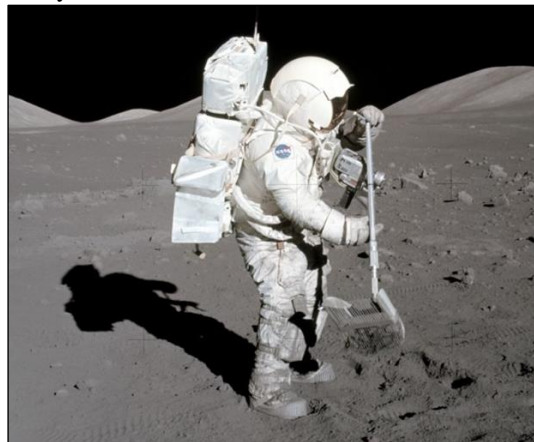


Figure 1 (above): Apollo astronaut using the rake on the lunar surface.

Out of this research the team selected eight high-priority tools to accomplish the Artemis science objectives to start developing in fiscal year 2020. These eight tools were not meant to be an all-inclusive list of the tools that would be needed, but rather a starting point in lunar sampling capability. These eight tools include:

- Extension Handle
- Contingency Sampler
- Sample Bags
- Drive Tube
- Geology Hammer
- Rake
- Scoop
- Tongs

This suite of tools will enable the collection of float, chip, regolith, and regolith-core samples. Taking what was learned in Apollo, the design team is looking for ways to improve designs with an emphasis on minimizing mass, compensating for the lunar polar environment and simplifying tool operation.

There are several other tools that a need has been identified for and the EVA Tools Team has those on the docket as well. Funding levels will dictate how many of these can be worked and the schedule for development. The list of these tools currently includes:

- Vacuum-Sealed Containers
- Powered Core Drill
- Drive Tube Cap
- Drive Tube Cap Dispenser
- Drive Tube Ramrod
- Sample Bag Dispenser
- Sample Return Pack
- Sample Transport Pack(s)
- Chisel
- Scale
- Utility Belt
- Tool Holsters
- Sample Marker
- Contact Sampler
- Slide Hammer
- Tool Cart
- Cuff Checklist

This list is just a starting point based on what the community currently understands and believes will be required and useful. As the mission requirements and prioritized science objectives are further defined and suited testing with astronauts is completed, this list may change. It should be noted that the current strategy is to create a catalog of certified geology sampling tools that the decision-makers in the science community can choose from for each mission. It will be the science community, not the engineers, who decide how to utilize their mass allocation for each surface mission.

The team has been employing a “test often” strategy. The goal is to manufacture multiple prototypes quickly, integrate them into testing facilities with stakeholders (astronauts, planetary geologists, EVA Operations, human factors, the Exploration Extravehicular Mobility Unit (xEMU) team, and Safety), and ultimately iterate designs based on feedback (Figure 2). This methodology has worked well over the first year of this project and yielded critical feedback that has informed design changes and highlighted important requirements.



Figure 2 (above): NASA astronaut and planetary scientist crew members doing a simulated EVA at the JSC rock yard to evaluate prototype geology tools and operational concepts in October 2020.

Furthermore, a Contamination Control Plan is being developed and will build on lessons learned from other extraterrestrial sample return missions (like OSIRIS-REx and Mars 2020). This plan will ensure compliance with the Artemis III SDT Report by working with experts in the field including the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM) Lunar Science Subcommittee and the NASA Artemis Curation Team.

Project Schedule: This project is following a modified version of NASA’s system engineering process. A kickoff meeting was held at JSC on October 23, 2019 to share the scope of the project with the stakeholders, followed by a Technical Interchange Meeting (TIM) for the Requirements on February 26, 2020 and a PDR on October 30, 2020. Another Requirements TIM will be held in Feb 2021 for some of the other tools with additional milestone reviews to follow. A schedule for the outyears is currently in work with the EVA Office and pending funding and priorities.

Conclusion: The development of geology sampling tools for the Artemis Program has been underway for over a year. The EVA Tools Team is engaged with the planetary science community to ensure the proper requirements are being levied on the tools. The team is looking forward to working with all the stakeholders to meet the major milestones that are currently funded and developing the rest of the tools and equipment needed to support human exploration of the moon.