Extravehicular Activity (EVA) Tools

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Purpose and Outline

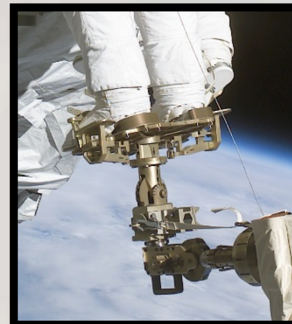
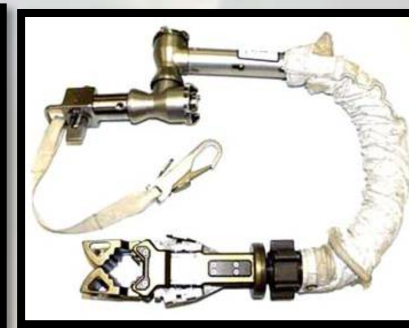
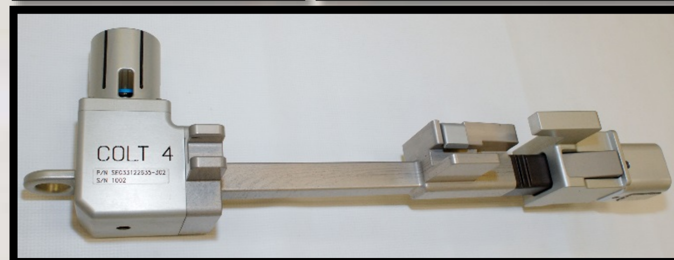
- **Purpose:** Provide an overview of existing EVA tools development.
- **Outline**
  - The Team
  - Flight Hardware
  - Z2 Tool Integration
  - EVA HH&P Benchmarking Study
  - Microgravity NExT
  - Integrated Testing
  - Current Exploration Tools Work

EVA Tools and Equipment

- The team is comprised of employees at NASA JSC working in the Tools, Equipment and Habitability Systems Branch of the Crew and Thermal Systems Division.
- The team houses Project Managers, Project Engineers, and ISS EVA Tools System Management that develop Flight Hardware for ISS and lead early development of Exploration focused tools.
- Exploration EVA Tool Development
  - The goal is to use a lean funding model to develop and test hardware in support of Operations Concept formulation at the program level AND becoming "smart buyers" for future Flight Hardware development.
  - Hardware development guided by EVA System Maturation Team (SMT) Gap List
  - Methodology:
    - Rapid development cycles
    - Focus on functionality
    - Low cost solutions

Flight Hardware

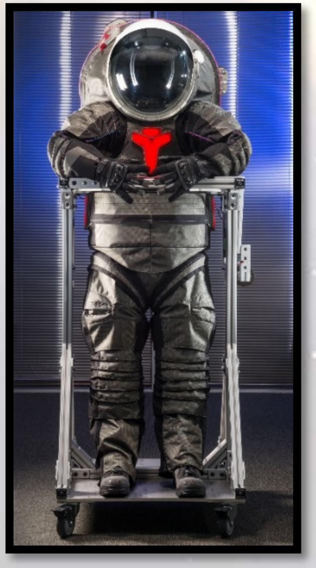
- EC7 houses project managers with experience developing and certifying Flight hardware.
- Previous project
  - Articulating Portable Foot Restraint (APFR)
  - Body Restraint Tether (BRT)
  - Contingency Operations LAPA Tool (COLT)
- Recent projects
  - EVA GoPro
  - Dual Tether Points
  - EVA Inspection Mirror
  - EVA Cap Keeper
- Current Projects
  - Alpha Magnetic Spectrometer (AMS) Repair Tools

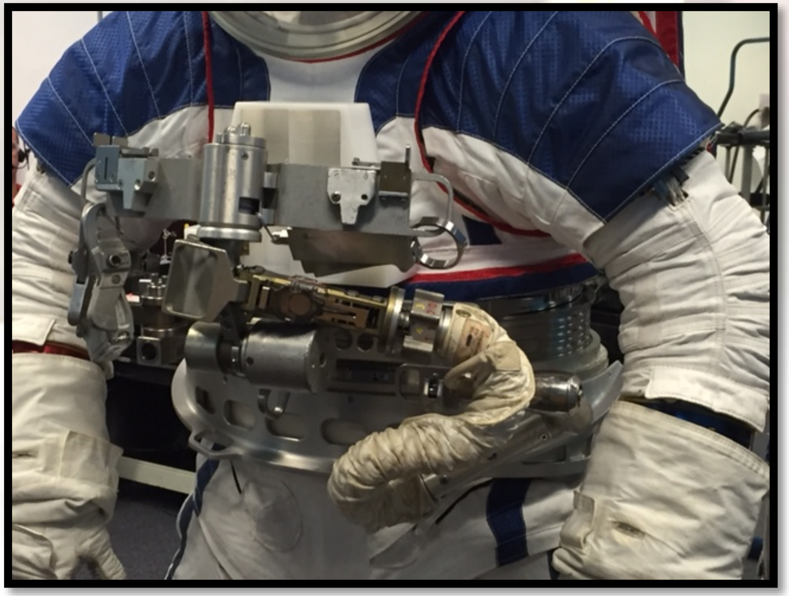







Z2 Tool Integration

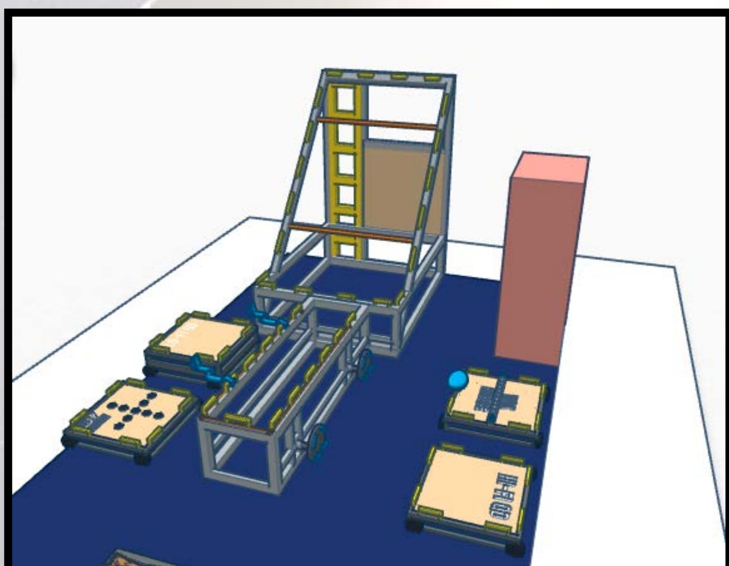
- The Z2 spacesuit will be tested in the NBL in order evaluate it’s mobility.
- To enable a high fidelity simulation a Modular Mini Workstation (MMWS) is being integrated onto the suit.
- Due to differences between the Z2 and the EMU, positioning, sizing, and mounting locations had to be modified.

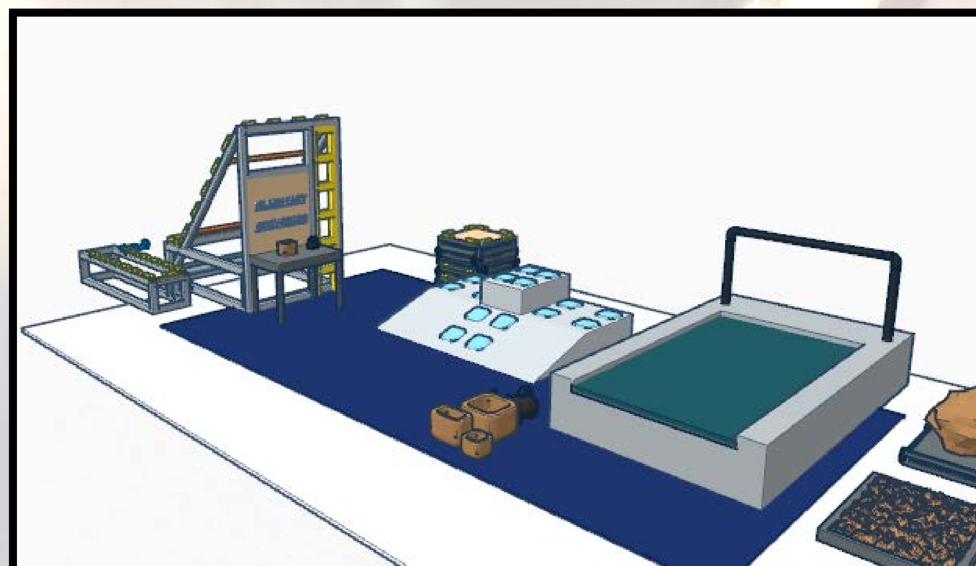




EVA HH&P Benchmarking Study

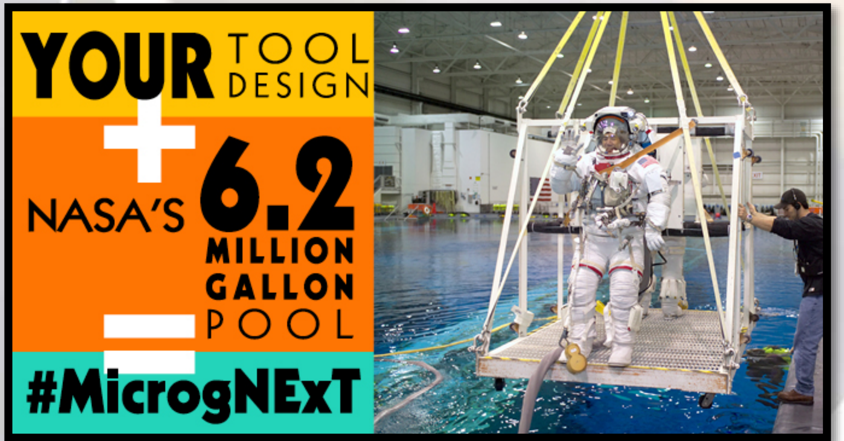
- Collaborating with colleagues in Human Health and Performance (HH&P) Directorate on EVA HH&P Benchmarking Study.
- Tasked with designing, building, and testing a reconfigurable EVA circuit for micro and partial gravity.
- Structure will enable repeatable testing of tasks with different suits in different gravity environments.



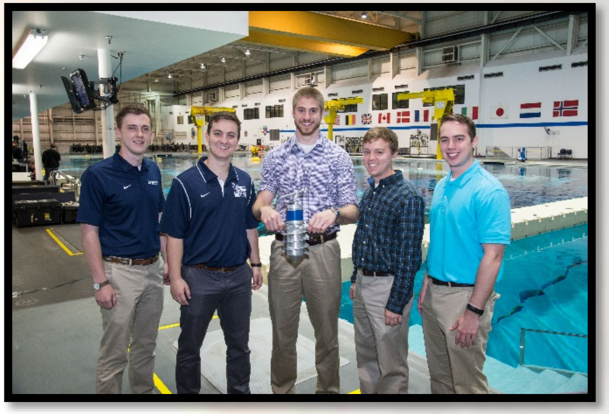


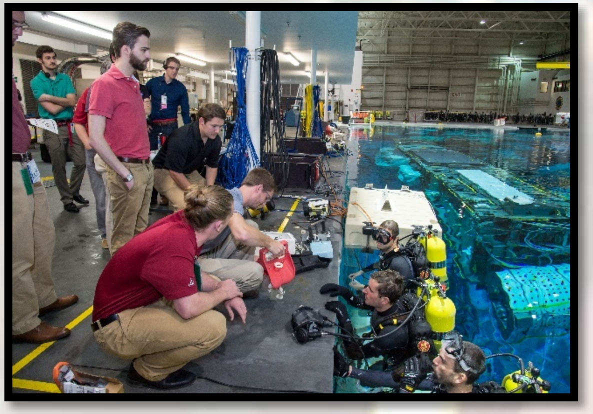
Micro-G NExT

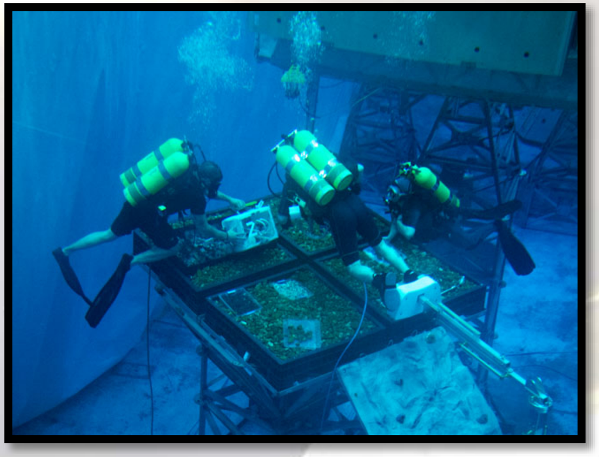
- The Micro-G Neutral Buoyancy Experiment Design Teams (Micro-G NExT) Program challenges undergraduate students to propose, design, build, and test a tool that addresses an authentic, current space exploration problem.
- Enables the EVA tools team to crowdsource tool concepts during the prototyping phase.
- Teams are self-funded for tool development and travel.
- The JSC EVA Community supports the program by reviewing proposals and volunteering as team mentors.
- The first 2 years of the program produced 43 unique tools.
- Micro-G 2017 was announced Aug 24 (https://microgravityuniversity.jsc.nasa.gov).



Micro-G NExT







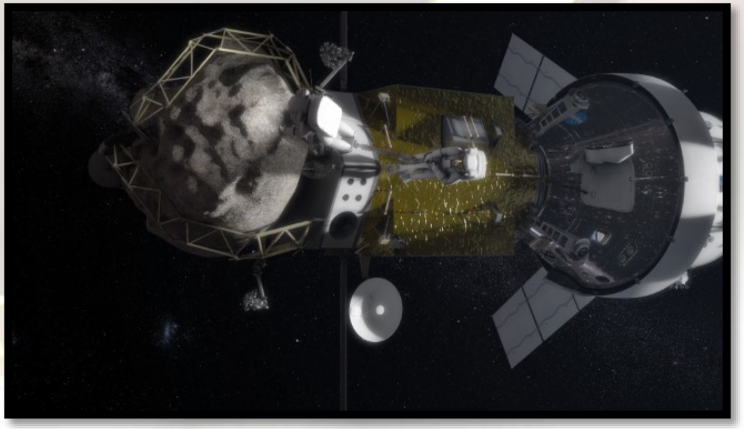
Testing

- Work with colleagues across the center to utilize the appropriate testing facilities for each level of our EVA tool development.
- Current test environments
  - Neutral Buoyancy Laboratory (NBL)
  - Aquarius Habitat, Islamorada, FL
    - NEEMO 15, 16, 18, 19, 20, 21
    - SEATEST II
  - Advanced Materials Lab (AML)
  - Thermal/Vacuum Chambers
  - Active Response Gravity Offload System (ARGOS)

- Previous test environment
  - Flagstaff, Arizona
    - Desert RATS 08, 09, 10, 11
  - Building 9, JSC
    - RATS 12

Current Exploration Work

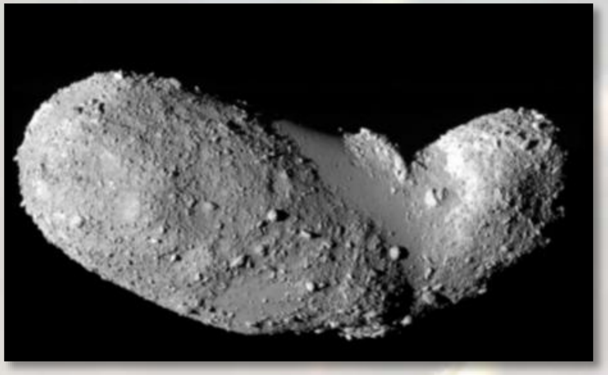
- Developing tools for geology sampling and curation on Small Bodies, primarily focused on missions such as the Asteroid Redirect Crewed Mission (ARCM).
- Working requirements derived from Exploration EVA knowledge gaps.
  - EVA SMT Gap List
  - CAPTEM Findings
- Development effort is integrated with relevant EVA stakeholders.
  - Scientists (XI)
  - Engineers (EA)
  - EVA Operations (CX3)
  - Crew Office (CB)



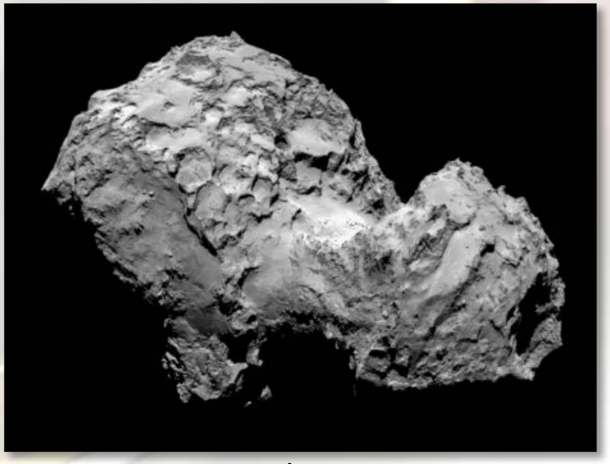
ICES 2016 - *A Geology Sampling System for Small Bodies* @ http://hdl.handle.net/2346/67698

Small Bodies

- **Definition:** Non-planetary bodies such as asteroids and comets.
- Microgravity to milligravity
- Why Small Bodies?
  - Hold key information about formation of solar system
  - Help understand origin of life
- History of Small Body Exploration
  - 11 robotic missions to date
  - 2 have attempted retrieving samples (Hayabusa, Rosetta)
    - Hayabusa successfully returned 1mg of sample to Earth
    - Rosetta unsuccessful at obtaining sample
- Planned/In Progress Sampling Missions
  - Hayabusa 2
    - Launch Dec 2014
    - Arrival Jul 2018
  - OSIRIS-Rex
    - Launch Sept 2016
    - Arrival Aug 2018



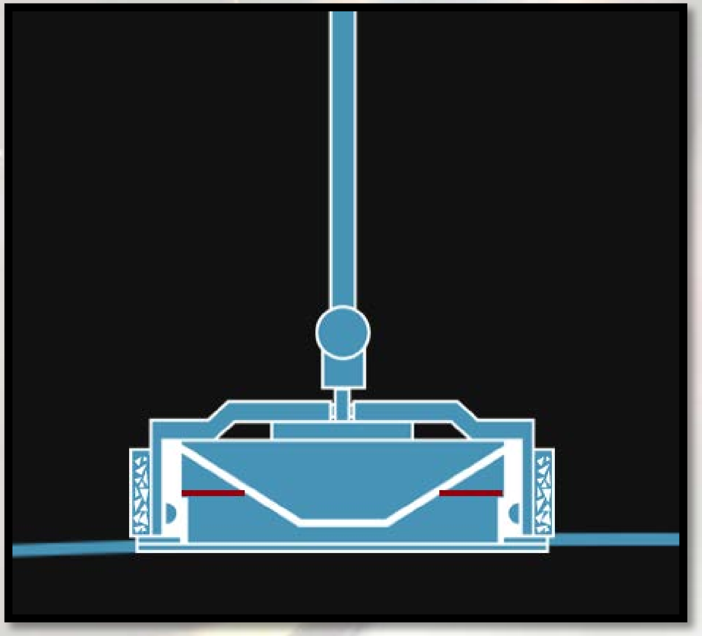
Asteroid Itokawa
Credit: JAXA Hayabusa Mission



Comet 67P/Churyumov–Gerasimenko
Credit: ESA Rosetta Mission

Sampling of Small Bodies

- Humans have never performed geological sampling in microgravity.
- Robotic mission collection techniques can provide design inputs.
  - **Hayabusa 2** – small impactor will be launched into surface, regolith will be ejected and captured in sample catcher.
  - **OSIRIS-REx** – compressed gas will be shot into the surface, stirring up regolith, which will then be captured in small bins.
- Human missions can increase the amount and variety of collected samples.
- Lessons learned are applicable to any Small Body mission, including those to Phobos or Deimos.



OSIRIS-REx TAGSAM Sample Collection Device

Science Requirements

- In support of ARM, the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM) released a list of scientific objectives, or Findings. The subset below has been used to drive tool design requirements.

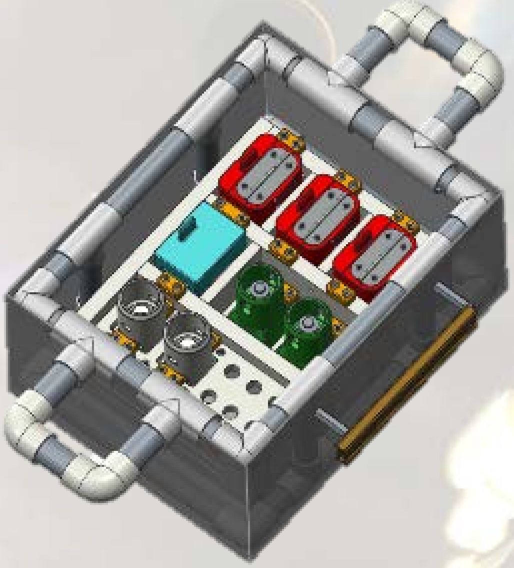
Finding	Description
3	Hand-held high-resolution cameras and supporting analytical instruments will be valuable for sample selection during EVAs.
4	Contamination control is vitally important.
5	We recommend the collection of at least 1000 g of material from two sites that sample the apparent diversity of the body.
6	We recommend the collection of at least one 5-cm diameter core sample of regolith from each of the two sites.
7	Preservation of volatiles is desirable, particularly if the sampled asteroid is of type C, P, or D.

Science Requirements

- Conversations with JSC scientists yielded five major sample types.
  - *Float:* Rocks that are loosely adhered to the surface
  - *Regolith:* A collection of unconsolidated rock fragments loosely adhered to the surface
  - *Surface:* The very top layer of dust on the surface
  - *Chip:* Pieces of a parent body forcibly removed
  - *Core:* Cylindrical section of the parent body

Integrated Geology Sampling System

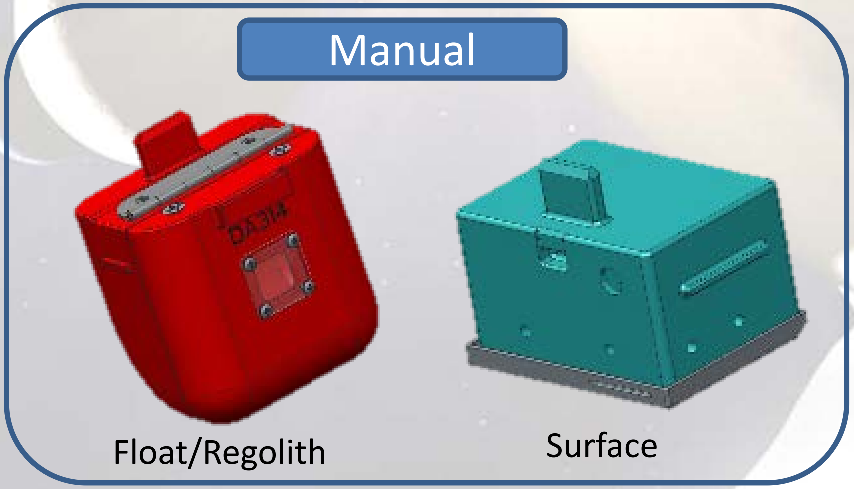
- After testing individual sampling methods an *integrated* sampling kit was created focusing on sample containment and cross-contamination protocol.
- Sample Briefcase
  - The **Sample Briefcase** is the carrying case in which the end effectors are housed prior to and after use.
  - Serves as a method to transport end effectors to and from worksites and provides final containment once a sample is collected.
  - Volume is allocated for soft sample bags to collect contingency samples and/or targets of opportunity once all end effectors have been used.



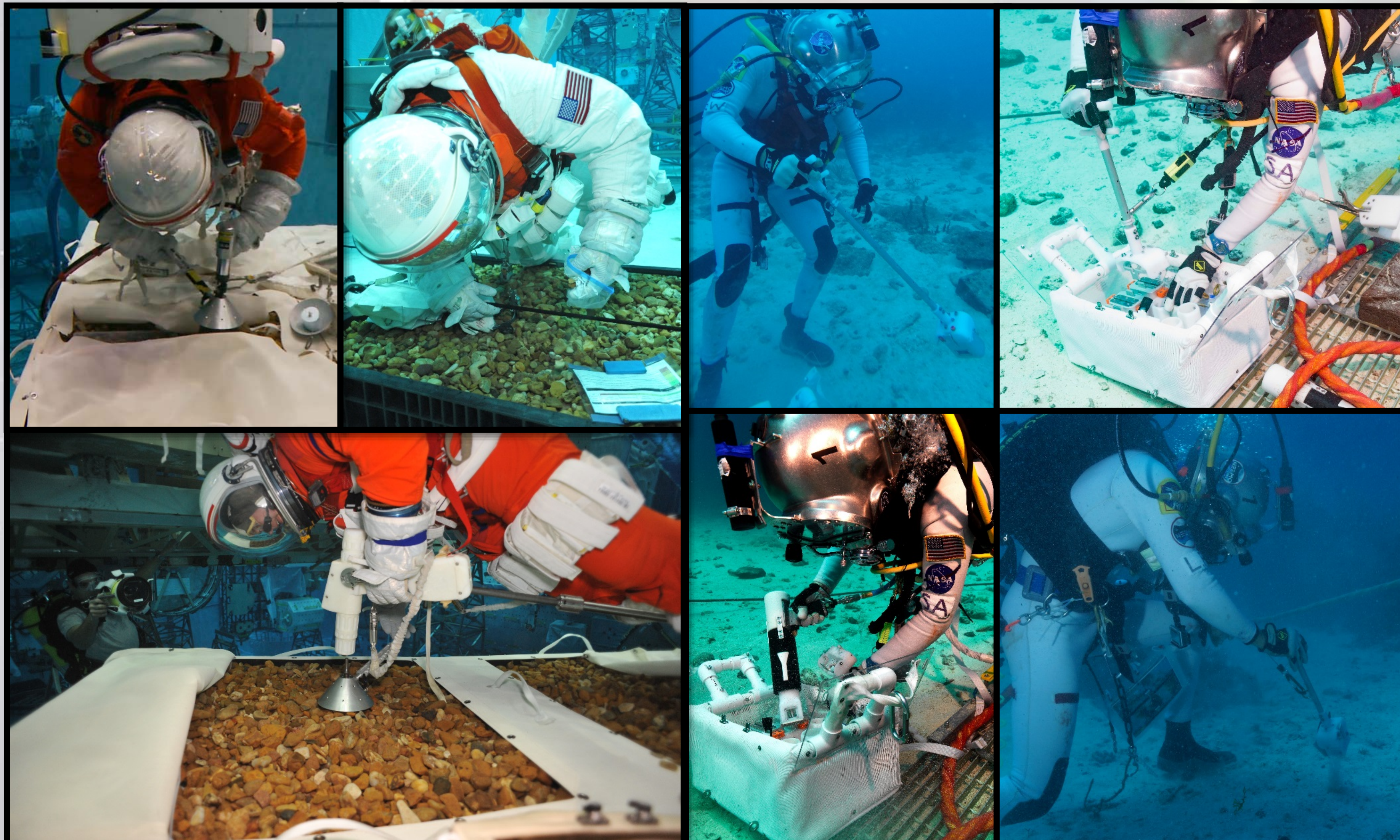
- Drivers
  - **Manual Driver** is used to obtain loosely adhered samples that can be liberated using hand strength alone.
  - **Powered Driver** is used when an increased force is needed to remove samples from the surface.

End Effectors

- Various End Effector were designed to facilitate the retrieval of all sample types of interest.
  - **Float/Regolith:** Dual purpose clamshell end effect including a window and integrated color/scale bar.
  - **Surface:** Stamp version using aluminum foam to capture particulate and a simple hinged containment lid.
  - **Chip:** Utilizes an embedded chisel that extends when in use and a sliding containment door.
  - **Core:** A lo-fi version of a core collection system.



Field Testing



Forward Work

- Continue participating in Integrated Testing
- Continue building partnerships with the science community and understanding how exploration science affects EVA Tool design.
- Maintain and grow partnerships with Industry and Academia.
- Develop prototype and eventually Flight hardware for Exploration class missions