ARTEMIS INTERNAL SCIENCE TEAM UPDATE: HARDWARE AND INTEGRATED TESTING. T. G. Graff[1], K. E. Young[2], C. A. Evans[3], the Artemis Internal Science Team, and the Joint EVA & HSM Test Team. [1]Jacobs, NASA/JSC, Houston, TX 77058 (*trevor.g.graff@nasa.gov*), [2]NASA/GSFC, [3]NASA/JSC.

Introduction: The Artemis campaign will reestablish human presence on the Moon and lead to a new era of scientific discovery and exploration. Led by the National Aeronautics and Space Administration (NASA), Artemis is a collaboration of space agencies and companies from around the world [1]. In support of Artemis activities, a cross-disciplinary effort integrating science, engineering, operations, and human factors is currently identifying and developing the best methods, facilities, and field locations to test hardware, train astronauts, and evaluate concepts of operations.

NASA's Science Mission Directorate (SMD) and Exploration Systems Development Mission Directorate (ESDMD) established a comprehensive Science Team structure to support the Artemis campaign. This structure includes 1) an Artemis Internal Science Team (AIST), 2) a Geology Team (GT) with additional Participating Scientists (PS) roles, and 3) Payload Teams (PT) for the inclusion of scientific instruments. The GT, PS and PT will be competitively selected for each mission as part of NASA's Research Opportunities in Space and Earth Sciences (ROSES) solicitations. The AIST provides multi-mission continuity and has been working closely with Artemis program elements to best integrate science into all aspects of planning and development [2]. This abstract serves to provide an AIST update on science-relevant hardware developments and integrated testing efforts that occurred in 2022.

Hardware: The Extravehicular Activity (EVA) and Human Surface Mobility (HSM) Program, collectively known as EHP, was approved in January 2022 and is managed out of Johnson Space Center (JSC). EHP's mission is to provide safe, reliable, and effective EVA and HSM capabilities that allow astronauts to safely work outside the confines of a spacecraft on and around the Moon. EHP is comprised of several elements including Exploration EVA (xEVA), International Space Station (ISS) EVA, the Lunar Terrain Vehicle (LTV), Pressurized Rover (PR) systems, and EVA and HSM-related technology development and partnerships. The xEVA element includes the spacesuit and tools required for lunar science during all surface missions, while the LTV and PR elements will provide long-ranged EVA mobility and telerobotic capability as Artemis missions progress.

Spacesuit: The spacesuits Artemis astronauts will utilize for lunar surface exploration will be provided through NASA's Exploration Extravehicular Activity Services (xEVAS) contract, which is managed by EHP. In June 2022, both Axiom Space and Collins Aerospace were selected as the two potential vendors to provide services for next generation spacesuit and associated systems via competitive task orders [3]. In September 2022, Axiom Space was awarded the task order to provide the lunar surface spacesuit and tools for the Artemis III lunar landing [4]; and in December 2022, Collins Aerospace was awarded the task order to deliver a spacewalking system for demonstrated use outside the ISS [5]. These commercial partners are responsible for all design, development, qualification, certification, and production of the spacesuits and support equipment. In support of these efforts the NASA-led Exploration Extravehicular Mobility Unit (xEMU) design reference spacesuit has been used extensively in 2022 for a series of Design Verification Tests (DVT) for hardware evaluations, as well as operational testing events. Lessons learned, data, and technical information has been made available to the xEVAS companies to accelerate development and reduce risk. The AIST has been involved in both xEMU testing and xEVAS developments to ensure science considerations are incorporated in the next generation lunar spacesuit.

Tools: The Artemis III xEVAS contract will also provide lunar surface exploration tools including the geology tools required for sample collection, transportation, and storage. The NASA-led efforts by the JSC EVA Tools Team culminated in a xEVA Tools Project Technical Review (PTR) in July of 2022, after ~two years of detailed requirements generation, design reviews, multiple generations of prototypes, and extensive field and lab testing [6]. This information was also made available to xEVAS to provide access to NASA's previous investments in xEVA lunar tools. The AIST has been closely integrated in the xEVA tools project from its initiation and continues to be involved in the xEVAS lunar geology tools developments.

Lunar Terrain Vehicle (LTV) and Pressurized Rover (PR): Apollo demonstrated that science is greatly enhanced by missions that include capability to traverse beyond the crew walking distance from the lander [7]. The Artemis LTV, or unpressurized rover, will greatly extend traverse range, enabling more diverse science discoveries and increase operational capabilities by EVA-suited crewmembers, while uncrewed telerobotic operations between missions will further enable exploration. The Lunar Terrain Vehicle Services (LTVS) contract is the acquisition strategy to provide an

unpressurized rover and is progressing towards a contract award in 2023 [8]. Additionally, efforts to develop requirements and technologies needed for a PR system to establish a long-term presence during future Artemis missions continue. For both the LTV and PR systems, the AIST science and utilization groups have been engaged in requirements definition and contract efforts to ensure these critical assets have the capabilities to achieve science goals and objectives.

Testing: Artemis-related test events in 2022 significantly increased in frequency, scope, and complexity across numerous facilities at NASA centers and at remote field locations. This diverse testing portfolio is required to satisfy the variety of conditions needed for hardware, con ops, and training objectives. Integrated testing events and facility developments are coordinated by EHP's Joint EVA Testing Forum (JETF) and approved by the Integrated Testing & Facilities (ITF) Panel. The JETF consists of numerous stakeholders across the xEVA community, and serves to synchronize test objectives, resources, milestones, and programmatic-level goals. The Joint EVA & HSM Test Team (JETT) is a multi-disciplinary group of subject matter experts from the JETF that plan and execute integrated tests. AIST members participate in the JETF, ITF, and serve in key roles of the JETT leadership ensuring strong science representation throughout. Below is a summary of a few significant 2022 science-related testing facilities developments and field events.

Testing Facilities: The Neutral Buoyancy Laboratory (NBL) and the Active Response Gravity Offload System (ARGOS) facilities have been progressively developing new lunar testing capabilities. The NBL, a large indoor pool for simulating EVA tasks at various gravity offloads, has dedicated pool floor space for a lunar terrain mockup. This terrain currently includes regolith, rocks, boulders, and large mockup features to facilitate science observation, sampling, and other tasks in a pressurized spacesuit at simulated lunar gravity. This facility has also demonstrated a low-angle lighting environment to simulate lunar south pole illumination conditions using a high-powered underwater lighting rig and dark curtains. During a comprehensive testing series in 2022 this new lunar capability was utilized to 1) determine how to operate the xEMU in the NBL in as near a flight-like manner as possible and 2) demonstrate use of the NBL lunar area to inform continued facility upgrades. The ARGOS facility has supported numerous lunar-gravity offloaded spacesuit events in 2022 for DVT and Human Health and Performance (HHP) measures. ARGOS is a robotic system that simulates various gravity offloads using an inline load cell to continuously offload a portion of a suited subject's weight during dynamic motions. This facility has also included lunar simulants (rocks and regolith) for testing purposes while conducting science tasks with geology tools and payload mockups. A larger ARGOS facility is currently in the development phase to provide increased floor space and simultaneous two-person operations. Numerous other NASA-facilities are continuing to develop their lunar support capability for hardware and operational testing including lighting labs, outdoor rock yards, HHP labs, and simulant labs.

Field Test Events: Testing events in 2022 at remote terrestrial field sites included numerous locations and testing objectives for both near-term (Artemis III/IV) and longer-term (Artemis V+) missions. The near-term testing was developed, planned, and executed by the JETT and included a comprehensive series of three field deployments that successively built upon capability and lessons learned. The JETT1 field test was conducted in April 2022 at the Potrillo Volcanic Field, New Mexico with the primary purpose to deploy and evaluate field mockup spacesuits and the design reference geology tools. The JETT2 field test was conducted in July 2022 in the Icelandic highlands with a focus of deploying xEVA field mockup equipment (spacesuit mockup and backpack configurations along with geology tools and their transport/management) and testing xEVA concepts of operation in a high-fidelity lunar-like environment. The JETT3 capstone field test was conducted in October 2022 in the San Francisco Volcanic Field, Arizona and focused on integrating a Mission Control Center and Science Team [9]. The longer-term Artemis testing activities also were conducted in October 2022 in the San Francisco Volcanic Field by the Desert Research Analog Test Studies (DRATS) team in collaboration with JAXA and focused on a study of potential PR requirements and design solutions. The suite of 2022 field test events all had strong AIST leadership, as well as science participation from various other community sources. In addition, these field tests provided a baseline for the training and logistics at these key locations for future events with the Artemis assigned crew [10].

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References: [1] Artemis Lunar Exploration Plan (2020). [2] LPSC (2022) Artemis Town Hall. [3] NASA Release 22-055 (2022). [4] NASA Release 22-093 (2022). [5] NASA Release 22-128 (2022). [6] Naids A. J. et al. LPSC (2020), #2715. [7] Apollo Program Summary Report (1975) JSC-09423. [8] LTVS Solicitation (2022). [9] Young K. E. et al. LPSC (2023). [10] Evans C. A. et al. LPSC (2023).