EXTRAVEHICULAR ACTIVITY MISSION SYSTEM SOFTWARE (EMSS) - ENABLING HUMAN PLANETARY EXPLORATION DATA WITHIN THE BROADER PLANETARY DATA ECOSYSTEM.

M. J. Miller[1,3], B. Feist[1,3], C. W. Pittman[1,3], A. Alexander[2,3], A. Britton[1,3], A. Jagge[1,3], J. Montalvo[2,3], T. Graff[1,3], A. Abercromby[3] and A. Kanelakos[3], [1]Jacobs Technology, Inc.; [2]KBR Wyle, [3]NASA JSC; corresponding author email: matthew.j.miller-1@nasa.gov

Introduction: The planetary science community is once again on the verge of generating, capturing and analyzing human planetary exploration data, this time via the Artemis program. Artemis missions will involve robotic missions in addition to human extravehicular activity (EVA) where crew will be generating scientific data [1]. Present-day robotic mission data expectations for data archiving involves ingesting data into the Planetary Data System (PDS), but how might PDS be leveraged/adapted/ready (or not) for human spaceflight mission data, particularly EVA data that includes non-scientific data that provides important context to the scientific data gathered on the lunar surface? This question has broader implications than what this abstract can answer, but we wanted to pose the question to 1) get conversations started and 2) highlight how operations software data handling could play a role in overall data curation.

An initiative known as EVA Mission System Software (EMSS) at NASA Johnson Space Center has emerged as a way to infuse software support capabilities for the EVA flight control team. The EMSS team comprises a multi-directorate cohort of personnel with backgrounds in EVA flight control, science operations, human health and performance, data engineering, and software development. Central to this effort is matching the Flight Operations Directorate flight mantra of 'plan, train, fly', and the underlying software support and data needs so the flight team and in particular science communities can 'explore'. Enabling this requires answering persistent questions such as 'where are we?', 'what are we doing?' and 'what are we learning?' The remainder of this paper focuses describing EMSS components and proposes how Artemis EVA mission data might integrate with the broader planetary data ecosystem (PDE) [2-3].

EMSS - Where are we?: Figure 1 shows a software prototyping effort to understand geographic information system (GIS) capabilities and EVA flight operator needs. The figure shows the latest images/illumination basemaps of the lunar south pole annotated with estimates of boulder counts, regions of interest identified, alongside a possible EVA traverse all of which are pulling from the latest lunar planetary data sets/analysis. For Artemis EVA, features of this system could include photography, video, sensor data, space suit consumables, all spatially correlated to the map products and underlying scientific layers. By uniting this information geospatially, on demand and automatically, these synthesized data products can begin to support the EVA flight team's decision making processes. Note that this data synthesis is novel to the EVA workspace which has historically united all activities data exclusively in a temporal, rather than a geospatial, context.

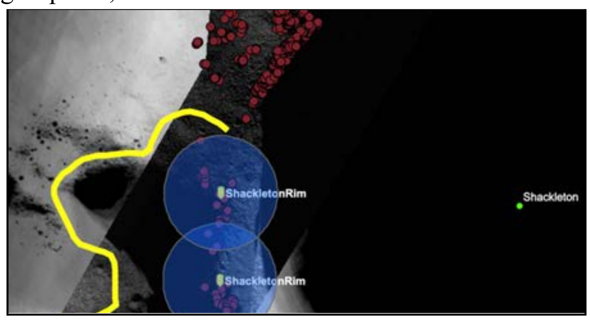

Figure 1: EVA details overlaid on Lunar surface.

EMSS - What are we doing?: EMSS Maestro is a digital EVA task authoring and real time tracking application. Figure 2 shows an excerpt of Maestro in authoring mode with detailed lists of steps for each member of the flight team to perform. Maestro is helping standardize input fields using templates that remove the need for authors to spend time on formatting details. During execution, Maestro features include the ability to 'check off' steps as they are completed and facilitate the ability to alter the procedures 'on the fly' to accommodate necessary changes throughout operations. In doing so, Maestro provides digital, timestamped, temporal written records of what happens on an EVA as it occurs. These efforts are on-going and developing alongside Artemis EVA procedure development.

Figure 2: Maestro EVA procedure editing view

EMSS - What are we learning?: Figure 3 shows the tool CODA (Collaborative Operations Data Activation), which consolidates EVA timeline data (provided by Maestro) alongside audio, video, telemetry feeds (provided by ground infrastructure) as well as map products (provided by GIS solutions). This consolidated view provides the opportunity to relive every moment of the EVA as it happened for the flight team to review on-demand. Additionally, this effort provides a long-term, mission context vantage point for long term analysis and review, particularly for the scientific community who will depend on the source data gathered during Artemis EVAs.

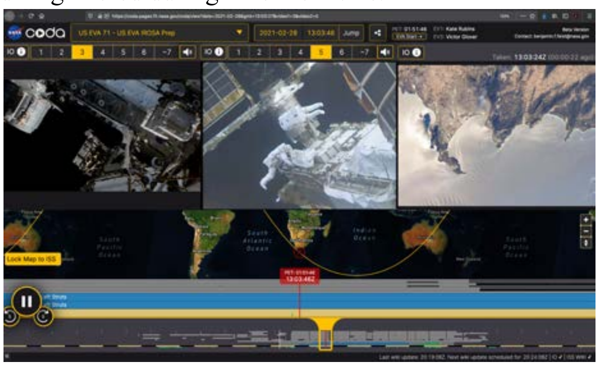

Figure 3: CODA integrated EVA display

Why Mission Context? The EMSS components emphasize the need to make mission context as transparent and accessible as possible. By embedding mission context into the dataset itself, we have the opportunity to directly alleviate the challenges of integrating different datasets to promote shared common knowledge. Context, or "the circumstances that form the setting for an event, statement, or idea, … in terms of which it can be fully understood and assessed," implies the data generated from the mission should be coalesced temporally. All events can then be understood within the sequencing of mission activities and geospatially. It is unacceptable to allow data produced within a mission to live in isolation, devoid of the opportunity to be placed alongside all the other data generation activities taking place within the mission.

Mission Context in Planetary Data Curation: One central challenge of promoting team science is the integration of knowledge from disparate disciplines to a shared research problem, and by extension a shared, integrated, data set from which research problems can be answered [4]. This is further complicated by the fact that the scientists that worked to produce the data from planetary missions are not necessarily the scientists that examine and make meaning of the data many years after the missions are completed. As a result, scientists are left to piece together disparate and incomplete sources of data before being able to begin assessing possible scientific lines of inquiry. The 50+ years of subsequent study of the Apollo lunar surface missions is one obvious example [5]. Therefore, we have the opportunity now to serve the scientific community an integrated data set embedded with the appropriate mission context.

The Apollo in Real Time website [6] shows how this temporal alignment of disparate data sets for the Apollo lunar missions was employed to enable an entirely new, modern Apollo experience. In doing so, human relatable information, such as timeline information about who was doing what when, is aligned with video and photography data. The whole becomes greater than the sum of the parts. Taking mission context one step further, having the mission data instantiated in this way then enables every single event to be associated with all subsequent follow-on activities. This traceability is made tangible by linking the source capture of a specific sample collected such as Bag 469 during Apollo 17 and all subsequent imagery and in-depth studies (with links to all publications) that were derived from this specific sample.

Proposed Concepts: Discussions of Artemis planetary data curation must take a proactive stance in establishing standards for mission and instrument teams to adopt that will facilitate the capture of "mission-context-ready" data as it is produced during missions. This concept can be decomposed as follows:

- **Level 1:** collect data and metadata for Principal Investigator use
- **Level 2:** Level 1 plus storage and metadata expansion into the PDS/PDE
- **Level 3:** Level 2 plus local data compatibility and cross-disciplinary context within mission across (engineering and scientific) systems
- **Level 4:** Level 3 plus universal data standards that facilitate globally understood data, metadata available across missions (Open data)

Central to this layered approach is applying a consistent universal indexing standard such as timestamp formats, clocks synchronized within a tight tolerance to an agreed-to standard mission clock, and single source of truth expectations in the PDE. As the use-cases within each progression level are addressed, interested parties will not have to retroactively answer simple questions like, what did or did not happen during the mission? Are there other samples collected from the mission that are of particular interest? Why was this sample collected?

References: [1] EVA Exp 0042: https://www.nasa.gov/sites/default/files/atoms/files/eva-exp-0042_xeva_system_con_ops_rev_b_final_dtd_10192020_ref_doc.pdf;[2]Miller et al. 2020 LSSW [#3022]; [3] Pittman et al. 2020 [#3026] LSSW; [4] Cook & Hilton, 2015 NAS; [5] Neal, 2008 *Geochemistry* 69(1); [6] Feist, (2015). https://apolloinrealtime.org