ENABLING MODERN FLIGHT CONTROL AND GROUND SCIENCE SUPPORT TEAMS USING SOFTWARE SUPPORT SYSTEMS.

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Introduction: Lunar surface extravehicular activity (EVA) and the necessary flight team support needs remain largely unchanged since Apollo. However, modern-day tools and technologies are vastly more complex than the analog systems employed during Apollo. Artemis will be executed in an era where people are accustomed to real-time digital data that is accessible on demand. So the question remains: how might mission support be executed by using modern era software support systems?

This paper contends that as Artemis flight control teams become established, a clear understanding of roles, responsibilities, and computer data handling/production expectations need to be defined. Software tools must be created to support the flight teams' work needs to cope with the pressures of real-time Artemis EVA operations.

An initiative known as EVA Mission System Software (EMSS) at NASA Johnson Space Center has emerged in the past year as a way to help address these mission software support needs. 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 explore' with the underlying software support needs the EVA flight team will rely upon to support Artemis EVAs. Given the focus of this Lunar Surface Science Workshop, the remainder of this paper focuses on what the 'fly' component specifically might look like with modern software support systems and an Artemis EVA flight control team.

Imagining Artemis Real-Time Science Data Handling: Apollo was built on the work practices of the missions that preceded it, e.g. Mercury, and Gemini [1]. Artemis will build upon the flight team developed and proven in the Shuttle and ISS programs. In the current world of ISS EVA operations, an EVA discipline consists of front room, support room and engineering personnel working in concert with each other to support EVA crew [2]. For Artemis, the inclusion of science expertise will be a new addition bringing with it the need to consider 1) the new, unique data products required by scientists and 2) understanding how this new discipline integrates with the existing flight support structure to ensure Artemis can be successful.

To help facilitate both these changes, the EMSS project has supplemented the 'plan, train, fly, explore' mantra with three persistent questions that span across all phases of an EVA: *Where are we? What are we doing?* and *What are we learning?* The remainder of this paper discusses the software support systems being developed to help answer these questions and, in doing so, start to reimagine how the Artemis flight team will have the necessary support systems to successfully perform lunar planetary surface EVA.

Artemis EVA - Where are we?: The ability to capture and analyze spatial data is performed within the construct of a geographic information system (GIS). There is an extensive professional and academic industry surrounding the topic of GIS. The challenge now is how to leverage modern GIS technologies to meet the needs of real-time EVA flight operations. Previous disparate efforts have looked at this problem in various ways, how to understand reachability on a planetary surface [3], optimally traverse from point to point [4], geotag data as collected to location data [5].

Figure 1 shows an example of a software prototyping effort built by the EMSS team to begin to understand GIS capabilities and EVA user needs. The figure shows the latest images/digital elevation models of the Lunar south pole annotated with estimates of boulder counts, regions of interest identified, alongside a possible EVA traverse.

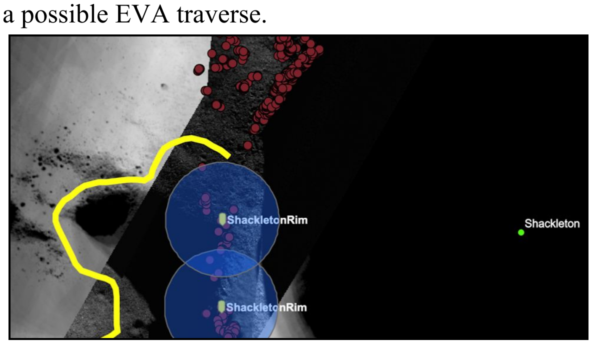

Figure 1: Example depiction of EVA details overlaid on Lunar south pole remote sensing data.

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 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 geospatial context (as discussed in the next section).

Artemis EVA - What are we doing?: The ability to ensure successful EVA operations relies on the completion of EVA procedures. These procedures ensure all expected tasks are performed and used to verify tasks are performed correctly. For ISS EVA, these detailed procedures contain a step by step set of instructions that are methodically executed [6]. For Artemis EVA, engineering type tasks will likely follow a similar approach. However, science exploration tasks will likely entail a lesser degree of prescriptive structure to allow for crew and flight team to react to the natural environment to satisfy science objectives (Hodges paper). Nonetheless, the flight team needs to know what crew are doing at all times and what needs to be performed to ensure the EVA is successful.

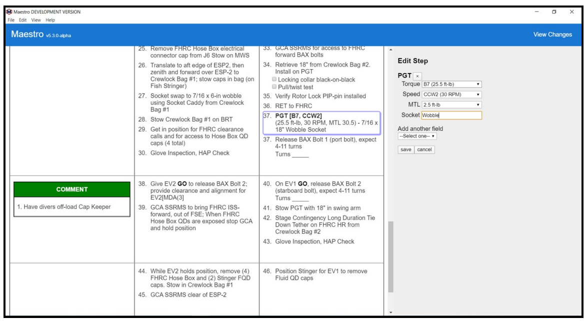

Figure 2: Maestro EVA procedure editing view

The EMSS team has been building a software tool known as Maestro to translate what has historically been a pen and paper flight execution tool (printed EVA procedures) into a digital medium. Figure 2 shows an excerpt of Maestro in authoring mode with detailed lists of steps for each member of the flight team to perform. Given the structured nature of ISS EVA, 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, written records of what happens as it happens. The EMSS team is actively researching how to best incorporate scientific procedures into Maestro. These efforts are on-going and developing alongside Artemis EVA procedure development. See additional prototyping efforts at [7-8].

Artemis EVA - What are we learning?: Deriving meaning from disparate datasets is a persistent challenge. To help ensure the Artemis flight team can derive meaningful insights from what happened during EVA, the EMSS team is building a tool known as CODA (Collaborative Operations Data Activation). The concept for CODA emphasizes the fact that all operations data is temporally dependent. Everything happens at a given moment in time, so why not associate all data products as time-series data and provide it all in a common interface for enabling an integrated playback ability? This idea in action can be found on the Apollo in real-time works [9].

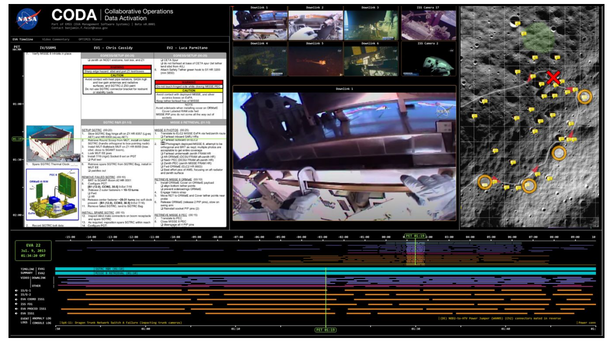

Figure 3: CODA integrated EVA prototype design

As shown in Figure 3, EVA timeline data (provided by Maestro) can be placed 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 in near-real time for the flight time 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 depend on the source data gathered during Artemis EVAs.

Conclusions: The success of Artemis EVA operations depends in part on the team's ability to make the right decisions throughout execution. This will require the support systems the flight team uses to meet the needs of the teams' work goals. The way in which their work is accomplished is ripe for the application of novel software support systems. This paper presented three integrated software development efforts that begin to address how we could consolidate in near-real time: location information (note this was a major resource demand by people during Apollo), sample descriptions, photography, video, audio, sensor information, and task details for flight console operators to comprehend and synthesize to support the flight team decision-making process. In doing so, we can capture a mission context rich data set necessary for real-time decision making as well as produce a data set future generations can study.

References: [1] Feist et al, (2020) this issue, [2] Miller et al. (2016) *J. Cog. Eng. and Dec. Mak.* 11, 2., [3] Mackin et al., (2012) NASA TM-2010-216361, [4] Norheim, (2018) MIT Thesis, [5] Marquez et al., (2019), *Astrobiology*, [6] Miller et al., (2015), IEEE Aerospace, [7] Miller et al. (2019) *J. Cog. Eng. and Dec. Mak.* 14, 1., [8] Miller et al., (2017), International Astronautical Congress, [9] Feist, (2019) https://apolloinrealtime.org/11/