SUPPORTING REAL-TIME EVA SCIENCE VIA HORIZONTALLY INTEGRATED INFORMATICS STRUCTURE ACROSS ARTEMIS ACTIVITIES. C. W. Pittman[1,2], B. F. Feist[1,2], M. J. Miller[1,2], T. D. Glotch[3], [1]Jacobs Technology, Inc.; [2]NASA JSC; [3] Stony Brook University; corresponding author email: cameron.w.pittman@nasa.gov

Introduction: Many systems will be designed and developed for the Artemis program. A subset of these systems will be relevant to scientific activities conducted during the program, but it is important to consider that these scientific activities will be conducted within the context of the larger program. Thinking about the program data holistically, and deliberately structuring its data products in a way that preserves the data's *mission context* will enable new opportunities for real-time science support, and long-term analysis of the mission and its data for generations to come.

Here, we show that horizontally integrated mission data products are valuable by describing two Artemis relevant examples: Apollo in Real-Time, and the SSERVI RISE2 field program. As Artemis activities become more defined, having a horizontally integrated data management plan will be paramount to ensuring successful mission context is captured for generations to come.

Temporal Mission Context: "Context" implies that the data generated during the mission should necessarily be captured and stored in a way that preserves meaning, and one way to accomplish this is to associate data *temporally*. The sequence of events that occur within the silo of each mission system, element, or experiment is made immediately cross-compatible with the other systems via synchronization with a master mission clock.

Temporally contextualized data introduces relationships that do not need to be predefined. One field that greatly benefits from freeform relationship building between disparate datasets is anomaly investigation, where investigators need to follow lines of evidence that may not be *a priori* apparent. Building relationships between data enables accident investigators to react faster to time-sensitive incidents during EVA operation and other critical human spaceflight activities. Another advantage is in temporal alignment is the long-term data preservation that enables unplanned or yet-to-be conceived applications or study of this data many years in the future.

Illustration: Bringing Archived Apollo Data Back to Life: The benefits of temporally synced data sets are illustrated in Apollo in Real Time (AiRT)[1], an online web application that has restored the temporal mission context of several Apollo missions. Figure 1 shows how this temporal alignment of disparate data types for the Apollo lunar missions was employed on AiRT to enable an entirely new way to research the historical Apollo missions. In doing so, human relatable information, such as timeline information about who was doing what and when is aligned with audio, video, photography, and geological sample data. The whole becomes greater than the sum of the parts. Having the mission data instantiated in this way enables every single event to be associated with all previous and subsequent activities.

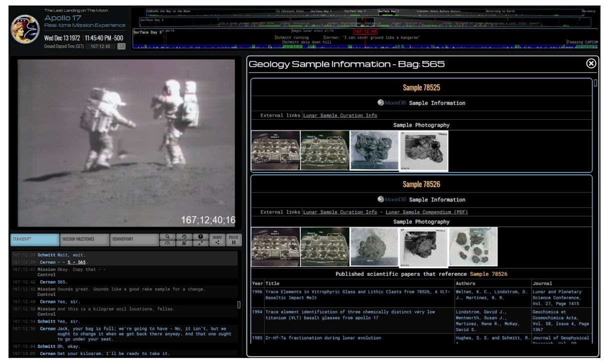

Figure 1: AiRT's alignment of disparate Apollo data types to establish their temporal mission context.

This effort illustrates the benefit of establishing temporal mission context for the long-term study of science data gathered in the context of a mission and poses the question of how such a system, if enabled in the design of future missions, could benefit the operations of, and the long-term study of the data gathered during those missions.

Capturing Scientific Data On Analog Field Operations; RIS^{4}E and RISE2: The Solar System Exploration Research Virtual Institute (SSERVI) Remote, In Situ, and Synchrotron Studies for Science and Exploration (RIS^{4}E)[2] and its successor program, RISE2 continue to provide relevant analog scenarios where scientific data is gathered in the field across a variety of instruments during simulated EVAs (fig. 2).

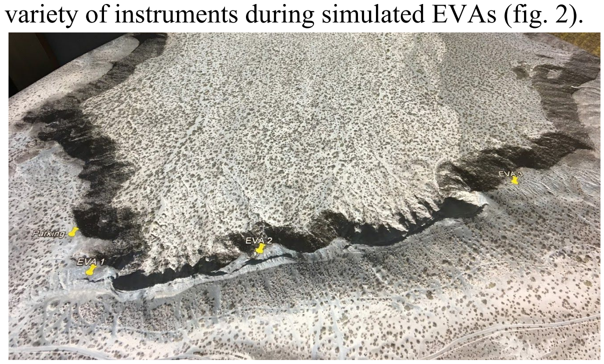

Figure 2: RIS^{4}E Analog EVA plan for three days of field activities.

The informatics considerations for these analogs include accommodating a wide variety of instruments of different types and applications. Hand-held instruments such as X-ray fluorescence spectrometer (XRF) and laser-induced breakdown spectrometer (LIBS) (fig. 3) are used on demand on targets of interest. Larger instruments such as a hyperspectral camera and LiDAR system (fig. 3) require setup, processing time, and post-processing activities in order to yield useful data products. Real-time data sources such as GPS crew tracking and chest-worn audio/video recorders provide a detailed time-based record of activities. Lastly, field notebooks catalogued actions taken and logged measurement locations which added important contextual information to the data collected across instruments.

Figure 3: LiDAR (left) and Laser-induced breakdown spectroscopy (LIBS) (right) being used during a RIS⁴E analog EVA.

These diverse data products produced by different instruments are difficult to integrate into an overall mission context. Being commercial off-the-shelf (COTS) products, each instrument was designed in a silo to be used independently from any other instrument's data. Not having the opportunity to provide each instrument manufacturer with a master set of informatics requirements will always result in the yielded data being difficult to pull back into its mission context. Clocks are not synchronized, data are stored on local storage devices rather than a central location, and native data formats are not designed to be compatible with a universal system.

The RIS^{4}E program was a useful opportunity to study these problems and gather data required to work towards solutions. As part of this effort, instrumentation data were gathered and restructured into a temporal mission context with many interim work-arounds and human intensive data curation to overcome the COTS instrument abilities, resulting in the ability to "replay" an analog EVA using a prototype software solution (fig. 4). This solution demonstrates the value of being able to view specific scientific data in the context of an EVA and illustrates the value to science support operations of potentially having real-time access to such data during Artemis EVAs. For example, having direct access to XRF results from a point reading could help to determine the best course of action, or provide the ability to triage sample collection during an EVA designed to have access to such information.

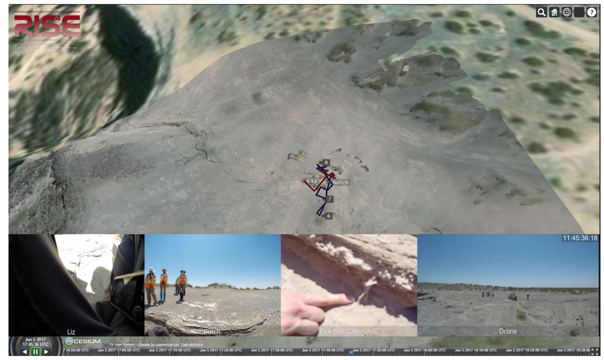

Figure 4: RIS^{4}E prototype temporal replay software solution horizontally integrating instrument data

The question of how these kinds of information would be gathered, transmitted, presented, digested in mission control, and turned into EVA directives is being investigated by the EVA Mission System Software (EMSS) effort at JSC[3].

Conclusion and Advantages to Artemis Science: Collecting Artemis science data with its mission context intact has three primary benefits:

1. The Science Support Room is provided the opportunity to process and analyze science data during real-time activities to provide rapid response EVA directives.
2. The science community is provided the ability to identify and eliminate anomalies within science data that were caused by operational influences.
3. The scientific community is afforded the opportunity to make novel discoveries via "happy accidents" of insight introduced via the temporal and correlational presentation of seemingly unrelated information alongside data of interest.

These technological capabilities can be enabled with modern software. If the Artemis program prioritizes this goal of horizontally structured data, it will enable the scientific data gathered by the program to be used in the new ways described in this paper and likely in yet unimagined ways in the future.

References: [1] Feist, B. F. (2015-2020) *https://apolloinrealtime.org* [2] Glotch, T. D. https://news.stonybrook.edu/facultystaff/nasa-selects-sbu-team-to-collaborate-on-space-research/ [3] Miller, M. J. et al. (2020) *Enabling Modern Flight Control And Ground Science Support Teams Using Software Support Systems.*