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Operational Assessment of Apollo Lunar Surface Extravehicular Activity

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Abstract

Quantifying the operational variability of extravehicular activity (EVA) execution is critical to help design and build future support systems to enable astronauts to monitor and manage operations in deep-space, where ground support operators will no longer be able to react instantly and manage execution deviations due to the significant communication latency. This study quantifies the operational variability exhibited during Apollo 14-17 lunar surface EVA operations to better understand the challenges and natural tendencies of timeline execution and life support system performance involved in surface operations. Each EVA (11 in total) is individually summarized as well as aggregated to provide descriptive trends exhibited throughout the Apollo missions. This work extends previous EVA task analyses by calculating deviations between planned and as-performed timelines as well as examining metabolic rate and consumables usage throughout the execution of each EVA. The intent of this work is to convey the natural variability of EVA operations and to provide operational context for coping with the variability inherent to EVA execution as a means to support future concepts of operations.

Contents

Nomenclature

ALSEP	Apollo Lunar Surface Experiment Packages
CDR	Commander
EVA	Extravehicular Activity
LM	Lunar Module
LRV	Lunar Rover Vehicle
LR3	Laser Ranging Retro-Reflector
LMP	Lunar Module Pilot
MESA	Modular Equipment Stowage Assembly
MET	Modular Equipment Transporter
MR	Metabolic Rate
MCC	Mission Control Center
PSE	Passive seismic Experiment

1 Introduction

Safe and effective extravehicular activity (EVA) will be a critical component of any future human space exploration mission. EVA is the means by which astronauts explore and interact with their surroundings within the habitable environment of their spacesuit [1]. A defining characteristic of future human EVA exploration is the transition from operating on engineered surfaces such as the International Space Station to exploring unknown 'natural' environments such as the moons and surface of Mars. As of July 2016, only 9 out of 391 EVAs ever performed by NASA have been performed on planetary bodies and focused on exploration objectives (e.g. Apollo J-class missions performed during Apollo 15 through 17). Therefore, a more detailed inspection of past operational experiences must be performed to in order to better prepare for future operations. This study explores the inherent operational variability exhibited during the Apollo program as they conducted lunar surface operations in order to quantify and charactertize the conditions future crew may face while conducting Mars surface operations. EVA is a highly choreographed event that leverages detailed timelines to guide and instruct every component of an EVA and ensure astronaut safety and mission success.

Though a vast repository of historical data for surface EVAs exist from the Apollo program, limited quantitative analysis has been applied to understanding the variability and cadence of surface EVA timeline execution. The lack of quantitative timeline execution data limits our capability to inform timeline and operational support tool development to enable future surface EVA operations. Therefore, in this paper, we quantify the operational variability to address two main gaps in the operational understanding of EVA execution: (1) Timelined task execution and performance and (2) life support system variability, as shown in Table 1. With regards to timeline performance, this study addresses two objectives: (1.1) quantify variability exhibited throughout EVA timeline execution, and (1.2) categorize task execution performance and associated deviation magnitudes from the planned timeline. Coupled with timeline performance is the variability exhibited by the life support systems during execution. This paper pursues two objectives with regard to life support system variability: (2.1) quantify metabolic rate variability exhibited throughout EVA timeline execution (2.2) characterize metabolic rate trends per task execution and consumable prediction trends.

This research leveraged publicly available Apollo documentation to coalesce and process a comprehensive database of Apollo lunar surface EVAs, specifically from Apollo 14 through 17. EVA timelines were decomposed into specific modes of operation to quantify a mission level assessment of the execution tendencies exhibited by the Apollo astronauts. The work presented here does not exhaustively investigate or explore causal relations for timeline execution deviations in detail. Rather, we coalesce existing experiential insight scattered among the existing literature and specifically focus on quantifying the variation across the entire data set as well as the variation exhibited *throughout* the execution of the global Apollo data set. Additionally, the specific regions where deviations took place throughout each EVA were identified to help direct future investigative studies. The intent of this assessment is to characterize the operational environment of exploration EVA to inform future

Table 1: Apollo EVA Study Objectives

ID	Objective Description
1	**Timeline Execution Performance**
1.1	Quantify task execution variability exhibited throughout EVA timeline execution
1.2	Categorize task execution performance and associated deviation limits from the planned timeline
2	**Life Support System Performance**
2.1	Quantify metabolic rate variability exhibited throughout EVA timeline execution
2.2	Characterize metabolic rate trends per task execution and consumable prediction trends

EVA operaitonal concepts.

This report is divided into five primary sections. The remainder of Section 1 describes relevant EVA elements and artifacts related to EVA operations under consideration for this study. Section 2 describes the data analysis process utilized. Section 3 provides a description of the presented results formats. Section 4 presents the analysis results and provides a summary description of each EVA as well as an aggregated results description of the global data set. Finally, Section 5 presents a synthesized discussion of the aggregate data set and explore potential avenues for future work. The raw data collected for this study can be found in Appendix A and B.

1.1 Brief Review of EVA Operations

The Apollo program is still arguably one of humankind's greatest technological achievements. Aside from overcoming the vast number of scientific training [2, 3] and engineering challenges [4, 5] to prepare the Apollo crew, the Apollo program pioneered the operational methods and practices for executing field science on natural environments during EVA operations. In particular, the Apollo program pioneered the concept of incorporating a team of scientists to support real-time and strategic decision making regarding human surface operations [2]. During Apollo, there existed extensive ground support presence in Mission Control that the flight crew rely upon for all phases of flight, including EVA [6]. To facilitate operations, the Apollo EVA architecture consisted of two EV crew members who communicated with Mission Control on Earth as shown in Figure 1. A common theme throughout the Apollo program was that the EV crew relied on real-time input from ground support personnel during the execution of EVA . In addition, the Apollo crew leveraged paper-based procedures and manuals to execute EVA tasks which were arranged in a detailed timeline document that is described in the subsequent section.

To date, limited quantitative analysis has been applied to understand the variability and cadence of lunar surface EVA execution. Much of the lessons derived from the Apollo EVAs exist in qualitative format, scattered throughout volumes of mission reports and technical documents. Limited statistical descriptions of execution performance metrics of EVA operations (e.g. average metabolic rate, locomotion, or total percent timeline deviation) were documented (For examples, see Refs: [8–10]). In recent years, some research efforts have provided methods and case study examples which examined EVA timeline execution performance and attempted to quantify EVA task efficiency [11,12]. The work presented in this study extends previous timeline analysis techniques and applies them across the Apollo 14-17 lunar surface EVAs to provide a comprehensive synthesis of lunar surface EVA operations. Additionally, this study simulaneously examines the distribution and trends exhibited in the EVA telemetry data (e.g. metabolic rate and consumable values). By quantifying the variability exhibited by Apollo crew, we can calibrate our expectations for future missions.

Over the past 50+ years of human spaceflight activities, EVA has played an integral component in the expansion and enhancement of humans working and living in space [13]. Many of the earliest EVA analyses dating back to the Gemini program focused on the engineering, physiological, and environmental challenges of enabling humans to survive in the vacuum of space [14–16]. Once EVA became feasible, the focus shifted to refining and improving EVA hardware and crew capabilities. Many of the advancements made in EVA development were pioneered during the Apollo program, whereby through an incrementally phased approach, development and operational testing advanced the state-of-the-art in EVA tools/hardware and crew capabilities. The Apollo lunar surface EVAs serve as the only flight demonstrations for surface exploration EVA operations and therefore are a primary source of operational knowledge, particularly as NASA aims to perform EVA on the surface of other planetary bodies [17]. Unfortunately, analyses of the Apollo EVAs vary in both their scope, focus and consistency. More specifically, the operational variability exhibited by the crew as they completed EVA tasks throughout planned timelines has not been well studied. A few notable Apollo EVAs have been analyzed in detail, as shown in Table 2, however no consistent examination has been performed across all Apollo surface EVA operations.

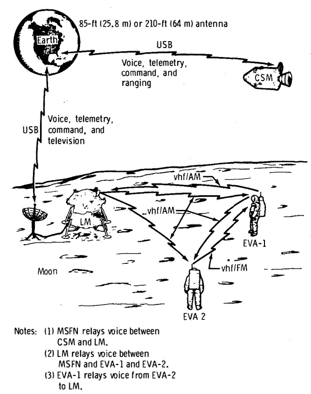


Figure 1: Apollo EVA communication architecture [7]

The EVA literature can be divided into two two main categories: astronaut biomedical assessments and timeline task/hardware studies. Each Apollo mission was examined from a human physiological perspective. Notably, Apollo 14 EVA 2 and Apollo 15 EVA 1 were studied in detail and summary statistics of crew operational metrics were calculated, such as metabolic rate expenditure [8, 28, 29] (a more recent examination of EVA metabolic rate can be found in Ref: [30]). Human EVA physiology and EVA tools/hardware development studies have been applied throughout the history of EVA operations which include EVAs performed during Skylab [31–33], Shuttle, [34–36] and International Space Station (ISS) programs [30, 37–42]. However, the bulk of these studies emphasized EVA hardware

Table 2: Existing Apollo EVA analyses.

Apollo	EVA	EVA Analysis References
11	1	Apollo 11 Mission Report [18]
12	1 2	Apollo 12 Mission Report [19]
14	1 2	Apollo 14 Mission Report [20], Slaybaugh [21], Carr [22], Marquez [23]
15	1 2 3	Apollo 15 Mission Report [24], Apollo 15 Time and Motion Study [9]
16	1 2 3	Apollo 16 Mission Report [25], Apollo 16 Time and Motion Study [10], Muehlberger [26]
17	1 2 3	Apollo 17 Mission Report [27]

development needs and only offered summary descriptions of nominal or proposed EVA timeline characteristics. Executing an EVA requires a host of ground support operators to ensure the crew and their systems are all operating within safe operational limits [43, 44]. Understanding and quantifying the operational variability of EVA execution is critical to help design and build future support systems to enable astronauts to monitor and manage EVA operations in deep-space, where ground support operators will no longer be able to react instantly and manage execution deviations due to the significant communication latency.

Unfortunately, a detailed temporal examination of Apollo EVA execution is not readily available from existing data sources. The respective mission reports as shown in Table 2 do provide some limited qualitative descriptions of the major deviations that occurred during EVA execution. Furthermore, two studies specifically focused on the locomotion data from Apollo 15 and 16 and related metabolic rate expenditures to the physical motions of the crew [9, 10]. These locomotion studies assessed the as-performed task executions times with *a priori* trained execution times. However, these studies were only applied to Apollo 15 and 16 and not applied to Apollo 17. Furthermore, these studies emphasized as-performed timeline task performance as it related to training data collected during Earth-based testing, as opposed to comparing directly to planned EVA timelines. Nonetheless, these studies did establish an initial set of common task terminology and provided the basis for characterizing EVA tasks.

The most recent examinations of EVA timeline performance were conducted by Looper and Ney, who focused on quantifying EVA task efficiency for ISS EVA operations. [11, 45, 46] By studying the audio/video data for ISS EVAs, task types and durations were extracted and quantified across various EVA timelines and compared to Earth-based analog research environments. In the latest EVA examination, Marquez extended Looper's and Ney's timeline analysis methodology and applied that framework to Apollo 14 EVA 2 as a case study example. [23] The work presented in this study extends Marquez's work by applying a similar timeline assessment protocol as described in Section 2 to all Apollo 14 through 17 lunar surface EVAs.

1.2 Apollo EVA Timeline Description

An EVA is a highly choreographed event that leverages a detailed timeline to maintain task progress and ensure the EVA objectives are met. An EVA timeline is a compiled, sequenced set of tasks at various levels of description which contains the geospatial and temporal information associated with all tasks to be performed. The Apollo EVA timelines were structured in a hard-copy paper format in the form of summary timelines and detailed timeline procedures with crew cuff checklists as shown in Figure 2. The timelines analyzed in this study typically contained 7 hours of planned tasks to 1 minute resolution in most cases (Apollo 14 EVAs we approximately 4 hours in duration). The detailed procedure documents contained the expected minute by minute sequence of task descriptions whereas the summary timeline provided a global view of the major phases of the EVA. The EVA cuff checklists provided an abridged version of the task procedures that the crew carried on their suit for reference during execution. All EVA timelines are described by the term: Phased Elapsed Time (PET), which as the name suggests is the relative time since the official start of the timeline. The standard format for PET is written in Hours:Minutes, e.g. 4:08, which signifies a position of four hours and eight minutes into an EVA timeline. All task start and stop times and integrated into the timeline using the PET format.

Each lunar surface EVA consisted of two crew members: the Commander (CDR) and a Lunar Module Pilot (LMP). The general format of each EVA begins with the crew preparing to leave the Lunar Module (LM), exiting the vehicle (egress), performing the tasks associated with the particular EVA objectives that includes traversing away from the LM, and finally returning to the LM, stowing equipment and reentering the LM (ingress). A "buddy system" was utilized throughout the EVA timeline where both the CDR and LMP followed similar overall timelines while completing different detailed task procedures.

The traditional approach to EVA timeline formulation and execution is to *a priori* script the entire series of EVA events prior to execution. The EVA planning process considers a multitude of factors such as science ojectives, engineering objectives, and mechanical constraints such as power and communication availability. [47, 48] As a consequence, the EVA timeline generation process is incredibly time and resource intensive which holds true even to present-day EVA timeline development. [47, 49] The intent of scripting timelines to such a high level of fidelity is to miminize risk. By prescribing the exact sequence of events, EVA operators can effectively maintain awareness of their respective tasks and anticipate when and what tasks will be performed. For more detail about the general challenges of human spaceflight planning, see Refs. [50–53]. As shown in Section 4, even the most carefully planned and trained EVA timeline inevitably experiences timeline execution deviations.

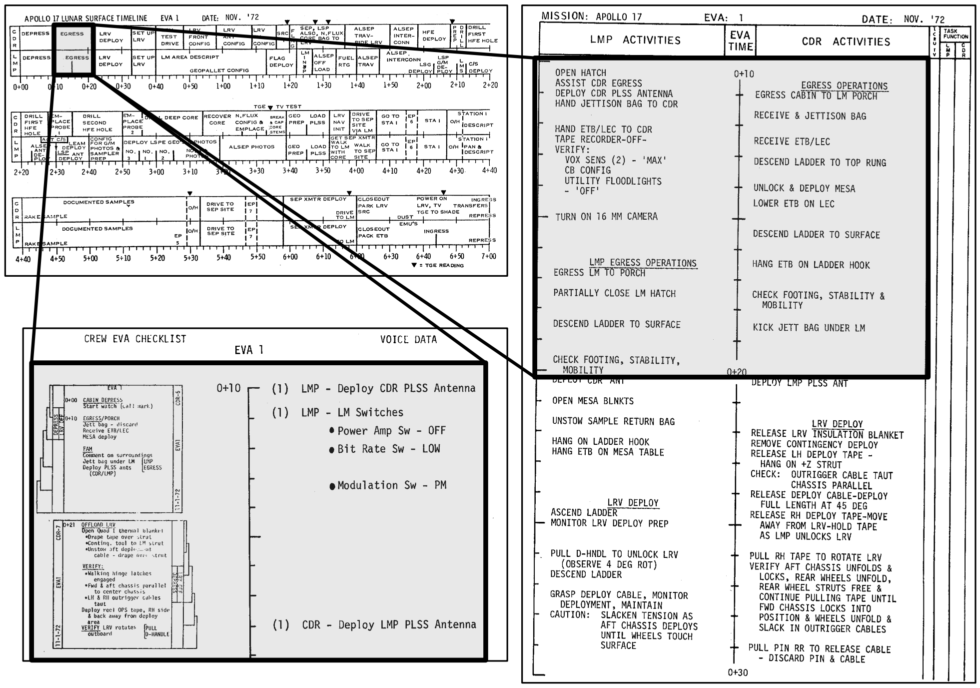


Figure 2: Apollo 17 EVA 1 timeline elements: the summary timeline (upper left), the detailed procedures (right), and crew cuff checklist (lower left). [54]

1.3 Apollo EVA Extravehicular Mobility Unit Description

Successful execution of EVA operations requires crewmembers to rely on their spacesuits, see Figure 3, to provide life support for hours at a time throughout an extremely variable environment. While there are many factors that affect one's health in space, the space suit's life support focused on short-term, operational survivability. As such, only the most important resources were monitored, while others were assumed nominal (such as radiation levels). Among the spacesuit's core functionality, it must provide breathable oxygen, scrub carbon dioxide and other contaminants from the internal atmosphere, and be able to remove excess hardware and body heat, while also maintaining a survivable pressure for the crewmember. Numerous factors influence the spacesuit's ability to maintain its core functionality, including exposure to direct sunlight and radiation, intensity of physical activity performed, and the presence of gas leaks. These factors can affect the crewmembers' survivability in various ways: Direct sunlight

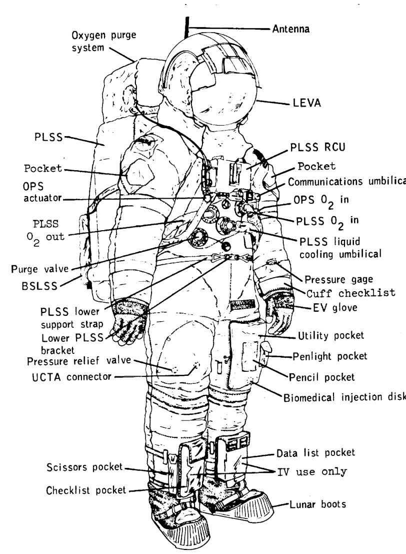


Figure 3: Apollo EVA spacesuit schematic [55]

can cause body temperature to rise to unsafe levels, physical activity can raise both body temperature and heart rate, and gas leakage can reduce available breathable air. Because there are so many variables that can affect the crewmembers survivability, a concise and accurate method of determining the crewmembers health was desired. It was determined that the basic determinants of operational survivability were heart rate, body temperature, and respiration, along with power to support the suit's life support. As such, the Apollo engineers and physiologists chose to use metabolic rate (MR), or the rate at which ATP is converted into ADP and energy in the body. This was chosen because it is affected by heart rate, oxygen consumption/carbon dioxide production, and body heat production. Metabolic rate estimation by heart rate, by oxygen tank pressure, and by heat removed were all used in an algorithm to determine a single metabolic rate estimate. (For additional details, refer to the Refs: [8, 56, 57] .

Increased physical activity requires more oxygen and energy supplied to the blood, which increases heart rate and respiration rate, thereby increasing metabolic rate. Before conducting the Apollo missions, the crewmembers performed extensive testing in order for a relatively accurate correlation between heart rate and metabolic rate to be determined. During the Apollo missions, electrocardiogram electrodes were used to measure heart rate using sensors placed on the crew members' skin surface. This was the fastest method of determining metabolic rate, and a by-minute estimate of MR was able to be created. This allowed the MCC operators to make operational decisions for the crewmembers that took into account their health and life support system status. The time-lag between MCC and IV did not allow any other method to have such a quick estimate of MR [8].

In addition to monitoring metabolic rate, MCC monitored key consumables that were utilized by the life support system: power, water, and oxygen. The life support system was designed to enable about hours of operations and once these resources were depleated, the system could no longer sustain crew life. While the suit was designed to operate for specified periods of time, how the crew performed during the EVA impacted the ultimate capacity of the life support system. If the crew expend energy at a higher rate than expected, the depletion of consumables is increased, thereby shortening the overall capacity of the spacesuit. Conversely, if the crew exibited lower than expected energy expenditures, there may be more available capacity to continue operations longer than planned. Life support system operations are inherently coupled with timeline execution. The capacity of the life support system dictates what tasks can be executed and how those tasks are executed impacts the capacity of the life support system. As shown in Section 4, the interdependant nature of these EVA elements is variable and difficult to predict.

2 Methods

This study analyzed the differences between planned and as-performed EVA timeline information. The Apollo program, in total, performed 14 lunar surface EVAs. However, the initial set of EVAs were objectively different than the latter EVAs. Figure 4 shows a summative view of the performed EVAs during the Apollo program and shows the growth in crew capabilities using two operational metrics: 1) the cumulative distance traveled and 2) the mass of scientific samples collected per EVA. Apollo 11 and 12 EVAs were considered proof-of-concept, or 'pioneering' EVAs and focused specifically on engineering/hardware objectives, supplemented with scientific data collection. Apollo 14 EVAs marked the transition where scientific objectives became the the bulk of primary EVA objectives. Collectively, Apollo 11 through 14 constitute the Pioneering EVAs of Apollo missions. The hardware and procedure validation and verification performed during the Pioneering EVAs enabled subsequent missions to perform Exploration EVAs.

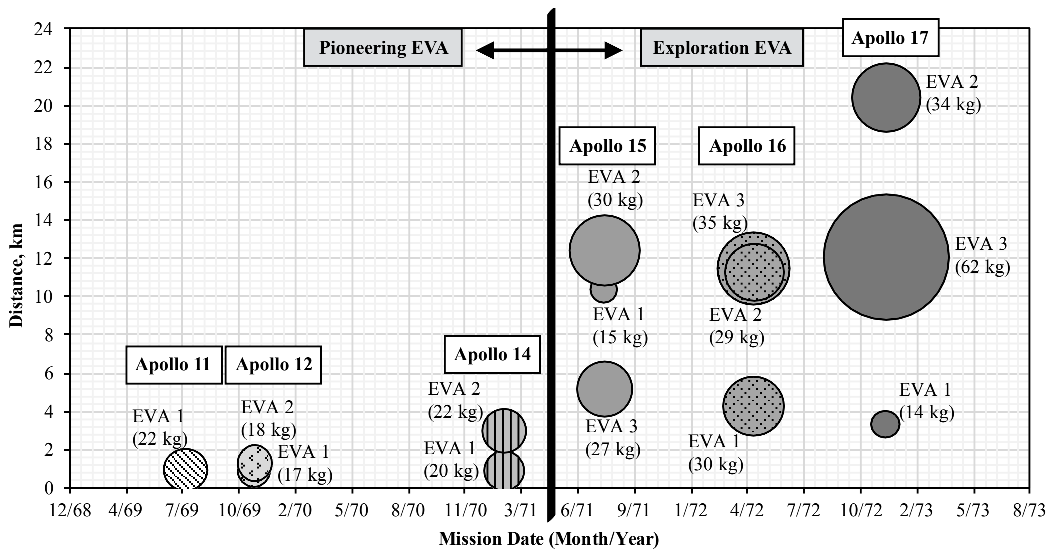


Figure 4: The evolution of Apollo capabilities per EVA over time (x-axis) in terms of total distance traveled (y-axis) and total mass of scientific samples collected (size of the bubbles) per EVA. [58]

Apollo 15 through 17 exhibited a substantial increase in scientific productivity and exploration activity. Exploration EVAs utilized a lunar rover [59] (LRV) which significantly expanded crew capability to reach scientifically interesting locations and traverse much larger regions of the Moon's surface. Figure 5 shows the maximum linear distance the crew traveled from the lunar module (LM) for each Apollo Mission. Notably, the maximum distance the crew ventured from the LM more than double when the EVA objectives transition from Pioneering to Exploration timelines after Apollo 14. The maximum distance crew ever ventured from their LM was approximately 7.6 kilometers during Apollo 17. Furthermore, the planned EVA timelines nearly doubled from Pioneering EVAs to Exploration EVAs from 4 hours to 7 hours in duration and the crew performed three instead of two EVAs per Apollo mission.

Aside from the different objectives and distances covered, fundamentally, exploration EVA forced a shift in the EVA timeline planning and execution process. The geospatial distribution of assets and tasks being executed expanded by orders of magnitude to accommodate exploration objectives. In doing so, the operational limits of the tools/hardware and life support systems were utilized to a much greater degree than had been previously experienced during the pioneering EVAs. The aforementioned exploration characteristics of Apollo 15-17 resemble similar future concepts of operations as stated in the NASA Design Reference Mission 5.0. [60,61] Understanding the operational environment and situations the crew faced during Apollo EVA execution will help identify and inform what situations future EVA operations may encounter.

The results presented in this study exclude all EVAs conducted during Apollo 11 and 12. Additionally, Apollo 15 EVA 2 and 3, and Apollo 16 EVA 3 were only partially analyzed due to extensive timeline deviations and limited available data. These three EVAs in particular exhibited significant changes to the planned timeline such that the as-performed timeline could not be adequately mapped to the published planned timeline data to make any quantitative comparisons from the documented sources. In summary, the EVAs included in this paper are shown in Table 3 and were deemed representative of long duration (7 hour) exploration EVA operations dedicated to scientific discovery.

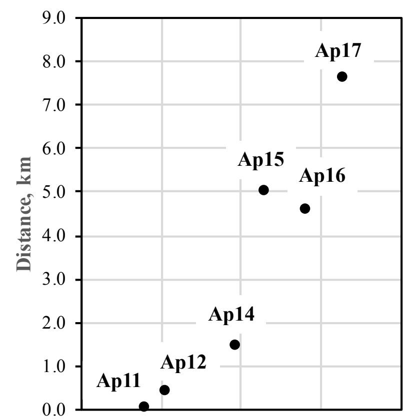


Figure 5: The maximum distance between crew and LM during each Apollo mission. [58]

Table 3: Apollo EVAs Included/Excluded in this study & associated data sources

Apollo Mission	EVA	Included(✓) Excluded(✗)	Planned References	As-Performed References
11	1	✗	Apollo 11 Lunar Surface Operations [62]	Apollo 11 Mission Report [18]
12	1 2	✗ ✗	Apollo 12 Lunar Surface Procedure [63], Press Kit [64]	Apollo 12 Mission Report [19]
14	1 2	✓ ✓	Apollo 14 Lunar Surface Procedure [65], Press Kit [66]	Apollo 14 Mission Report [20]
15	1 2 3	✓ ✓ ✓	Apollo 15 Lunar Surface Procedure [67], Press Kit [68]	Apollo 15 Mission Report [24], Apollo 15 Time and Motion Study [9]
16	1 2 3	✓ ✓ ✓	Apollo 16 Lunar Surface Procedure [69], Press Kit [70]	Apollo 16 Mission Report [25], Apollo 16 Time and Motion Study [10]
17	1 2 3	✓ ✓ ✓	Apollo 17 Lunar Surface Procedure [54], Press Kit [71]	Apollo 17 Mission Report [27]

2.1 Summary of References

The majority of the data for this study originated from the Apollo Final Lunar Surface Procedures and the Apollo Mission Reports as cited in Table 3. On occasion, other supplemental sources such as the Apollo Press Kits, the Lunar and Planetary Institute resources[1], and NASA Technical Reports Server[2] were referenced to provide additional understanding of the EVA timelines and procedures. Most of the Apollo documentation referenced in Table 3 can be found online at the Apollo Lunar Surface Journal[3].

The Apollo Lunar Surface Procedures were published prior to EVA execution for each Apollo mission. Each of these documents contained hundreds of pages which detailed each EVA's objectives, summary timelines, detailed nominal timelines, and contingency timelines. The data for the planned timelines were derived directly from the detailed nominal timelines for each EVA described in each Lunar Surface Procedure document.

2.2 Data Collection Methods

The raw data for planned and as-performed timelines, as-performed metabolic and consumable consumption rates were extracted from the Lunar Surface Procedures and Mission Reports. Unfortunately, the planned and as-performed timeline data are presented in a variety of forms and are somewhat inconsistent in content between Apollo mission. Therefore all of the collected data for this study had to be either digitized using a plot digitizer or manually copied into a structured digital format. Data tables found in the Appendix provide all digitized raw data used in this study.

2.2.1 Data Collection from Planned EVA Timeline

The planned timeline details were extracted from the nominal planned timelines in the Apollo Final Lunar Surface Operations documents (see Figure 2). The detailed timelines for each EVA depicted the tasks and allocated task times for both the CDR and the LMP. The detailed timelines also provided an abstracted task description on the right-hand side of each page to categorize the primary purpose of the detailed tasks. Each planned task had an associated start time and duration with resolution to the nearest minute.

2.2.2 Data Collection of As-Performed Timeline

The majority of the as-performed timeline data exist in a graphical format. Therefore, the raw data for as-performed timelines were extracted from the Mission Reports provided in Table 3 using a plot digitizer[4] when in graphical format. Data was manually copied when timeline data was available in text or tabular formats. Figure 6 shows an example of the graphical as-performed data, from which the raw data was

[1]LPI: http://www.lpi.usra.edu/
[2]NASA NTRS: http://www.sti.nasa.gov/
[3]Apollo LSJ: http://www.hq.nasa.gov/alsj/frame.html
[4]Plot Digitizer: http://plotdigitizer.sourceforge.net/

extracted. The task descriptions provided in the as-performed timeline data were matched to the planned timeline task descriptions. Fortunately, the terminology remained almost exactly the same between the planned and as-performed reference materials such that the task descriptions could be directly associated. Therefore, task start times could be associated. In cases where task description discrepancies occurred, the supplemental sources were used to confirm or refute the task associations.

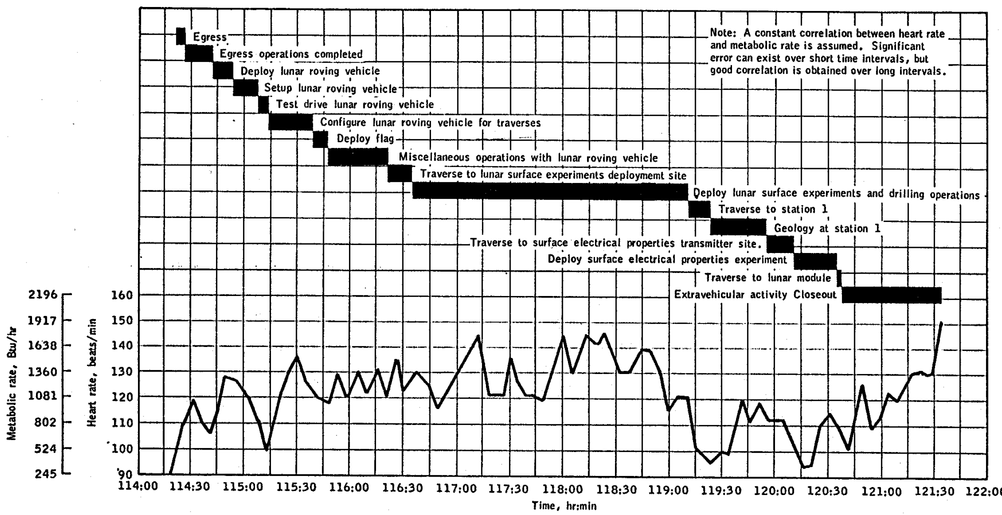


Figure 6: Apollo 17 EVA 1 - CDR as-performed graphical timeline data. [27]

2.2.3 Data Collection of EVA Telemetry Data

Telemetry data was collected from each Apollo mission report, and was compared to available references such as Ref: [8] in order to ensure consistency. Each metabolic rate plot was digitized using a plot digitizer[5]. The predicted and remaining consumable values were presented in table format throughout each mission report. This study extracted those values and presented an aggregated summary in the results.

2.3 Timeline & Telemetry Analysis Methods

Each EVA timeline was coded in a manner similar to the timeline analyses performed by Looper and Ney [45] and Marquez [23]. Table 4 shows the task categories and general descriptions previously applied to EVA timelines. This study utlized three primary task categories: 1) Overhead, 2) Station Activity, and 3) Traverse. Their respective associations to the previous studies are shown in Table 4. These three task categories were derived from the highest level phase descriptions of operations highlighted in the planned summary timeline documents. By utilizing these categories, each EVA timeline was analyzed in a reasonable amount of time. Futures studies

[5]Plot Digitizer: http://plotdigitizer.sourceforge.net/

could aim to apply the more granular descriptive task categories such as those proposed by Marquez by incorporating the flight audio transcripts to supplement the as-performed timeline data. For the purposes of this study, three categories provided the task description resolution needed to convey the primary phases of operation exhibited during Apollo surface operations.

The timeline analyses resulted in the calculation of two groups of operational measures: 1) minutes behind schedule and 2) task durations and normalized task duration deviation. The Minutes behind schedule variable was calculated by subtracting the start times from each associated as-performed and planned task throughout each EVA timeline (e.g. as-performed minus planned start time). Task durations were calculated for each task by subtracting the current task time from the subsequent task start time. Normalized task duration deviation was calculated by dividing the difference between as-performed and planned durations by the planned duration for each associated task. Furthermore, each measure was classified based on the task categories described in Table 4. We do not specifically quantify a measure of productivity or success for EVA execution. Rather, we utilize minutes behind schedule, task durations and normalized task duration deviation to quantitatively describe operational variability exhibited by the Apollo crew.

In order to quantify how often planned and performed timeline data could be associated, given the available data, a 'sync point' metric was calculated. A 'sync point' is a data point where two tasks can be confidently identified as the same task, and a start time existed for both tasks, therefore enabling the association of their respective start times. To ensure the sync points were indeed the same task, a word for word comparison of the task descriptions from the as-performed timeline tasks were matched with planned timeline tasks. The start time of multiple timeline tasks were sometimes grouped together, resulting in the confirmation that a task was performed, but no times associated with those discrete tasks were tabulated. The measure 'sync point' is quantified for each analyzed timeline as a way of measuring the frequency of associating tasks throughout a given timeline. The number of 'sync points' is track for each analyzed timeline to measure the frequency of task associations or samples quantified. For instance, a small mean and standard deviation distribution sync point summary means the timeline tasks were associated at a frequent interval. A high mean, high distributed sync point indicates there are significant separations in time between associated tasks throughout a timeline, i.e. there are larger periods of unknown task time occuring throughout the timeline that is not explicitly known.

Finally, metabolic rate values were analyzed in two ways: (1) summary statistics were calculated based on the raw values and (2) a 9-point moving average was applied to the raw data to smooth the data profiles. Subsequent statistical analyses were performed on the smoothed data and compared to the raw data trends. A 9-point moving average was applied to the raw data to align with current-day operational perspectives of EVA flight controllers. Metabolic rate data is examined both in 'raw' and 'averaged' forms to assess trends and energy expenditure implications. Metabolic rate estimates can be noisy, therefore a moving average is used to dampen the effects of outliers. Finally, the task classifications were applied to the metabolic rate data and summary distributions were calculated.

Table 4: Modified EVA Task Categories

Task Categories			Adapted Category Definition	Example timeline terminology
Looper [45]	Marquez [23]	This Study		
Work Objectives	Science Task	Station Activity	Tasks associated with offloading or preparing tools, be it science or operational equipment Previous definition and also includes mounting and dismounting of vehicle	Performing science tasks: photography, sample collection, observations & science experiments, Relocation of hardware, equipment prep, Experimental hardware set-up, LRV management & tool stowage
	Operations Task			
Support Equipment	Science-related Setup			
	Operations-related Setup			
Worksite Prep	EVA Logistics	Overhead	Tasks not associated with work objectives but that support conducting tasks related to starting the EVA and ending the EVA	Egress/Ingress, Familiarization, Equipment Prep associated with LM/LRV, EVA Closeout
EVA Translation	Traverse	Traverse	Tasks associated with moving across the surface traverse only	the act of moving across the surface (walking and/or driving)

2.4 Data Verification & Limitations

Numerous methods for verifying accuracy in the data collection methods were employed. The task times gathered from the planned summary timelines for each Apollo EVA were confirmed to match the detailed planned timelines to within one minute in most cases. In the event of a mismatch in the start times of a task, the detailed timeline start time was used. The as-performed timeline task times were cross checked with other task analyses studies [?, 9, 10, 23] to ensure consistent measurements. For example, all as-performed cumulative task times equaled, to within one minute, the total as-performed timeline durations found in Orloff's Apollo EVA statistical analysis. [?] Additionally, the tasks times included in this study were only included if the task descriptions between the as-planned and as-performed task descriptions were a near identical match to ensure task association was accurate. Finally, at least two researchers cross-checked the collected data to limit potential clerical errors made during the data collection process.

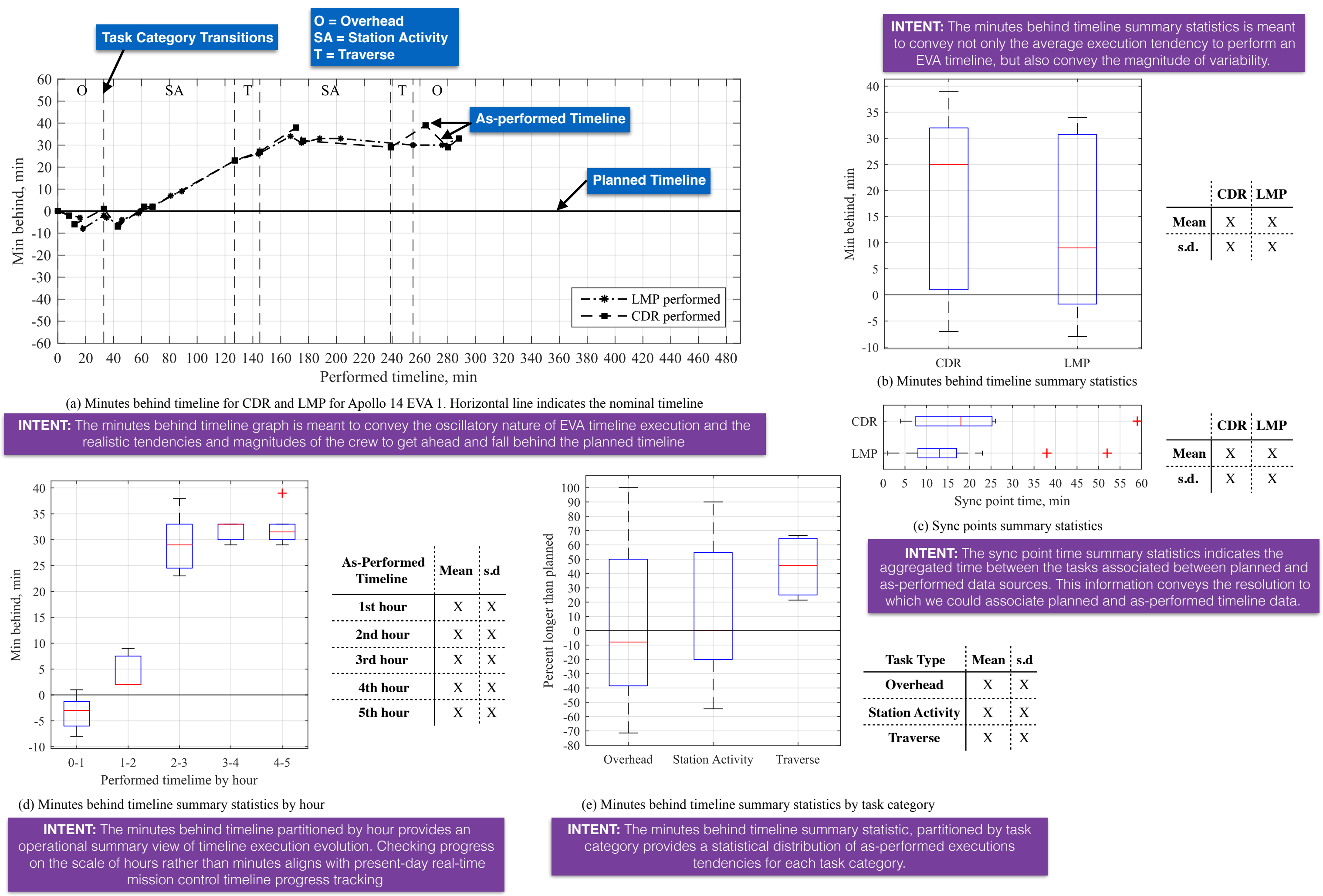
A few limitations of this methodology warrant discussion: 1) The resolution to which tasks could be defined within the timeline was limited by the as-performed timeline data available; 2) Task durations were assumed to equal the time spans between sequential associated task start times. While each start time for each synchronized data point is accurate, the durations between each associated task are limited to the resolution of the as-performed timeline task descriptions. In other words, the duration of a task may be shorter than the duration between the start times of tasks; 3) Task categories capture only the highest-level task descriptions of the timeline. A variety of different detailed procedures were performed within Overhead and Station Activity task categories. The intent of decomposing the timeline at this level of granularity is to quantify bulk execution tendencies throughout approximately 7 hours of work, rather than focus on any one short duration task that utilized a specific set of hardware or procedures. The minutes behind scheduled figures, as shown in Figure 31 provide a to the minute depiction of EVA operations to assess areas of major execution deviation to direct future studies. In summary, the as-performed data collected from the mission reports provide a first order attempt to decompose EVA timelines by task descriptions. However, additional task detail must be included from sources such as the audio transcripts to obtain finer resolution in timeline description. Finally, 4) the data analyzed in this study is limited and biased by the availability of the performed timeline data and all published Apollo planned and performed data is assumed to be accurate.

3 Results Presentation Preface

In order to simplify and organize the data presentation, each analyzed EVA is presented in two 'quick-look' summary description pages. The first page provides all pertinent timeline execution performance summary statistics. The second page provides a similar layout of images and tables describing the metabolic rate data. The presentation format is meant to facilitate the quick synthesis of relavant data. Each summary sheet is accompanied by a short synthesized description extracted from the mission reports as well as a summary of the resultant data. The aim is not to present an in-depth discussion of *why* the described trends occur but rather to identify *what* trends occured and *when* they occured.

3.1 EVA Timeline Results

Figure 7 shows the five figures and four tables that describe the timeline analysis measures. Minutes behind timeline for both CDR and LMP are provided in Figure (a) as a function of as-performed time. The planned timeline is represented by a horizontal black line running through the '0' value. Overlaid on the graph are the segments of task categories, which are divided by vertical dashed lines. The task category is marked by their respective letter indication. The remaining four graphs, and their assocaited data tables, provide various summarized perspectives of the minutes behind variable. Refer to Figure 7 for a summary description of the intent of each graph and table.



	CDR	LMP
Mean	X	X
s.d.	X	X

	CDR	LMP
Mean	X	X
s.d.	X	X

As-Performed Timeline	Mean	s.d
1st hour	X	X
2nd hour	X	X
3rd hour	X	X
4th hour	X	X
5th hour	X	X

Task Type	Mean	s.d
Overhead	X	X
Station Activity	X	X
Traverse	X	X

Figure 7: Apollo timeline summary statistics descriptions

3.2 EVA Telemetry Results

Figure 8 shows the seven figures and three tables that describe the metabolic rate analysis. Metabolic rate values for both CDR and LMP are provided in Figure (a/d) as a function of as-performed timelime PET. The 9-point moving average data is also shown for each crew member. Overlaid on the graph are the segments of task categories, which are divided by vertical dashed lines. The task category is marked by their respective letter indication. The remaining five graphs provide various summarized perspectives of meteabolic rate trends. Refer to Figure 7 for a summary description of the intent of each graph and table.

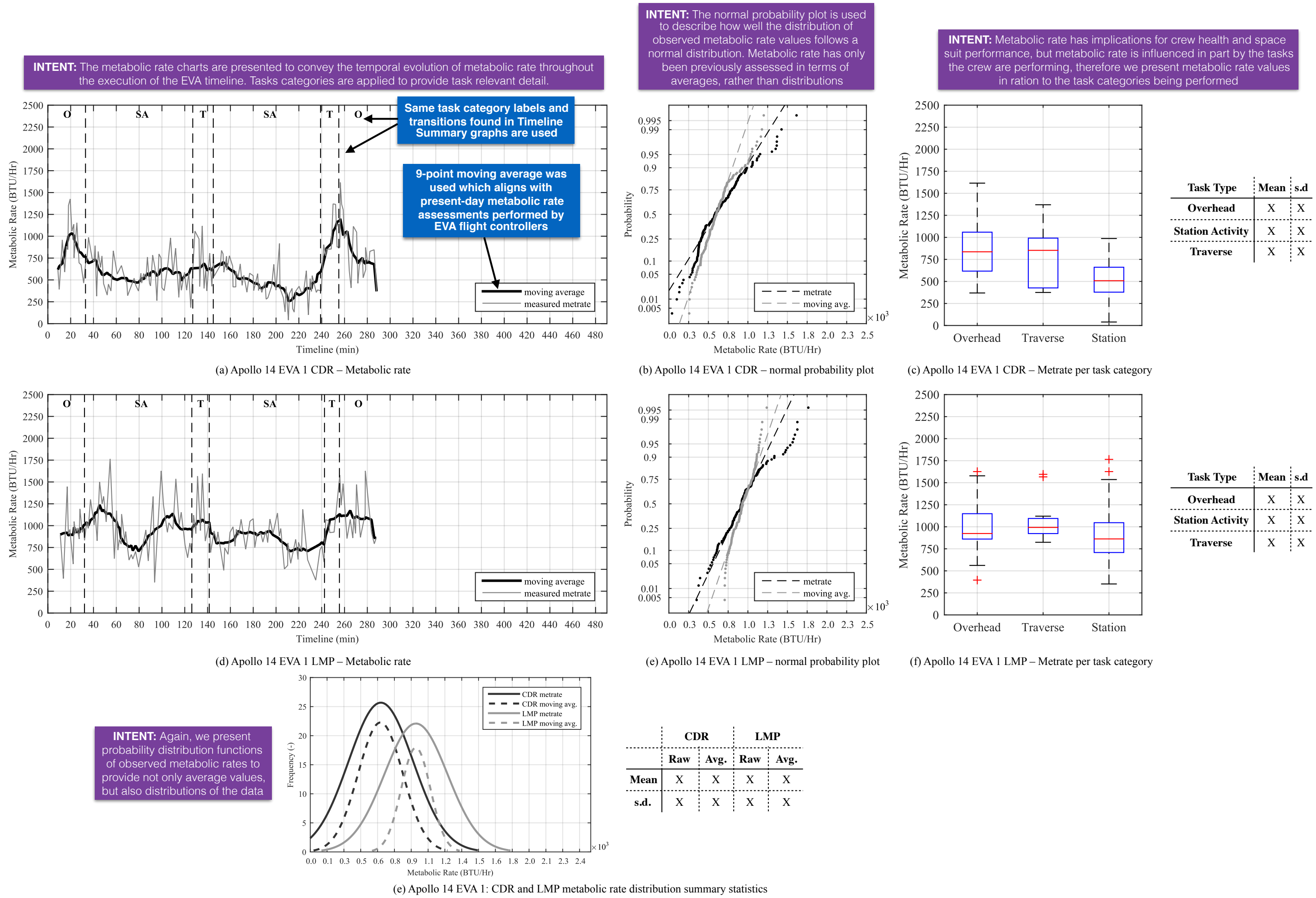


Figure 8: Apollo metabolic rate summary statistics descriptions

4 EVA Timeline & Telemetry Results

4.1 Apollo 14

The nominal plan for the Apollo 14 mission involved two two-astronaut EVAs, over a period of 33.5 hours in which the LM was on the lunar surface. Both EVAs were planned to last 4 hours and 15 minutes. The four primary objectives for Apollo 14 EVAs are shown in Table 5. Table 6 shows the associated operational requirements implemented during Apollo 14. Finally, Table 7 shows the specific task priorities to be performed during EVA 1 and 2, respectively.

Overall the primary lunar surface mission objectives were completed by the two EVAs. However, as stated in the Apollo 14 mission report, operations on the lunar surfaces were found to take approximately 25 to 30% longer than in one-g conditions. Given the experiences of Apollo 14, subsequent Apollo missions were developed to with alternative activities in the event that certain portions of the EVA must be canceled. Sections 4.1.1 and 4.1.2, provide a more detailed account of timeline execution performance for each EVA.

Table 5: Apollo 14 Mission Objectives

Priority	Apollo 14 Mission Objectives Descriptions
1	Perform selenological inspection, survey and sampling of materials in a preselected region of the Fra Mauro formation
2	Deploy and activate ALSEP (Apollo Lunar Surface Experiment Packages)
3	Develop man's capability to work in the lunar environment
4	Obtain photographs of candidate exploration sites

Table 6: Apollo 14 EVA Requirements.

ID	Apollo 14 EVA Requirements
a)	Stay time on lunar surface is open ended and the planned maximum will not exceed 50 hours
b)	Two EVAs (each approximately 4-1/4 hours in duration) will be conducted by both astronauts
c)	Radius of operations is constrained to be within the limits imposed by the capability of the Buddy SlSS/oxygen purge system

From a biomedical perspective, during Apollo 14, the average heart rates and metabolic rates were considered nominal, as well as physiological parameters. An issue with the oxygen tank sensor necessitated loading less oxygen than planned. Prior to liftoff, the commander's electrocardiogram was malfunctioning, but resumed functionality during orbit. A waiver was created to prevent liftoff until all crewmembers had readable electrocardiograms. One of the sensors for the CDR was leaking paste, which was easily patched. However, the CDR still had issues with noise for his electrocardiogram (ECG), and heart rate had to be manually counted on two occasions.

Table 7: Apollo 14 Lunar Surface Task Priorities

Mission Priority	Lunar Surface Priority	Priority Description
1	1	Contingency Sample Collection
2	2	Apollo Lunar Surface Experiment Packages (ALSEP)
3	3	Selected Sample Collection
4	4	Lunar Field Geology
7	5	Laser Ranging Rectro-Reflector
8	6	Soil Mechanics
9	7	Portable Magnetometer
11	8	Modular Equipment Transporter Evaluation
17	9	Solar Wind Composition
18	10	Thermal Coating Degradation
19	11	EVA Communication System Performance

The lunar module pilot also had noise due to a loose sensor, which occurred three times. The EVA garment was modified for this mission to provide for greater loads than previous Apollo missions. Additionally, an oxygen pressure regulator band was shifted to allow for longer EVA time, and a system for sharing cooling water was implemented. Sections 4.1.1 and 4.1.2, provide a more detailed account of metabolic rate performance during EVA 1 and 2, respectively.

4.1.1 EVA 1

TIMELINE EXECUTION TRENDS

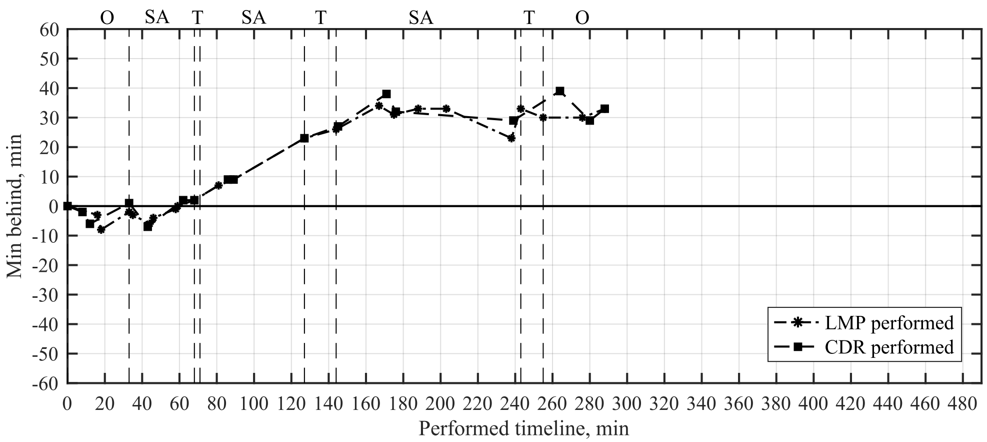
Apollo 14 EVA 1 consisted of two main stations, unloading equipment at the lunar module, and traversing to the ALSEP deployment site. Figure 9 shows the the minutes behind schedule trend evolution throughout the EVA. The crew successfully executed the planned tasks and completed the primary mission objectives, as stated in Table 7. During the first hour of the performed EVA the crew completed the egress and overhead tasks a few minutes ahead of schedule. However, after the first hour the crew began to fall behind schedule due to a communication delay where crew could hear ground support but the commander could not communicate back to ground. The commander had to reset his audio circuit breaker to re-establish communication. This communication error lead to a nearly 50-minute delay relative to the planned timeline. The time lost from the communication failure resulted in the crew remaning approximately 30 to 40 minutes behind schedule for the remainder of the EVA. The oxygen, feedwater and power consumption allowed for the EVA to be extended by 30 minutes to complete the lunar objectives.

METABOLIC RATE AND CONSUMABLES TRENDS

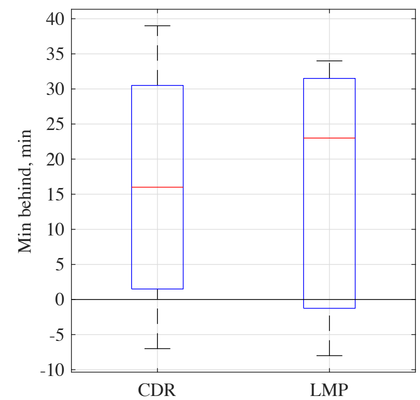
Figure 10 shows the metabolic rate trends for each crew member for Apollo 14 EVA 1. The CDR consistently exhibited an overall lower metabolic rate value throughout the EVA. Correspondingly, the CDR oxygen and feedwater consumables ended the EVA with a 20% surplus, even after performing an extended EVA timeline, as shown in Table 8. The LMP ended the EVA by using more oxygen and power than predicted by 3.8% and 5.0%, respectively.

Table 8: Apollo 14 EVA 1 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

	Actual % Remaining	Predicted % Remaining	% Difference
CDR			
Oxygen	46.6%	26.0%	20.6%
Feedwater	43.5%	17.2%	26.3%
Power	19.1%	20.9%	-1.8%
LMP			
Oxygen	22.1%	26.0%	-3.8%
Feedwater	34.1%	17.2%	16.9%
Power	16.0%	20.9%	-5.0%

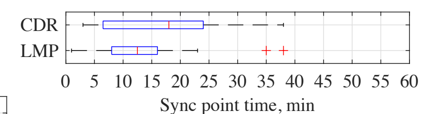


(a) Minutes behind timeline for CDR and LMP for Apollo 14 EVA 1. Vertical line indicates transitions in as-performed timeline



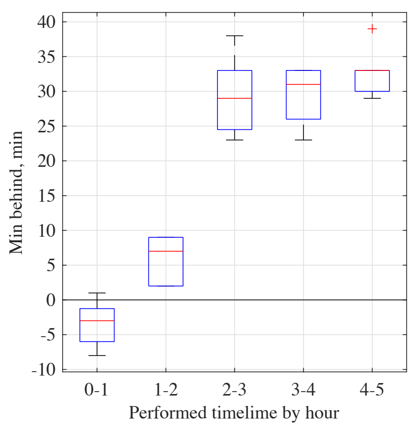
	CDR	LMP
Mean	16	15
s.d.	17	16

(b) Minutes behind timeline summary statistics



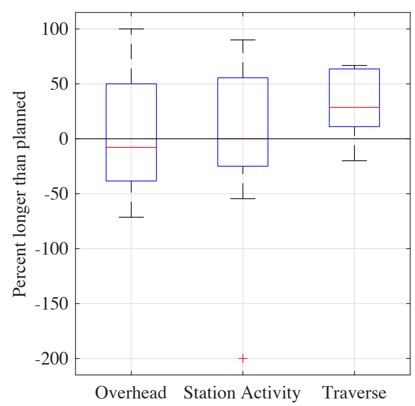
	CDR	LMP
Mean	19	14
s.d.	16	10

(c) Sync points summary statistics



(d) Minutes behind timeline summary statistics by hour

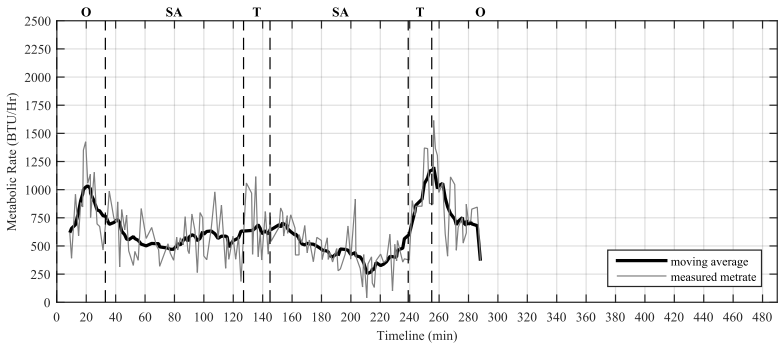
As-Performed Timeline	Mean	s.d.
1st hour	-3	3
2nd hour	6	4
3rd hour	29	5
4th hour	30	5
5th hour	32	3



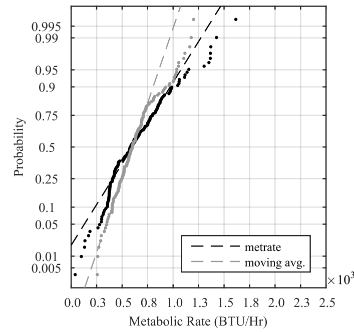
(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	5	55
Station Activity	6	62
Traverse	32	35

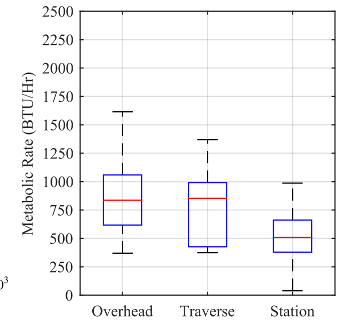
Figure 9: Apollo 14 EVA 1 Timeline Execution Summary Statistics



(a) Apollo 14 EVA 1 CDR – Metabolic rate

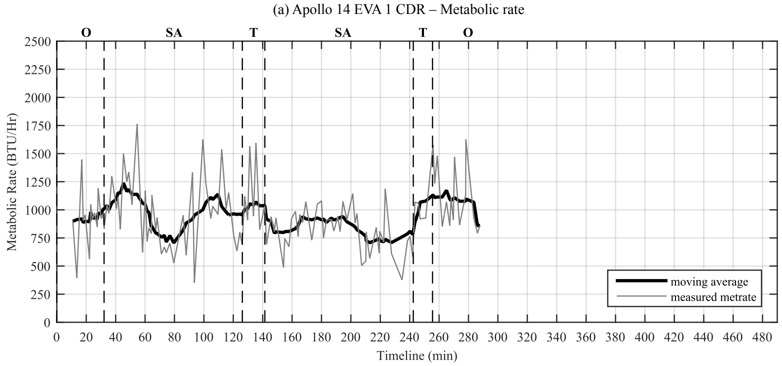


(b) Apollo 14 EVA 1 CDR – normal probability plot

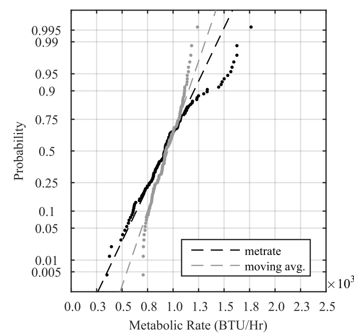


Task Type	Mean	Median	s.d.
Overhead	854	836	314
Traverse	798	852	325
Station	519	508	199

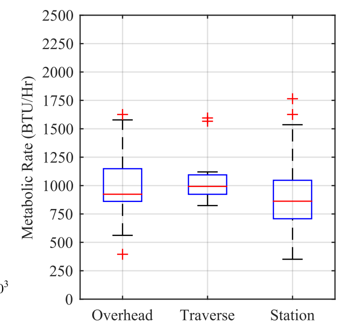
(c) Apollo 14 EVA 1 CDR – Metrate (BTU/Hr) per task category



(d) Apollo 14 EVA 1 LMP – Metabolic rate

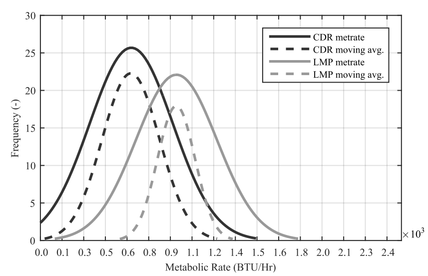


(e) Apollo 14 EVA 1 LMP – normal probability plot



Task Type	Mean	Median	s.d.
Overhead	1021	924	285
Traverse	1075	992	250
Station	893	862	274

(f) Apollo 14 EVA 1 LMP – Metrate (BTU/Hr) per task category



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	629	626	942	940
Median	581	599	920	928
s.d.	288	199	281	130

(e) Apollo 14 EVA 1: CDR and LMP metabolic rate distribution summary statistics

Figure 10: Apollo 14 EVA 1 Metabolic Rate Summary Statistics

4.1.2 EVA 2

TIMELINE EXECUTION TRENDS

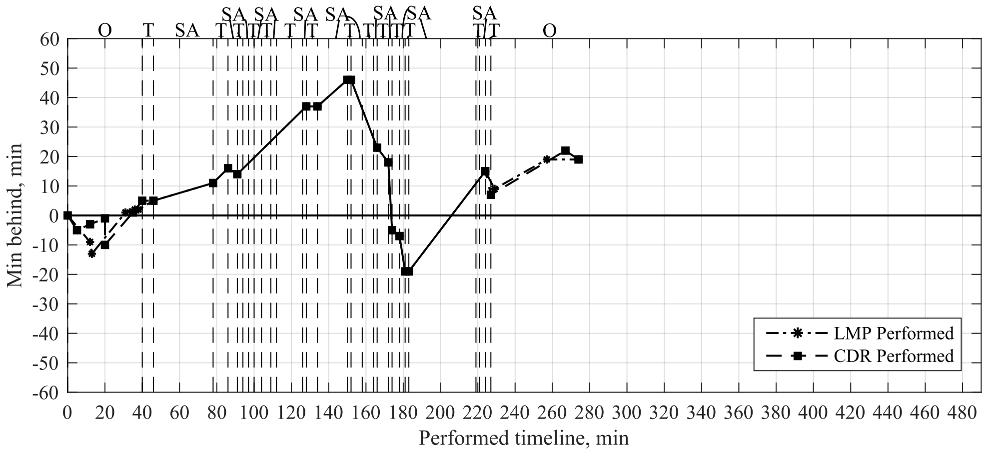
Apollo 14 EVA 2 involved traversing to the edge of Cone Crater, stopping at various sample stations on the outbound and inbound traverse. The primary mission objectives were successfully completed. As shown in Figure 11, the crew performed the overhead tasks nearly on schedule. However, navigation proved to be difficult. Recognizing small features and reduced visibility lead to trouble with judging distances, which ultimately lead to the crew members stopping approximately 50 ft short of the rim of the Cone Crater. Although the crew did not enter the crater, the mission objectives associated with reaching the vicinity of the crater and collecting samples were successfully achieved. Several of the planned sample and photographic stations on the return traverse from the crater rim were omitted due to the crew being behind schedule. Another notable source of delay resulted in difficulty with driving core tubes to the desired length due to the granularity of the lunar surface.

METABOLIC RATE AND CONSUMABLES TRENDS

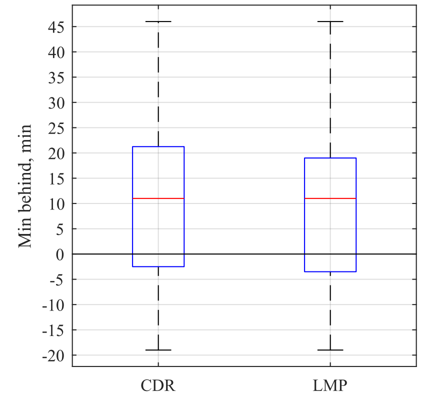
Figure 12 shows the metabolic rate trends for each crew member for Apollo 14 EVA 2. The CDR and LMP exhibited similar trends throughout the EVA with maximum values occuring at approximately 130 minutes into the performed EVA. All consumables except for the CDR power were underpredicted by anywhere from 1% to 15% shown in Table 9.

Table 9: Apollo 14 EVA 2 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power.

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	31.7%	22.1%	9.6%
Feedwater	26.9%	1.7%	15.2%
Power	20.2%	20.2%	0.0%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	23.8%	22.1%	1.7%
Feedwater	19.0%	11.7%	7.3%
Power	21.3%	20.2%	1.1%

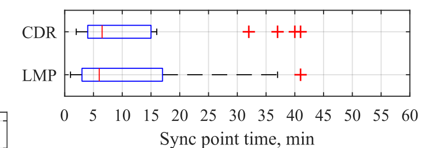


(a) Minutes behind timeline for CDR and LMP for Apollo 14 EVA 2. Vertical line indicates transitions in as-performed timeline



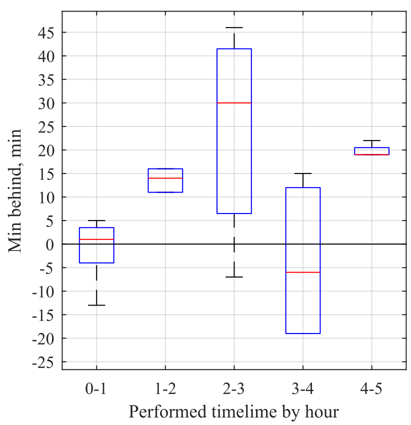
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	14	13
s.d.	18	19



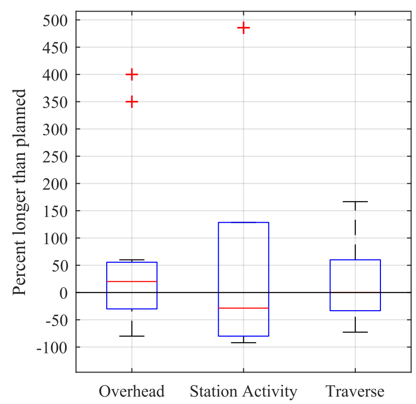
(c) Sync points summary statistics

	CDR	LMP
Mean	10	11
s.d.	11	11



(d) Minutes behind timeline summary statistics by hour

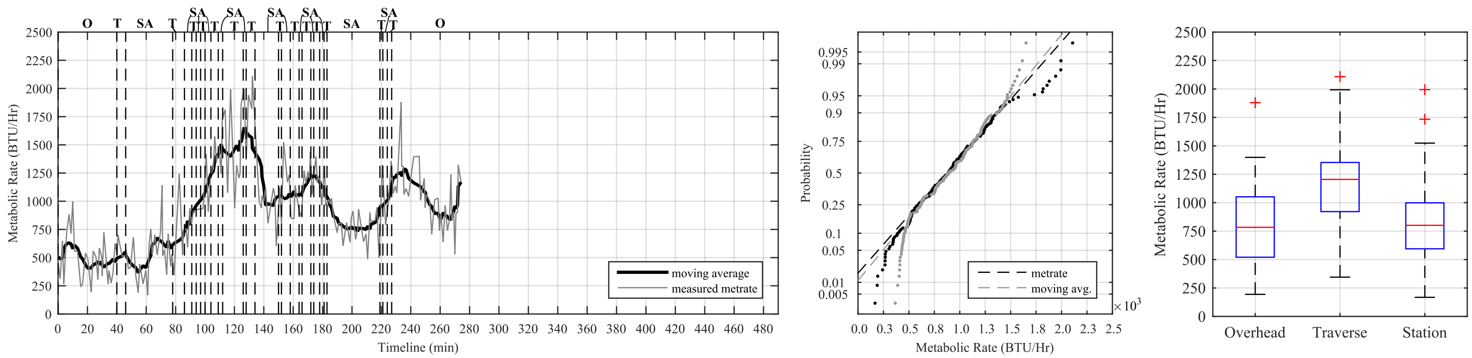
As-Performed Timeline	Mean	s.d
1st hour	-1	6
2nd hour	17	7
3rd hour	26	19
4th hour	-4	17
5th hour	20	2



(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	55	142
Station Activity	142	295
Traverse	9	66

Figure 11: Apollo 14 EVA 2 Timeline Execution Summary Statistics

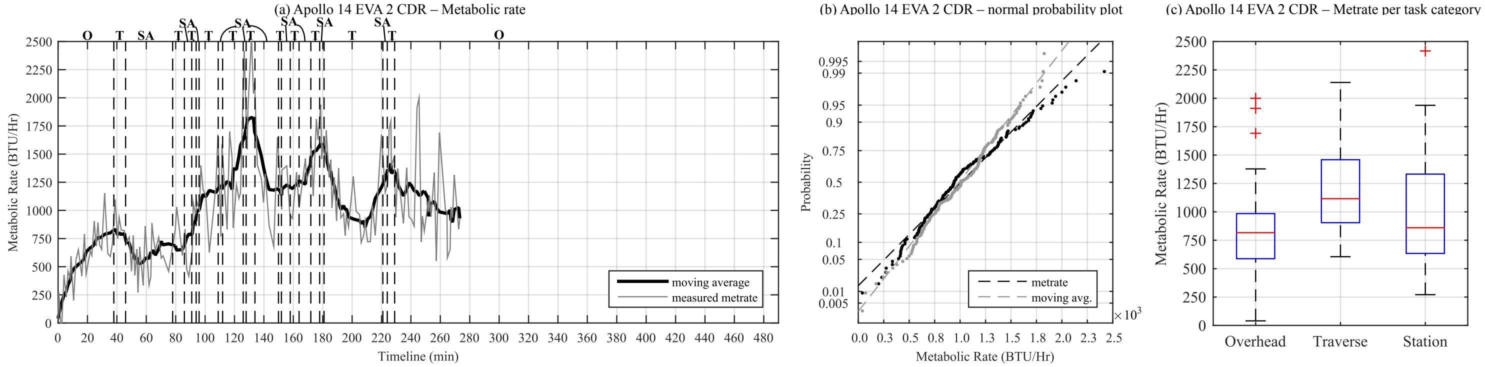


(a) Apollo 14 EVA 2 CDR – Metabolic rate

(b) Apollo 14 EVA 2 CDR – normal probability plot

(c) Apollo 14 EVA 2 CDR – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	794	783	362
Traverse	1174	1205	801
Station	821	801	339

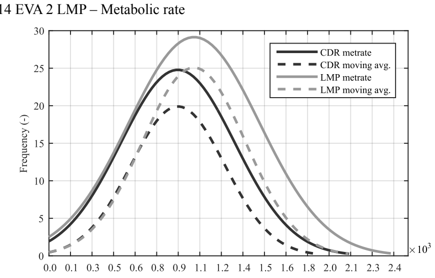


(d) Apollo 14 EVA 2 LMP – Metabolic rate

(e) Apollo 14 EVA 1 LMP – normal probability plot

(f) Apollo 14 EVA 2 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	815	817	412
Traverse	1202	1116	408
Station	960	861	471



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	897	898	1011	1009
Median	889	892	941	1012
s.d.	397	328	456	358

(e) Apollo 14 EVA 2: CDR and LMP metabolic rate distribution summary statistics

Figure 12: Apollo 14 EVA 2 Metabolic Rate Summary Statistics

4.2 Apollo 15

The nominal plan for the Apollo 15 mission involved three two-astronaut EVAs, over a maximum duration of 67 hours on the lunar surface. The four primary objectives for Apollo 15 EVAs are shown in Table 10. Table 11 shows the associated operational requirements implemented during Apollo 15. Finally, Table 12 shows the specific task priorities to be performed during EVA.

Overall the primary lunar surface mission objectives were completed by the three EVAs, despite delays and restructuring that occured for two of the EVAs. Significant delays originated in the form of equipment troubleshooting and failures, stations taking longer than planned, EMU difficulties, and high levels of oxygen consumption which caused EVA 2 and 3 to be restructured and shortened.

Table 10: Apollo 15 Mission Objectives.

Priority	Apollo 15 Mission Objectives Descriptions
1	Perform selenological inspection, survey, and sampling of materials and surface features in a pre-selected area of the Hadley-Apennine region
2	Emplace and activate surface experiments
3	Evaluate the capability of the Apollo equipment to provide extended lunar surface stay time, increased EVA operations, and surface mobility
4	Conduct in-flight experiments and photographic tasks from lunar orbit

Table 11: Apollo 15 EVA Requirements.

ID	Apollo 15 EVA Requirements
a)	Stay time on lunar surface is open ended and the planned maximum will not exceed approximately 67 hours
b)	Three periods of EVA planned: First & Second EVA planned to be approximately 7 hours; Third EVA planned for 6 hours
c)	The traverse planning provides for the capability of the crew to return to the LM under each of the following single-failure conditions:
c.1)	Use of buddy-secondary life support system due to an inoperative PLSS anytime during a riding traverse (based upon the assumptions that the LRB will operate properly during the return to the LM)
c.2)	Use of the two PLSS's for a walking return to the LM from an inoperative LRV anytime during a riding traverse (based upon the assumption that both PLSS's will operate properly during the return to the LM)

Table 12: Apollo 15 Lunar Surface Task Priorities

Lunar Surface Priority	Priority Description
1	Contingency Sample Collections
2	Documented Sample Collection at Apennine Front (Part of Lunar Geology Investigation)
3	Apollo 15 ALSEP ARRAY A-2
4	Drill Core Sample Collection (Part of Lunar Geology Investigation)
5	Laser Ranging Retro-Reflector
6	Lunar Geology Investigation
7	Lunar Rover Vehicle Evaluation
8	EVA Communications with the LCRU/GCTA
9	EMU Assessment on Lunar Surface
10	LM Landing Effects Evaluation
11	Solar Wind Composition
12	Soil Mechanics
N/A	LM Descent Engine Performance

From a biomedical performance perspective, heart rate and metabolic rate readings were nominal for Apollo 15. During the third EVA, the LMP had a trapped gas bubble in his feedwater, which caused higher feedwater pressure and a lower gas-outlet temperature than expected. Both crewmembers depleted their main feedwater tanks and had to use the auxillary tanks, and the oxygen redline limit was hit for both crewmembers during the first EVA and for the CDR in the second EVA. A sponge/pellet electrode were used in the ECG to reduce irritation. The EVA system was again modified for greater loads, along with increased mobility and visibility than previous Apollo missions. New tanks and batteries were added for extended stay time on the lunar surface. A higher pressure life support system was incorporated with an added oxygen tank, and a tank was added for urine and PLSS condensate. Finally, an adapter was implemented to allow crewmembers to connect their LCG's to the lunar module water supply. Overall, the major PLSS modifications allowed for more water, power, and oxygen, thereby increasing PLSS operational capacity.

4.2.1 EVA 1

TIMELINE EXECUTION TRENDS

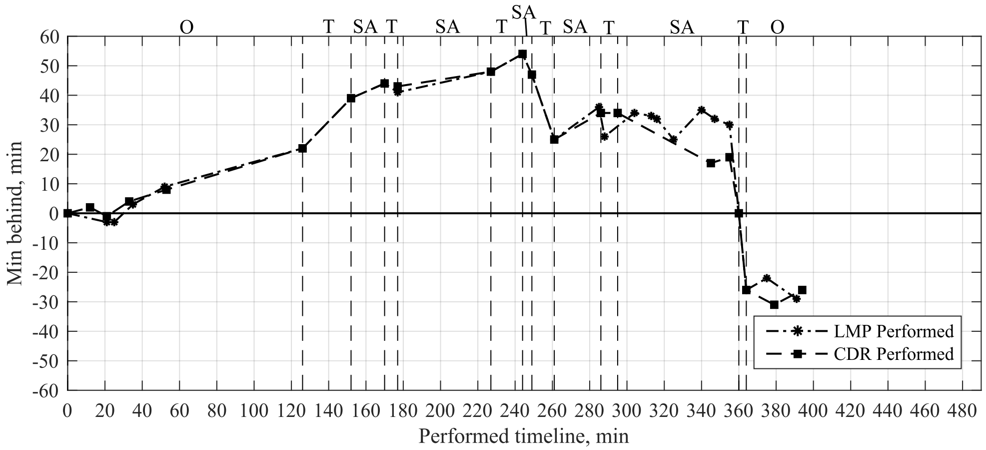
For Apollo 15 EVA 1, the crew started the EVA by preparing the lunar roving vehicle for its first use on the lunar surface. The crew then proceeded to the primary destination of the EVA, the Elbow Crater along the edge of Hadley Rille. On the return traverse to the LM the crew deployed the ALSEP. As shown in Figure 13, the crew completed the initial overhead on schedule, then proceeded to configure the LRV and traverse to two stations to collect samples. Station 3 was omitted due to the crew falling behind schedule which originated from difficulty in the LRV configuration tasks. Delays to task execution continued to accumulate during the first two stations. The commander also exhibited high levels of oxygen consumption which resulted in the the termination of the EVA approximately 30 minutes earlier than planned. The decision to end the EVA early did not allow sufficient time to deploy all of the ALSEP as planned for the first EVA. The second EVA was restructured to complete the experiments in the ALSEP that were missed.

METABOLIC RATE AND CONSUMABLES TRENDS

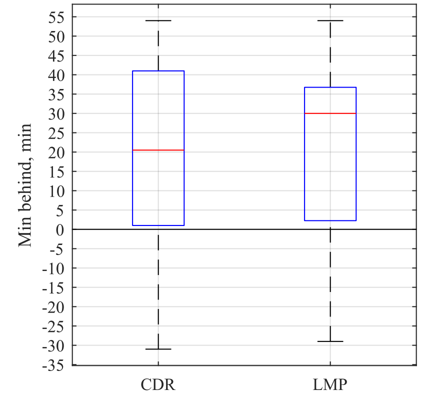
Figure 14 shows the metabolic rate trends for each crew member for Apollo 15 EVA 1. The CDR and LMP exhibited higher overall metabolic rate values throughout the EVA. Correspondingly, the CDR and LMP oxygen and feedwater consumables usage at the EVA was approximately 7% to 12% more than predicted, respectively. Only power usage end with a surplus remaining at the end of the EVA for both crew members.

Table 13: Apollo 15 EVA 1 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	21.1%	33.4%	-12.3%
Feedwater	20.9%	29.5%	-8.6%
Power	27.6%	24.9%	2.7%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	24.2%	33.4%	-9.2%
Feedwater	21.3%	28.7%	-7.4%
Power	27.2%	24.9%	2.3%

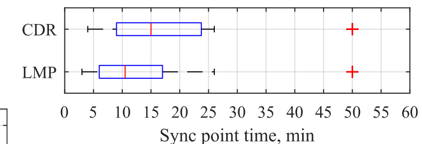


(a) Minutes behind timeline for CDR and LMP for Apollo 15 EVA 1. Vertical line indicates transitions in as-performed timeline



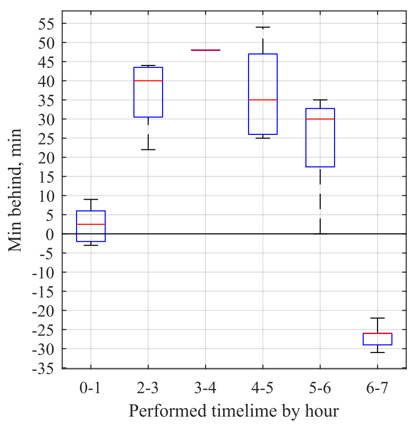
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	18	21
s.d.	26	23



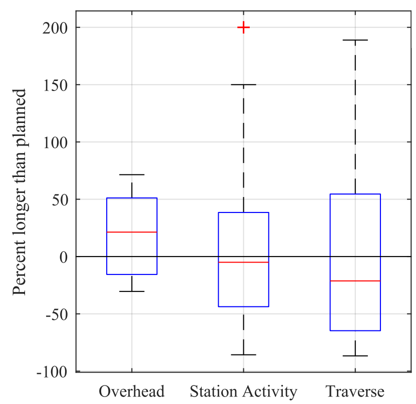
(c) Sync points summary statistics

	CDR	LMP
Mean	20	15
s.d.	18	16



(d) Minutes behind timeline summary statistics by hour

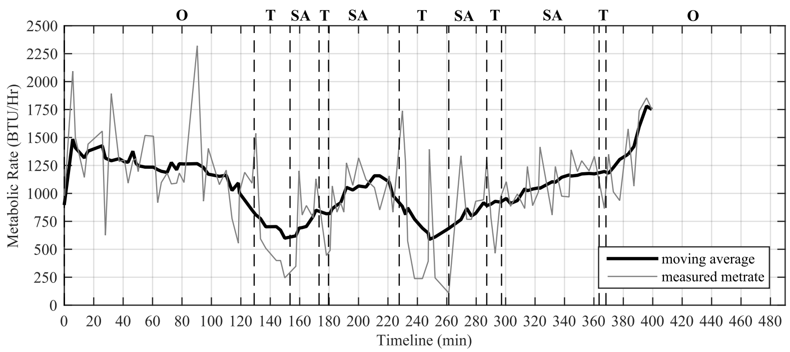
As-Performed Timeline	Mean	s.d
1st hour	2	5
2nd hour	NA	NA
3rd hour	37	9
4th hour	48	0
5th hour	38	12
6th hour	23	13
7th hour	-27	3
8th hour	NA	NA



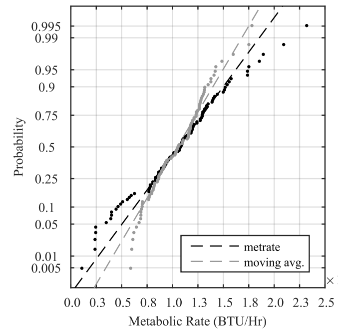
(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	17	34
Station Activity	14	75
Traverse	5	99

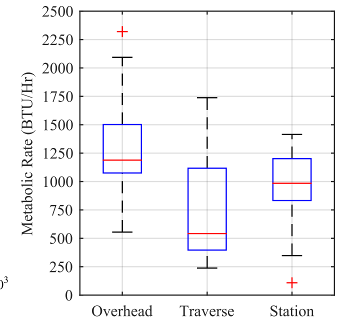
Figure 13: Apollo 15 EVA 1 Timeline Summary Statistics



(a) Apollo 15 EVA 1 CDR – Metabolic rate

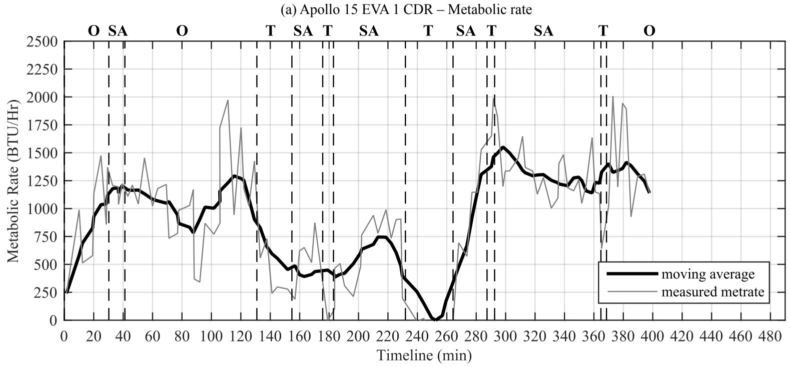


(b) Apollo 15 EVA 1 CDR – normal probability plot

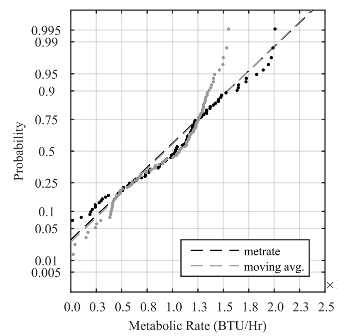


(c) Apollo 15 EVA 1 CDR – Metrate per task category

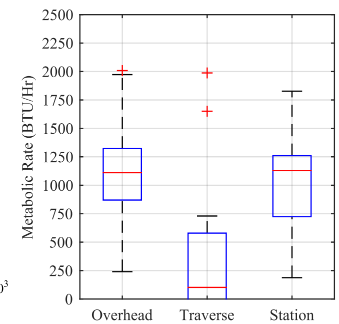
Task Type	Mean	Median	s.d.
Overhead	1271	1188	371
Traverse	730	518	478
Station	991	985	271



(d) Apollo 15 EVA 1 LMP – Metabolic rate

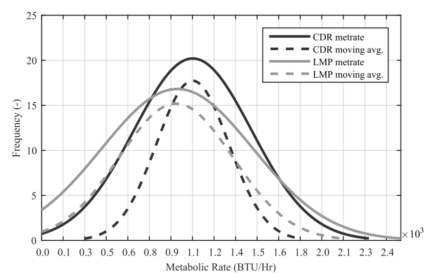


(e) Apollo 15 EVA 1 LMP – normal probability plot



(f) Apollo 15 EVA 1 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1123	1110	429
Traverse	329	102	639
Station	1009	1128	397



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	1052	1051	945	936
Median	1079	1054	1028	1065
s.d.	409	251	527	397

(e) Apollo 15 EVA 1: CDR and LMP metabolic rate distribution summary statistics

Figure 14: Apollo 15 EVA 1 Metabolic Rate Summary Statistics

4.2.2 EVA 2

TIMELINE EXECUTION TRENDS

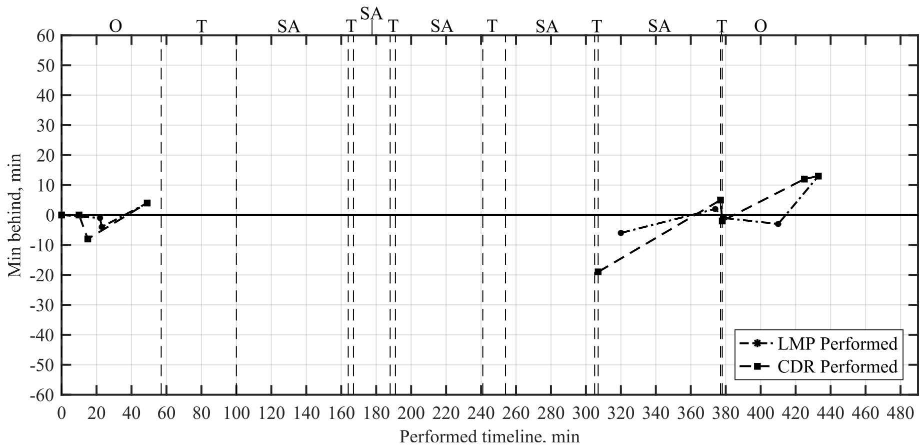
For Apollo 15 EVA 2, the first two planned stations, station 4 and station 5, were initially skipped to allow for additional time to deploy the ALSEP components which were not completed during EVA 1. Once the crew initialized the LRV, they proceeded to Mount Hadley Delta. The crew went to multiple stations for different sample collections and site characterization. On the return traverse the crew deployed some of the remaining ALSEP components as well as completed a few experiments that were skipped during EVA 1. Station 4, the first planned station for EVA 2, was accomplished along the return traverse after visiting station 6, 6a and 7. As shown in Figure 15, the crew performed the egress and initial overhead task on schedule, then proceeded to the planned stations in the restructured order. Due to a compressed duration at station 8, the soil mechanics experiment only performed by the LMP and not by the CDR. The commander also approached operational oxygen limits during the second EVA. Even with the major restructuring of the time, the mission report stated the crew were able to performed the main objectives in the compressed timeline. Unfortunately, the restructured planned timeline was never published, therefore direct association between the planned and as-performed timeline was limited.

METABOLIC RATE AND CONSUMABLES TRENDS

Figure 16 shows the metabolic rate trends for each crew member for Apollo 15 EVA 2. The CDR exhibited higher overall metabolic rate values throughout the EVA. Correspondingly, the CDR oxygen, feedwater, and power consumption was underpredicted by 8%, 7%, and 5%, respectively. The LMP power was underpredicted by almost 5% while oxygen and feedwater was overpredicted by approximately 5%.

Table 14: Apollo 15 EVA 2 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	22.3%	30.9%	-8.6%
Feedwater	19.6%	26.4%	-6.8%
Power	19.5%	24.9%	-5.4%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	36.4%	30.9%	5.5%
Feedwater	31.1%	26.4%	4.7%
Power	20.2%	24.9%	-4.7%



(a) Minutes behind timeline for CDR and LMP for Apollo 15 EVA 2. Vertical line indicates transitions in as-performed timeline

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(b) Minutes behind timeline summary statistics

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(c) Sync points summary statistics

N/A

As-Performed Timeline	Mean	s.d
1st hour	X	X
2nd hour	X	X
3rd hour	X	X
4th hour	X	X
5th hour	X	X

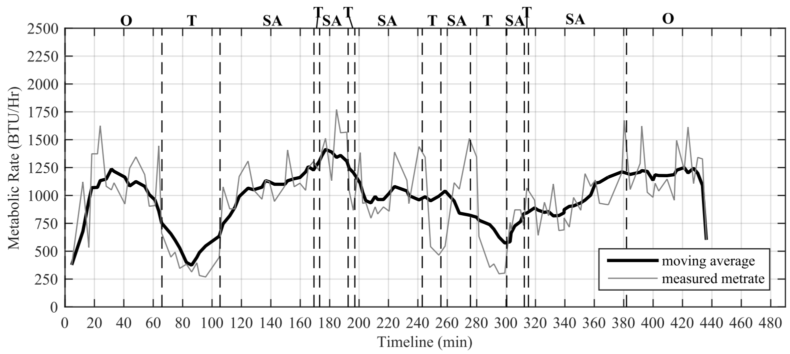
(d) Minutes behind timeline summary statistics by hour

N/A

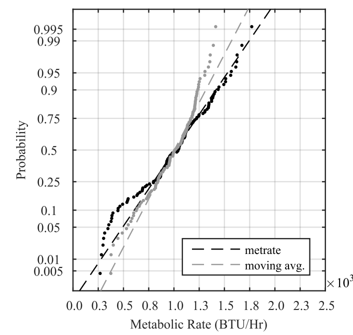
Task Type	Mean	s.d
Overhead	X	X
Station Activity	X	X
Traverse	X	X

(e) Minutes behind timeline summary statistics by task category

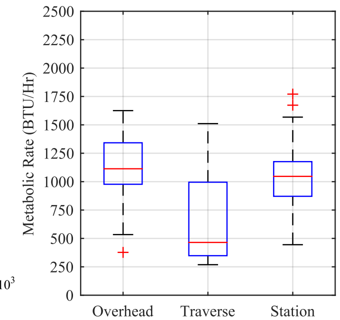
Figure 15: Apollo 15 EVA 2 Timeline Summary Statistics



(a) Apollo 15 EVA 2 CDR – Metabolic rate

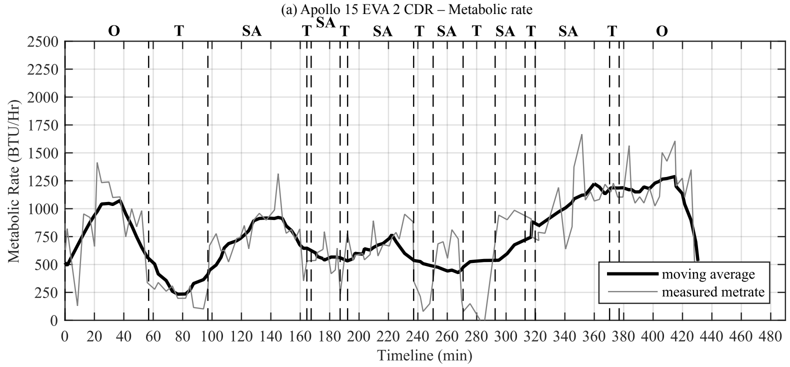


(b) Apollo 15 EVA 2 CDR – normal probability plot

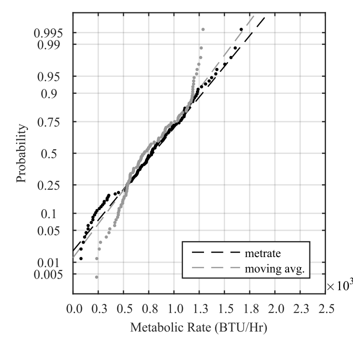


(c) Apollo 15 EVA 2 CDR – Metrate per task category

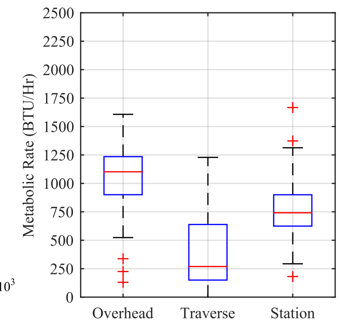
Task Type	Mean	Median	s.d.
Overhead	1128	1113	301
Traverse	657	465	407
Station	1046	1046	273



(d) Apollo 15 EVA 2 LMP – Metabolic rate

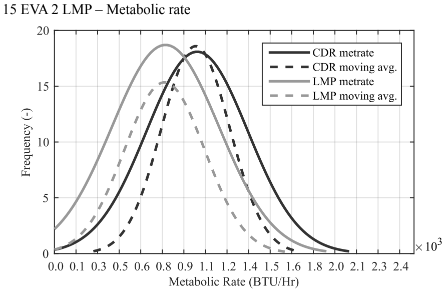


(e) Apollo 15 EVA 2 LMP – normal probability plot



(f) Apollo 15 EVA 2 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1017	1101	359
Traverse	411	269	377
Station	778	741	256



	CDR		LMP	
	Raw	Avg.	Raw	Avg.
Mean	993	982	772	766
Median	1040	1008	779	704
s.d.	352	237	373	279

(e) Apollo 15 EVA 2: CDR and LMP metabolic rate distribution summary statistics

Figure 16: Apollo 15 EVA 2 Metabolic Rate Summary Statistics

4.2.3 EVA 3

TIMELINE EXECUTION TRENDS

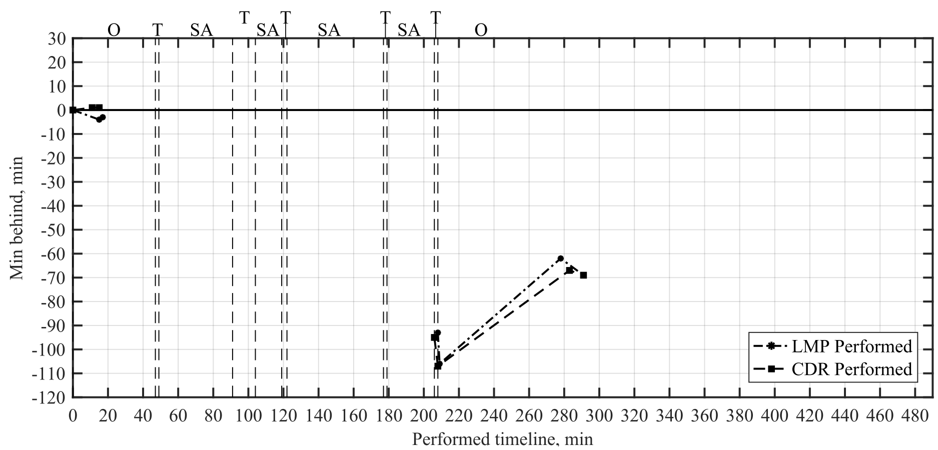
The crew performed another condensed timeline for EVA 3 where they traversed to different locations along the Hadley Rille taking multiples samples and photographs. The crew then traversed back to the LM were they stopped by the ALSEP site one last time before ingress. The start of the third EVA was delayed to allow for the crew to rest after high levels of physical exertion on the first two EVAs. The delayed start and previous delays with the ALSEP caused the third EVA to be compressed from 6 hours to 4.5 hours, which involved omitting the Stations 11 through 14. The first station the crew visited was the ALSEP sight to retrieve the deep core samples left at the end of the second EVA. Upon returning to the ASLEP location in EVA 3 the crew experienced trouble with removing some of the deep core samples. The crew removed two of the six samples and left the other four samples for retrieval at the end of the EVA. The crew then proceeded to follow the compressed timeline accordingly. After completing the traverse for the three stations planned for EVA 3, the ASLEP site was visited one last time to retrieve the final four deep core samples. As shown in Figure 17, limited data could be associated between the planned and as-performed timeline data sources due to the significant restructuring of the timeline that occured prior to EVA execution.

METABOLIC RATE AND CONSUMABLES TRENDS

Figure 18 shows the metabolic rate trends for each crew member for Apollo 15 EVA 3. The CDR exhibited higher overall metabolic rate values throughout the EVA. Correspondingly, the CDR oxygen, feedwater, and power consumption was higher than the LMP. However, the EVA was restructured to end early by over an hour which resulted in all consumables usage being overpredicted as shown in Table 15.

Table 15: Apollo 15 EVA 3 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power.

	CDR		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	42.7%	36.8%	5.9%
Feedwater	38.9%	33.6%	5.3%
Power	44.7%	35.0%	9.7%
	LMP		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	56.3%	36.8%	19.4%
Feedwater	48.9%	33.6%	15.3%
Power	45.9%	35.0%	10.9%



(a) Minutes behind timeline for CDR and LMP for Apollo 15 EVA 3. Vertical line indicates transitions in as-performed timeline

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(b) Minutes behind timeline summary statistics

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(c) Sync points summary statistics

N/A

As-Performed Timeline	Mean	s.d
1st hour	X	X
2nd hour	X	X
3rd hour	X	X
4th hour	X	X
5th hour	X	X

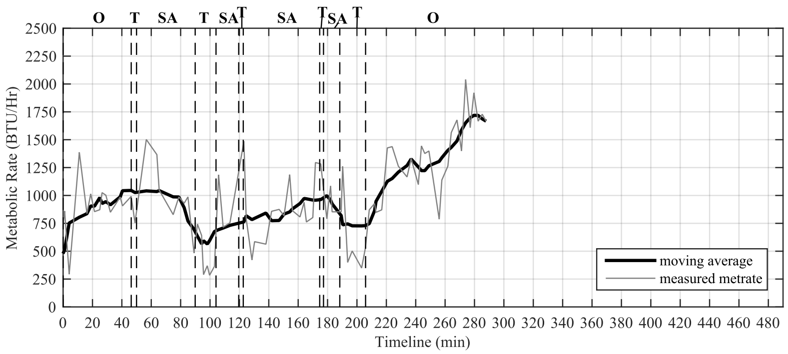
(d) Minutes behind timeline summary statistics by hour

N/A

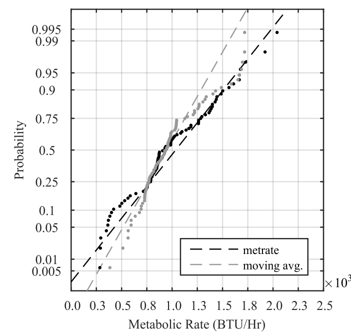
Task Type	Mean	s.d
Overhead	X	X
Station Activity	X	X
Traverse	X	X

(e) Minutes behind timeline summary statistics by task category

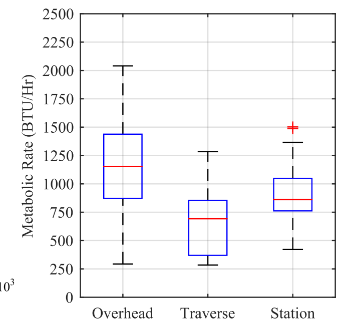
Figure 17: Apollo 15 EVA 3 Timeline Summary Statistics



(a) Apollo 15 EVA 3 CDR – Metabolic rate

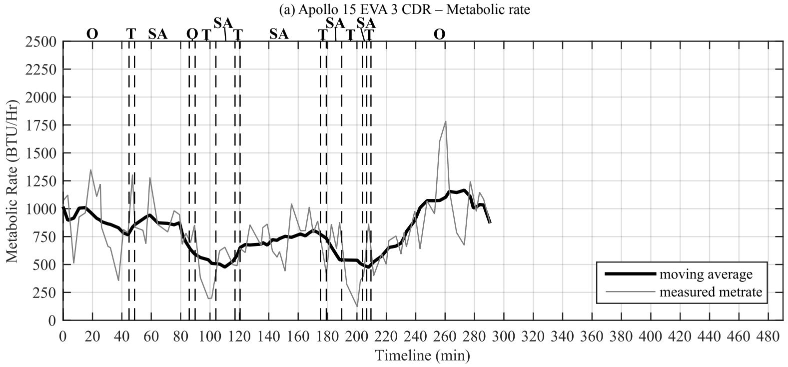


(b) Apollo 15 EVA 3 CDR – normal probability plot

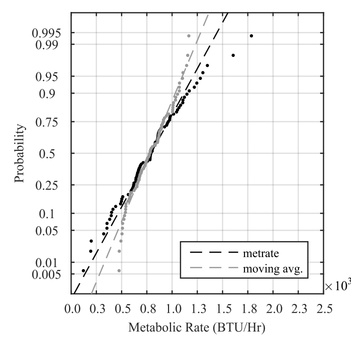


(c) Apollo 15 EVA 3 CDR – Metrate per task category

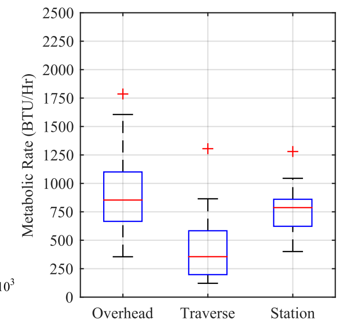
Task Type	Mean	Median	s.d.
Overhead	1189	1152	393
Traverse	686	692	325
Station	917	861	284



(d) Apollo 15 EVA 3 LMP – Metabolic rate

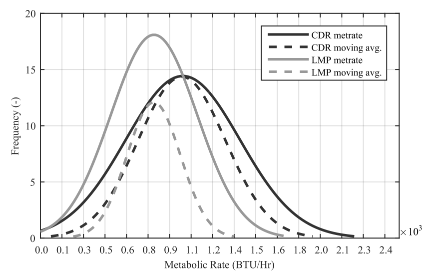


(e) Apollo 15 EVA 3 LMP – normal probability plot



(f) Apollo 15 EVA 3 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	897	854	307
Traverse	471	356	382
Station	755	787	190



	CDR		LMP	
	Raw	Avg.	Raw	Avg.
Mean	992	985	791	789
Median	917	936	790	779
s.d.	398	304	301	187

(e) Apollo 15 EVA 3: CDR and LMP metabolic rate distribution summary statistics

Figure 18: Apollo 15 EVA 3 Metabolic Rate Summary Statistics

4.3 Apollo 16

The nominal plan for the Apollo 16 mission involved three two-astronaut EVAs to be conducted within 73 hours while on the lunar surface. The four primary objectives for Apollo 16 EVAs are shown in Table 16. Table 17 shows the associated operational requirements imposed during Apollo 16. Finally, Table 18 shows the specific task priorities to be performed during EVA.

Overall, the crew were able to accomplish the primary objectives of the EVAs, but due to mission delays that originated from the descent to the lunar surface, the 2nd EVA and the 3rd EVA had to be shortened. The crew also experienced mechanical issues, but they were able to overcome these difficulties.

Table 16: Apollo 16 Mission Objectives.

Priority	Apollo 16 Mission Objectives Descriptions
1	Perform selenological inspection, survey, and sampling of materials and surface features in a pre-selected area of the Descartes region
2	Emplace and activate surface experiments
3	Conduct in-flight experiments and photograph tasks from lunar orbit

Table 17: Apollo 16 EVA Requirements.

ID	Apollo 16 EVA Requirements
a)	Stay time on lunar surface is open ended and the planned maximum will not exceed approximately 73 hours
b)	Three periods of EVA planned: All 3 EVAs are planned to be approximately 7 hours in duration
c)	The traverse planning provides for the capability of the crew to return to the LM under each of the following single-failure conditions:
c.1)	Use of buddy-secondary life support system due to an inoperative PLSS anytime during a riding traverse (based upon the assumptions that the LRB will operate properly during the return to the LM)
c.2)	Use of the two PLSS's for a walking return to the LM from an inoperative LRV anytime during a riding traverse (based upon the assumption that both PLSS's will operate properly during the return to the LM)
d)	Traverse planning will not be provided for dual failure conditions such as two PLSS failures or an LRV failure combined with a PLSS failure. ALSEP deployment operations will be accomplished during the first EVA within the limitations and constraints define in the SDM/LM Spacecraft Data Book, SNA-8D-027, Vol. V, ALSEP data Book for Apollo 16

Life support systems checkout was nominal for each EVA. The CDR maintained one-quarter of cooling capability, and minimum cooling was maintained while driving. Metabolic rate correlated well with heart-rate data. Heat loads were higher than expected and caused higher feedwater consumption. Telemetry data was not

Table 18: Apollo 16 Lunar Surface Task Priorities

Lunar Surface Priority	Priority Description
1	Documented sample collection at highest priority traverse station (Part of Lunar Geology Investigation)
2	Heat Flow (S-037) (Part of Apollo 16 ALSEP)
3	Lunar Surface Magnetometer (S-034) (Part of Apollo 16 ALSEP)
4	Passive Seismic (S-031) (Part of Apollo 16 ALSEP)
5	Active Seismic (S-031) (Part of Apollo 16 ALSEP)
6	Drill Core Sample Collection (Part of Lunar Geology Investigation)
7	Lunar Geology Investigation (S-059) (Portions other than priority items 1 and 6 above)
8	Far UV Camera/Spectroscope (S-201)
9	Solar Wind Composition
10	Soil Mechanics (S-200)
11	Portable Magnetometer (S-198)
12	Cosmic Ray Detector (Sheets) (S-152)

available while driving due to an antenna malfunction. The PLSS often got caught on the lunar module, causing periodic time delays. The CDR drink bag leaked, preventing consumption of his food bar, and dust prevented him from closing his overvisor and reading his remote control unit. The LMP depleted his feedwater during the first EVA, causing ingress to be rushed at the end of the EVA and the CDR to damage his antenna. The crew often awoke due to thirst while sleeping. Vents were included in the electrodes to prevent trapped air, and the water hoses were made longer to improve donning characteristics. Other modifications to the EMU were made for improved mobility.

4.3.1 EVA 1

TIMELINE EXECUTION TRENDS

Overall the first EVA of the Apollo 16 mission followed the planned timeline with only a few delays. The crew began the EVA by configuring the LRV for traversing and preparation to move to the ALSEP site. The crew then proceed to 2 different crater locations before returning back towards the LM where a third station was visited to perform LRV testing, sampling and arm the active seismic experiment mortar package.

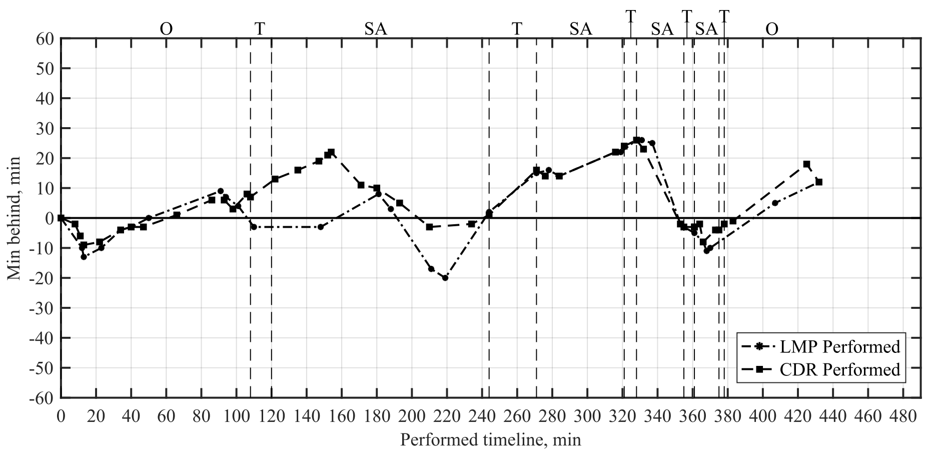
As shown in Figure 19, the crew exited the lunar module as normal, but soon after encountered the first equipment trouble. The steerable antennas on the lunar modules we not functioning, thus delaying television coverage until the lunar roving vehicle systems were activated. Once the lunar rover was configured the crew traversed to the ALSEP site where the experiments with deployed as expected, except for the heat flow experiment. An electronic cable was accidentally broken leaving the experiment inoperable. The remainder of the EVA followed the planned procedures, which entailed the crew driving to the Flag Crater, then to Spook Crater and finally deploying the solar wind composition after their return to the experiment site outside lunar module.

METABOLIC RATE AND CONSUMABLES TRENDS

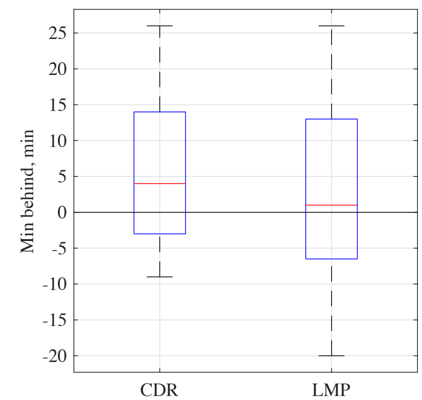
Figure 20 shows the metabolic rate trends for each crew member for Apollo 16 EVA 1. The LMP exhibited higher overall metabolic rate values throughout the EVA. Both the CDR and LMP feedwater and power usage were underpredicted as shown in Table 19. The LMP oxygen usage was also underpredicted by 5%.

Table 19: Apollo 16 EVA 1 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

	CDR		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	35.8%	26.9%	8.9%
Feedwater	25.3%	25.7%	-0.3%
Power	18.5%	23.6%	-5.1%
	LMP		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	21.8%	26.9%	-5.1%
Feedwater	4.0%	25.7%	-21.6%
Power	17.3%	23.8%	-6.5%

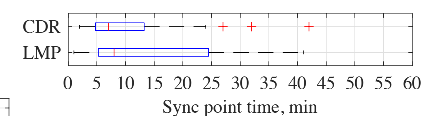


(a) Minutes behind timeline for CDR and LMP for Apollo 16 EVA 1. Vertical line indicates transitions in as-performed timeline



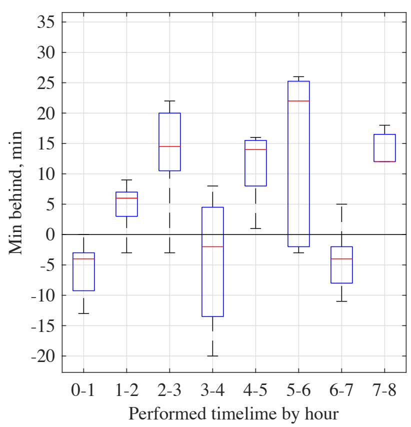
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	6	3
s.d.	10	13



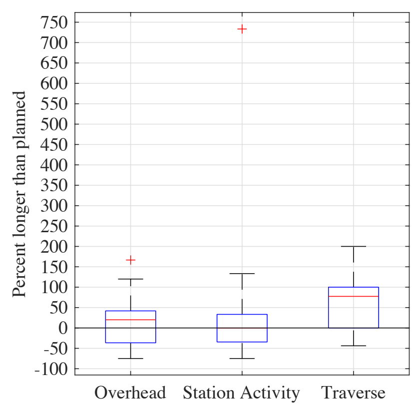
	CDR	LMP
Mean	10	14
s.d.	9	12

(c) Sync points summary statistics



(d) Minutes behind timeline summary statistics by hour

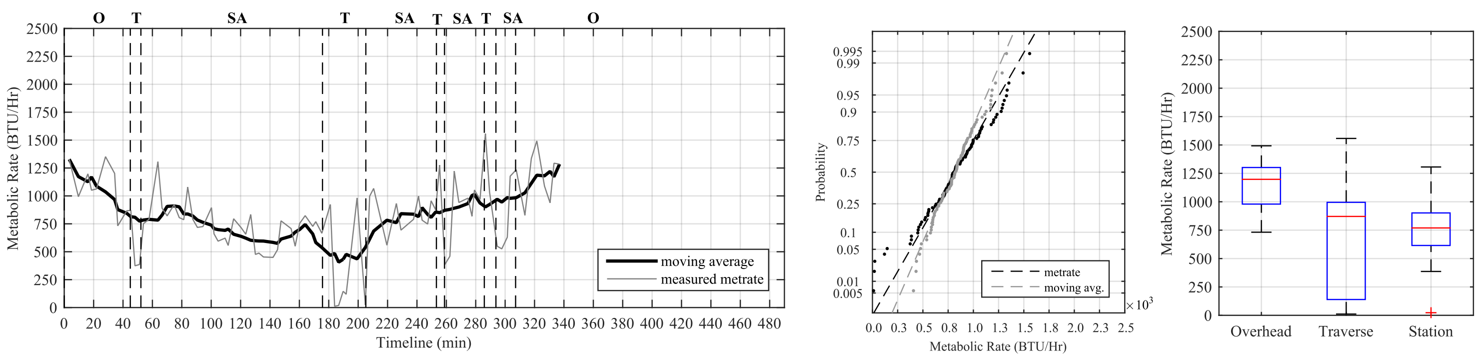
As-Performed Timeline	Mean	s.d
1st hour	-6	4
2nd hour	-5	4
3rd hour	14	8
4th hour	-4	11
5th hour	12	6
6th hour	16	13
7th hour	-4	4
8th hour	14	3



(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	12	57
Station Activity	19	130
Traverse	64	74

Figure 19: Apollo 16 EVA 1 Timeline Summary Statistics

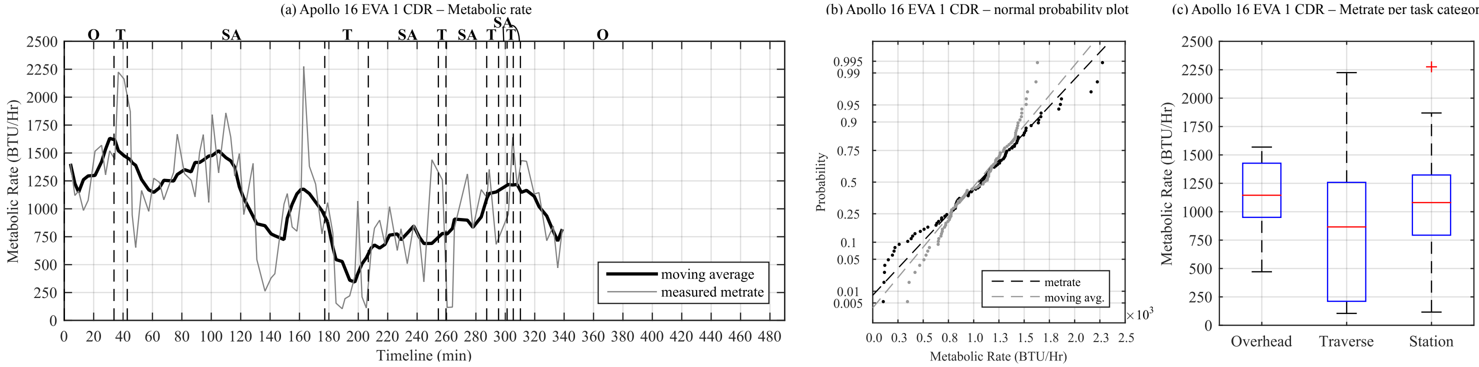


(a) Apollo 16 EVA 1 CDR – Metabolic rate

(b) Apollo 16 EVA 1 CDR – normal probability plot

(c) Apollo 16 EVA 1 CDR – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1134	1198	212
Traverse	660	871	511
Station	757	770	226

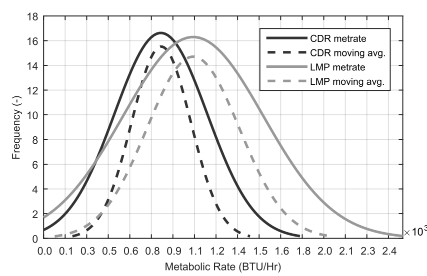


(d) Apollo 16 EVA 1 LMP – Metabolic rate

(e) Apollo 16 EVA 1 LMP – normal probability plot

(f) Apollo 16 EVA 1 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1155	1145	314
Traverse	860	866	669
Station	1065	1081	458



	CDR		LMP	
	Raw	Avg.	Raw	Avg.
Mean	816	819	1041	1041
Median	806	820	1078	1104
s.d.	323	206	489	321

(e) Apollo 16 EVA 1: CDR and LMP metabolic rate distribution summary statistics

Figure 20: Apollo 16 EVA 1 Metabolic Rate Summary Statistics

4.3.2 EVA 2

TIMELINE EXECUTION TRENDS

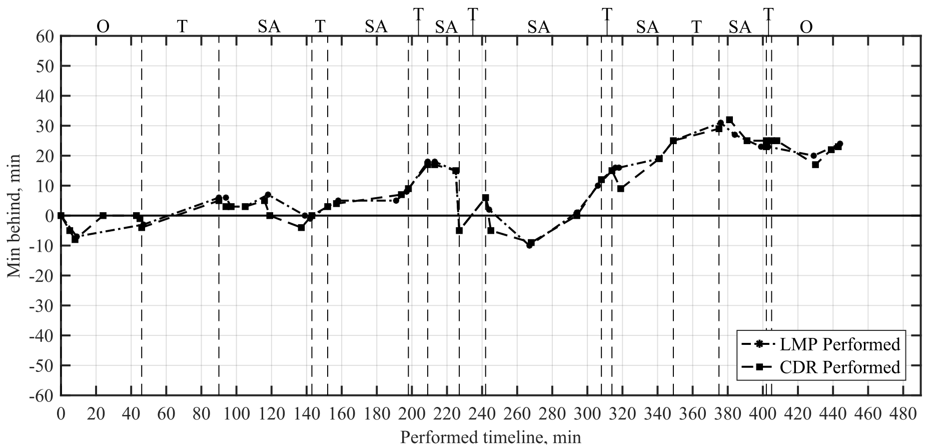
Apollo 16 EVA 2 consisted of the crew making a geological traverse to Stone Mountain to collect samples and photography. As shown in Figure 21, EVA 2 execution followed the planned schedule well, except for the omission of station 7. The EVA had 7 planned stations along multiple traverses to the Cinco, the Stubby and Wreck Craters. Based on crew progress at 3 hours into the EVA, the decision was made to omit station 7 to allow for more time to sample at the ASLEP experiment site. The crew were able to perform the planned tasks, but ran into equipment trouble with the Far U.V. experiment, a battery on the lunar rover, and the navigation system. The Far U.V. was experiencing high sun angles, due the delayed start of the 2nd EVA, which meant the camera had to be moved to the shade. The additional heat from the sun also caused the one of the lunar rover's to display 4 times higher than normal battery usage. The problem was resolved once the normal switch and break configurations were restored. The navigation system data was not updating after station 8 and required a reset to become operational again.

METABOLIC RATE AND CONSUMABLES TRENDS

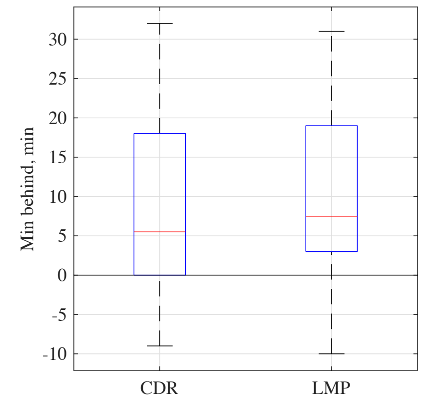
Figure 22 shows the metabolic rate trends for each crew member for Apollo 16 EVA 2. The CDR and LMP exhibited similar overall metabolic rate values throughout the EVA. Both the CDR and LMP feedwater and power usage were underpredicted as shown in Table 20. The CMD and LMP oxygen usage was overpredicted by 5% and 2.8%, respectively.

Table 20: Apollo 16 EVA 2 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	32.6%	27.6%	5.0%
Feedwater	23.9%	26.1%	-2.2%
Power	15.7%	23.6%	-7.9%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	30.4%	27.6%	2.8%
Feedwater	17.2%	26.1%	-8.9%
Power	17.3%	23.6%	-6.3%

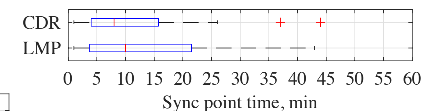


(a) Minutes behind timeline for CDR and LMP for Apollo 16 EVA 2. Vertical line indicates transitions in as-performed timeline



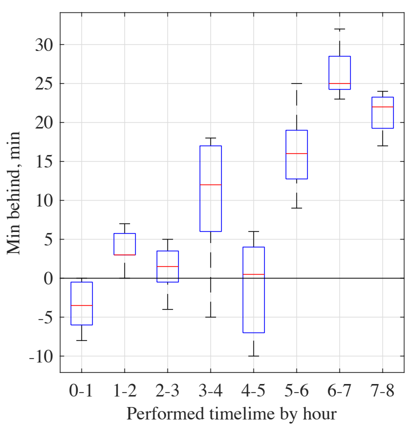
	CDR	LMP
Mean	9	10
s.d.	12	11

(b) Minutes behind timeline summary statistics



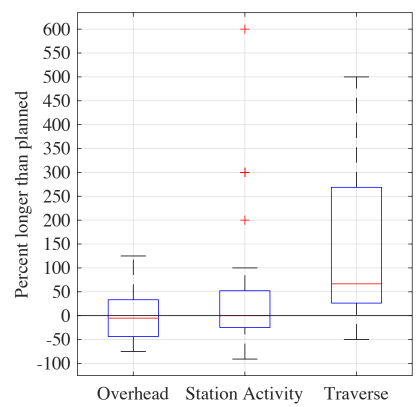
	CDR	LMP
Mean	11	13
s.d.	10	11

(c) Sync points summary statistics



As-Performed Timeline	Mean	s.d
1st hour	-4	3
2nd hour	4	2
3rd hour	1	3
4th hour	10	8
5th hour	-1	6
6th hour	16	5
7th hour	26	3
8th hour	21	3

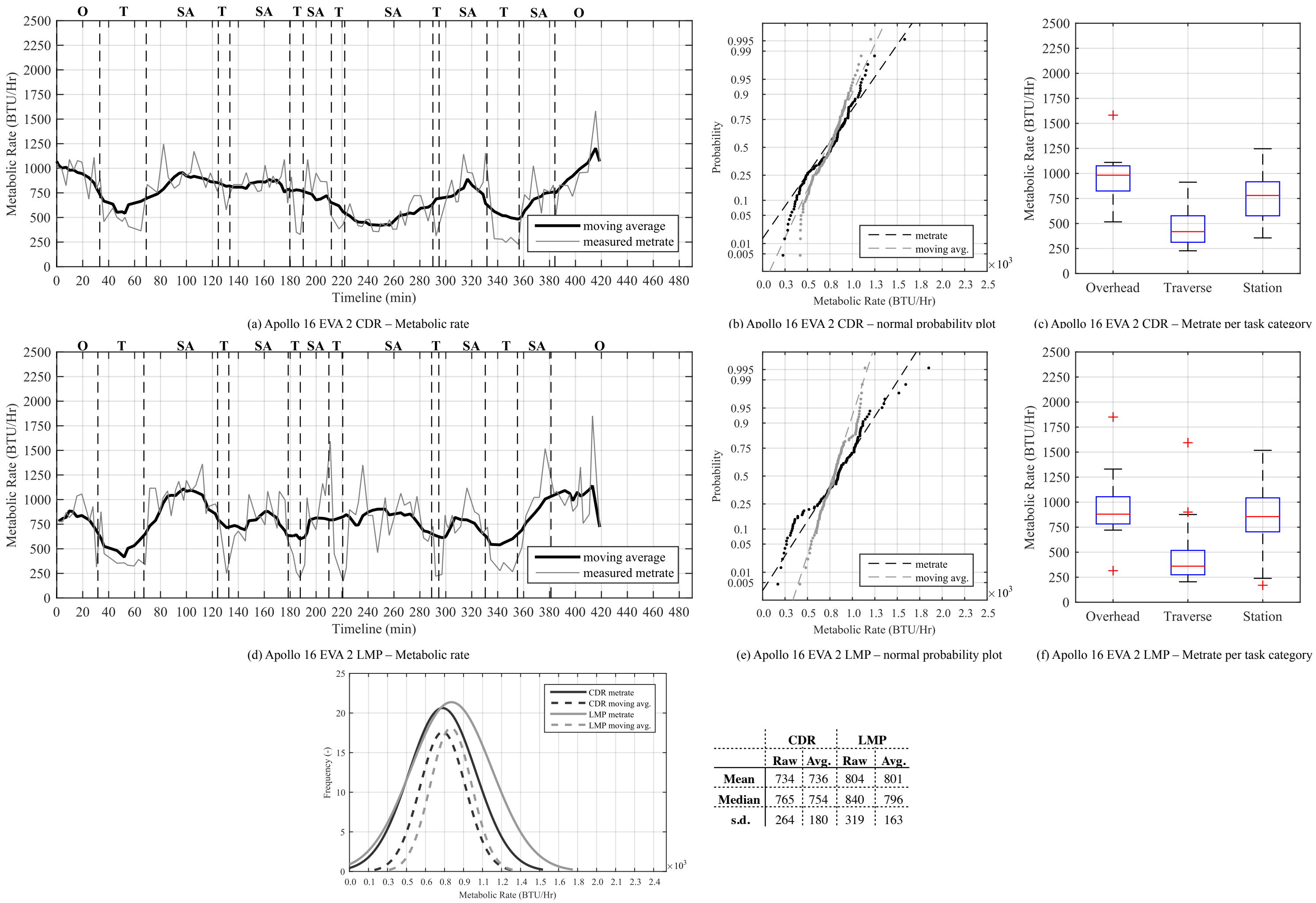
(d) Minutes behind timeline summary statistics by hour



Task Type	Mean	s.d
Overhead	1	57
Station Activity	37	124
Traverse	135	155

(e) Minutes behind timeline summary statistics by task category

Figure 21: Apollo 16 EVA 2 Timeline Summary Statistics



(a) Apollo 16 EVA 2 CDR – Metabolic rate

(b) Apollo 16 EVA 2 CDR – normal probability plot

(c) Apollo 16 EVA 2 CDR – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	956	982	223
Traverse	474	418	212
Station	755	779	221

(d) Apollo 16 EVA 2 LMP – Metabolic rate

(e) Apollo 16 EVA 2 LMP – normal probability plot

(f) Apollo 16 EVA 2 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	937	880	286
Traverse	483	360	326
Station	860	851	263

	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	734	736	804	801
Median	765	754	840	796
s.d.	264	180	319	163

(e) Apollo 16 EVA 2: CDR and LMP metabolic rate distribution summary statistics

Figure 22: Apollo 16 EVA 2 Metabolic Rate Summary Statistics

4.3.3 EVA 3

TIMELINE EXECUTION PERFORMANCE DISCUSSION

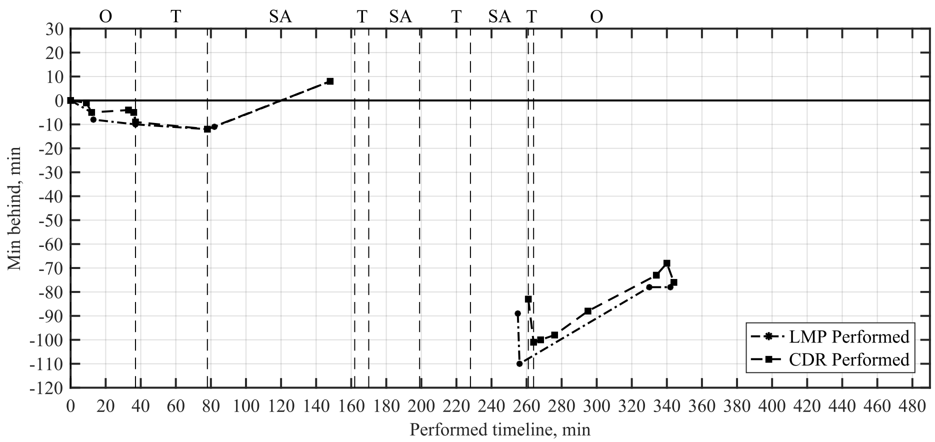
The third EVA was largely restructured from the initial planned EVA. Stations 14-17 from the planned stations were omitted due to mission time constraints and the crew only visited 3 of the originally planned 7 stations near North Ray Crater. However, the crew did return to the stop near the ALSEP site to finish up an ALSEP activity and collect additional samples. As shown in Figure 23, the crew drove to North Ray Crater, House Rock and Shadow Rock, then returned to the lunar module. During the third EVA, the crew experienced similar equipment trouble as in the second EVA. Battery 2 on the lunar rover was over heating, which caused the crew to switch the rover's rear wheel drive power to the first battery. Trouble with the sun angle on the Far U.V. camera caused it to need to be relocated, similar to EVA 2, and there was minor alignment trouble with the deployment of the mortar package. Due to the significant alterations to the timeline, limited data was able to be associated and presented here.

METABOLIC RATE AND CONSUMABLES TRENDS

Figure 24 shows the metabolic rate trends for each crew member for Apollo 16 EVA 3. The CDR and LMP exhibited similar overall metabolic rate values throughout the EVA. All consumables usage for both crew members were overpredicted as shown in Table 20.

Table 21: Apollo 16 EVA 3 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	42.5%	26.0%	16.6%
Feedwater	34.1%	25.0%	9.1%
Power	34.3%	23.6%	10.6%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	43.6%	26.0%	17.7%
Feedwater	32.5%	25.0%	7.4%
Power	35.4%	N/A	N/A



(a) Minutes behind timeline for CDR and LMP for Apollo 16 EVA 3. Vertical line indicates transitions in as-performed timeline

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(b) Minutes behind timeline summary statistics

N/A

	CDR	LMP
Mean	X	X
s.d.	X	X

(c) Sync points summary statistics

N/A

As-Performed Timeline	Mean	s.d
1st hour	X	X
2nd hour	X	X
3rd hour	X	X
4th hour	X	X
5th hour	X	X

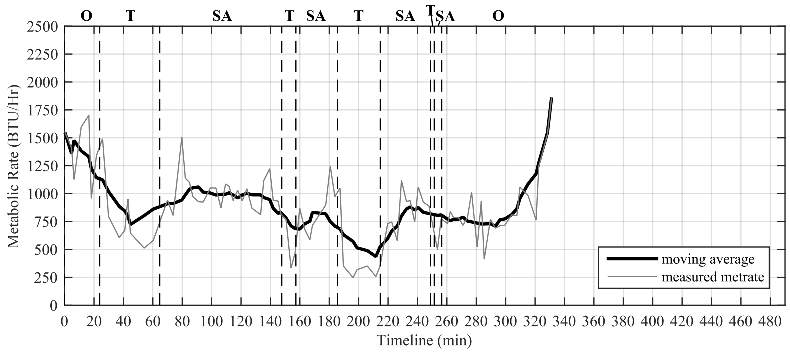
(d) Minutes behind timeline summary statistics by hour

N/A

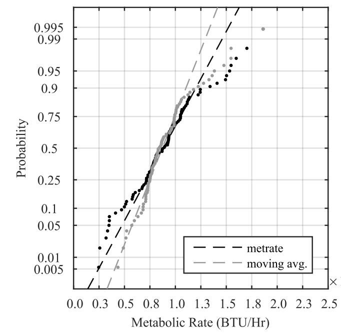
Task Type	Mean	s.d
Overhead	X	X
Station Activity	X	X
Traverse	X	X

(e) Minutes behind timeline summary statistics by task category

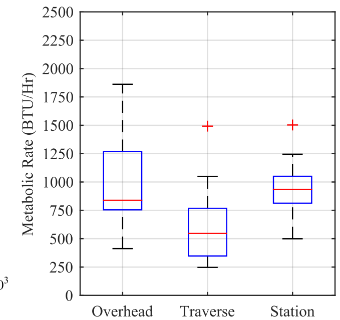
Figure 23: Apollo 16 EVA 3 Timeline Summary Statistics



(a) Apollo 16 EVA 3 CDR – Metabolic rate

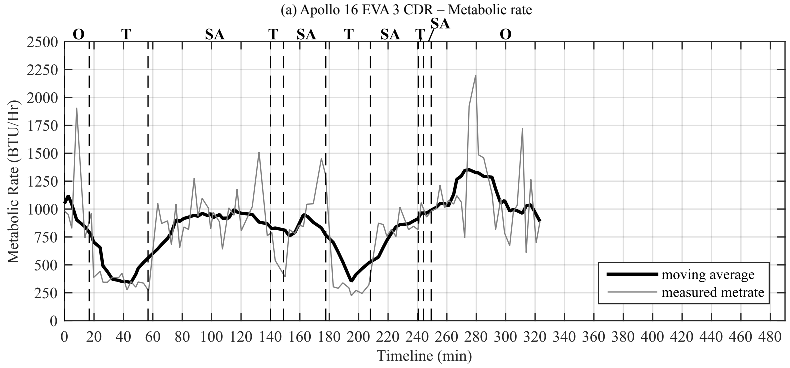


(b) Apollo 16 EVA 3 CDR – normal probability plot

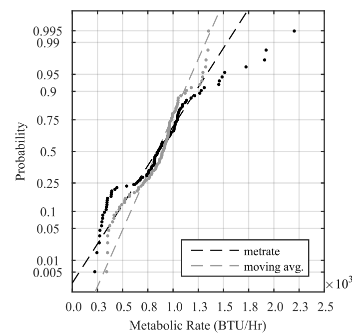


(c) Apollo 16 EVA 3 CDR – Metrate per task category

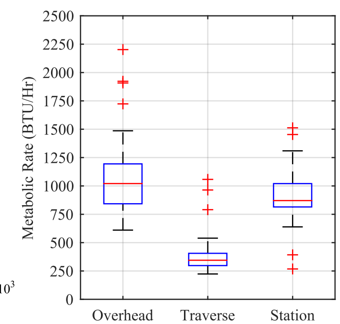
Task Type	Mean	Median	s.d.
Overhead	1005	839	372
Traverse	597	546	325
Station	930	934	189



(d) Apollo 16 EVA 3 LMP – Metabolic rate

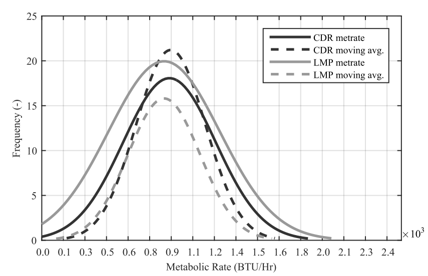


(e) Apollo 16 EVA 3 LMP – normal probability plot



(f) Apollo 16 EVA 3 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1109	1021	388
Traverse	415	347	216
Station	907	871	230



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	888	897	850	850
Median	882	838	852	898
s.d.	321	241	388	250

(e) Apollo 16 EVA 3: CDR and LMP metabolic rate distribution summary statistics

Figure 24: Apollo 16 EVA 3 Metabolic Rate Summary Statistics

4.4 Apollo 17

The nominal plan for the Apollo 17 mission involved three two-astronaut EVAs, to be conducted over a period no longer than 75 hours while on the lunar surface. The three primary objectives for Apollo 17 EVAs are shown in Table 22. Table 23 shows the associated operational requirements imposed during Apollo 17. Finally, Table 24 shows the specific task priorities to be performed during EVA.

Overall, as stated in Apollo 17 mission report: "Apollo 17 mission was the most productive and trouble-free manned mission. This represents the culmination of the continual advancement in hardware, procedures, training, planning and scientific experiments." All Apollo 17 EVAs successfully followed the planned timeline and met all of the EVA objectives. The only major source of discrepancies occured from minor difficulty with the deployment of some scientific experiments. Also stated directly from the Apollo 17 Mission report: "The Apollo 17 flight demonstrated the practicality of training scientists to become qualified astronauts and yet retain their expertise and knowledge in the scientific field...In summarizing the operations on all three EVA, one of the most important ingredients for total efficiency was the crew staying near one another and working together, remaining in close proximity when, required to work independently, and complementing each other's activities. Only in rare instances was there separation to the extent that the crew could not correlate each other's geological observations and/or physically come to one another's assistance."

Table 22: Apollo 17 Mission Objectives.

Priority	Apollo 17 Mission Objectives Descriptions
1	Perform selenological inspection, survey, and sampling of materials and surface features in a pre-selected area of the Descartes region
2	Emplace and activate surface experiments
3	Conduct in-flight experiments and photograph tasks from lunar orbit

All physiological readings were nominal, with metrate being slightly higher than expected. The metabolic rates were measured using oxygen consumption and heat loss while lunar EVA were performed; heart-rate-based measurements were only available for the command module pilot during transearth EVA. No significant biomedical issues were reported for Apollo 17. The EMU was modified to improve donning and comfort. Dust covers and spare antennae were added, as well as glove modifications for improved mobility.

4.4.1 EVA 1

TIMELINE EXECUTION TRENDS

Apollo 17 EVA 1 began by testing the LRV, once ready to traverse the crew moved to the ASLEP site. Due to a delay with the deployment of the ALSEP ex-

Table 23: Apollo 17 EVA Requirements.

ID	Apollo 17 EVA Requirements
a)	Stay time on lunar surface is open ended and the planned maximum will not exceed approximately 75 hours
b)	Three periods of EVA planned: All 3 EVAs are planned to be approximately 7 hours in duration
c)	The traverse planning provides for the capability of the crew to return to the LM under each of the following single-failure conditions:
c.1)	Use of buddy-secondary life support system due to an inoperative PLSS anytime during a riding traverse (based upon the assumptions that the LRB will operate properly during the return to the LM)
c.2)	Use of the two PLSS's for a walking return to the LM from an inoperative LRV anytime during a riding traverse (based upon the assumption that both PLSS's will operate properly during the return to the LM)
d)	Traverse planning will not be provided for dual failure conditions such as two PLSS failures or an LRV failure combined with a PLSS failure. ALSEP deployment operations will be accomplished during the first EVA within the limitations and constraints define in the SDM/LM Spacecraft Data Book, SNA-8-D-027, Vol. V, ALSEP data Book for Apollo 17

Table 24: Apollo 17 Lunar Surface Task Priorities

Lunar Surface Priority	Priority Description
1	Documented Sample Collection at highest priority traverse station
2	Heat Flow (S-037) ALSEP
3	Lunar Surface Gravimeter (S-207) (Part of Apollo 17 ALSEP)
4	Lunar Seismic Profiling (S-203) (Part of Apollo 17 ALSEP)
5	Lunar Atmospheric Composition (S-205) (Part of Apollo 17 ALSEP)
6	Lunar Ejecta and Meteorites (S-202) (Part of Apollo 17 ALSEP)
7	Lunar Geology Investigation (S-059)
8	Drill Core Sample Collection
9	Surface Electrical Properties (S-204)
10	Lunar Neutron Probe (S-299)
11	Traverse Gravimeter (S-199)
12	Cosmic Ray Experiment

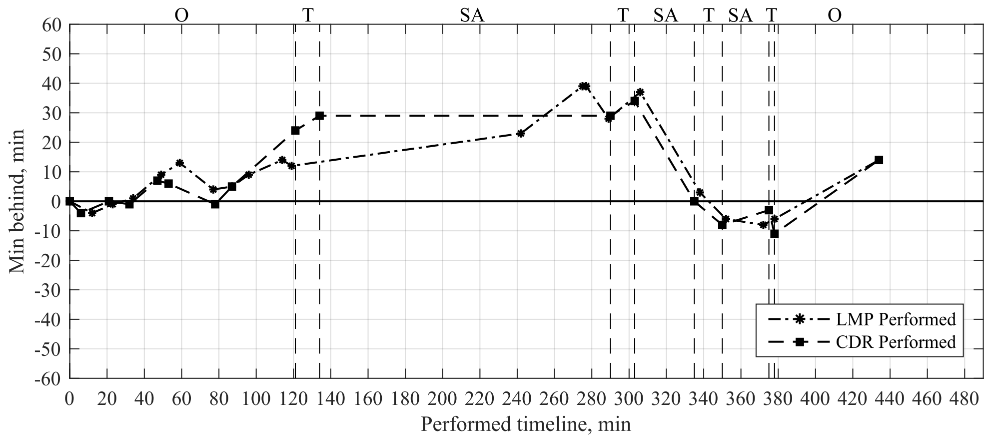
periment, the crew shortened their geological traverse to half as far as originally planned alongside the Steno Crater. The crew then traversed to the Surface Electrical Properties experiment site before performing closeout activities. The primary tasks were to configure the LRV for operation, deploy the ALSEP, traverse to the geology station and to deploy the electrical properties experiments. The crew was able to successfully complete all intended objectives and were able to follow the planned timeline and meet all of the primary EVA objectives with only one slight revision. Figure 25 shows the shortening of time spent on geology at Station 1 at approximately 300 minutes into the performed timeline. Shortening the activity by over 30 minutes allowed the crew to get back on schedule and to end the EVA in 7 hours and 14 minutes.

METABOLIC RATE AND CONSUMABLES TRENDS

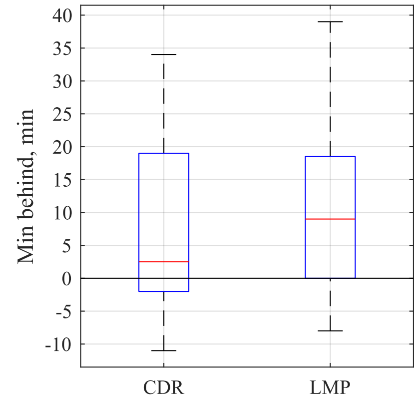
Figure 26 shows the metabolic rate trends for each crew member for Apollo 17 EVA 1. The CDR and LMP exhibited similar overall metabolic rate values throughout the EVA. Both the CDR and LMP oxygen and feedwater consumables usage were underpredicted as shown in Table 25. Only CDR power usage ended with a surplus at the end of the EVA.

Table 25: Apollo 17 EVA 1 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	19.7%	32.3%	-12.6%
Feedwater	7.9%	17.9%	-10.0%
Power	27.6%	25.6%	2.0%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	19.1%	32.3%	-13.2%
Feedwater	10.4%	17.9%	-7.5%
Power	20.5%	25.6%	-5.1%

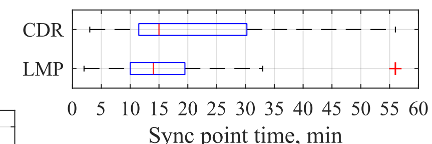


(a) Minutes behind timeline for CDR and LMP for Apollo 17 EVA 1. Vertical line indicates transitions in as-performed timeline



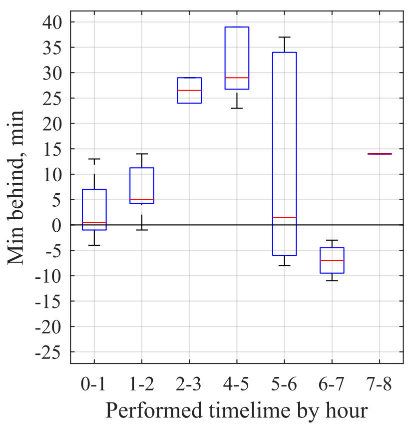
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	8	11
s.d.	14	15



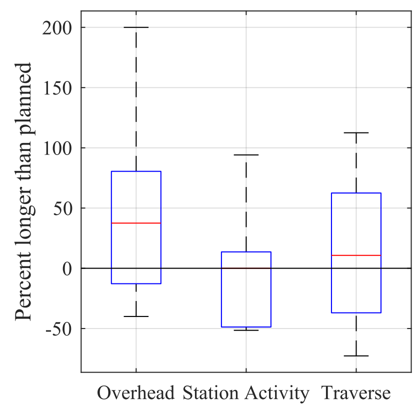
(c) Sync points summary statistics

	CDR	LMP
Mean	29	22
s.d.	38	27



(d) Minutes behind timeline summary statistics by hour

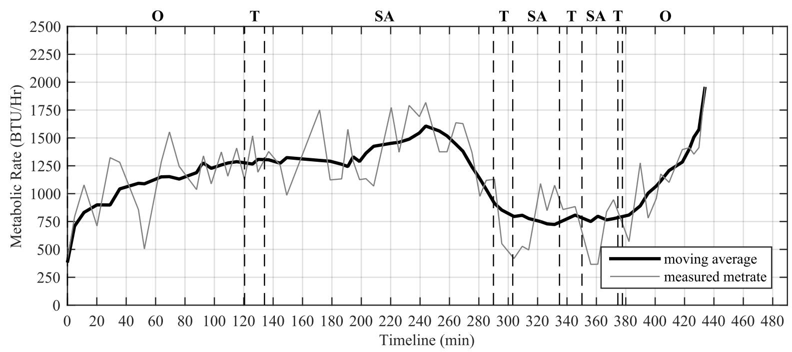
As-Performed Timeline	Mean	s.d.
1st hour	3	6
2nd hour	7	5
3rd hour	27	4
4th hour	NA	NA
5th hour	32	7
6th hour	10	20
7th hour	-7	3
8th hour	14	0



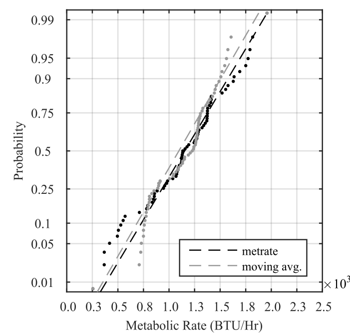
(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	44	64
Station Activity	-3	46
Traverse	14	66

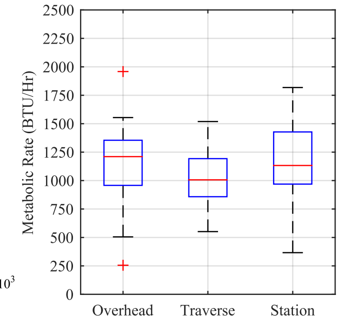
Figure 25: Apollo 17 EVA 1 Timeline Summary Statistics



(a) Apollo 17 EVA 1 CDR – Metabolic rate

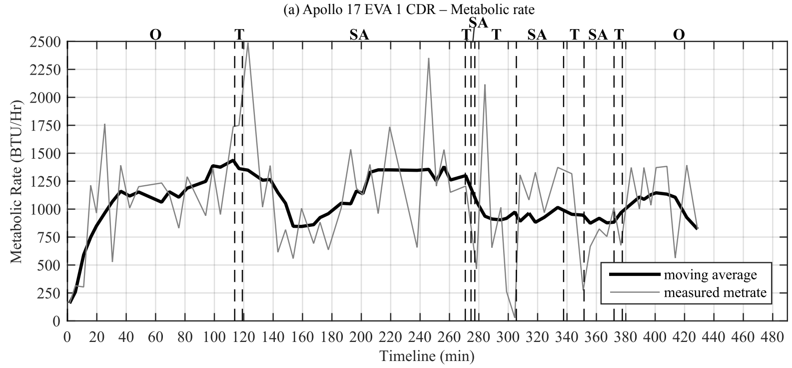


(b) Apollo 17 EVA 1 CDR – normal probability plot

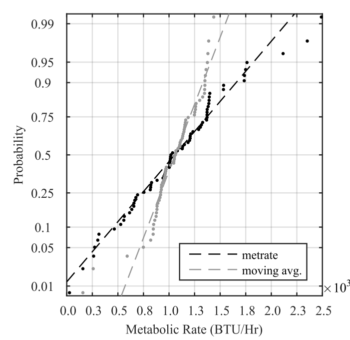


(c) Apollo 17 EVA 1 CDR – Metrate per task category

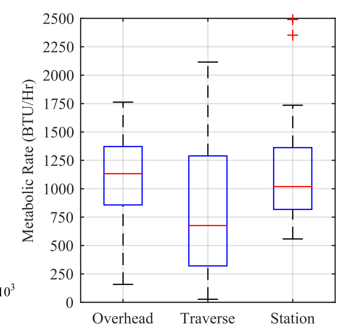
Task Type	Mean	Median	s.d.
Overhead	1136	1210	346
Traverse	1022	1006	333
Station	1173	1133	422



(d) Apollo 17 EVA 1 LMP – Metabolic rate

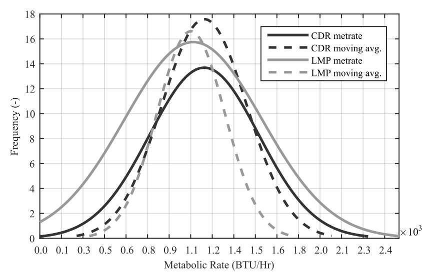


(e) Apollo 17 EVA 1 LMP – normal probability plot



(f) Apollo 17 EVA 1 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1061	1133	412
Traverse	887	676	659
Station	1138	1019	458



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	1144	1145	1068	1051
Median	1135	1227	1019	1062
s.d.	380	296	478	236

(e) Apollo 17 EVA 1: CDR and LMP metabolic rate distribution summary statistics

Figure 26: Apollo 17 EVA 1 Metabolic Rate Summary Statistics

4.4.2 EVA 2

TIMELINE EXECUTION TRENDS

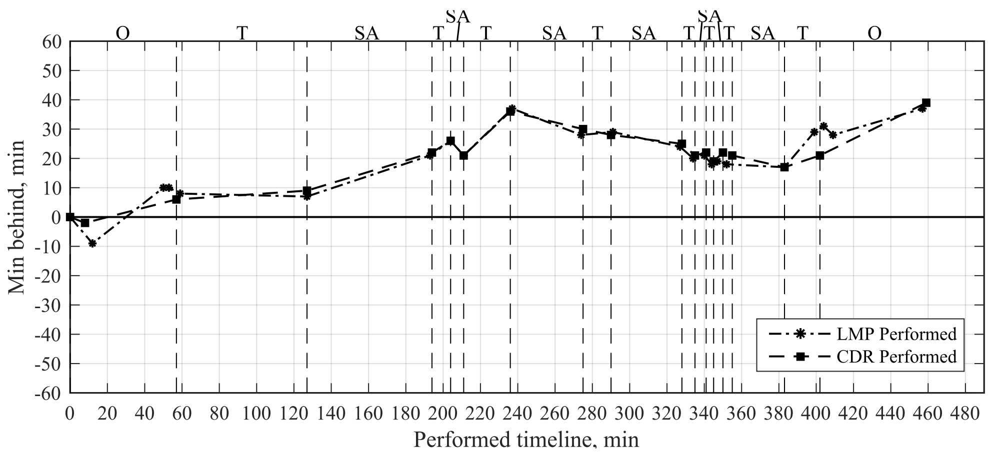
Apollo 17 EVA 2 consisted of a long distance (20.4 km) geological traverse consisting of four station locations with with eight minor stops. The second EVA was executed as intended. Additional time was spent at Station 2 and a brief station 2A was added to provide additional time to troubleshoot a problem with the traverse gravimeter. The extra time spent at Station 2 and 3 caused Station 4 to be shortened. Towards the end of the EVA the LMP spent additional time at the ALSEP site to ensure the proper deployment of the surface gravimeter. Despite readjustments in the time spent at each station, the second EVA followed the planned timeline. Stations 2 through 5 were all visited and the primary planned tasks were achieved. Figure 27 shows the crew starting to experience delays about 1 hour in to the performed timeline when the crew started the traverse to Station 2. The delay continued to accumulate with the additional time spent at Station 2 and 3. The crew maked up a little bit of time by cutting execution time at Station 4 and 5 to end the EVA in 7 hours and 39 minutes. As stated in the Apollo 17 mission report, "All hardware systems were operating as expected, except for the noticeable difficulty in the movement of some mechanical parts because of dust permeation."

METABOLIC RATE AND CONSUMABLES TRENDS

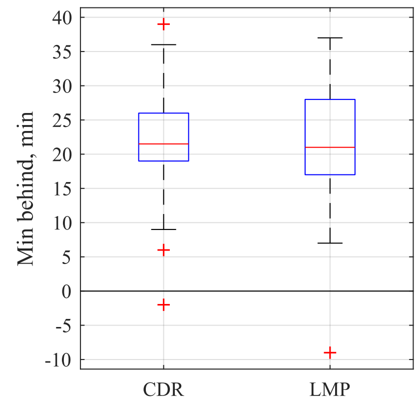
Figure 28 shows the metabolic rate trends for each crew member for Apollo 17 EVA 2. The CDR and LMP exhibited similar overall metabolic rate values throughout the EVA. All consumables usage for both crew members were underpredicted as shown in Table 26.

Table 26: Apollo 17 EVA 2 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

CDR			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	25.3%	35.9%	-10.6%
Feedwater	20.3%	26.7%	-6.5%
Power	25.2%	25.6%	-0.4%
LMP			
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	24.9%	35.9%	-11.0%
Feedwater	20.6%	26.7%	-6.1%
Power	16.1%	25.6%	-9.4%

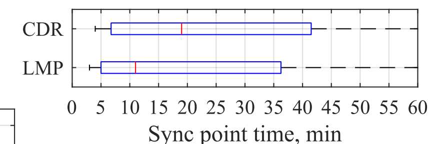


(a) Minutes behind timeline for CDR and LMP for Apollo 17 EVA 2. Vertical line indicates transitions in as-performed timeline



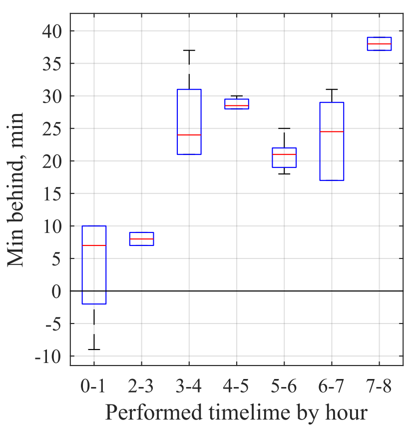
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	21	21
s.d.	10	10



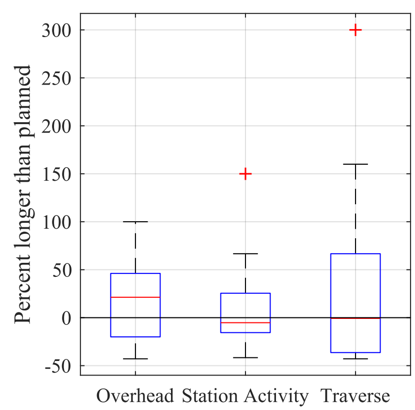
(c) Sync points summary statistics

	CDR	LMP
Mean	27	21
s.d.	23	21



(d) Minutes behind timeline summary statistics by hour

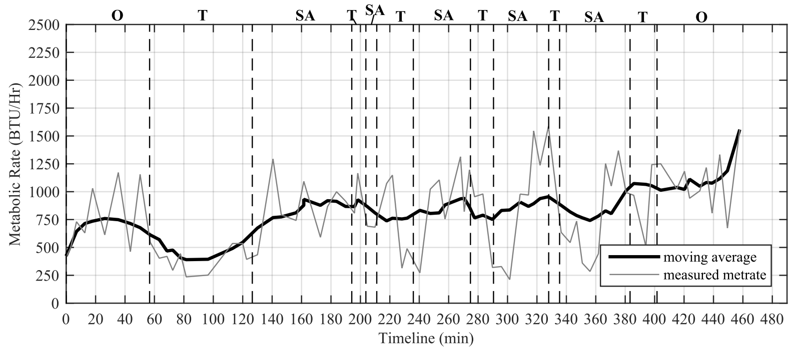
As-Performed Timeline	Mean	s.d.
1st hour	5	6
2nd hour	NA	NA
3rd hour	8	1
4th hour	26	7
5th hour	29	1
6th hour	21	2
7th hour	24	6
8th hour	38	1



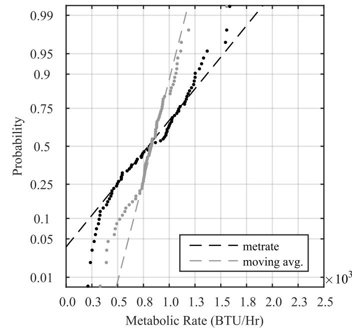
(e) Minutes behind timeline summary statistics by task category

Task Type	Mean	s.d
Overhead	17	37
Station Activity	11	48
Traverse	30	91

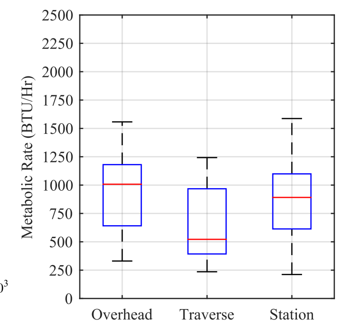
Figure 27: Apollo 17 EVA 2 Timeline Summary Statistics



(a) Apollo 17 EVA 2 CDR – Metabolic rate

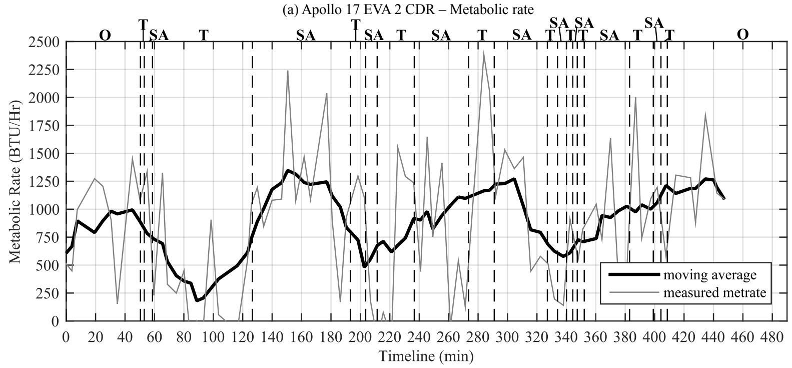


(b) Apollo 17 EVA 2 CDR – normal probability plot

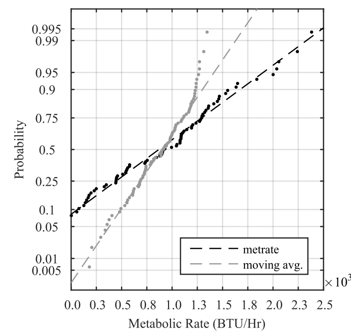


(c) Apollo 17 EVA 2 CDR – Metrate per task category

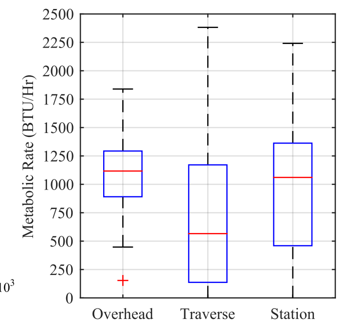
Task Type	Mean	Median	s.d.
Overhead	927	1008	335
Traverse	638	522	335
Station	867	891	365



(d) Apollo 17 EVA 2 LMP – Metabolic rate

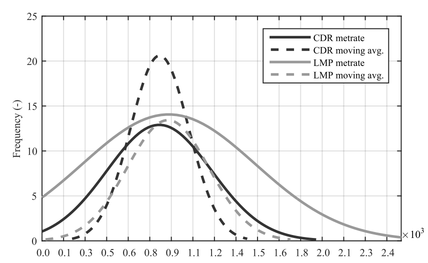


(e) Apollo 17 EVA 2 LMP – normal probability plot



(f) Apollo 17 EVA 2 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1060	1117	411
Traverse	714	566	691
Station	957	1061	564



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	816	818	882	877
Median	807	819	920	910
s.d.	364	203	603	284

(e) Apollo 17 EVA 2: CDR and LMP metabolic rate distribution summary statistics

Figure 28: Apollo 17 EVA 2 Metabolic Rate Summary Statistics

4.4.3 EVA 3

TIMELINE EXECUTION TRENDS

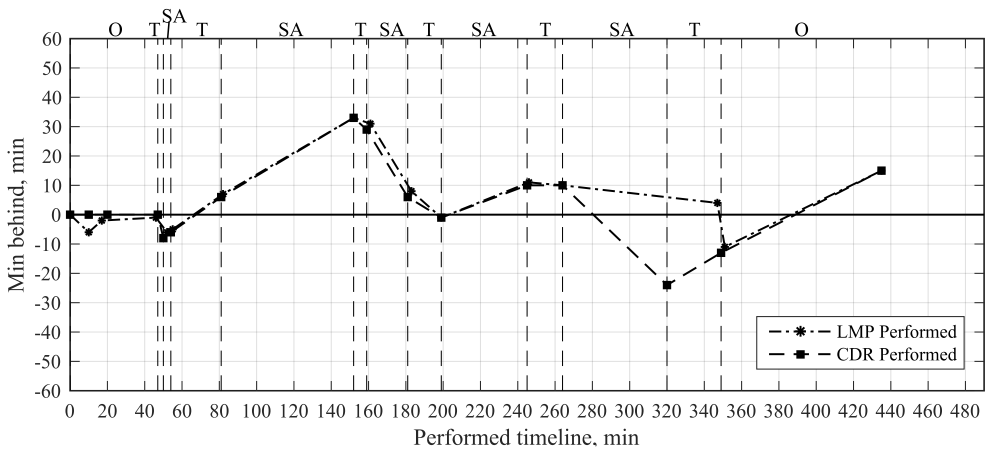
The final lunar EVA was another geological traverse which visited 4 station visits near the North Massif along with 4 short-duration sample stops. The crew also visited the electrical and ALSEP sites to finish and collect experiments prior to their return to Earth. As stated in the Apollo 17 mission report, “The third extravehicular activity was conducted essentially as planned and met all of the pre-mission traverse objectives." The only notable change to the EVA timeline was the elimination of station 10; however the objectives of station 10 were “largely fulfilled during all three of the extravehicular activities." The elimination of station 10 was due to additional time being added for the close out time to account for dusting the EMUs and an effort to “solve the problems being experienced by the lunar surface gravimeter." Figure 29 shows the crew moving “ahead" of the planned schedule at 260 minutes due to the elimination of Station 10, but ending the EVA in 7 hours and 15 minutes due to the additional closeout activities.

METABOLIC RATE AND CONSUMABLES TRENDS

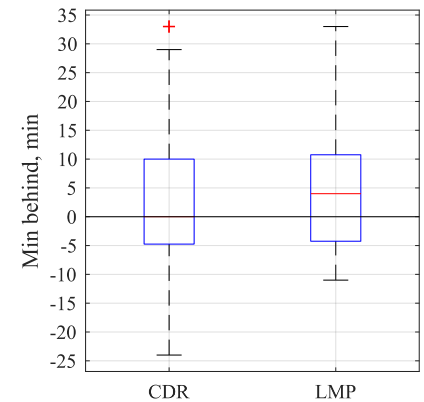
Figure 30 shows the metabolic rate trends for each crew member for Apollo 17 EVA 3. The CDR and LMP exhibited similar overall mean metabolic rate values throughout the EVA. All consumables usage for both crew members were underpredicted as shown in Table 26, except for CDR power usage.

Table 27: Apollo 17 EVA 3 Consumables: actual vs. predicted percent remaining of oxygen, feedwater, and power. *Gray cells indicate underpredicted consumable usage.*

	CDR		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	24.9%	30.9%	-6.1%
Feedwater	11.2%	20.8%	-9.6%
Power	29.1%	25.6%	3.5%
	LMP		
	Actual % Remaining	Predicted % Remaining	% Difference
Oxygen	21.0%	30.9%	-9.9%
Feedwater	9.4%	20.8%	-11.4%
Power	20.1%	25.6%	-5.5%

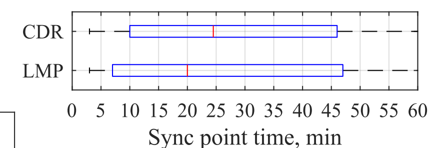


(a) Minutes behind timeline for CDR and LMP for Apollo 17 EVA 3. Vertical line indicates transitions in as-performed timeline



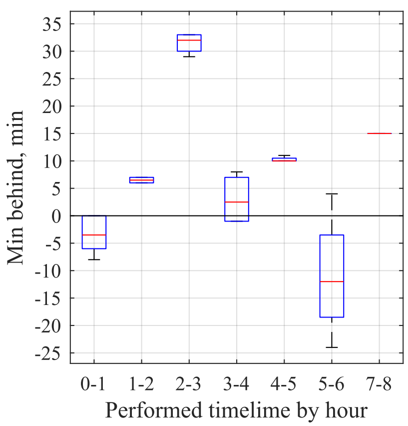
(b) Minutes behind timeline summary statistics

	CDR	LMP
Mean	4	6
s.d.	15	13



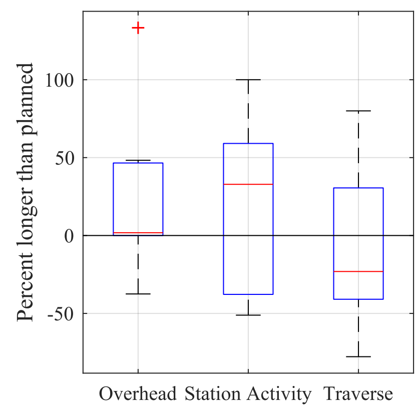
(c) Sync points summary statistics

	CDR	LMP
Mean	30	30
s.d.	25	29



(d) Minutes behind timeline summary statistics by hour

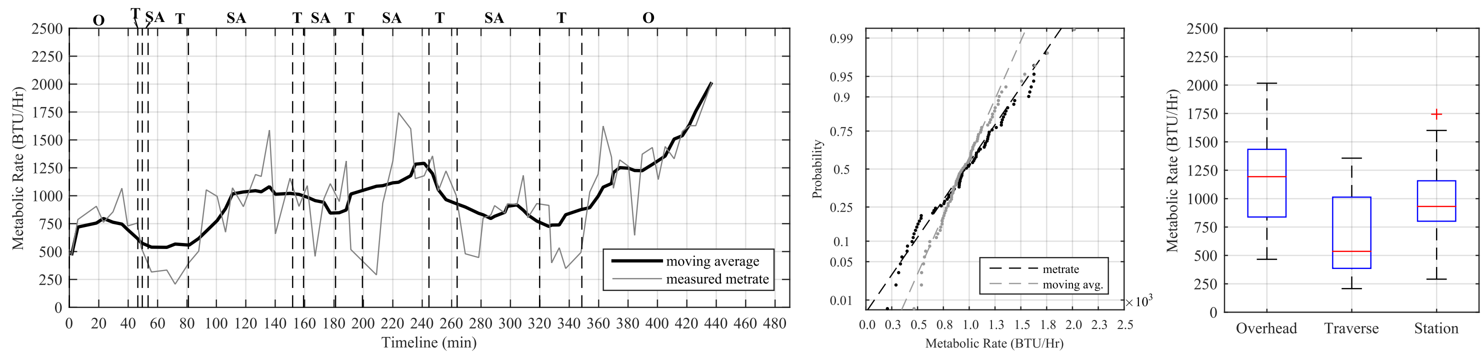
As-Performed Timeline	Mean	s.d
1st hour	-3	3
2nd hour	7	1
3rd hour	32	2
4th hour	3	5
5th hour	10	1
6th hour	-11	12
7th hour	NA	NA
8th hour	15	0



(e) Minutes behind timeline summary statistics by task category

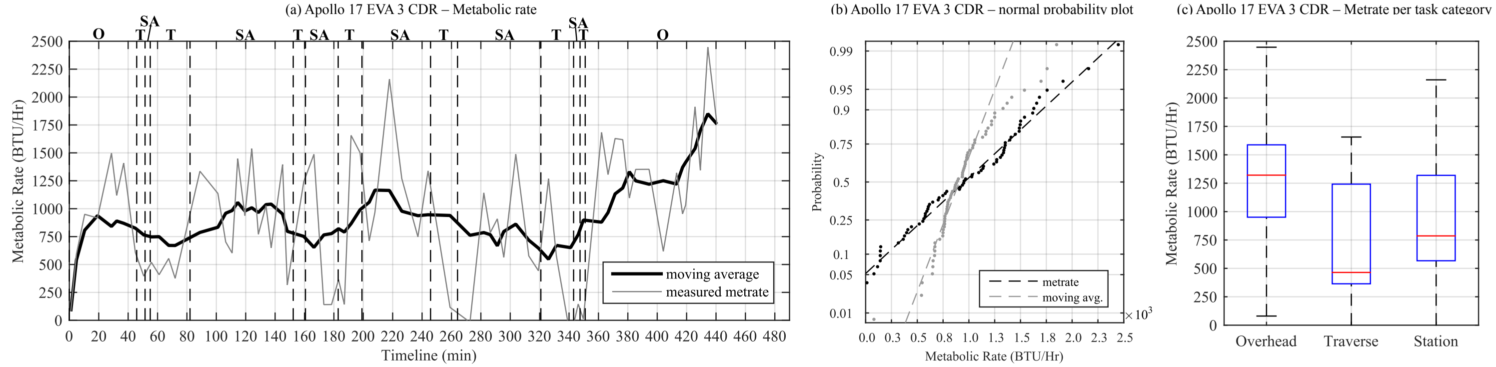
Task Type	Mean	s.d
Overhead	24	52
Station Activity	19	53
Traverse	-8	55

Figure 29: Apollo 17 EVA 3 Timeline Summary Statistics



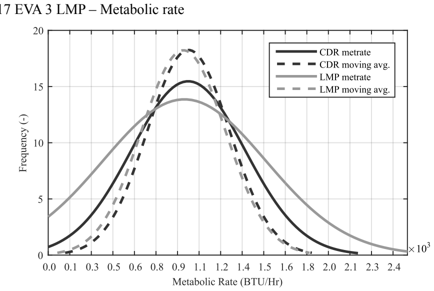
(a) Apollo 17 EVA 3 CDR – Metabolic rate (b) Apollo 17 EVA 3 CDR – normal probability plot (c) Apollo 17 EVA 3 CDR – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1176	1194	378
Traverse	729	536	378
Station	950	931	341



(d) Apollo 17 EVA 3 LMP – Metabolic rate (e) Apollo 17 EVA 3 LMP – normal probability plot (f) Apollo 17 EVA 3 LMP – Metrate per task category

Task Type	Mean	Median	s.d.
Overhead	1243	1321	509
Traverse	641	464	553
Station	867	786	524



	CDR		LMP	
	Raw	**Avg.**	**Raw**	**Avg.**
Mean	974	976	947	941
Median	960	935	951	884
s.d.	394	286	566	293

(e) Apollo 17 EVA 3: CDR and LMP metabolic rate distribution summary statistics

Figure 30: Apollo 17 EVA 3 Metabolic Rate Summary Statistics

4.5 Aggregate EVA Timeline Execution Trends

In order to maintain symmetry in the aggregate analysis process, Apollo 14 was omitted from the aggregated data analysis as they were structurally different from Apollo 15-17. Additionally, Apollo 15 EVA 2 and 3 as well as Apollo 16 EVA 3 were omitted from the aggregate data set due to limited available data. From this point forward, we will only consider the data from Exploration Class EVAs observed during Apollo 15-17 when discussing aggregate data trends.

The aggregate results are divided in two main sections based on the aforementioned measures: 1) timeline execution trends based on minutes behind schedule and 2) task duration deviation performance. Section 4.5.1 details the timeline execution analysis per EVA and as an aggregate data set. A Fourier series model was applied to the aggregate data set to attempt to model the evolution of the minutes behind timeline throughout the planned timelines. A station alteration table (Table 29) provides additional description of the structural changes made to each EVA based on the inclusion/exclusion of planned station visits. Finally, the tasks for each timeline are decomposed into the aforementioned task categories. In Section 4.5.2, summary statistics of task duration and normalized task duration deviations are provided.

The data presented here is intended to better quantify the variability exhibited by Apollo lunar surface EVA operations, not necessarily provide prescriptive models or explanation of the specific reasons for deviations. In order to better support future EVA operations, we must first establish a baseline understanding of the natural state of variability experienced throughout EVA execution. Futhermore, despite the variability quantified and described in this paper, the EVA objectives were accomplished.

4.5.1 Timeline Execution Analysis Results

Figure 31 shows the crew timeline execution variability in terms of minutes behind schedule for each Apollo EVA. Collectively, the minutes behind schedule aggregate data set included a total of 311 associated task start times. In terms of overall timeline performance, only Apollo 15 EVA 1 finished ahead of schedule. However, much of that EVA was spent behind schedule. Over 66% of the assocaited tasks were performed while behind schedule. If the first hour of as-planned data points are excluded, 79% of the assocaited tasks were situated behind schedule. The largest observed deviation occurred 55 minutes behind schedule during Apollo 15 EVA 1. Coincidentally, the largest deviation ahead of schedule was 30 minutes, which also occurred during Apollo 15 EVA 1, due to the replanning that occured during timeline execution.

Figure 32 shows a summary of the percentage over the total planned EVA duration each EVA performed during Apollo. Out of the 11 EVAs examined in this study, only three EVAs finished ahead of the planned timeline duration. Two out of those three experienced significant timeline replanning which occured in the last EVA of each respective mission (Apollo 15 and 16).

In order to quantify aggregate variability from the individual timelines from Apollo 15-17 shown in Figure 31, a 4th order Fourier series regression model was

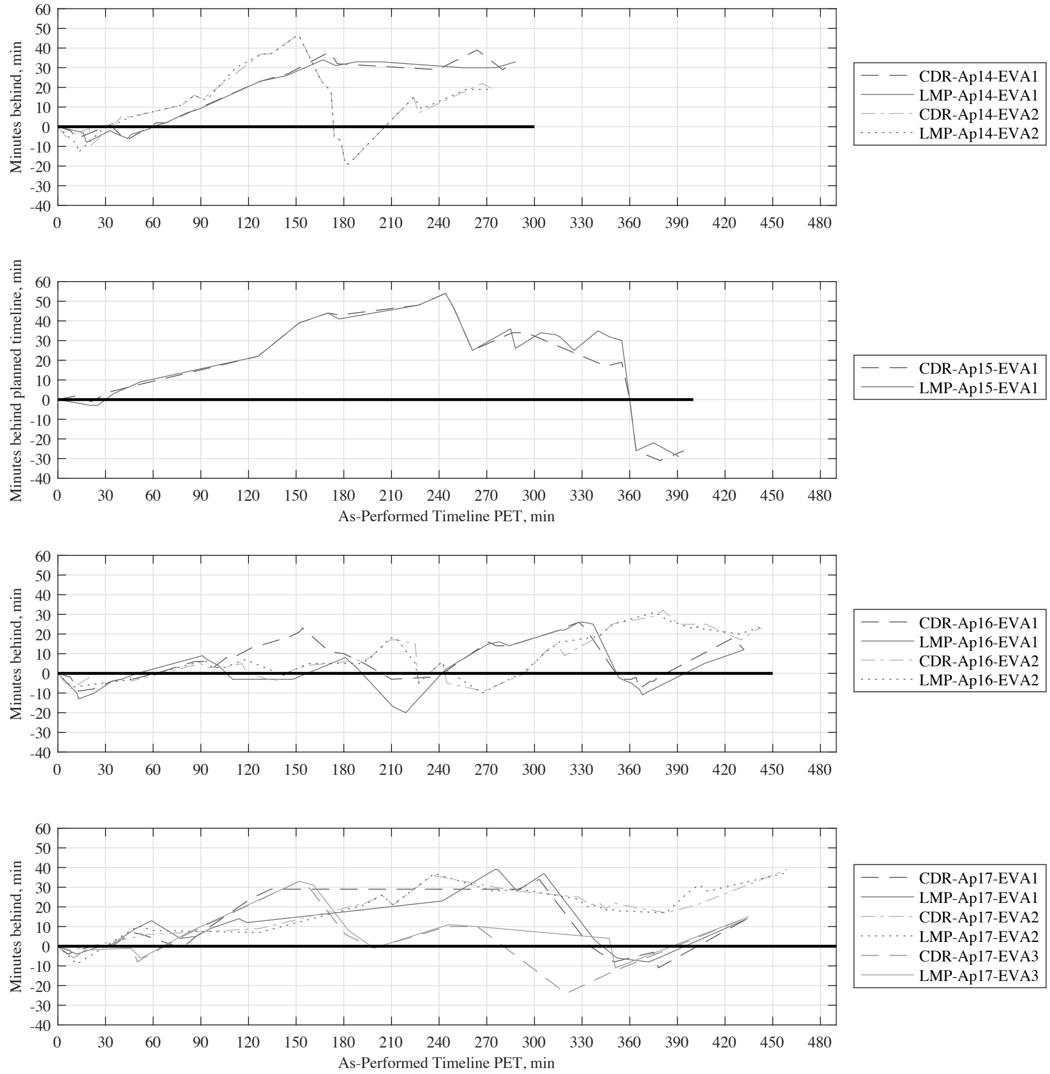


Figure 31: Minutes behind planned timeline for CDR and LMP for Apollo 14 through Apollo 17 (Top to Bottom). Bold horizontal line indicates the nominal timeline.

constructed. A Fourier series model was used as way to depict and characterize the temporal, oscillatory trends to fall behind or get ahead of schedule during EVA execution. However, the best-fit model could only explain 30% of the variability observed within the aggregate data set as shown in Figure 33. Even though the regression model does not necessarily yield predictive power, the model does provide a suitable illustration of the distribution of variability throughout a prototypical Exploration EVA timeline. From the trend data shown in Figure 33, the execution variability was classified into four operational phases: 1) Initial overhead, 2) Science objective initiation, 3) Science objective execution, and 4) Final overhead.

Phase 1 occurred from the start of the EVA timeline and lasted for approximately the first hour of operations. This period of operation typically included overhead tasks such as egress from the LM and equipment set-up, and the crew tended to

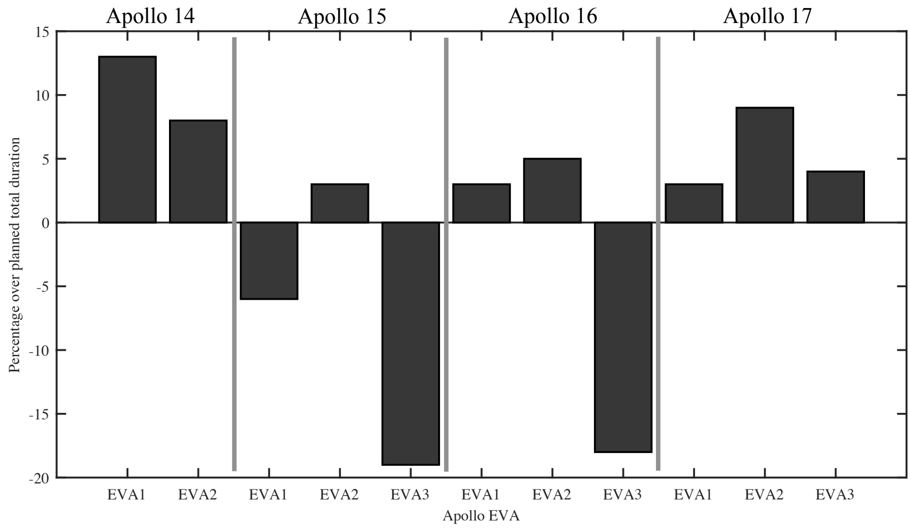


Figure 32: Percentage over planned total EVA duration per each Apollo EVA.

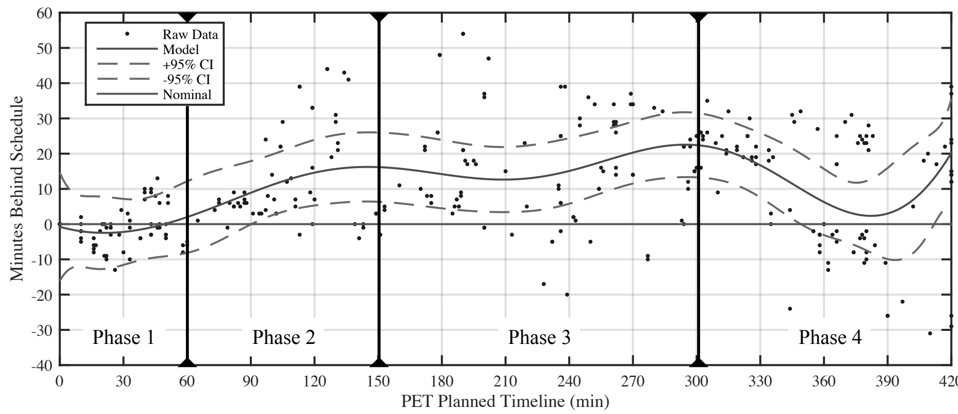


Figure 33: Minutes behind schedule as a function of PET planned timeline with Fourier series model with the following model characteristics: SSE = 5.13e+04; R-square=0.32; Adjusted R-square = 0.30; RMSE = 13.05.

perform these tasks ahead of schedule by up to 10 minutes. Once the overhead and preparatory tasks were completed, the Apollo crew entered Phase 2 which marks the transition to traversing and station activity. During this phase, the crew tended to slip behind schedule, ranging anywhere between 10 and 30 minutes behind schedule. After approximately 2 1/2 hours of EVA execution, the crew entered Phase 3, which consisted of continuing to cycle between station activity and traversing. Phase 3 exhibited highly variable behavior which fluctuated anywhere from 50 minutes behind schedule to 20 minutes ahead of schedule. Regardless of the reasons for the deviations, this cyclic behavior appears to hold true across all the EVAs examined during this segment of the timeline. Finally, the crew entered Phase 4 which encapsulated the last two hours of the planned EVA timeline. The crew tended towards the nominal timeline as they completed station activities and traversed back to the

LM. However, the end of the EVA rarely ended exactly on schedule. Notably, the crew tended to get back on schedule only to fall behind schedule within the last hour of every EVA. Timeline extensions up to 39 minutes were experienced, with the exception of Apollo 15 EVA 1. A summary of minutes behind schedule statistics for each phase of operation is shown in Table 28.

Table 28: Apollo EVA minutes behind schedule summary statistics per phase of operation.

Phase	Mean	S.D.	Median	25th % -ile	75th % -ile	min	max
1	-1.3	5.3	-2.0	-5.0	0.8	-13.0	13.0
2	12.8	13.7	7.0	3.0	22.0	-4.0	44.0
3	17.0	15.8	15.5	5.5	28.0	-20.0	50.0
4	10.9	17.3	18.0	-3.0	24.5	-31.0	39.0

Figures 31 and 33 show individual and aggregate temporal deviations associated with EVA timeline execution. However, timelines can also deviate in terms of their tasks and task objectives. Table 29 shows the breakdown of work stations for each EVA for Apollo 15 through 17. The gray cells indicate the EVAs that experienced significant deviations between the planned and as-performed timelines that resulted in them being omitted from this analysis. Nonetheless, the station data from those EVAs can be leveraged to compare across all Apollo 15 through 17 EVAs. Stations are geographic locations where specific tasks were to be performed and therefore are major structural components of the timeline and any adjustments to stations corresponds to significant timeline restructuring. For the nine Exploration EVAs performed, 68% of the planned stations were visited. Only on two occasions were a station added to the timeline during execution (Apollo 16 EVA 3 and Apollo 17 EVA 2). Stations were more commonly dropped from the timeline due to time constraints.Notably, the EVAs that closely followed their planned timelines made minimal structural changes to the EVA in terms of adding or dropping stations. A typical mechanism to cope with timeline execution perturbations was to add or drop detailed procedure tasks such as omitting a sample collection task to maintain overall timeline progress. Only when the timeline was adjusted prior to EVA execution were significant structural changes made to the target stations as opposed to during EVA execution. For each EVA, footnotes provide additional detail taken from the Apollo mission reports that describe of the major deviations experienced. Unfortunately, the mission report only provides high level summary descriptions of timeline execution perturbations.

An alternate view of the temporal variation exhibited during EVA execution is shown in Figure 34 which shows that both crew members exhibited similar execution tendencies among all three task categories. Also, the data shown in Figure 34 provide some indication as to the relative position within the timeline when the crew were performing each type task. For example, for 50% of the station activity tasks executed, the crew were situated typically up to 15 minutes behind schedule when while performing that type of task. If we consider 90% of the station activity tasks,

Table 29: Planned vs. As-performed Apollo EVA Stations. Grey cells indicate timelines that added stations to their timeline.

Apollo	EVA	Stations			
		Planned	Visited as Planned	Skipped	Added
15	1[a]	3	2	1	0
	2[b]	5	3	2	0
	3[c]	6	2	4	0
16	1[d]	4	4	0	0
	2[e]	7	6	1	0
	3[f]	7	2	5	1
17	1[g]	3	3	0	0
	2[h]	4	4	0	1
	3[i]	5	4	1	0
Total	9	44	30	14	2

[a]Station 3 was dropped because of time constraints [24]

[b]Two stations were dropped because of the time require to complete the ALSEP tasks that were not completed during Apollo 15 EVA 1 EVA and because of time constraints [24]

[c]The start of EVA was delayed and the time required to remove the deep core sample from its hole required that the traverse to the North Complex and station 14 be omitted. [24]

[d]Stations were visited as planned and only a subset of sampling tasks were dropped at Spook Crater. [25]

[e]Station 7 was deleted to allow more time for sampling at the LM and ALSEP area. [25]

[f]Timeline was limited to 5 hours which permitted only the North Ray Crater to be studied [25]

[g]The only revision made was the shortening of the geology traverse time, necessitated by delays in the ALSEP deployment [27]

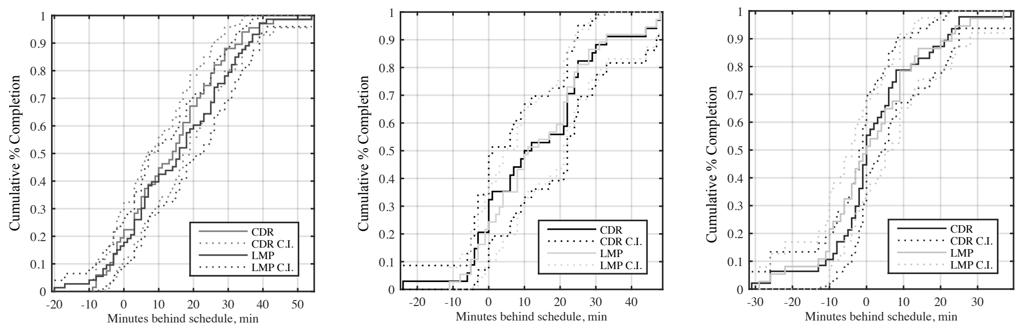
[h]The time extension was granted while at station 2 which also included the addition of a new station (2A), between stations 2 and 3. This station addition decreased the time available at station 4. [27]

[i]Timeline proceeded normally except for the elimination of station 10, which resulted from the increased time required for closeout activities and additional time taken at other stations prior to station 10. [27]

the crew were situated up to approximately 35 minutes behind schedule. Finally, the upper and lower values on x-axis limits indicated in Figure 34 show the extrema of minutes behind schedule the crew exhibited during the execution of the EVA timelines.

4.5.2 Task Execution Analysis Results

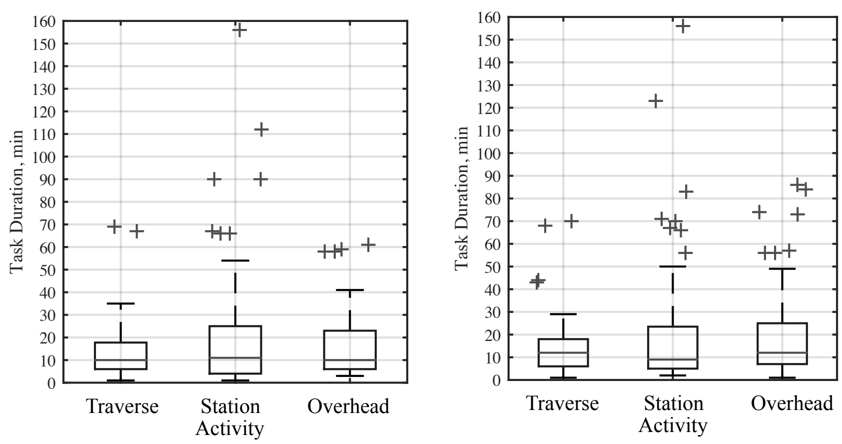
In addition to examining the global tendencies of EVA timeline execution shown in the previous section, the data was analyzed on a per task basis. Figure 35, accompanied by Table 30, shows aggregate planned and as-performed task durations were similar across all task categories. The majority of individual task durations ranged on average from 13.8 min to 16.1 min for planned tasks and 14.9 min to 20.2 min for performed tasks. Both the planned and as-performed data sources contained a limited set of task which were defined with lengthy task durations, as indicated by



(a) Station Activity (b) Traverse (c) Overhead

Figure 34: Apollo EVA minutes behind schedule cumulative percent completion with 95% confidence intervals per task category.

outliers shown in Figure 35. The majority of tasks were defined with more granular time durations. While aggregate task duration distributions are valuable from a general timeline composition perspective, the distributions do not necessarily help explain the cascading temporal perturbations exhibited between the planned and as-performed durations of each individual task throughout a timeline. For that, we must assess the normalized task duration deviations between each individual planned and as-performed task as discussed below.



(a) Planned Tasks (b) As-Performed Tasks

Figure 35: Apollo lunar surface task durations for both planned and as-performed tasks, per task category.

Figure 36 shows the normalized task duration deviation for each task category exhibit general tendencies of taking longer to be performed than planned. For Overhead tasks, the Apollo crew performed their tasks at a mean value of 27.4% longer than planned with a standard deviation of 55.9%. During Station Activity, the crew performed their tasks at a mean duration of 21% longer than planned with a standard deviation of 105.2%. Finally, for traverse tasks, the crew spent a mean duration of 43.5% longer than planned with a standard deviation of 107.1%. Overall, the crew

Table 30: Apollo EVA task duration summary statistics in minutes per task category.

Task Type	Timeline	Mean	S.D.	Median	25th % -ile	75th % -ile
Traverse	Plan.	13.8	12.7	10.0	6.0	17.8
	As-Perf.	14.9	13.1	12.0	6.0	18.0
Station	Plan.	19.3	22.7	11.0	4.0	25.0
	As-Perf.	18.0	22.2	9.0	5.0	23.5
Overhead	Plan.	16.1	14.7	10.0	6.0	23.0
	As-Perf.	20.2	20.0	12.0	7.0	25.0

exhibited a large amount of variability in individual task performance, and generally took longer than expected for their performed tasks. Crew tended to execute overhead tasks, which tend to be clearly defined engineering tasks, more consistently to planned times. However, executing actions such as traversing and station activities were more challenging to execute per the planned timeline. Note the data shown in Figure 31 omits outlier values greater than three to make the graph legible. The entire distribution of normalized duration deviation values are shown in Figure 37.

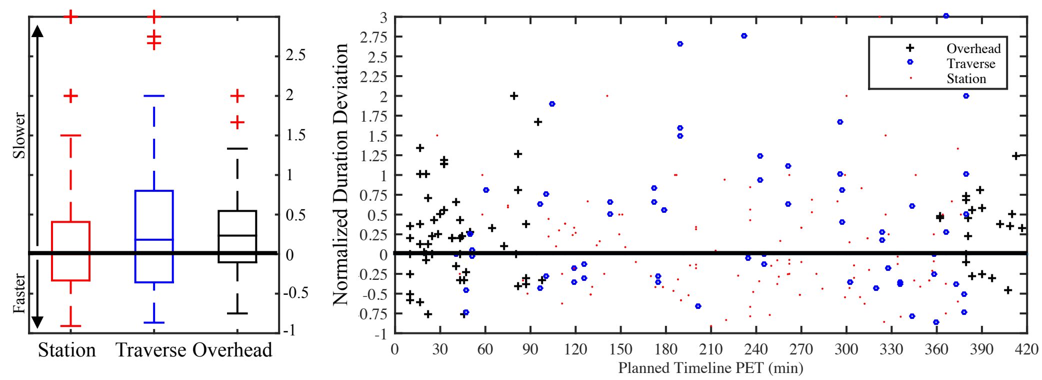
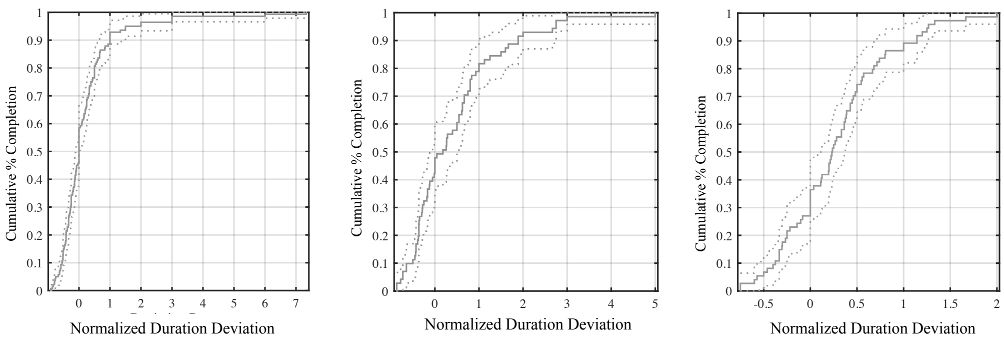


Figure 36: Normalized duration deviation [e.g. As-performed duration minus planned duration divided by planned duration] for the three task categories: Overhead, Station Activity, and Traverse.

Table 31: Apollo EVA normalized duration deviation summary statistics.

Task Category	Mean	S.D.	Median	25th Percentile	75th Percentile
Station	0.205	1.048	0.0	-0.333	0.406
Traverse	0.436	1.071	0.181	-0.356	0.800
Overhead	0.273	0.559	0.234	-0.103	0.545

Finally, Figure 37 shows the relative spread of task duration deviations per task category in the form of cumulative percent completion plots. For station activities, the crew performed 50% of their tasks within the planned duration time. Alternatively, when considering 90% of the traverse tasks performed during Apollo, the crew required potentially up to 200% more time to complete than originally planned. Station activity and Overhead tasks required up to 100% additional time to complete their respective tasks, considering 90% of their respective tasks performed.



(a) Station Activity **(b)** Traverse **(c)** Overhead

Figure 37: Apollo EVA normalized deviate distribution functions (with 95% confidence intervals) per task category (CDR and LMP tasks are combined).

4.6 Aggregate EVA Telemetry Results

In order to maintain symmetry in the aggregate analysis process, Apollo 14 was also omitted from the aggregated telemetry data analysis since Apollo 14 EVAs were structurally different from Apollo 15-17. From this point forward, we will only consider the data from Exploration Class EVAs observed during Apollo 15-17 when discussing aggregate data trends.

The aggregate results are divided in two main sections based on the aforementioned measures: 1) metabolic rate trends per EVA per crew member and 2) consumables usage. Section 4.6.1 details the metabolic rate analysis per EVA and as an aggregate data set. A linear model was applied to the aggregate data set to attempt to model the metabolic rate trends. Metabolic rate trends are then presented as box and whisker plots and cumultative distribution funcitons to describe the variability exhibited during Apollo EVA operations. Finally, the consumable usage for each timeline are presented in Section 4.6.2.The intent of this section is to emphasize that metabolic rate is highly variable, and is an important parameter to assess during EVA execution realtime to understand how to proceed with execution in a safe manner.

4.6.1 Metabolic Rate Results

As shown in Figure 38, metabolic rate varied widely for each crew member during each EVA. The calculated metabolic rates exhibited peaks of extreme highs (>2000 BTU/Hr) and extreme lows (>350 BTU/Hr). The Apollo mission reports stated values less than 350 BTU/Hr were unreliable, however we included all data in our analysis.

The raw metabolic rate was modeled as a linear function of the planned timeline to generalize the metabolic trends and confidence intervals exhibited during Apollo. The general trend shown in Figure 39 increases as an EVA progresses, but given the nearly uniform distribution of metabolic rate values, no statistically significant trends are apparent. None the less, the inherent variability of metabolic rate is high throughout EVA execution. Metabolic rate is inherently variable because every single person's body operates in a unique fashion, which also means consumables estimates have to be tested/estimated in a manner that caters to the individual. Metabolic rate is also affected by nearly all functions of the body both physiological and psychological. As discussed in the next section, Metabolic rate is difficult to predict prior to execution and subsequently it is difficult to predict the consumables usage associated to a particular EVA timeline.

4.6.2 Consumables Results

Figure 42 shows the percent difference between the actual consumables usage and predicted usage values. In effect, positive values indicate that the crew ended the EVA with more consumables than expected. However, negative values indicate the crew ended the EVA with less consumable values, i.e. less life support capacity, than predicted. Notably the only EVAs where predictions exceeded actual values were the EVAs that conducted truncated timelines. In particular, Apollo 17 demonstrates

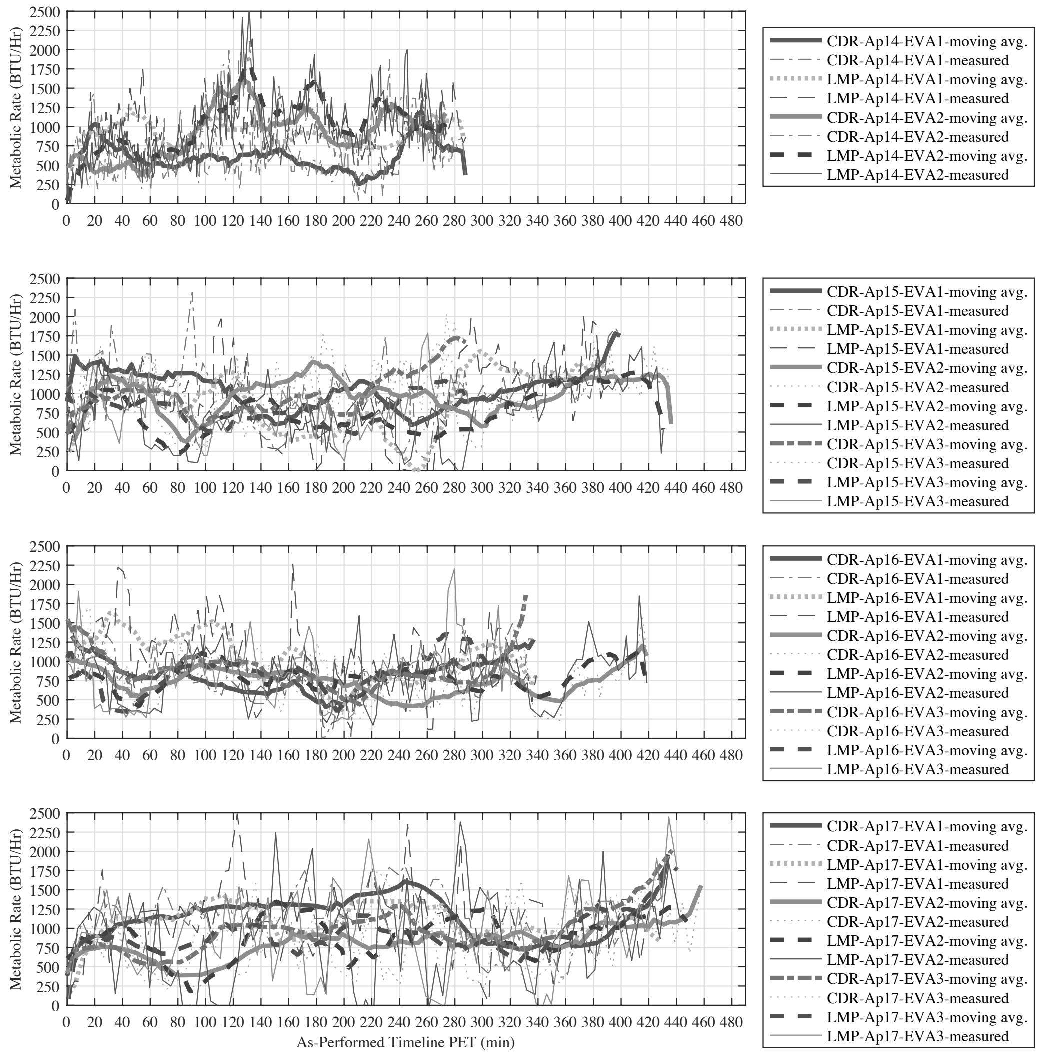


Figure 38: Metabolic Rate (BTU/Hr) per crewmember and EVA across the duration of the mission.

that even though the timelines may have been successfully executed from a task objective perspective, consumables were used to a greater degree than predicted, over 10% predictive error in some instances.

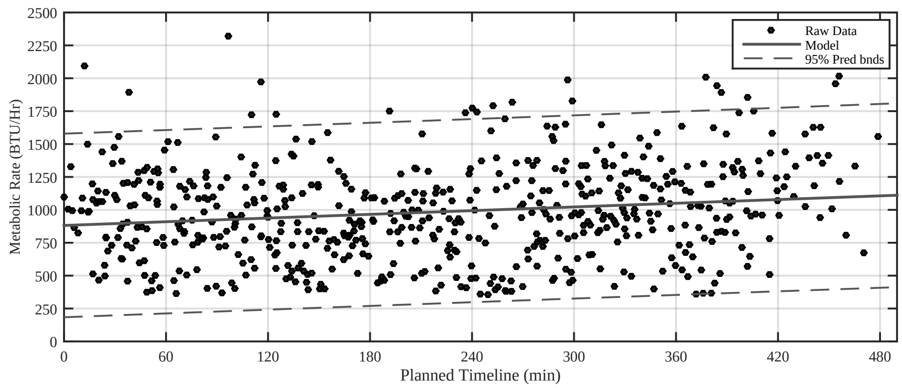


Figure 39: Metabolic rate modeled as a linear function [SSE = 7.205e+07; R-square=0.02672; Adjusted R-square = 0.02503; RMSE = 354]

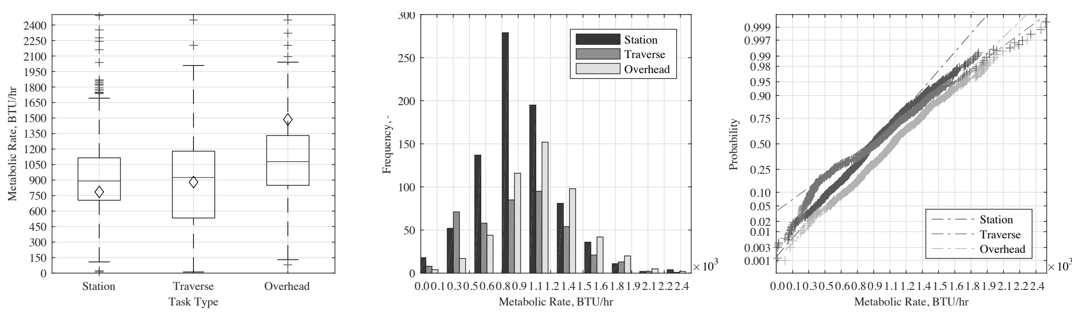
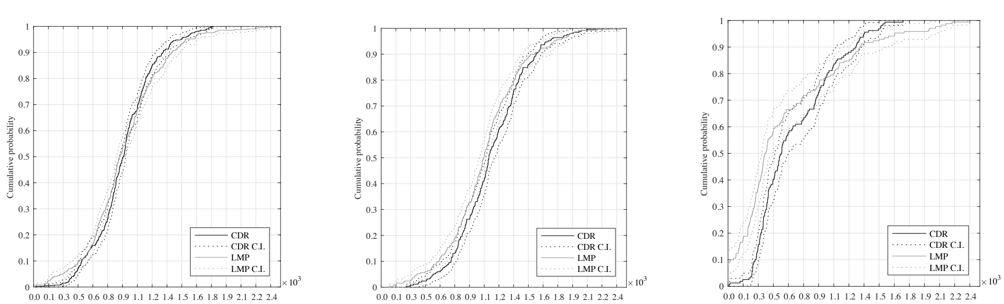


Figure 40: Box and whisker plots (with mean values) of metabolic rate per task type for Apollo 15 through 17.



(a) Station Activity **(b)** Traverse **(c)** Overhead

Figure 41: Apollo EVA Metabolic Rate cumulative probability plots with 95% confidence intervals per task category.

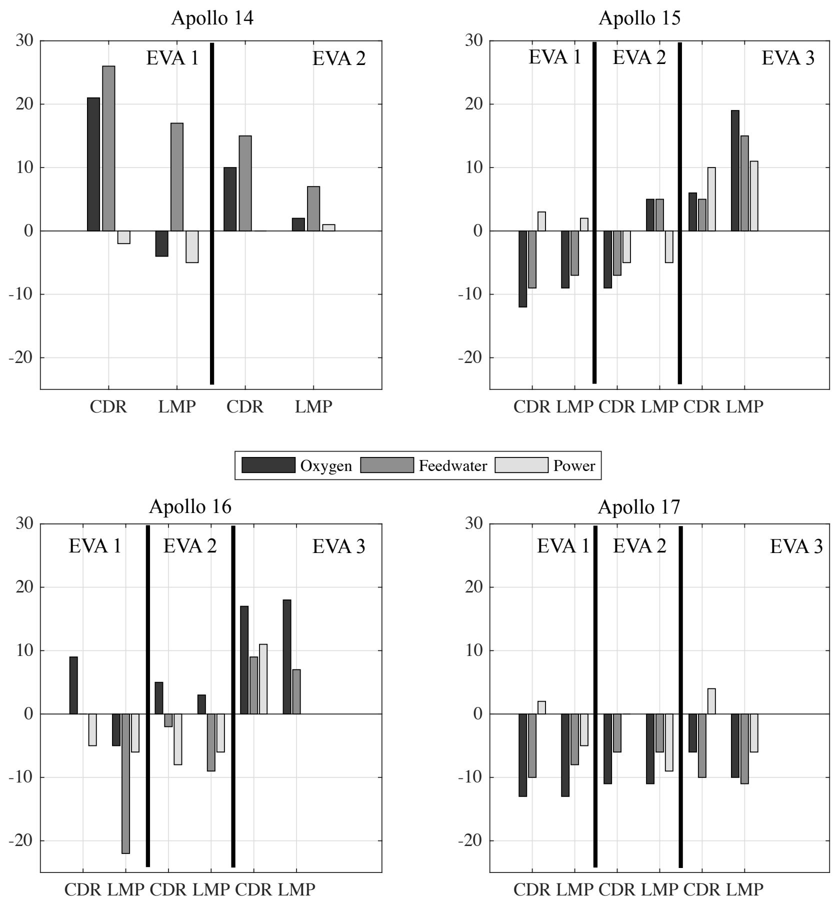


Figure 42: Percent difference between Actual and Predicted consumable usage for Apollo 14 through 17. Positive values indicate usage was overpredicted whereas negative values indicated underpredicted usage.

5 Discussion & Implications for Future EVA Operations

Coping with real-time schedule perturbations is not a phenomenon unique to the EVA community. In fact, many other disciplines have developed sophisticated methodologies to recognize, respond and rectify schedule perturbations. For example, air traffic control operations research has decades of literature that isolate, define, and resolve operational perturbations [72–75]. To date, the EVA work domain does not yet have the detailed operational literature comparable to well-studied domains such as air traffic control operations. The opportunity exists to systematically structure the EVA work domain as a formal area of research by first identifying and quantifying perturbations that exist during EVA timeline execution. Additionally, we can leverage the volumes of operational insight from other work domains that face many of the same real-time operational challenges of coping with schedule perturbations such as air traffic control [72, 73], manufacturing systems [76], and health care operations [77, 78] to help shape and inform future EVA concepts of operations.

Future exploration EVAs will likely mimic the Apollo-style timeline structure and execution tendencies quantified in the aforementioned sections. The vast majority of EVAs performed by NASA have been performed with engineered objectives on engineered surfaces. However, future EVAs will entail science objectives and operations on natural surfaces similar to those conducted during Apollo EVA. There is now a pressing need to leverage the operational experience of previous missions such as Apollo to help inform the development of future missions. The execution of EVA timelines are inherently dynamic. Even though the Apollo timelines were scripted to the minute and crew underwent years of training, the crew faced challenges that caused of timeline execution deviations. While this study does not comprehensively identify and quantify the reason for deviations, we quantify the specific regions of the timeline where the crew did experience deviations to spur further investigation. In general, timeline execution deviations can be caused by many reasons, and in most cases are unpredictable. Improper/unexpected procedure execution, hardware malfunctions, and crew fatigue were common challenges the Apollo crew faced. Through July 27, 2016, NASA performed a total of 391 EVAs and 110 (28%) experienced significant incidents such as systems issues, operational incidents or inadvertent releases. [79] The task of assessing timeline validity and potential changes while considering crew safety has been a joint endeavor between astronauts and ground support personnel for the entire history of EVA operations. Future crew will need to contend with this operational variability in a more independent manner in future deep-space missions..

The EVA execution deviations for lunar surface operations were calculated to be on the order of minutes to tens of minutes. Those values may not readily appear significant, particularly in comparison to 7 hours worth of tasks. However, within the context of EVA operations, time utilization is at a premium both in terms of acheiving task objectives and maintaining a safe operaitonal environment. As an example, if the crew take 15% longer on a 7 hour planned EVA, they have effectively reached the 8 hour limit with regards to their life support systems. Furthermore, the capacity of the life support systems vary throughout the EVA, as tasks are executed which creates a moving life support system deadline that must be considered. As demonstrated by the Apollo EVAs, the ability to stay on schedule and end with desired consumable states is difficult to acheive.

If we consider an analogous work domain such as air traffic control operations, an aircraft follows a prescribe flight profile, or trajectory, to take passengers from one airport to another. The pilots and air traffic controllers must collectively manage the taxi, take off, cruise and landing phases of operations to ensure a successful transit. During each phase of operation, considerations of fuel usage and flight time must be weighed against the demands of aircraft traffic (both air and ground) and weather conditions. The EVA work domain faces similar challenges. The astronauts and ground support personnel collaboratively execute a sequence of phases (e.g. overhead, traverse, and station activities) under the constraints imposed by life support system variables such as oxygen, water, power, environmental factors, and task procedures. If the crew work harder or take longer than expected to complete tasks, tasks later in the timeline could be impacted by the capabilities of the life support systems.

The Apollo missions demonstrated that lunar surface EVAs could successfully be performed within the variability quantified in this study. However, if we consider the aforementioned timeline execution deviations in relation to the life support consumables at the end of each EVA, a more nuanced, and critical aspect of EVA operations is revealed. Only in 7 instances did estimated remaining consumable values at the end of the EVA exceed actual values. In some cases, predicted values were under estimated by more than 20% compared to what was actually required by the crew to complete the EVA. Excessive engineering margins designed into the spacesuit capabilities and conservative flight rules were the safeguard against exceeding consumable limits. Futhermore, the ability to cope with these variations were a joint-effort between the crew and mission control. A challenge for future missions will be to enable crew to manage this variability to ensure mission success.

6 Conclusions

A quantitative assessment of lunar surface EVA operations was generated from the planned and performed timeline data published in the Apollo mission literature. Rather than computing only averaged statistics, this paper quantified a more complete description of the statistical variability experienced throughout the execution of the Apollo lunar surface EVA timeline and life support system variables. Modeling and quantifying the distribution of variability provides the opportunity to understand the inherent variability and challenges of conducting future EVA operations. This study depicted that even the most highly skilled crew still exhibit lagging and fluctuating trends in timeline execution. Additionally, the ability to predict consumable states at the end of the EVA can be difficult to estimate. The notion of nominal operations must consider these fluctuations as part of the expect execution tendancies. Future operations will likely contend with similar deviation tendencies which inevitably must be accommodated, managed, and mitigated. More specifically, how might future support systems assist with making this variability more transparent to crew to that they can cope with the timeline exeuction and life support system deviations? While this study did not specifically examine the sources of the exhibited variation, the results illustrate that EVA execution has inherent variability and the data presented provides avenues to perform more targeted studies within the volumes of Apollo documents available.

Quantifying the variability of EVA execution provides an opportunity to calibrate expectations for future missions. Present-day EVA variability is managed extensively by ground support personnel to ensure successful task completion. In addition to executing the timeline, ground personnel must manage the variability of life support systems to ensure a safe operational environment for the crew. Future operations will require crew to manage the circumstances that cause timeline deviations in the absence of real-time influence from ground support personnel, due to the significant time-delayed communication environment of deep-space. A future challenge will be to enable crew capability to manage the wealth of information contained within an EVA timeline in a way that does not burden or prohibit their ability to perform their mission objectives. Future work is also needed to refine EVA operational understanding and facilitate the transition of ground support functions to crew so that the crew may be able to cope with the variability in operations they will surely face.

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Appendix A

Apollo 14 through 17 EVA Timeline Data

Table Formatting:

- Grayed out boxes indicate that a direct time comparison between the planned and performed time line could not be made
- NA indicates times were not readily available or tasks were not confirmed

A.1 Apollo 14 - EVA 1 - CDR Timeline

Table A32: Apollo 14 EVA 1 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress Operations	8	0	Pre-Egress and Egress Operations	Overhead
-2	8	10	Egress	4	8	Egress	Overhead
-6	4	18	Environment Familiarization	21	12	Environment Familiarization	Overhead
NA	4	22	Met Offload	NA	NA	Modular Equipment Transporter (MET) Unloading	Station
NA	6	26	TV Deploy	NA	NA	Television Deployment	Station
1	18	32	S-Band Antenna Depolyment	10	33	S-Band antenna Deployment	Station
-7	10	50	Expendables Transfer	19	43	Expendables Transfer	Station
2	6	60	Flag Deployment	6	62	Flag Deployement & Photography	Station
2	8	66	LM & Site Inspections/Photo	18	68	Lunar Module and Site Inspection	Station
NA	3	74	Met Deploy	NA	NA	NA	NA
9	3	77	Carry Tv to View Alsep Offload	3	86	Television transfer to Scientific Equipment Bay	Station
9	24	80	ALSEP Offload	14	89	Experiments Package Off Loading	Station
NA	NA	NA	NA	3	103	Television Positioning	Station
NA	NA	NA	NA	15	106	Modular Equipment Transporter Deployment	Station
NA	NA	NA	NA	6	121	Unknown Activity	Station
23	7	104	ALSEP Travese	18	127	Traverse to Experiment Package Deployment Site	Traverse

NA	7	111	ALSEP Site Survey	NA	NA	NA	NA
27	10	118	ALSEP System Interconnect	26	145	Experiment Package System Interconnect	Station
NA	5	128	PSE Offload	NA	NA	Passive Seismic Offloading	Station
NA	NA	NA	NA	NA	NA	Laser Ranging Retro-Reflector Deployment	Station
38	11	133	Sunshield Deployment	5	171	Charged Particle Lunar Environment Experiment Deployment	Station
32	10	144	ALSEP Antenna Installation	63	176	Deployment of Experiment Package Antenna	Station
NA	6	154	PSE Deployment	NA	NA	Passive Seismic Experiment	Station
NA	6	160	LR3 Deploy	NA	NA	Laser Ranging Retro-Reflector	Station
NA	10	166	ALSEP Photography	NA	NA	NA	NA
NA	19	176	Samples Collection	NA	NA	Sample Collect	Station
NA	15	195	Samples Collection	NA	NA	NA	NA
29	15	210	Return Traverse	16	239	Return Traverse	Traverse
NA	NA	NA	NA	6	255	Unknown Activity	Station
NA	NA	NA	Sample Collect	3	261	Sample Collect	Station
39	26	225	EVA Closeout	16	264	Closeout Activites	Overhead
29	4	251	Ingress	8	280	Ingress	Overhead
33		255	END		288	END	Overhead
Total Durations		**255 4 hours 15 mins**			**288 4 hours 48 mins**		

A.2 Apollo 14 - EVA 1 - LMP Timeline

Table A33: Apollo 14 EVA 1 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	19	0	Pre-Egress Operations	16	0	Cabin Depressurization	Overhead
-3	7	19	Egress	2	16	Egress	Overhead
-8	6	26	Environment Familiarization	15	18	Environmental Familiarization	Overhead
NA	3	32	Conting. Sample	NA	NA	Contingency Sample Collection	Station
-2	4	35	SWC	2	33	Deployment of Solar Wind Composition Experiment	Station
-3	12	38	LR3	9	35	Laser Range Retro-Reflector Unloading	Station
-6	2	50	Ingress	2	44	Ingress	Station
-6	7	52	S-Band Switching & Transfer	12	46	S-Band Switching in Lunar Module	Station
-1	1	59	Egress	1	58	Egress	Station
NA	NA	NA	NA	5	59	Camera Setup	Station
4	6	60	Flag Deployment & Photography	4	64	U.S. Flag Deployment and Photography	Station
2	2	66	Traverse to Television	3	68	Traverse to Television	Traverse
3	6	68	Television Panorema	10	71	Television Panorema	Station
7	6	74	Met Deploy	8	81	Modular Equipment Transporter Deployment	Station
9	24	80	ALSEP Offload	38	89	Experiment Package Offloading	Station
23	7	104	ALSEP Travese	17	127	Traverse to Experiment Package Deployment Site	Traverse
NA	7	111	ALSEP Site Survey	NA	NA	NA	NA
26	10	118	ALSEP Systemm Interconnect	23	144	Experiment Package System Interconnect	Station
NA	5	128	Thumper/Geophone Offload	NA	NA	Thumper and Geophone Unloading	Station
34	11	133	Motor Package & CPLEE Deployment	8	167	Mortar Offload	Station
31	11	144	Side/CCIG Deployment	13	175	Suprathermal Ion Detector Experiment Unloading and Deployment	Station
33	15	155	Geophone Deployment	15	188	Geophone Deployment	Station

NA	NA	NA	NA	NA	NA	Penetrometer Activity	Station
33	40	170	Thumper Activity	35	203	Thumper Activity	Station
23	10	215	Mortar Packing Arming	5	238	Mortar Pack Arming	Station
33	5	210	Return Traverse	12	243	Return Traverse	Traverse
30	21	225	EVA Closeout	21	255	Extravehicular Activity Closeout	Overhead
30	9	246	Ingress	12	276	Ingress	Overhead
33		255	END		288	END	Overhead
Total		**255**			**288**		
Durations		**4 hours 15 mins**			**4 hours 48 mins**		

A.3 Apollo 14 - EVA 2 - CDR Timeline

Table A34: Apollo 14 EVA 2 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress Operations	5	0	Cabine Depress	Overhead
-5	5	10	Egress	7	5	Egress	Overhead
-3	6	15	Fam/ETB Transfer	8	12	Familiarization and Transferal of Equipment Transfer Bag	Overhead
-1	9	21	Met Load	0	20	Modular Equipment Transporter Loading	Overhead
-10	4	30	Lunar Portable Magnetorquer Offload	15	20	Lunar Portable Magnetometer Offloading	Overhead
1	1	34	MET Track & Foot Print EVA1	5	35	Evaluation of Modular Equipment Transporter Track	Overhead
5	6	35	Lunar Module to A Traverse	6	40	Lunar Module to A Traverse	Traverse
5	9	41	Station A Activity-TDS Experiment	32	46	Station A Activity	Station
NA	9	50	Photo LMP & Targets of Oppurtunity	NA	NA	NA	NA
NA	8	59	Double Core	NA	NA	NA	NA
11	3	67	Go to Station B	8	78	A to B Traverse	Traverse
16	7	70	Station B	5	86	Station B Activity	Station
14	3	77	Go to Bend Area	3	91	B to Delta Traverse	Traverse
14	2	80	Activites at Bend Area	3	94	Station Delta Activity	Station
NA	NA	NA	NA	3	97	Delta to B1 Traverse	Traverse
NA	NA	NA	NA	4	100	Station B1 Activity	Station
NA	NA	NA	NA	5	104	B1 to B2 Travese	Traverse
NA	NA	NA	NA	3	109	Station B2 Activity	Station
30	8	82	Go to N side, Station D	14	112	B2 to B3 Traverse	Traverse
36	1	90	Station D	2	126	Station B3 Activity	Station
37	6	91	Go to cone Crater Rim	6	128	B3 to C Traverse	Traverse
37	7	97	Cone Crater Rime Activity	16	134	Station C Activity	Station
46	2	104	Proceed to S Side of Cone Rim	2	150	C to C1 Traverse	Traverse
46	15	106	S side of Cone Crater Rim Activity-Polarimetirc Survey	6	152	Station C1 Activity	Station
37	7	121	EVA Comm Evaluation	6	158	C1 to C2 Traverse	Traverse
NA	NA	NA	NA	2	164	Station C2 Activity	Station

NA	7	128	Go to Station D	NA	NA	NA	NA
NA	8	135	Station D	NA	NA	NA	NA
23	11	143	Go to Station E	6	166	C2 to E Traverse	Traverse
18	25	154	Station E Activity	2	172	Station E Activity	Station
-5	6	179	Go to Station F	4	174	E to F Traverse	Traverse
-7	15	185	Station F Activity	3	178	Station F Activity	Station
-19	2	200	Go to G	2	181	F to G Traverse	Traverse
-19	7	202	Station G Activity	36	183	Station G Activity	Station
NA	NA	NA	NA	2	219	G to G1 Traverse	Traverse
NA	NA	NA	NA	3	221	Station G1 Activity	Station
15	5	209	Go to LM	3	224	G1 to Lunar Module	Traverse
NA	6	214	Arrive at LM	NA	NA	NA	NA
7	25	220	EVA Closeout	40	227	Extravehicular Activity Closeout	Overhead
22	10	245	Eva Termination	7	267	Extravehicular Activity Termination	Overhead
19		255	END		274	END	Overhead
Total Durations		**255 4 hours 15 mins**			**288 4 hours 48 mins**		

A.4 Apollo 14 - EVA 2 - LMP Timeline

Table A35: Apollo 14 EVA 2 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	21	0	Pre-Egress Operations	12	0	Cabin Depress	Overhead
-9	5	21	Egress	1	12	Egress	Overhead
-13	4	26	Met Load Assist	18	13	Modular Equipment Transporter Preparation	Overhead
1	4	30	Lunar Portable Magnetometer Offloading	5	31	Lunar Portable Magnetometer Offloading	Overhead
2	2	34	Uncage meters & turn on electronics, discard pallet	2	36	Lunar Portable Magnemeter Operation	Overhead
2	5	36	Station A Traverse	8	38	Lunar Module to A Traverse	Traverse
5	18	41	Station A - LPM Point Meausurement	32	46	Station A Activity	Station
NA	8	59	Double Core	NA	NA	NA	NA
11	3	67	Go to Station B	8	78	A to B Traverse	Traverse
16	7	70	Station B	5	86	Station B Activity	Station
14	3	77	Go to Bend Area	3	91	B to Delta Traverse	Traverse
14	2	80	Activites at Bend Area	3	94	Station Delta Activity	Station
NA	NA	NA	NA	3	97	Delta to B1 Traverse	Traverse
NA	NA	NA	NA	4	100	Station B1 Traverse	Traverse
NA	NA	NA	NA	5	104	B1 to B2 Travese	Traverse
NA	NA	NA	NA	3	109	Station B2 Activity	Station
30	8	82	Go to N side, Station D	14	112	B2 to B3 Traverse	Traverse
36	1	90	Station D	2	126	Station B3 Activity	Station
37	6	91	Go to cone Crater Rim	6	128	B3 to C Traverse	Traverse
37	7	97	Cone Crater Rime Activity	16	134	Station C Activity	Station
46	2	104	Proceed to S Side of Cone Rim	2	150	C to C1 Traverse	Traverse
46	15	106	S side of Cone Crater Rim Activity- Polarimetirc Survey	6	152	Station C1 Activity	Station
NA	7	121	EVA Comm Evaluation	6	158	C1 to C2 Traverse	Traverse
NA	NA	NA	NA	2	164	Station C2 Activity	Station
NA	7	128	Go to Station D	NA	NA	NA	NA
NA	8	135	Station D	NA	NA	NA	NA
23	11	143	Go to Station E	6	166	C2 to E Traverse	Traverse
18	25	154	Station E Activity	2	172	Station E Activity	Station
-5	6	179	Go to Station F	4	174	E to F Traverse	Traverse

-7	15	185	Station F Activity	3	178	Station F Activity	Station
-19	2	200	Go to G	2	181	F to G Traverse	Traverse
-19	7	202	Station G Activity	36	183	Station G Activity	Station
NA	NA	NA	NA	2	219	G to G1 Traverse	Traverse
NA	NA	NA	NA	3	221	Station G1 Activity	Station
15	5	209	Go to LM	5	224	G1 to Lunar Module	Traverse
NA	6	214	Arrive at LM	NA	NA	NA	NA
9	18	220	EVA Closeout	28	229	Extravehicular Activity Closeout	Overhead
19	17	238	Eva Termination	17	257	Extravehicular Activity Termination	Overhead
19		255	END		274	END	Overhead
Total Durations		**255 4 hours 15 mins**			**288 4 hours 48 mins**		

A.5 Apollo 15 - EVA 1 - CDR Timeline

Table A36: Apollo 15 EVA 1 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Depressurize LM	12	0	Pre-Egress	Overhead
2	12	10	CDR Egress	9	12	Egress	Overhead
-1	7	22	TV Deploy	12	21	TV Deploy	Overhead
4	16	29	LRV Offload and Deploy	20	33	LRV Offload and Deploy	Overhead
8	59	45	LRV Config. and Trav. Prep.	73	53	LRV Config. and Trav. Prep.	Overhead
22	9	104	Trav. to Station #1	26	126	Trav. to Station #1	Traverse
39	13	113	Station #1 Tasks:	18	152	Station #1 Tasks:	Station
NA	NA	NA	-Geol. Site Selection	4	152	-Geol. Site Selection	Station
NA	NA	NA	-Radial Sample	9	156	-Radial Sample	Station
NA	NA	NA	-Trav. Prep.	5	166	-Trav. Prep.	Station
44	8	126	Trav. to Station #2	7	170	Trav. to Station #2	Traverse
43	45	134	Station #2 Tasks:	51	177	Station #2 Tasks:	Station
NA	NA	NA	-Geol. Description & Doc. Samples	22	177	-Geol. Description & Doc. Samples	Station
NA	NA	NA	-Comprehensive Sample	8	199	-Comprehensive Sample	Station
NA	NA	NA	-Double Core	11	207	-Double Core	Station
NA	NA	NA	-500mm Photo and Trav. Prep.	10	218	-500mm Photo and Trav. Prep.	Station
48	11	179	Trav. to Station #3	17	227	Trav. to Station #3	Traverse
54	12	190	Station #3 Tasks:	4	244	Station #3 Tasks:	Station
NA	NA	NA	-Samples and Trav. Prep.	4	244	-Samples and Trav. Prep.	Station
47	34	202	Trav. to LM	12	249	Trav. to LM	Traverse
25	16	236	ALSEP Offload	25	261	ALSEP Offload	Station
34	9	252	ALSEP Trav.	9	286	ALSEP Trav.	Traverse
NA	99	261	ALSEP Tasks:	65	295	ALSEP Tasks:	Station
34	67	261	-HFE Deploy	51	295	-HFE Deploy	Station
17	8	328	-LR 3 Deploy	9	345	-LR 3 Deploy	Station
19	24	336	-ALSEP Photo and Trav. Prep.	5	355	-ALSEP Photo and Trav. Prep.	Station
0	30	360	Trav. to LM	4	360	Trav. to LM	Traverse
-26	20	390	EVA Closeout	15	364	EVA Closeout	Overhead
-31	10	410	EVA Termination	15	379	EVA Termination	Overhead
-26		420	END		394	END	Overhead
Total Durations		**420 7 hours**			**394 6 hours 34 mins**		

A.6 Apollo 15 - EVA 1 - LMP Timeline

Table A37: Apollo 15 EVA 1 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	24	0	Depressurize LM	21	0	Pre-Egress	Overhead
-3	4	24	LMP Egress	4	21	Egress	Overhead
-3	4	28	Contingency Sample	10	25	Contingency Sample	Station
3	11	32	LRV Offload and Deploy	17	35	LRV Offload and Deploy	Overhead
9	61	43	LRVConfig.	74	52	LRV Config.	Overhead
22	9	104	Trav. to Station #1	26	126	Trav. to Station #1	Traverse
39	13	113	Station #1 Tasks:	18	152	Station #1 Tasks:	Station
NA	NA	NA	-Photo Pan	4	152	-Photo Pan	Station
NA	NA	NA	-Radial Sample	9	156	-Radial Sample	Station
NA	NA	NA	-Trav. Prep.	5	166	-Trav. Prep.	Station
44	10	126	Trav. to Station #2	7	170	Trav. to Station #2	Traverse
41	43	136	Station #2 Tasks:	51	177	Station #2 Tasks:	Station
NA	NA	NA	-Photo Pan and Documented Samples	22	177	-Photo Pan and Documented Samples	Station
NA	NA	NA	-Comprehensive Sample	8	199	-Comprehensive Sample	Station
NA	NA	NA	-Double Core	11	207	-Double Core	Station
NA	NA	NA	-70mm Pan and Trav. Prep.	10	218	-70mm Pan and Trav. Prep.	Station
48	11	179	Trav. to Station #3	17	227	Trav. to Station #3	Traverse
54	12	190	Station #3 Tasks:	4	244	Station #3 Tasks:	Station
NA	NA	NA	-Monitor CDR From LRV	4	244	-Monitor CDR From LRV	Station
47	34	202	Trav. to LM	12	249	Trav. to LM	Traverse
25	13	236	ALSEPOffload	24	261	ALSEP Offload	Station
36	13	249	ALSEP Trav. (walking carrying ALSEP Barbell)	3	285	ALSEP Trav. (walking carrying ALSEP Barbell)	Traverse
NA	98	262	ALSEP Tasks:	72	288	ALSEP Tasks:	Station
26	8	262	-ALSEP Interconnect	16	288	-ALSEP Interconnect	Station
34	10	270	-PSE Deploy	8	304	-PSE Deploy	Station
33	4	280	-SWE Deploy	4	313	-SWE Deploy	Station
32	16	284	-LSM Deploy	9	316	-LSM Deploy	Station
25	5	300	-Sunshield Deploy	14	325	-Sunshield Deploy	Station
35	10	305	-ALSEP Antenna Installation	7	340	-ALSEP Antenna Installation	Station
32	10	315	-Side Deploy	8	347	-Side Deploy	Station

30	35	325	-C/S Activate & LSM Sunshield Deploy	5	355	-C/S Activate & LSM Sunshield Deploy	Station
0	30	360	Trav. to LM	4	360	Trav. to LM	Traverse
-26	7	390	EVACloseout	11	364	EVACloseout	Overhead
-22	23	397	EVA Termination	16	375	EVA Termination	Overhead
-29		420	END		391	END	Overhead
Total Durations		**420 7 hours**			**391 6 hours 31 mins**		

A.7 Apollo 15 - EVA 2 - CDR Timeline

Table A38: Apollo 15 EVA 2 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	10	0	Pre-Egress	Overhead
0	7	10	Egress	5	10	Egress	Overhead
NA	6	17	Pallet and ETB xfer	NA	NA	NA	NA
-8	22	23	Equipment Prep	34	15	Equip. Prep.	Overhead
4	5	45	LRV Nav. Initialization	7	49	LRV Nav. Init.	Overhead
NA	10	50	Traverse to Checkpoint	NA	NA	NA	NA
NA	2	60	Arrive at Checkpoint	NA	NA	NA	NA
NA	15	62	Traverse to Station 4	NA	NA	NA	NA
NA	20	77	Station 4 Geology	NA	NA	NA	NA
NA	10	97	Trav to 1st checkpoint	NA	NA	NA	NA
NA	4	107	Arrive at 1st checkpoint	NA	NA	NA	NA
NA	9	111	Trav to 2nd checkpiont	NA	NA	NA	NA
NA	5	120	Arrive at 2nd checkpoint	NA	NA	NA	NA
NA	5	125	Trav to 3rd checkpoint	NA	NA	NA	NA
NA	4	130	Arrive at 3rd checkpoint	NA	NA	NA	NA
NA	12	134	Traverse to Station 5	NA	NA	NA	NA
NA	51	146	Station 5 Geology	NA	NA	NA	NA
-140	15	197	Traverse to Station #6	43	57	Trav. to Station #6	Traverse
-112	41	212	Station 6 Geology:	65	100	Station #6 Tasks:	Station
NA	NA	NA	-Description of Sampling Area and Comparison to Others	NA	NA	NA	NA
NA	NA	NA	-Document Samples	31	100	-Documented Samples	Station
NA	NA	NA	-Explore Trench	9	131	-Soil Mech. Trench	Station
NA	NA	NA	-Core Tube	4	141	-Single Core	Station
NA	NA	NA	NA	5	145	-Documented Samples	Station
NA	NA	NA	-500 mm Lens Camera Photograph	15	150	-500 mm Photo and Trav. Prep.	Station

NA	NA	NA	-70 mm Stereo Pairs of Upsloping Targets of Oppurtunity	NA	NA	NA	NA
NA	NA	NA	NA	3	164	Trav. to Station #6A	Traverse
NA	NA	NA	NA	22	167	Station #6A Tasks:	Station
NA	NA	NA	NA	22	167	-Samples and Trav. Prep.	Station
-65	8	253	Traverse to Station #7	3	188	Trav. to Station #7	Traverse
-70	40	261	Station 7 Geology:	50	191	Station #7 Tasks:	Station
NA	NA	NA	-Description of Sampling Area	NA	NA	NA	NA
NA	NA	NA	-Comparison of Area to Other Front	NA	NA	NA	NA
NA	NA	NA	-Document Samples	32	191	-Documented Samples	Station
NA	NA	NA	NA	10	223	-Comprehensive Sample	Station
NA	NA	NA	NA	9	233	-Documented Samples & Trav. Prep.	Station
NA	NA	NA	NA	13	241	Trav. to Station #4	Traverse
NA	NA	NA	NA	17	254	Station #4 Tasks:	Station
NA	NA	NA	NA	13	254	-Documented Sample	Station
NA	NA	NA	NA	4	267	-Trav. Prep.	Station
NA	NA	NA	NA	22	271	Trav. to LM	Station
NA	NA	NA	NA	11	294	Config. LRV for ALSEP Tasks	Station
NA	25	301	Traverse to Station #8	2	305	Trav. to ALSEP Site	Traverse
-19	46	326	Station 8 Geology	70	307	ALSEP Site Tasks:	Station
NA	NA	NA	NA	36	307	-HFE Deploy Completion	Station
NA	NA	NA	NA	17	343	-Select Geol. Site for LMP	Station
NA	NA	NA	NA	17	360	-Deep Core and Trav. Prep.	Station
5	8	372	Trav. To LM	1	377	Trav. to LM	Traverse
-2	33	380	EVA Closeout	47	378	EVA Closeout:	Overhead
NA	NA	NA	NA	21	378	-Closeout Activities	Overhead
NA	NA	NA	NA	4	399	-Flag Deploy	Overhead
NA	NA	NA	NA	21	403	-Continue Closeout Activities	Overhead
12	7	413	EVA Termination	9	425	EVA Termination	Overhead
13		420	END		433	END	Overhead
Total Durations		**420 7 hours**			**433 7 hours 13 mins**		

A.8 Apollo 15 - EVA 2 - LMP Timeline

Table A39: Apollo 15 EVA 2 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	23	0	Pre-Egress	22	0	Pre-Egress	Overhead
-1	4	23	Egress	2	22	Egress	Overhead
-4	18	27	Equipment Prep	26	23	Equip. Prep.	Overhead
4	5	45	LRV Nav. Initialization	7	49	LRV Nav, Init.	Overhead
NA	10	50	Traverse to Checkpoint	NA	NA	NA	NA
NA	2	60	Arrive at Checkpoint	NA	NA	NA	NA
NA	15	62	Traverse to Station 4	NA	NA	NA	NA
NA	20	77	Station 4 Geology	NA	NA	NA	NA
NA	10	97	Trav to 1st Checkpoint	NA	NA	NA	NA
NA	4	107	Arrive at 1st checkpoint	NA	NA	NA	NA
NA	9	111	Trav to 2nd Checkpoint	NA	NA	NA	NA
NA	5	120	Arrive at 2nd checkpoint	NA	NA	NA	NA
NA	5	125	Trav to 3rd Checkpoint	NA	NA	NA	NA
NA	4	130	Arrive at 3rd checkpoint	NA	NA	NA	NA
NA	12	134	Traverse to Station 5	NA	NA	NA	NA
NA	51	146	Station 5 Geology	NA	NA	NA	NA
-140	15	197	Traverse to Station #6	43	57	Trav. to Station #6	Traverse
-112	41	212	Station 6 Geology:	65	100	Station #6 Tasks:	Station
NA	NA	NA	-Description of Sampling Area andComparison to Others	NA	NA	NA	NA
NA	NA	NA	NA	4	100	-Photo Pan	Station
NA	NA	NA	-Document Samples	28	104	-Documented Samples	Station
NA	NA	NA	-Explore Trench	9	132	-Soil Mech. Trench	Station
NA	NA	NA	-Core Tube	4	141	-Single Core	Station
NA	NA	NA	NA	5	145	-Documented Samples	Station
NA	NA	NA	-500 mm Lens Camera Photograph	NA	NA	NA	NA
NA	NA	NA	-70 mm Stereo Pairs of Upsloping Targets of Oppurtunity	15	150	-70mm Mag. Ch. &Trav. Prep.	Traverse
NA	NA	NA	NA	3	164	Trav. to Station #6A	Station
NA	NA	NA	NA	22	167	Station #6A Tasks:	Station

NA	NA	NA	NA	18	167	-Photo Pan and Geol, Desc.	Station
NA	NA	NA	NA	4	185	-Trav. Prep.	Station
-65	8	253	Traverse to Station #7	3	188	Trav. to Station #7	Traverse
-70	40	261	Station 7 Geology:	50	191	Station #7 Tasks:	Station
NA	NA	NA	-Description of Sampling Area	NA	NA	NA	NA
NA	NA	NA	-Comparison of Area to Other Front	NA	NA	NA	NA
NA	NA	NA	NA	9	191	-Photo Pan	Station
NA	NA	NA	-Document Samples	21	200	-Documented Samples	Station
NA	NA	NA	NA	12	221	-Comprehensive Sample	Station
NA	NA	NA	NA	9	233	-Documented Samples &Trav. Prep.	Station
NA	NA	NA	NA	13	241	Trav. to Station #4	Traverse
NA	NA	NA	NA	17	254	Station #4 Tasks:	Station
NA	NA	NA	NA	13	254	-Photo Pan and Documented Samples	Station
NA	NA	NA	NA	4	267	-Trav. Prep.	Station
NA	NA	NA	NA	22	271	Trav. to LM	Traverse
NA	NA	NA	NA	22	294	Config. LRV for ALSEP and Photo	Station
NA	25	301	Traverse to Station #8	4	316	Trav. to ALSEP Site (walking)	Traverse
-6	46	326	Station 8 Geology	54	320	ALSEP Site Tasks:	Station
NA	NA	NA	NA	14	320	-ALSEP Photo and Ch. 70mm Mag.	Station
NA	NA	NA	NA	7	334	-Samples and C/S Align Check	Station
NA	NA	NA	NA	7	341	-Photo and Description	Station
NA	NA	NA	NA	15	348	-Soil Mech. Trench	Station
NA	NA	NA	NA	11	363	-Penetrometer	Station
2	8	372	Trav. To LM	5	374	ALSEP Photo and Trav. to LM (walking)	Traverse
-1	33	380	EVA Closeout:	31	379	EVA Closeout:	Overhead
NA	NA	NA	NA	19	379	-Closeout Activities	Overhead
NA	NA	NA	NA	5	398	-Flag Deploy	Overhead
NA	NA	NA	NA	7	403	-Continued Closeout Activities	Overhead
-3	7	413	EVA Termination	23	410	EVA Termination	Overhead
13		420	END		433	End	Overhead
Total Durations		**420 7 hours**			**433 7 hours 13 mins**		

A.9 Apollo 15 - EVA 3 - CDR Timeline

Table A40: Apollo 15 EVA 3 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	11	0	Pre-Egress	Overhead
1	4	10	Egress	4	11	Egress	Overhead
1	25	14	Equip. Prep. & LCRU Activate	32	15	Equip. Prep. & LCRU Activate	Overhead
NA	NA	NA	NA	3	47	Trav. to ALSEP Site	Traverse
NA	NA	NA	NA	38	49	ALSEP Site Tasks:	Station
NA	NA	NA	NA	11	49	-Recover Core Tubes	Station
NA	NA	NA	NA	19	60	-Disassemble Core Tubes	Station
NA	NA	NA	NA	9	79	-LRV Photo/16mm	Station
49	2	39	LRV Nav Init.	3	88	-LRV Nav. Init.	Station
NA	13	41	Trav. To Supplemental Sample Stop	NA	NA	NA	NA
37	12	54	Trav. To Station 9	13	91	Trav. to Station #9	Traverse
38	50	66	Arrive at Station 9	15	104	Station #9 Tasks:	Station
NA	NA	NA	NA	15	104	-Documented Samples &Trav. Prep.	Station
NA	NA	NA	NA	3	119	Traverse to Station #9A	Traverse
NA	NA	NA	NA	55	122	Station #9A Tasks:	Station
NA	NA	NA	NA	17	122	-Geol. Desc. & 500mm Photo	Station
NA	NA	NA	NA	17	138	-Documented Samples	Station
NA	NA	NA	NA	8	156	-Comprehensive Sample	Station
NA	NA	NA	NA	8	163	-Double Core	Station
NA	NA	NA	NA	6	171	-Samples &Trav. Prep.	Station
61	3	116	Trav. to Station 10	2	177	Trav. to Station #10	Traverse
60	10	119	Arrive at Station 10	27	179	Station #10 Tasks:	Station
NA	NA	NA	NA	12	179	-500mm Photo, Samples &Trav. Prep.	Station
NA	NA	NA	NA	15	191	Trav. to ALSEP Site	Station
NA	6	129	Trav. To Station 11	NA	NA	NA	NA
NA	19	135	Arrive at Station 11	NA	NA	NA	NA
NA	7	154	Trav. To Supplemental Sample Stop	NA	NA	NA	NA

NA	5	161	Arrive at Sample Stop	NA	NA	NA	NA
NA	12	166	Trav. To Station 12	NA	NA	NA	NA
NA	23	178	Arrive at Station 12	NA	NA	NA	NA
NA	9	201	Trav. To Station 13	NA	NA	NA	NA
NA	52	210	Arrive at Station 13	NA	NA	NA	NA
NA	19	262	Trav. To Station 14	NA	NA	NA	NA
NA	20	281	Arrive at Station 14	NA	NA	NA	NA
-95	14	301	Trav. To LM	2	206	Trav. to LM	Traverse
-107	35	315	EVA Closeout	75	208	EVA Closeout:	Overhead
NA	NA	NA	NA	29	208	Closeout Activities	Overhead
NA	NA	NA	NA	8	237	Demonstration (Stamp and Gravity)	Overhead
NA	NA	NA	NA	29	245	Position LRV for Liftoff	Overhead
NA	NA	NA	NA	8	275	Continue Closeout Activities	Overhead
-67	10	350	Ingress/EVA Termination	8	283	EVA Termination	Overhead
-69		360	END		291	END	Overhead
Total Durations		**360 6 hours**			**291 4 hours 51 mins**		

A.10 Apollo 15 - EVA 3 - LMP Timeline

Table A41: Apollo 15 EVA 3 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	19	0	Pre-Egress	15	0	Pre-Egress	Overhead
-4	1	19	Egress	2	15	Egress	Overhead
-3	19	20	Equip. Prep.	28	17	Equip. Prep.	Overhead
NA	NA	NA	NA	5	45	Trav. to ALSEP Site (walking)	Traverse
NA	NA	NA	NA	38	49	ALSEP Site Tasks:	Station
NA	NA	NA	NA	11	49	-Recover Core Stems	Station
NA	NA	NA	NA	4	60	-Disassemble Core Stems	Station
NA	NA	NA	NA	7	64	-ALSEP Photo	Station
NA	NA	NA	NA	8	71	-Disassemble Core Stems	Station
NA	NA	NA	NA	9	79	-LRV Photo & Trav. Prep.	Station
49	2	39	LRV Nav Init.	3	88	LRV Nav. Init.	Station
NA	13	41	Trav. To Supplemental Sample Stop	NA	NA	NA	NA
37	12	54	Trav. To Station 9	13	91	Trav. to Station #9	Traverse
38	50	66	Arrive at Station 9	15	104	Station #9 Tasks:	Station
NA	NA	NA	NA	7	104	-Troubleshoot Camera Malfunction	Station
NA	NA	NA	NA	8	111	-Documented Samples & Trav. Prep.	Station
NA	NA	NA	NA	3	119	Trav. to Station #9A	Traverse
NA	NA	NA	NA	55	122	Station #9A Tasks:	Station
NA	NA	NA	NA	34	122	-Documented Samples	Station
NA	NA	NA	NA	8	156	-Comprehensive Sample	Station
NA	NA	NA	NA	8	163	-Double Core	Station
NA	NA	NA	NA	6	171	-Samples & Trav. Prep.	Station
61	3	116	Trav. To Station 10	2	177	Trav. to Station #10	Traverse
60	10	119	Arrive at Station 10	12	179	Station #10 Tasks:	Station
NA	NA	NA	NA	3	179	-70mm Photo Pan	Station
NA	NA	NA	NA	9	182	-Samples & Trav. Prep.	Station
NA	NA	NA	NA	15	191	-Trav. to ALSEP Site	Traverse
NA	NA	NA	NA	2	206	-Retrieve Core Stems	Station
NA	6	129	Trav. To Station 11	NA	NA	NA	NA

NA	19	135	Arrive at Station 11	NA	NA	NA	NA
NA	7	154	Trav. To Supplemental Sample Stop	NA	NA	NA	NA
NA	5	161	Arrive at Sample Stop	NA	NA	NA	NA
NA	12	166	Trav. To Station 12	NA	NA	NA	NA
NA	23	178	Arrive at Station 12	NA	NA	NA	NA
NA	9	201	Trav. To Station 13	NA	NA	NA	NA
NA	52	210	Arrive at Station 13	NA	NA	NA	NA
NA	19	262	Trav. To Station 14	NA	NA	NA	NA
NA	20	281	Arrive at Station 14	NA	NA	NA	NA
-93	14	301	Trav. To LM	1	208	Trav. to LM (walking)	Traverse
-106	25	315	EVA Closeout	69	209	EVA Closeout	Overhead
NA	NA	NA	NA	27	209	Closeout Activities	Overhead
NA	NA	NA	NA	41	236	Transfer Samples & Film Mags. To MESA	Overhead
-62	20	340	Ingress/EVA Termination	13	278	EVA Termination	Overhead
-69		360	END		291	END	Overhead
Total Durations		**360 6 hours**			**291 4 hours 51 mins**		

A.11 Apollo 16 - EVA 1 - CDR Timeline

Table A42: Apollo 16 EVA 1 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	8	0	Pre-Egress	Overhead
-2	7	10	Egress	3	8	Egress	Overhead
-6	5	17	Familiarization	2	11	Familiarization	Overhead
-9	8	22	Deploy TV Camera	9	13	Deploy TV Camera	Overhead
-8	8	30	Offload LRV	12	22	Offload LRV	Overhead
-4	5	38	Set Up LRV	6	34	Set Up LRV	Overhead
-3	7	43	Checkout LRV	7	40	Checkout LRV	Overhead
-3	15	50	Offload Far UV Camera	18	47	Offload Far U.V. Camera	Overhead
1	15	65	Load LRV	21	66	Load LRV	Overhead
6	7	80	Flag Deploy	7	86	Flag Deploy	Overhead
6	8	87	ALSEP Prep.	5	93	ALSEP Prep.	Overhead
3	3	95	Set Far UV Cam to Target #2	7	98	Reset Far U.V. Camera	Overhead
NA	NA	NA	NA	1	105	Deploy Cosmic Ray Exp.	Overhead
8	3	98	Trav. Prep.	2	106	Trav. Prep.	Overhead
7	8	101	LRV to ALSEP Traverse	12	108	Trav. to ALSEP Site 3	Traverse
NA	134	109	ALSEP Station Tasks:	124	120	ALSEP Station Tasks:	Station
NA	NA	NA	NA	3	120	-ALSEP Site Prep.	Station
13	10	109	-Connect RTG	13	122	-Connect RTG	Station
16	9	119	-Deploy PSE	12	135	-Deploy PSE	Station
19	3	128	-Offload Mortar Package	5	147	-Offload Mortar Package	Station
21	1	131	-Remove LSM	2	152	-Remove LSM	Station
22	18	132	-Erect Central Station	17	154	-Erect C/S & Assemble & Align Antenna	Station
NA	10	150	-Assemble & Align Antenna	NA	NA	NA	NA
11	10	160	-Deploy LSM	9	171	-Deploy LSM	Station
10	18	170	-Deploy Geophones	13	180	-Deploy Geophones	Station
5	25	188	-Thumper Geophone Experiment	17	193	-Thumper Geophone Experiment	Station
-3	23	213	-Setup Mortar Package	21	210	-Setup Mortar Package	Station
NA	NA	NA	NA	4	230	-Doc. Samples	Station
-2	7	236	-Trav. Prep.	9	234	-Trav. Prep.	Station
1	12	243	Traverse to Station #1	27	244	Trav. to Station #1	Traverse
	42	255	Geology Station #1:	50	271	Station #1 Tasks:	Station
16	7	255	-Geol. Prep./ Describe Area	5	271	-Geol. Prep.	Station
14	8	262	-Rake Samples	8	276	-Rake Samples	Station

14	24	270	-Collect Document Samples	32	284	-Doc. Samples	Station
22	3	294	-Trav. Prep.	5	316	-Trav. Prep.	Station
24	5	297	Traverse to Station #2	7	321	Trav. to Station #2	Traverse
NA	56	302	Geology Station #2:	27	328	Station #2 Tasks:	Station
26	7	302	-Geol. Prep./ Describe Area	3	328	-Geol. Prep.	Station
23	46	309	-LPM Measurement	21	332	-LPM Measurement	Station
NA	NA	NA	-Document Samples	NA	NA	NA	NA
-2	3	355	-Trav. Prep.	2	353	-Trav. Prep.	Station
-3	6	358	Traverse to Station #3	6	355	Trav. to Station #3	Traverse
-3	15	364	Station #3:	14	361	Station #3 Tasks:	Station
-3	2	364	-Prep	2	361	-Photo Prep.	Station
-2	8	366	-Drive Grand Prix	3	364	-LRV "Grand Prix" Driving	Station
-8	3	374	-Arm Mortar Package	7	366	-Mortar Pack Activation	Station
-4	2	377	-Trav Prep	2	373	-Trav. Prep.	Station
-4	1	379	Traverse to LM	3	375	Trav. to LM	Traverse
-2	27	380	EVA Closeout:	48	378	EVA Closeout:	Overhead
NA	NA	NA	NA	3	378	-Station Prep.	Overhead
NA	NA	NA	NA	2	381	-Closeout Activities	Overhead
-1	23	384	-Reset Far U.V. Camera	2	383	-Reset Far U.V. Camera	Overhead
NA	NA	NA	NA	4	385	-Redeploy CRE	Overhead
NA	NA	NA	NA	31	389	-Closeout Activities	Overhead
NA	NA	NA	NA	5	420	-Reset Far U.V. Camera	Overhead
18	13	407	EVA Termination	7	425	EVA Termination	Overhead
12		420	END		432	END	Overhead
Total Durations		**420 7 hours**			**432 7 hours 12 mins**		

A.12 Apollo 16 - EVA 1 - LMP Timeline

Table A43: Apollo 16 EVA 1 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	22	0	Pre-Egress	12	0	Pre-Egress	Overhead
-10	4	22	Egress	1	12	Egress	Overhead
-13	7	26	Familiarization	10	13	Familiarization	Overhead
-10	5	33	Offload LRV	12	23	Offload LRV	Overhead
-4	5	38	Set Up LRV	5	34	Set Up LRV	Overhead
-3	7	43	LM Inspection and Pans	10	40	LM Inspection and Pans	Overhead
0	32	50	Load LRV	33	50	Load LRV	Overhead
NA	NA	NA	NA	9	82	ALSEP Prep.	Overhead
9	5	82	Flag Deploy	3	91	Flag Deploy	Overhead
7	10	87	ALSEP Prep.	7	94	ALSEP Prep.	Overhead
4	16	97	ALSEP Trav. (Walking Carrying ALSEP Barbell)	9	101	ALSEP Trav. (Walking Carrying ALSEP Barbell)	Traverse
NA	129	113	ALSEP Tasks:	134	110	ALSEP Tasks:	Station
-3	38	113	-HFE Deploy	39	110	-HFE Deploy	Station
-3	22	151	-Bore hole 2	33	148	-Drill Core Sample	Station
8	12	173	-Assist in Geophone Deploy	7	181	-Assist in Geophone Deploy	Station
3	43	185	-ALSEP Photos	23	188	-ALSEP Photos	Station
-17	11	228	-Drill Core Disassemble	8	211	-Drill Core Disassemble	Station
-20	3	239	-Trav. Prep.	25	219	-Trav. Prep. and Doc. Samples	Station
2	14	242	Trav. to Station #1	27	244	Trav. to Station #1	Traverse
NA	41	256	Station #1 Tasks:	48	271	Station #1 Tasks:	Station
15	6	256	-Geol. Prep.	7	271	-Geol. Prep.	Station
16	8	262	-Rake Samples	6	278	-Rake Samples	Station
14	24	270	-Doc. Samples	32	284	-Doc. Samples	Station
22	3	294	-Trav. Prep.	3	316	-Trav. Prep.	Station
22	5	297	Trav. to Station #2	9	319	Trav. to Station #2	Traverse
NA	56	302	Station #2 Tasks:	27	328	Station #2 Tasks:	Station
26	3	302	-Geol. Prep.	3	328	-Geol. Prep.	Station
26	7	305	-Photo Pan and 500mm Photos	6	331	-Photo Pan and 500mm Photos	Station
25	43	312	-Doc. Samples	16	337	-Doc. Samples	Station
-2	3	355	-Trav. Prep.	2	353	-Trav. Prep.	Station
-3	8	358	Trav. to Station #3	6	355	Trav. to Station #3	Traverse
NA	13	366	Station #3 Tasks:	7	361	Station #3 Tasks:	Station
-5	8	366	-Photo Prep. and Photo CDR/LRV "Grand Prix"	5	361	-Photo Prep. and Photo CDR/LRV "Grand Prix"	Station
-8	5	374	-Trav. Prep.	2	366	-Trav. Prep.	Station
-11	1	379	Trav. to LM (Walking)	2	368	Trav. to LM (Walking)	Traverse
-10	22	380	EVA Closeout	37	370	EVA Closeout	Overhead

5	18	402	EVA Termination	25	407	EVA Termination	Overhead
12		420	END		432	END	Overhead
Total		**420**			**432**		
Durations		**7 hours**			**7 hours 12 mins**		

A.13 Apollo 16 - EVA 2 - CDR Timeline

Table A44: Apollo 16 EVA 2 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	5	0	Pre-Egress	Overhead
-5	6	10	Egress	3	5	Egress	Overhead
-8	8	16	Reset Far U.V. Camera	16	8	Reset Far U.V. Camera	Overhead
0	19	24	Trav. Prep.	6	24	Trav. Prep.	Overhead
NA	NA	NA	NA	7	30	Doc. Samples	Overhead
NA	NA	NA	NA	6	37	Trav. Prep.	Overhead
0	3	43	Reset Far U.V. Camera	2	43	Reset Far U.V. Camera	Overhead
-1	4	46	Trav. Prep.	1	45	Trav. Prep.	Overhead
-4	35	50	Trav. to Station #4	44	46	Trav. to Station #4	Traverse
NA	58	85	Station #4 Tasks:	53	90	Station #4 Tasks:	Station
5	6	85	-Geol. Prep.	4	90	-Geol. Prep.	Station
3	3	91	-Geol. Description	3	94	-Geol. Description	Station
3	8	94	-Rake Samples	7	97	-Rake Samples	Station
3	9	102	-Solo Samples	11	105	-Doc. Samples	Station
5	8	111	-Double Core	3	116	-Trenching	Station
0	22	119	-Doc. Samples	14	119	-Doc. Samples	Station
NA	NA	NA	NA	5	132	-Rake Samples	Station
-4	2	141	-Trav. Prep.	6	137	-Trav. Prep.	Station
0	6	143	Trav. to Station #5	9	143	Trav. to Station #5	Traverse
	40	149	Station #5 Tasks:	47	152	Station #5 Tasks:	Station
3	4	149	-Geol. Prep.	5	152	-Geol. Prep.	Station
4	34	153	-General Sampling	25	157	-Rake Samples	Station
NA	NA	NA	NA	12	182	-LPM Measurement & Samples	Station
7	2	187	-Trav. Prep.	4	194	-Trav. Prep.	Station
9	3	189	Trav. to Station #6	11	198	Trav. to Station #6	Traverse
NA	20	192	Station #6 Tasks:	18	209	Station #6 Tasks:	Station
17	4	192	-Geol. Prep.	4	209	-Geol. Prep.	Station
17	14	196	-Doc. Samples	12	213	-Doc. Samples	Station
15	2	210	-Trav. Prep.	2	225	-Trav. Prep.	Station
NA	4	212	Trav. to Station #7	NA	NA	NA	NA
NA	16	216	Station #7 Tasks:	NA	NA	NA	NA
-5	4	232	Trav. to Station #8	15	227	Trav. to Station #8	Traverse
NA	60	236	Station #8 Tasks:	66	242	Station #8 Tasks:	Station
6	14	236	-Geol. Prep.	3	242	-Geol. Prep.	Station
-5	27	250	-Rake Samples	9	245	-Rake Samples	Station
NA	NA	NA	-Doc. Samples	6	254	-Doc. Samples	Station
NA	NA	NA	NA	8	260	-LRV Troubleshooting and Repositioning	Station
-9	17	277	-Doc. Samples	26	268	-Doc. Samples	Station
0	2	294	-Trav. Prep.	14	294	-Trav. Prep.	Station
12	3	296	Trav. to Station #9	7	308	Trav. to Station #9	Traverse

NA	25	299	Station #9 Tasks:	34	314	Station #9 Tasks:	Station
15	11	299	-Geol. Prep.	5	314	-Geol. Prep.	Station
9	12	310	-Doc. Samples	22	319	-Doc. Samples	Station
19	2	322	-Trav. Prep.	8	341	-Trav. Prep.	Station
25	22	324	Trav. to Station #10	27	349	Trav. to Station #10	Traverse
NA	33	346	Station #10 Tasks:	27	375	Station #10 Tasks:	Station
29	3	346	-Geol. Prep.	6	375	-Geol. Prep.	Station
32	17	349	-Double Core	10	381	-Double Core	Station
25	11	366	-Doc. Samples and Photo	11	391	-Doc. Samples and Photo	Station
25	2	377	-Trav. Prep.	1	402	-Trav. Prep.	Station
23	1	379	Trav. to LM	2	402	Trav. to LM	Traverse
25	3	380	EVA Closeout	3	405	EVA Closeout	Overhead
25	30	383	Reset Far U.V. Camera	22	408	Reset Far U.V. Camera	Overhead
17	4	413	Reset Far U.V. Camera	2	430	Reset Far U.V. Camera	Overhead
NA	NA	NA	NA	7	432	Closeout Activities	Overhead
22	3	417	Ingress	4	439	EVA Termination	Overhead
23		420	END		443	END	Overhead
Total Durations		**420 7 hours**			**443 7 hours 23 mins**		

A.14 Apollo 16 - EVA 2 - LMP Timeline

Table A45: Apollo 16 EVA 2 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	16	0	Pre-Egress	9	0	Pre-Egress	Overhead
-7	34	16	Egress	1	9	Egress	Overhead
NA	NA	NA	NA	37	10	Trav. Prep.	NA
-3	34	50	Trav. to Station #4	43	47	Trav. to Station #4	Traverse
NA	59	84	Station #4 Tasks:	52	90	Station #4 Tasks:	Station
6	4	84	-Geol. Prep.	4	90	-Geol. Prep.	Station
6	6	88	-500mm Photos	4	94	-500mm Photos	Station
3	8	94	-Rake Samples	7	97	-Rake Samples	Station
3	9	102	-Penetrometer	13	105	-Penetrometer	Station
7	28	111	-Double Core	12	118	-Double Core	Station
NA	NA	NA	NA	8	129	-Rake Samples	Station
NA	NA	NA	NA	2	137	-Photo Pan	Station
0	4	139	-Trav. Prep.	3	139	-Trav. Prep.	Station
-1	6	143	Trav. to Station #5	10	142	Trav. to Station #5	Traverse
NA	40	149	Station #5 Tasks:	46	152	Station #5 Tasks:	Station
3	4	149	-Geol. Prep.	6	152	-Geol. Prep.	Station
5	33	153	-General sample	24	158	-Rake Samples	Station
NA	NA	NA	NA	9	182	-Doc. Samples	Station
5	3	186	-Trav. Prep.	6	191	-Trav. Prep.	Station
8	2	189	Trav. to Station #6	11	197	Trav. to Station #6	Traverse
NA	21	191	Station #6 Tasks:	18	209	Station #6 Tasks:	Station
18	4	191	-Geol. Prep.	4	209	-Geol. Prep.	Station
18	15	195	-General Sampling	12	213	-Doc. Samples	Station
15	2	210	-Trav. Prep.	2	225	-Trav. Prep.	Station
NA	4	212	Trav. to Station #7	NA	NA	NA	NA
NA	16	216	Station #7 Tasks	NA	NA	NA	NA
-5	4	232	Trav. to Station #8	15	227	Trav. to Station #8	Traverse
NA	60	236	Station #8 Tasks:	65	242	Station #8 Tasks:	Station
6	6	236	-Geol. Prep.	2	242	-Geol. Prep.	Station
2	35	242	-Double Core	19	244	-Double Core	Station
NA	NA	NA	NA	5	263	-LRV Troubleshooting & Walk a New Sampling Site	Station
-10	16	277	-Doc. Samples	27	267	-Doc. Samples	Station
1	3	293	-Trav. Prep.	12	294	-Trav. Prep.	Station
10	3	296	Trav. to Station #9	8	306	Trav. to Station #9	Traverse
NA	25	299	Station #9 Tasks:	34	314	Station #9 Tasks:	Station
15	1	299	-Geol. Prep.	2	314	-Geol. Prep.	Station
16	2	300	-500mm Photos	2	316	-500mm Photos	Station
16	20	302	-Single Core	18	318	-Single Core	Station
NA	NA	NA	-Doc. Samples	5	336	-Doc. Samples	Station
19	2	322	-Trav. Prep.	8	341	-Trav. Prep.	Station
25	21	324	Trav. to Station #10	27	349	Trav. to Station #10	Traverse
NA	33	345	Station #10 Tasks:	26	376	Station #10 Tasks:	Station
31	12	345	-Geol. Prep.	8	376	-Geol. Prep.	Station

27	19	357	-Penetrometer	16	384	-Penetrometer	Station
23	2	376	-Trav. Prep.	2	399	-Trav. Prep.	Station
24	2	378	-Trav. to LM (Mount)	1	402	-Trav. to LM (Walking)	Traverse
23	29	380	EVA Closeout	26	403	EVA Closeout	Overhead
20	11	409	Ingress	14	429	EVA Termination	Overhead
24		420	END		443	END	Overhead
Total Durations		**420 7 hours**			**443 7 hours 23 mins**		

A.15 Apollo 16 - EVA 3 - CDR Timeline

Table A46: Apollo 16 EVA 3 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	9	0	Pre-Egress	Overhead
-1	7	10	Egress	4	9	Egress	Overhead
-5	20	17	LRV Prep	21	12	LRV Load Trav, Prep.	Overhead
-4	4	37	Reset Far U.V. Camera	3	33	Reset Far U.V. Camera	Overhead
-5	5	41	Trav. Prep.	1	36	Trav. Prep.	Overhead
-9	44	46	Trav. to Station #11	41	37	Trav. to Station #11	Traverse
-12	50	90	Station #11 Tasks:	84	78	Station #11 Tasks:	Station
NA	NA	NA	NA	4	78	-Geol, Prep	-Station
NA	NA	NA	NA	8	81	-Geol. Description & Samples	Station
NA	NA	NA	NA	23	89	-Doc. Samples	Station
NA	NA	NA	NA	22	112	-Rake Samples	Station
NA	NA	NA	NA	15	134	-Doc. Samples at "House Rock"	Station
8	3	140	-Samples and Trav. Prep.	13	148	-Samples and Trav. Prep.	Station
NA	3	143	Trav to Station 12	NA	NA	NA	NA
NA	55	146	Station 12 activities	NA	NA	NA	NA
-39	5	201	Trav to Station 13	9	162	Trav. to Station #13	Traverse
-36	10	206	Station 13 activities	29	170	Station #13 Tasks:	Station
NA	NA	NA	NA	4	170	-Geol. Prep.	Station
NA	NA	NA	NA	6	174	-Rake Samples	Station
NA	NA	NA	NA	15	180	-LPM Measurements	Station
NA	NA	NA	NA	4	196	-Trav. Prep.	Station
NA	NA	NA	NA	29	199	Trav. to Station #10’	Traverse
NA	NA	NA	NA	33	228	Station #10’ Tasks:	Station
NA	NA	NA	NA	6	228	-Geol. Prep.	Station
NA	NA	NA	NA	14	235	-Rake Samples	Station
NA	NA	NA	NA	3	249	-Double Core	Station
NA	NA	NA	NA	4	251	-Doc. Samples	Station
NA	NA	NA	NA	6	255	-Trav. Prep.	Station
NA	6	216	Trav to Station 14	NA	NA	NA	NA
NA	42	222	Station 14 activities	NA	NA	NA	NA
NA	10	264	Trav to Station 15	NA	NA	NA	NA
NA	11	274	Station 15 activities	NA	NA	NA	NA
NA	8	285	Trav to Station 16	NA	NA	NA	NA
NA	11	293	Station 16 activities	NA	NA	NA	NA
NA	3	304	Trav to Station 17	NA	NA	NA	NA
NA	37	307	Station 17 activities	NA	NA	NA	NA
-83	21	344	Trav. to LM	2	261	Trav. to LM	Traverse
NA	43	365	EVA Closeout:	77	264	EVA Closeout:	Overhead
-101	3	365	-Closeout Activities	4	264	-Closeout Activities	Overhead

-100	6	368	-Reset Far U.V. Camera	2	268	-Reset Far U.V. Camera	Overhead
NA	NA	NA	NA	6	270	-Closeout Activities	Overhead
-98	9	374	-Retrieve Cosmic Ray Exp.	11	276	-Retrieve Cosmic Ray Exp.	Overhead
NA	NA	NA	NA	9	287	-Closeout Activities	Overhead
-88	24	383	Park LRV	4	295	-Park LRV	Overhead
NA	NA	NA	NA	10	300	-Closeout Activities	Overhead
NA	NA	NA	NA	11	310	-LPM Measurements	Overhead
NA	NA	NA	NA	13	321	-Closeout Activities	Overhead
-73	1	407	-Remove Far U.V. Camera Film Mag.	1	334	-Remove Far U.V. Camera Film Mag.	Overhead
NA	NA	NA	NA	5	335	-Closeout Activities	Overhead
-68	12	408	EVA Termination	4	340	EVA Termination	Overhead
-76		420	END		344	END	Overhead
Total Durations		**420 7 hours**			**344 5 hours 44 mins**		

A.16 Apollo 16 - EVA 3 - LMP Timeline

Table A47: Apollo 16 EVA 3 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	17	0	Pre-Egress	12	0	Pre-Egress	Overhead
-5	4	17	Egress	1	12	Egress	Overhead
-8	26	21	LRV Load and Trav. Prep.	25	13	LRV Load and Trav. Prep.	Overhead
-10	43	47	Trav. to Station #11	41	37	Trav. to Station #11	Traverse
-12	53	90	Station #11 Tasks:	84	78	Station #11 Tasks:	Station
-12	3	90	-Geol. Prep.	4	78	-Geol. Prep.	Station
-11	NA	93	-Photo Pan and Geol. Description	19	82	-Photo Pan and Geol. Description	Station
NA	NA	NA	-Doc. Samples	5	100	-Doc. Samples	Station
NA	NA	NA	-500mm Photos	3	105	-500mm Photos	Station
NA	NA	NA	-Doc. Samples	14	109	-Doc. Samples	Station
NA	NA	NA	-Rake Samples	11	123	-Rake Samples	Station
NA	NA	NA	-Doc. Samples at "House Rock"	15	134	-Doc. Samples at "House Rock"	Station
8	3	140	-Samples and Trav. Prep.	13	148	-Samples and Trav. Prep.	Station
NA	3	143	Trav to Station 12	NA	NA	NA	NA
NA	55	146	Station 12 activities	NA	NA	NA	NA
-39	5	201	Trav to Station 13	7	162	Trav. to Station #13	Traverse
-38	10	206	Station 13 activities	29	168	Station #13 Tasks:	Station
NA	NA	NA	NA	1	168	-Geol. Prep.	Station
NA	NA	NA	NA	4	170	-Photo Pan and Geol. Description	Station
NA	NA	NA	NA	5	174	-Rake Samples	Station
NA	NA	NA	NA	15	178	-Doc. Samples	Station
NA	NA	NA	NA	4	193	-Trav. Prep.	Station
NA	NA	NA	NA	29	197	Trav. to Station #10'	Traverse
NA	NA	NA	NA	28	226	Station #10' Tasks:	Station
NA	NA	NA	NA	5	226	-Geol. Prep.	Station
NA	NA	NA	NA	14	232	-Rake Samples	Station
NA	NA	NA	NA	8	245	-Double Core	Station
NA	NA	NA	NA	1	253	-Trav. Prep.	Station
NA	6	216	Trav to Station 14	NA	NA	NA	NA
NA	42	222	Station 14 activities	NA	NA	NA	NA
NA	10	264	Trav to Station 15	NA	NA	NA	NA
NA	11	274	Station 15 activities	NA	NA	NA	NA
NA	8	285	Trav to Station 16	NA	NA	NA	NA
NA	11	293	Station 16 activities	NA	NA	NA	NA
NA	3	304	Trav to Station 17	NA	NA	NA	NA
NA	37	307	Station 17 activities	NA	NA	NA	NA
-89	21	344	Trav. to LM (Planned to ride)	1	255	Trav. to LM (Walking)	Traverse
-109	43	365	EVA Closeout	75	256	EVA Closeout	Overhead
-77	12	408	EVA Termination	12	331	EVA Termination	Overhead
-78		420	END		342	END	Overhead

Total	**420**	**434**
Durations	**7 hours**	**7 hours 14 mins**

A.17 Apollo 17 - EVA 1 - CDR Timeline

Table A48: Apollo 17 EVA 1 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	6	0	Pre-Egress	Overhead
-4	11	10	Egress operations	15	6	Egress operations	Overhead
0	12	21	Deploy Lunar Roving Vehicle	11	21	Deploy Lunar Roving Vehicle	Overhead
-1	7	33	Setup Lunar Roving Vehicle	14	32	Setup Lunar Roving Vehicle	Overhead
7	7	40	Test Drive Lunar Roving Vehicle	6	47	Test Drive Lunar Roving Vehicle	Overhead
6	32	47	Configure Lunar Roving Vehicle For Traverse	25	53	Configure Lunar Roving Vehicle For Traverse	Overhead
1	3	79	Deploy Flag	9	78	Deploy Flag	Overhead
5	15	82	Miscellaneous Operations with Lunar Roving Vehicle	34	87	Miscellaneous Operations with Lunar Roving Vehicle	Overhead
24	8	97	Traverse to Lunar Surface Experiments Deployment Site	14	121	Traverse to Lunar Surface Experiments Deployment Site	Traverse
29	156	105	Deploy Lunar Surace Experiments and Drilling Operations	156	134	Deploy Lunar Surace Experiments and Drilling Operations	Station
29	8	261	Traverse to Station 1	13	290	Traverse to Station 1	Traverse
34	66	269	Geology at Station 1	32	303	Geology at Station 1	Station
0	23	335	Traverse to Surface Electrical Properties Transmitter Site	15	335	Traverse to Surface Electrical Properties Transmitter Site	Traverse
-8	20	358	Deploy Surface Electrical Properties Experiments	24	350	Deploy Surface Electrical Properties Experiments	Station
3	11	378	Traverse to Lunar Module	3	375	Traverse to Lunar Module	Traverse
-11	31	389	Extravehicular Activity Closeout	56	378	Extravehicular Activity Closeout	Overhead
14		420	End of EVA		434	End of EVA	Overhead
Total Duration		**420 7 hours**			**420 7 hours 14 mins**		

A.18 Apollo 17 - EVA 1 - LMP Timeline

Table A49: Apollo 17 EVA 1 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	16	0	Depress	12	0	Egress	Overhead
-4	8	16	Egress operations	12	12	Egress operations	Overhead
-1	9	24	LRV Deploy	10	23	Deploy Lunar Roving Vehicle	Overhead
1	7	33	Set Up LRV	15	34	Set Up Lunar Roving Vehicle	Overhead
9	6	40	LM Area Descript & Photography	10	49	Photograph and Describe Landing Site	Overhead
13	27	46	LRV Configuration	19	59	Configure Lunar Roving Vehicle for Traverse	Overhead
4	9	73	Flag Deploy	10	77	Deploy Flag	Overhead
5	5	82	LM Inspection	9	87	Inspect Lunar Module	Overhead
9	13	87	Alsep Off Load	18	96	Unload Lunar Surface Experiments	Overhead
14	7	100	Alsep Trav	5	114	Traverse to Lunar Surface Experiments Deployment Site	Traverse
12	129	107	ALSEP Deployment:	152	119	Deploy Lunar Surface Experiments:	Station
NA	43	107	-Alsep Interconn & LSG, LSG,C/S, Ant,Deploy & LMS	NA	NA	NA	Station
NA	10	150	-LEAM Deploy LSP ANT Deploy	NA	NA	NA	Station
NA	10	160	-Config for G/M Photos and Sampler Prep	NA	NA	NA	Station
NA	29	170	-Deploy LSPE GEO's & Photos	NA	NA	NA	Station
NA	20	199	-Alsep Photos	NA	NA	NA	Station
23	17	219	-Configure for Traverse & Load Sampler	29	242	-Sample Collection and Prepare for Traverse	Station
NA	NA	NA	NA	4	271	Traverse to Lunar Module	Traverse
39	2	236	SEP XMTR Deploy Prep	3	275	Unload Surface Electrical Properties Experiments	Station
39	23	238	Traverse to SEP XMTR Deploy Site	12	277	Traverse to Surface Electical Properties Experiment Deployment Site	Station
28	8	261	Go to Sta 1	16	289	Traverse to Station 1	Traverse
37	66	269	Station 1	32	306	Geological Activites at Station 1	Station

3	23	335	Return to SEP Site	14	338	Traverse to Surface Electrical Properties Experiment Site	Traverse
-6	22	358	SEP Site	20	352	Deploy Surface Electrical Properties Experiment	Station
-8	4	380	Traverse Termination	6	372	Traverse to Lunar Module	Traverse
-6	36	384	Closeout	56	378	Extravehicular Activity Closeout	Overhead
14		420	End of EVA		434	End of EVA	Overhead
Total Duration		**420 7 hours**			**434 7 hours 14 mins**		

A.19 Apollo 17 - EVA 2 - CDR Timeline

Table A50: Apollo 17 EVA 2 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	8	0	Pre-Egress	Overhead
-2	41	10	Egress Ops	48	8	Egress	Overhead
6	67	51	Go to Sta 2	70	57	Traverse to Station 2	Traverse
9	54	118	Station 2	68	127	Geological Activities to Station 2	Station
22	6	172	Go to Sta 3	10	194	Traverse toward Station 3	Traverse
26	12	178	Sample Around Lunar Roving Vehicle	7	204	Sample Around Lunar Roving Vehicle	Station
21	10	190	Complete Traverse to Station 3	25	211	Complete Traverse to Station 3	Traverse
36	45	200	Station 3	39	236	Geological Activites to Station 3	Station
30	17	245	Go to Sta 4	16	275	Traverse to Station 4	Traverse
28	41	262	Station 4	38	290	Geological Activites at Station 4	Station
25	11	303	Go to Sta 5	7	328	Traverse toward Station 5	Traverse
21	5	314	Photograph Area Around Lunar Roving Vehicle	6	335	Photograph Area Around Lunar Roving Vehicle	Station
22	7	319	Continue Traverse Toward Station 5	3	341	Continue Traverse Toward Station 5	Traverse
19	2	326	Sample Area Around Lunar Roving Vehicle	5	345	Sample Area Around Lunar Roving Vehicle	Station
22	6	328	Complete Traverse to Station 5	6	350	Complete Traverse to Station 5	Traverse
21	32	334	Station 5	28	355	Geological Activites to Station 5	Station
17	15	366	Trav to LM	18	383	Traverse Via Lunar Surface Experiments Site to Lunar Module	Traverse
21	39	381	Closeout	57	402	Extravehicular Activity Closeout	Overhead
39		420	END		459	END	Overhead
Total Duration		**420 7 hours**			**459 7 hours 39 mins**		

A.20 Apollo 17 - EVA 2 - LMP Timeline

Table A51: Apollo 17 EVA 2 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	17	0	Depress	12	0	Pre-Egress	Overhead
-5	4	17	Egress	0	12	Egress	
-9	19	21	Preparations for Traverse	39	12	Preparations for Traverse	Overhead
10	3	40	Traverse to Surface Electrical Properties Experiment Site	3	50	Traverse to Surface Electrical Properties Experiment Site	Traverse
10	8	43	Activites with Surface Electric Properties Experiment	6	53	Activites with Surface Electric Properties Experiment	Station
8	69	51	Go to Sta 2	68	59	Traverse to Station 2	Traverse
7	52	120	Station 2	67	127	Geological Activites to Station 2	Station
21	6	172	Go to Sta 3	10	193	Traverse Toward Station 3	Traverse
26	12	178	Sample Around Lunar Roving Vehicle	8	204	Sample Around Lunar Roving Vehicle	Station
21	10	190	Complete Traverse to Station 3	25	211	Complete Traverse to Station 3	Traverse
37	45	200	Station 3	37	237	Geological Activities to Station 3	Station
28	17	245	Go to Sta 4	17	274	Traverse to Station 4	Traverse
29	41	262	Station 4	36	291	Geological Activites to Station 4	Station
24	11	303	Go to Sta 5	7	327	Traverse Toward Station 5	Traverse
20	5	314	Photograph Area Around Lunar Roving Vehicle	6	334	Photograph Area Around Lunar Roving Vehicle	Station
21	7	319	Continue Traverse Toward Station 5	4	340	Continue Traverse Toward Station 5	Traverse
18	2	326	Sample Area Around Lunar Roving Vehicle	3	344	Sample Area Around Lunar Roving Vehicle	Station
19	6	328	Complete Traverse to Station 5	5	347	Complete Traverse to Station 5	Traverse
18	32	334	Station 5	31	352	Geological Activities at Station 5	Station
17	4	366	Traverse to Lunar Surface Experiment Site	16	383	Traverse to Lunar Surface Experiment Site	Traverse
29	3	370	Activites to Lunar Surface Experiements Site	5	399	Activites to Lunar Surface Experiements Site	Station
31	8	373	Traverse to Lunar Module	4	404	Traverse to Lunar Module	Traverse

28	39	381	Closeout	48	409	Extravehicular Activity Closeout	Overhead
37		420	END		457	END	Overhead
Total		**420**			**457**		
Duration		**7 hours**			**7 hours 37 mins**		

A.21 Apollo 17 - EVA 3 - CDR Timeline

Table A52: Apollo 17 EVA 3 CDR Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**CDR Planned**	**Dur**	**Start Time**	**CDR Performed**	**Task Type**
0	10	0	Pre-Egress	10	0	Pre-Egress	Overhead
0	10	10	Egress	10	10	Egress	Overhead
0	27	20	Preparations for Traverse	27	20	Preparations for Traverse	Overhead
0	11	47	Go to Station 6	3	47	Traverse Toward Station 6	Traverse
-8	2	58	Sample Area Around Surface Electrial Properties Site	4	50	Sample Area Around Surface Electrial Properties Site	Station
-6	15	60	Complete Traverse to Station 6	27	54	Complete Traverse to Station 6	Traverse
6	44	75	Station 6	71	81	Geological Activities at Station 6	Station
33	11	119	Go to Station 7	7	152	Traverse to Station 7	Traverse
29	45	130	Station 7	22	159	Geological Activites at Station 7	Station
6	25	175	Go to Station 8	18	181	Traverse to Station 8	Traverse
-1	35	200	Station 8	45	199	Geological Activites to Station 8	Station
10	19	235	Go to Station 9	19	245	Traverse to Station 9	Traverse
10	30	254	Station 9	56	264	Geological Activites at Station 9	Station
NA	13	284	Go to Station 10	NA	NA	NA	Traverse
NA	47	297	Station 10	NA	NA	NA	Station
-24	18	344	Return to LM	29	320	Traverse to Lunar Module	Traverse
-13	58	362	Closeout	86	349	Extravehicular Activty Closeout	Overhead
15		420	END		435	END	Overhead
Total Duration		**420 7 hours**			**435 7 hours 15 mins**		

A.22 Apollo 17 - EVA 3 - LMP Timeline

Table A53: Apollo 17 EVA 3 LMP Planned vs Performed Timeline (min)

Source							
Mins Behind	**Dur**	**Start Time**	**LMP Planned**	**Dur**	**Start Time**	**LMP Performed**	**Task Type**
0	16	0	Pre-Egress	10	0	Pre-Egress	Overhead
-6	3	16	Egress	7	10	Egress	Overhead
-2	28	19	Preparations for Traverse	29	17	Preparations for Traverse	Overhead
-1	11	47	Go to Station 6	6	46	Traverse Toward Station 6	Traverse
-6	2	58	Sample Area Around Surface Electrial Properties Site	4	52	Sample Area Around Surface Electrial Properties Site	Station
-5	15	60	Complete Traverse to Station 6	27	55	Complete Traverse to Station 6	Traverse
7	44	75	Station 6	70	82	Geological Activites at Station 6	Station
33	11	119	Go to Station 7	8	152	Traverse to Station 7	Traverse
31	45	130	Station 7	22	161	Geological Activites at Station 7	Station
8	25	175	Go to Station 8	16	183	Traverse to Station 8	Traverse
-1	35	200	Station 8	47	199	Geological Activities to Station 8	Station
11	19	235	Go to Station 9	18	246	Traverse to Station 9	Traverse
10	30	254	Station 9	57	264	Geological Activities at Station 9	Station
NA	13	284	Go to Station 10	NA	NA	NA	NA
NA	47	297	Station 10	NA	NA	NA	NA
NA	NA	NA	NA	22	321	Traverse to Surface Electrical Properties Experiment Site	Station
NA	NA	NA	NA	4	343	Sample Collection	Station
4	18	344	Return to LM	4	347	Traverse to Lunar Module	Traverse
-11	58	362	Closeout	84	351	Extravehicular Activity Closeout	Overhead
15		420	End		435	End	Overhead
Total Duration		**420 7hours**			**435 7 hours 15 mins**		

Appendix B

Apollo 14 through 17 EVA Metabolic Data

B.1 Apollo 14 - EVA 1 - CDR Telemetry

Code Legend: 0.1=overhead, 0.2=traverse, 0.3=station

Table B54: Apollo 14 EVA 1 CDR Metabolic Rate (BTU/hr) per unit time (min)

Minutes	MetRate	Code	Minutes	MetRate	Code	Minutes	MetRate	Code
6827.8	618	0.1	6921.0	378	0.3	7018.9	383	0.3
6829.0	391	0.1	6924.0	651	0.3	7022.0	917	0.3
6831.7	959	0.1	6926.5	980	0.3	7022.4	407	0.3
6833.8	591	0.1	6928.6	567	0.3	7025.3	299	0.3
6835.2	886	0.1	6931.0	862	0.3	7026.9	135	0.3
6836.6	847	0.1	6933.8	301	0.3	7027.7	425	0.3
6837.1	1351	0.1	6934.8	574	0.3	7029.9	40	0.3
6838.6	1426	0.1	6936.0	381	0.3	7030.6	340	0.3
6840.0	1057	0.1	6938.8	586	0.3	7033.0	403	0.3
6841.8	1137	0.1	6940.6	382	0.3	7033.6	171	0.3
6841.9	751	0.1	6942.6	581	0.3	7034.9	132	0.3
6844.4	1155	0.1	6944.3	185	0.3	7036.2	370	0.3
6846.4	696	0.1	6947.9	1059	0.2	7039.2	427	0.3
6848.1	673	0.1	6951.5	969	0.2	7041.2	354	0.3
6850.4	464	0.1	6952.1	425	0.2	7043.2	372	0.3
6852.3	720	0.3	6954.3	1117	0.2	7045.6	605	0.3
6853.2	726	0.3	6955.9	403	0.2	7047.3	100	0.3
6854.7	987	0.3	6957.4	619	0.2	7048.9	515	0.3
6857.8	744	0.3	6958.3	375	0.2	7050.1	368	0.3
6859.6	710	0.3	6960.8	807	0.2	7050.7	549	0.3
6860.4	892	0.3	6962.7	427	0.2	7054.3	357	0.3
6861.7	313	0.3	6964.2	762	0.3	7055.4	386	0.3
6863.1	824	0.3	6964.7	541	0.3	7058.7	375	0.2
6865.2	643	0.3	6970.2	667	0.3	7060.7	903	0.2
6866.4	774	0.3	6971.2	837	0.3	7062.5	773	0.2
6867.9	457	0.3	6972.6	798	0.3	7063.2	853	0.2
6871.0	327	0.3	6973.3	588	0.3	7067.4	854	0.2
6872.1	452	0.3	6975.7	770	0.3	7069.0	1370	0.2
6874.3	373	0.3	6975.9	612	0.3	7071.2	1365	0.2
6876.4	833	0.3	6978.1	777	0.3	7072.5	877	0.2
6879.8	567	0.3	6981.0	658	0.3	7074.9	872	0.1
6883.5	664	0.3	6981.3	420	0.3	7075.3	1615	0.1
6886.7	506	0.3	6983.7	421	0.3	7076.5	1366	0.1
6888.2	467	0.3	6983.7	602	0.3	7077.8	1304	0.1
6888.9	320	0.3	6985.7	529	0.3	7078.8	975	0.1
6894.6	519	0.3	6987.6	682	0.3	7081.5	1061	0.1
6896.2	435	0.3	6989.3	439	0.3	7083.2	608	0.1
6898.4	373	0.3	6990.8	553	0.3	7084.8	409	0.1
6900.6	577	0.3	6993.5	360	0.3	7086.7	1113	0.1
6901.3	464	0.3	6995.8	576	0.3	7089.6	1046	0.1
6903.0	572	0.3	6999.0	549	0.3	7090.7	462	0.1
6905.0	510	0.3	6999.5	379	0.3	7092.0	666	0.1

6906.2	760	0.3	7002.9	572	0.3	7094.8	752	0.1
6908.1	460	0.3	7003.7	380	0.3	7095.3	525	0.1
6909.0	432	0.3	7004.7	442	0.3	7097.5	616	0.1
6910.9	784	0.3	7006.5	358	0.3	7097.4	872	0.1
6912.9	637	0.3	7009.4	477	0.3	7099.0	713	0.1
6914.6	263	0.3	7010.3	279	0.3	7100.6	725	0.1
6916.4	797	0.3	7011.9	296	0.3	7101.2	827	0.1
6918.2	752	0.3	7015.1	428	0.3	7105.0	845	0.1
6919.0	411	0.3	7017.0	678	0.3	7107.1	369	0.1

B.2 Apollo 14 - EVA 1 - LMP Telemetry

Table B55

Minutes	MetRate	Code	Minutes	MetRate	Code	Minutes	MetRate	Code
6830.3	898	0.1	6911.7	1334	0.3	7007.9	812	0.3
6833.0	395	0.1	6913.0	351	0.3	7010.5	943	0.3
6836.4	1447	0.1	6918.7	1626	0.3	7012.1	806	0.3
6837.4	904	0.1	6920.8	1232	0.3	7014.0	1075	0.3
6838.7	956	0.1	6924.2	924	0.3	7016.7	910	0.3
6841.6	562	0.1	6925.5	1032	0.3	7020.7	1144	0.3
6842.4	1047	0.1	6929.0	958	0.3	7022.3	882	0.3
6843.6	910	0.1	6931.6	1536	0.3	7023.6	967	0.3
6845.1	973	0.1	6934.6	1010	0.3	7026.7	505	0.3
6846.9	848	0.1	6936.3	1153	0.3	7029.6	545	0.3
6847.5	1191	0.1	6939.7	777	0.3	7029.8	802	0.3
6849.6	922	0.1	6941.9	634	0.3	7032.3	568	0.3
6850.9	968	0.1	6943.9	800	0.3	7036.6	843	0.3
6851.6	831	0.1	6945.5	691	0.3	7038.7	615	0.3
6853.5	1048	0.3	6947.2	1120	0.2	7039.1	809	0.3
6854.9	969	0.3	6949.2	909	0.2	7041.8	712	0.3
6856.8	1300	0.3	6950.6	1566	0.2	7042.8	1186	0.3
6859.9	1009	0.3	6953.2	944	0.2	7047.1	610	0.3
6861.0	1118	0.3	6954.8	1595	0.2	7054.2	376	0.3
6862.6	826	0.3	6957.4	824	0.2	7057.9	725	0.3
6864.7	1501	0.3	6960.9	1042	0.2	7059.7	765	0.3
6867.0	1250	0.3	6962.1	693	0.3	7061.5	583	0.3
6868.3	1336	0.3	6965.1	939	0.3	7063.0	1068	0.2
6870.6	1044	0.3	6967.4	808	0.3	7065.4	1057	0.2
6874.0	1765	0.3	6968.4	928	0.3	7066.5	920	0.2
6877.7	622	0.3	6973.6	488	0.3	7070.3	926	0.2
6879.6	1171	0.3	6974.4	746	0.3	7075.3	1578	0.1
6880.8	720	0.3	6977.3	672	0.3	7076.4	1235	0.1
6882.1	840	0.3	6979.1	923	0.3	7078.2	1481	0.1
6883.7	788	0.3	6981.7	986	0.3	7081.6	853	0.1
6884.1	1131	0.3	6983.5	764	0.3	7084.4	1070	0.1
6886.8	823	0.3	6984.6	958	0.3	7086.7	859	0.1
6887.6	932	0.2	6986.6	890	0.3	7087.5	1105	0.1
6890.6	606	0.3	6988.8	1073	0.3	7089.1	911	0.1
6892.5	669	0.3	6992.8	730	0.3	7089.9	1471	0.1
6893.9	618	0.3	6996.5	1051	0.3	7093.3	866	0.1
6896.3	704	0.3	6999.4	1079	0.3	7097.5	1135	0.1
6899.0	527	0.3	7000.8	748	0.3	7097.6	1626	0.1
6905.3	951	0.3	7002.8	908	0.3	7103.1	924	0.1
6907.4	596	0.3	7006.1	914	0.3	7105.5	792	0.1
						7107.3	861	0.1

B.3 Apollo 14 - EVA 2 - CDR Telemetry

Table B56: Apollo 14 EVA 1 LMP Metabolic Rate (BTU/hr) per unit time (min)

Minutes	MetRate	Code	Minutes	MetRate	Code	Minutes	MetRate	Code
7867.5	511	0.1	7956.1	592	0.3	8052.1	1015	0.3
7869.4	314	0.1	7957.7	938	0.3	8053.0	975	0.3
7871.0	647	0.1	7958.8	794	0.3	8054.0	1028	0.3
7871.9	266	0.1	7959.8	903	0.2	8055.3	879	0.3
7873.9	731	0.1	7961.9	925	0.2	8057.9	722	0.3
7875.5	885	0.1	7966.7	935	0.2	8058.9	805	0.3
7876.8	714	0.1	7968.8	1417	0.3	8060.8	801	0.3
7878.0	999	0.1	7970.2	909	0.3	8061.9	604	0.3
7879.2	556	0.1	7971.8	1229	0.3	8064.3	810	0.3
7881.3	557	0.1	7973.7	1286	0.2	8066.7	635	0.3
7883.4	241	0.1	7974.6	1575	0.2	8067.5	854	0.3
7884.7	268	0.1	7975.8	1343	0.2	8068.7	912	0.3
7886.7	540	0.1	7977.6	1488	0.3	8070.4	662	0.3
7888.4	483	0.1	7978.9	1243	0.3	8071.9	754	0.3
7890.6	194	0.1	7979.8	1734	0.3	8072.5	930	0.3
7891.9	558	0.1	7981.7	1813	0.2	8075.9	641	0.3
7893.8	506	0.1	7983.4	1077	0.2	8077.5	711	0.3
7895.1	304	0.1	7985.4	1993	0.2	8078.6	488	0.3
7896.1	585	0.1	7988.2	937	0.2	8080.2	900	0.3
7897.8	502	0.1	7989.6	1319	0.2	8080.8	821	0.3
7898.0	340	0.1	7991.1	1205	0.2	8083.8	830	0.3
7899.2	725	0.1	7991.9	1249	0.2	8085.0	944	0.3
7902.0	265	0.1	7992.6	1858	0.2	8086.4	497	0.3
7902.6	384	0.1	7994.6	1994	0.3	8088.7	1321	0.2
7904.1	274	0.1	7996.0	1368	0.2	8090.9	791	0.3
7905.4	362	0.1	7997.5	1942	0.2	8092.7	976	0.2
7906.7	625	0.1	7999.9	1819	0.2	8094.7	1357	0.2
7908.2	525	0.2	8000.2	2109	0.2	8096.0	1068	0.1
7908.8	700	0.2	8004.9	992	0.3	8097.5	1134	0.1
7911.6	512	0.2	8006.4	939	0.3	8098.5	1073	0.1
7913.7	517	0.2	8006.8	1049	0.3	8101.5	1879	0.1
7914.3	574	0.3	8008.0	1001	0.3	8101.8	1305	0.1
7915.8	403	0.3	8009.3	1119	0.3	8102.9	1310	0.1
7917.3	412	0.3	8010.8	804	0.3	8103.4	1060	0.1
7919.3	679	0.3	8014.5	1116	0.3	8104.8	1113	0.1
7920.8	347	0.3	8015.6	1046	0.3	8106.5	1043	0.1
7922.5	189	0.3	8016.5	603	0.3	8110.0	1394	0.1
7923.5	443	0.3	8018.9	1125	0.2	8113.7	1399	0.1
7925.9	268	0.3	8020.0	792	0.3	8114.7	1009	0.1
7927.7	387	0.3	8021.5	1524	0.3	8117.1	1202	0.1
7929.0	168	0.3	8024.1	1169	0.3	8117.8	944	0.1
7930.0	615	0.3	8025.3	1235	0.3	8118.6	1062	0.1
7931.2	755	0.3	8026.5	850	0.2	8120.9	1001	0.1
7932.1	528	0.3	8028.6	846	0.2	8122.3	707	0.1
7933.9	703	0.3	8029.3	1139	0.2	8124.3	1014	0.1
7935.4	524	0.3	8031.9	920	0.2	8126.6	1028	0.1
7937.7	725	0.3	8033.6	859	0.3	8127.5	739	0.1
7938.8	1142	0.3	8035.4	1271	0.2	8128.5	888	0.1
7939.2	515	0.3	8036.6	1158	0.2	8130.0	638	0.1
7940.4	572	0.3	8038.1	1263	0.2	8131.4	963	0.1

7941.9	349	0.3	8038.9	1206	0.2	8132.9	739	0.1
7942.9	713	0.3	8039.7	1438	0.2	8134.4	836	0.1
7944.6	424	0.3	8040.8	1062	0.3	8135.3	1239	0.1
7945.4	529	0.3	8043.5	1399	0.2	8136.0	827	0.1
7947.0	345	0.2	8044.4	1167	0.2	8137.3	906	0.1
7950.5	1244	0.2	8046.0	1233	0.3	8138.0	530	0.1
7952.8	526	0.2	8047.4	966	0.3	8138.7	889	0.1
7953.3	745	0.2	8049.4	1308	0.2	8139.8	902	0.1
7955.2	758	0.3	8050.1	962	0.2	8140.3	1323	0.1
						8142.2	1170	0.1

B.4 Apollo 14 - EVA 2 - LMP Telemetry

Table B57: Apollo 14 EVA 2 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	MetRate	Code	Minutes	MetRate	Code	Minutes	MetRate	Code
7868.0	40	0.1	7959.3	632	0.2	8054.4	1021	0.2
7868.6	275	0.1	7960.1	1069	0.2	8056.0	1294	0.2
7870.3	-99	0.1	7961.7	955	0.2	8057.5	908	0.2
7872.1	427	0.1	7962.3	1082	0.3	8058.9	1377	0.2
7873.6	231	0.1	7964.2	1006	0.2	8060.4	934	0.2
7874.8	459	0.1	7965.2	1399	0.2	8062.3	972	0.2
7876.3	396	0.1	7966.7	1184	0.2	8063.4	776	0.2
7876.9	592	0.1	7968.6	1133	0.2	8064.2	960	0.2
7878.6	200	0.1	7971.0	627	0.2	8065.7	852	0.2
7880.2	561	0.1	7975.5	1223	0.2	8068.9	1302	0.2
7881.9	650	0.1	7976.8	1673	0.2	8070.8	992	0.2
7884.2	416	0.1	7978.9	768	0.3	8073.1	961	0.2
7886.0	790	0.1	7979.6	1585	0.3	8074.2	714	0.2
7887.1	436	0.1	7983.0	832	0.2	8076.1	784	0.2
7890.0	639	0.1	7984.8	1700	0.2	8076.9	905	0.2
7891.1	601	0.1	7986.5	1459	0.2	8078.6	721	0.2
7892.7	905	0.1	7987.2	845	0.2	8080.5	722	0.2
7894.0	684	0.1	7989.4	1226	0.2	8081.9	1045	0.2
7895.2	893	0.1	7991.1	1106	0.2	8083.8	779	0.2
7896.3	697	0.1	7992.2	1156	0.2	8088.0	1673	0.2
7897.7	653	0.1	7994.6	2417	0.3	8090.6	1160	0.3
7899.7	1153	0.1	7996.7	1543	0.2	8092.3	1230	0.2
7901.9	616	0.1	7997.2	1904	0.2	8093.2	1718	0.2
7903.6	591	0.1	7999.6	2544	0.2	8094.5	1794	0.2
7905.0	705	0.1	8001.0	2038	0.2	8094.8	1395	0.2
7906.8	1098	0.2	8001.8	2139	0.2	8096.6	1472	0.2
7908.6	750	0.2	8003.6	1405	0.3	8097.8	940	0.1
7909.6	940	0.2	8006.3	1285	0.3	8099.1	1371	0.1
7911.1	826	0.2	8007.8	1070	0.3	8103.0	884	0.1
7913.2	820	0.2	8009.0	1324	0.3	8105.2	1378	0.1
7914.4	713	0.3	8011.6	868	0.3	8106.7	942	0.1
7916.5	764	0.3	8014.8	679	0.3	8108.4	923	0.1
7918.0	460	0.3	8017.3	1648	0.3	8110.3	860	0.1
7919.2	777	0.3	8018.6	1376	0.2	8112.2	1911	0.1
7920.3	423	0.3	8020.1	1009	0.3	8113.6	2000	0.1
7921.7	657	0.3	8020.3	1357	0.3	8115.1	721	0.1
7922.4	271	0.3	8023.6	1396	0.3	8115.9	949	0.1
7923.6	676	0.3	8025.8	959	0.3	8117.2	817	0.1
7926.0	335	0.3	8027.5	928	0.2	8119.9	1083	0.1
7927.3	861	0.3	8030.3	1340	0.2	8120.3	988	0.1
7929.9	336	0.3	8032.0	1024	0.3	8120.7	1134	0.1
7931.2	412	0.3	8036.3	1461	0.3	8121.8	944	0.1
7931.9	887	0.3	8037.0	1272	0.3	8124.0	1337	0.1
7933.0	748	0.3	8039.7	1367	0.3	8125.4	552	0.1
7934.3	646	0.3	8040.1	1614	0.2	8127.5	1692	0.1
7936.5	761	0.3	8041.6	1127	0.2	8131.6	1003	0.1
7938.2	578	0.3	8043.8	1811	0.2	8132.6	984	0.1
7939.5	597	0.3	8044.9	1627	0.2	8132.9	579	0.1
7943.3	458	0.3	8046.7	1938	0.3	8134.7	655	0.1
7947.8	826	0.2	8047.4	1457	0.3	8135.3	1029	0.1

7948.8	1029	0.2	8048.0	1577	0.3	8136.4	934	0.1
7952.6	605	0.2	8049.9	1464	0.2	8137.5	1314	0.1
7954.5	833	0.3	8050.5	1711	0.2	8140.6	833	0.1
7955.6	479	0.3	8052.4	1293	0.2	8141.4	928	0.1

B.5 Apollo 15 - EVA 1 - CDR Telemetry

Table B58: Apollo 15 EVA 1 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
7175.9	865	0.1	7313.2	509	0.2	7453.1	768	0.3
7182.0	2094	0.1	7320.4	400	0.2	7455.9	930	0.3
7183.8	1499	0.1	7323.3	400	0.2	7461.3	943	0.3
7189.9	1143	0.1	7326.1	244	0.2	7463.4	1298	0.2
7192.4	1441	0.1	7333.7	348	0.3	7466.3	781	0.2
7202.1	1557	0.1	7335.8	1201	0.3	7469.2	464	0.2
7204.2	626	0.1	7338.0	807	0.3	7472.8	962	0.2
7208.2	1893	0.1	7340.8	891	0.3	7476.7	1104	0.3
7213.6	1285	0.1	7345.5	781	0.3	7479.6	885	0.3
7217.1	1298	0.1	7347.3	1130	0.3	7484.2	994	0.3
7219.7	1091	0.1	7354.5	445	0.2	7489.3	865	0.3
7222.9	1292	0.1	7357.0	490	0.3	7491.1	1240	0.3
7225.0	1311	0.1	7358.4	1066	0.3	7494.6	891	0.3
7226.5	1195	0.1	7361.6	833	0.3	7498.6	1014	0.3
7231.1	1518	0.1	7364.1	917	0.3	7499.7	1415	0.3
7236.9	1512	0.1	7366.3	833	0.3	7507.9	807	0.3
7239.7	917	0.1	7368.1	1272	0.3	7510.1	1240	0.3
7242.2	1098	0.1	7372.4	1072	0.3	7514.4	975	0.3
7246.2	1182	0.1	7376.3	1318	0.3	7519.4	969	0.3
7249.1	1085	0.1	7381.3	1124	0.3	7520.8	1389	0.3
7252.6	1091	0.1	7387.1	1053	0.3	7525.1	1195	0.3
7254.4	1182	0.1	7390.7	852	0.3	7528.0	1292	0.3
7257.7	1098	0.1	7397.1	1156	0.3	7533.0	1201	0.3
7266.6	2320	0.1	7399.6	833	0.3	7536.6	1331	0.3
7270.9	930	0.1	7406.1	1738	0.2	7543.4	865	0.2
7274.2	1402	0.1	7408.2	1272	0.2	7546.3	1350	0.1
7281.7	1079	0.1	7409.7	574	0.2	7549.5	1014	0.1
7286.3	1208	0.1	7414.3	238	0.2	7553.8	936	0.1
7290.3	775	0.1	7419.7	238	0.2	7559.5	1576	0.1
7294.6	555	0.1	7423.7	393	0.2	7563.5	1066	0.1
7295.3	1007	0.1	7424.4	1395	0.2	7567.1	1738	0.1
7298.9	1188	0.1	7428.3	244	0.2	7572.1	1854	0.1
7303.9	1091	0.1	7437.6	109	0.3	7575.7	1751	0.1
7306.4	1538	0.2	7445.9	1337	0.3			
7309.6	594	0.2	7449.8	768	0.3			

B.6 Apollo 15 - EVA 1 - LMP Telemetry

Table B59: Apollo 15 EVA 1 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
7176.1	241	0.1	7307.7	558	0.2	7458.0	1526	0.3
7184.7	988	0.1	7312.3	730	0.2	7464.9	1651	0.2
7187.0	513	0.1	7315.7	240	0.2	7466.2	1988	0.2
7193.8	579	0.1	7319.4	298	0.2	7469.0	1827	0.3
7194.6	1133	0.1	7326.4	279	0.2	7472.8	1199	0.3
7199.5	1475	0.1	7331.4	188	0.3	7474.4	1336	0.3
7203.1	858	0.1	7334.5	622	0.3	7477.2	1337	0.3
7204.0	1370	0.1	7337.7	651	0.3	7483.1	1452	0.3
7207.4	1207	0.3	7342.7	517	0.3	7486.1	1647	0.3
7211.2	1194	0.3	7344.9	873	0.3	7487.9	1368	0.3
7211.4	1038	0.3	7353.7	-6	0.2	7493.0	1336	0.3
7213.8	1223	0.3	7358.3	102	0.2	7496.1	1129	0.3
7217.8	1110	0.1	7358.4	464	0.3	7500.2	1277	0.3
7220.9	1211	0.1	7362.0	508	0.3	7505.6	1003	0.3
7224.9	1041	0.1	7365.0	310	0.3	7510.1	1095	0.3
7229.1	1454	0.1	7371.1	212	0.3	7510.8	1402	0.3
7234.6	1022	0.1	7376.0	483	0.3	7513.9	1484	0.3
7238.1	1179	0.1	7376.7	762	0.3	7516.8	1186	0.3
7243.9	1216	0.1	7384.7	940	0.3	7520.8	1159	0.3
7245.7	734	0.1	7387.8	779	0.3	7524.2	1254	0.3
7251.6	778	0.1	7393.2	989	0.3	7526.3	1047	0.3
7252.3	984	0.1	7396.8	734	0.3	7529.3	1213	0.3
7259.8	1029	0.1	7400.1	901	0.3	7533.4	1635	0.3
7262.3	1171	0.1	7403.4	906	0.3	7535.5	1148	0.3
7262.9	369	0.1	7404.4	197	0.3	7538.4	1135	0.3
7266.7	342	0.1	7414.4	-9	0.2	7539.8	643	0.2
7270.2	868	0.1	7419.0	16	0.2	7544.6	1028	0.1
7276.3	770	0.1	7424.2	-130	0.2	7547.5	2008	0.1
7280.4	871	0.1	7426.9	-49	0.2	7550.8	1195	0.1
7280.3	1723	0.1	7431.6	-275	0.2	7554.0	1944	0.1
7285.8	1973	0.1	7434.0	-212	0.2	7556.6	1892	0.1
7290.0	944	0.1	7437.6	-240	0.2	7559.8	927	0.1
7294.8	1726	0.1	7442.7	694	0.3	7564.3	1288	0.1
7296.6	1180	0.1	7448.2	572	0.3	7568.9	1308	0.1
7300.1	1025	0.1	7451.7	1146	0.3	7572.4	1139	0.1
7303.8	1423	0.1	7455.3	1147	0.3			

B.7 Apollo 15 - EVA 2 - CDR Telemetry

Table B60: Apollo 15 EVA 2 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
8533.7	377	0.1	8689.0	1110	0.3	8832.6	688	0.3
8541.3	1121	0.1	8692.8	1046	0.3	8835.1	871	0.3
8545.4	534	0.1	8694.7	1248	0.3	8839.0	871	0.3
8547.4	1373	0.1	8698.2	1305	0.2	8841.1	732	0.2
8551.3	1373	0.1	8702.1	1222	0.3	8843.3	1066	0.2
8553.1	1626	0.1	8703.9	1399	0.3	8848.6	958	0.3
8557.2	1082	0.1	8706.4	1512	0.3	8851.0	642	0.3
8560.8	1050	0.1	8710.5	1133	0.3	8855.3	939	0.3
8562.5	1113	0.1	8713.9	1771	0.3	8858.1	819	0.3
8569.9	923	0.1	8716.6	1562	0.3	8861.3	1102	0.3
8573.2	1245	0.1	8720.9	1568	0.3	8865.1	686	0.3
8577.4	1346	0.1	8722.5	1038	0.2	8868.7	692	0.3
8583.4	1188	0.1	8725.3	867	0.2	8868.7	799	0.3
8586.5	903	0.1	8730.0	1384	0.3	8872.2	717	0.3
8590.4	909	0.1	8731.7	930	0.3	8875.1	981	0.3
8593.0	1446	0.1	8733.8	936	0.3	8880.0	867	0.3
8594.9	663	0.1	8737.3	797	0.3	8882.9	1195	0.3
8601.2	448	0.2	8740.1	897	0.3	8886.8	1082	0.3
8604.1	491	0.2	8741.9	834	0.3	8890.0	1138	0.3
8607.2	346	0.2	8745.8	897	0.3	8892.7	930	0.3
8611.8	384	0.2	8749.7	859	0.3	8898.7	916	0.3
8615.3	314	0.2	8753.3	1389	0.3	8908.0	1206	0.3
8618.9	396	0.2	8761.7	1136	0.3	8909.5	1673	0.3
8620.6	282	0.2	8763.1	927	0.3	8913.6	1054	0.1
8624.8	269	0.2	8769.9	1438	0.3	8920.4	1287	0.1
8634.1	445	0.3	8774.2	1343	0.2	8921.5	1622	0.1
8636.7	1076	0.3	8777.8	541	0.2	8925.2	1028	0.1
8641.2	880	0.3	8783.5	465	0.2	8929.1	983	0.1
8644.8	880	0.3	8787.7	546	0.3	8930.6	1110	0.1
8647.7	1170	0.3	8793.9	1114	0.3	8933.0	1040	0.1
8653.7	1308	0.3	8797.4	1057	0.3	8938.7	1147	0.1
8657.5	1049	0.3	8804.2	1511	0.2	8943.6	957	0.1
8663.2	967	0.3	8809.1	1346	0.2	8945.1	1494	0.1
8665.7	1137	0.3	8810.7	633	0.2	8950.4	1228	0.1
8668.1	1124	0.3	8818.1	355	0.2	8952.9	1613	0.1
8671.6	947	0.3	8820.9	386	0.2	8956.7	1108	0.1
8678.7	1085	0.3	8824.4	297	0.2	8959.6	1341	0.1
8680.6	1407	0.3	8828.3	303	0.2	8962.8	1328	0.1
8685.1	1079	0.3	8831.9	758	0.3	8965.4	602	0.1

B.8 Apollo 15 - EVA 2 - LMP Telemetry

Table B61: Apollo 15 EVA 2 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
8536.1	524	0.1	8686.9	780	0.3	8821.4	-53	0.2
8537.9	821	0.1	8690.5	813	0.3	8831.5	942	0.3
8545.0	130	0.1	8693.0	725	0.3	8837.2	901	0.3
8549.2	953	0.1	8696.1	819	0.3	8842.1	986	0.3
8553.5	921	0.1	8698.7	355	0.3	8853.6	909	0.2
8556.6	662	0.1	8701.0	531	0.2	8854.1	746	0.2
8558.3	1414	0.1	8707.1	537	0.3	8858.7	714	0.3
8561.3	1234	0.1	8708.1	607	0.3	8858.3	789	0.3
8566.3	1239	0.1	8712.0	635	0.3	8862.9	780	0.3
8568.9	1100	0.1	8712.9	793	0.3	8872.1	1190	0.3
8573.9	1106	0.1	8717.5	418	0.3	8876.9	638	0.3
8577.8	749	0.1	8720.3	451	0.3	8881.4	839	0.3
8581.8	1000	0.1	8721.5	646	0.3	8882.6	1373	0.3
8585.2	838	0.1	8723.7	238	0.2	8888.1	1667	0.3
8588.6	983	0.1	8728.5	777	0.3	8890.4	1077	0.3
8592.4	338	0.1	8732.3	536	0.3	8893.9	1152	0.3
8597.4	278	0.2	8733.7	583	0.3	8896.4	1069	0.3
8599.9	339	0.2	8739.0	598	0.3	8900.0	1083	0.3
8605.3	261	0.2	8740.1	542	0.3	8903.8	1219	0.3
8609.5	308	0.2	8744.0	589	0.3	8907.7	1150	0.2
8613.2	197	0.2	8746.2	892	0.3	8909.4	1229	0.2
8618.5	198	0.2	8749.3	576	0.3	8912.4	1104	0.2
8621.6	310	0.2	8752.8	679	0.3	8916.0	1104	0.1
8623.9	115	0.2	8757.1	666	0.3	8920.2	1565	0.1
8630.7	102	0.2	8758.8	740	0.3	8921.6	1161	0.1
8633.7	293	0.3	8761.6	787	0.3	8924.2	1050	0.1
8634.8	669	0.3	8763.8	727	0.3	8927.3	1106	0.1
8639.3	777	0.3	8767.5	951	0.3	8930.2	1051	0.1
8642.6	620	0.3	8773.2	882	0.2	8934.0	1186	0.1
8644.8	629	0.3	8773.7	348	0.2	8937.7	1024	0.1
8647.7	523	0.3	8778.1	214	0.2	8940.8	1108	0.1
8653.2	733	0.3	8780.0	80	0.2	8942.6	1503	0.1
8655.7	742	0.3	8784.6	150	0.2	8945.9	1425	0.1
8658.4	850	0.3	8790.1	685	0.3	8951.4	1607	0.1
8661.5	641	0.3	8793.7	704	0.3	8952.1	1203	0.1
8664.8	897	0.3	8796.7	556	0.3	8956.3	1273	0.1
8668.6	958	0.3	8799.6	812	0.3	8957.9	1102	0.1
8673.3	898	0.3	8804.0	729	0.3	8962.3	1349	0.1
8678.9	988	0.3	8806.2	181	0.3	8965.5	225	0.1
8681.5	1313	0.3	8807.4	79	0.2	8967.0	532	0.1
8684.3	923	0.3	8812.0	150	0.2			

B.9 Apollo 15 - EVA 3 - CDR Telemetry

Table B62: Apollo 15 EVA 3 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
9796.4	384	0.1	9902.5	364	0.2	10005.2	531	0.2
9800.5	860	0.1	9905.3	1186	0.3	10007.8	871	0.1
9803.6	293	0.1	9908.4	715	0.3	10011.4	928	0.1
9810.5	1388	0.1	9913.0	755	0.3	10012.4	848	0.1
9815.7	838	0.1	9922.5	1487	0.3	10016.3	871	0.1
9818.2	1014	0.1	9924.1	789	0.3	10020.1	1427	0.1
9820.8	855	0.1	9928.0	421	0.3	10023.4	1438	0.1
9824.4	872	0.1	9929.7	586	0.3	10027.6	1262	0.1
9825.9	1025	0.1	9937.5	563	0.3	10033.5	1166	0.1
9828.5	1003	0.1	9941.3	858	0.3	10036.3	1331	0.1
9831.6	850	0.1	9946.5	875	0.3	10041.2	1098	0.1
9838.3	986	0.1	9949.8	818	0.3	10043.3	1444	0.1
9839.9	907	0.1	9953.7	1187	0.3	10045.6	1376	0.1
9845.8	992	0.2	9955.5	864	0.3	10048.4	1399	0.1
9848.4	754	0.2	9960.6	807	0.3	10055.4	787	0.1
9856.1	1502	0.3	9963.5	938	0.3	10057.2	1138	0.1
9863.3	1366	0.3	9965.0	762	0.3	10061.3	1263	0.1
9864.8	1049	0.3	9969.4	802	0.3	10063.6	1564	0.1
9874.4	828	0.3	9971.2	1295	0.3	10067.5	1677	0.1
9878.2	987	0.3	9974.8	1284	0.2	10070.6	1399	0.1
9881.8	930	0.3	9978.9	791	0.2	10073.4	2040	0.1
9884.4	987	0.3	9981.5	1086	0.2	10076.5	1609	0.1
9888.5	483	0.3	9982.5	853	0.2	10079.0	1921	0.1
9890.9	743	0.2	9988.7	853	0.2	10081.9	1666	0.1
9893.7	641	0.2	9989.7	1261	0.2	10084.7	1729	0.1
9895.0	290	0.2	9993.1	400	0.2	10087.3	1666	0.1
9897.6	369	0.2	9996.2	502	0.2			
9899.1	284	0.2	10002.6	349	0.2			

B.10 Apollo 15 - EVA 3 - LMP Telemetry

Table B63: Apollo 15 EVA 3 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
9797.5	1054	0.1	9897.4	194	0.2	10000.8	356	0.2
9801.6	1122	0.1	9899.6	199	0.2	10003.0	401	0.3
9805.7	512	0.1	9905.0	623	0.3	10006.4	865	0.2
9809.4	926	0.1	9908.6	655	0.3	10009.8	398	0.1
9813.6	962	0.1	9914.0	498	0.3	10015.3	596	0.1
9817.2	1350	0.1	9916.9	490	0.2	10018.4	502	0.1
9821.3	1108	0.1	9919.0	643	0.3	10020.2	714	0.1
9823.8	1220	0.1	9922.4	608	0.3	10025.0	755	0.1
9824.6	834	0.1	9925.6	855	0.3	10028.5	594	0.1
9829.0	664	0.1	9933.3	668	0.3	10030.6	788	0.1
9830.7	651	0.1	9934.4	830	0.3	10032.1	658	0.1
9836.2	355	0.1	9937.4	862	0.3	10037.8	978	0.1
9839.5	814	0.1	9941.0	620	0.3	10041.4	641	0.1
9842.7	783	0.1	9944.1	566	0.3	10046.2	1069	0.1
9845.7	1305	0.2	9945.8	616	0.3	10051.3	953	0.1
9847.4	833	0.3	9949.5	441	0.3	10054.8	1606	0.1
9852.8	807	0.3	9953.9	1045	0.3	10058.9	1786	0.1
9854.8	686	0.3	9960.0	803	0.3	10061.3	1171	0.1
9857.5	1280	0.3	9963.4	803	0.3	10066.3	785	0.1
9862.9	858	0.3	9966.0	1015	0.3	10071.5	673	0.1
9869.7	792	0.3	9968.7	782	0.3	10075.6	1245	0.1
9874.0	982	0.3	9971.7	890	0.3	10077.7	1106	0.1
9877.7	946	0.3	9977.7	415	0.3	10079.7	976	0.1
9879.6	681	0.3	9981.0	860	0.3	10081.9	1147	0.1
9882.1	781	0.3	9984.6	641	0.3	10084.7	1085	0.1
9885.2	696	0.1	9986.7	879	0.3	10089.1	869	0.1
9887.9	854	0.1	9991.5	323	0.2			
9891.9	382	0.2	9998.7	121	0.2			

B.11 Apollo 16 - EVA 1 - CDR Telemetry

Table B64: Apollo 16 EVA 1 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
7204.0	1328	0.1	7315.8	795	0.3	7438.2	790	0.3
7210.2	993	0.1	7321.0	715	0.3	7441.6	998	0.3
7216.7	1197	0.1	7324.1	657	0.3	7444.0	783	0.3
7219.1	1051	0.1	7327.5	834	0.3	7447.8	748	0.3
7222.5	1063	0.1	7330.6	476	0.3	7450.2	956	0.3
7228.6	1352	0.1	7333.0	488	0.3	7453.3	875	0.2
7234.8	1202	0.1	7336.1	453	0.3	7456.0	1276	0.2
7237.0	732	0.1	7342.6	449	0.3	7459.5	386	0.3
7243.1	867	0.1	7345.7	519	0.3	7463.0	460	0.3
7245.9	871	0.2	7348.0	777	0.3	7465.9	1222	0.3
7248.7	374	0.2	7354.9	708	0.3	7469.0	941	0.3
7251.8	386	0.2	7357.7	550	0.3	7475.2	980	0.3
7254.5	752	0.3	7360.7	754	0.3	7478.0	818	0.3
7258.2	790	0.3	7364.5	823	0.3	7479.7	1053	0.3
7264.3	1306	0.3	7369.7	727	0.3	7483.4	968	0.3
7267.1	891	0.3	7371.7	770	0.3	7487.1	1558	0.2
7270.6	821	0.3	7375.8	666	0.3	7489.9	1034	0.2
7275.3	921	0.3	7381.6	924	0.2	7495.2	549	0.3
7278.8	806	0.3	7384.5	11	0.2	7498.3	526	0.3
7281.9	787	0.3	7387.3	19	0.2	7502.0	630	0.3
7284.6	1080	0.3	7390.3	146	0.2	7504.0	1177	0.3
7288.0	791	0.3	7392.4	119	0.2	7508.1	1235	0.1
7291.1	718	0.3	7399.8	982	0.2	7514.0	826	0.1
7294.9	726	0.3	7405.4	23	0.3	7518.4	1335	0.1
7300.7	895	0.3	7408.4	997	0.3	7522.1	1493	0.1
7302.5	660	0.3	7411.1	1067	0.3	7527.3	1089	0.1
7305.2	595	0.3	7420.1	559	0.3	7531.1	939	0.1
7310.0	622	0.3	7426.5	932	0.3	7533.8	1293	0.1
7312.1	556	0.3	7429.7	694	0.3	7537.6	1285	0.1

B.12 Apollo 16 - EVA 1 - LMP Telemetry

Table B65: Apollo 16 EVA 1 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
7203.7	1403	0.1	7312.7	1644	0.3	7417.6	683	0.3
7206.7	1119	0.1	7315.4	1294	0.3	7420.7	1020	0.3
7209.3	1160	0.1	7318.6	1494	0.3	7426.0	627	0.3
7212.6	985	0.1	7321.7	948	0.3	7428.5	821	0.3
7215.8	1076	0.1	7327.9	1407	0.3	7432.8	509	0.3
7220.4	1516	0.1	7330.5	546	0.3	7437.2	858	0.3
7224.9	1569	0.1	7336.1	262	0.3	7441.1	734	0.3
7227.6	1304	0.1	7340.2	381	0.3	7444.1	347	0.3
7230.4	1519	0.1	7342.8	418	0.3	7449.6	1439	0.3
7234.0	1442	0.2	7349.0	1043	0.3	7456.7	1258	0.2
7236.3	2225	0.2	7351.2	1136	0.3	7460.0	116	0.3
7240.2	2163	0.2	7354.5	837	0.3	7463.5	120	0.3
7244.4	1869	0.3	7357.8	800	0.3	7464.9	831	0.3
7245.7	946	0.3	7360.5	1096	0.3	7473.7	1312	0.3
7248.1	652	0.3	7362.4	2276	0.3	7477.5	822	0.3
7252.1	1164	0.3	7366.2	1380	0.3	7483.1	1172	0.3
7257.0	977	0.3	7370.5	1221	0.3	7487.0	1100	0.2
7260.4	1274	0.3	7374.8	775	0.3	7488.5	1353	0.2
7264.3	1237	0.3	7378.6	1056	0.2	7493.3	682	0.2
7267.2	1081	0.3	7382.2	782	0.2	7501.5	951	0.2
7273.9	1327	0.3	7384.4	154	0.2	7504.5	1641	0.3
7276.4	1668	0.3	7388.6	105	0.2	7507.6	1204	0.3
7281.3	1315	0.3	7390.5	195	0.2	7510.4	1432	0.1
7285.8	1256	0.3	7393.7	220	0.2	7513.9	1426	0.1
7288.5	1106	0.3	7397.2	395	0.2	7519.2	1132	0.1
7291.5	1503	0.3	7399.2	1069	0.2	7522.4	1145	0.1
7294.1	1665	0.3	7402.0	211	0.2	7527.7	714	0.1
7297.8	1057	0.3	7405.0	111	0.2	7532.1	846	0.1
7300.1	1843	0.3	7408.3	636	0.3	7535.2	471	0.1
7304.5	1322	0.3	7410.5	826	0.3	7538.3	818	0.1
7309.4	1859	0.3	7414.0	898	0.3			

B.13 Apollo 16 - EVA 2 - CDR Telemetry

Table B66: Apollo 16 EVA 2 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
8580.0	1097	0.1	8727.1	955	0.3	8849.8	417	0.3
8582.5	1005	0.1	8729.8	841	0.3	8853.0	627	0.3
8584.9	994	0.1	8732.9	837	0.3	8856.5	722	0.3
8588.2	824	0.1	8736.0	763	0.3	8861.7	722	0.3
8590.8	1089	0.1	8738.8	774	0.3	8867.4	464	0.3
8594.2	982	0.1	8741.7	1032	0.3	8870.6	633	0.3
8597.0	1078	0.1	8745.0	803	0.3	8873.5	312	0.2
8600.4	1063	0.1	8747.8	921	0.3	8885.6	882	0.3
8605.8	687	0.1	8750.5	840	0.3	8888.9	657	0.3
8609.8	1110	0.1	8754.0	917	0.3	8890.7	661	0.3
8611.7	790	0.1	8756.6	1090	0.3	8894.7	1143	0.3
8614.5	893	0.2	8759.1	648	0.3	8897.7	959	0.3
8617.4	458	0.2	8762.0	912	0.2	8901.5	951	0.3
8624.4	597	0.2	8765.8	349	0.2	8905.6	756	0.3
8627.4	502	0.2	8768.9	327	0.2	8909.8	855	0.3
8631.5	461	0.2	8774.5	1088	0.3	8911.7	1153	0.3
8633.6	501	0.2	8777.8	746	0.3	8918.4	284	0.2
8636.3	409	0.2	8781.0	952	0.3	8924.6	280	0.2
8646.0	364	0.2	8784.4	867	0.3	8927.4	246	0.2
8650.7	835	0.3	8789.2	863	0.3	8931.2	298	0.2
8658.6	754	0.3	8792.2	531	0.3	8937.0	227	0.2
8663.4	1247	0.3	8798.6	384	0.2	8939.7	577	0.3
8667.0	908	0.3	8801.8	428	0.2	8941.8	731	0.3
8671.8	797	0.3	8807.1	641	0.3	8945.6	676	0.3
8675.6	837	0.3	8810.8	486	0.3	8948.5	1025	0.3
8678.1	958	0.3	8813.5	416	0.3	8954.8	543	0.3
8680.8	921	0.3	8816.6	408	0.3	8956.7	786	0.3
8684.3	958	0.3	8819.4	478	0.3	8961.2	760	0.3
8686.8	1171	0.3	8822.2	481	0.3	8964.0	829	0.3
8696.0	803	0.3	8824.9	360	0.3	8965.9	516	0.1
8699.5	953	0.3	8829.4	356	0.3	8968.8	829	0.1
8704.9	765	0.3	8830.8	440	0.3	8975.0	825	0.1
8707.8	898	0.2	8835.3	414	0.3	8978.8	714	0.1
8711.7	577	0.2	8837.7	477	0.3	8984.1	953	0.1
8714.2	732	0.2	8840.1	381	0.3	8990.6	960	0.1
8717.4	834	0.3	8843.2	381	0.3	8996.5	1582	0.1
8724.0	834	0.3	8846.1	568	0.3	8999.7	1070	0.1

B.14 Apollo 16 - EVA 2 - LMP Telemetry

Table B67: Apollo 16 EVA 2 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
8580.7	780	0.1	8720.9	651	0.3	8862.2	610	0.3
8583.8	773	0.1	8724.7	579	0.3	8865.6	575	0.3
8586.6	870	0.1	8727.5	1053	0.3	8869.4	728	0.2
8589.0	818	0.1	8733.0	818	0.3	8871.5	222	0.2
8591.7	859	0.1	8736.4	828	0.3	8876.3	239	0.3
8594.8	1036	0.1	8739.9	741	0.3	8878.7	842	0.3
8598.6	1057	0.1	8742.0	1084	0.3	8879.8	752	0.3
8604.5	783	0.1	8749.2	707	0.3	8881.5	707	0.3
8607.2	929	0.1	8750.9	1084	0.3	8884.3	842	0.3
8610.0	315	0.1	8755.4	994	0.3	8886.3	658	0.3
8613.4	877	0.2	8756.8	613	0.3	8890.8	728	0.3
8615.8	450	0.2	8761.6	440	0.2	8895.6	1119	0.3
8625.8	353	0.2	8764.0	267	0.2	8901.5	877	0.3
8631.3	357	0.2	8766.8	204	0.2	8904.9	845	0.3
8634.1	333	0.2	8770.5	340	0.3	8907.3	648	0.3
8638.9	326	0.2	8772.3	1019	0.3	8911.5	721	0.2
8642.4	392	0.2	8774.3	821	0.3	8913.9	392	0.2
8647.5	336	0.3	8779.2	693	0.3	8921.1	277	0.2
8651.0	1116	0.3	8784.3	1164	0.3	8923.9	360	0.2
8655.5	1116	0.3	8786.4	1039	0.3	8930.8	267	0.2
8658.6	866	0.3	8790.2	1594	0.2	8938.0	516	0.3
8661.3	1019	0.3	8793.3	447	0.2	8941.1	835	0.3
8664.8	1088	0.3	8800.2	170	0.3	8947.3	1022	0.3
8667.5	835	0.3	8802.6	308	0.3	8951.4	1022	0.3
8671.0	1098	0.3	8805.0	897	0.3	8955.9	1518	0.3
8673.4	1185	0.3	8809.8	845	0.3	8962.8	1060	0.1
8677.2	991	0.3	8811.9	970	0.3	8964.9	1084	0.1
8679.2	1195	0.3	8815.3	1351	0.3	8971.1	939	0.1
8683.0	1091	0.3	8819.5	838	0.3	8974.9	1053	0.1
8686.5	1143	0.3	8822.9	838	0.3	8977.3	880	0.1
8691.6	1362	0.3	8826.7	461	0.3	8980.7	939	0.1
8694.4	856	0.3	8832.6	1019	0.3	8983.1	1330	0.1
8696.1	929	0.3	8835.7	638	0.3	8985.2	759	0.1
8701.6	956	0.3	8844.6	1064	0.3	8990.0	852	0.1
8703.4	901	0.2	8847.4	942	0.3	8992.4	1850	0.1
8710.3	250	0.2	8851.9	977	0.3	8998.0	721	0.1
8716.5	631	0.3	8854.3	821	0.3			
8719.2	679	0.3	8857.0	1033	0.3			

B.15 Apollo 16 - EVA 3 - CDR Telemetry

Table B68: Apollo 16 EVA 3 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
9942.2	1547	0.1	10062.8	935	0.3	10174.5	930	0.3
9946.7	1409	0.1	10066.0	1043	0.3	10177.0	937	0.3
9948.4	1127	0.1	10069.4	869	0.3	10180.1	745	0.3
9953.3	1597	0.1	10075.3	811	0.3	10182.5	1060	0.3
9958.5	1702	0.1	10077.4	1115	0.3	10186.0	922	0.3
9960.1	957	0.1	10081.5	1224	0.3	10189.8	890	0.3
9963.6	1341	0.1	10083.9	938	0.3	10195.6	499	0.3
9967.8	1492	0.2	10087.1	934	0.3	10198.1	774	0.3
9971.9	794	0.2	10089.1	819	0.3	10202.5	731	0.1
9979.1	606	0.2	10092.6	768	0.2	10204.3	839	0.1
9982.9	671	0.2	10096.0	334	0.2	10206.4	788	0.1
9985.0	953	0.2	10098.8	471	0.2	10210.2	781	0.1
9986.7	646	0.2	10101.9	869	0.3	10212.9	716	0.1
9996.1	512	0.2	10105.4	677	0.3	10216.0	785	0.1
10002.3	581	0.2	10108.8	587	0.3	10218.8	1013	0.1
10012.0	942	0.3	10110.6	717	0.3	10222.6	521	0.1
10015.8	805	0.3	10119.6	898	0.3	10225.4	933	0.1
10021.7	1503	0.3	10122.7	1245	0.3	10227.4	412	0.1
10024.1	1137	0.3	10125.8	974	0.3	10231.6	770	0.1
10026.9	1101	0.3	10129.3	1050	0.2	10235.0	690	0.1
10029.3	971	0.3	10131.6	352	0.2	10238.2	712	0.1
10033.1	928	0.3	10138.2	247	0.2	10241.3	716	0.1
10036.2	924	0.3	10140.9	319	0.2	10246.1	810	0.1
10041.1	1050	0.3	10147.9	351	0.2	10249.6	802	0.1
10044.9	1050	0.3	10153.7	257	0.2	10251.7	1059	0.1
10048.3	873	0.3	10156.5	348	0.2	10257.2	983	0.1
10051.5	1087	0.3	10161.7	731	0.3	10262.7	763	0.1
10053.9	1065	0.3	10164.5	745	0.3	10264.5	1243	0.1
10056.6	938	0.3	10168.3	575	0.3	10270.4	1533	0.1
10059.7	1029	0.3	10171.1	1118	0.3	10273.2	1862	0.1

B.16 Apollo 16 - EVA 3 - LMP Telemetry

Table B69: Apollo 16 EVA 3 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
9944.5	890	0.1	10051.9	971	0.3	10176.2	753	0.3
9947.3	1021	0.1	10056.2	885	0.3	10178.9	1018	0.3
9953.3	952	0.1	10058.2	639	0.3	10184.8	815	0.3
9955.7	827	0.1	10062.5	1011	0.3	10188.2	847	0.3
9959.1	1908	0.1	10066.1	945	0.3	10191.2	815	0.3
9964.6	741	0.1	10068.2	1178	0.3	10193.4	1058	0.2
9969.1	964	0.2	10071.0	805	0.3	10197.0	928	0.3
9970.6	387	0.2	10078.5	1021	0.3	10200.5	984	0.1
9975.0	443	0.2	10083.1	1512	0.3	10203.6	1003	0.1
9976.9	345	0.2	10088.7	762	0.3	10206.2	1214	0.1
9980.0	344	0.2	10091.8	791	0.2	10209.3	1009	0.1
9983.4	388	0.2	10094.1	539	0.2	10211.9	1077	0.1
9987.5	385	0.2	10100.8	393	0.3	10215.5	1045	0.1
9989.9	424	0.2	10103.7	816	0.3	10217.6	1120	0.1
9993.3	275	0.2	10107.5	781	0.3	10220.7	1062	0.1
9996.0	350	0.2	10110.2	856	0.3	10223.0	740	0.1
9999.3	301	0.2	10113.3	844	0.3	10226.0	1923	0.1
10000.9	347	0.2	10115.6	1043	0.3	10230.5	2202	0.1
10004.5	337	0.2	10120.0	1048	0.3	10232.3	1486	0.1
10008.0	268	0.3	10125.5	1453	0.3	10235.9	1459	0.1
10014.2	1051	0.3	10128.3	1309	0.3	10241.6	1134	0.1
10016.8	871	0.3	10133.6	303	0.2	10244.0	815	0.1
10020.9	894	0.3	10136.9	291	0.2	10247.5	1092	0.1
10023.5	680	0.3	10140.1	339	0.2	10250.1	785	0.1
10026.6	1042	0.3	10144.2	295	0.2	10253.6	673	0.1
10029.1	652	0.3	10145.9	224	0.2	10256.1	977	0.1
10031.9	840	0.3	10149.0	272	0.2	10258.7	1035	0.1
10035.2	817	0.3	10153.1	245	0.2	10262.3	1724	0.1
10039.0	1279	0.3	10157.8	320	0.2	10264.8	610	0.1
10041.6	936	0.3	10164.3	874	0.3	10268.0	1265	0.1
10044.4	1096	0.3	10167.6	861	0.3	10271.6	700	0.1
10048.6	1010	0.3	10170.0	756	0.3	10274.2	889	0.1

B.17 Apollo 17 - EVA 1 - CDR Telemetry

Table B70: Apollo 17 EVA 1 CDR Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
6857.8	256	0.1	7009.0	986	0.3	7163.7	419	0.3
6864.6	792	0.1	7031.4	1750	0.3	7169.3	528	0.3
6871.1	1078	0.1	7038.6	1123	0.3	7173.7	495	0.3
6879.9	710	0.1	7046.4	1133	0.3	7181.8	1091	0.3
6888.8	1323	0.1	7050.6	1577	0.3	7186.2	848	0.3
6895.4	1282	0.1	7054.2	1293	0.3	7191.4	1075	0.3
6908.1	856	0.1	7058.6	1126	0.3	7197.1	858	0.2
6912.2	505	0.1	7063.0	1135	0.3	7205.3	884	0.2
6923.7	1285	0.1	7068.2	1068	0.3	7216.0	366	0.3
6929.2	1554	0.1	7080.2	1773	0.3	7220.7	367	0.3
6935.8	1245	0.1	7085.5	1372	0.3	7226.7	836	0.3
6947.7	1037	0.1	7092.3	1791	0.3	7231.4	946	0.3
6951.1	1272	0.1	7099.3	1692	0.3	7242.0	570	0.1
6952.4	1339	0.1	7103.6	1818	0.3	7249.6	1275	0.1
6957.7	1088	0.1	7112.9	1375	0.3	7255.0	781	0.1
6964.5	1374	0.1	7118.1	1376	0.3	7260.6	958	0.1
6969.0	1157	0.1	7124.2	1636	0.3	7263.6	1176	0.1
6975.0	1409	0.1	7128.9	1628	0.3	7269.2	1101	0.1
6980.3	1125	0.1	7135.1	1370	0.3	7278.3	1395	0.1
6985.8	1519	0.2	7140.5	977	0.3	7283.1	1413	0.1
6989.4	1193	0.2	7144.8	1120	0.3	7286.1	1355	0.1
6996.7	1378	0.3	7150.4	1129	0.2	7289.6	1414	0.1
7004.6	1253	0.3	7155.4	551	0.2	7293.8	1958	0.1

B.18 Apollo 17 - EVA 1 - LMP Telemetry

Table B71: Apollo 17 EVA 1 LMP Metabolic Rates (Btu/hr) per unit time (min)

Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
Minutes	Met Rate	Code	Minutes	Met Rate	Code	Minutes	Met Rate	Code
6859.1	158	0.1	7006.1	816	0.3	7156.5	263	0.2
6863.1	315	0.1	7011.3	558	0.3	7162.2	27	0.2
6868.7	303	0.1	7017.0	1007	0.3	7165.7	1306	0.3
6873.5	1213	0.1	7025.2	692	0.3	7171.8	1082	0.3
6877.4	966	0.1	7029.6	883	0.3	7176.1	1329	0.3
6883.1	1763	0.1	7035.2	636	0.3	7182.2	969	0.3
6888.3	527	0.1	7043.9	1006	0.3	7191.4	1373	0.3
6894.0	1392	0.1	7050.5	1534	0.3	7200.9	1317	0.2
6900.0	1010	0.1	7054.4	1186	0.3	7208.7	272	0.2
6906.1	1201	0.1	7058.7	1129	0.3	7213.5	665	0.3
6921.8	1234	0.1	7063.5	1399	0.3	7219.6	822	0.3
6927.0	1133	0.1	7069.2	961	0.3	7224.8	755	0.3
6933.5	829	0.1	7077.0	1735	0.3	7229.6	1013	0.3
6939.2	1290	0.1	7095.7	657	0.3	7234.4	676	0.2
6951.8	941	0.1	7103.6	2352	0.3	7241.4	1372	0.1
6956.6	1368	0.1	7108.7	1207	0.3	7247.0	1001	0.1
6961.8	952	0.1	7114.0	1532	0.3	7250.0	1372	0.1
6970.5	1738	0.1	7118.3	1150	0.3	7254.8	1035	0.1
6974.4	1749	0.2	7128.7	1206	0.2	7258.3	1372	0.1
6980.5	2490	0.3	7136.1	465	0.2	7265.7	1383	0.1
6990.5	1019	0.3	7141.8	2115	0.2	7271.3	563	0.1
6995.7	1389	0.3	7146.5	656	0.2	7279.2	1393	0.1

B.19 Apollo 17 - EVA 2 - CDR Telemetry

Table B72: Apollo 17 EVA 2 CDR Metabolic Rates (Btu/hr) per unit time (min)

Time	Metrate	Code	Time	Metrate	Code	Time	Metrate	Code
8267.9	331	0.1	8448.6	866	0.3	8593.1	1237	0.3
8274.0	497	0.1	8454.7	1000	0.3	8598.8	1587	0.3
8278.0	731	0.1	8460.8	916	0.3	8607.4	636	0.3
8283.6	630	0.1	8466.9	807	0.2	8613.5	544	0.3
8288.9	1030	0.1	8469.2	1166	0.2	8617.9	735	0.3
8297.2	613	0.1	8475.7	690	0.3	8621.8	360	0.3
8306.4	1172	0.1	8480.9	682	0.3	8627.0	285	0.3
8314.6	462	0.1	8488.8	1074	0.2	8632.7	443	0.3
8321.2	1154	0.1	8492.7	1149	0.2	8637.6	1252	0.3
8328.1	545	0.2	8499.2	314	0.2	8641.5	1052	0.3
8334.2	403	0.2	8502.7	489	0.2	8646.3	1368	0.3
8339.5	420	0.2	8511.4	272	0.3	8651.5	993	0.3
8343.4	295	0.2	8518.4	1023	0.3	8656.8	968	0.2
8348.6	444	0.2	8524.6	1106	0.3	8665.0	509	0.2
8352.6	236	0.2	8528.5	755	0.3	8669.0	1242	0.2
8367.4	252	0.2	8539.0	1314	0.3	8675.1	1251	0.1
8384.0	535	0.2	8541.6	821	0.3	8686.0	1025	0.1
8391.0	535	0.2	8545.1	1197	0.3	8691.3	1183	0.1
8393.6	393	0.2	8548.6	955	0.2	8694.7	941	0.1
8401.0	434	0.3	8554.2	980	0.2	8701.7	1008	0.1
8411.6	1293	0.3	8560.7	320	0.2	8706.1	1216	0.1
8417.2	792	0.3	8566.8	328	0.3	8710.0	807	0.1
8427.2	742	0.3	8572.5	211	0.3	8715.3	1333	0.1
8432.5	1092	0.3	8579.5	979	0.3	8720.5	673	0.1
8432.5	1092	0.3	8585.2	970	0.3	8728.8	1557	0.1
8443.8	591	0.3	8588.8	1546	0.3			

B.20 Apollo 17 - EVA 2 - LMP Telemetry

Table B73: Apollo 17 EVA 2 LMP Metabolic Rates (Btu/hr) per unit time (min)

Time	Metrate	Code	Time	Metrate	Code	Time	Metrate	Code
8269.2	560	0.1	8428.3	1078	0.3	8583.0	1462	0.3
8276.2	448	0.1	8434.0	1469	0.3	8588.1	445	0.3
8279.8	995	0.1	8438.3	1088	0.3	8594.6	578	0.3
8291.6	1273	0.1	8449.4	2037	0.3	8599.8	511	0.2
8297.2	1205	0.1	8453.1	896	0.3	8604.1	197	0.2
8302.8	903	0.1	8458.6	169	0.3	8610.2	141	0.3
8307.1	154	0.1	8462.7	929	0.3	8614.7	911	0.2
8317.3	1449	0.1	8470.6	1297	0.2	8620.3	553	0.2
8322.5	1079	0.1	8474.9	1106	0.2	8623.4	821	0.2
8327.3	1336	0.3	8479.1	178	0.3	8632.6	1043	0.3
8331.9	229	0.2	8483.9	-169	0.2	8636.5	730	0.3
8337.8	1323	0.2	8487.8	77	0.2	8642.3	1634	0.3
8341.1	328	0.2	8493.4	-159	0.2	8647.7	349	0.3
8347.2	249	0.2	8497.7	1551	0.2	8653.4	460	0.3
8352.4	450	0.2	8502.8	1293	0.2	8659.3	2001	0.2
8357.1	-210	0.2	8508.5	1236	0.2	8663.5	738	0.2
8361.0	2	0.2	8513.1	442	0.3	8669.6	1095	0.2
8365.4	-66	0.2	8517.7	1649	0.3	8674.0	1195	0.3
8370.8	906	0.2	8521.5	754	0.3	8680.0	579	0.2
8375.9	56	0.2	8527.7	1413	0.3	8686.7	1305	0.1
8388.5	-91	0.2	8533.5	-52	0.3	8696.7	1282	0.1
8395.6	546	0.2	8538.9	540	0.3	8700.1	879	0.1
8398.3	1048	0.2	8543.6	126	0.3	8706.8	1839	0.1
8402.2	1193	0.3	8556.2	2382	0.2	8712.4	1358	0.1
8406.5	846	0.3	8560.0	2057	0.2	8714.5	1145	0.1
8412.2	1080	0.3	8564.2	1118	0.3	8719.7	1089	0.1
8418.7	1090	0.3	8570.4	1531	0.3			
8422.9	2241	0.3	8576.9	1363	0.3			

B.21 Apollo 17 - EVA 3 - CDR Telemetry

Table B74: Apollo 17 EVA 3 CDR Metabolic Rates (Btu/hr) per unit time (min)

Time	Metrate	Code	Time	Metrate	Code	Time	Metrate	Code
9650.4	466	0.1	9816.1	458	0.3	9960.8	803	0.3
9654.7	787	0.1	9822.1	973	0.3	9966.9	930	0.3
9667.3	906	0.1	9826.4	1108	0.3	9975.1	913	0.2
9672.1	762	0.1	9832.5	948	0.2	9977.0	399	0.2
9678.6	855	0.1	9837.3	1311	0.2	9982.2	534	0.2
9684.7	1067	0.1	9840.4	518	0.2	9986.5	348	0.2
9688.6	729	0.1	9857.8	291	0.3	9996.9	493	0.2
9695.2	755	0.1	9862.1	933	0.3	10002.9	1033	0.1
9697.8	536	0.2	9869.0	1313	0.3	10008.6	1194	0.1
9704.8	317	0.2	9872.9	1743	0.3	10012.0	1624	0.1
9715.2	334	0.2	9881.1	1600	0.3	10017.7	1346	0.1
9720.9	208	0.2	9884.2	1153	0.3	10019.0	1068	0.1
9730.4	402	0.3	9890.3	1179	0.3	10023.3	1321	0.1
9736.9	504	0.3	9896.0	1356	0.2	10029.4	1262	0.1
9742.1	1053	0.3	9899.9	1044	0.2	10033.4	646	0.1
9749.5	994	0.3	9905.1	1222	0.2	10038.6	1372	0.1
9755.2	674	0.3	9912.1	1003	0.2	10045.5	1432	0.1
9759.9	1071	0.3	9918.2	480	0.3	10049.5	1145	0.1
9767.3	902	0.3	9927.4	447	0.3	10054.2	1441	0.1
9775.5	1190	0.3	9930.4	801	0.3	10060.3	1331	0.1
9779.5	1173	0.3	9935.6	827	0.3	10065.9	1576	0.1
9785.0	1587	0.3	9938.2	911	0.3	10070.7	1627	0.1
9789.1	659	0.3	9945.2	844	0.3	10075.0	1628	0.1
9799.0	1157	0.3	9946.9	929	0.3	10085.9	2016	0.1
9805.1	904	0.2	9953.4	921	0.3			
9810.8	1090	0.3	9957.7	1182	0.3			

B.22 Apollo 17 - EVA 3 - LMP Telemetry

Table B75: Apollo 17 EVA 3 LMP Metabolic Rates (Btu/hr) per unit time (min)

Time	Metrate	Code	Time	Metrate	Code	Time	Metrate	Code
9649.6	80	0.1	9793.8	1396	0.3	9961.3	577	0.3
9653.5	593	0.1	9797.0	317	0.3	9967.8	444	0.3
9659.1	950	0.1	9808.2	1242	0.2	9974.7	1268	0.2
9667.8	917	0.1	9815.1	1487	0.3	9980.0	579	0.2
9677.3	1497	0.1	9821.8	141	0.3	9989.7	-155	0.2
9680.9	1119	0.1	9827.1	141	0.3	9994.9	146	0.3
9685.6	1409	0.1	9831.8	364	0.2	9998.4	13	0.3
9693.6	608	0.1	9835.8	142	0.2	10010.8	1684	0.1
9699.3	397	0.2	9840.4	1657	0.2	10015.2	1305	0.1
9704.5	520	0.2	9846.5	1501	0.2	10020.0	1629	0.1
9709.8	409	0.2	9852.7	712	0.3	10025.2	1618	0.1
9716.3	554	0.2	9856.6	968	0.3	10029.7	1095	0.1
9720.7	376	0.2	9866.5	2160	0.3	10034.0	1352	0.1
9737.5	1335	0.3	9874.9	1270	0.3	10043.1	1353	0.1
9749.8	1136	0.3	9885.8	748	0.3	10052.8	619	0.1
9755.1	702	0.3	9892.7	1339	0.3	10061.9	1321	0.1
9759.4	603	0.3	9907.7	115	0.2	10065.9	954	0.1
9763.2	1449	0.3	9921.3	-17	0.3	10068.0	1032	0.1
9768.1	937	0.3	9930.7	1142	0.3	10074.4	1912	0.1
9772.8	1539	0.3	9935.1	786	0.3	10078.0	1345	0.1
9777.3	771	0.3	9939.9	909	0.3	10083.1	2447	0.1
9782.5	1028	0.3	9944.3	564	0.3	10089.3	1758	0.1
9786.0	650	0.3	9952.4	1489	0.3			

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14. ABSTRACT
Quantifying the operational variability of extravehicular activity (EVA) execution is critical to help design and build future support systems to enable astronauts to monitor and manage operations in deep-space, where ground support operators will no longer be able to react instantly and manage execution deviations due to the significant communication latency. This study quantifies the operational variability exhibited during Apollo 14-17 lunar surface EVA operations to better understand the challenges and natural tendencies of timeline execution and life support system performance involved in surface operations. Each EVA (11 in total) is individually summarized as well as aggregated to provide descriptive trends exhibited throughout the Apollo missions. This work extends previous EVA task analyses by calculating deviations between planned and as-performed timelines as well as examining metabolic rate and consumables usage throughout the execution of each EVA. The intent of this work is to convey the natural variability of EVA operations and to provide operational context for coping with the variability inherent to EVA execution as a means to support future concepts of operations.

15. SUBJECT TERMS
Apollo, EVA, Mission Operations, Timeline

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