CC5/15

APOLLO 15

Time and Motion Aspects

"QUICK LOOK REPORT"

Submitted by
Fordham University
NASA Contract NAS 9-11839
August 18, 1971

SUMMARY

Kinescopes of Apollo 15 EVA provided the basis for a "Quick Look" Time and Motion analysis of several phases of crewman activity. Actual EVA timelines were developed for each crewman. Three basic mobility characteristics were identified. A specific example provided two types of elemental activities, one of which took less time during lunar EVA, while the other appeared to take more time. On an overall basis, characteristic deployment activities on the lunar surface take almost 50% more time than they do during the last training session. A study of falls and near-falls has been initiated with a view towards determining their dynamic characteristics and identifying their most probable causes. Four recommendations have been offered to make Time and Motion analyses more efficient and informative in the utilization of lunar EVA data.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

REPLY TO
ATTN OF: DE3/8-71/02

AUG 20 1971

MEMORANDUM

TO: Distribution

FROM: DE3/Chief, Biomedical Data Systems Office

SUBJECT: Apollo 15 Time and Motion Study "Quick Look Report"

Enclosed is a "Quick Look Report" for the Apollo 15 Time and Motion Study Detailed Objective which is in the nature of a progress report for the Medical Research and Operations Directorate (MR&OD) management personnel.

Because the content could be misconstrued as an evaluation of training, use of the information should be restricted to MR&OD until more complete analysis can be made and reviewed internally.

A completed preliminary report and briefing for MR&OD is anticipated by mid-September 1971.

Original Signed By
JAMES E. BOST

Edward C. Moseley, Ph. D.

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ACKNOWLEDGMENTS

The principal investigator wishes to thank the entire Fordham staff for their unstinting cooperation and whole-hearted effort over and above the call of duty during the hurried days of the "Quick Look Report."

He sincerely appreciates the graciousness of Dr. Moseley and Dr. Humbert in making facilities available at NASA to view the Apollo 15 EVA.

0.0 PRELIMINARY CONSIDERATIONS

0.1 The three EVA's of Apollo 15 were observed by five members of the Fordham University team on July 31, August 1 and 2, 1971, at NASA. The objectives of these intensive observation sessions were to establish preliminary timelines, provide an overall evaluation of various segments of the EVA, and to identify critical areas for further thorough analyses.

0.2 The three EVA's were presented simultaneously on two TV screens, one in black and white, the other in color. The relative advantages of the color TV for Time and Motion analysis were thereby clearly delineated.

0.3 The analyses submitted in this "Quick Look Report," however, were based on the black and white kinescopes supplied by NASA.

0.4 In view of the hurried nature of these analyses and because we may have access to the higher resolution tapes, the results presented in this report must be considered preliminary and tentative.

1.0 DATA RETURN: QUANTITY AND QUALITY

1.1 Television

For general viewing, the quality of the TV transmission from the lunar surface probably exceeded expectations. Time and Motion requirements, however, are much more stringent and a number of problems associated with the actual TV coverage have limited both the quantity and quality of the data available for analysis. In particular these problems were:

a. Deviations from planned TV coverage.

b. The direction of the camera during the coverage.

c. The poor quality of the black and white kinescopes compared to the color TV transmissions made from the lunar surface.

Despite the limitations brought on by these problems, a good portion of the planned post-flight analysis can be made. However, additional equipment (video) will be required before any detail motion analysis can be performed.

In evaluating the discrepancy between the planned versus actual TV coverage, careful consideration should be given to the analysis included in Table 1.

One of the major problems was the ground-control of the TV camera itself. Our primary interest was in the activities of the crewmen as they performed their assigned tasks. However, due to geological and hardware priorities for TV coverage, several important activities were missed, such as, the removal of the deep-core which was probably the hardest work performed, and the ALSEP off-load which was of prime interest to us. In particular, there seemed to be more redundancy in the geological pans than were necessary. Astronaut movement and activity are not only important because they meet our project needs but also because they fulfill essential human interest needs on the part of all viewers.

Another obstacle to efficient analysis is the poor quality of the black and white kinescopes compared to the color TV transmissions during the lunar EVA's. These kinescopes are some of the best we have received.

Table 1
PLANNED AND ACTUAL TV COVERAGE
(APOLLO 15)

Planned TV Coverage	Actual TV Coverage
EVA 1	
CDR and LMP Egress	As planned.
* LRV Off-load	As planned but too distant for detail.
LRV Configuration	Same as LRV off-load.
* Station #1 Geology	Activity in poor position in relation to sun. Extensive geological pans.
* Station #2 Geology	As planned - Generally good data.
Station #3 Geology	Omitted entirely.
* ALSEP Off-load	No coverage - TV not activated.
* ALSEP Deploy	As planned - Coverage confused by attempt to document both crewmen.
EVA Closeout	No coverage - TV not activated.
EVA 2	
Preparation for Traverse	No coverage - TV not activated.
* 5 Geological Stops Planned	Real-time Planning.
Station #6	TV coverage - good data for analysis.
Station #6A	TV - not activated.
Station #7	TV coverage - good data for analysis.
Station #4	TV - not activated.
At LM (Real-time change)	TV - not activated.
* ALSEP Operations Completion including Station #8	TV - Station #8 coverage was good - but ALSEP coverage poor.
* EVA Closeout (included Flag deploy)	TV activated - poor coverage (Flag ok).
EVA 3	
Preparation for Traverse	TV activated - but poor coverage.
* Core Stem Recovery	TV activated - very poor coverage.
* Station #9	TV activated - very poor coverage.
* Station #9A	TV activated - good coverage.
Station #10	TV coverage - limited activity.
EVA Closeout	TV coverage - Some parts excellent - ground control poor in parts.

* Where TV coverage was expected to give best crew activity for TAMS analysis.

However, the pronounced loss of resolution and detail inherent to the kinescope reproduction coupled with the added loss of the color dimension makes detailed analysis almost impossible. Because of this problem, we have requested the purchase of a laboratory color video tape system with which to record the color transmissions and then use these as the basis for analysis.

1.2 16mm Lunar Surface Movie Film

One of the greatest disappointments of the Apollo 15 EVA's was the almost total failure of the 16mm Data Acquisition Camera (DAC) system. The advantages of DAC are that it uses a fixed lens system, is not panned during use, and has a much higher resolution than the TV camera. Only one roll of film was usable. The sequences on this roll were shot during one of the LRV rides and have little or no relevance to the objectives of this project. Failure of the DAC system means that any accurate measurement of the crewman's locomotion is almost impossible. An important phase of our analysis was dependent upon the 16mm DAC system.

1.3 Voice Data

Official transcripts of the voice transmissions during the three EVA periods have been received and are being used in our analyses. However, some discrepancy between the time given on the voice transcript as compared to the kinescopes has been observed. These are in the process of verification.

1.4 Astronaut Technical Crew Debriefing

This information will be taken into account during our analysis and should prove helpful in resolving difficulties in interpretation of the data.

1.5 Physiological Data

Our contract technical monitor has promised to deliver a copy of all the metabolic, heart rate and other medical data to help complete our analysis. The correlated physiological data should make the interpretation of results more meaningful.

1.6 General Comments

In spite of the fact that a good portion of the planned data was not returned, there has been adequate TV coverage. The analysis, however, will be more difficult than anticipated.

2.0 EVA TIMELINES

2.1 Table 2 through Table 7 present the actual timelines associated with EVA's 1, 2, and 3. Within each EVA, a table is allotted to each crewman.

2.2 The time points were determined from kinescopes and voice transcripts.

2.3 These tables present a succinct but synoptic view of the varied characteristics involved in the three EVA activities. They are valuable as quick reference markers to identify specific areas for analysis and to point up important correlations among variables.

Table 2

CDR EVA #1	GET	ΔT	GET	ΔT
Start EVA Watch			04:23:38:33	
Pre-Egress			04:23:50:45	12.20
Egress			04:23:59:28	8.72
TV Deploy			05:00:11:13	11.75
LRV Off-load and Deploy			05:00:31:40	20.45
LRV Configuration and Traverse Preparation			05:01:44:35	72.92
Traverse to Station #1			05:02:10:46	26.18
Station #1 Tasks			05:02:28:36	17.83
Geologic Site Selection	02:14:52	4.10		
Radial Sample Collection	02:24:04	9.20		
Traverse Preparation	02:28:36	4.53		
Traverse to Station #2			05:02:35:20	6.73
Station #2 Tasks			05:03:26:02	50.70
Geologic Description & Documented Sample Collection	02:57:22	22.03		
Comprehensive Sample Collection	03:05:11	7.82		
Double Core	03:16:04	10.88		
500mm Photo and Traverse Preparation	03:26:02	9.97		
Traverse to LM			05:03:59:35	33.55
ALSEP Off-load			05:04:24:05	24.50
ALSEP Traverse (LRV)			05:04:33:28	9.38
ALSEP Tasks			05:05:38:17	64.81
HFE Deploy	05:05:24:01	50.55		
LR^3 Deploy	05:05:33:21	9.33		
ALSEP Photo and Traverse Preparation	05:05:38:17	4.93		
Traverse to LM			05:05:42:36	4.32
EVA Closeout			05:05:57:40	15.07
SWC Deploy and EVA Termination			05:06:12:23	14.72

Total EVA #1 6 hr 33.83 min

Table 3

LMP - EVA #1	GET	ΔT	GET	ΔT
Start EVA Watch			04:23:38:33	
Pre-Egress			05:00:00:00	21.45
Egress			05:00:03:39	3.65
Contingency Sample			05:00:13:45	10.10
LRV Off-load and Deploy			05:00:30:51	17.10
LRV Configuration			05:01:15:41	44.83
Pallet Transfer, LM Power Down & Trav. Prep.			05:01:44:35	28.90
Traverse to Station #1			05:02:10:46	26.18
Station #1 Tasks			05:02:28:36	17.83
Photo Pan	02:14:35	3.82		
Radial Sample Collection	02:24:04	9.48		
Traverse Preparation	02:28:36	4.53		
Traverse to Station #2			05:02:35:20	6.73
Station #2 Tasks			05:03:26:02	50.70
Photo Pan and Documented Samples	02:57:22	22.03		
Comprehensive Sample Collection	03:05:11	7.82		
Double Core	03:16:04	10.88		
70mm Pan and Traverse Preparation	03:26:02	9.97		
Traverse to LM			05:03:59:35	33.55
ALSEP Off-load			05:04:23:42	24.12
ALSEP Traverse (Walking while carrying ALSEP Packages 1 and 2)			05:04:28:20	4.63
ALSEP Tasks			05:05:38:33	70.22
ALSEP Interconnect	05:04:42:49	14.48		
PSE Deploy	05:04:51:06	8.28		
SWE Deploy	05:04:54:45	3.65		
LSM Deploy	05:05:10:22	15.62		
Sunshield Deploy	05:05:18:14	7.87		
ALSEP Antenna Installation	05:05:25:05	6.85		
Side Deploy	05:05:33:30	8.42		
C/S Activate and LSM Sunshield Deploy	05:05:38:33	5.05		
Traverse to LM (LRV)			05:05:42:49	4.27
EVA Closeout			05:05:53:32	10.72
EVA Termination			05:06:12:23	18.85

Total EVA #1 6 hr 33.83 min

Table 4

CDR - EVA #2	GET	ΔT	GET	ΔT
Start EVA Watch			05:22:14:20	
Pre-Egress			05:22:24:03	9.72
Egress			05:22:29:28	5.42
Equipment Preparation			05:23:03:45	34.28
LRV Navigation Initialize			05:23:11:13	7.47
Traverse to Station #6			05:23:53:56	42.72
Station #6 Tasks			06:00:58:29	64.55
Documented Sample Collection	06:00:25:33	31.45		
Soil Mechanics Trench	00:34:50	9.45		
Single Core	00:38:55	4.08		
Documented Sample Collection	00:43:57	5.03		
500mm Photo and Traverse Preparation	00:58:29	14.54		
Traverse to Station #6A			06:01:00:59	2.50
Station #6A Tasks			06:01:22:40	21.68
Sample Collection and Traverse Preparation	01:22:40	21.68		
Traverse to Station #7			06:01:25:46	3.10
Station #7 Tasks			06:02:15:28	49.70
Documented Sample Collection	01:57:20	31.57		
Comprehensive Sample Collection	02:06:28	9.13		
Documented Sample Collection & Trav. Prep.	02:15:28	9.00		
Traverse to Station #4			06:02:28:24	12.93
Station #4 Tasks			06:02:45:44	17.33
Documented Sample Collection	02:41:35	13.18		
Traverse Preparation	02:45:44	4.15		
Traverse to LM			06:03:08:08	22.40
Configure LRV For Tasks			06:03:19:33	11.42
Traverse to ALSEP Site			06:03:21:15	1.70
ALSEP Site Tasks			06:04:30:11	68.94
HFE Deploy Completion	03:57:13	35.97		
Select Geologic Site for LMP	04:14:05	16.87		
Deep Core and Traverse Preparation	04:30:11	16.10		
Traverse to LM			06:04:32:17	2.10
EVA Closeout			06:05:18:51	46.56
Closeout Activities	04.53:14	20.95		
Flag Deploy	04:57:40	4.43		
Continue Closeout Activities	05:18:51	21.18		
EVA Termination			06:05:27:21	8.50

Total EVA #2 7 hr 13.02 min

Table 5

LMP - EVA #2	GET	ΔT	GET	ΔT
Start EVA Watch			05:22:14:20	
Pre-Egress			05:22:35:56	21.60
Egress			05:22:37:33	1.62
Equipment Preparation			05:23:03:46	26.22
LRV Navigation Initialize			05:23:11:13	7.45
Traverse to Station #6			05:23:53:56	42.72
Station #6 Tasks			06:00:58:29	64.55
Photo Pan	05:23:58:17	4.35		
Documented Sample Collection	06:00:26:01	27.73		
Soil Mechanics Trench	00:34:50	8.82		
Single Core	00:38:55	4.08		
Documented Sample Collection	00:43:57	5.03		
70mm Magazine Change and Traverse Preparation	00:58:29	14.54		
Traverse to Station #6A			06:01:00:59	2.50
Station #6A Tasks			06:01:22:40	21:68
Photo Pan and Geological Description	01:19:10	18.18		
Traverse Preparation	01:22:40	3.50		
Traverse to Station #7			06:01:25:46	3.10
Station #7 Tasks			06:02:15:28	49.70
Photo Pan	01:34:30	8.73		
Documented Sample Collection	01:56:28	21.97		
Comprehensive Sample Collection	02:06:20	9.87		
Documented Sample Collection and Trav. Prep.	02:15:28	9.13		
Traverse to Station #4			06:02:28:24	12.93
Station #4 Tasks			06:02:45:44	17.33
Photo Pan and Documented Sample Collection	02:41:35	13.18		
Traverse Preparation	02:45:44	4.15		
Traverse to LM			06:03:08:08	22.40
Configure LRV for ALSEP and Photo			06:03:30:24	22.27
Traverse to ALSEP Site (Walking)			06:03:34:31	4.12
ALSEP Site Tasks			06:04:28:18	53.78
ALSEP Photo and Change 70mm Magazine	03:48:26	13.92		
Sample Collection and C/S Align Check	03:55:15	6.82		
Photo and Description	04:02:10	6.92		
Soil Mechanics Trench	04:17:39	15.49		
Penetrometer	04:28:18	10.65		
Traverse to LM (Walking) and Photo			06:04:33:11	4.88
EVA Closeout			06:05:04:22	31.18
Closeout Activities	04:52:18	19.11		
Flag Deploy	04:57:40	5.37		
Continued Closeout Activities	05:04:22	6.70		
EVA Termination			06:05:27:21	22.98

Total EVA #2 7 hrs 13.02mi

Table 6

CDR - EVA #3	GET	ΔT	GET	ΔT
Start EVA Watch			06:19:17:38	
Pre-Egress			06:19:28:16	10.63
Egress			06:19:32:19	4.05
Equipment Preparation and LCRU Activate			06:20:03:40	31.35
Traverse to ALSEP Site			06:20:07:07	3.45
ALSEP Site Tasks			06:20:45:15	38.13
Remove Core Tubes from Ground	20:17:57	10.83		
Disassemble Core Tubes	20:36:42	18.75		
LRV Evaluation Traverse and Trav. Prep.	20:45:15	8.55		
LRV Navigation Initialize			06:20:48:26	3.18
Traverse to Station #9			06:21:01:44	13.30
Station #9 Tasks			06:21:16:50	15.10
Documented Sample Collection & Trav. Prep.	21:16:50	15.10		
Traverse to Station #9A			06:21:19:26	2.60
Station #9A Tasks			06:22:14:25	54.98
Geologic Description and 500mm Photo	21:36:00	16.57		
Documented Sample Collection	21:53:10	17.17		
Comprehensive Sample Collection	22:00:58	7.80		
Double Core	22:08:34	7.60		
Undocumented Sample Collection & Trav. Prep.	22:14:25	5.85		
Traverse to Station #10			06:22:16:45	2.33
Station #10 Tasks			06:22:28:49	12.07
500mm Photo, Sample Collection & Trav. Prep.	22:28:49	12.07		
Traverse to ALSEP Site			06:22:43:40	14.85
Traverse to LM			06:22:45:45	2.08
EVA Closeout			07:00:00:37	74.78
Closeout Activities	23:15:08	29.38		
Demonstration (Stamp and Gravity)	23:23:06	7.97		
Position LRV For Liftoff	23:52:30	29.40		
Continue Closeout Activities	00:00:37	8.03		
EVA Termination			07:00:08:09	7.62

Total EVA #3 4 hr 50.52 min

Table 7

LMP - EVA #3	GET	ΔT	GET	ΔT
Start EVA Watch			06:19:17:38	
Pre-Egress			06:19:32:21	14.88
Egress			06:19:34:11	1.67
Equipment Preparation			06:20:02:30	28.32
Traverse to ALSEP Site (walking)			06:20:05:49	3.32
ALSEP Site Tasks			06:20:45:15	39.43
Remove Core Stems from Ground	20:15:57	12.13		
Disassemble Core Stems	20:21:43	3.77		
ALSEP Photo	20:28:35	6.87		
Disassemble Core Stems	20:36:42	8.12		
LRV Photo and Traverse Preparation	20:45:15	8.55		
LRV Navigation Initialize			06:20:48:26	3.18
Traverse to Station #9			06:21:01:44	13.30
Station #9 Tasks			06:21:16:50	15.10
Troubleshoot Camera Malfunction	21:08:53	7.15		
Documented Sample Collection & Trav. Prep.	21:16:50	7.95		
Traverse to Station #9A			06:21:19:26	2.60
Station #9A Tasks			06:22:14:25	54.98
Documented Sample Collection	21:53:10	33.73		
Comprehensive Sample Collection	22:00:58	7.80		
Double Core	22:08:40	7.70		
Undocumented Sample Collection & Trav. Prep.	22:14:25	5.75		
Traverse to Station #10			06:22:16:45	2.33
Station #10 Tasks			06:22:28:49	12.07
70mm Photo Pan	22:20:02	3.28		
Sample Collection and Traverse Preparation	22:28:49	8.78		
Traverse to ALSEP Site			06:22:43:40	14.85
Retrieve Core Stems			06:22:45:23	1.72
Traverse to LM (walking)			06:22:46:47	1.40
EVA Closeout			06:23:55:34	68.79
Closeout Activities	23:14:06	27.32		
Transfer Samples and Film Mags. to MESA	23:55:34	41.47		
EVA Termination			07:00:08:09	12.58

Total EVA #3 4 hr 50.52 min

3.0 MOBILITY CHARACTERISTICS

Differences in mobility were noticeable, particularly between EVA's 1 and 2. The improvement was due undoubtedly to adaptation and to increased confidence in ability to move about on the lunar surface after the first EVA.

The modes of mobility were varied, consisting of three main types:

a. A walking motion, used for longer, straight "runs" where the surface was relatively level.

b. A hopping motion, in which one foot remained ahead of the other to a large extent. This was used for short distances, primarily where directional changes were needed.

c. A side-shuffle, boxer-like dance, using primarily the ball and the toe of the foot to align himself to his work. This motion was used principally to manuever in a small area, around a piece of equipment, or other limited and/or confined space.

Estimates of traversing rates are difficult to determine in Apollo 15, but from observation, seem to be comparable to previous flights' EVA's. An analysis will be made of these rates in later reports.

It is apparent that the rather loose, "deep" nature of the lunar soil on Apollo 15 probably caused more of the hopping type (item b above) motion than on Apollo 11 for example, in which the soil seemed to be more compacted. This loose soil also tended to produce slower rates for a given type of locomotion. A detailed analysis of these rates and modes will be presented in a later report.

4.0 ACTIVITY ANALYSIS - EXAMPLE

4.1 To illustrate a typical EVA activity for comparison between training simulations and performance on the lunar surface, a simple two-man, tool manipulation task "Comprehensive Sample Collection" was selected.

The task also involved the repetition of elements which provided additional information and insight into the nature of such activities.

4.2 The task consisted of the LMP using the rake handle to scoop a swath of soil about ten inches (10") wide and one (1) meter long to a depth of approximately 2-3 inches. After scraping up the soil, LMP shakes the rake to drop out the fine particles while retaining the larger ones which are then carried to and transfered to the Sample Bag held by the CDR. The CDR and LMP must exercise considerable caution and coordination to assure that the sample actually gets into the bag. The CDR's primary function is to place the Sample Bag in sich a position that the LMP has minimum difficulty in rotating the rake and transfering (by gravity) the sample to the bag.

4.3 The data for these activities are presented in Table 8 which gives the complete sequence, with elemental times, averages, and ranges to show relationships between sequential performance and between two different training sessions and three EVA's. Training times were computed during direct observation; EVA times were determined from kinescope analysis.

4.4 Several factors may influence the performance of the CDR and LMP on the lunar surface. Some of these which this study considers are listed below:

a. Adaptation to the lunar environment.
b. The lunar soil composition and surface.
c. Work schedule and fatigue.
d. Amount and types of training in a particular activity.

Although the lunar environment may affect certain activity, task, or work elements, it appears that some elements may not be affected and therefore would require the same amount of time to perform as in one g. The data in Table 8 indicates that the element of "Fill the bag" falls into this category.

TABLE 8

COMPREHENSIVE SAMPLE COLLECTION

Time Analysis

		LUNAR MODULE PILOT (LMP)			
	TRAINING (7-19-71)		EVA		
TRIALS	1	2	1	2	3
1. Rake and Shake*	.65#	.60	.42	.38	.42
Fill Bag*	.20	.20	.25	.40	.28
(Total)	(.85)	(.80)	(.67)	(.78)	(.70)
2. Rake and Shake	.70	.75	.45	.38	.33
Fill Bag	.20	.26	.25	.30	.17
(Total)	(.90)	(1.01)	(.70)	(.68)	(.50)
3. Rake and Shake		.85		.52	.62
Fill Bag		.34		.22	.20
(Total)		(1.19)		(.74)	(.82)
4. Rake and Shake					.33
Fill Bag					.22
(Total)					(.55)
Average: Rake & Shake	.675	.733	.435	.427	.425
Fill Bag	.200	.267	.250	.307	.218
(Total)	(.875)	(1.000)	(.685)	(.730)	(.643)
Range: Rake & Shake	.05	.25	.03	.14	.29
Fill Bag	.00	.14	.00	.18	.11
(Total)	(.05)	(.39)	(.03)	(.10)	(.32)

(#) All times are in minutes.

(*) Activity Description:

(1) Rake and Shake: using the rake, LMP scrapes swath approximately 1 meter long by 10" wide by 2-3" deep of lunar soil, then shakes out the fine particles.

(2) Fill Bag: after shaking, LMP lifts rake with rock fragments inside, positions it over sample bag held and positioned by CDR, and then rotates rake so that rocks pour out of the rake into the bag. This requires close coordination by both men.

The lunar soil composition, however, has an effect on the elements which have to do with raking and shaking the soil. The element "Rake and Shake" shown in Table 8 is an example of these elements. The time to perform this element appears to be shorter on the lunar surface than on the sandy ground used in training.

4.5 Additional analysis is needed to reveal the types of activities that may be differentially affected by lunar gravity.

5.0 LUNAR EVA PERFORMANCE VERSUS TRAINING DATA

The comparison of activities done on the lunar surface with those performed during one g suited training sessions is important on both practical and theoretical accounts. For the "Quick Look Report" those activities were chosen for which there are reliable records on two of the last three training sessions before launch. The following table lists the activities, performance time (in minutes) during training sessions, performance time on the lunar surface, and the source of information specifying the end points of characteristic activities. Training times were obtained through direct observation; EVA times were determined from kinescope and voice transcripts.

TABLE 9

ACTIVITY COMPARISONS: TRAINING VERSUS LUNAR EVA

ACTIVITY	1 G TRAINING SESSION			EVA 1	
	6/4/71	7/1/71	7/16/71	7/31/71	Source
CDR					
Deploy Lunar Roving Vehicle		5.75	3.64	11.28*	TV
Deploy High Gain Antenna & TV Camera		6.34	6.10	7.57	Voice
LMP					
Align High Gain Antenna	2.10	3.10	1.42	2.78	Voice
Contingency Sample Collection (Stowage not included)	1.30		1.30	2.42	Voice
Deploy Lunar Surface Magnetometer	7.10	5.85	5.67	8.93	TV
Deploy Passive Seismic Experiment	8.05	7.02	6.91	8.27	TV & Voice
Deploy Solar Wind Experiment	3.10	2.70	1.85	3.65	Voice

* Considerable time was spent troubleshooting the rover deployment difficulty.

5.0 (continued)

The significant characteristic of these data is the relatively greater time it takes to perform activities on the moon as compared to the last training session. For both astronauts the time increase is almost 50% greater on the lunar surface (excluding LRV deployment).

The activities listed in Table 9 are relatively gross in character. Wherever possible a further breakdown into finer elements will be made in a subsequent report both for the training sessions and lunar surface activity.

6.0 FALL AND NEAR-FALL ANALYSIS

6.1 Introduction

During the Apollo 15 lunar EVA's there were some instances where the astronauts momentarily lost their balance and sometimes even fell. A study is in progress to determine the characteristics of such falls with a view towards identifying the specific reasons for their occurrence. At present, this involves analyzing the black and white kinescopes and the in-flight voice transcripts to determine when the falls or near-falls occurred, followed by a detailed analysis of the fall or near-fall.

One important and obvious reason for the falls would seem to be the lunar surface with its protruding rocks, various depressions, and sometimes loose and soft surface soil. Other related reasons may include the limited vision that a suited astronaut experiences; a decreased awareness of what is in the way when an astronaut is involved in something other than just traversing; and possibly even a limited experience in walking on surfaces with obstacles that are concealed as well as out in the open.

6.2 Procedure

Black and white kinescopes (frame rate - 24 FPS) of all three lunar EVA's plus the voice transcripts were available for analysis. The segments of film involving the falls or near-falls were identified for further analysis. The detailed analysis was done on a Vanguard motion analyzer with every three or six frames being analyzed just before and after the fall and every frame analyzed during the fall. The in-flight voice transcripts were used with the films to establish the events that occurred before and after the actual fall. The method of analysis involved a description of each frame analyzed, the angles of the right and left knees, the angle of the body with the lunar surface, and the positioning of arms and legs during the fall.

6.3 The Fall

The segment analyzed for this "Quick Look Report" occurred at GMT 214:11:06:28 (GET 6:21:32:28) during the third lunar EVA. Commander Scott and lunar module pilot Irwin were at geology station 9, an area around Hadley Rille shown by the TV pans to have many rock fragments. Scott and Irwin had just arrived at the Rille and were busy describing the area. In addition, Scott was taking photographs with the 500mm lens camera. He had just given the camera reading and was summarizing the descriptions of the area as he began moving to a new photo site. Immediately in front of him were some rock fragments. Scott took a few steps toward the rocks; his right foot went around one side of the rocks and his left foot went around the other side. It was when his right foot went down into a small depression beside the rock that he started to lose his balance. He probably would have regained his balance but when he stepped on his left foot, it slid off a smaller rock and continued sliding on the loose surface soil. In continuing to attempt to regain his balance, Scott greatly increased his forward velocity while trying to drive his feet back under his center of gravity. This method was unsuccessful and Scott continued to fall.

6.4 Results

Table 10 which summarizes the information obtained during the analysis of the fall follows.

TABLE 10
ANALYSIS OF THE FALL AT HADLEY RILLE

Time (1) (in seconds)	Frame Number	Right Knee Angle	Left Knee Angle	Angle of Body with Surface	Description
28	000	170°	170°	90°	CDR is standing with knees slightly bent, camera in both hands. There are some rocks in front of his feet. Arms are chest-high.
28	006	170°	170°	90°	CDR turned slightly to left, his arms coming down a little.
29	012	170°	160°	90°	Picking up left foot. Right hand letting go of camera. Left hand (with camera) moving down slightly
29	018	170°	140°	90°	Both hands moving out from the center of the body. Left foot is off the ground.
29	124	165°	160°	90°	Left foot coming forward and down, right foot coming up.
30	030	160°	170°	90°	Left foot coming down, right foot coming up.
30	036	155°	165°	90°	Left foot down; right foot coming around rock, kicking dust.
30	042	155°	160°	90°	Right foot kicking more dust.
30	048	170°	155°	90°	Right foot coming down; left foot coming up.
31	054	175°	95°	90°	Right foot coming down; left foot kicking dust.
31	055	175°	95°	90°	Right foot coming down; left foot kicking dust.
31	056	175°	95°	90°	Right foot down; left foot dragging dust.
31	057	170°	115°	90°	Right foot down in a small depression, left foot dragging.
31	058	165°	120°	87°	Left foot slid to the left (stepped on a small rock and slid).

Table 10 (continued)
ANALYSIS OF THE FALL AT HADLEY RILLE

Time (1) (in seconds)	Frame Number	Right Knee Angle	Left Knee Angle	Angle of Body with Surface	Description
31	059	150°	140°	81°	Body turn slightly to the left; left foot slid more; right foot coming up.
31	060	145°	150°	75°	Body bend to right side and forward; right hand coming forward.
31	061	120°	160°	72°	Body falling forward more; right hand extended more; right foot coming up, kicking dust.
31	062	120°	160°	70°	Hand extended more; body down more.
31	063	125°	150°	65°	Down more; right hand extended; right foot coming down.
31	066	150°	90°	57°	Right foot down; left foot up.
31	069	145°	85°	50°	Body down more; left foot up.
31	072	145°	90°	42°	Body down more; both hands out in front, left knee is forward.
31	076	*	85°	35°	Falling to front and left; both hands forward.
32	082	120°	120°	20°	Left knee close to ground; right foot in air.
32	088	130°	165°	0°	Right leg in air; left leg on ground; left side of body on ground.
32	094	170°	175°	0°	Starting to roll to the right and on back, right foot coming down; body on ground; going out of camera view.

*Cannot see right leg.

(1) Begins at GMT 214:11:06:28 (GET 6:21:32:28)

6.5 Summary of Analysis

Scott had stepped around the larger part of the rock fragment without any problem. It was a combination of two factors that caused the fall: 1) His right foot went into a depression beside the fragment and he momentarily lost his balance; and 2) In attempting to regain his balance, his left foot slid on a smaller rock and continued sliding on the loose surface soil, causing him to lose his balance even more. In addition, there were other factors that may have contributed to the fall. He was describing the area as he was walking so he probably was not fully aware of the surface characteristics immediately before his feet. Had he not been carrying the 500mm lens camera in his left hand, he might have been able to use his left arm more effectively in breaking his fall. In addition, the suit restricts the range of vision so in order to see the rocks and depression, Scott would have had to make a special effort (in fact, a short time after the fall, Scott did check the area in front of his feet in order not to "fall over some silly rock." After the fall Irwin stated that it was "very soft there" and Scott said "I stumbled over that rock," which supports the conclusion that it was a combination of the soft surface and the rocks that caused the fall.

6.6 The Hazards Associated with Falling

In discussing the nature of falls of crewmen during lunar EVA, the hazard of possible damage to one of the suit subsystems should be considered. The analyses of the other "fall or near-fall" segments will be reported later and a discussion of the hazards will be correlated with the possible circumstances associated with lunar falls.

7.0 RECOMMENDATIONS

7.1 To enable us to make precise comparisons between training sessions and lunar EVA performance, it is recommended that we be given permission to film various experiment deployments during the last three training sessions before the Apollo 16 mission.

7.2 To enable us to get necessary performance data during the lunar EVA, it is recommended that we meet with and advise the ground-control staff in charge of TV deployment of our specific needs for the Apollo 16 mission.

7.3 To enable us to obtain the best resolution of TV data for our Time and Motion analysis, it is recommended that we be given permission to purchase a laboratory color video tape system as the source of our TV data.

7.4 To enable us to make refined analysis of EVA performances, it is recommended that a human factors review be made of the 16mm Data Acquisition Camera (DAC) system for the express purpose of eliminating the difficulties associated with its use in the suited mode.