Goal-Directed Information Seeking in Time-Synchronized and Topic-Linked Records of the Apollo Lunar Missions

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ABSTRACT

We live in an era in which ubiquitous networks bring together information from a vast array of sources. The resulting confluence creates new opportunities for providing integrated access. This paper describes the use of a system for exploring the rich recorded legacy of the Apollo missions to the Moon, using the event structure of each mission as an organizing principle. Qualitative analysis of a study with five journalism students indicates that the system is capable of supporting goal-directed information seeking.

1. INTRODUCTION

In a four-year period between 1968 and 1972, 24 people traveled to Earth's moon, twelve of whom walked the surface. Apollo astronauts lived on the surface for a total of nearly two weeks, spending more than 81 hours outside their spacecraft. The Apollo missions remain, to this day, among the most extensively documented events in human history. As is the case for any complex undertaking, many people know a little about what happened and some people know a lot, but nobody knows the whole story. This is why making sense of the historical record requires that we consult multiple sources. As primary sources become increasingly available online, new opportunities emerge to support analysis and synthesis of the historical record. This paper explores two such opportunities: time-synchronized and topic-linked event reconstruction. The Apollo missions offer an outstanding testbed for applying event reconstruction to archival materials for three reasons: (1) several large collections of primary source materials from Apollo are already available online, (2) a substantial subset of this record has sufficiently precise timing information to support straightforward automatic alignment, and (3) the combination of individual records in the form of documents, audio recordings, still images, moving images, and digital data (e.g., trajectory and telemetry data) offers diversity in content. This paper describes our work to date with a substantial subset of those materials.

2. THE APOLLO ARCHIVE EXPLORER

The Apollo program included two crewed spacecraft, the Lunar Module (LM), which was designed to land on the moon, and the Command Module (CM), which remained in lunar orbit awaiting the return of the LM from the surface and then returned the crew to Earth. Each spacecraft had a combined voice and data recorder. NASA made a vast trove of Apollo mission transcripts from those recorders, and from radio communication between the spacecraft and the Mission Control Center, available at the turn of the century [4]. The Apollo astronauts also took about 6,000 still photographs in their 81 hours of moonwalks, for an average rate of about one a minute. The high resolution Hasselblad film cameras that were used to take these photographs were almost always mounted on the astronaut's chest, yielding an unmatched sequence of ego-centric views of lunar surface operations [3]. Fairly precise times have been reconstructed from radio reports and television observations for a substantial number of those photographs. Video from the Apollo missions is available from three sources: Earth-based cameras for launch and splashdown, television sent back during the mission, and 16-mm motion picture film shot during the mission. Maps and other types of cartographic products offer a further perspective on what happened.

This set of content has led to a small cottage industry focused on consolidating media that had initially been separate. One of the most ambitious projects was the Apollo Lunar Surface Journal (ALSJ), an extensively annotated set of hand-corrected transcripts [2]. The ALSJ was later augmented with the Apollo Flight Journal (AFJ) for other portions of the Apollo missions. One limitation of the ALSJ and AFJ is that they are transcript-centric: readers can view linked photographs, maps, or video, or listen to linked audio, but those sources are displayed separately, out of context from the transcript that brought the reader there. An alternative approach is illustrated by the Apollo Archive Explorer (AEX), which we use in this paper [1]. The AEX organizes events temporally on a timeline that represents Ground Elapsed Time (GET), the elapsed time since launch from Earth. The AEX includes the ALSJ and AFJ, scanned transcripts, photographs, audio, video and flight plans, all of which are time-synchronized. While many things can be time-synchronized, some cannot. The NASA Johnson Space Center oral history project has interviewed several hundred people from the Apollo era, and transcripts from almost all of those are available online in PDF format. Topic-linking is an alternative in the case where a source cannot be time-synchronized. These oral history interviews are currently the only topic-linked source in the AEX, although other sources (e.g., technical reports) could also be added.

We started with Version 4.0 of the AEX system [1] and made modifications to simplify the layout for use by novice users, thus creating version 4.1.[1] Figure 1 depicts the user interface of the modified AEX, which is a Java application. The screen is divided into four regions: control (leftmost), two tab-selectable document [2] display zones (middle), and images (rightmost). The control region on the left provides a term-based search capability and a pause button to start and stop the replay. That region also displays the

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[1] AEX download: http://www.umiacs.umd.edu/~oard/apollo/aex

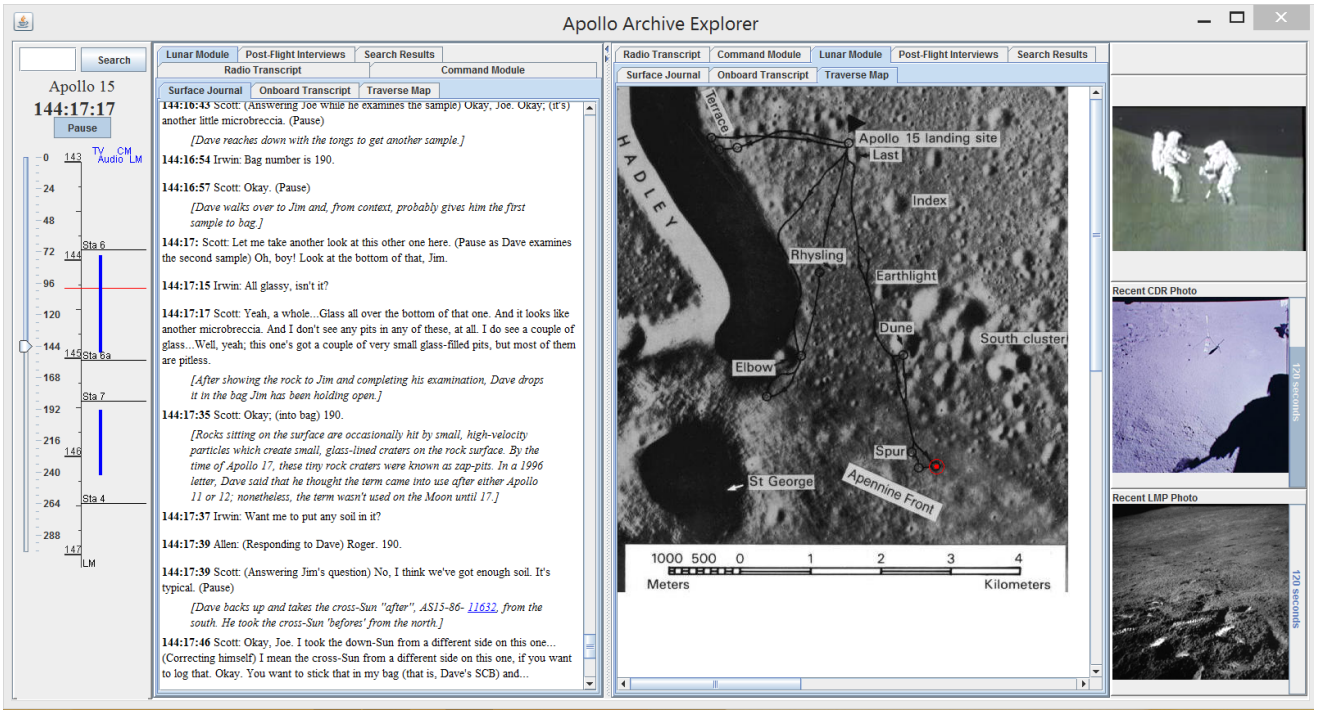

Figure 1. The Apollo Archive Explorer

Apollo lunar landing mission number (currently Apollo 11, 14, 15, 16 or 17), and the Ground Elapsed Time (GET). Below the top row of controls, a major-event timeline is displayed with availability indicators for television (TV), audio (for periods when audio but no video is available), the scanned transcript from the CM recorder (CM), and the scanned transcript from the LM recorder (LM). Clicking in the major event timeline resets the GET to the selected point. The slider bar and the more detailed timeline at the left of the control region work together to allow the user to reset the replay to any time during the mission in one-hour increments. Two document display regions function identically but independently, thus permitting the user to view any selectable content on either side. At most, two levels of tabs are used to control the selection of content for the displays. The top set of tabs can be seen in Figure 1. Selecting the Command Module, Lunar Module or Search Result tab reveals a second set of tabs. As shown for the Lunar Module tab the second set of tabs are for the Surface Journal (the ALSJ, which appears on the left in Figure 1), the Onboard Transcript (from the LM recorder), and the Traverse Map (which appears on the right in Figure 1). On the lowest level, each tab displays some document (or in the case of the traverse map, image), often with added time-specific annotation. For the Surface Journal, the GET of the most recent utterance is highlighted. For scanned transcripts, a bounding box is drawn around the most recent utterance and labeled with the GET. Selecting the traverse map displays the route taken by the astronauts (from post-flight analysis), overlaid with a moving bulls-eye symbol to show their approximate location at the current GET.

3. STUDY DESIGN

To this point, AEX has evolved principally as a platform for experimenting with integration of diverse content. Our ultimate goal has always been to help users to manage complexity, and we are now shifting to a more user-centered design process. For this first user study, we sought to learn how the AEX would actually be used during a focused information seeking task. We chose journalism students as participants because we believed their experience with focused investigation and information seeking would be greater than that of the general population. We recruited five undergraduate students, they were compensated twenty dollars each for their time and participation. Sessions lasted approximately one hour, and participants were tasked with writing brief stories describing specific events.

Apollo Missions Events List

These events occurred during an Apollo Mission to the Moon

1. Proving Galileo's Theory The Hammer And Feather Experiment (Apollo 15)
2. First use of an ultraviolet camera/spectrograph on the Moon (Apollo 16)
3. Alan Shepard hitting 2 golf balls on the Moon (Apollo 14)
4. John Young's Salute On The Moon (Apollo 16)
5. James Irwin and David Scott's discovery of the Genesis Rock (Apollo 15)

Figure 2. Story topics.

As prompts, we wrote one-sentence descriptions for five events as shown in Figure 2. These events were specifically chosen for their potential insight into: (1) the use of time-synchronized sources and (2) the use of topic-linked sources. Our version of the AEX includes many types of time-synchronized sources, but only a single pair of topic-linked sources (from the radio transcript to oral history interviews). Thus, we selected events for which information was available from transcripts, oral history interviews, and at least one other time-synchronized source.

Because of the AEX's complexity, we expected to see substantial learning effects as each user became acquainted with the system. To account for user learning, we asked each participant to perform two tasks. For Task 1, we chose the first event shown in Figure 2, for which the information regarding the event was concentrated at a single point in the mission. Through this first activity, the user could gain experience with time synchronization and topic linking without the need for extensive timeline navigation (this reasoning was not described to participants, however). For Task 2, participants were invited to pick event 2, 3, 4, or 5—if they expressed no preference, an event was chosen for them. These events were designed to be more difficult to summarize, requiring

information from multiple sources, or information from different times in a mission.

Participants conducted their session individually. In the first study, both a study conductor (the first author of this paper) and an observer (the second author) were present; for the other sessions a single person (the first author) served both as study conductor and observer. At the start of each session, the participant was shown a seven-minute training video which included screen captures and voice narration. The first half of the video sought to give the participant general knowledge about the Apollo missions to the Moon. The remainder of the video focused on how to use the AEX system, and reviewed each region of the interface separately. The video concluded with an example of how to find information about a specific event. To aid in visualizing the scope of the Apollo program, infographics and images were provided with an outline of the video in a two-page handout. Participants were given this handout at the outset, and could stop the video at any point to ask questions. The study conductor paused the video occasionally to clarify details for participants. Together with the time required to obtain written informed consent, the training phase of each session took about 15 minutes. We allowed at most 15 minutes for the first story generation task and 25 minutes for the second. The two tasks were separated by 5-minute break, and participants could finish either task early if they were satisfied with their story.

We gave participants a written description of their task (to write a brief story), one assigned event (Task 1) and a list of events from which to select (Task 2). Participants were asked to verbalize their thoughts while completing the tasks, and we recorded that audio with their permission. The first author of this paper later transcribed these recordings. The observer (the second author) made notes during the session to record impressions that might not be as well captured by that transcript or the visual screen capture. Because of the complexity of the system and the specialized jargon that might be encountered, participants were invited to ask the study conductor questions for clarification. The study conductor also answered questions concerning the task itself. In a few cases, answers were crafted to highlight sources of information not previously considered by that participant, but such hints were offered in the latter half of the task, and without specificity about what might be found. After completing both tasks, participants completed a questionnaire and a brief semi-structured interview. The questionnaire consisted of six questions to gauge self-reported computer proficiency and prior familiarity with the events, reported on a five-point scale. In the interview, the study conductor asked participants about their search and navigation strategies, opinions about aspects of the AEX system, and about the overall user experience. The questions were tailored to the participant's actions, as observed during the study. Interviews for later participants were also shaped by the interviewer's experience in prior sessions. Together the questionnaire and interview took about 15 minutes.

The primary technique used for analysis was grounded theory [5]. We started with an initial coding frame that included two phases (information seeking and synthesis) and five activities (search, timeline navigation, fact finding, contextualization, and writing). As sessions were completed, we transcribed the user session and coded the observer's notes, the stories created for each event, and the screen capture, initially using that coding frame. As coding proceeded, we evolved the coding frame by identifying actions and sequences of actions that better described the behaviors we observed. For example, we identified problem solving as an additional phase, and learning new terminology as an additional action, with an ordering in which learning new terminology sometimes preceded a refined search. The two authors initially coded parts of one session independently and then met to review and reconcile the resulting coding frames. After arriving at a unified coding frame, the remaining four sessions were conducted and coded by the first author of this paper, further evolving the coding frame as new phenomena were observed. The second author then performed peer review of the resulting coding frame and a sample of coding decisions.

4. FINDINGS

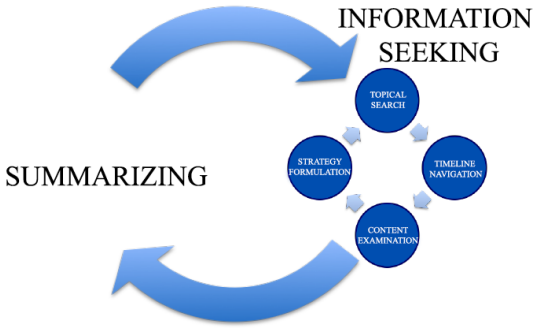

Figure 3. User Activities

As illustrated in Figure 3, we observed two dominant activity phases, information seeking and information synthesis. Within the information seeking phase, we observed four dominant activities: topical search, timeline navigation, content examination, and strategy formulation. Strategy formulation served as a typical entry point, with content examination serving as the exit point. During strategy formulation the user's goal was to figure out how to get to the information that they wanted to see. Often this required getting the AEX to display information from a specific point in the mission (i.e., some specific GET). Although the GET could be set through timeline navigation, at the start of a task our participants did not know where in the mission timeline they might find the event they were looking for, thus they invariably used search to find some content in the temporal vicinity of their event. All of our users had Web search experience and therefore required only a few queries to get to some useful content. Topical search thus emerged as the dominant outcome of strategy formulation. As Table 1 shows, participants were able to find the content they sought for the first task with no more than three queries, and they typically found at least some useful content with their first query. Subsequent queries were used to explore the interviews or to reach other times in the transcripts. Four of the five participants issued markedly more queries for their second task than for their first, reflecting the greater complexity of that second task. This called for experimentation with alternative strategies. Participant 1 (with a single query for each task) was the only exception.

Table 1. Number of queries issued

Participant	*1*	*2*	*3*	*4*	*5*
Task 1	1	1	2	3	3
Task 2	1	6	4	7	5

Three participants stated during the semi-structured interview that search was the most useful AEX system capability. Once a participant had gotten in the neighborhood, the natural next step was to examine some content. Video and photographs were displayed continuously, but tab selection was sometimes needed to get to a specific transcript or journal after first setting the system's GET by selecting a search result. We were surprised to see users making more use of the scanned transcripts than of the ALSJ, despite the fact that the ALSJ includes richer content. The topical

search in the present AEX system is based on scanned transcripts, however, and clicking on a search result therefore brings the user to a scanned transcript by default. Users typically did ultimately select the ALSJ at some point, and when they did they often found the extensive commentary in that source to be useful.

When topical search yielded little relevant content, users were seen developing other strategies. As an example, while examining search results for oral history interviews, Participant 3 during the second task, stated that reading questions asked during those interviews helped them determine whether the result was relevant to their event. We observed no productive use of the map showing the path taken during the moonwalks, although none of the tasks were designed specifically to exercise that capability of the system. We did, however, observe that the multimedia content (the audio, video, and photographs) were particularly important to some users. Participant 2 described having multimedia as essential to writing their story. Indeed, when that user found no useful audio or video during the second task, they expressed discomfort and continued using the AEX up to the time limit. This was the only participant to express concern that a report might be incomplete. The same participant explained during the interview that using systems like the AEX allows for a larger amount of information to be conceptualized than if they had to work only with Google or textbooks. In other cases, we found that users were satisfied with only written sources. For example, Participant 1 mentioned that the journals and transcripts were enough to complete both tasks. Notably, that participant did not use all of the time allotted for either task. Another participant stated, "In my research the picture and video function wasn't necessarily a huge aid."

Participants generally found the AEX's time synchronization valuable. At the start of their first task, users were inclined to select the first search result from the radio transcript, they then could navigate to and read the time-synchronized journals. One participant indicated that time synchronization was the most helpful AEX capability, drawing an analogy to the interviews that journalists do: "if you're interviewing five different people in five different places it's hard to line them up and see how they all fit together and so this is nice because everything already is together." Timeline navigation, by contrast, proved to be problematic. A total of four participants tried using timeline navigation, two of whom did not find the timeline navigation process easy to conceptualize, at least in part because the AEX includes separate capabilities for coarse (whole hour) and fine (minute and second) navigation. For example, one participant said: "Getting to an exact time or searching times was not as precise as it could have been."

We found that all participants exhibited similar examination patterns, initially clicking through the tabs for different time-synchronized sources, and only later looking at the oral history interviews. Early participants looked at those interviews only when we reminded them of their availability, emphasis was therefore placed on how to access oral history interviews during training for later participants. The majority of participants used search to find oral history interviews, which was a sensible choice since the content linking capability in the present implementation is constantly searching based on what was said most recently in the linked transcript, and thus the results are only stable when the replay is paused. All participants who searched oral histories at their own initiative did so for both tasks. One participant explained that they found the oral history interviews to be useful because it provided a motive for the event. All users would examine the post-flight interview search results only after including information they had found from images, video (if available), transcripts or journals in their stories. They also quickly demonstrated an understanding of what they were seeing, either through their think-aloud or through their written stories. Often this would occur in a matter of seconds. We observed several participants learning new terms from the content they were examining and then using those terms to search more effectively. This was despite having little prior knowledge to their tasked events. Questionnaire results indicated that every participant reported no prior familiarity with at least one of the events they wrote about. Each participant was also offered the opportunity to do Web searches if they felt that necessary to augment what they were getting from the AEX system, but none chose to do so. A participant inquired only once about event-related content (in that case, asking for the full name of an astronaut).

When working on their second task, for which information was scattered across multiple sources and at different points in the timeline, all participants expressed some confusion or discomfort. However, in all cases participants produced more detailed stories for their second task than their first. They also spent more time on their second task. Three participants worked more quickly than we had allowed for, but Participants 3 and 4 worked up to the time limit, and both expressed a desire for more time in order to add more information to their story. From these and our other results, we conclude that participants were able to master the use of the AEX system in a relatively brief time and that it aided in the synthesis process used to construct their stories.

5. CONCLUSION

From our study, we have learned about how people might use the AEX system, and in particular about which capabilities were most helpful for focused information seeking. In the future we are interested in learning more about how the AEX's content linking capabilities can best be employed. We would also like to extend the range of user and task types, perhaps by initially involving history and communication undergraduates. In terms of system design, our results clearly point to the need for a more intuitive timeline navigation capability. In 1969, few organizations outside NASA could assemble such rich content, but today any of us can use email, Skype, smartphone cameras, and a myriad of other technologies to create similarly rich records. Some of this material can be time synchronized (e.g., [6]), others perhaps topic linked. If we think of Apollo Program's records as a sort of prehistoric lifelogging, then we might even use the AEX to draw some insight from our study of the past into how those in the future might study us.

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