

Lunar e-Library: Putting Space History to Work

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As NASA plans and implements the Vision for Space Exploration, managers, engineers, and scientists need historically important information that is readily available and easily accessed. The Lunar e-Library – a searchable collection of 1100 electronic (.PDF) documents – makes it easy to find critical technical data and lessons learned and put space history knowledge in action. The Lunar e-Library, a DVD knowledge database, was developed by NASA to shorten research time and put knowledge at users' fingertips. Funded by NASA's Space Environments and Effects (SEE) Program headquartered at Marshall Space Flight Center (MSFC) and the MSFC Materials and Processes Laboratory, the goal of the Lunar e-Library effort was to identify key lessons learned from Apollo and other lunar programs and missions and to provide technical information from those programs in an easy-to-use format. The SEE Program began distributing the Lunar e-Library knowledge database in 2006. This paper describes the Lunar e-Library development process (including a description of the databases and resources used to acquire the documents) and the contents of the DVD product, demonstrates its usefulness with focused searches, and provides information on how to obtain this free resource.

I. □ Introduction

When the President announced the Vision for Space Exploration in January 2004 and directed NASA to return to the Moon and use this experience as a stepping stone for exploring Mars and other worlds, there were no completed architecture plans or requirements documents. The Crew Exploration Vehicle and Crew Launch Vehicle were not even twinkles in an engineer's eyes. Engineering efforts across NASA were rightly focused on returning the Space Shuttle safely to flight and operating the International Space Station (ISS). Yet this bold new vision energized engineers and scientists and made them look toward the Moon – a location last visited by humans in 1972.

In recent years, many of the engineers and scientists at NASA and aerospace companies have focused their efforts on learning to live and work in low-Earth orbit, the environment in which the Space Shuttle and the ISS operate. They have learned valuable lessons not only about building and operating large structures in space but also about collaborating with international partners on space research projects. They have a thorough understanding of the low-Earth-orbit environment and the hazards it poses: atomic oxygen, plasma interactions, ultraviolet radiation, and meteoroid/space debris impacts to name a few.

While many of these same hazards pose threats to lunar missions, the lunar environment is not the same as in low-Earth orbit. Another consideration is that low-Earth orbit is closer to home than the Moon, so it is easier for crews to return home or be rescued from environmental hazards. Most engineers today have little or no hands-on experience in designing human-piloted vehicles to go to the Moon, support long lunar missions, and return safely to Earth. The present research effort started with the idea that a good step in preparing for any type of lunar mission would be to acquire as much knowledge as possible about the lunar environment – including lessons learned about getting to the Moon, living there and returning to Earth – and to organize that information so that it would be readily

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available and accessible to NASA and aerospace professionals who would be planning and implementing the Vision for Space Exploration.

II. Guiding Philosophies

"As for the future, your task is not to see it, but to enable it." Antoine de-Saint Exupery (1900-1944), The Wisdom of the Sands

This quote from the *Vision for Space Exploration*, a report issued February 2004, reflects the philosophies of the engineers and scientists who had the idea for the Lunar e-Library. With a vision clearly before them, they needed to be equipped with the knowledge to accomplish that goal. At that time, the NASA engineers who started this data collection project were working long hours analyzing External Tank insulating foam and preparing the Space Shuttle for return to flight. Most of their efforts were concentrated on materials and processes and on the launch environment. Their current work was visible evidence of the necessity to understand precisely the environment and its effects on materials. To go back to the Moon successfully, they knew they would need to know about myriad environments: (1) launch (2) low-Earth orbit, (3) the translunar environment, and (4) the lunar environment. These engineers also realized the challenges of long-duration flights and recognized that materials, which worked best for a 12-day Apollo missions might not work for an extended mission or even still be commercially available after 30 years.

Rather than pursuing this quest individually, leaders from NASA's Space Environments and Effects (SEE) Program at the Marshall Space Flight Center (MSFC) in Huntsville, AL, and from the Materials and Processes Laboratory in the MSFC Engineering Directorate decided to pool their resources to mine the numerous collections of existing data and create an extensive but more manageable compilation of lunar data that could be made available to all NASA and aerospace professionals. Their goal was to identify knowledge from the past that would enable the future.

They also had the foresight to realize that while some sources of valuable information would be easy to find and identify, for example, the Apollo Mission Reports, some more obscure yet invaluable publications or data might be lost or hard to locate. Who were the best people to lead them to these treasures? They were the people who helped NASA successfully journey to the Moon during the Apollo/Saturn Program. Where were these people? Many of them had retired, and many were about to retire. NASA scientists and engineers suggested interviewing the experts: the Apollo scientists and engineers who successfully enabled the first human missions to another world. These experts could not only identify valuable sources of documents and data but also could relate personal experiences – information that might not appear in any formal documentation.

A. Casting a Wide Net

One goal of this project was to provide a research tool that did not duplicate current resources. First, the researchers cast a wide net to see what resources were available and what they might provide. There were a lot of fish to be caught. The NASA Aeronautic and Space Database, which is available to NASA civil servants and contractors with NASA computer IP addresses, has 3.9 million citations that date back to the early 20th century and the days of the National Advisory Committee for Aeronautics (NACA). It is a wonderful resource that can be searched in many ways (author, title, NASA report number). For one lunar geologist, there were 350 citations. When the project began, this new arm of NASA's Scientific and Technical Information (STI) network was about a year old. All new documents were in a digital format, and the database managers were just starting to scan some of the older Apollo-age documents as people requested them.

Other resources, such as the Apollo Lunar Surface Journals web site and the Johnson Space Center Oral History web site, provided valuable documents: transcripts from the air-to-ground transmissions during the Apollo missions and interviews with Apollo astronauts. In addition to NASA's extensive online collections, history offices, and document repositories at NASA Headquarters and the field centers, private collections were available through other online sources. Retirees had donated documents in archives at the University of Alabama in Huntsville, the University of Houston in Clear Lake, Texas, and the U.S. Space and Rocket Center in Huntsville, to name a few locations. Lunar e-Library researchers also consulted with MSFC Historian Mike Wright, as well as other archivists and historians, who offered insights into their collections.

The Smithsonian National Air and Space Collection had not only documents but also extensive collections of archives, such as the world's largest collection of space suits. NASA materials engineer Miria Finckenor, co-author of this paper, was able to inspect this collection and interview curator Amanda Young about the materials

degradation that had occurred in the suits. A paper in the Lunar e-Library collection describes the Smithsonian's analysis and work to preserve the space suit collection.

To bolster research and make other resources readily available without duplicating them, the Lunar e-Library DVD includes a descriptive list and web links to sites containing document sources, databases, and oral history interviews identified during the effort.

B. Refining the Collection

The goal of the Lunar e-Library effort was to create a product that would be valuable to working engineers and scientists. Therefore, it was imperative that they guide the product from start to finish. The technical experts guiding the research decided that the collection should focus on documents that could provide information on (1) the space and lunar environment, including launch and landing environments for vehicles such as the Saturn V and other Apollo Program spacecraft and (2) materials research. To properly mine existing collections for the best documents, engineers and scientists helped develop a set of key words that focused on areas of interest within these broad topics. The goal was to collect information that would help NASA use lessons learned to develop new launch and crew vehicles, extend operations experience in a hostile lunar environment, and develop capabilities and technologies (particularly in the area of materials and processes) that would enable the Moon to be used as a stepping stone for exploring Mars and the universe beyond.

In addition to identifying topics of interest, technical experts helped develop a list of pertinent types of documents:

- A. Apollo Mission and Preliminary Science Reports
- B. Saturn V Flight Evaluation Reports
- C. Key historical documents and summary documents that contained data and/or the recollections of the Apollo crews, engineers, and scientists
- D. Saturn V Hardware documents, particularly those dealing with materials and processes or the launch environment
- E. Apollo Experience Reports
- F. Space Vehicle Design Criteria documents developed after Apollo and before the Space Shuttle, particularly those dealing with the space environment or materials
- G. Lunar data from all missions: Surveyor, Apollo, Clementine, Lunar Prospector, *etc.*
- H. Lunar Roving Vehicle documents
- I. Major lunar reference missions and studies, especially for the Space Exploration Initiative and the First Lunar Outpost.

A vast amount of data existed in many locations and in both digital and hard formats, but with the help of historians and the experts that we interviewed, key documents were identified. The final collection is not all-inclusive but has enough crucial documents to give researchers a good start in finding critical information related to the Moon.

III. □Putting Space History to Work

Once data collection was under way, it became clear that NASA engineers already required the information. Research teams were in need of knowledge to help guide architecture studies and planning. They were asking questions and looking for answers: What is the lunar dust really like? How big a problem was dust for Apollo astronauts? What studies were accomplished before the Apollo missions? How well did the Lunar Roving Vehicle thermal protection system work? What kind of rovers would best benefit future lunar missions? What is the environment at the Moon's South Pole? What scientific tasks would we need to accomplish to set up a base there and in other lunar locations? NASA and contractor researchers were already at work examining these and many other issues. Many answers could be found in previous reports and studies in which Apollo astronauts had talked about their experiences on the Moon, and in which scientists had published data from lunar experiments or remote sensing probes.

As information was compiled, Subject Matter Experts (SMEs) were invited to assess the literature's value. A tracking database was designed to log in all collected documents, along with bibliographic information: title, author, key words, source, data release restrictions, *etc.* The tracking database included a searchable index to avoid

document duplication and make it possible to search the entire collection for specific documents. The documents were posted on an internal MSFC server where registered users downloaded them for use in technical projects. At the same time, the SMEs provided input on which documents were valuable and recommended other documents for inclusion. They requested in-depth literature searches on special topics of interest: lunar dust, the lunar poles, contamination, radiation, lunar science, the lunar atmosphere and plasma environment, Saturn V tanking issues, Saturn V heat shield design, the Apollo Command Module cooling and thermal control systems, and spacesuit design – and the results of these searches were added to the e-Library. Engineers and scientists were putting space history to work immediately in their everyday jobs.

A. Interviews

In addition to the literature collection, researchers determined early on in the project that it would be wise to consult experts who worked on the Apollo program. These experts provided guidance on valuable documents and studies and were interviewed to obtain information that did not exist as part of formal documentation or supplemented information in formal documentation. Focused interviews (1 to 4 hours long) were conducted with 16 people; many were retired, but most still support aerospace programs as contractors, consultants, or researchers.

Interview subjects were selected to address a variety of topics, and some critical topics were recommended by the SMEs. While some of the interview subjects became managers, all started their careers in the trenches during the Apollo/Saturn era. Since numerous interviews had already been conducted with top NASA officials and the Apollo astronauts, this effort aimed at interviewing key managers, engineers, and aerospace employees who worked on the Apollo/Saturn program. Many of them started their NASA careers at that time and transferred that knowledge to the Space Shuttle Program and other efforts, such as the Hubble Space Telescope. Their early experience influenced later projects and applied not only to engineering topics, such as rocket engine design, but also to other areas such as system engineering, and non-technical topics such as mentoring, education, and communications.

The interview topics included Saturn rocket design, the history of engine design from the early missiles to the Space Shuttle Main Engines, the Lunar Roving Vehicle design, dust problems, thermal control, lunar surface studies, and project management; materials selection and materials processes such as welding, materials requirements and testing for metals and non-metals; and many aspects of the space environment with particular emphasis on materials durability and dust.

Since the number of interviews was limited as was the time for each interview, each was focused on select key topics. This strategy also allowed correlation and comparison of the answers to certain interview topics. Researchers worked with the SMEs to develop a questionnaire in which the majority of questions focused on the lunar environment and materials and processes, with a few general questions aimed at lessons learned. Interview subjects were requested to return this completed questionnaire along with a biography, a list of publications, and a list of publications that they recommended for inclusion in the Lunar e-Library. This information, along with additional input and specific questions submitted by SMEs was used to create a more in-depth set of interview questions that were covered during the oral interview.

SMEs also participated in the interviews. In one interview, for example, a materials specialist asked a series of questions related to how welding criteria were developed and established for large space structures. During an interview with a lunar scientist, engineers developing methods for *in situ* resource utilization asked a series of questions related to lunar soil properties and the potential of specific processing techniques. A contamination expert asked an Apollo engineer who had worked on the lunar roving vehicle design about dust studies and control methods.

The interviews were recorded by digital video or audio. The final Lunar e-Library DVD contains a short biography of each interview subject and the interview questions. The DVD also links to many web-based interview collections, such as those conducted by the Johnson Space Center Oral History Program, the NASA Alumni League, and the Smithsonian Air and Space Museum Oral Histories, as well as lists of collections available at NASA Centers.

B. The Lunar e-Library DVD Product

The final Lunar e-Library DVD product is an export-controlled, searchable knowledge database (Figure 1). The technical experts guiding this project wanted to ensure that the information was not only collected but that it was made readily accessible. The DVD product features an easy-to-use Acrobat-based search engine that employs key words to search through the entire 1100 documents at once, list the documents by relevance, and take the user directly to the key words in the various documents (Figure 2). A document index also is included so that the user can check for particular documents of the interest, and then conduct advanced searches by title, author, and other information criteria.

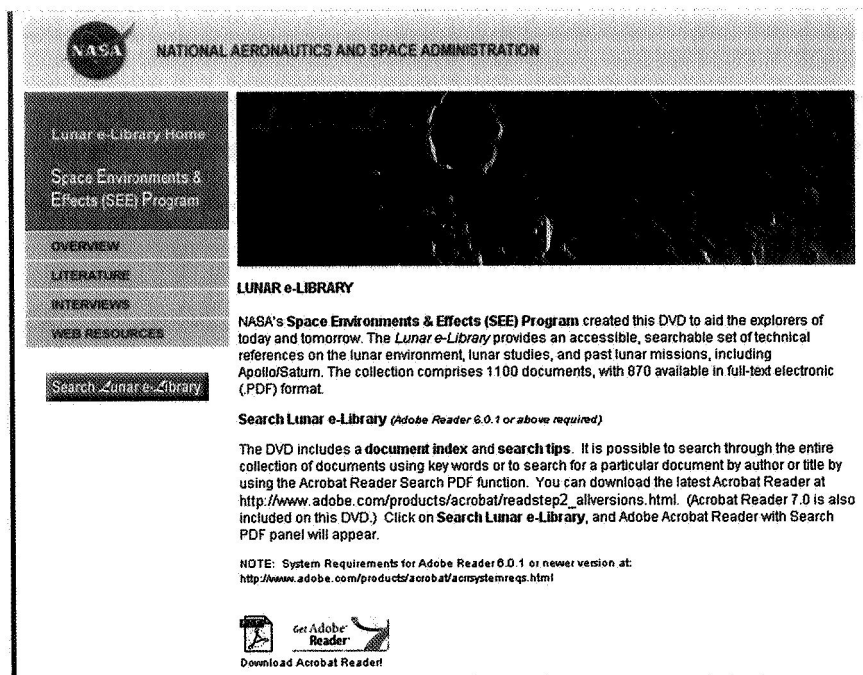


Figure 1. Lunar e-Library home page.

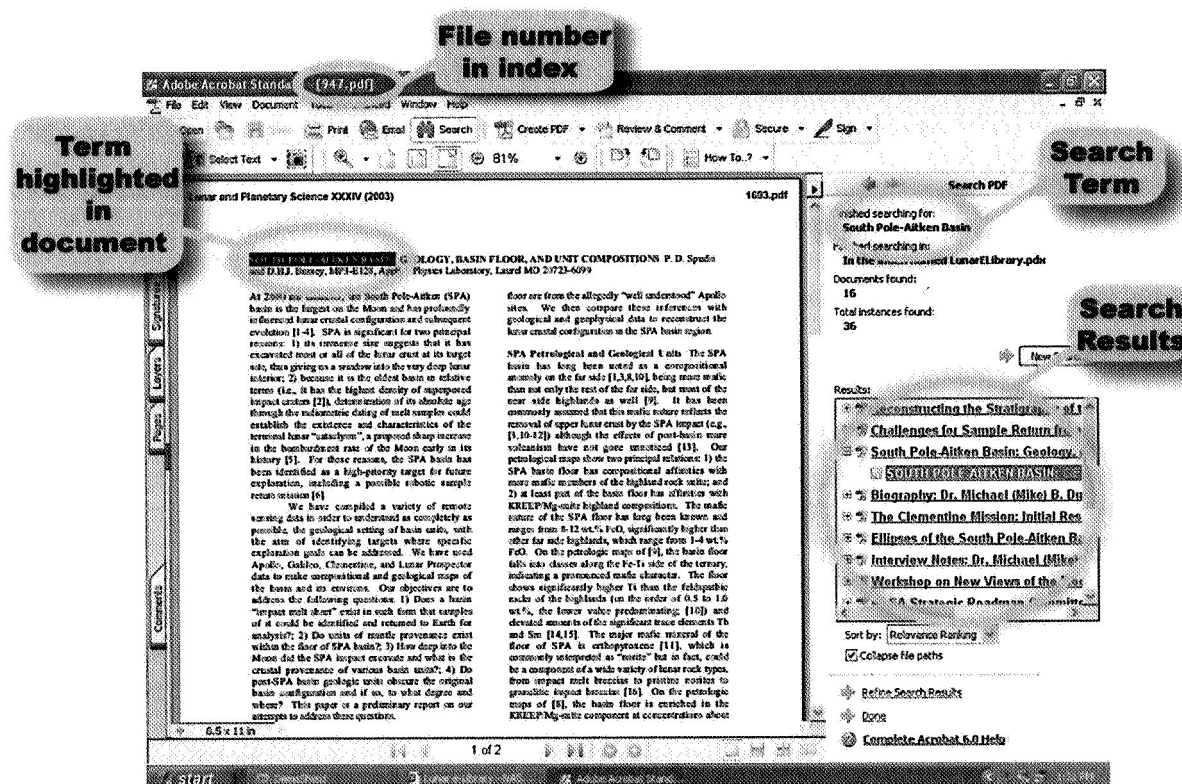


Figure 2. Sample search results

In addition to documents, the DVD includes a section on the interviews conducted for the project, a description of the literature collection process, and a web resources section that links to numerous online collections of documents as well as databases and image libraries.

Although the DVD is export controlled, it is free and can be obtained by NASA and aerospace professionals by filling out two forms, located on the SEE web site (Figure 3):

(1) The SEE Product Access Form: an online form required for export-control purposes. Click on SEE Product Access Form to fill it out and submit it online.

(2) A SEE Product Access and Software Release Agreement Form: required for software licensing agreements. It must be printed, filled out, and faxed to Sopo Yung, the SEE software developer, at 256-544-8480. To print the form, under General on the Web page, click on Lunar E-Library-knowledgebase.

Both forms are located at:

<http://see.msfc.nasa.gov/ModelDB/ModelDB.htm>

This DVD is designed to operate with Windows-based operating systems. More details and computer system requirements for running the Lunar e-Library DVD, and information for downloading Acrobat Reader 7.0 are posted on the SEE Web site at:

<http://see.msfc.nasa.gov/dmia/LunarELibrary.htm>

The screenshot shows the SEE web page with the following elements:

- Header:** NASA logo, "NATIONAL AERONAUTICS AND SPACE ADMINISTRATION", and a search bar with "FIND IT @ NASA:" and a "GO" button.
- Left Navigation Menu:**
 - SEERS
 - SEE Home
 - Space Environments & Effects (SEE) Program
 - WHAT'S NEW
 - INTRODUCTION
 - ORGANIZATION
 - TECH WORKING GROUP
 - SEE PRODUCTS
 - FLIGHT EXPERIMENTS
 - PUBLICATIONS
 - LINKS
 - Tech Development Activity - present and past... [learn more>>](#)
 - High School Lesson Plan. toolkit... [learn more>>](#)
 - Image Gallery - SEE, SEERS images>>
 - SEARCH + GO
- Main Content Area:**
 - SEE PRODUCTS / SEE Related Model & DB**
 - SEE PRODUCT ACCESS FORMS**
 - ATTENTION - All software developed or provided through the SEE Program server has been determined to have export restrictions. If a requester does not live in the United States and/or the requester is a foreign national, you must obtain an international agreement through NASA Headquarters before being eligible to access the software. You may contact the appropriate NASA Headquarters office at 202-358-0330 or visit the NASA Office of External Relations web site for more information.**
 - In order to meet export control and maintain the integrity of the models, the SEE Program has agreed to review the provided information and perform the necessary paperwork. All models are executable only and the source code can only be obtained by contacting the SEE Program Office.
 - Before access is granted, you must send us the following TWO forms:
 - 1. **SEE Product Access Form** (submit thru online)
 - 2. **Software Usage Agreement (SUA) Form/s** (link below) - *one copy of the form must be completed, signed, and FAX (just the first and last pages with your signature and information) to Sopo Yung at 256-544-8480*
 - SEE PRODUCT SOFTWARE USAGE AGREEMENT (SUA) FORMS**
 - General**
 - Lunar E-Library - knowledgebase
 - Electromagnetic Effects & Spacecraft Charging**
 - Electronic Propulsion Interactions Code (EPIC) - model
 - NASA/Air Force Spacecraft Charging Analyzer Program (NASCAP-2K) - model
 - Interactive Spacecraft Charging Handbook - model
 - The Charge Collector - knowledgebase
 - Ionizing Radiation Environment**
 - Trapped Proton Model (TPM) - model
 - Cosmic Ray Effects on Microelectronics (CREME96) - model

Figure 3. SEE web page with instructions for ordering the Lunar e-Library DVD.

IV. □ Conclusion

The Vision for Space Exploration comprises a broad range of missions – from robotic to human – and requires a vast number of technologies in every engineering discipline. Success will depend upon combining experience (historical knowledge) and innovative thinking. Since the vision will be sustained over decades, information must not only be accessible to current aerospace professionals but also must be available to guide young engineers who join the journey. The Lunar e-Library DVD knowledgebase is a research tool that will bolster NASA's return to the Moon.

V. □ Acknowledgments

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