History and Archives Contribute to the Success of Space Flight Programs

John L. Goodman

Odyssey Space Research, LLC
NASA Johnson Space Center
Houston, TX

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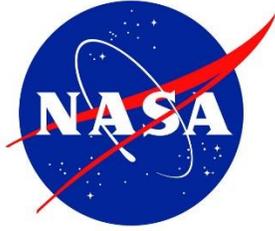
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John L. Goodman
Odyssey Space Research, LLC

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
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Contents

I. Preface

This report discusses how history can be used by management, engineering, and operations personnel within space flight programs. Works by professional historians and sociologists inform key decision makers and policy specialists on lessons learned from space flight program management successes and failures, as well as from legislative affairs, policy making, and commercial space efforts. Vehicle engineering history written by engineers for an engineering or operations audience informs project management and technical personnel on lessons learned, best practices, and the rationale behind the design and operation of flight vehicles and supporting ground systems. Archives play a critical role in supporting the efforts of both professional historians and flight program personnel. Suggestions are made concerning how professional historians could leverage the interests and knowledge of flight program personnel to obtain more insight that is needed to support historical research efforts.

This report is based on a draft paper and presentation originally prepared by the author for the "To Boldly Preserve: Archiving for the Next Half-Century of Space Flight" conference. The conference was sponsored by the National Science Foundation and was held at the Center for the History of Physics at the American Institute of Physics in College Park, Maryland on March 1 and 2, 2018.

The purpose of the conference was to promote and facilitate the collection and preservation of historical documentation and artifacts related to space exploration. This is becoming more challenging due to the expansion of the commercial space industry, the proliferation of multiple types of electronic media, and legal concerns. On the other hand, the widespread use of social media is increasing opportunities for flight program participants to preserve their experiences. During the conference archival best practices and experiences were shared by professional archivists and historians.

The conference served as a starting point for future activities that will help archivists and historians deal with the new challenges facing space history in the 21st century. Post conference activities include sharing of best practices and lessons learned among historians and archivists, relationship building with government organizations and commercial companies involved in space flight, and providing assistance to government and commercial entities to help them preserve and document their history. [1] [2]

II. Introduction

Documented space history has played an important role in achieving an understanding of how politics, policy, and commercial interests have shaped the development of space flight programs and technology. Management, engineering, and scientific achievements are contextualized by professional historians and communicated to academic or general audiences. Professional historians can identify leadership, policy, technical, and organization cultural factors that contributed to successes or failures. This information assists spaceflight program personnel in the successful execution of current and future flight programs. As the space industry has progressed and evolved over the decades, new challenges are emerging. These challenges must be identified and addressed for space history to continue to play the role it has in the past.

In this report, space history and archiving is examined from the point of view of an aerospace engineer who has spent his career supporting NASA's human space flight program (Space Shuttle, X-38, Constellation, Commercial Crew, and Orion) at the NASA Johnson Space Center (NASA/JSC). The report covers how space flight program personnel use history written by professional historians and why vehicle engineering history is needed to equip the space flight workforce. The use of engineers and managers with communication skills to document their experiences for historians is discussed. The challenges of preserving paper documentation are covered along with the advantages and challenges of electronic storage. Finally, the new challenges facing space historians and archivists due to the growing commercial space sector are identified.

III. Space History that Equips the Workforce

Most space history is written for either an academic audience or for members of the general public. The media used for these histories takes many forms (books, blogs, videos, etc.). The highest quality work is done by professional historians and some of these works have application within a flight program. However, technical vehicle engineering history is Do-It-Yourself history, written by engineers to assist other engineers and managers as they do their jobs.

A. Space History Written for the Public

Historical works are written for the general public with a human interest angle to increase understanding of and appreciation for space flight management, engineering, and scientific accomplishments. [3] [4] Space history is written for children and teenagers as a part of Science, Technology, Engineering, and Math (STEM) school curriculum. Space history is also written for adult space enthusiasts who have a deeper interest in space flight than most members of the general public. In addition to a human interest angle, this type of space history contains technical details that may not be of interest to the general public. Well-written history for adult space enthusiasts is also read by young people that have an interest in space flight. It can influence them to pursue engineering or science careers in the space industry. [5]

B. Space History Written for Specialist Audiences

Former President of the United States Harry S. Truman wrote about the value of history for decision making in volume 1 of his memoirs, *Year of Decisions*:

> "These lessons were to stand me in good stead years later, when I was to be confronted with similar problems. There were countless other lessons which history taught that would prove valuable to me. …… I could deal with the situation calmly because I knew something about its background that students of history would know but perhaps not appreciate. When we are faced with a situation, we must know how to apply the lessons of history in a practical way." [6]

> "I was beginning to realize – almost forty years before I had any thought of becoming President of the United States – that almost all current events in the affairs of governments and nations have their parallels and precedents in the past. It was obvious to me even then that a clear understanding of administrative problems presupposes a knowledge of similar ones as recorded in history and of their disposition. Long before I ever considered going into public life I had arrived at the conclusion that no decision affecting people should be made impulsively, but on the basis

of historical background and careful consideration of the facts as they exist at the time." [7]

Dr. Vannevar Bush, who led the U.S. Office of Scientific Research and Development during World War II, wrote in the introduction to the book *Scientists Against Time*: [1]

> "We study history, it is true, to avoid the mistakes of the past. But we also study history, or should do so, to discern past relationships and methods that achieved success, for the purpose of adopting them, as far as they may apply, to new conditions." [8]

Formal space histories researched and written by professional historians address broad programmatic, policy, political, diplomatic, economic, business, cultural, and space program management topics. These works are of value to historians, space policy specialists, and space enthusiasts. Some engineers, scientists, and managers in flight programs may read formal histories out of an interest in space flight. These histories can provide useful background information on how policy decisions shaped high-level space vehicle requirements. [9] [10] This information is also valuable to personnel working in a flight program. Works by professional historians can expound on the keys to successful space flight program management, such as leadership and innovation, along with the organizational and cultural problems that led to spacecraft mishaps. Below are listed several examples of this.

The decision to adopt the Lunar Orbit Rendezvous (LOR) mission profile over other profiles for Apollo was a key to meeting President Kennedy's goal of landing a crew on the Moon and returning them safely to Earth before 1970. The NASA history monograph, *Enchanted Rendezvous,* by Dr. James R. Hansen of Auburn University describes the advocacy role played by John Houbolt during the lunar mission profile debates in 1961 and 1962 that led to the adoption of LOR. [11] The monograph illustrates the important role of advocacy and communication skills in convincing a flight program to adopt the best and lowest risk technical solution.

The book, *Truth, Lies and O-Rings* is an example of a professional historian (Dr. James R. Hansen) assisting a member of contractor management (Allan J. McDonald of Morton Thiokol) in the telling of a story about the loss of the Space Shuttle *Challenger*. [12] The book details the efforts of McDonald to communicate concerns about the *Challenger* solid rocket boosters before the launch. It is an

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[1] Most U.S. research and development during World War II was led and coordinated by the Office of Scientific Research and Development (OSRD), chaired by Dr. Vannevar Bush. He also served as a science advisor to President Roosevelt. Development projects overseen by the OSRD included radar, loran, the proximity fuze, guided weapons, fire control systems, anti-submarine warfare, blood substitutes, mass production of penicillin, and the Manhattan Project.

important cautionary tale for any engineer or manager working in a high-risk profession where the consequences of organizational failure can be catastrophic. [13]

Based on his research into the Apollo Program, author Andrew Chaikin developed a one-day "Principles of Success in Spaceflight" class that is offered at NASA/JSC. The class examines the keys to success and causes of failure in spaceflight by focusing on human behavior and thinking. [14]

The book, *NASA Spaceflight: A History of Innovation*, edited by Roger D. Launius and Howard E. McCurdy, covers the history of innovation at NASA in terms of public-private and international partnerships. The twelve case studies included in this book were written by professional historians. The resulting insights are useful to policy makers, government officials, and personnel in commercial space companies. [15]

There are other topics that could be tackled by professional historians. For example, much has been written about Mission Control, most of it focusing on the Mercury, Gemini, and Apollo missions. Most of the books and documentaries are of a "war story" genre, recounting the missions and events that took place. What is missing is an academic study using the skills of the historian, sociologist, and psychologist to examine the Mission Control leadership and team culture, what was required to establish it, why it has succeeded, and how it has changed since the early 1960s. How did the Mission Control organization evolve to meet the requirements of the different flight programs (i.e., Mercury, Gemini, Apollo, Skylab, Apollo/Soyuz, Space Shuttle, International Space Station (ISS), Commercial Cargo and Crew, Orion)? How did lessons from those programs change how flight control was led and performed? How did the backgrounds of the early Mission Control flight directors (e.g., Kraft, Kranz, Lunney) equip them to create, train, and lead the Mission Control organization? What challenges did later flight directors of the Space Shuttle, ISS, Commercial Cargo and Crew, and Orion face and how did they respond to them? What people challenges (e.g., training, communication, work-life balance, team work) were encountered and how were they addressed? How have the values and skills of the Mission Control organization been preserved and passed on to successive generations of flight controllers over almost 60 years? What lessons are there for future high-reliability organizations?

Peer-reviewed books and articles written by professional historians may be used as secondary sources by an engineer writing a paper. A presentation or conference paper may be a more effective way to reach those engineers and managers that are unlikely to read one or more books on a topic. The conference paper, "Innovation Experiences from Vanguard, Explorer 1, Sidewinder, and NOTSNIK," examines four programs in the 1950s that faced significant challenges in engineering development. [16] The term "innovation experiences" in the title catches the attention of engineers working on applying advanced technology to future space

missions. The term "history" could have been used, but it is viewed by some engineers as backward looking and therefore not relevant to the present or future. Topics covered in the paper are of current interest to space flight engineers and managers and include the amount of discipline and rigor needed in a spacecraft development process. This topic is frequently debated at NASA and in commercial space companies.

C. Oral History Conducted by Professional Historians

Audio or video interviews may be the only practical way of capturing experiences and knowledge of busy technical personnel and program leaders who may not possess strong written communications skills. Oral history efforts tend to focus on interviewing people late in their careers or in retirement, years or decades after the events in question. These interviews are valuable, but memories fade, details are forgotten, and stories change over time. To better capture experiences, key personnel (including their early and mid-career) could be interviewed by historians soon after an important event or accomplishment, rather than waiting to interview them until after they have acquired legendary status.

Since the summer of 1997, 967 people (as of May of 2018) have been interviewed by the NASA/JSC Oral History Project. [17] Oral histories produced by professional historians are valuable for obtaining insight into management and cultural aspects of flight programs. This includes the rationale behind management-level decisions, factors for success, and lessons learned. Some engineers and managers are motivated to read oral history transcripts by their general interest in space flight. Transcripts are also read to learn more about a person, flight program, or space flight event that has been mentioned in technical discussions. Oral history can provide a clearer picture of who was working on what and who they worked for, and has provided useful background information on personnel and organizations whose technical work is of interest to engineers and managers.

D. Vehicle Engineering History for Flight Program Personnel

Works by professional historians are valuable for understanding the broader aspects of how space flight programs are created, the impact they have on the space industry and society as a whole, and lessons learned from success and failures. But these resources contain little specific technical detail and are not used by engineers and managers on a daily basis. One can learn some vehicle design and operation concepts from history written for adult space enthusiasts (such as the Springer-Praxis Space Exploration series of books), but these books are written for an audience that may require a simplified presentation of the information. Much detail is left out and official program documentation is more authoritative.

Documentation produced by NASA human flight programs is focused on defining what is to be done and how it is to be done (e.g., software and hardware

requirements, vehicle design, trajectories, crew and ground procedures). It also defines, in terms of basic functionality, how the hardware and software in the vehicle or ground systems is to be operated either by an astronaut or by an engineer. Much less coverage is given to why it is to be done that way, or to describing the process that led to vehicle and ground hardware and software design, crew and ground procedures, and trajectory design. Every internal document, internal presentation, conference paper, and journal article has a story behind it that does not exist in written form.

Flight programs do not usually create documents devoted to engineering history for a particular piece of hardware, software, or trajectory design. Engineers and managers who work in a program for a long time typically acquire an understanding of the rationale behind engineering decisions and the process over years or decades that led to the vehicle design and operations concepts. Some members of management are familiar with this information due to participation in management forums where decisions are made. Some of this information may be contained in memos, presentations, Mission Control console handbooks, and Mission Control flight rule documents. Over time, this tribal knowledge is passed from program veterans to newer personnel in an informal manner.

It is this knowledge that can be called vehicle engineering history. It is more focused and technical than most history written by professional historians. Vehicle engineering history communicates information and experiences to a specialized audience. It bridges the gap between space flight program and policy history written by professional historians and detailed technical reports and presentations written by engineers. Vehicle engineering history traces the development and use of a particular flight or ground system (hardware or software) or trajectory design over the life of the program. [18] The subject matter may span years or decades. It can trace the evolution of a particular technology or phase of flight within a flight program (such as from 1970 to 2011 for the Space Shuttle) or from flight program to flight program (such as from Apollo to Space Shuttle to Orion). Example topics of some vehicle engineering history publications include rendezvous and proximity operations, powered flight guidance, rocket engines, and navigation. [19-27]

Vehicle engineering history does not typically include the details of equations, data, and implementation. However, this information may be included if it helps tell the story. Individuals discussed in vehicle engineering history are typically lower in a corporate organization or government agency than key figures highlighted in histories written by professional historians.

Vehicle engineering history permits management and engineering personnel to quickly gain a high level understanding of a topic and equip them to make informed decisions in a timely manner. It answers the many questions that these personnel should be asking like the following: What challenges did they encounter that we have not thought of yet? Is there something from the past we can use to ensure

success and lower development risk? What new mission techniques and technology applications need to be developed? Have we properly identified and managed risk areas in the flight program? Where did that equation come from? What drove the adoption and implementation of a particular technology or mathematical algorithm?

Vehicle engineering history is written to fill a void in available documentation to preserve knowledge for less experienced engineers and managers, and to prevent corporate knowledge loss. [28-31] Due to cost and schedule constraints, vehicle engineering history is not normally a deliverable in a project, and it is highly unlikely that a flight program would hire a professional historian, writer, or knowledgeable engineer to research and write it. The subject matter expert may be teamed with a technical writer or another engineer who possesses writing and illustrating skills. It is usually developed informally and at a lower priority than other tasks. Budget, schedule, priorities, and a lack of subject matter experts with research and writing skills hinders the creation of vehicle engineering history. Most is written on personal time.

Source material for vehicle engineering history is collected from conversations and emails with other engineers and managers and from meeting minutes. Some technical documents, informal memos, and presentations may also contain some vehicle engineering history. It may also be collected and preserved as part of knowledge management activities, such as audio oral history, video of an interview or panel discussion, or during an effort to preserve documents. While this type of technical history is typically not written at the same level of quality as that written by professional historians, it does serve a purpose for a particular audience.

While it is usually internal to a flight program, vehicle engineering history may be written to exclude detail and avoid export control (more formally called International Traffic in Arms Regulations/Export Administration Regulations or ITAR/EAR) and proprietary concerns and is therefore publicly releasable while still remaining useful to engineers. Vehicle engineering history may be documented in publicly-available peer-reviewed journal articles or conference papers. A journal article or conference paper covering vehicle engineering history is typically broader in scope than the average journal article or conference paper that is narrowly focused on a particular technical topic. [32]

Vehicle engineering history is not covered in textbooks or professional development short courses, nor is it covered at the undergraduate or graduate levels at universities. Professors of engineering are usually not conversant in it unless they have worked on a spacecraft program in some capacity.

Where such history is available, it is beneficial for programs lasting long enough to employ multiple generations of engineers and managers that need to be trained on vehicle and ground systems design. Documents devoted to vehicle engineering history are particularly helpful to less experienced engineers that do

not have access to more experienced engineers. Vehicle engineering history does benefit future programs but those programs are usually not funded and underway when the history is written.

The *Apollo Experience Reports* documented the technical and management knowledge and experience of the Apollo Program. [33] The 121 reports have been valuable for quickly identifying challenges faced by Apollo, and to determine if those challenges and associated technical approaches are applicable to future development efforts.

An excellent example of a book length vehicle engineering history is *X-15: Extending the Frontiers of Flight* by Dennis Jenkins. [34] The book contains a significant amount of technical detail, woven into a story with the programmatic and historical aspects of the X-15 that make it a useful resource for personnel working on aeronautic and hypersonic flight programs. Books containing this level of history are not available for most flight programs.

Figure 1 is a vehicle engineering history timeline for the development of spacecraft rendezvous and proximity operations (final approach and docking) techniques. The two boxes with heavy lines represent topics covered by professional historians that touch on rendezvous. Vehicle engineering history goes beyond those high level topics such as program management and policy to cover why and how new technologies and new rendezvous and proximity operations trajectories were developed, or why some techniques from a previous program were adapted for a new one.

No flight program is a carbon copy of a previous program. Mission planning and operations best practices (e.g., coelliptic rendezvous, stable orbit rendezvous, inertial approaches, low energy approaches) from previous programs are often adapted to meet the requirements of new flight program, when appropriate. In some cases, as with the Space Shuttle, new final approach techniques had to be developed. New requirements, such as safety requirements for robotic vehicles, may drive development of new flight techniques. The technologies (e.g., propulsion systems, relative navigation sensors) and mathematics (i.e., software algorithms) used to implement either new or inherited flight techniques and best practices are typically new with each flight program. In the context of Figure 1, the goal of vehicle engineering history concerning rendezvous is to educate engineers and managers on why different engineering choices were made, why some rendezvous and proximity operations flight techniques were used by multiple flight programs, and why new flight techniques had to be developed.

Vehicle engineering history of rendezvous and proximity operations can be written to address the entire near 60-year time span across multiple flight programs (Gemini to Orion), or it could focus on just one flight program, such as the Space Shuttle in Figure 1. Senior engineers may be aware of most of the history depicted in the figure, including what happened in flight programs that they did not work on.

But less experienced engineers typically are familiar only with the programs they work on (i.e., one or two boxes in Figure 1).

Gemini/Apollo Era

Early Rendezvous Studies at Langley

Circa 1961

Lunar Orbit Rendezvous Decision

1962

Apollo Rendezvous Development

1962-1970

Gemini Rendezvous Development

•Coelliptic Rendezvous
•High Energy Inertial Approach

1961-1966

Skylab Rendezvous Development

Late 60s-1973

Apollo/Soyuz Rendezvous Development

1970-1975

Some Skylab Techniques

Space Shuttle, ISS, and Orion Eras

Policy Decisions That Led to a Reusable Winged Vehicle With a Large Payload Bay

1970-1972

Higher Thrust RCS Jets Than Apollo

1970-1972

RCS Plume Impingement Problem

1973-1975

Development of Low Energy Prox Ops

•V Bar approach.
•R Bar approach.

1976-1978

Early Shuttle Prox Ops Development

1979-1995

Development of Stable Orbit for Space Shuttle Rendezvous

1981-1983

Shuttle Prox Ops Development for Freedom

~1984-1993

Prox Ops Development for Shuttle to Mir & ISS

•ORBT.
•RPM.

1993-2005

Rendezvous & Prox Ops Development for Robotic Cargo Vehicles to ISS

•New safety requirements.
•Coelliptic rendezvous for some vehicles.

Late 90s, Early 00s

Rendezvous & Prox Ops Development for Orion to ISS

2006-2010

Rendezvous & Prox Ops Development for Commercial Cargo & Crew to ISS

2008 -

Orion Rendezvous & Prox Ops Development for Lunar Orbital Platform-Gateway

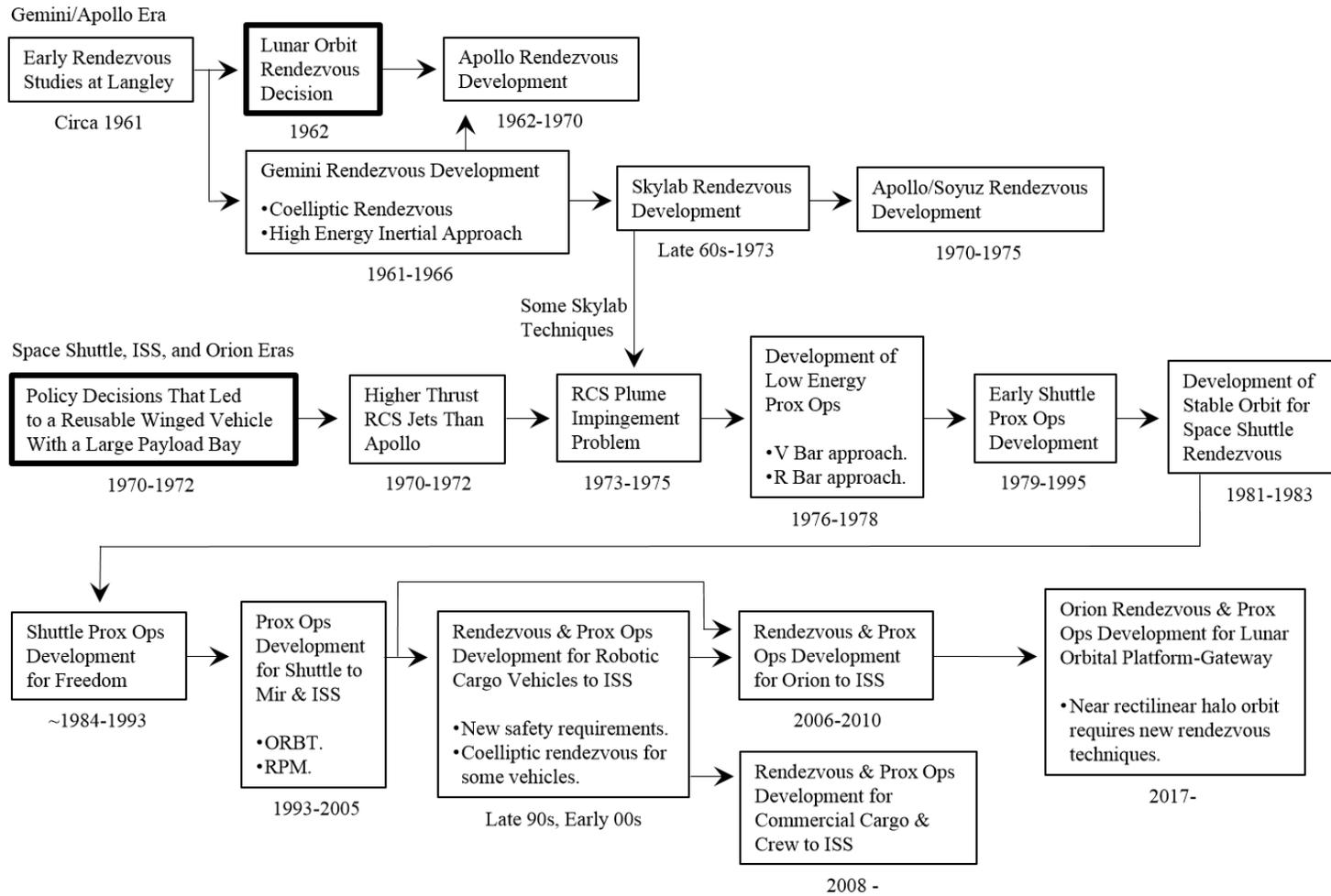•Near rectilinear halo orbit requires new rendezvous techniques.

2017-

Figure 1: Simplified Timeline Depicting Evolution Of Rendezvous And Proximity Operations (Final Approach) Techniques.

IV. Leveraging the Talents and Knowledge of Subject Matter Experts

Developments in information technology and social media have equipped and empowered people to preserve and share their stories. Effectively acquiring and preserving archival quality source material is more of a problem of selecting people with the right communication skills and experience than an information technology problem. The quality of the material depends on the communication skills and subject matter knowledge of the person using the software application rather than the technology in the application.

A. Identifying the Right People

It is important to identify engineers, scientists, and managers that have some communication skills, either oral or written, who also have the experiences worth documenting. Most managers have the ability to communicate at a conceptual level that engages non-specialists. However, many engineers communicate at a technical detail level and have difficulty adjusting their communication style to a non-technical audience.

NASA and contractor management can help identify key personnel who can be either interviewed or can create primary source material documenting their experiences. NASA Knowledge Management organizations may be able to identify engineering, scientific, and management personnel with good communications skills based on their participation in lessons learned efforts. [35-38] Professional engineering and scientific organizations could also help identify such personnel. Individuals that supply source material should not be limited to those typically interviewed by professional historians for oral history (e.g., senior NASA management, astronauts, and Mission Control personnel). Engineering, scientific, and contractor management personnel also have stories and experiences that are of interest.

Some engineers may be better equipped to assist historians and archivists. Identifying these specific engineers can be aided by examining past performance. Engineers with writing, speaking, archival research, leadership, and STEM outreach experience may have good oral, written, or illustrative communication skills. An engineer that can create a narrative out of their experiences can assist historians in researching a topic and for preparing historians to conduct oral history sessions. The ability to switch from detailed engineering level thinking to conceptual thinking is a rare but important skill. Some members of upper level management may be capable of this.

Most engineers have a knowledge of past programs such as Gemini, Apollo, and the Space Shuttle. Others have more detailed knowledge based on reading space history books and talking to program veterans. The reading habits of an

engineer can be an important clue to the level of knowledge they have, and how much they know of the work of historians. In terms of detailed historical knowledge, the knowledge of most engineers starts when they began employment and is limited to the projects they worked on. Engineers who are of use to historians and archivists are those who are interested in historical inquiry and develop a knowledge of the programs they participate in that extends beyond their period of employment and beyond the projects they worked on. Some engineers maintain relationships with retired engineers and managers. These relationships can be important for making contacts and obtaining primary source material. Engineers who value the work of historians and have some experience in writing are more likely to willingly accept advice and editorial comments from historians, archivists, technical writers, and editors.

B. Team Building with Flight Program Personnel

It is useful for archivists and historians to build relationships with engineering and management personnel in a flight program. Many engineers enjoy opportunities to talk about their work with people outside the flight program. Exhibiting good listening skills is a way for archivists and historians to build relationships with engineers and managers, even if it means listening to more technical detail than is desired.

Many archivists and historians have interesting and informative space and aviation stories from their work and research experience, and many are good story tellers. Engineers enjoy hearing space mission stories. What insights have archivists and historians gained into how technical, business, policy, or political challenges were overcome? Sharing stories and insights that might be of interest or of use in their work can help establish a working relationship.

Some flight program personnel are frustrated with the way space flight is simplified to communicate with the general public or a non-engineering academic audience. They may have unrealistic expectations about the topics and levels of technical detail that historians include in publications. Historians and archivists can talk about the objectives and challenges of archiving and historical research, how they perform their work, and what levels of detail are required to communicate with various audiences.

Initially, some engineering and management personnel may not know how they could be of help to archivists and historians. Provide examples of how flight program personnel have been of assistance in the past.

C. Equipping Subject Matter Experts to Preserve Their Experiences

Motivated subject matter experts that are willing to spend personal time on a project can be of assistance where budget considerations limit what professional historians and archivists can accomplish. Some subject matter experts possess the

communication skills to tell their own stories or conduct interviews while others do not. Professional historians can provide guidelines on what topics are of interest to them and how to organize thoughts and experiences into a narrative that could be communicated in writing, in audio, or on video. They can take a consulting role as they assist the subject matter experts in creating higher-quality documentation or media. Advice from historians, archivists, and media professionals on the technical aspects of audio and video production would also be helpful.

Program participants may focus on engineering developments while appearing to ignore the people responsible for those developments. Many engineers feel it is more important to cover technical aspects of flight programs that have not been documented by historians. Asking participants questions about the people involved will bring out stories and insights that they have not mentioned or written about before. Some engineers and managers are enthusiastic about discussing the roles of key engineering and management personnel whose achievements they believe have been overlooked by historians and the news media.

The information technology revolution has facilitated a growth in self-publishing. People who are not professional authors are now able to record and publish their own stories without the help of a major publishing house. However, not all non-professional authors produce well-researched and well-written memoirs. The quality of self-published books, blogs, and essays can be enhanced through the use of an editor, even if that editor is an English teacher at a local school. Fact checking is also needed.

It is important that subject matter experts have a positive attitude about working with people possessing liberal arts degrees. They must recognize that an editor does not have to understand the engineering or science in order to improve the quality of written, verbal, and illustrated communication. Unfortunately, some consider an "editor" to be merely some who can manipulate a word processor to fix formatting problems in a document. A real editor has university-level training and the professional experience to enhance communication and not simply resolve document format issues. Higher quality material will be produced by subject matter experts that are willing to perform library and archival research and understand that an internet search engine is not a substitute for a professional archivist.

D. Do-It-Yourself Written Preservation of Experiences

Some engineers and managers want to preserve their own experiences in writing either late in their careers or after they have retired. These works record events from the perspective of participants but are not professional studies of space history. [39-41] Their motivations vary. Some are not happy with how professional historians or journalists have written about things they worked on. Others may feel that contributions they made to space flight have been ignored. Still others simply wish to pass on their experiences to family members. These writers possess varying

levels of communications skills. Inaccurate memories and lack of access to primary source material makes it difficult to reconstruct events and tell a story decades later. Some late-career or retired personnel regret not having preserved their experiences when the events of interest occurred and they had access to primary source material. Recording personal life experiences is not something most people think of when they are young.

Some engineers and managers attempt to document their experiences and important projects they worked on through professional conference papers or peer reviewed journal articles. Peer reviewed articles are generally more informative and better written than articles that have not been peer reviewed. Most conference papers are not peer reviewed and sometimes the treatment of a historical topic is too general and repeats commonly known information. Presenting a paper at a conference can be a challenge due to a lack of travel budgeting. Most journal articles and conference papers tend to focus on technical topics, but do not detail the story behind the topic that may be of interest to historians. An exception is the historically focused papers in the History of Key Technologies series that occasionally appears in the AIAA Journals.

Engineers and managers with good communications skills can produce high-quality writings to preserve their experiences. One example of this is Dr. George Ludwig's book *Opening Space Research*, concerning his work on a team led by Dr. James Van Allen to develop scientific payloads for the early Explorer satellites. [42] Another example is the blogs of former Space Shuttle Program Manager and Mission Control Flight Director Wayne Hale. [43] [44]

Subject matter experts can collaborate to produce high-quality publications with historical value with assistance from professional historians, editors, and illustrators. The book, *Wings in Orbit, Scientific and Engineering Legacies of the Space Shuttle* was written in the final years of the Space Shuttle Program by NASA engineers, scientists, managers, and astronauts. [45] A similar book concerning the ISS is *The International Space Station – Operating an Outpost in the New Frontier*. [46]

Memoirs written by flight program participants with the help of a professional writer can provide insight into management and technical challenges, rationale for decision making, and factors for program success or failure. Books researched and written by professional historians and sociologists over a long period of time are often more informative and comprehensive on these topics. This is due to university training and professional experience in performing archival research, interviewing, and conducting written historical analysis.

E. Near Real-Time Documenting of an Event

If an engineer or manager has good communication skills, they can document a space event for posterity soon after the event occurs. The author wrote a 28-page

chapter for the book *History of Space Shuttle Rendezvous* to provide a description of a Space Shuttle rendezvous with the ISS. [19] The chapter documents the rendezvous aspects of STS-130 flown in February of 2010. The author worked the rendezvous and separation phases of the mission in the Spacecraft Analysis (SPAN) room above Mission Control. The chapter was written for an engineering audience but at a level that would permit the book to be approved for public release.

For this project, writing concerning pre-mission planning and mission objectives began even before launch. Much primary source material on many topics was readily available during the mission. This included the author's interactions with the Mission Control team, issues that arose and how they were resolved, crew activities, and other mission events of interest. Much of the chapter was written in draft form in the days between docking and separation. After the mission returned to Earth, the chapter was finished and put out for review by Mission Control personnel. The mission commander answered questions about the flight. The chapter was finished within a month of the end of the mission. It would be impossible to write the chapter at this level of detail years after the event.

F. Do-It-Yourself Interviews

Technically oriented audio or video interviews for an engineering audience can be performed to document important topics, such as the rationale for the selection of a particular technology for a spacecraft, the description of an important program event such as a critical design review, or research and development for new projects. Professional historians can act as consultants and mentor subject matter experts that have an aptitude for inquiry to perform technically oriented interviews. Engineers may perform Do-It-Yourself interviews with experienced engineers and managers to investigate engineering topics that are typically not covered in oral histories produced by professional historians. These sessions are usually not recorded as some interviewees are uncomfortable being recorded. Interviews can be used to add context to technical documentation. Questions can be answered, such as "why was the document written," "what was the organizational and political situation surrounding it," and "what action was taken based on the work detailed in the document?" Answers to these questions can help engineers understand technical decisions and engineering solution approaches.

V. The Archiving Challenge

In a flight program, some documentation is preserved in on-site or off-site formal libraries and archives. These facilities have dedicated staff and budgets. Other documentation is preserved on a less formal basis by smaller organizations or individuals. Passing key documents from veteran program personnel to newer personnel is an important aspect of preservation. Electronic storage has increased the survivability of documentation, but file format obsolescence and long-term custodianship of informal electronic repositories is a challenge.

A. Archiving in the Pre-Online Era at the NASA Johnson Space Center (NASA/JSC)

From Project Mercury through much of the Space Shuttle Program, paper documentation and other media was stored in formal or informal libraries and archives. NASA/JSC has a formal library and archive, called the Scientific and Technical Information Center (STI Center).[2] Documentation in the STI Center tends to be only that deemed important and needed by multiple organizations at JSC. Documentation created by contractors and defined as deliverables to NASA under a contract are also stored in the STI Center. Contents of the STI Center are maintained by a dedicated staff.

During the Apollo and early Space Shuttle eras, NASA/JSC was organized by directorates, divisions, branches, and sections.[3] The directorate was the broadest umbrella organization, the section was the smallest. Much directorate and division level documentation has survived in the STI Center and at the National Archives and Records Administration (NARA). Less of the branch and section level documentation has been preserved in the STI Center or at NARA.

Smaller organizations at the branch and section level at NASA/JSC maintained less formal archives in filing cabinets and in binders on bookshelves. These less formal archives contained informal memos and other documentation deemed relevant only to that specific organization. Each branch and section typically had a numbering system for identifying informal memos. Some of these branch and section level collections were well organized with indexes that made it easy for personnel to locate items of interest.

Many of the less formal organizational archives containing Gemini, Apollo, and early Space Shuttle documentation had disappeared by the year 2000 since there

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[2] Although the JSC STI Center is now more of an archive than a library, it is informally referred to by many personnel as the JSC Library.

[3] The NASA Manned Spacecraft Center in Houston was renamed the Lyndon B. Johnson Space Center (JSC) in 1973. Circa 1994, sections were eliminated and the smallest organization at JSC is now the branch.

was often a need for office floor space consolidation. Some of these archives were considered to present a fire hazard. In some organizations, personnel who took care of the archives, were knowledgeable about them, and appreciated their contents, retired or moved to other jobs. There was no longer anyone present to champion the need for the documentation or explain why the informal archives were of value. These factors resulted in content being recycled, sent to an off-site archive, or distributed among engineers in the organization.

Much important and informative documentation was not in the STI Center or in less formal organizational archives but was preserved by individuals on an ad hoc basis in desks, filing cabinets, and computer hard drives. Important documentation can be lost during government agency and corporate reorganizations and contract transitions. However, personnel tend to retain the documentation that was most important to them and pass it on to other interested personnel.

Some branch and section level informal memos that disappeared with the informal archives were preserved by retired engineers along with their working papers. Retired personnel have been an important source of informal memos that were not preserved in the STI Center or at NARA. It was easier for retirees to preserve such material since there is no cost involved, nor were there floor space or safety concerns associated with such preservation.

Some of this documentation has been sent to NARA as part of the formal NASA records management process. Engineers may have difficulty determining what paper documentation was sent to an off-site archive. While accession numbers can be located for archived documentation, the accompanying descriptions are often vague or too general to be of much use. Documentation often arrives at off-site archives with little or no information that would enable professional archivists to index it, catalog it, and assign keywords and other information (e.g., abstracts). This could force engineers to retrieve large amounts of documentation that requires time-consuming examination to find relevant documents. While on-site records management personnel and off-site archivists are helpful, they are not subject matter experts and they depend on the organizations donating the documentation to provide informative descriptions, key words, and organizational and historical context.

The cost of retrieving documentation from off-site archives can deter personnel from attempting to use archived resources. It may be more effective for personnel to visit an off-site archive to perform research, even if it is done on personal time. At the end of the Space Shuttle Program, a large amount of documentation destined for NARA was electronically scanned by JSC personnel. [47] This permits personnel to access the material electronically without having to visit the off-site archive or attempt to request a costly retrieval of hardcopies. In addition, the

NASA/JSC Knowledge Management organization created an electronic repository called the Shuttle Knowledge Console.

There is a misconception that formal records management processes focus on documents of legal and contractual importance as opposed to technical documentation. This can deter engineers from taking advantage of the records management process.

During the Constellation Program, NASA/JSC trajectory personnel attempted to locate magnetic tapes that contained trajectory data from the Apollo lunar missions. NASA management had protected the tapes for some years after Apollo, but they were eventually asked to give up the tapes to permit reuse and save money. By the start of the Constellation Program (circa 2007), the tapes and data had long since disappeared. This led Mission Control Flight Dynamics Officer Dan Adamo to reconstruct the Apollo 13 trajectory using tabular data that had survived in paper documentation in the STI Center. [48]

B. The Challenges of Electronic Preservation of Documents and Other Media

At NASA/JSC it has been observed that fewer informal memos and presentations prepared at JSC from approximately 1983 to 1993 have survived than from before 1983. This is believed to be due to the use at this time of floppy discs and desktop computers for electronic storage. By 1993 desktop computers were networked to external network hard drives, increasing the probability of preservation.

The STI Center maintains both hardcopy and electronic documents, but electronic is preferred. Microfiche readers have disappeared due to the transition to digital storage. These records can be scanned to create viewable electronic versions, but the readability of the electronic versions vary greatly. There is a cost associated with scanning microfiche, and this cost and the process to obtain budget approval can deter engineers from attempting to access documentation on microfiche.

In the internet age engineers tend to use search engines for locating documents, rather than taking advantage of the knowledge and experience of library staff. Librarians and archivists can often locate documentation faster than engineers, particularly documentation that may not be reachable through an internet search engine.

Before electronic distribution and storage of documents, paper documents were often printed by a print shop and then distributed to a list of personnel and organizations, including a formal library and archive. While organizations have transitioned to electronic document distribution and storage, formal libraries and archives are not necessarily on the distribution lists. This will limit the holdings of formal libraries and archives and decrease the likelihood of document preservation over the long term.

NASA and commercial companies have moved to electronic storage of documentation. This has eliminated the loss of older documents and reduction of informal paper libraries to gain floor space and reduce fire hazards. However, the long-term survivability of electronic documents and other electronic media, with the inevitable changes in computer hardware, application software, and operating systems, is in question. Informal electronic organizational archives need to have custodians to ensure preservation when organizational, computer software, and computer platform changes occur. Custodians need to have a close relationship with information technology specialists to ensure that future flight program personnel will continue to have access to the documentation. There is a need for software that permits inexpensive conversion of obsolete file formats to more modern and survivable formats. Conversion software needs to stay current and survive technological changes in the computer industry. Expensive licenses for conversion software could preclude the use of such software by organizations with a tight budget. To ensure survival of information, some engineers prefer to create electronic documentation in a format that will permit it to be useful if it only survives as a hardcopy. An example of this is a formal report stored as a PDF file.

There is a belief among many engineers and managers that once an electronic document is placed in a folder on a server that it has been "archived" and that personnel in the future will have the same ease of access to it as current personnel. Due to changes in computer systems, software, and organizations that occur over decades, this is not always the case. Mission Control personnel working on the ISS cannot locate some memos and documents referenced in their Mission Control console handbooks. This missing material was created in the 1990s in electronic form. It may be permanently lost or has survived in another location in a computer network or as a hardcopy in a desk, filing cabinet, or loose leaf binder.

Electronic contents of the STI Center are preserved by a dedicated staff. However, only documentation that is deemed important to multiple organizations in a flight program is placed in the STI Center. Furthermore, a process of multiple reviews is required for management approval and to ensure proper marking of the material (sensitive but unclassified, export controlled, etc.). This process can take anywhere from a week to months to complete.

The preservation of electronic archives at the division and branch level is left to each division and branch. The survivability of these secondary archives over decades with the inevitable changes in computer system hardware and software will depend on the level of attention the archives receive from division and branch staff. To ensure preservation of informal archives at the division and branch level, a NASA center wide electronic repository of less formal division and branch level documentation could be created. Dedicated staff, a sufficient budget, and center level policy would ensure the preservation of the contents of this repository. This electronic archive should not have the same submission criteria (e.g., level of

importance, relevant to multiple organizations) and admission process as the STI Center. Submission criteria would be the same as for informal memos currently determined by division and branch level management. It is important to preserve the informal nature of the submission process so that informal memos can be written and distributed quickly in response to project needs. This approach could ensure that the secondary archives of informal memos at the division and branch level are as survivable over time as the more formal contents of the STI Center.

With the increase of knowledge management activities, multiple entities across NASA centers are preserving documentation, particularly on internal websites. Some thought could be given to how these efforts could be consolidated to ensure preservation. Electronic preservation is not just a problem to be solved by the organizational information technology department. The skills, insight, and experience of professional archivists are needed.

C. Why Some Engineers Don't Use Archives and Libraries

The internet age has brought about a reduction in the use of libraries and archives by engineers. Some younger engineers think they can find everything they need quickly with a search engine. They rely on social networking within a flight program to find internal memos and documents. Some flight program personnel are not aware of the collections within corporate and government agency archives and libraries. They may be unaware of what collections archivists have access to and that archivists can save time when searching for documents. Archivists and librarians have a considerable amount of research knowledge that can be beneficial to an engineer. Such advice cannot be obtained by searching the internet.

Many engineers spent time at the JSC STI Center to conduct research and read books and journal articles. This provided opportunities for flight program personnel to get to know the STI Center staff and learn about how the library could be of use. The transition of JSC STI Center from housing hardcopy books and journals to facilitating access to online subscription content has removed the motivation to visit the STI Center. As a result many engineers do not think of using the STI Center when performing research.

Engineers who have used the services of a library or archive to solve a problem, or whose research succeeded, thanks to advice from an archivist or librarian, tend to use libraries and archives. The best advertising for archives and libraries are success stories shared by flight program personnel.

D. Primary Source Material with Context Saves Time

Primary source material is more useful to a researcher if it has context and it saves researchers valuable time. Detailed archival finding aids present in formal archives run by professional archivists are not usually available for internal documentation within a flight program. Important context, such as background and

career information on authors, why the memo was written, what action was taken based on the memo, and where the memo fits into the larger picture of the flight program, is usually not available to flight program personnel. This lack of context makes it more difficult for flight program personnel to use internal documentation when researching technical topics. Donors and creators of primary source material need to do better job of supplying context.

Figure 2 is an illustration of primary source material on Space Shuttle orbital rendezvous created in the 1970s. The illustration enables an engineer to understand how each document was related to other documents and what activities during Space Shuttle development drove the creation of each document. Flowcharts and timelines can be used to illustrate how primary source documents fit into the larger picture of the history of a flight program. Such documentation can also be an important source of mathematical algorithms that can save development time in other flight programs.

FEB '72 — RENDEZVOUS TARGETING SPACE SHUTTLE GN&C EQUATION DOCUMENT NO. 7 (REV. 2)

JULY '73 — RENDEZVOUS TARGETING SPACE SHUTTLE GN&C EQUATION DOCUMENT NO. 7 (REV. 3)

JAN '75 — ORBITAL MANEUVER PROCESSOR (OMP) JSC-09339

SOFTWARE FOR ABSOLUTE AND RELATIVE NAV PHASE BURNS NC-NH-NSR1-NCC-NSR2-TPI-TPM

JULY '75 — ORBITAL MANEUVER PROCESSOR (OMP) JSC-09339, REVISION 1

SOFTWARE FOR RELATIVE NAV PHASE BURNS NCC-NSR-TPI-TPM CORE = 1.00

SCRUB

JULY '76 — RENDEZVOUS TARGETING SPECIALIST FUNCTION JSC-11446

APRIL '77 — RENDEZVOUS TARGETING SPECIALIST FUNCTION JSC-11446, REVISION 1

MARCH '78 — FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS, GUDIANCE, ONORBIT I, SD 76-SH-0003A

SECTION 4.7 RENDEZVOUS TARGETING SPECIALIST FUNCTION SCRUBBED

SOFTWARE FOR RELATIVE NAV PHASE BURNS NCC-NCC-TPI-TPM PLUS PROXIMITY OPERATIONS CORE = 0.85

TASKS FROM RENDEZVOUS TARGETING SPECIALIST FUNCTION
• STATE VECTOR UPDATE
• PRECISION VELOCITY REQUIRED
• ELEVATION ANGLE SEARCH

NEW TASKS
• LAMBERT
• ORTHOGONAL BRAKING

COMBINE

ORBIT TARGETING SPECIALIST FUNCTION JSC-14393 — AUG '78

NEW SECTION 4.7 ORBIT TARGETING SPECIALIST FUNCTION CHANGE REQUEST 12813A — AUG '78

COMBINE

FUNCTIONAL SUBSYSTEM SOFTWARE REQUIREMENTS, GUDIANCE, ONORBIT I, SD 76-SH-0003A PAGE CHANGE 3 — DEC '78

JAN '77 — PROXIMITY OPERATIONS SIMULATIONS & TARGETING STUDIES

AUG '77 — PROXIMITY OPERATIONS SOFTWARE PRELIMINARY REQUIREMENTS JSC-13027

MAY '78 — PROXIMITY OPERATIONS SPECIALIST FUNCTION JSC-13993

SOFTWARE FOR PROXIMITY OPERATIONS CORE = 0.4
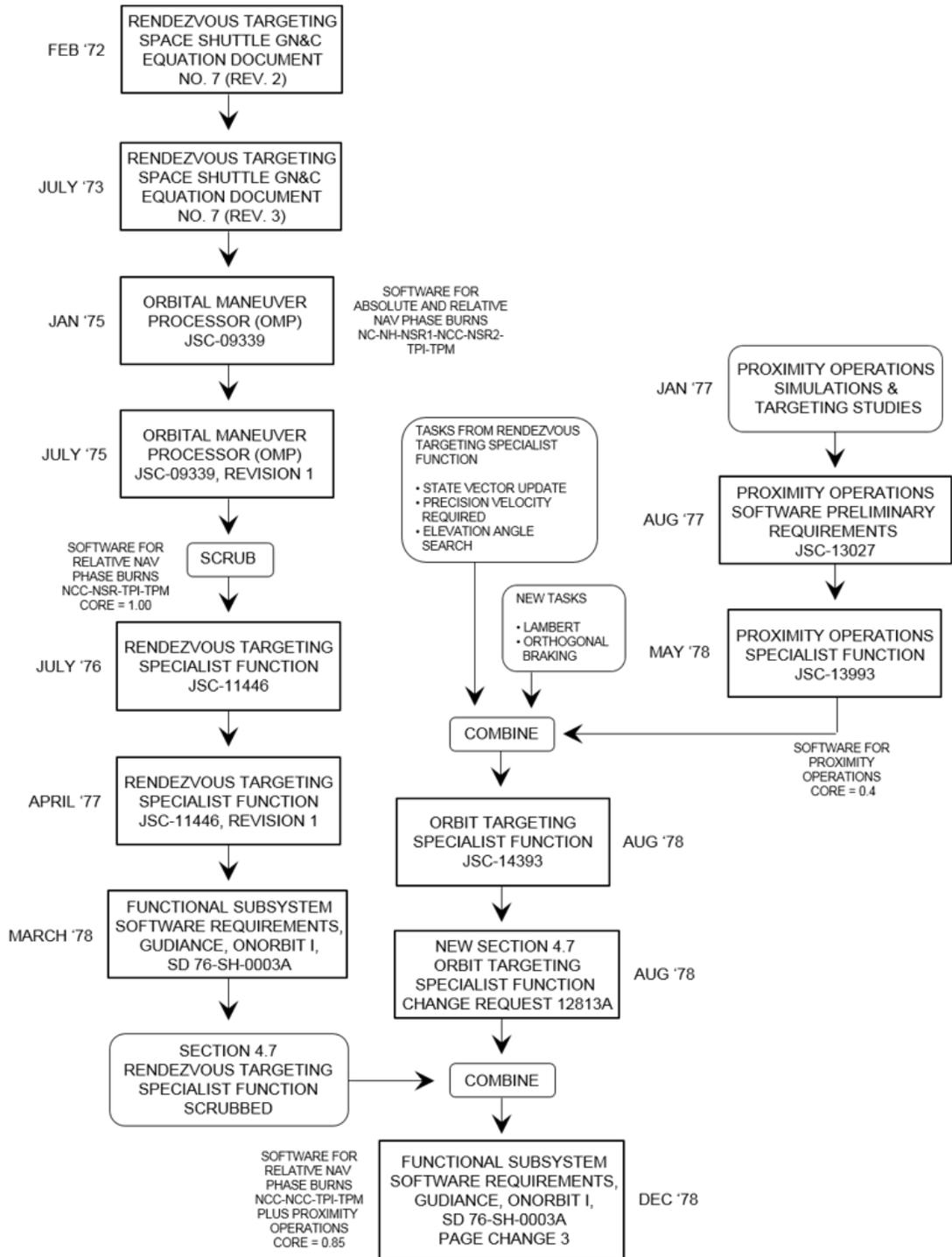
Figure 2: Primary Source Material Timeline

E. Example of Do-It-Yourself Archiving

Near the end of the Space Shuttle Program, the author compiled 21 volumes of vehicle engineering history to preserve selected primary source material in an organized fashion. The total page count was 21,480. Each volume contains introductory material to provide context to the primary sources preserved in the compilation. The compiled volumes were scanned to Portable Document Format (PDF) and bookmarked to provide on-demand mouse click access that facilitates efficient and timely learning experiences for engineers. With the addition of these volumes to the STI Center, key memos, reports, and presentations were preserved that might have otherwise ended up in the recycling bin. [36] Much of the content was not originally stored in the STI Center but was preserved by retired personnel.

F. What Documentation Should Be Preserved for Historians and Archivists?

Space flight programs generate large amounts of documentation and data. This documentation is now primarily digital in nature and takes many different media formats. Preserving the vast array of documentation would require time, funding, and adherence to many legal policies. While preservation does protect against corporate knowledge loss and benefits safety of flight and mission success, preservation efforts also can be perceived as having a negative impact on cost and schedule.

More effective preservation could be facilitated if historians and archivists can identify what kinds of communications are the most useful. For example, historians frequently research decisions made by government and corporate leaders. Documents and communications detailing decision making by upper level management could be a focus of preservation efforts. However, in the corporate world, rationale concerning decision making by upper level management may be considered competition sensitive for decades.

There may also be large amounts of documentation that are of less importance to archivists and historians, but are important to engineers. One example could be simulation studies using various types of numerical algorithms as part of the vehicle and mission design process.

Government and corporate leaders would have to be convinced of the value of preservation. Preservation should fit with the overall organizational strategy for document and knowledge preservation within a flight program. Document capture needs to be conducted on a non-interference basis with respect to the working level employees and their immediate management to avoid the perception that it adds to employee workload, cost, and schedule. It is unrealistic to expect flight programs to capture and preserve everything since electronic storage comes with a cost, just like storage of paper documentation.

VI. Commercial Space and Other Archiving Challenges in the 21st Century

Legacy NASA programs (such as Apollo and the Space Shuttle) provided historians and archivists with access to flight program personnel and primary source materials, mostly in paper format. The increasing commercialization of space, while desirable, threatens to restrict access to these personnel and primary source materials, and therefore limit the insight historians can achieve.

Management and engineering personnel in flight programs, whether traditional NASA programs or commercial programs, are not usually concerned with the challenges faced by archivists and historians. There are many restrictions in flight programs, both government and commercial, that represent challenges for archivists and historians. These include export control regulations, proprietary data, competition sensitive data, contractor rights-in-data, and choosing to communicate or preserve information in a manner that would prevent it from be released in response to a Freedom of Information Act (FOIA) request.

The emphasis on building organizations that are lean, agile, and disruptive, coupled with high workloads of employees and management, makes government organizations and commercial companies less interested in helping archivists and historians with the challenges they face.

Corporations focus on improving the bottom line and maintaining a competitive edge. They may not be interested in supporting archival and historical activities that do not serve a marketing purpose and are perceived to represent a threat to the security of corporate information.

Many people think that space history and archiving is only about the past. Flight program personnel appreciate and value aviation and space museums, space history retrospectives on television, movies, books, and websites about space history. However, they may not appreciate the value of space history for informing the leadership of current and future flight programs, and may perceive space history as not having applicability to their current or future work. Space history is not just about the past, it is of value for the present and the future.

A. Commercial Space

The push to adopt a Silicon Valley approach to spacecraft development with an emphasis on disruption, lean teams, and agility has led to significant cost cutting, decreased development and mission preparation times, and a reduction in the amount of documentation that a flight program creates. While legacy flight programs generated documentation that was useful to historians later, a prevailing current view is that documentation is an overhead cost and should be minimized as much as possible. What impact this could have on the availability of primary source

material for space history remains to be seen. In some flight programs it could have a negative impact on ensuring mission success or even flight safety.

Private companies working on commercial space projects have broader definitions for what constitutes proprietary and competition sensitive information than traditional NASA flight programs. Nondisclosure agreements will make it harder for historians to record for posterity the experiences of management and engineering personnel working in commercial space. Commercial space companies may publish conference papers that contain some history or hire a professional to write a corporate history as part of their marketing efforts. Such works can serve a corporate marketing purpose but may not tell the whole story.

Commercial space experiences and accomplishments can be discussed at a high enough level to avoid proprietary and competition sensitive concerns. However, the emphasis on protecting engineering information and business strategies through non-disclosure agreements discourages personnel from discussing anything. Employees of commercial space companies present fewer papers at conferences than employees working in traditional NASA flight programs.

B. International Traffic in Arms Regulations / Export Administration Regulations (ITAR/EAR)

When considering ITAR/EAR and proprietary data restrictions, it is important to identify the audience and message for the type of history or media in question. Most space history can be written in a manner that avoids issues with ITAR/EAR or proprietary data.

U.S. citizens can legally access and read documents that are marked "export controlled." However, authors are often told during the document review process not to include references to export-controlled documents in a paper or document intended for release to the public. This is to prevent people from filing FOIA requests for export-controlled and other documentation internal to a flight program. This can prevent U.S. citizens in other space flight programs, commercial or government funded, from discovering and accessing government documentation that may be of importance to the project they are working on.

C. Proprietary Data and Rights-in-Data

Many technical libraries, including some NASA center libraries and archives, will not accept documentation marked proprietary. If the originating company or legal follow-on (after a merger or buy-out) company does not exist years later, a process will not be available to request access to the document. This is an issue in government contracting where companies may go out of business or lose their contract at any point.

Rights-in-data in a government contract is governed by Federal Acquisition Regulation Clause 52.227, Rights-in-Data. On some contracts, the contractor may

have rights-in-data, rather than the government. A contractor with rights-in-data is not required to place the documentation it produces under the contract in a government technical library and archive. However, the contractor must, rights-in-data notwithstanding, provide form, fit, and function data. If there is contract-related documentation protected by the rights-in-data clause and that documentation is mistakenly placed in a government technical library, the contractor can have that documentation removed from the library by contacting the government contracting officer. Government contractors exercising rights-in-data may further limit the documentation that historians and archivists have access to.

D. Obtaining Support in the Face of These Challenges

Legal issues and processes such as export control, proprietary and competition sensitive data, non-disclosure agreements, and rights-in-data do not take into account the interests of and challenges faced by historians and archivists. Preserving documents and media of historical importance in the 21st century requires the cooperation and assistance of government and corporate leaders that have insight into and control over such processes.

In January of 2018, Thomas Zurbuchen, NASA Associate Administrator of the Science Mission Directorate, made the following comment about the efforts to reduce the time and cost required to develop and fly spacecraft.

> "What we're trying to do is really do the right practices without the administrative overhead and certification and the 'waterproofing' that is required for a complex mission." [49]

Historians can respond to comments like this with demonstrations of the use of historical research and analysis for helping leaders make informed decisions. Industries, corporations, government agencies, and laboratories have faced these same challenges in the past. What can be learned from successful and unsuccessful efforts to address similar challenges? Efforts can be made to reach key decision makers with historical thinking that can equip them to better face the challenges of today and tomorrow.

Key decision makers who see value in applying the observations and lessons of history to current and future programs and policies may be more sympathetic to the challenges facing historians and archivists, and more inclined to be of assistance. Sympathetic leaders could exert influence on information control processes so that reasonable and legally-acceptable judgments are made, as opposed to overly-conservative judgments. NASA managers in traditional NASA programs may be in a better position to assist archivists and historians than corporate leaders who are in a highly-competitive business environment.

One example of a key decision maker overcoming bureaucracy to preserve primary source material occurred in the late 1970s at the Defense Intelligence

Agency (DIA). The DIA had inherited from the U.S. Armed Services a large amount of German intelligence. These were first generation contact prints from photographic negatives taken over the Soviet Union before and during World War II. The General Services Administration asked the DIA to lower costs by throwing out the prints. A DIA employee believed the collection of prints was of historic value and should be preserved. His manager, a former naval officer and National Photographic Interpretation Center analyst, agreed and used his management position and bureaucratic skills to have the collection preserved and transferred to the National Archives and Records Administration. [50]

Professional historians and archivists have skills that can be applied to the knowledge management problem faced by many government and commercial organizations. [29] [35] This kind of assistance with a flight program could make leaders more aware of the talents and importance of historians and archivists and raise awareness of the challenges they face.

For example, a historian could act as a mentor to train an engineer to conduct technically oriented interviews intended for an engineering audience. Current and future flight programs would benefit from knowledge capture efforts similar to the Apollo Experience Reports. [33] These reports documented the engineering approaches and experiences of the Apollo missions to the Moon. The quality of such efforts would be improved with input from professional historians and archivists.

Historical reports that tell stories can be created at end of flight programs, along with the lists of lessons learned. Lessons learned and identification of best practices requires stories to effectively catch the attention of the audience and get the message across. A list of lessons learned and best practices does not communicate as effectively as a stories that are created out of historical research.

VII. Final Thoughts

Professional historians can identify leadership, policy, technical, and organization cultural factors that contributed to the successes or failures of space flight programs. This information assists spaceflight program personnel in the successful execution of current and future flight programs. It is important to demonstrate the value of historical and archival skills to a flight program to gain allies among key decision makers who possess budget authority. A positive view of historical efforts can be cultivated through several activities. Key decision makers could be introduced to historical works that detail program management topics such as leadership, policy, legislative affairs, business strategies, commercial and government partnerships, innovative cultures, and the organizational and cultural problems that led to spacecraft mishaps. Leaders in government and industry that value the insight of space historians can be of assistance when dealing with complex issues and processes that restrict access to flight program personnel and primary source material.

Professional historians and archivists can use their research experience and communication skills to help government and commercial organizations address knowledge management issues. They can mentor and train subject matter experts to perform technically oriented interviews or to research and write vehicle engineering history. Spaceflight program personnel could also be encouraged and equipped by historians and archivists to preserve and share their experiences using a variety of media, if it is legally permissible to do so. Professional engineering organizations can assist budget constrained professional historians and archivists by organizing the efforts of flight program personnel working on personal time. Key personnel could be interviewed for oral history soon after an important event when memories are fresh, rather than waiting until they are in late career or retirement.

Electronic storage has increased the survivability of documentation, but file format obsolescence and long-term custodianship of informal electronic archives are challenges to overcome. A problem that needs to be addressed concerns the survival of numerous informal hardcopy and electronic repositories that exist throughout a flight program. Decades of organizational and computer network changes threaten the survival of these repositories. Old online databases and repositories can become lost and non-functional over time. Reliable access to primary source material benefits not just professional historians, but it is an important mission assurance (or flight safety) function that can prevent corporate knowledge loss. The electronic archival preservation problem is not just an issue for the organizational information technology department; professional archivists have skills and experience that can be applied to it as well.

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