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Chapter 26

"Houston, We Have a Problem"[1]: A History of Air-to-Ground Voice Transmissions from the U.S. Manned Space Program*

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Abstract

The U.S. manned civil space program unfolded before the public through a vast array of sights and sounds. Beginning with Alan Shepard's first flight into space and continuing through the early Space Shuttle program, nearly every word spoken between spacecraft and space center was recorded, transcribed, and published for the world to see. This article presents a history of these voice transmissions, their resulting mission transcripts, and what is being done to help preserve these valuable resources and make them more accessible to the public.

Introduction

From the beginning, nearly every aspect of the U.S. manned space program has been an open book. From President John F. Kennedy's bold announcement before Congress in which he committed this nation "to achieving the goal before this decade is out, of landing a man on the moon."[2] and astronaut Neil Arm-

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strong's triumphant words "That's one small step for [a] man, one giant leap for mankind,"[3] to the haunting last words "uh oh" as heard from the ill-fated *Challenger* crew moments before it exploded, the triumphs and tragedies of NASA's manned programs have unfolded before the public through a vast array of sights and sounds. Essentially every word uttered between Earth and astronaut was recorded, transcribed, and published for the world to see—all in real time—resulting in a permanent written record chronicling humankind's first forays into space.

Engineers installed onboard tape recorders, which, as part of their data-saving function, recorded nearly every spoken word. Some of these recordings were made during critical phases of each flight when the preservation of all data was essential. These tapes along with hundreds of others that were gathered on the ground during each mission became the focused attention of NASA typists whose single job was converting voice to paper. Armed with reel-to-reel tape players, electric typewriters, and reams of paper, these folks hammered out thousands of pages of transcripts often within hours of when the words were first spoken. Collectively, these transcripts offer one of the most complete written records of the U.S. manned space program. Like eavesdropping on Lewis and Clark or Magellan, each page offers compelling reading often presenting a different side to its superhuman human players; one in which its participants are shown to be both professional and profane, calm and excited, confident and unsure, healthy and sick—in a word, "human."

The Need for Data

In the high-risk arena of flight, the need for data is essential. When an aircraft is traveling at supersonic speeds, things can go wrong fast and the pilot does not have the time or the ability to record his observations with pen and paper. Both hands and feet are being used to fly the aircraft, so the pilot's voice is the only remaining tool available to record events as he sees them happening in real time.

Both test pilots and commercial airline captains are all too familiar with the cockpit voice recorder that has become standard flight hardware. The "black box," as it is more commonly known, captures voice data coming from the cockpit and is designed to withstand the rigors of flight both intentional and accidental. Indeed, during an accident in which the aircraft is lost, the flight data recorder is one of the first things that officials try to recover. Both the audio and instrument data that it contains may prove helpful in figuring out what went wrong and, in so doing, help prevent the same events from happening again. This essential tool was soon adopted by NASA engineers as the nation focused its attention from building aircraft to spacecraft in order to land men on the Moon.

The challenges faced by engineers to go from controlled human flight through air to controlled human flight through space were enormous. The need for data became even more important when every rocket launch took its precious human cargo through a multitude of extreme environments while riding atop a controlled explosion. Capturing the voices of the spacecraft occupants on their history-making missions became paramount, especially when odds were high that they might not survive the journey.

Engineers used the voice data to help with their systems analysis and, as more than one engineer was fond of saying, "to cover our ass if something went wrong." At the conclusion of every mission, subsystem managers gathered and assembled their data to evaluate problems. James Gibbons, a retired NASA employee with NASA's Johnson Space Center (JSC) who served as test engineer and data manager in the Test and Evaluation Division of the Apollo Spacecraft Program Office (ASPO), recalled that "the transcripts were used to cross-check against the mission data to try and determine what happened at any one given point in time during the mission."[4]

Both astronauts and flight controllers used the transcripts to help them recall key events. Resulting transcripts from onboard voice tapes served to supplement existing air-to-ground narratives, filling holes in the dialogue caused by periodic communications blackouts with the spacecraft. Onboard recordings were also made during reentry since the blazing stream of ionized gas, which engulfed the spacecraft as it fell back through Earth's atmosphere, effectively blocked all radio communications with the ground making direct communication impossible.

In addition to the obvious need by engineers for data, the press made use of the words to help its readers experience events as they unfolded. "In the early days of the Manned Space Program, you could not feed the media enough," said Paul Fjeld, then a reporter with the *Montreal Star,* who covered the Apollo program. "NASA was always very good about providing news and information for each mission, including stacks of transcripts."[5]

The Pathfinding Missions of Mercury and Gemini

The Mercury spacecraft carried into space a combined onboard voice and data recorder. During the relatively short duration of each flight, these recorders ran continuously during launch and descent, capturing the voice of their precious human cargo. During orbital flights, the onboard recorders were set to automatic mode where they were on one minute then off three minutes. The onboard astronaut could override this automatic mode at any time by simply pressing the PUSH-TO-TALK switch. The tapes were then recovered after each mission, analyzed, and the voice data transcribed.[6]

During the longer and more sophisticated follow-on two-person Gemini missions, onboard voice recordings were made using a small tape recorder mounted inside the spacecraft crew cabin. This unit allowed onboard voice recordings from the crew on removable tape cartridges, which were recovered after each flight for later transcription.[7]

The tape recorder used during the Gemini flights proved to be troublesome and problem plagued. "We always had problems with the damn thing," said John Young, pilot of *Gemini 3* and commander of *Gemini 10*. "It never really worked right through the whole program."[8]

Wally Schirra, commander of *Gemini 6* noted the shortcomings of the tape recorder that he encountered during his flight. During the crew post-flight technical debriefing, he did not hesitate to describe its flaws. "The voice tape recorder was a total loss," Schirra said. "We believe we got one cartridge through and that was all." In the debriefing, he goes on to explain how critical this piece of hardware was to the mission and that the problem needed to be fixed:

> I think it is about time that we recognized this voice tape recorder as a major deficiency for the Gemini flights. We should go into a crash program to initiate an acceptable voice tape recorder. We gave this particular device all the chances it deserves and we cannot afford to lose this valuable piece of equipment. When we were at McDonnell checking the voice tape recorder, we realized that there was no way of checking it and I had an engineering study performed in-house to determine if there was any way possible to make an access hole so that we could see the tape cartridge in motion. Of course, I mean the tape in the tape cartridge in motion. This apparently is not capable of being accomplished. This is a very sore point with me. I came off a Mercury flight with a perfect onboard tape and had no problem debriefing. This caused us probably more concern than any other item on the whole mission including malfunctions with the stowage equipment, malfunctions with the urine system. This was probably the most critical item to us. We didn't have time to take notes on these trying circumstances. We were working very rapidly in real time, and I cannot stress this point enough and I will make this evident to management as well.[9]

As with the Mercury program, the Gemini spacecraft did not have the ability to download or "dump" onboard recorded audio to ground controllers. As a result, mission engineers and planners could not effectively troubleshoot problems, as they were limited to only the data that was sent to the ground live during the course of the actual mission. This proved to be a handicap, especially during the aborted *Gemini 8* mission. It would not be until the Apollo program that engineers incorporated into the spacecraft design the ability to download recorded audio during a mission.[10]

Project Apollo and the Lunar Landing Missions

As the U.S. moved closer to achieving President Kennedy's goal of landing men on the Moon, the size and complexity of the spacecraft needed to accomplish this task grew, and with it came a host of new requirements to capture data. Apollo introduced not only a three-member crew to each new spaceflight, but two separate spacecraft: the bug-like Lunar Module (LM) that allowed two crewmembers to land on the Moon and return and the gumdrop-shaped Command Module (CM) attached to the large cylindrical Service Module (SM), collectively referred to as the Command and Service Module (CSM). The purpose of the CSM was to safely transport its three-member crew first to lunar orbit then back home, where the CM would separate, reenter Earth's atmosphere, and splashdown for recovery.

While in lunar orbit, one man waited patiently aboard the CSM while his two crewmates explored the lunar surface. Both spacecraft and crew worked in tandem during each mission—missions that for the first time placed humans a quarter of a million miles away and out of direct radio communications with Earth. Each time the spacecraft passed behind the Moon, the Moon's mass blocked all radio communications putting them and their spacecraft out of touch with mission control. During these periods of loss of signal (LOS), important flight performance characteristics would be lost along with any onboard crew dialogue and observations. As a result, NASA introduced a new type of voice and data recorder that, for the first time, allowed ground controllers to periodically perform "tape dumpings" of voice and data during the course of an actual mission. A tape dumping involved downloading the onboard tape contents via radio telemetry from the spacecraft for either immediate or delayed playback on the ground.[11]

Handling the recording of voice and data onboard the CM was a very sophisticated unit referred to in NASA parlance as the Data Storage Equipment (DSE). This self-contained device included two eight-inch reels that spooled some 2,250 ft of one-inch Mylar magnetic tape through read-write heads. The 14-track tape had a storage capacity of more than four hours of voice and data.[12] Subsystem information, normally sent directly from the spacecraft, was recorded by the DSE along with voice at a high or low bit rate and could then be transmitted to the ground by Mission Control. The DSE was used during the critical Lunar Orbit Insertion (LOI) burn performed by the CSM while on the far side of the

Moon when the spacecraft was out of communications with Earth. During this period, the DSE recorded crew voices, along with important engine and system parameters, that were then dumped to the ground for engineering analysis as soon as the vehicle flew into Earthrise and regained radio communications with mission control.[13]

The ever weight-conscious engineers designed a much simpler and lighter data storage unit for use onboard the LM. This unit, called a Data Storage Electronics Assembly (DSEA), used a single-speed, four-track, magnetic tape recorder to record up to 10 hours of voice communication from inside the LM.[14] While the LM was on the far side of the Moon, data was sent live over VHF circuits and saved on a special track of the CM's DSE. Even before the LM came back over the lunar horizon, engineering parameters of the critical first firing of the descent engine during the LM's Descent Orbit Insertion (DOI) burn were being studied on the ground via a tape dump from the DSE.

The controls division of the Leach Corporation in Azusa, California, built both the DSE and DSEA for each Apollo spacecraft.[15] Their managers reported to NASA's instrumentation subsystem manager at the Manned Spacecraft Center in Houston. David E. O'Brien was the manager for the units onboard each LM. The instrumentation subsystem included the timers, transducers, a signal conditioning electronics assembly, a caution and warning system, and the DSEA. The recorder system originally included telemetry data, which was the same as that for the CM but because of weight restrictions, its role was reduced to recording voice only.

Before working on the LM, O'Brien worked on the CM's DSE. During this time, he recalls, "one particular experience worth telling." During an early, unmanned test of the CM, he and his colleagues learned that an atmospheric pressure transducer made a pretty good microphone. "When we listened to the data, we heard this strange sound that made no sense," said O'Brien. "It went 'cling, cling, cling, (pause) cling, cling, cling, etc.' It turned out to be a 14-in glass thermometer that had accidentally been left inside the spacecraft after a ground test. Zero-g must have loosened the thing and, after reentry, as the CM was swinging back and forth on the recovery parachutes, the thermometer could be heard rolling back and forth on the floor of the lower equipment bay."[16]

A few problems were associated with the LM's tape recorder. Originally, the DSEA's 10-hour tape duration lasted longer since the unit would start recording only when the astronaut spoke. It would then automatically shut down when there was no sound, only to start back up again when the astronaut resumed speaking. This method helped conserve tape, capturing more voice and less dead air during a mission. Because the automatic voice activation (VOX) keying was not good enough to catch the start of an astronaut's voice, engineers decided to use the tape in a continuous record mode which made the 10 hours available a carefully husbanded resource. In each mission's flight plan, a table was included which listed for the astronauts, exactly what was to be recorded.

Another problem associated with the DSEA centered on the delicate cartridge containing the recording tape. The original plan was to use several tapes that the astronauts would load and unload during their mission. Getting the tape cartridges in and out of the unit, however, proved difficult and crews often damaged the tapes in the process. As a result, engineers designed a special tool to help the crew load and unload the tapes correctly. After numerous simulations, the astronauts found that even with the tool, it took far too long to change out a tape. Engineers eventually settled on just having one tape in the unit, thus eliminating the tape change-out requirement. In addition, the revised mission plans called for bringing the whole unit, tape and all, back to the ground for removal, playback, and transcription. As a result, the special loader tool was never employed except as a useful ground-handling tool.

Engineers discovered an unexpected, and beneficial, capability of the DSEA: the recording system had a circuit that would automatically pull up low sounds. This turned out to be a bonus. "We could hear the ground communications loud and clear, which wasn't supposed to happen," said O'Brien. "We thought we had a configuration problem but it was just the pickup from the astronaut's earphones in the background!"[17]

Only one recorder ever malfunctioned during the Apollo program. On *Apollo 11* several of the 26-gauge wires leading to the recorder broke, resulting in reduced audio levels and a constant 400 Hz background tone. Because the entire DSEA unit from the mission was brought back, engineers were able to carefully study the hardware, deduce the problem, and develop a fix. They were also able to extract Armstrong and Aldrin's comments from the noise, incorporating their words into the Command Module's final DSE transcript.[18]

Skylab

The Skylab program marked a giant leap forward for long-term human presence in space. For the first time, the United States would have an orbiting laboratory where crews would come and work for progressively longer periods. Before Skylab, the longest U.S. manned space mission was the record-breaking flight of *Gemini 7,* in which astronauts Frank Borman and Jim Lovell spent nearly 14 days in orbit (330 hours, 35 minutes, and 31 seconds to be exact). During Skylab, this old record fell as crews spent 28, 59, and then 84 days respectively in space aboard the orbiting workshop.

Because of the duration of each Skylab mission, the transcript methods that were put into place during Apollo were taxed to the limit. At the close of the Skylab program in 1974, approximately 50,000 pages of mission transcripts were produced at an estimated cost of nearly $1 million.[19] As for all previous manned space missions, the Skylab transcripts also provided an invaluable written record of the program's achievements. Indeed, it was during the Skylab program that the transcripts and their contents became more a news item than the events themselves.

During the Skylab program, science became the main objective—science that included using crewmembers themselves to study how the human body adapts and works in the microgravity environment of space for extended periods of time. During the three manned visits to Skylab, almost all of the crews experienced symptoms of what is now referred to as Space Adaptation Syndrome (SAS). One of Skylab's main scientific objectives was to study this phenomenon of human adjustment to microgravity. The first crew to Skylab remained relatively untroubled but subsequent crewmembers fell to SAS culminating in an incident during *Skylab 4*, the last manned mission, which received the most media attention due, in part, to the mission transcripts.

Skylab had 13 internal speakers and intercommunications systems inside the orbital workshop. This included an Extravehicular Activity (EVA) communications system, a network of measurement sensors to gather and process data around the active station systems and experiments, and a spacecraft-to-ground or ground-to-spacecraft communications system that routed communications through the Command Module system.

Two forms of voice information were transcribed during the Skylab program—real-time air-to-ground voice and dump voice. Real-time air-to-ground voice was recorded when Skylab was in direct radio contact with a ground station. The real-time transcripts included both sides of the conversation, that is, both the air-to-ground and ground-to-air voice. The dump voice was recorded using the Command Module data storage equipment and Skylab's airlock module recorder. Data from these two recorders was telemetered (dumped) to Space Tracking and Data Acquisition Network (STADAN) sites for retransmission to the Manned Spacecraft Center in Houston.[20] The onboard voice recorders were usually dumped approximately every 90 minutes when the orbiting outpost passed over the nearest STADAN site. The whole transmission/relay process from delivery to receipt usually required a minimum of 60 minutes to complete. Out of these two forms of voice information emerged five different types of finished transcripts: quick-look air-to-ground, quick-look dump-voice, technical air-to-ground, technical dump-voice, and in-flight debriefing.[21]

Before Skylab, all communication between the astronauts and the ground were open, with private communication reserved for special medical situations or emergencies. With the longer duration missions of Skylab and the greater focus on life science activities, NASA proposed to have the astronauts schedule daily private medical conversations involving only the flight surgeon and crewmembers for the purpose of "doctor/patient detailed discussion of crew well-being and response." After the conversation, the flight surgeon would immediately give a statement on crew status to the flight director and public affairs officer, along with preparing a daily medical bulletin stating the crew medical status for public release. This brief bulletin would be the only public comment on the conversation. The public affairs office disagreed with this plan, arguing that the information on the men in their spacecraft was of far more interest to the media than the spacecraft itself. The astronauts agreed that the public had a right to know what they were doing but they were reluctant to let the world know how their stomachs felt, knowing that any admission of such frailties might jeopardize the mission. And as every career astronaut knows, success of the mission is paramount.

Several months before the launch of *Skylab 1*, NASA Administrator James Fletcher addressed the thorny issue of private air-to-ground communication through a memo, which seemed to offer a healthy compromise. In the memo, Fletcher outlined that private conversations for morale purposes to their families would be recorded but the tapes and their resulting transcripts would not be released. Private conversations for operational reasons were to be held only in the case of an extreme operational emergency. When such a conversation is required, the public affairs officer on duty would announce to the media that a decision had been made to hold a private operational conversation. Depending on the nature of the conversation, the appropriate ground support people would participate in the call and the public affairs officer would monitor it. The tape and resulting transcripts of the call would not be released, only a paraphrase of its contents. Finally, Fletcher determined that the astronauts would schedule daily private medical conversations involving only the flight surgeon and crewmembers. This brief bulletin would be the only public comment on the conversation.[22]

The medical reporting process would be tested in full during the third crew visit to Skylab, but before that astronaut Pete Conrad, commander of the first crew to visit the workshop, initiated his own reporting controversy. Early in the *Skylab 2* mission, Conrad requested a private conversation with mission control. Knowing the definitions of a private conversation as laid out by Fletcher, mission control believed they had a serious problem on their hands. Officials were summoned and when Conrad came on the loop, he surprised everyone by simply stating that he wished to "apologize for the difficulties that he experienced in riding the ergometer."

When the media heard the summary of the "private communication," they wondered how this warranted being an emergency. As a result of this incident, mission control requested that for future similar calls, CapCom would first ask the crew to verify if an emergency had actually occurred and if it required a private communication. This request was later rescinded by NASA as they did not want to place the astronauts in the difficult situation of not wanting to use the private communication loop when there was a genuine need.

During a press conference earlier that same year, Conrad mistakenly mentioned to everyone that the "B Channel Dump Data" would be released to the media even though NASA had no plans to do so. This created an awkward situation as the media were now expecting the release of the transcripts from Conrad's private communication about the ergometer. NASA reluctantly agreed to release the transcripts but the decision was made to censor all medical data from them. From this point on, Skylab crews were apprehensive about using the private operational channel for anything for fear of sparking a new controversy. In reality, the private channel was never really private, which is one reason why a problem aboard the third Skylab became a media nightmare for NASA.[23]

Shortly after the *Skylab 4* crew docked and prepared to enter the orbiting workshop, Pilot Bill Pogue became nauseated and vomited. During a brief communications link with the ground, Pogue's illness was not mentioned by his other crewmembers Gerald Carr and Ed Gibson. Officially, they should have reported the nausea and the vomiting. In addition, all food taken or left was to be reported each day but in a desire to prevent an over-reaction from ground controllers, Carr only reported that Pogue had not felt hungry and had left some of his food. Forgetting that the onboard CM tape recorder was running, the crew members discussed the matter among themselves. Knowing that the evening status report was coming up, Carr decided to tell mission control that Pogue was nauseated but not that he had vomited. Carr also determined that even though mission rules dictate that the vomit bag should be accounted for, they would simply throw it down the trash airlock. Gibson agreed adding that management on the ground would be happier if the bag was disposed without reporting what actually happened.

> CARR: Well, Bill, I think we better tell the truth tonight because we're going to have a fecal vomitus bag to turn in. Although I guess we could throw that down the trash airlock, and just forget the whole thing and just say, "Bill doesn't feel well, and he's not eating; we got him immobilized with prom-eph."[24]

POGUE: I hate to say it, but I think all the managers would be happy.

CARR: Well let's do that then. We won't mention the barf; we'll just throw that down the trash airlock, I doubt if you threw up any more than what you've taken in, and what you took in a few seconds, a few minutes earlier—

GIBSON: They're not going to be able to keep track of that.

POGUE: Let's do that, because they seem to make a big distinction between the—whether you throw up or not—

CARR: Yeah.

POGUE: It's always a distinction . . . to you so it's just you, me, and the couch.

CARR: You know damn well that every manager at NASA would probably under his breath want you to do that.[25]

The next day as the crew prepared to enter Skylab, the onboard CM tapes were dumped and transcribed as routinely scheduled. Had Carr remembered that the tape recorder was running, he most likely would have reported the incident but instead decided to keep quiet about it and while discussing the best course of action, the tape of the earlier comments about throwing away the evidence was being played back on the ground as the tapes were transcribed.

In subsequent meetings with science and medical personnel, the tape contents were discussed. Concerns were raised that data was not only being kept from them but hidden. The resulting fall-out went straight up the chain of command to the chief of the astronaut office, Al Shepard, who gave Carr and his crew a public reprimand during an open channel uplink saying "I just want to tell you that on the matter of your status reports, we think you made a fairly serious error in judgment here in the reporting of your condition." Carr replied: "OK Al. I agree with you. It was a dumb decision."[26]

In retrospect, Carr knew he had to report the vomiting of his crewmate but he also knew that this might be misinterpreted as an "emergency" and he wanted to wait and more fully review the situation before reporting it. Unfortunately, the CM tape dump combined with the subsequent open reprimand from Shepard and the public release of the tape contents caused the media to question NASA as to whether this represented a serious breakdown in communication between ground controllers and crew members. It would not be until the Space Shuttle program that all medical conditions of each crewmember would be classified as "private" and therefore not to be released to the media other than in general reports outside of "real emergencies."[27]

Apollo-Soyuz Test Project

The Apollo-Soyuz Test Project (ASTP) was the first human spaceflight mission managed jointly by two nations. It was designed to test the compatibility of rendezvous and docking systems for U.S. and Soviet spacecraft in order to open the way for future joint human flights.

The Apollo spacecraft was the same design as that used on lunar exploration missions and Skylab. Several modifications were made for the Apollo-Soyuz mission, however, including the addition of propellants for the reaction control system, heaters for temperature control, and extra equipment needed to operate the Docking Module. The standard DSE used during Apollo was still used onboard during ASTP.

The mission began with the Soyuz launch on 15 July 1975, followed by the Apollo launch seven hours later. The docking in space of the two spacecraft took place at 2:17 p.m. U.S. central time on 17 July. Two days worth of joint operations followed. After separation, the Soyuz remained in space for almost two days before landing in the Soviet Union on 21 July. The Apollo spacecraft remained in space for another three days before splashing down near Hawaii on 24 July.

The resulting ASTP transcripts produced were the onboard DSE transcripts and the Public Affairs Officer (PAO) commentary and Air-to-Ground Technical that were standard during Apollo. One additional feature however was that the Russians also provided what amounted to the equivalent of the U.S. PAO commentary transcripts recorded from their mission control center in Moscow.

Space Shuttle

By the time NASA entered the operational phase of the Space Shuttle program, requirements for detailed air-to-ground transcriptions for both mission analysis and media coverage diminished. Gone were the days of early human spaceflight when each pioneering mission produced reams of pages chronicling every spoken word by astronaut crews and ground controllers.

By the mid 1980s, advances in the Manned Spaceflight Network (MSFN) combined with full deployment of the Tracking and Data Relay Satellite Systems (TDRSS) allowed mission controllers the luxury of near continuous air-to-ground telemetry and communication for every Shuttle mission—something that earlier manned spaceflight programs only dreamed of having.[28]

The configuration of Shuttle systems did not allow continuous onboard recording of voice. What limited onboard voice-storage capability the orbiter had was reserved for recording crew audio during critical in-flight periods, such as liftoff, ascent, EVA, entry, and landing. These resulting onboard crew audio transcripts were used for post-flight crew debriefings and not normally made available to the public. As a result, mission transcripts produced from the early Shuttle era were limited to live air-to-ground communications.

The individual responsible for heading transcript operations for Shuttle flights was Steve Nesbitt, a public affairs officer at NASA JSC.[29]

"I had just come over to PAO in December 1980," said Steve explaining how he got the operation started, "when my boss, John McLeaish, assigned me to set up and run a transcript operation."

NASA's goal was to have a quick-look transcript, complete with inherent inaccuracies, of the air-to-ground and PAO commentary loops available to the media within two hours of when it was first heard. Resources were borrowed and secretarial help recruited from across JSC to compile the transcripts.

> We used a primitive mainframe-based word processing system called 'Word One,' said Nesbitt. "It was indeed basic as the system could accept typed text but you couldn't do much with it. 'Dot commands' were the method of making small edits, and you could save and print your work but that was about it. In retrospect to what we have available on our desktops today, it was pretty crude. Copies were made using a giant Xerox machine that looked like a '50s Iron Lung. The machine was slow, loud and smelly but it worked.

As with previous transcription efforts encountered during Mercury through Apollo, the process remained a labor-intensive task requiring a great deal of staffing and coordination. Three around-the-clock shifts of 20 part-time people were employed. A person in the sound room manned a pair of cassette machines into which the mission audio circuit was fed from the Mission Control Center. The mission audio was a mixture of air-to-ground and PAO commentary that was originally recorded in the Mission Control Center on a Stancil-Hoffman CRM-5600 56-track reel-to-reel machine. The recordist ran one tape while preparing a second machine that would start as soon as the first was done. After about five minutes of voice activated (voxed) sound, the recordist started tape two, letting them overlap for several seconds, stopping tape one and placing it in a case with a label indicating the Mission Elapsed Time (MET) start and end time. The recordist then replaced the tape with a blank, ready to swap again when tape two finished. Hundreds of five-minute long audio tapes for each mission were produced. A runner then picked up the tape as it came off the machine and carried it to one of the legions of typists who placed it on a dictation playback machine operated with a foot pedal. These typists did their best in transcribing what they heard but the technical language and infamous NASA acronyms still remained a challenge to the uninitiated. The results were that they often made mistakes with such lines as "Press to MECO*" transcribed as "pressed amigo."

After the typists did their magic, the editor played the tape and checked it against the transcript. "This was a bit hit or miss," said Nesbitt in describing the process. "We had a hard time getting enough staff to do the work. I ended up working about 18 hours on day one of *STS-1* because of lack of staff."

The "edited" transcripts were then printed and volunteer co-ops made copies to be placed on a table in the media work area for pickup.

With minor refinements, this process continued through *STS-41C*. At that point, NASA stopped making air-to-ground transcripts and focused instead on just transcribing the various mission briefings, news conferences, and other highlights associated with each flight.[30] "We stopped because there wasn't much demand from the media and resources were too hard to get," said Steve. In addition, mission operations no longer required transcripts for post-flight analysis and technical crew debriefings because the audio tapes were determined to be sufficient. To this day, audio tapes are still maintained for each Shuttle mission.

What about the Original Audio Tapes?

It remains to be found where the original onboard audio tapes from Mercury, Gemini, and Apollo are located. Since each of these units were brought back from their respective missions and retrieved from their spacecraft, it is assumed that the original flown tapes were excessed or destroyed once analyzed and copies of their contents made.

The original mission control audio tapes from the Mercury through Apollo programs consist of audio gathered from different flight controller console stations at NASA's Mission Control Center (originally based at Cape Canaveral, Florida, then moved to Houston). Each console fed an audio loop into a 30-track Soundscriber-brand tape recorder, which recorded audio from up to 30 different flight controller console positions per mission.

Examples of loops recorded during a mission include audio from the flight director, capsule communicator (CAPCOM), and PAO. The flight director loop includes all audio from the flight director, such as queries, status checks, and commands given to other flight controllers. The CAPCOM loop includes all air-to-ground communication between the CAPCOM and the astronauts in their spacecraft. The PAO commentary loop includes mission status updates and other

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* Main Engine Cut-Off.

observations given by the public affairs officer who monitored each mission from his console in mission control.

At the close of the Apollo program, the 1-inch 30-track tape was replaced by a newer 1/4-inch 2- and 7-track format used by NASA today.[31] With the retirement of the 1-inch 30-track tapes, the original hardware used to support this format was no longer needed, so the Soundscriber tape recorders fell into disrepair.

Although the requirement to record mission audio on the older 1-inch, 30-track format was replaced by the newer system, there still remained a historical need to capture and preserve the original audio. NASA recognized this need and soon came to realize the only way to preserve the older audio was to transfer the 1-inch, 30-track tapes to a newer format.

This task was given to Greg Wiseman, an audio engineer with the public affairs office at NASA JSC. Wiseman led the task of dubbing the remaining 1-inch, 30-track mission audio tapes containing the audio from the Mercury through Gemini missions in addition to tapes from ASTP. Wiseman was faced with the challenge of coaxing the only remaining machine capable of playing these tapes back into operation.

"It was a love/hate relationship," said Wiseman, who worked on the project off and on beginning in 1999. "The original Soundscriber was found onsite and it didn't work. We couldn't find a manual or someone still around that knew how to operate it. We also couldn't get parts for it, so we faced a real challenge to try and get the thing working."

Persistence paid off, however, as both he and coworker John Stoll got lucky when they found another unit. "We found another machine underneath a subfloor in the same building," said Wiseman, adding that the found unit was "in pretty bad shape, so we ended up taking parts from it to make the other one work."[32] With spare parts plus a little spit, glue, and bungee cords, Wiseman proceeded to dub the remaining tapes.

"Bungee cords were not factory equipment," said Wiseman with a grin. "We had to add them in order to provide the necessary pressure between the pinch roller and capstan. Without it, the tape speed over the read/write heads wouldn't stay constant. It may look strange, but it works."[33]

After nearly a year, Wiseman's patience paid off as he succeeded in transferring the 20 remaining Mercury through Gemini 1-inch, 30-track tapes and the 36 tapes left over from ASTP. "We now have all of the older format mission audio tapes transferred," said Wiseman. "We'll still keep around the Soundscriber just in case we find any other older format tapes that need to be transferred, but I'm pretty sure we got them all."

Even though an extensive inventory was completed of all the air-to-ground mission audio housed at JSC, that inventory reveals gaps in the collection. For example, several tapes are missing from *Apollo 11* and *Apollo 13*. It should also be pointed out that only audio tapes that include the PAO commentary loop remain in the JSC collection. Very few, if any, tapes from the other original console loops remain. Recall that for each mission, literally hundreds of audio tapes were produced that recorded each of the mission control console loops and the supporting backroom loops. Mission rules dictated that these tapes were to be used for post-flight debriefings and analysis. What happened to the tapes at the end of each successful mission's debriefing is anyone's guess.

Sy Liebergot, a long-time flight controller who received celebrity status for his role as EECOM during drama of the *Apollo 13* mission recalls that some of his colleagues kept their console tapes as souvenirs of the mission. Indeed, audio from Sy's personal copies of his console tapes can be heard in an excellent interactive CD-ROM called Apollo 13: *A Race against Time.*[34]

The National Archives and Records Administration (NARA) is the final keeper of all federal records. Initial research by this author shows that several NARA facilities including those at Fort Worth, Texas, and College Park, Maryland, may still have copies of many of the original audio tapes. However, it requires additional research to verify exactly how extensive their collections are in this area.

Preservation Efforts

Numerous requests throughout the years from researchers and the general public for print copies of the mission transcripts prompted a serious examination by NASA's history office about how best to more effectively preserve this valuable historical resource in addition to a more efficient method of distribution. Because most transcripts are hundreds, if not thousands, of pages in size, producing hardcopies and distributing them is both expensive and time consuming. In addition, repeated handling can damage the original documents.

Beginning in 1999, both NASA Headquarters and NASA JSC began a joint project to gather and digitally scan all the transcripts made from both the onboard tapes and those tape recordings made on the ground from the air-to-ground transmissions of the Mercury through Apollo missions.

Because the number of pages of paper to be scanned in this project was enormous there were concerns about how to ensure that each transcript set was complete, that no pages were missing and that every page was readable. Almost every transcript originally produced by NASA was gathered and organized by tape number and not page number. As a result, if the binding of each transcript was somehow lost, the page order could easily be compromised. Because all of the transcripts that are housed in NASA's history collections are designed to be easily used by researchers and copied, these original bindings were long since removed. The end results were collections of loose pages that, during years of repeated use, lost their original organization and in some case, pages were missing altogether.

Because the transcripts would be scanned into searchable Adobe Acrobat Portable Document Files (PDF), it was important that each be as complete as possible with all pages accountable, of good readable quality and in correct page order. The scans would preserve the original document's integrity, but they had to be verified before each document could be scanned. The daunting task of reviewing nearly 50,000 pages was beyond the limited resources of NASA's history personnel.

Calls went out requesting volunteers to help with the project. The response was overwhelming. From all over the world e-mail requests came from people willing to help. Once volunteers were chosen, a process was set up in which initial scans of each of the mission transcripts were made and then reviewed. The transcript files were posted on an Internet server, where volunteers could go and download each assignment along with instructions directing them what to do.

Volunteers served as reviewers of each scanned transcript. There were 60 volunteers assigned to review 80 mission transcripts. After downloading their assigned transcripts from the server, each volunteer was told not to review, edit, or judge content, spelling, typos, et cetera. They were scanning the original transcripts as is and not editing them. Instead, they were encouraged to think of each scanned file as the electronic equivalent of Xerox copies. All that was asked was that each volunteer check for print quality (was it readable?), page order, missing pages, page duplication, and blank pages. NASA's task was to "correct" each scanned file according to each volunteer's submitted results. Typically, this required finding missing pages, removing duplicate or blank pages, rearranging pages in their correct order, or finding better quality originals if reviewers indicated that initial scanned copies were of poor quality.

All this was done on a global effort via the Internet. In addition to volunteers from the United States, participants came from Canada, Sweden, Belgium, and the United Kingdom. The whole process went remarkably well with all 50,000 pages of transcripts completed in just less than six weeks. None of this would have been possible without the help of volunteers.

Since all communication was limited to e-mail, it was important to maintain a steady correspondence with each volunteer. In addition to answering their questions, weekly status updates were given along with supplemental information that would help each volunteer better understand the scope of the project.

Feedback was important and throughout the project volunteers expressed their enthusiasm for being able to participate in a "hands-on" experience that helped preserve a portion of NASA's human spaceflight record. Here are some of the e-mail comments given by volunteers during the project:

> Glad it all went to plan, it was nice to temporarily work for NASA.
>
> Hey, man, this has been great fun. Kinda hard to catch the time to do the reviews, but it has been neat trying to decipher some of the "meaning" behind the "words." One that was NOT hard to decipher in the *Apollo 8* CM transcription: Borman: "Get your ass to bed, now! Both of you!"
>
> Thanks for inviting the public to participate here. All too often managing volunteers is more trouble than it's worth. I hope we were extraordinary and well worth that extra effort.
>
> It is really interesting reading the transcripts and obviously we don't have time to read everything! Process first, read later! :-) I am very excited about this project. What an awesome endeavor.
>
> I commend you on the organization of this project. You have done wonders considering the limited personnel and funds at your disposal!
>
> I was honored to be a part of the saving the mission transcripts to CD, and I think we, as a group, did something that future generations will be gratified to have.

The end result of this collaborative effort between NASA and Internet-based volunteers was the production of a two CD-ROM set titled *The Mission Transcript Collection: U.S. Human Space Flight Missions from Mercury Redstone 3 to Apollo 17* (NASA SP-2000-4602). Each CD-ROM set features 80 transcripts totaling nearly 45,000 pages of text covering every U.S. human spaceflight from the first Mercury mission through the last lunar landing flight of *Apollo 17*. By making high-quality, one-time scans and packing them in a user-friendly, mass-produced CD-ROM, complete sets of these transcripts are now easily available to anyone with the added benefit of allowing users to perform extensive text searches using the scanned files or print hard copies that are close to original quality. The two CD-ROM set includes an index listing each transcript file by name. Some of the transcripts include a detailed explanation of their contents and how they were made. Also included in this collection is a listing of all the original air-to-ground audio tapes housed in NASA's archives from which many of these transcripts were made.

Based on the success of this first preservation effort, the NASA JSC history office began a subsequent project that took the mission transcript scanning idea one step further. This second preservation effort focused on gathering all of the known air-to-ground audio tapes from the *Apollo 11* mission to compare what was said on these tapes to what was actually transcribed. In addition, the project allowed JSC to assess the current condition of the *Apollo 11* audio tapes and, while doing so, determine if any tapes were missing. Finally, the project allowed JSC to review its entire collection of mission audio tapes, taking inventory of exactly what it has on file, assessing their condition and finally, transferring those tapes in greatest jeopardy from their aging media to a new media to help assure their preservation.

Like the mission transcript CD project, the subsequent *Apollo 11* Audio Transcript Project relied heavily on a cadre of Internet-based global volunteers, many of whom continued as volunteers after working on the original CD project.

Because of the obvious historical significance of the *Apollo 11* mission, most of the original air-to-ground audio tapes remain on file and were easily accessible. In fact, a complete set of audio tapes was transferred onto cassette from the original tape reels, making access and duplication even easier. Since all the volunteers for this project already had complete sets of the mission transcript scans, what remained was to circulate copies of the audio files. One of the challenges in the project was how to effectively duplicate and distribute the audio to the volunteers. The solution came from one of the volunteers himself.

Michael Smithwick served as a volunteer on the first CD transcript project. He works for an Internet-based company known as Live65.com, which promotes itself as being the "world's largest Internet radio network." Smithwick kindly agreed to convert each of the original audio tapes to .wav format in an effort to help maintain as much of their original fidelity as possible for the project. He then edited out the gaps and removed much of the filtered hiss. The end results were a set of MP3 files that could easily fit onto one CD, e-mailed or uploaded to a server for easy Internet access. Volunteers then had access to both the transcripts and the audio files.

During the tape conversion process, Smithwick was the first to actually listen to every minute of audio from *Apollo 11*. What he found was not encouraging. "Unfortunately, the quality of the tapes has suffered due to aging," reports Smithwick. "Many of them had suffered from 'tape stretch' or the gradual stretching on their reels, year after year, which caused the audio to slow down or to introduce a 'wow' in the track. Others lost volume, due to slow and subtle effects of the Earth's magnetic field, which erased the material."[35]

The *Apollo 11* audio transcript project is a much more time-demanding effort than the original mission transcript CD project. The project began in August 2001 and, as of this writing, is only now nearing completion. The entire *Apollo*

11 mission audio was broken up into 147 audio segments or files with each volunteer assigned a set of files to listen to and compare with the corresponding transcripts. In listening to the audio, volunteers were instructed to note any differences from what was said on the tapes to what was recorded in the transcripts. What volunteers found is that there is a surprising disparity between what was actually said on tape versus what was recorded in the transcripts.

Realizing that each person can pick up different items while listening to the same audio, to help assure greater accuracy, each audio tape segment was reviewed by three different volunteers. Each volunteer then turned in separate results in the form of spreadsheets. The first column of each spreadsheet lists the physical page number of the transcribed portion in question. The second column lists the line number of the text, the third column lists the questioned segment as originally transcribed, and the fourth column lists the corrected transcription as entered by the volunteer. Once the three spreadsheet results have been turned in for each audio file, an assigned tape captain takes these and collaborates the results with their volunteers to produce a final master result that all agree on. In this manner, the most accurate final results for each tape are produced. It is hoped that through this project the most complete audio and the most accurate transcribed account of the *Apollo 11* mission will be produced.

Why Preserve This Resource?

Perhaps no single event in the history of mankind was so well documented as the Apollo program. It was often said among engineers that if they did not generate at least enough paper equal to the weight of the vehicle that it would never fly. The hundreds of remaining mission audio tapes and their resulting tens of thousands of pages of transcripts capture not only the dry, well-rehearsed acronyms and NASA-speak that characterized these missions, but also the unrehearsed spur-of-the moment emotions by those who were fortunate enough to witness the events they experienced firsthand. For the sake of future generations wanting to relive the same experience as told and heard from those that first lived it, the audio and corresponding transcripts are the next best thing to being there.

There were detractors who questioned the need for transcripts. After all, it was an expensive and time-consuming process to transcribe each and every word spoken during each mission. One of the transcripts for *Apollo 17*, the last lunar landing mission and the longest in the Apollo lunar program, numbers more than 2,000 pages in length. In addition, revealing every spoken word to the public during a mission sometimes proved to be a public relations nightmare. More than one astronaut was known to be unhappy about having his every word, and perhaps every mistake, recorded, transcribed, and laid bare for the entire world to see. After all, these transcripts captured every crew utterance, some pleasant, others not.

"I remember those days of listening to the mission tapes and typing every word," said Nancy Hutchins, a civil servant with NASA's Manned Spacecraft Center during Apollo. Hutchins served among the legions of typists who faithfully transcribed each mission tape. "We spent hundreds of hours cueing up tapes, typing, stopping, rewinding, playing, typing . . . it was hard work. Every time one of the astronauts swore, we jumped up in our seats. We were surprised when they said such words."[36]

The human side of the apparent "superhuman" astronaut was often hidden by their official role as cold war warriors. Strengths and weaknesses—traits they were taught not to show, came out in voice and print. The astronauts had cause for concern. Such traits could come back to haunt them, especially with their fellow astronauts waiting on the sidelines for their chance to fly—a chance that could come sooner rather than later if someone found an excuse to replace or exclude you from a mission.

Owen Morris, the LM spacecraft manager, couldn't see a need. "Owen Morris had been trying to remove the tape recorder to save weight," said David O'Brien, manager of the LM DSEA units. The LM was always on the ragged edge of being too heavy. But during an Apollo post-flight technical debriefing, one of the crew members raved about how helpful it was to have the tape recorder jog their memories about what had happened and when. O'Brien recalls that at that moment Morris knew he was licked. "Owen just turned to me and sorta said 'Well okay. That's the end of that.'"[37]

Through projects such as those led by NASA, the mission transcripts have now been preserved in a scanned digital format that helps assure their preservation in a compact and easily reproducible form, thereby making them more accessible to researchers. The fact that every page of these transcripts can now be text searchable makes them an even more valuable tool to the end user. However, where the transcripts fail is in conveying the actual emotions of those participants—emotions that can only be captured in their original audio form. Reading Neil Armstrong's famous words "That's one small step for [a] man, one giant leap for mankind" is not the same as hearing the words spoken as they were said during that historic moment. Preservation of the original audio tapes is an essential complement to maintaining their textual counterpart. As explained in this article, steps have been taken to help preserve the contents of those remaining original audio tapes, but more needs to be done.

The simple fact is that audio tapes are missing and need to be accounted for, especially those of greater historic significance such as *Apollo 8, 11,* and *13.* A more aggressive accountability of these original audio apes needs to be undertaken and once these tapes are found, they need to be properly assessed and their audio converted to digital format to help preserve their contents from both dying media and obsolete hardware.

Mission planners of the Mercury, Gemini, and Apollo programs felt that it was significant enough to build into their spacecraft the capability to record words spoken by their precious human cargo during their history-making missions. These same engineers knew that every ounce of hardware that went into their spacecraft required hundreds of pounds of rocket propellant to get it into space. These engineers were motivated less by the historic significance and more by the need for data to help assure the success of their missions, nevertheless, the surviving audio tapes are no less significant in value nearly 40 years later.

Both the air-to-ground and onboard tape recordings have become one of the most valuable resources in researching and writing the history of human space exploration. Because every moment of a mission was not played out to the world, many of the transcripts reveal completely unguarded ones. "Everything is hanging out," says Andrew Chaikin, author of *A Man on the Moon,* the basis for the critically acclaimed HBO mini-series "From the Earth to the Moon." "It's a window on their personalities. Those tapes let us be stowaways on mankind's greatest adventure."[38]

The subtle humor of Neil Armstrong, the glee of Pete Conrad and his crew, the panic inducing scare for Gene Cernan—all would be lost without the engineering function of "voice data." Says Chaikin, "I knew that if I wanted to make the Moon experience real to the reader, I had to make the astronauts seem like real people. Next to my interviews with them, those tapes were the single most important means of doing that."[39]

Appendix A: Resources

Available Voice Transmission Resources

For those wishing to make use of the mission audio or transcripts in their research, there are a variety of excellent resources available to assist you, most of which are easily accessible online through the Internet.

Perhaps the single most complete transcript resource is the previously mentioned *The Mission Transcript Collection* CD set (NASA SP-2000-4602) produced by NASA Headquarters. Some 5,000 copies of these two-CD sets were initially produced in 2000 and distributed free of charge. Unfortunately, because they were free and received positive reviews in several publications, they "flew off the shelves" and are now difficult to find.

In addition, the NASA JSC History website has posted the transcripts from this same CD collection. The JSC website does not have the complete formatting of the original CDs, but they have posted all the scanned transcripts for users to either view online or download to their computers.

The single best resource for detailed annotated transcripts of the lunar surface activities during the six successful manned lunar Apollo missions is Eric Jones's phenomenal online resource called "Apollo Lunar Surface Journal (ALSJ)." This exhaustive work is legendary among researchers as its creator has spent more than 10 years assembling the most complete documentary tool of not only what was said during every minute on the lunar surface but why, as most of the transcripts are accompanied by detailed annotations provided by the astronauts themselves. In addition, this Webpage is filled with images, video, and audio as only a Web resource can provide, making this as much an entertaining tool as it is a scholarly one. The beauty of having such information available online as a Webpage is that it is never static but continually changes as legions of faithful volunteers add additional details to this ever-growing massive body of work, making it by far the definitive source in its field.

Eric Jones's resource is limited to covering those mission transcripts beginning with each LM undocking with the CM and subsequent descent to the lunar surface and concluding with each LM ascent, rendezvous, and return docking with the CM. Several volunteers who have worked on Jones's project have taken up their own efforts to extend the ALSJ model of completeness to covering the rest of each mission. Editors David Woods and Frank O'Brien have picked up where the ALSJ leaves off with the "Apollo Flight Journal." Their goal is to detail all the Apollo missions not covered in the ALSJ. So far, they have completed *Apollo 15* and are currently working on *Apollo 8*. Like the ALSJ, the Apollo Flight Journal is intended to be a "living document" that will continue to grow and evolve as new material is brought together by contributors and volunteers.

As mentioned previously, as part of the *Apollo 11* Audio Transcript Project, all of the audio from PAO air-to-ground commentary loop from the *Apollo 11* mission was converted to mp3 format to assist volunteers in working on the project. Volunteer Michael Smithwick kindly donated his time and resources to convert each of the original audio tapes to .wav format in an effort to help maintain as much of their original fidelity as possible for the project. He then edited out the gaps and removed much of the filtered hiss. The end results were then placed online at www.live365.com, the world's largest Internet radio network, where people can listen to the original audio of the complete *Apollo 11* mission streamed live through the Internet.

The NASA Headquarters history office has a website devoted to ASTP. Included are links to scans of the complete ASTP mission transcripts. They have posted the onboard voice recorder mission transcript, the technical air-to-ground voice transcript, and the PAO commentary transcript. In addition, they include mission transcripts of the Russian equivalent PAO commentary for the flight from the Soviet Mission Control Center.

Hardcopies of the original mission transcripts can be found among the history collections at NASA Headquarters, NASA JSC, and the National Archives and Records Administration.

One of the most complete collections of original mission transcripts can be found at NASA JSC. The JSC history collection has recently been moved to a new archive facility at the University of Houston—Clear Lake (UHCL). The UHCL archive is open to the public with an online searchable index to its collections.

The National Archives and Records Administration (NARA) also has an extensive collection of mission transcripts in addition to the original audio tapes. The NARA facility in Fort Worth, Texas, has a sizeable collection as part of their NASA records group holdings.

Many of the original audio tapes from the air-to-ground transmissions can be found at NARA's College Park, Maryland, facility. This facility houses most of NARA's audiovisual records.

Appendix B: Photos

Figure 1: Flight controllers often used downloaded data and voice transmission tapes for real-time analysis during a mission. Shown here at NASA's Manned Spacecraft Center (MSC) Mission Control Center (MCC) are Eugene F. Kranz (left), flight director for the *Gemini 7* White Team, and George M. Low, MSC's deputy director, reviewing a transmission tape received on 9 December 1965 from *Gemini 7*. In the background, wearing glasses, is flight controller Manfred von Ehrenfried. NASA Photo No. S65-61513.

Figure 2: One of the legions of typists, shown transcribing the air-to-ground audio tapes at MSC. Photo courtesy of NASA, S68-55408.

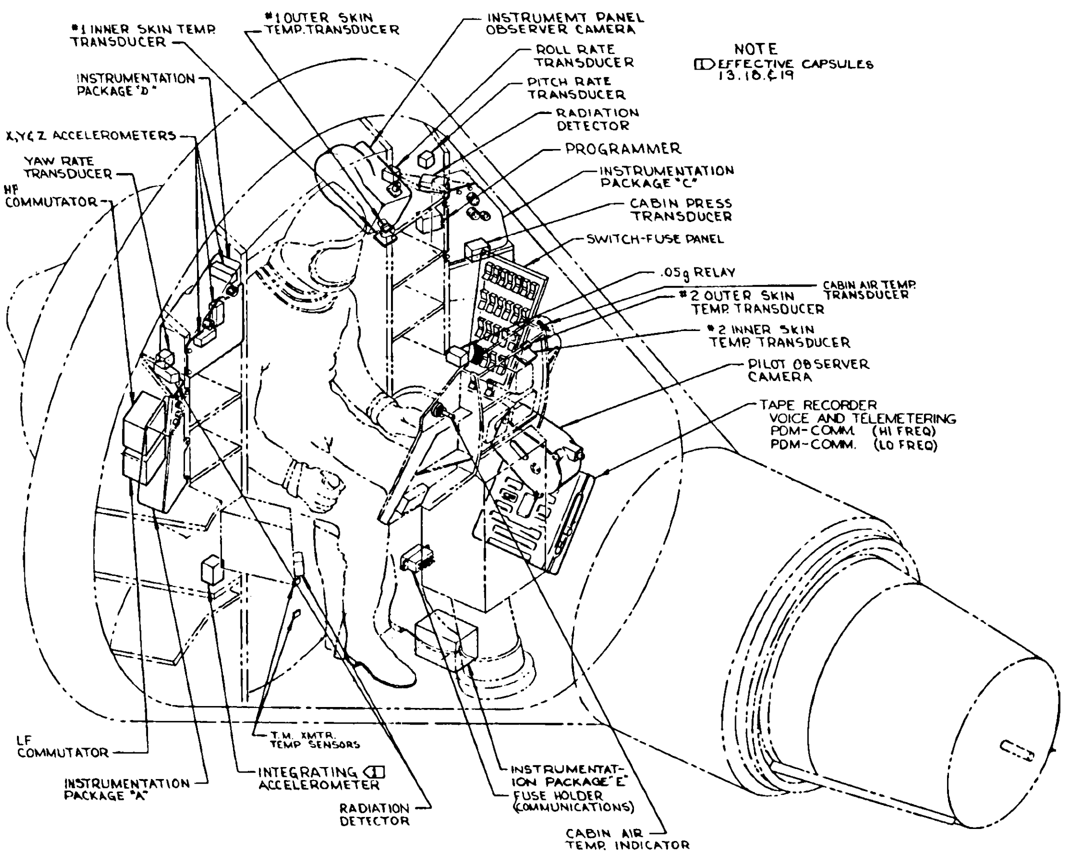


Figure 3: Shown here is a cutaway drawing illustrating the location of the onboard voice and data tape recorder for the Mercury spacecraft. The tape recorder is the large square box shown mounted on the inside spacecraft bulkhead wall, to the lower left of the main forward instrumentation panel as viewed by the seated astronaut. This drawing originally appeared in the *Mercury Familiarization Manual, NASA CR-55226* as published by McDonnell Aircraft SEDR-104-3, Section 13—Instrumentation Systems, page 13-3, publication date: 1 November 1961, revised 1 February 1962.

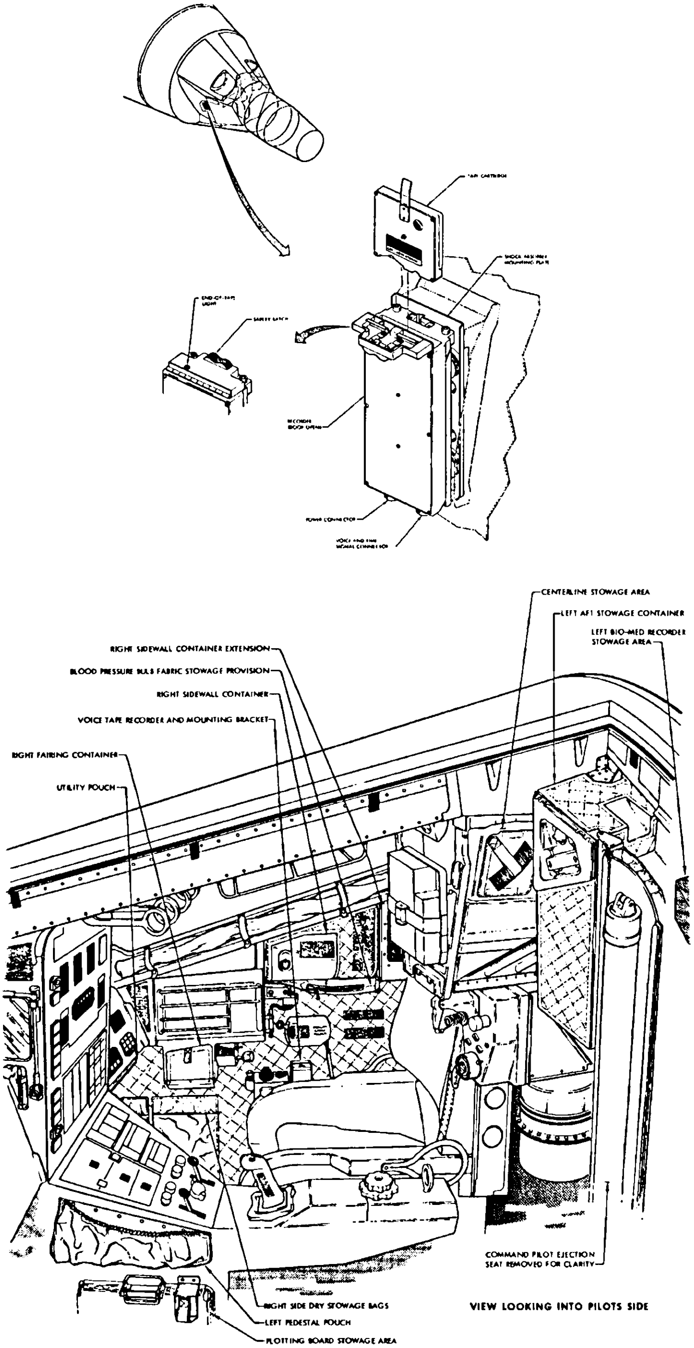
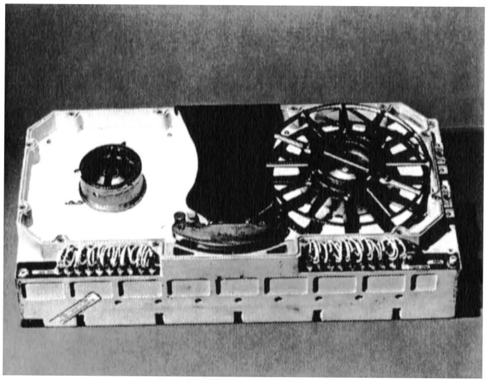


Figure 4: These two drawings show the onboard Gemini voice tape recorder and the relative position of the unit inside the Gemini cockpit. The actual position of the tape recorder varied from spacecraft to spacecraft. Drawings taken from the *NASA Project Gemini Familiarization Manual, Long Range and Modified Configurations*, Manned Satellite Spacecraft, McDonnell, SEDR 300 Volume 1, 30 September 1965.



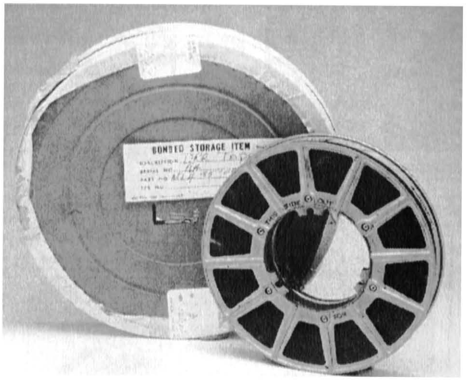


Figure 5 (left): The Apollo Command Module's onboard Data Storage Equipment (DSE) is shown here with outer cover removed. Shown at right is one of two eight-inch reels that spooled the 2,250 ft of 1-in Mylar magnetic tape through the 14-track read-write heads. The DSE was a self contained unit housed in the CM's lower equipment bay. NASA Photo No. S66-22993.

Figure 6 (right): Shown above is the actual spool of magnetic tape removed from the DSE used during *Apollo 15*. The 1-in wide Mylar tape is shown contained on the original 8-in diameter metal. This particular item sold to a private collector for nearly $3,000 during a Superior Galleries Space Memorabilia Auction held in May 2000.

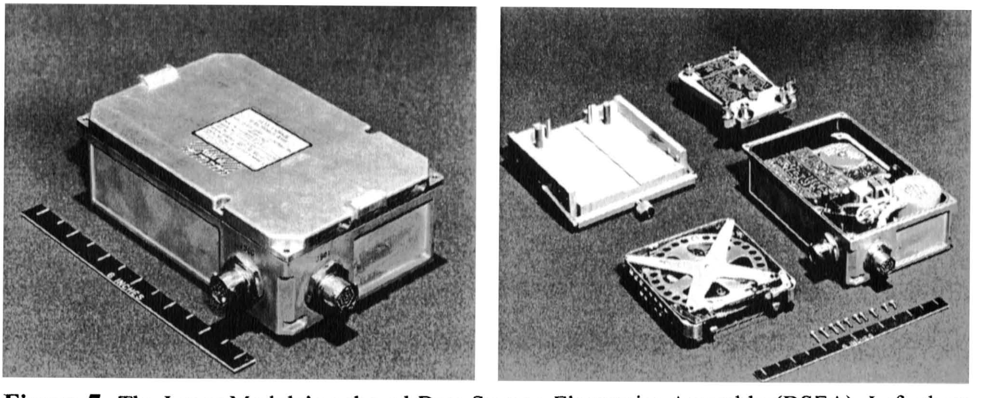


Figure 7: The Lunar Module's onboard Data Storage Electronics Assembly (DSEA). Left photo shows the finished unit. Right shows the DSEA, with cover and tape cartridge removed, revealing the interior electronics. Note the tape cartridge loader tool in the upper right portion of the right photo. NASA Photo No. S73-37044 and S73-37047.

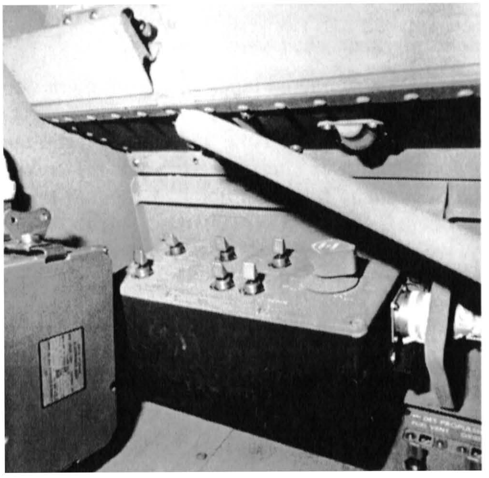



Figure 8: Left photo shows the DSEA in its mounted position inside LM-11 (*Apollo 16*'s LM "Orion") during final closeout. The right photo shows the DSEA's relative position behind the commander's station onboard a LM trainer. NASA Photo No. S72-35124 and No. S70-30949.

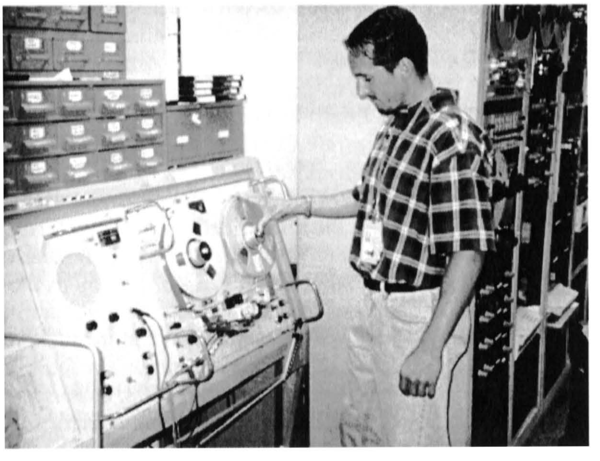



Figure 9: Left photo shows copies of the original mission control audio tapes as they are stored in the public affairs vault at NASA JSC in Houston, Texas. Right photo shows the last remaining operational 30-track Soundscriber tape recorder as originally used in Mission Control. NASA JSC audio engineer Greg Wiseman is shown at work dubbing a tape to the newer recording equipment seen in the background. Photos courtesy of the author.

Reference Notes

[1] In a classic example of the importance played by the original audio tapes and resulting mission transcripts, the crew of *Apollo 13* never actually said "Houston, we have a problem." On Monday, 13 April 1970 at 9:07 p.m. CDT (Ground Elapsed Time 55:54:53) oxygen tank number 2 explodes onboard the Service Module, forever altering history for the crew of *Apollo 13*. Immediately after the explosion, Command Module Pilot Jack Swigert reports to Houston "I believe we've had a problem here." (The PAO commentary Air-to-Ground transcript records Swigert as saying "Hey, we've got a problem here.") Jack Lousma, the CAPCOM on duty at the time replies back "This is Houston. Say again, please." Then mission Commander Jim Lovell comes on the loop and says "Houston, we've had a problem. We've had a main B bus undervolt." Only Hollywood and the media continue to mislead the public as to what exactly was said. "*Apollo 13* Technical Air-to-Ground Voice Transcription" as prepared by the Test Division, Apollo Spacecraft Program Office, NASA Manned Spacecraft Center, Houston, Texas, April 1970, 167. Also refer to page 231 of the "PAO Commentary Air-to-Ground Voice Transcription."

[2] President John F. Kennedy made his famous "Freedom's Cause" speech before a joint session of Congress on 25 May 1961 in which he set forth the goal to land a man on the Moon before the end of the decade.

[3] Author Andrew Chaikin points out in his book *A Man on the Moon* that this quote "would be forever footnoted." Armstrong reported after his historic flight that he had intended to say, "one small step for a man," but somehow the indefinite article did not make it to the final transmission. In a 1971 interview, writer Robert Sherrod asks Armstrong whether the "a" had been lost in the transmission or just forgotten. Armstrong simply replied "We'll never know." In listening to the actual voice tapes and noting the rhythm and cadence in Armstrong's voice, it sounds obvious that the "a" was forgotten, not lost. Besides, the phrase does not make sense without the missing "a." Refer to Andrew Chaikin's *A Man on the Moon: The Voyage of the Apollo Astronauts* (New York: Viking Penguin Books, 1994), 209. Also refer to "*Apollo 11* Technical Air-to-Ground Voice Transcription" as prepared for the Data Logistics Office, Test Division, Apollo Spacecraft Program Office, NASA Manned Spacecraft Center, July 1969, 379; "*Apollo 11* Spacecraft Commentary" transcript, 16–24 July 1969, 378. The interview by Robert Sherrod with Neil Armstrong was conducted on 22 September 1971 at NASA Headquarters. Audio copies of this interview can be found in the history collections at both NASA Headquarters and the Johnson Space Center. As to the origins of Armstrong's famous words, Armstrong mentions in the Sherrod interview that he had given some previous thought to what he would say when he first stepped onto the lunar surface but that he had not written anything down. A memo released by NASA Headquarters several months prior to the launch of *Apollo 11* may have given Armstrong the initial inspiration for the words that he final used. Distributed on 19 April 1969 by Willis H. Shapley, NASA's Associate Deputy Administrator and directed to Dr. George Mueller, Associate Administrator for Manned Spaceflight, the subject of the memo is "Symbolic Items for the First Lunar Landing." The memo outlines ideas and discussions that emerged from members of the Symbolic Activities Committee regarding symbolic activities associated with the first lunar landing, including articles to be left on the Moon and articles to be taken to the Moon and returned. The memo specifies that "the intended overall impression of the symbolic activities and of the manner in which they are presented to the world should be to signalize the first lunar landing as an historic forward step of all mankind [underline added by author for emphasis] that has been accomplished by the United States of America." Though there is no direct evidence linking this document to having influenced Armstrong in the formulation of his chosen words, the memo's release date three months prior to launch combined with the fact that the crew must have been consulted at some point by the symbolic activities committee regarding its activities

meant that Armstrong was aware of what was being considered. In addition, this committee appears to have been made up of senior management officials both at NASA Headquarters and in Houston. As a result, Armstrong along with his crewmates most certainly was reminded of the importance of the "intended overall impression of the symbolic activities" that their mission would bring and that the "historic step for all mankind" phrase used by the committee may have remained in Armstrong's mind long enough for him to incorporate portions thereof into his famous lunar surface quote.

[4] Author interview with James Gibbons, 21 August 2000.

[5] Author interview with Paul Fjeld, 27 July 2000.

[6] *Project Mercury Familiarization Manual,* NASA CR-55226, McDonnell Aircraft SEDR-104, publication date: 1 November 1961, Section 13—Instrumentation Systems, page 27, paragraph 64; page 31, paragraph 82. The combined data/voice recorder has seven channels with channel assignments as follows: channel 1—HF VCO output (basically data converted into audio tones); channel 2—not used; channel 3—voice communication; channel 4—not used; channel 5—LF commutator PDM (data that is slow changing in nature); channel 6—not used; channel 7—HF commutator PDM (faster changing data). Channel assignments did change from each mission. Tape speed was 17/8 inches per second, though the recorder could be converted to 15 in/sec. Tape capacity was 4,800 ft of 1/2-in wide Mylar base tape. The tape transport consisted of a capstan drive, supply reel, and take-up reel mechanism. A DC motor was used, through reduction gearing, for the capstan drive. A limit switch was provided to interrupt recorder power should the tape break during the mission.

[7] The voice tape recorder for Gemini was located inside the cabin in a vertical position between the pilot's seat and the right hand inside wall on *Gemini 3–7*. On *Gemini 8–12*, the recorder was located on the left-hand sidewall, aft of the abort handle. The voice tape recorder assembly consisted of the recorder, tape cartridge, and shock absorber mounting plate. The recorder was 6.25 inches long, 3 inches wide, and weighed 20 oz. Each removable tape cartridge was 2.25 inches square and 3/8 inches thick and weighed two oz. The recorder tape door contained a red plastic lens so that light from the end-of-tape bulb was visible. A safety latch prevented accidental opening of the door. Pressing down on the latch and sliding it sideways opened the door. When the latch was released, the spring loaded hinge caused the door to open, exposing the tape cartridge removal tab. Each tape cartridge contained about 180 ft of magnetic tape, a supply reel, a take-up reel, and associated gears and clutches. The recorder was a two-channel transistorized unit. One channel was for the voice circuit, the other for a digital timing signal so that voice may be correlated with data. Either VOX or a continuous/momentary switch could energize the voice tape recorder. The end-of-tape circuit was energized by conductive foil on the tape, causing the end-of-tape light to illuminate. The pilot could replace the tape cartridge and resume recording. Each tape cartridge provided one hour of recording time. The tape speed was 0.6 inches/sec. *NASA Project Gemini Familiarization Manual, Long-Range and Modified Configurations,* Manned Satellite Spacecraft, McDonnell, SEDR 300 Volume 1, 30 September 1965.

[8] Author telephone conversation with John Young, 9 November 2000.

[9] *Gemini 6* Technical Debriefing, 20 December 1965.

[10] One of the more interesting air-to-ground exchanges that occurred during the Gemini program was brought to light as the result of a more recent request by a film crew. A production company was putting together an anniversary tribute to the original 1960s television comedy series "Get Smart." The company contacted NASA's Johnson Space Center to inquire about obtaining an audio snippet from *Gemini 7*. Frank Borman and Jim Lovell experienced a rather embarrassing incident during their record-breaking mission. While spending

nearly two weeks orbiting Earth inside their spacecraft, a spacecraft with interior crew space equivalent to "the front seat of a Volkswagen," a urine sample bag broke while in the hands of Jim Lovell "spilling" its contents inside the spacecraft. When mission control heard about the incident, the flight surgeon on duty at the time could not help but reply "Sorry about that, chief" a common remark made by "Get Smart's" bumbling agent Maxwell Smart. The film crew wanted the audio segment that included the show's popular catch phrase that was uttered during *Gemini 7* to be included in their special. The mission transcripts were consulted, and the comical exchange was found, which helped audio engineers locate the actual segment on the original air-to-ground voice tapes for the production crew. Here is the transcribed portion of the incident as it originally appeared in the "Gemini VII Voice Communications (Air-to-Ground, Ground-to-Air and On-Board Transcription)", Volume II of III, MAC Control, pages 348–349:

117:47:49 (LOVELL) Serial number 95573-485-3 just came to pieces in my hand. Thanks a lot, doctor.

117:49:53 (LOVELL) Yes. One of his urine samples just came to pieces in my hand.

117:49:58 (CC) Just came to pieces?

117:50:02 (LOVELL) That's affirmative.

117:50:03 (CC) Before or after?

117:50:05 (LOVELL) After.

117:50:06 (CC) Very good. You just struck a blow.

117:50:10 (BORMAN) Help!

117:52:47 (CC) *Gemini 7*, Houston.

117:52:49 (BORMAN) Yes.

117:52:51 (CC) Flight surgeon's message is, "Sorry about that, chief."

[11] What about the "beep"? Those fortunate enough to listen to any of the actual mission control air-to-ground audio tapes, will notice a high-pitched beep emitted before and after every air-to-ground communication between mission control and the astronauts. This sound is called a Quindar tone and Steve Schindler, an engineer with voice systems engineering at NASA's Kennedy Space Center, offers the following history of its origins:

> Quindar tones, named after the manufacturer of the tone generation and detection equipment, are actually used to turn on and off, or "key," the remote transmitters at the various tracking stations (MILA, Bermuda, Australia, et cetera) that were used to communicate with the Mercury through Apollo spacecraft and, in some cases, are still used with the Space Shuttle. A one-half second tone burst is generated when someone in a control room depresses the push-to-talk (PTT) button of their headset. The decoder at the remote transmitter site detects this tone and keys the transmitter. When the PTT button is released, a different frequency tone burst is generated. When the decoder detects this second tone, it unkeys the transmitter. Because the telephone lines between the control rooms and the remote transmitters were originally designed to carry only voice frequencies, the tones had to be in the voice frequency range ("in-band signaling") and thus audible to humans. The tone signaling could have been done on a separate phone line, but to keep costs down, signaling and audio were done on the same line. Although it usually worked well, there were a couple of peculiarities with this system. If the transmitter was keyed and the telephone line connection broken, the transmitter would never get the tone to turn off. To prevent this there was a "transmitter on" light at each remote site that would come on when the transmitter was keyed. Someone was supposed to monitor the circuit and if the audio dropped, but the "transmitter on" light was still on, they would have to manually unkey the transmitter. Also, just before communications was handed over to a new tracking station, the key-unkey tone pair was sent 10 times to ensure that everything was functioning correctly. This was done before the audio was patched to the tracking station's line so it wasn't heard in the

control room or on NASA select audio. The Quindar system was actually built from a piece of equipment that was used to put multiple teletype circuits on a single phone line by means of frequency domain multiplexing. Because replacement parts are no longer available, an "out-of-band signaling" system was installed several years ago for the transmitters located in the U.S. This system uses a continuous tone that is below the normal audio frequency range. When the tone is present, the transmitters are keyed. When the tone is not present the transmitters are unkeyed. It worked fine, but the Astronaut Office complained about the lack of tones, which everyone had become accustomed to as an alert that a transmission was about to start. So, the Quindar tone generator, which was still installed in case it was necessary to key the transmitters at an overseas site, was re-enabled.

From author e-mail and voice correspondence with Steve Schindler dated 4–6 October 1999.

[12] Command/Service Module Systems Handbook CSM 114, 23 August 1972, MSC-07274.

[13] Apollo Operations Handbook Block II Spacecraft, Volume I Spacecraft Description, SM2A-03-Block II-(1), 15 October 1970, Section 2 "Systems Data."

[14] Apollo Operations Handbook Lunar Module LM10 and Subsequent Volume I Subsystems Data, NAS 9-1100, Grumman Publication LMA790-3-LM10, 1 April 1971.

[15] Leach Corporation is still in business today. Though larger and more diversified than during the time of Apollo, it is now known as Leach International and is based in Buena Park, California.

[16] Paul Fjeld phone interview with David O'Brien, 4 August 2000.

[17] Paul Fjeld phone interview with David O'Brien, 4 August 2000.

[18] "Grumman Flight Performance Evaluation Report on the *Apollo 11* DSEA Malfunction, Flight Anomaly #2" (360-05-10).

[19] This total number of 50,000 pages for the Skylab transcripts is a rounded figure based on the 47,444 pages of mission transcript scanned to date by the author. The author attempted to locate every known mission transcript for Skylab that was found in the history collections of JSC, Headquarters, and Kennedy Space Center. In addition, this author made a sincere effort to find any documentation that would address the production costs of the mission transcripts. The only document found was a memo at JSC dated 30 October 1972 from Alfred A. Bishop, Manager of the Mission Office to the Skylab Program Manager titled "Skylab Voice Transcripts." In this memo, Bishop addresses a means to reduce the costs of the voice transcript task stating that "The costs for preparing voice transcripts for Skylab have been estimated as approximately $900,000 for SL-3 and SL-4. This cost includes support to PAO and FCOD for transcribing, debriefings, and PAO releases and for the printing of these transcripts." This author used this figure and rounded up to $1 million in order to include the cost of SL-2 realizing that this figure most likely is a conservative one.

[20] The Space Tracking and Data Acquisition Network (STADAN) was a worldwide network established to support all NASA's Earth and near-Earth orbiting spacecraft programs. It consisted of 19 fixed stations and 2 mobile stations located in a band that stretched around the globe between latitudes 50 degrees north and 50 degrees south. For the Skylab program, 12 ground stations were used: Merritt Island, Florida; Bermuda; Ascension Island; Grand Canaria; Carnarvon, Australia; Guam; Hawaii; Corpus Christi, Texas; Goldstone, California; Canberra, Australia; Madrid, Spain; and Newfoundland, Canada. The instrument ship "Vanguard" (VAN) was also called back into service for Skylab from Apollo and was stationed at the port of Mar Del Plata, Argentina, to help ensure additional coverage in the southern hemisphere. The fleet of eight Apollo Range Instrumentation Aircraft (ARIA) was also utilized to help fill in any anticipated gaps in coverage.

[21] **Quick-look air-to-ground**—These transcripts are a verbatim transcript of all air-to-ground conversations originally prepared in near-real time with a minimum amount of editing. At the end of each Skylab pass, the audio tape recorded from that pass was annotated by public affairs with start and end times in 10-minute tape segments. The typists then transcribed the voice using a Magnetic Tape IBM Selectric Typewriter. An editor would review the transcript while listening to the voice tape and make any required corrections. The IBM Selectric Magnetic Tape typewriters were state of the art during the early 1970s allowing typists to record their keystrokes onto a magnetic tape. This magnetic tape could then be replayed by another similarly equipped typewriter, which would automatically type out a duplicate transcript without having the typists lift a finger. The corrected copy then went to printing and distribution to mission operations users, while the typewriter magnetic tape was electronically transmitted to the Marshall Space Flight Center where copies would be made on similar equipment. All of this was done in a matter of hours after the initial audiotape became available to the public affairs office; **Quick-look dump-voice**—These transcripts were produced on receipt of the dump-voice tapes from the Mission Control Center and were initially distributed only to mission operation users at JSC and the Marshall Space Flight Center. These tapes have voice on one track and an electronic time code on another. A typist transcribed the voice using an electronic digital time reader, which provided the time code annotations. On proof and editing, as with the quick-look air-to-ground transcripts, the magnetic tape was used to electronically transmit copies to the Marshall Space Flight Center. These transcripts are a verbatim transcript of all the dumped voice, except in-flight debriefings. The transcripts are unedited and contain at least one time annotation per page of transcript. In addition, a time annotation was inserted any time 20 minutes or more elapsed with no voice communication. The time of the end of the tape was also inserted; **Technical air-to-ground**—These are the final edited, verbatim, and time-annotated transcripts. These were prepared and distributed in increments of approximately 1-1/2 hours of elapsed mission time. Edited to assure technical and timing accuracy and to minimize errors, no material was removed during the editing process. Each utterance is annotated as to the speaker (that is, commander, pilot, science pilot, or capcom) and the start of each utterance related to operations in progress is time annotated. In addition, any significant item, such as "Marks," end of countdown sequences, indications of switch activations, et cetera, is time annotated. All time annotations are in Greenwich Mean Time (GMT) to the nearest second. The technical transcripts were begun immediately after the quick-look transcripts became available with editors using the quick-look transcripts as the basis for their first drafts. The transcripts were retyped, errors and omissions corrected, and time annotations inserted. Magnetic tapes containing both voice and timing signals were used for the final edit and time annotations. Complete mission technical air-to-ground transcripts were compiled approximately one month after the end of each Skylab mission; **Technical dump-voice**—These are the final edited and time annotated transcripts, produced incrementally on an individual dump basis. Editing, time annotation, and scheduling are identical to the technical air-to-ground transcripts. Complete transcripts of the dump voice were compiled approximately one month after the end of each Skylab mission. It should be pointed out that one copy of both the quick-look and final technical dump voice transcripts were reviewed and edited by the Life Sciences directorate at JSC in order to eliminate any crew medical and medical experiment data from the finished transcripts. No combined air-to-ground and dump-voice transcripts were made; **In-flight debriefing**—This is a special edited, but not time annotated, dump-voice transcript of the weekly in-flight crew debriefings. Editing is identical to the other technical transcripts except that only the beginning and ending of the debriefing is time annotated. The in-flight debriefings are included in the finished technical dump-voice transcript volume for each mission. "Skylab Voice Transcription Plan" as prepared by the Program Operations Office Test Division Instrumentation Integration Branch, NASA Johnson Space Center, July 1973, 1–6.

[22] Memo "Private Communications for Skylab" from James Fletcher, NASA Administrator, 29 March 1973. Memo "Private Air-to-Ground Voice Communications" from Kenneth S. Kleinknecht, Skylab Program Manager, 7 May 1971; Memo "Request for Editing Out Medical Experiment Data from Skylab Voice Transcripts" from Charles A. Berry, Director of Medical Research and Operations, NASA Johnson Space Center, 30 August 1971;. Memo "Skylab Air-to-Ground Communication" from Kenneth S. Kleinknecht, Skylab Program Manager, 9 November 1971; Memo "Policy on Voice Transcript" from Kenneth S. Kleinknecht, Skylab Program Manager, 22 November 1971.

[23] David J. Shayler, *Skylab: America's Space Station* (New York: Springer-Praxis Publishing, 2001), 284–285.

[24] Carr may be referring to promethazine hydrochloride (an anti-nausea plus sedative) plus ephedrine sulphate (stimulant), which may have been called "prom-eph" by the astronauts. Thanks to Dr. John Charles of NASA's JSC Life Science directorate for clarification on this reference.

[25] "Skylab 4 DSE Voice Dump Transcription," tape dump 320-1, 16 November 1973—tape dump 328-04, 24 November 1973. This particular exchange appears on page 15 of 19 Dump Tape 321-01 transcript, physical page number 107.

[26] "Skylab 1/4 Technical Air-to-Ground Voice Transcription" prepared by Test Division Program Operations Office, November 1973, (JSC-08652). This particular exchange appears on TAG Tape 322-01/T-20 page 2 of 3/106 transcript, physical pages 100–101 of 722.

[27] Interestingly enough, the privacy issues raised in the tapes and transcripts during Skylab and the subsequent enactment of the Privacy Act of 1974 may have collectively combined to influence the way NASA would approach medical confidentiality during the Shuttle era. All Apollo, Skylab, and ASTP in addition to all preceding reports identified medical issues by specific crewmember, something that NASA cannot do nor will tolerate today. Though difficult to find specific documents that seem to shed any light on the details of NASA's change in policy toward handling crew medical confidentiality, one document appears to be the source of NASA's current policy. A memo dated 15 December 1982 from Harold Stall, then Director of the NASA Johnson Space Center Public Affairs Office, was distributed to all senior staff at JSC. Titled "STS Crew Medical information," Stall presents a proposed new policy on handling all crew medical information and outlines the following:

> Significant crew medical problems that affect or have the potential to affect mission operations will be reported to the media at the time the problem is brought to the attention of the flight director; Medical problems which the flight surgeon feels do not merit the attention of the flight director can be assumed to have no potential impact on the mission or the manned flight program and will not be reported to the media; If necessary, flight crewmembers will be asked to sign a waiver before flight permitting release of medical information protected by the Privacy Act and identifying the individual affected; Should one or more crewmembers decline to sign a waiver, NASA will advise the media of this fact prior to flight and will not divulge the names of affected crewmembers in discussing medical problems; NASA will continue to provide information normally released to the media and not otherwise restricted even though information such as timelines, crew activity plans and air-to-ground conversations may lead to media speculation on the health status of individual crewmembers not named by NASA; NASA will respond promptly and fully to media inquiries on the nature of significant crew medical problems, related symptoms, course of treatment including medications, prognosis and anticipated impact on the mission or program insofar as these facts are known or my be ascertained.

[28] Author interview with Robert Legler and Gary Morse, Manager, Space Operations Services, NASA JSC, 17 October 2001.

[29] Author interview with Steve Nesbitt, NASA JSC, 4 September 2001.

[30] The following are all known mission transcripts available for Shuttle flights. These can be found either in the NASA Johnson Space Center PAO vault or in the JSC history collection housed in the archives at the University of Houston—Clear Lake: Approach and Landing Captive-Active (ALCA) flights of OV-101 *Enterprise* ALTCA1, ALTCA2, ALTCA3; Approach and Landing Free-Flights (ALTFF) of OV-101 *Enterprise* ALTFF1, ALTFF2, ALTFF3, ALTFF4, ALTFF5; STS-1, STS-2, STS-3, STS-4, STS-5, STS-6, STS-7, STS-8, STS-9, STS-41B, STS-41C, STS-41D, STS-41G, STS-51A, STS-51D, STS-51B, STS-51G, STS-51F, STS-51I. Note that STS-51C was the first DoD dedicated Shuttle mission, so no transcript was made available to the public. Mission STS-41C was the last Shuttle flight to have a complete air-to-ground mission transcript made. Transcripts for Shuttle missions after STS-41C consist only of preflight and post-flight press conference and change-of-shift briefings, in addition to mission highlights such as crew EVA, satellite retrieval, and associated in-flight science/experiment briefings.

[31] Mercury, Gemini, and ASTP used 30-track 1/2-inch tape, *Apollo 13* used 1/4-inch 7-track tape. Everything else used 1/4-inch 2-track tape. On the 30-track tapes, the IRIG or time code for Greenwich Mean Time (GMT) was always placed on Track 1. A 7-track tape is actually 8-tracks with the eighth track used for the IRIG.

[32] Author interview with Greg Wiseman, 25 May 2000.

[33] Author interview with Greg Wiseman, 25 May 2000.

[34] Copies of the CD-ROM *Apollo 13: A Race Against Time* can be purchased directly from Computer Support Corporation, 15926 Midway Road, Dallas, TX 75244; phone: 214-661-8960, FAX: 214-661-5429.

[35] Author e-mail correspondence with Michael Smithwick, 31 July 2001.

[36] Author interview with Nancy Hutchins, 16 July 2000.

[37] Paul Fjeld phone interview with David O'Brien, 4 August 2000.

[38] Paul Fjeld phone interview with Andrew Chaikin, 8 August 2000.

[39] Paul Fjeld phone interview with Andrew Chaikin, 8 August 2000.