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We have liftoff!

The story behind the Mercury, Gemini and Apollo air-to-ground transmissions

By Glen E. Swanson

Aboard every US manned spacecraft, from Mercury through Apollo, engineers installed tape recorders which, as part of their data-saving function, recorded astronaut intercom communications. These recordings were made during critical phases of each flight when the preservation of all data was essential. These tapes and their resulting transcripts reveal a different side to America's space program; one in which its astronauts are professional and profane, calm and excited, confident and nervous, healthy and sick - in a word, "human."

NASA

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) is Eugene F. Kranz (left), Flight Director for the Gemini VII White Team, and George M. Low, MSC's Deputy Director, reviewing a transmission tape received on December 9, 1965 from the Gemini VII spacecraft. In the background wearing glasses is flight controller Manfred von Ehrenfried.

Introduction

From the beginning, nearly every aspect of America'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…" to astronaut Neil Armstrong's triumphant words on the Moon "That's one small step for man, one giant leap for mankind," the Mercury through Apollo 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 mankind's first forays into space.

Beginning with Alan Shepard's first flight into space and continuing through the early Space Shuttle Program, NASA Public Affairs employed legions of typists stationed in telephone booth-sized rooms 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 transcripts within hours of when the astronauts first spoke the words.

The Pathfinding missions of Mercury and Gemini

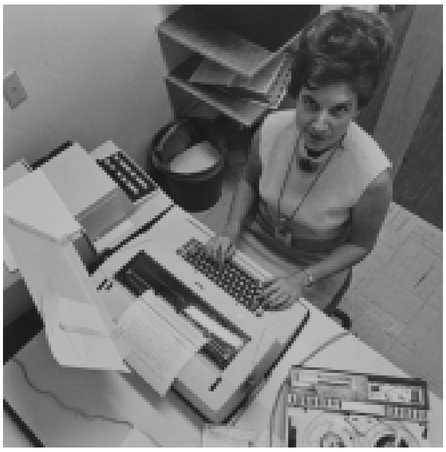
The Mercury spacecraft carried into space a combined onboard voice and data recorder. During the relatively short duration of each Mercury mission, these recorders ran continuously during launch and descent, capturing the voice of their precious human cargo. During orbital flights, the on-board recorders were set to automatic mode where they were on one minute then off three minutes. The on-board 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, analysed, and the voice data transcribed. [1]

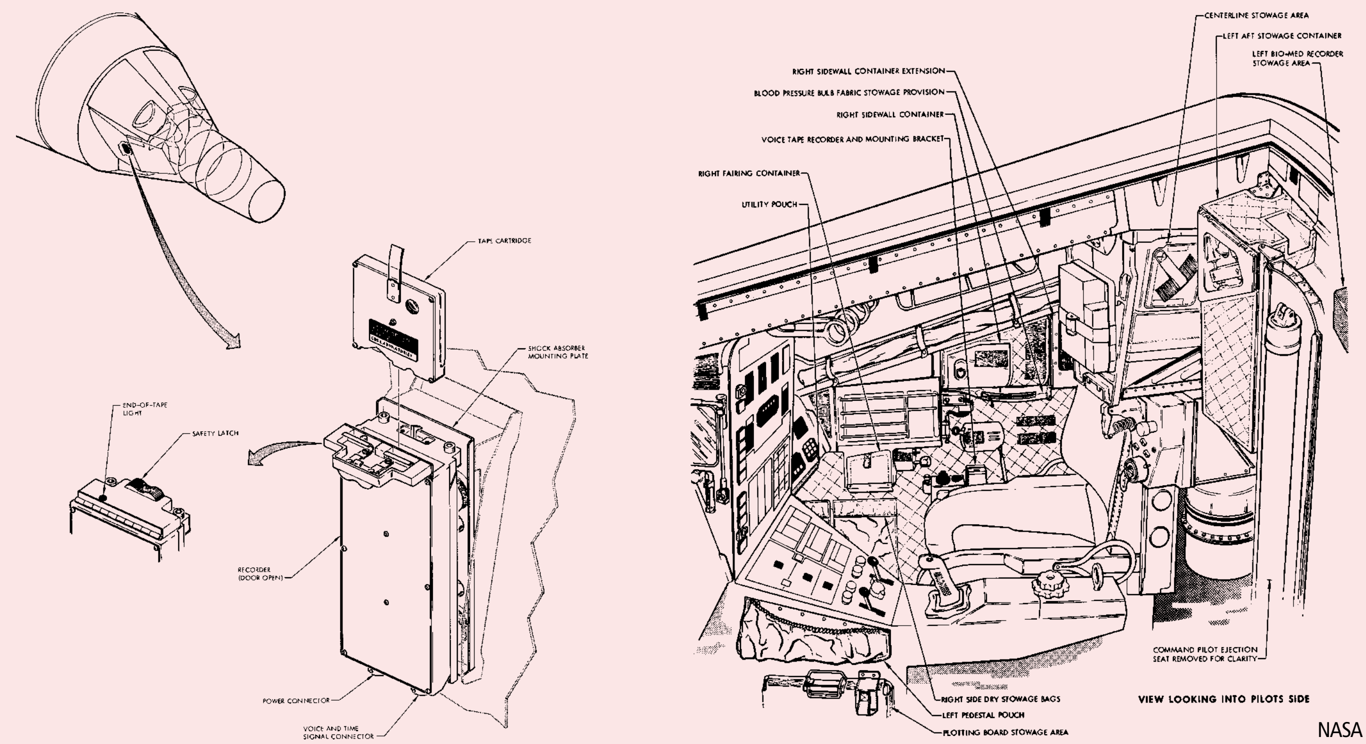
During the longer and more sophisticated follow-on two-person Gemini missions, onboard voice recordings were made using a small tape recorder mounted inside the spacecraft crew cabin between the pilot's seat and the right-hand inner side wall. This unit allowed the crew to record their personal observations on removable tape cartridges which were recovered after each flight for transcription. [2]

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. "It never really worked right throughout the whole program." [3]

Wally Schirra, commander of Gemini 6 noted the short comings of the tape recorder that he encountered during his flight. During the crew post-flight technical debriefing, he did not hesitate to describes 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

One of the legions of typists shown transcribing the air-to-ground audiotapes at NASA's Manned Spacecraft Center in Houston, Texas. NASA





NASA

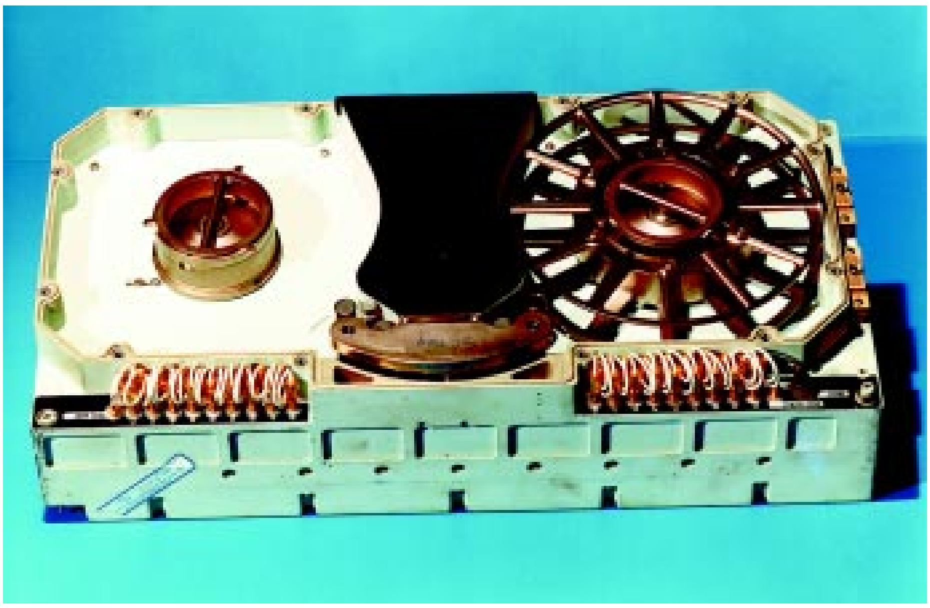
Above left: A detailed drawing showing the onboard Gemini voice tape recorder. Above right: Another drawing showing the relative position of the unit inside the Gemini cockpit. [2]

how critical this unit was to the mission and that the problem needed to be fixed:

> "I think it is about time that we recognised 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 realised 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 and real time, and I cannot stress this point enough and I will make this evident to management as well." [4]

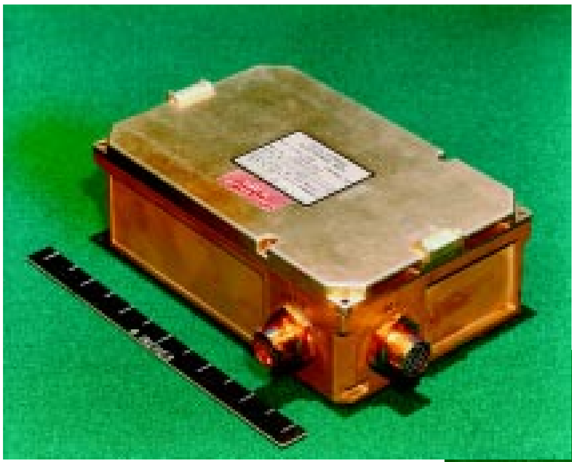
The resulting transcripts from these onboard voice recorders served to supplement existing air-to-ground narratives, filling in holes in the dialogue caused by periodic communication blackouts. On-board recordings were also made during re-entry since the blazing stream of ionised gas which engulfed the spacecraft as it fell back through the Earth's atmosphere, effectively blocked all radio communications with the ground, making direct communication impossible.

The Apollo Command Module's onboard Data Storage Equipment (DSE) is shown here with outer covered removed. Shown at right is one of two eight-inch reels that spooled the 2,250-feet of one-inch 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



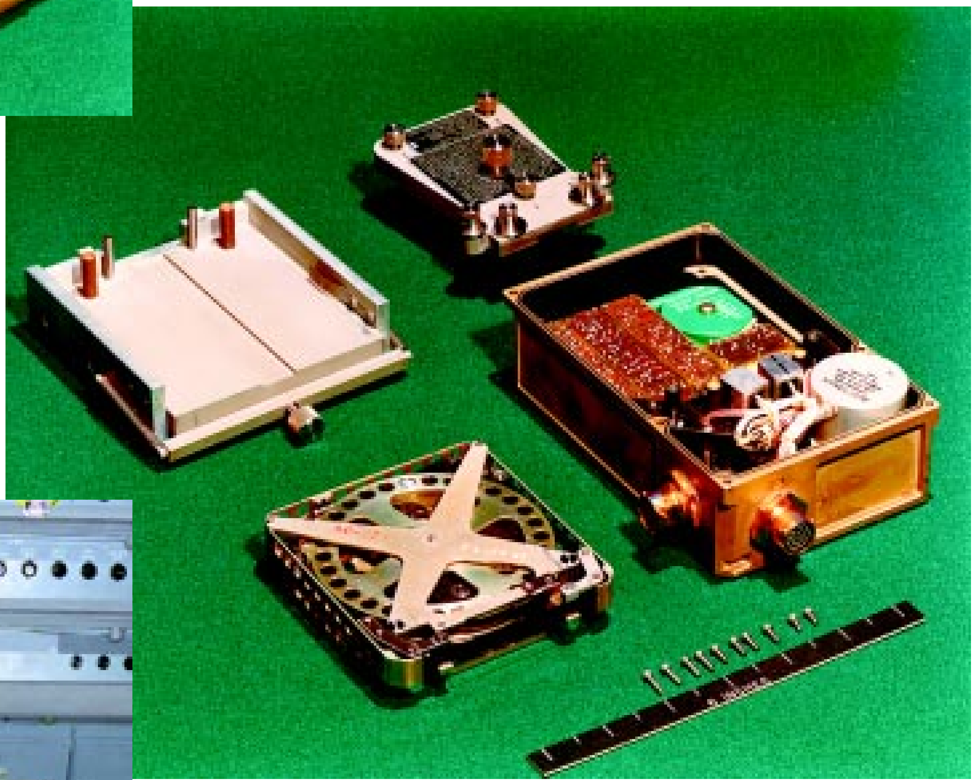
Project Apollo and the Lunar Landing Missions

As America moved closer to achieving President Kennedy's goal of landing humans 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 space flight, but two separate spacecraft: the



The Lunar Module's onboard Data Storage Electronics Assembly (DSEA).

A more detailed photo (below) showing the DSEA, with cover and tape cartridge removed, revealing interior electronics (note the tape cartridge loader tool in the middle upper right portion of this photo).



The DSEA shown in its mounted position inside LM-11 (Apollo 16's LM "Orion") during final closeout.

All photos: NASA

Arrow points to close-up of DSEA as installed behind the commander's station onboard a LM trainer.

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, re-enter the 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 which for the first time placed humans a quarter of a million miles away and out of direct radio communication 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 dump" of voice as well as data during the course of an actual mission. A tape dump involved downloading, via radio telemetry from the spacecraft, the onboard tape contents for either immediate or delayed playback on the ground.

Handling the recording of voice and data aboard 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 feet of one-inch Mylar magnetic tape through read-write heads. The 14-track tape had a storage capacity of over four hours of voice and data [5]. 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 communication with the 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 communication with mission control [6].

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

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Copies of the original mission control audiotapes are shown housed in the Public Affairs Office vault at NASA's Johnson Space Center in Houston, Texas.

single-speed, four-track, magnetic tape recorder to record up to 10-hours of voice communications from inside the LM [7]. 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. 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 aboard 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 due to 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-inch glass thermometer that had accidentally been left inside the spacecraft after a ground test. Zero-g must have loosened the thing and, after re-entry, 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." [8]

A few problems were associated with the

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 in the background. Glen E. Swanson

Glen E. Swanson

Spare parts found in another Soundscriber along with skill, patience and a little luck helped Wiseman repair the original unit so that they could successfully dub the remaining 30-track tapes. Shown here is a close-up of the Soundscriber read/write heads, complete with bungee cords.

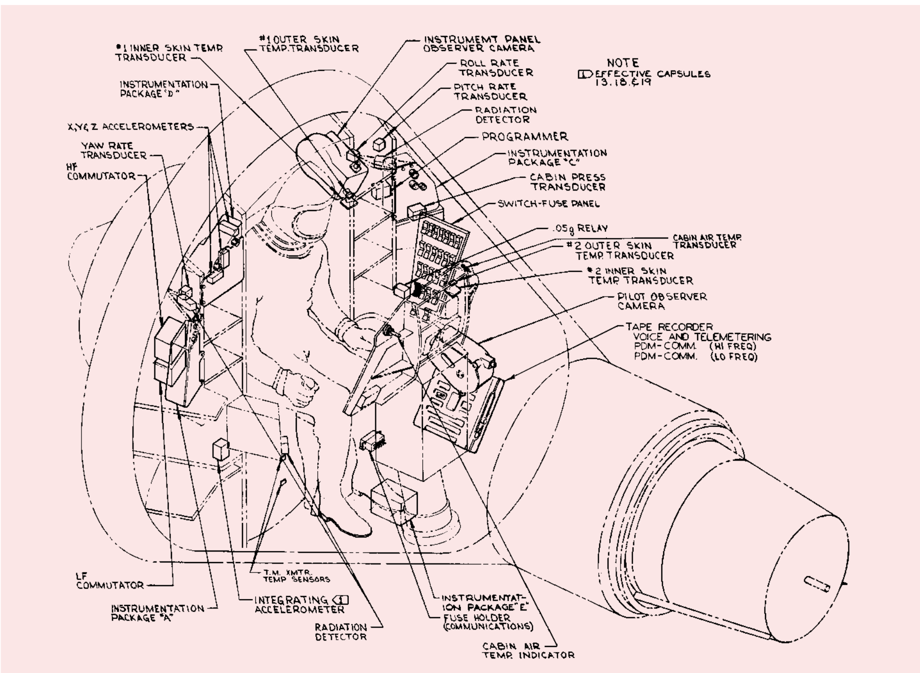
LM's tape recorder. Originally, the DSEA was designed to start recording only when the astronaut spoke. It would then automatically shut down when there was no sound, only to start back up again when the astronaut resumed speaking. This method helped conserve the 10-hours maximum of recording tape, capturing 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 centred upon 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!" [9]

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 background 400hz 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 [10].

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 flat 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 February 1, 1962.



Where Are the Air-to-Ground Audiotapes Today?

The original mission control audiotapes 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 tape recorder which recorded audio from up to 30 different flight controller console positions per mission. Copies of these audiotapes are currently housed in the Public Affairs Office vault at NASA's Johnson Space Center in Houston, Texas.

Examples of loops recorded during a mission include audio from the flight director, capsule communicator (CAPCOM) and public affairs officer (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 communications between the CAPCOM and the astronauts in their spacecraft. The PAO commentary loop includes mission status updates and other observations given by the public affairs officer who monitored each mission from his console in mission control. The resulting PAO commentary transcript was made available to the media during and after each mission.

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 still used by NASA today. 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 recognised this need and soon came to realise the only way to preserve the older audio was to transfer the 1-inch, 30-track tapes to a newer format.

Enter Greg Wiseman, an audio engineer with JSC's Public Affairs Office. Wiseman led the task of dubbing the remaining 1-inch, 30-track mission audiotapes containing audio from the Mercury through Gemini missions as well as tapes from the Apollo-Soyuz Test Project (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 for nearly a year. "The original Soundscriber was found onsite in building 145A, 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 co-worker 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." [11] 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." [12]

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 the Apollo-Soyuz Test Project. "We now have all of the older format mission audiotapes 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."

The story behind the "Beep"

"Those fortunate enough to listen to any of the actual mission control air-to-ground audiotapes, will notice a high-pitched beep emitted before and after every ground-to-air communication between mission control and the astronauts. This sound or beep 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, etc.) 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 signalling") and thus audible to humans. The tone signalling could have been done on a separate phone line, but to keep costs down, signalling 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 US 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 flight controllers and crew complained about the lack of tones. Flight controllers heard the tones at the beginning and end of each ground transmission to the spacecraft. Part of those same tones were transmitted to the spacecraft crew helping to signal to them the beginning and end of each ground transmission. As a result, everyone became accustomed to these tones. To "keep the beep" in communications, a tone generator was installed to simulate the original Quindar tones. A piece, or rather sound, of history has become tradition and now remains a standard part of US human spaceflight air-to-ground communications."

Why Record Voice and Make Transcripts?

Why was recording voice so important? An obvious need was the requirement by engineers for data to help with their systems analysis.

"At the conclusion of every mission, all subsystem managers gathered and assembled their data to evaluate problems," said James Gibbons, a retired NASA JSC employee who served as test engineer and data manager in the Test and Evaluation Division of the Apollo Spacecraft Program Office (ASPO). "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. Both the astronauts and flight controllers used the transcripts as well to help them recall key events." [13]

In addition to the obvious need by engineers for data, the press made use of the words to help

The NASA Mission Transcript Scanning Project

For the first time ever, NASA has digitally scanned all of 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 and placed them on a two CD-ROM set. Entitled The Mission Transcript Collection: US Human Space Flight Missions from Mercury Redstone 3 to Apollo 17 (NASA SP-2000-4602) this special CD-ROM collection contains 80 transcripts totalling nearly 45,000 pages of text covering every US human space flight from the first human Mercury mission through the last lunar landing flight of Apollo 17.

Through the combined efforts of the history offices at NASA Headquarters and the Johnson Space Center, searchable Adobe Acrobat PDF scans of these mission transcripts were made from the best available copies housed in NASA's historical archives. The need for a more efficient distribution form of this primary historical resource was prompted by numerous requests from researchers and the public for print copies of the mission transcripts. Because many of these transcripts number thousands of pages in size, producing hardcopies and distributing them is both an expensive and time-consuming task. In addition, duplication exposes the original copies to unnecessary handling and risk of damage. By making high-quality one-time scans and packaging them in a user friendly CD-ROM, complete sets of these documents become more easily available to the public with the added benefit of allowing users to do text searches using the scanned Adobe Acrobat PDF 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 audiotapes housed in NASA's archives from which many of these transcripts were made. Copies of the CD set are available free through NASA by sending a self-addressed, padded envelope with $4.00 affixed in postage (for North American Orders) or $8 affixed in postage for all overseas orders, to: NASA Headquarters Information Center, Mail Code CI-4, 300 E Street SW, Room 1H23, Washington, DC 20546-0001, PH: 202-358-0000.

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." [14]

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 over 2,000 pages in length. In addition, revealing every spoken word to the public during a mission sometimes proved to be a PR nightmare. More than one astronaut was known to be unhappy over having their every word, and perhaps every mistake, recorded, transcribed and laid bare for all the 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." [15]

The human side of the apparent "super human" 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 O'Brien. 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.'" [16]

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." [17]

The subtle humour 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." [18]

Notes

1. 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.
2. NASA Project Gemini Familiarization Manual, Long Range and Modified Configurations," Manned Satellite Spacecraft, McDonnell, SEDR 300 Volume 1, September 30, 1965.
3. Author telephone conversation with John Young, November 9, 2000.
4. Gemini 6 Technical Debriefing, December 20, 1965.
5. Command/Service Module Systems Handbook CSM 114, August 23, 1972, MSC-07274.
6. Apollo Operations Handbook Block II Spacecraft, Volume I Spacecraft Description, SM2A-03-Block II-(1), October 15, 1970, Section 2 "Systems Data."
7. Apollo Operations Handbook Lunar Module LM10 and Subsequent Volume 1 Subsystems Data, NAS 9-1100, Grumman Publication LMA790-3-LM10, April 1, 1971.
8. Paul Fjeld phone interview with David O'Brien on August 4, 2000.
9. IBID.
10. Grumman Flight Performance Evaluation Report on the Apollo 11 DSEA Malfunction, Flight Anomaly #2 (360-05-10).
11. Author interview with Greg Wiseman on May 25, 2000.
12. IBID.
13. Author interview with James Gibbons, August 21, 2000.
14. Author interview with Paul Fjeld, July 27, 2000.
15. Author interview with Nancy Hutchins, July 16, 2000.
16. Paul Fjeld phone interview with David O'Brien August 4, 2000.
17. Paul Fjeld phone interview with Andrew Chaikin on August 8, 2000.
18. IBID.

About the Author

Glen E. Swanson is founder of "Quest," the world's only publication focusing on the history of space flight. He currently works for NASA as the historian of the Johnson Space Center in Houston, Texas. During the summer he led a project to gather and scan nearly 80 mission transcripts, totalling some 45,000 pages of text.