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the missing
Apollo 11
tapes

Monitoring
and forecasting
space weather

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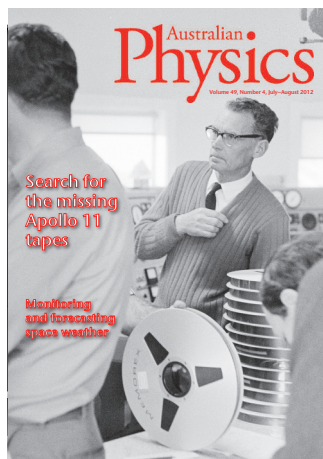
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Chief of the CSIRO Division of Radiophysics, Taffy Bowen, in the control room at Parkes during Apollo 11 [see p.106]. Bowen was the driving force behind the construction of the Dish. [courtesy: CASS]

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Search for the Missing Apollo 11 Tapes

John Sarkissian

It was one giant leap for mankind and it was taken at 12:56 PM (AEST) on 21 July 1969. Six hundred million people, one sixth of mankind at the time, witnessed the Apollo 11 moonwalk live on television. As a six-year old school boy, I was one of those millions. Sitting cross-legged on the floor of the school assembly room with my fellow first graders, we watched the events unfold on a small black and white television screen perched at the front of the assembly room. We were spellbound by the dark, fuzzy images flickering on the screen. How did they do it? How did those pictures get from the Moon to my Sydney school? Why were the pictures so dark and ghostly looking?

Little did I know then, but three decades later I would find myself working at the CSIRO Parkes Observatory, at the very place those images were received and that I would have the opportunity to answer those childhood questions. This article is a personal account of my research into the Parkes support of Apollo 11 and how it eventually morphed into a search for the missing Apollo 11 tapes. It's been a roller-coaster ride, with many highs and lows plus a few twists and turns to make it interesting. Along the way, I've met many fine and dedicated people, some of whom are now close friends. This is our story.

Some background

At 12:54 PM (AEST) Buzz Aldrin switched on the lunar module camera that would transmit the TV pictures of Armstrong descending the lunar module ladder. Three tracking stations received the signals simultaneously. They were the 64-metre Goldstone antenna in California, the 26-metre antenna at Honeysuckle Creek near Canberra and the CSIRO 64-metre dish at Parkes. The signals were relayed to Houston, where a controller selected what he thought were the best pictures for release to the US television networks and distribution to a worldwide audience.

In the first few minutes of the broadcast, Houston

alternated between its two stations at Goldstone and Honeysuckle Creek, searching for the best quality pictures. When they finally switched to Parkes, the pictures were so much better that they stayed with Parkes for the remainder of the 2½ hour moonwalk. From an analysis of the videotapes of the Extra Vehicular Activity (EVA) and of a recording of the NASA NET 2 communications loop (which controlled the TV reception), the timings for the TV switches are shown in the table.

Time (mm:ss)	Video Transmission
00:00	TV on (upside down) Picture is from Goldstone (GDS). Time is 02:54:00 (GMT)
00:27	Picture is inverted and is now the right way up. Very dark, high contrast image
01:39	Houston TV switches to Honeysuckle Creek (HSK)
02:20	Armstrong steps onto the Moon. The time is 02:56:20 (GMT)
04:42	Houston TV switches back to GDS. Picture is negative
05:36	Houston TV switches back to HSK
06:49	Houston TV switched back to GDS. Picture is positive again but still dark
08:51	Houston TV switches to Parkes (PKS). Remains with Parkes for the remainder of the 2½ hour lunar EVA

From these timings, and other evidence, it is clear that at the start of the EVA, Goldstone was experiencing problems with its TV, resulting in high contrast, dark images. The

Honeysuckle Creek pictures were better but they suffered from a lower signal-to-noise ratio, thus resulting in grainier images. The pictures from Parkes were the best of the three and it was these that NASA broadcast for the majority of the lunar EVA.

Television from the Moon

The Apollo Lunar Surface Camera was developed by Westinghouse and was a technological marvel of its time. The lunar module was power and bandwidth limited, so it was not possible to transmit commercial standard TV directly from the Moon. Instead, a slow-scan TV (SSTV) system was used that required less power and bandwidth. The SSTV system transmitted b/w pictures at 10 frames-per-second with only 320 lines-per-frame. In order to broadcast this to the watching world, it had to be scan-converted on Earth to commercial TV standards. An RCA scan-converter was used that operated on an optical conversion principle. It was a simple system that worked well on previous Apollo missions. Essentially, as each single SSTV frame was received on Earth, it was displayed on a small 10-inch b/w slow-scan monitor. A Vidicon camera was pointed at the screen and imaged the frame at the standard commercial TV frame rate. It was the output of this camera that was broadcast to the world. In this way, a 30 frames-per-second, 525 lines-per-frame, TV picture was achieved. As you can imagine, it's not an ideal method of scan-converting the pictures but it seemed adequate at the time.

The Goldstone TV was scan-converted on site and relayed directly to Houston via microwave relays and landline. The Honeysuckle Creek TV was scan-converted on site also, and relayed to the Overseas Telecommunications Commission (OTC) Paddington terminal in Sydney, referred to as 'Sydney Video'. Meanwhile, the Parkes baseband signals were relayed to Sydney Video, where the TV was separated from the telemetry stream and scan-converted there. At Sydney Video, a NASA controller would select the best of the Honeysuckle Creek or Parkes pictures, and pass that selection on to Houston. His selection would simultaneously be recorded onto 2-inch videotape on an

The Parkes Telescope tracking the Moon in a test a few weeks before the mission.



Ampex VR660 recorder. The selected TV would be sent via microwave relays to the Moree Earth Station in northern NSW, then via the Intelsat III geostationary satellite to the United States and then finally along the AT&T landlines to Houston. At Houston, the controller would select the best of the Goldstone or Australian feeds for worldwide distribution. In a further twist, the Australian selection at Paddington was split and sent to the ABC Gore Hill studios for distribution to Australian networks. Consequently, the Australian TV did not have to travel via satellite to the US and back again. This meant that a transmission delay was not present, so Australian audiences watched the moonwalk 300 milliseconds before the rest of the world!

It is clear that scan-converting the SSTV and relaying it to the world was not an ideal situation. Firstly, the picture being displayed on the scan-converter monitor had to be adjusted manually. This was a subjective exercise, as the scan-converter operator had to adjust the brightness and contrast settings to what he thought produced the best looking picture. Unfortunately, the operator at Goldstone was inexperienced, and with the pressure of the moment,



Sydney Video at the OTC Paddington Terminal. The RCA scan-converter is in the background with Elmer Fredd seated in front (red jacket). The TV comparison equipment is in the foreground, and the VR660 recorders are just off to the right. [courtesy: Richard Holl].

he got it wrong. At Sydney Video, the operator, Elmer Fredd, was vastly more experienced. He had helped design the scan-converter and knew it well. In December 1968, he had converted the TV pictures from Apollo 8 at Goldstone. It was no accident therefore, that the Parkes pictures looked the best. In addition, the slow-scan monitors in the scan-converters used high persistence phosphor screens so that the pictures could persist long enough for the Vidicon camera to image them. Unfortunately, a side effect of this was that the images, especially of bright, moving objects (like astronauts), persisted between frames, resulting in the ghosting of the images.

Another problem was that the scan-conversion process, introduced additional signal noise and a lower resolution picture. To make matters worse, relaying the signals via microwave relays, landlines and geostationary satellite added even more signal noise and transmission errors. The result of all these systematic problems was that the TV that the world saw was severely degraded and compromised. We could do much better today.

As the video and telemetry downlink was being received at the stations, it was recorded onto 1-inch magnetic data tapes at a rate of 120 inches-per-second. These tapes had to be changed every 15 minutes for the entire duration of the moonwalk. Clearly, if we could find these tapes, we could

replay them and recover the original SSTV pictures. With modern image processing techniques, we could enhance them even further and release them to the public.

The tape search begins

Soon after arriving at Parkes in 1996, I learned of a minor controversy about the exact time that the first TV from the Moon was received at Parkes. The Director of the Parkes Observatory at the time, John Bolton, had always insisted that he had received the TV signal from the very beginning when the camera was switched on at 12:54 PM (AEST). The Moon was not scheduled to come into view at Parkes until 1:02 PM – a full eight minutes later, so there was some doubt. However, I soon learnt that there were two feeds installed in the focus cabin on the day. Realising that the moonwalk was imminent, Bolton was able to receive the signals with the less sensitive off-axis receiver. He carefully aligned the off-axis beam on the Moon and was able to track it until it reached the telescope's 30-degree elevation horizon at 1:02 PM, after which he could track it normally with the main beam.

My calculations showed that this was indeed possible, but I wanted to know for certain. Also, the signal being received by the off-axis feed would have been unstable and probably of a much lower quality, so I wanted to know by

how much. I thought that if I could find the original data tapes that contained the signals recorded at Parkes, I could replay them and confirm my conclusions. At this time also, there was still some doubt about the sequence of switches in the broadcast of the TV, so by finding the tapes from the other stations, I could compare their picture quality with the existing video recordings and determine the sequence for certain. A bonus was that we could also recover the original SSTV, which I knew by then was of a much higher quality.

Beginning in the late 1990s I contacted various NASA centres requesting the whereabouts of the data tape recordings. I made countless phone calls, wrote emails and letters to whomever I thought might know where the tapes were located. But, it was all to no avail. No one seemed to know where the tapes were. In fact, many had trouble understanding what exactly I was after. I was convinced that the tapes must still exist somewhere, but where? In 2001 I obtained a Polaroid picture taken directly off a slow-scan monitor at Sydney Video. When compared to the existing scan-converted video image of the same scene, it clearly showed how much better the original SSTV was to the scan-converted videos. So, I persisted.

Also in 2001, the film *The Dish* premiered in the US and this prompted several past and present NASA personnel to contact me. Three in particular became good friends and search team members. Stan Lebar was the retired Westinghouse engineer who, in 1969, was the program manager for the Apollo Lunar Surface Camera. Dick Nafzger was the Goddard Space Flight Center (GSFC) engineer responsible for all ground systems hardware in support of Apollo TV in 1969, and was still with NASA. Bill Wood was a retired communications engineer who

was based at Goldstone in 1969. The search team was completed when, in 2002, I was contacted by Colin Mackellar, who is an amateur historian and the webmaster of the Honeysuckle Creek website. He is a trained geologist and an Anglican minister in Sydney. Together, we joined forces to search for, and recover, the SSTV recordings.

A breakthrough occurred in 2002 when a former technician from Honeysuckle Creek contacted his former colleagues and Colin Mackellar. He admitted that, in 1969, he had made an unauthorised copy of a data tape that he believed contained telemetry from the Apollo 11 lunar EVA. This caused great excitement. The tape had been stored in his garage for 33 years in less than ideal conditions. If it still contained data, the possibility existed that the SSTV could be recovered from it. Former Honeysuckle Creek personnel, Mike Dinn and John Saxon organised to have the tape transported to the Data Evaluation Lab (DEL) at the GSFC by the NASA representative in Australia, Neal Newman. The DEL contained the only machines in the world that could play and decode the Apollo data tapes. At the DEL, Dick Nafzger replayed the tape with his team. Unfortunately, they discovered that the tape only contained data from a 1967 simulation. The technician had copied the wrong tape. As heartbreaking as this was, it had a positive effect. People suddenly understood what we were after and why we were looking for it. We confirmed that the equipment to replay the data tapes still existed and, most importantly, that even after 34 years the tapes could still retain data.

In 2005, spurred on by this and by new Polaroids from Honeysuckle Creek, Stan and Dick visited the US National Archives in Washington, where all the data tapes from the Apollo era were deposited in the early 1970s – all 250,000

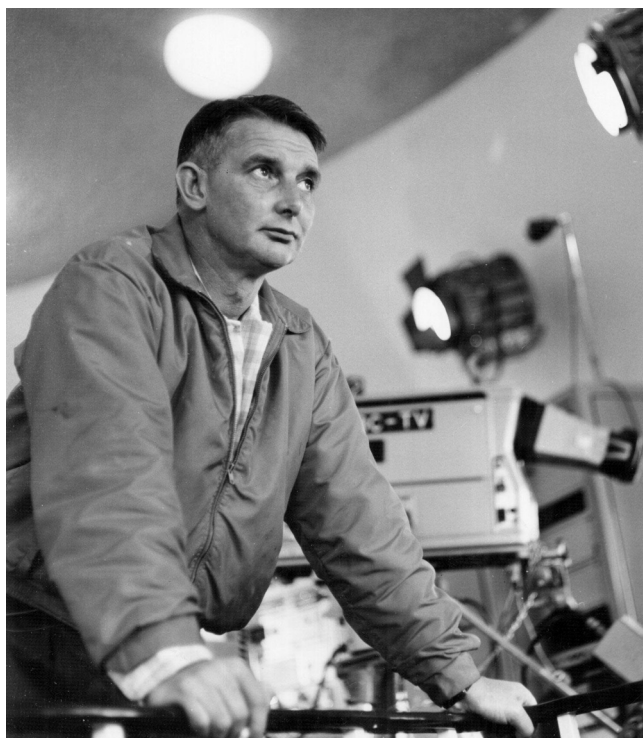


Parkes scan-converted video



Polaroid of SSTV from Sydney Video

A comparison of the Parkes scan-converted and SSTV pictures, illustrating the superiority of SSTV compared to the scan-converted TV witnessed by the world. [courtesy: Bob Goodman]



Director of the Parkes dish, John Bolton, during the filming of an ABC TV documentary in 1967. [courtesy: National Library of Australia]

plus tapes. Unfortunately, their search only uncovered a single box of tapes containing Apollo 9 telemetry. The label on the box had details that allowed us to continue the search. Soon after this discovery, we received the alarming news that the DEL was slated for closure in 2006. This would be a disaster because, without the DEL, there would be no way to replay the tapes, and recover the SSTV, if they were ever found. Something had to be done.

The formal search

In February 2006 I visited the DEL and also gave a series of talks at various NASA centres to explain our search. On my return, I compiled a report which slowly began to stir people's attention. Two months later in July, Stan and Dick were interviewed on national radio on the anniversary of the Apollo 11 mission. Finally in early August, the *Sydney Morning Herald* posted a front-page story with the provocative headline 'One giant blunder for mankind: how NASA lost moon pictures'. This caused a major stir with the story going viral on the internet and news reports appearing on the American TV networks and other news organisations worldwide. Interest became so intense that in August 2006 the NASA Administrator, Michael Griffin, formalised the search and appointed the GSFC deputy director, Dorothy Perkins, to head the search. Dick was the technical lead. The first decision made was to not close the DEL. With the full resources of NASA brought to bear

on our search, we were confident that we would now finally locate the tapes and release the SSTV to the public by Christmas. But it was not to be.

Soon after the formal search began, documents were found that suggested that the tapes may have been erased in the early 1980s. This was disturbing news. We were searching for just 45 tapes from over 250,000 tapes of the Apollo era. Surely, these few would have been put aside for historical reasons. Meanwhile, Colin and I followed up leads from the Australian end and provided advice. In the US, our colleagues Stan, Dick and Bill became first-class sleuths. They tracked down long retired personnel and uncovered dusty documents from NASA archives, people's attics and basements. Slowly and surely, the evidence mounted. We discovered that in the late 1970s and early 1980s NASA had withdrawn all the Apollo era data tapes from the National Archives and erased and recertified them for later use. But why? Apparently, these tapes were manufactured using whale oil to adhere the oxide to the backing. However, in the mid-1970s, the use of whale oil was banned and manufacturers switched to using synthetic oils. The drawback was that if the synthetic oil-based tapes were not stored correctly, they would absorb moisture from the air which made them sticky. Played back at high speed, they would stick to the recording heads and be shredded to pieces. The older Apollo era tapes didn't suffer from this drawback.

As NASA's budget was cut back severely in the late 1970s, the need for more tapes to record the increasing volume of data from satellite programs became acute. The enormous number of tapes in the National Archives were now seen as valuable assets. Over a period of several years, they were all removed, erased and recertified. The labels on the tape canisters were cryptic and there was little way of knowing what each of the tapes contained. Our team didn't find any evidence that the tapes containing the Apollo 11 lunar EVA data were treated differently to the others. We reluctantly concluded that the tapes were, in all likelihood, erased and reused with the rest. You can imagine how we felt.

To understand why the tapes were treated this way, it's important to realise that they were never intended to be the primary archival media. In fact, there was never any expectation that the magnetic data would survive more than a few decades. They were only meant to act as backups for the real-time communications relays and other data. If there was a failure during a mission, the tapes could be used to recover the information. If however, all went well, then the tapes were no longer necessary. All the vital infor-

mation was extracted in real-time and archived for analysis at the relevant NASA centres. The TV was successfully seen by the world and the scan-converted video was properly recorded onto archival b/w film that would last for centuries. Few people outside of the tracking stations were even aware of the SSTV or how much better it was. As far as everyone was concerned, all the data was believed to be properly archived – at least until we came along.

The restoration

What to do next? In late 2006 Colin noticed a video clip on Eric Jones' Apollo Lunar Surface Journal website. It showed Armstrong descending the lunar module ladder that was much clearer than anything we'd seen before. We learnt that the clip was sourced from someone who had previously worked at the GSFC. It appears that he found an old 2-inch videotape of the lunar EVA and made a crude VHS video copy of it. We obtained a copy of this videotape and found that it was most likely a copy of the video recording made at Sydney Video of the Australian selection. It contained the clearest pictures of Armstrong descending the ladder sourced from Honeysuckle. It also showed the switch to Parkes earlier than in any other known recording. Unfortunately, when the original copy was made, the Ampex recorder was not setup properly and this produced a jittery image with many defects. We spent the next few months searching for the original 2-inch tape, but it has mysteriously gone missing.

Early in the search Colin was contacted by Ed von Renouard, the former scan-converter operator from Honeysuckle. On the day of the lunar EVA, Ed had brought his home movie camera to work and recorded footage directly off the screens of his console. One of those scenes was the dumping of the astronauts' portable life support systems, or backpacks. This occurred several hours after the astronauts had re-entered the lunar module and the TV networks had by then ended their broadcasts. Consequently, as far as we could determine, no other footage existed of the dumping.

During the search, we came across many archived copies of the scan-converted TV. We decided to switch our search to finding the best of these scan-converted videos and have them archived properly. We also decided to digitise them along with the Sydney Video and Honeysuckle footage. We would take the best parts of each and compile and restore them into a single video of the lunar EVA. In 2008 we had a demo restoration produced of selected scenes, which we used to convince NASA to underwrite the \$245,000 cost of the full restoration.

In 2009 NASA contracted Lowry Digital in California, a pioneer in video enhancement, to process and restore this recording for the 40th anniversary of Apollo 11. The restoration involved digitally repairing damaged sections of the recordings, removing noise from the video, correcting for vignetting, stabilising and brightening the TV picture and other adjustments. The restoration was announced at a special news conference in Washington on 16 July 2009. The full restoration was completed in December 2009 and is the best and most complete video record to date.

The NASA GSFC produced three archival sets of hard drives containing the complete restored video – one set was sent to the National Archives in Washington and another went to the Johnson Space Center in Houston. The third set was destined for Australia in recognition of the substantial involvement of the Australian tracking stations. They arrived in Australia in August 2011 and were delivered to the Canberra Deep Space Communication Complex at Tidbinbilla, having been previously organised by the former Director, Dr Miriam Baltuck.



Colin Mackellar (left), Neil Armstrong and John Sarkissian in Sydney on 23 August 2011.

A week later, Neil Armstrong visited Sydney to address the CPA Australia 125th anniversary celebrations. During his address, Neil Armstrong paid a glowing tribute to the many Australians who worked at the tracking stations and helped to ensure the success of the Apollo 11 mission. Some were present in the audience and were individually acknowledged by him. In a brief ceremony following the event, Armstrong symbolically handed over the Australian disks to Dr Phil Diamond, Director of CSIRO Astronomy and Space Science (CASS) – the custodian of the disks in Australia. He noted that 'the restored video is a valuable contribution to space exploration and space communication history'. This ceremony effectively brought the restoration effort to a close.

The Australian disks will eventually be deposited in permanent archival storage, most likely with the National

Film and Sound Archive in Canberra. The restored Apollo 11 video can now be purchased online from www.apollo11video.com. The proceeds will go toward the continued search and restoration of the other Apollo mission videos.

Hope remains

In early September 2006, soon after we first received news that the tapes may have been erased, I received a phone call from Peter Robertson, the editor of this magazine. He had seen the news items regarding the missing Apollo 11 tapes. He phoned to tell me of a letter he had received from John Bolton in the early 1990s. Bolton had mentioned some videotape players that were in the Parkes control room during the Apollo 11 mission. I informed Peter, that we weren't looking for videotapes but rather magnetic data tapes containing telemetry of the mission. I asked him to send me a copy of the letter anyway.

For many years, I had photographs from the CASS Photo Archive of scenes taken inside the Parkes control room during Apollo 11. Several photos showed a man standing beside Ampex VR660 2-inch videotape players. The Ampex players could only record standard television pictures, so I had no idea what they were doing at Parkes. I also didn't know who the man standing beside them was, or what he was doing there. A few days after Peter phoned, the Bolton letter arrived and I was stunned. The letter did indeed describe the Ampex video recorders and, more importantly, Bolton mentioned that they came with their own engineer from Johns Hopkins University in Baltimore. Could this engineer be the mystery man? I knew that Johns Hopkins was the home of the Applied Physics Laboratory (APL), a regular NASA contractor. In late November 2006, we received definitive evidence that the tapes had been erased. It was then that I sent the information on the possible identity of the engineer to my US colleagues. They immediately set out to find him. Within a few weeks, they found old newsletters from APL that positively identified him. He was contacted and interviewed by Bill and Stan. What he told them lifted our spirits.

According to the engineer, in April 1969, the APL was contracted by the GSFC to modify existing Ampex VR660 video recorders to record the non-standard SSTV at Parkes. He was put in charge of this crash program. It was to be an experimental backup recording in case the TV could not be relayed to Houston. This secondary recording was only made at Parkes and if it worked, it could be used on future missions. He reported that the recording succeeded and that he returned to the US with two reels of 2-inch videotape containing the SSTV. The whereabouts of this videotape was now a mystery. An extensive search was conducted at APL that turned up two tapes that seemed to match the description. Dick organised the loan of an Ampex VR660 video player and a slow-scan monitor from two museums. His team played back the tapes at DEL and found that they were all blank. Again, we were disappointed. Importantly, there was no documentation to suggest the tapes were erased or destroyed. We are working on the assumption that they still exist somewhere, so our search for them continues.

The most striking thing for me was how, just as we were at our lowest ebb, John Bolton appeared, from beyond the grave, to direct us in our search. It was like he was saying, "Hey, look over there. That's where you'll find what you're looking for." Hope remains.

Acknowledgments

I wish to express my gratitude to Professor Marcus Price, officer-in-charge of the Parkes Observatory in 1997, for asking me to research the Observatory's support of the Apollo 11 mission, and to Dr John Reynolds, officer-in-charge from 1999–2008, for his continued support throughout. I also thank Marshall Cloyd for giving me the opportunity to search for the tapes a little closer to the source in the United States. Finally, to my friends Bill, Dick, Colin and Stan – thank you.

Photos are courtesy of the CASS Photo Archive and author unless indicated otherwise. For more detailed information on the Parkes Observatory's support of Apollo 11, and of the Honeysuckle Creek Tracking Station, see www.parkes.atnf.csiro.au and www.honeysucklecreek.net.

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John Sarkissian is an Operations Scientist at the CSIRO Parkes Radio Observatory. His main responsibilities are operations and systems development, and the support of visiting astronomers with their observations. John is a member of the Parkes Pulsar Timing Array team that is endeavouring to use precision pulsar timing to make the first direct detection of gravitational waves. In 1998–99 he acted as a technical advisor for the film *The Dish*. John has received two NASA Group Achievement Awards and, in 2010, received an official NASA commendation for his search for the missing Apollo 11 tapes.