Television on the Moon
Apollo 11

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<table>
<thead>
<tr>
<th>CONTENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>APOOL 11 ANNIVERSARY</td>
<td>3</td>
</tr>
<tr>
<td>INITIAL CONCEPTS FOR TV SIGNALS</td>
<td>4</td>
</tr>
<tr>
<td>EARLY MILESTONES</td>
<td>6</td>
</tr>
<tr>
<td>APOLO 11: INTERNATIONAL NETWORKS</td>
<td>10</td>
</tr>
<tr>
<td>APOLO 11: LUNAR SURFACE COMMUNICATIONS</td>
<td>13</td>
</tr>
<tr>
<td>APOLO 11: LUNAR CAMERA</td>
<td>15</td>
</tr>
<tr>
<td>APOLO 11: WHAT WENT WRONG?</td>
<td>20</td>
</tr>
<tr>
<td>APOLO 12 AND BEYOND</td>
<td>21</td>
</tr>
<tr>
<td>FINAL APOLO TV CAMERAS</td>
<td>22</td>
</tr>
<tr>
<td>QUESTIONS</td>
<td>23</td>
</tr>
<tr>
<td>REFERENCES/ACKNOWLEDGEMENTS</td>
<td>24</td>
</tr>
</tbody>
</table>
2019 marks the 50th anniversary of Apollo 11’s historic trip to the moon -- Spring 2019’s issue of the *Proceedings* included a special section celebrating this milestone

- Milestones In Space Exploration Leading To Apollo 11
- Upcoming Special Exhibits Relating To The Apollo 11 Anniversary
- “Communications to the Moon and Planets,” the 56th Annual Banquet Address at the Radio Club of America by Dr. Eberhardt Rechtin, Assistant Director of the Deep Space Instrumentation Facility of the Jet Propulsion Laboratory
- “Communications on the Moon” from the August 1969 issue of *Electronics World*
- “Apollo 11 Television” by Bill Wood, a former Apollo MSFN Station Engineer
Concept was already underway by 1962 -- all voice, telemetry, television, and ranging information for near-earth and lunar distances to be transmitted over a single frequency system: Unified S-Band (USB)

- Voice and biomedical data (1.25 MHz FM subcarrier)
- Telemetry data (1.024 MHz bi-phase modulated subcarrier)
- Pseudo-random ranging code using a common phase-modulated S-band downlink frequency (2287.5 MHz for the Command and Service Module, and 2282.5 MHz for the Lunar Module)
INITIAL CONCEPTS FOR TV SIGNALS

Frequency Modulation accommodated TV signals on the single Lunar Module downlink

- 700 kHz available for a narrow bandwidth television signal on the S-band downlink
- 320 horizontal progressive line, 10 frame per second, format was selected -- used only 1/10th of the 5 MHz bandwidth of the 525 interlaced lines, 30 frames per second format that was standard for US television at the time
- NASA contracted the special slow-scan, black/white TV cameras: RCA Astro Electronics Division, East Windsor, NJ (Command and Service Module), Westinghouse Electric Aerospace Division, Baltimore, MD (Lunar Module)
- RCA Astro Electronics Division also designed and provided ground station devices to convert the Apollo slow-scan TV format to the normal American TV format

![Lunar Module FM Downlink Spectrum](image)
EARLY MILESTONES

TV: 4.5 pounds, 6.75 watts, 28 vdc, 1” vidicon tube, wide angle lens (160°)

Apollo 7 TV Camera

Frank Borman on Apollo 8
Apollo 8’s slow-scan TV signals received by 3 primary Manned Space Flight Network stations and converted to NTSC black and white television images using devices manufactured by the RCA Astro Electronics Division
EARLY MILESTONES

Apollo 9 allowed tested Westinghouse’s lunar camera in the lunar module

Stan Lebar of Westinghouse displaying the Lunar Camera
EARLY MILESTONES

Apollo 10 brought color

Westinghouse field sequential color camera

Jim Stafford in the Lunar Module

Command Module as seen from the Lunar Module
Worldwide radio telescope and broadcasting networks were established
Worldwide radio telescope and broadcasting networks were established.
A worldwide radio telescope networks tracked and communicated with Apollo 11.
Communications from the lunar surface contemplated S-Band relays from the Lunar Lander

- Unified S-Band System (Collins Radio Company) incorporated multiple signals onto one uplink from the ground and one downlink per spacecraft
- S-Band grew out of the coherent doppler and the pseudo-random range tracking system developed by Jet Propulsion Laboratory
- Subcarriers for voice and telemetry were added to the tracking signal, allowing each to function without interference from the others
- At any time during a mission, one tracking station in view of the spacecraft with one high gain antenna could provide tracking, command, and communications services using the huge parabolic antennas of the Deep Space Network (DSN) and smaller antennas of the Apollo / Manned Space Flight Network (MSFN)

Apollo 11 did not deploy the separate antenna
RCA’S redesign after Apollo 14 (p. 21-22) included mobile rover operations.
Westinghouse designed the secondary electron conduction camera tube that reproduced objects in motion, at low light levels, without the normal smearing produced by vidicon or image orthicon tubes.

**Westinghouse Lunar Surface Camera**

**Secondary electron conduction (SEC) camera tube**

Secondary electron conduction (SEC) camera tube contains three main sections—an image intensifier, target assembly and hybrid gun. Image is amplified by intensifier and focused on the target assembly. Hybrid gun reads out image stored on target and produces output signal current, $i_s$. 

**APOLLO 11: LUNAR CAMERA**
APOLLO 11: LUNAR CAMERA

The TV camera was stowed on a special shock-mounted angled mount on the Lunar Module MESA -- It was positioned so the camera would be nearly vertical and upside down when the MESA was released by Neil Armstrong after he first emerged from the Lunar Module.

Lunar Camera mounted on the MESA

Buzz Aldrin deploys solar wind experiment with the S-Band antenna at the top left of the Lunar Module
APOLLO 11: LUNAR CAMERA

Initial images were upside down, flipped, and very dark as NASA control in Houston selected between Goldstone and Honeysuckle Creek options

- GDS’ Slow-Scan Converter’s internal-monitor black-level compressed shadow details into black
- HSK and Sydney Video scan converters were set properly
- NASA selected HSK’s Parkes telescope for the rest of the Apollo 11 EVA

DSS-14 video via Goldstone (upside down and dark)  
Parkes video via Sydney
The TV camera was placed onto a tripod and connected via cable to the Lunar Module.

Hasselblad (still) image showing Apollo 11 placement of TV camera and cable.
APOLLO 11: LUNAR CAMERA

Scan conversion at Sydney Video resulted in the loss of resolution and shadow detail that occurred during the conversion process.

Original 320 line, 10 fps Parkes image

Scan converted 525 line, 30 fps image
APOLLO 11: WHAT WENT WRONG?

Light output of the cathode ray tube normally used to view television signals was NOT proportional to the video signal applied to the cathode ray tube

- Westinghouse Apollo television cameras did not include a gamma correction circuit as did most broadcast TV cameras of the period
- A gamma correction circuit was developed for later moon TV cameras making the light output on TV screens proportional to the light on the camera tube
- During the early design phase, Westinghouse engineers decided that, since the television images might be used for scientific purposes, the video imaging device and the camera video circuits should operate in a linear, or a gamma 1.0, mode
- Thus, the EVA scene mid-tones were considerably darker than if the video signal been gamma altered to correct for the non-linear response of the cathode ray tubes used in broadcast TVs
- The Apollo Slow Scan Lunar Camera was never used after Apollo 11, but it was carried on Apollo 13, 14, 15 and 16 in case the later Westinghouse color cameras failed
Westinghouse adapted the Apollo 10 Command Module color camera for use on the lunar surface in Apollo 12.

But after less than optimal performance on Apollo 14, RCA was selected to build a Ground-Commanded Television Assembly (GCTA) for better lunar surface color television performance.
Apollo 17 was the last moon landing

- RCA’s color Ground Controlled Television Assembly (GCTA) and the Lunar Communications Relay Unit (LCRU) developed for Apollo 16 were nearly flawless on Apollo 17
- Apollo 17’s Lunar Rover color TV camera operated for 27 hours after the last man left the surface
- LCRU suffered an over-temperature failure preventing further use of the camera
QUESTIONS
REFERENCES/ACKNOWLEDGEMENTS

- S. Lebar and C P. Hoffman, TV Show of the Century: A Travelogue with No Atmosphere, Westinghouse reprint of March 6, 1967 *Electronics Magazine*.
- Smithsonian National Air and Space Museum.