DEVELOPMENT AND APPLICATION OF COLOR TELEVISON FOR APOLLO XV AND BEYOND

By Samuel Russell
RCA Astro-Electronics Division
Princeton, New Jersey

Television played a major role in the spectacular success of Apollo XV. From a research viewpoint, the quality of the video enhanced the value of the lunar surface observations. The real-time transmission of astronaut activity on the lunar traverses undoubtedly increased the popular appeal of the overall mission, also. What was actually done to develop and improve the quality of the television system used on the Apollo XV mission? In this paper, I would like to describe briefly the television system developed for the mission, identify the factors contributing to the high quality of the pictures generated on the lunar surface, and explore several possible present and future uses of the television equipment developed for Apollo XV.

Four factors contributed to the success of Apollo XV television. The first factor was mobility. The television camera accompanied the astronauts during their explorations of the lunar surface and permitted television coverage from a variety of locations on the moon. Remote control of the camera system from earth also was an important factor in the success of the mission. Now the camera could follow the action and zoom-in on details of the lunar surface! A third factor consisted of improvements in television camera performance. The "smears" and "blurs" seen on television during previous missions were eliminated. Gone also were the "Casper the ghost" images of the astronauts. But the new television camera alone was not the only technical improvement in the system.

The fourth and final factor contributing to the high quality of Apollo XV television was a major improvement in the overall television transmission system - mainly on earth. The original network of ground equipment used for the manned space program at NASA was not designed to receive and process color television signals for network distribution. Therefore, a joint NASA and RCA effort was organized to review and improve the entire television transmission system — from the lunar surface to the home receiver. The objective was to generate a television picture from the moon that was just as good as the pictures received of the local Saturday afternoon ballgame! A great deal of work was required to achieve this objective.

Considering the above factors in more detail, Figure 1 shows the components of the television system mounted on the Lunar Roving Vehicle (LRV). On the left-hand side is the completely self-contained color camera unit (CTV). During the lunar landing, the camera was mounted on the Lunar Module (LM) Falcon, in a position that could view the astronauts descending the steps. The camera then was mounted on a tripod to view deployment of the LRV from the LM. After deployment of the Rover, the camera was transferred to the television control unit (TCU) mounted on the vehicle. The television control unit decoded the radio commands from earth and performed the functions shown in Figure 1. The control unit also positioned the camera left or right and up or down in response to remote commands from earth.

The Lunar Communications Relay Unit (LCRU) is shown at the bottom of Figure 1. This unit contained the television transmitter and other communication equipment required for relaying voice and other signals between the backpacks carried by the astronauts and earth. The high-gain antenna beamed the television signal to earth. The camera (CTV), control unit (TCU), relay unit (LCRU), and antenna together were, in reality, a complete television station. The television shown in Figure 2 (taken by the equipment at Cape Kennedy 1 month prior to the mission) is mounted right on the front bumper of the Rover! When the astronauts stopped on the lunar surface, one of them got off, turned a power switch ON, aimed the antenna at earth, and the show began!

Figure 3 shows the color camera (CTV) and the remote control unit (TCU). The camera functions that can be operated by ground command are shown. The camera may be panned to the left or right, or tilted up and down. Motorized drives in the lens assembly allow changes in the lens focal length and aperture. Exposure control and power also may be controlled from earth. The ground controller at MSC-Houston has a set of 18 pushbuttons with which he can control all camera operations (Fig. 4). If the controller wanted the camera to pan left, he first depressed the PAN LEFT button, and the camera moved slowly to the left. The camera motion continued until he depressed the PAN STOP button.

The flight controllers at Houston faced a unique time delay problem. When a pushbutton was pressed, 3.5 sec passed before any response was seen on the television screen. Only through realistic simulation of the time delay before the mission were the controllers able to train themselves to follow the action.

In discussing the improvements in the Apollo XV camera, the difficulty in obtaining good television pictures on the moon must be stressed. Lighting on the moon consists of extreme contrasts. The astronauts appear brilliant because of the highly reflective cloth of the spacesuits. The lunar soil itself, however, is rather dark. Furthermore, shadows on the moon are extremely dark because no sky light exists to soften the shadows. One way to solve the lunar illumination problems was to develop a compatible camera tube. A tube under development at RCA, known as a Silicon Intensifier Target (SIT) tube, was found to have the characteristics needed for the Apollo XV camera. The tube is very sensitive and can see details in shadow areas. It also can withstand the direct rays of the sun without being damaged. Sensitivity of the SIT tube can be controlled electrically over a range of light levels of about 1000 to 1.

In conjunction with the SIT tube, all circuitry in the camera was of such a nature as to optimize performance under conditions expected on the moon. Figure 5, a good example of this optimization, shows the camera is imaging two astronauts on a scale model of the lunar surface. One of the astronauts is in direct sunlight (simulated) while the other is in shadow. The television system just does not have the dynamic range to simultaneously image properly both the astronaut in sunlight and the one in shadow. This problem may be resolved, however, by having two separate modes of automatic light control (ALC). A peak mode detects the brightest object in the scene, and adjusts the SIT tube sensitivity to give the highest modulation value of the picture signal for this object. In this way, a good image of the astronauts is obtained. An average mode is used for looking in the shadow, and picture highlights are allowed to saturate and "bloom." A brightly lit astronaut cannot be seen clearly in an average mode because his image has saturated. The astronaut in shadow, however, can be seen clearly. By using two modes of ALC, improved exposure control for the pictures seen during Apollo XV was possible.

When the Apollo XV television signal left the transmitter and antenna on the moon, the signal traveled to one of three ground stations on earth. Let us use, for example, the Australian station and trace the path of the television signal from there to a home television receiver. From the Australian ground station, the signal went via a groundline to a COMSAT ground station. From the COMSAT ground station, the signal was transmitted to INTELSAT, a satellite 22 000 miles above the Pacific, then back to a COMSAT ground station in California. Bell System then took the signal to MSC-Houston where the color television signal was changed to the form used for commercial color television transmissions. Finally, the signal was distributed to the television networks from MSC-Houston for transmission to the public. Along this complicated transmission path from the moon, potential system problems are constantly threatening television signal quality. The NASA and RCA systems team turned up quite a number of problems that could have caused picture degradation. In one case, the ground station receivers caused a breakup in the edge of the picture. In another case, a special processing amplifier was introducing noise. A filter, designed to separate the voice signal from the television signal, was producing ghosts in the picture. These and other problems were discovered and, for the most part, were fixed for the Apollo XV mission.

Another difficult task was isolating the location of ground system malfunctions during television transmissions. In commercial network operations in the U.S., the originating station gives the television signal to a common carrier (i.e., the Bell System) which then routes the signal to its destination. For the Apollo mission, however, many carriers were involved. There was one link from the moon to the earth, another link through a common carrier in Australia under the jurisdiction of the Australian Postal Department, then another through COMSAT and International Telecommunication Satellite Consortium (INTELSAT) over the Pacific, and finally one through the Bell System to the space center. A break in any one link would have spoiled the show. To pinpoint where problems were occurring was a difficult task. For this reason, a special NASA Television Flight Control Group was formed to supervise the entire television operation during the mission. The manager of this group was located in the control center right behind the controller operating the camera. From this vantage point, he could communicate with points all over the world and locate problems as they occurred. Fortunately, no serious problems occurred, and the show went off on schedule.

What sort of applications can the Apollo XV television system be used for? In science, there are a number of advantages in having high-quality television. One is just having a good record of scientific exploration. During the Apollo XV, the television signals provided invaluable documentation of the lunar surface investigations. This was really unexpected by scientists and the scientists realized the value in these analyses only after extensive replay of the videotapes. A film record of the same data would not have been practical because the weight of film would have reduced the weight allotment for lunar samples. Thus, television provided the ideal way to secure these data.

Television also may change the method of doing scientific research in two rather interesting ways. The use of high-quality television for costly scientific projects such as lunar exploration permits "real-time" scientific research. When a scientist wants to make a normal geological exploration of a region, he first researches the area, then plans an exploration, and goes into the field to take samples. Then he analyzes his field data and defines a geological model. Generally, his conclusions lead to the need for more additional field work and a new model. On earth, this iterative process for scientific research is acceptable.

In exploring the moon, however, the high cost involved precludes such luxury. Returning to the same place to gather data for an incomplete model is not feasible. Instead, the whole investigative procedure must be compressed within the available mission time. Scientific teams must work in real time to analyze data and decide how to proceed with the exploration as the exploration is taking place.

Television, for example, could have been used to an advantage during the Apollo XIV mission when the astronauts were on their second extravehicular activity (EVA) near the edge of Cone Crater. They reported seeing some white-rock formations, but did not elaborate. The response from Houston was for them to take a photograph of a sample of the white rock. When the films were developed after the mission, the photograph of the white rocks showed something completely unexpected. Never had formations like this been seen on the lunar surface nor have they been seen since. Due to the pressure of time, or perhaps limited geological training, the astronauts missed the significance of these formations. Scientists on earth may have seen the formations with television. The EVA timeline then would have been reorganized to sample this region more fully in an attempt to explain these formations.

A second use of the television camera during future Apollo missions is as a multispectral sensor. The SIT pickup tube has a broader spectral response than the human eye, and the moon exhibits much higher contrast in the infrared spectral region than in the visible region. A television camera, therefore, can enable scientists on earth to see scene details that even the astronauts themselves cannot see.

Television also is important as a tool to educate and to give everyone a unique sense of participation in the Apollo missions. The many applications of space technology to our more earthly needs must be realized by the public, especially in the fields of communications, weather forecasting, navigation, and earth resources surveying. The space program is really beginning to bear fruit, and yet many exploratory parts of the space program are difficult to justify to the American public. For the Apollo missions, the justification is science. Much stress has been placed on the importance of discovering how the moon was formed, what relationships it has with earth, and how the moon may hold the secrets to the origin of the solar system.

To the man on the street, the "need to know" is often a little difficult to understand. He probably has justified to himself why we are exploring space, the moon, and the planets - just as a mountain climber has reasons to climb a mountain. By allowing him to see and experience space exploration through television, as we did on Apollo XV, perhaps we have the key for his continuing support of our endeavors in space.

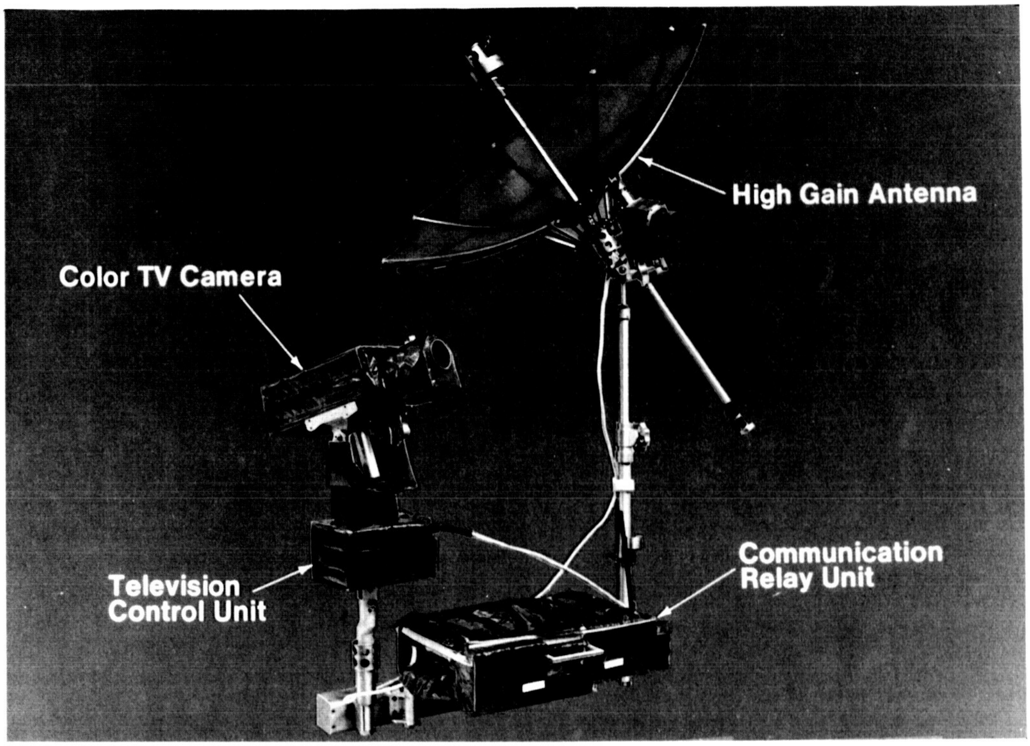

Figure 1. Lunar Communication/Television System

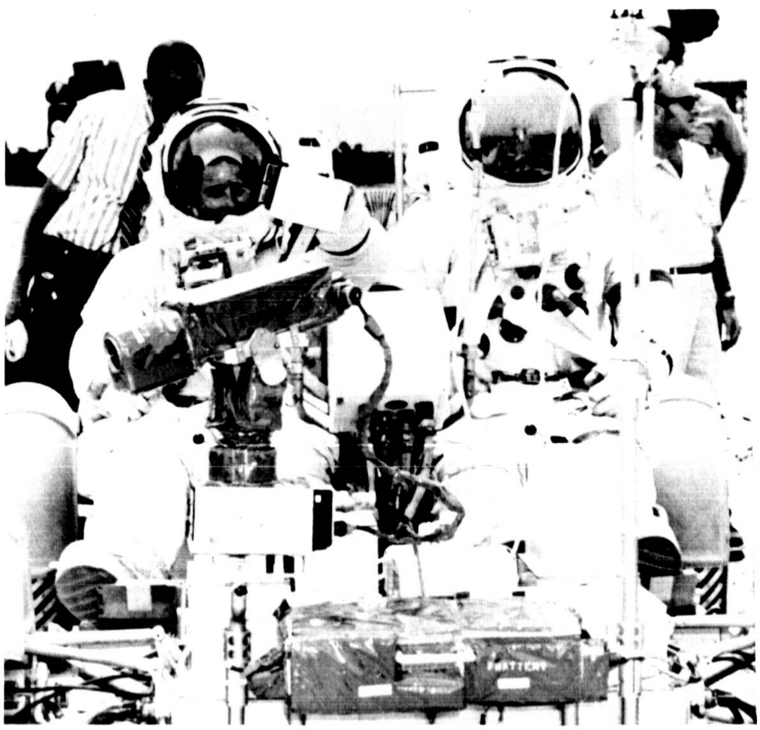

Figure 2. Television installation on Rover.

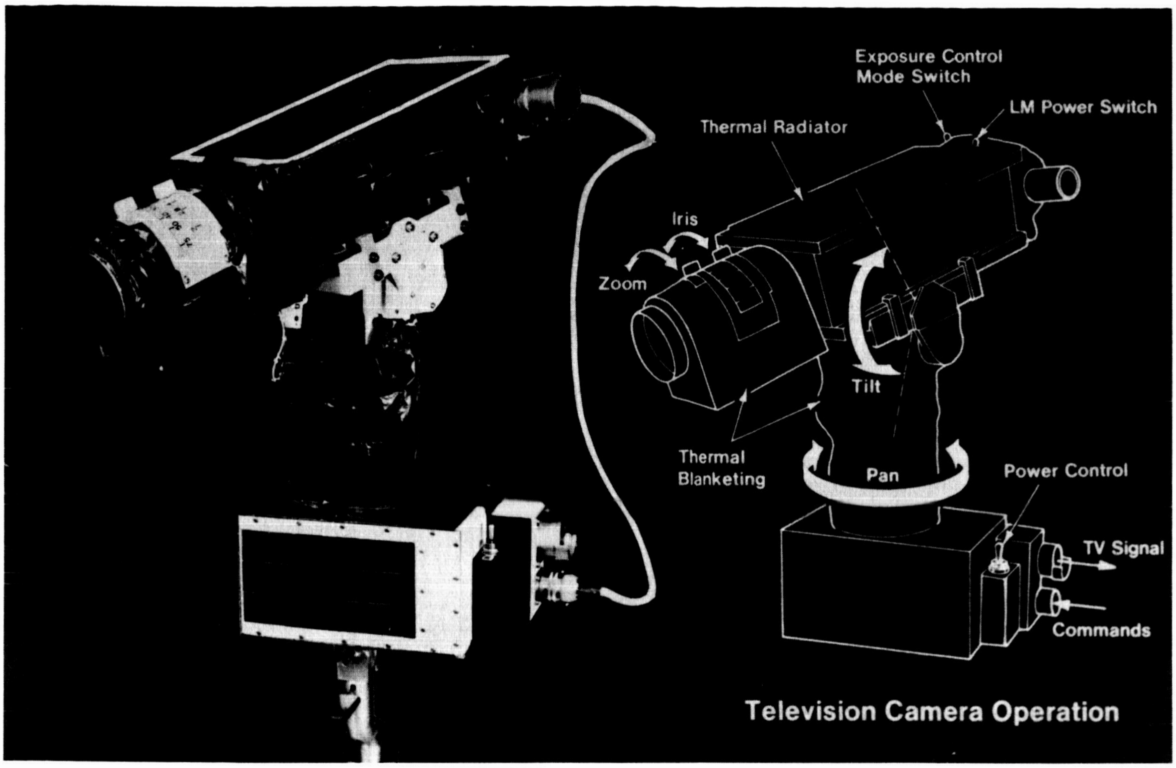

Figure 3. Ground Commanded Television Assembly (GCTA).

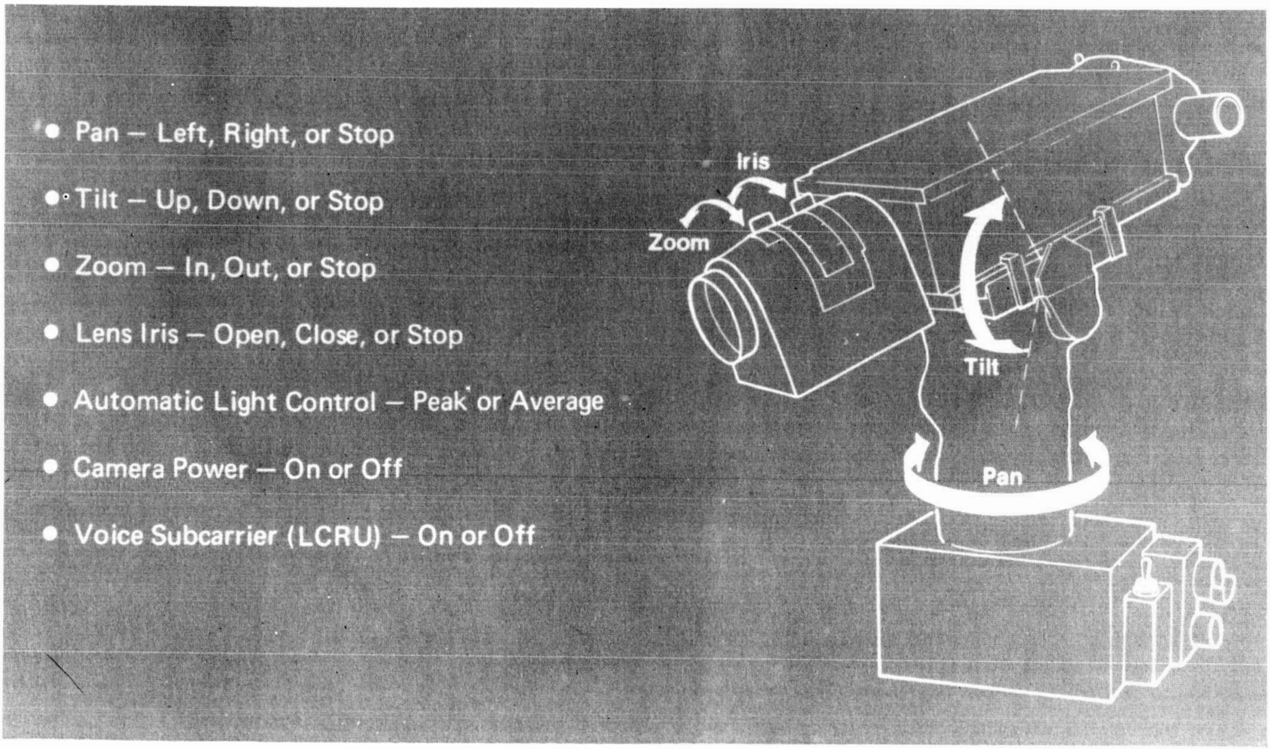

Figure 4. Command functions.

Figure 5. Automatic light control.