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For Immediate Use

APOLLO 13 TELEVISION CAMERAS

Since the television pictures sent back from space in the last five Apollo flights were beamed around the world and were seen by millions of people, the cameras used to produce the pictures have become one of the best known items of equipment in the program.

Two color television cameras are scheduled to be used during the Apollo 13 mission. One is for use in the command module for interior views and the scenes the astronauts see from their windows. The other camera is for use on the moon's surface. Carried in the lunar module's descent stage, it will be removed and put into operation by one of the astronauts at the beginning of the first moon walk.

- more -





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Television equipment designed and built for NASA's Manned Spacecraft Center by the Westinghouse Aerospace and Electronic Systems Division includes:

- Black and white camera used in the spacecraft during Apollo 9.
- Black and white camera used on the moon's surface during Apollo 11.
- Black and white camera scheduled to be carried as a lunar backup camera on Apollo 13.
- Color cameras used within the spacecraft in Apollo 10, 11 and 12.
- Color camera used on the moon's surface in Apollo 12.
- Color cameras scheduled to be used in the spacecraft and on the moon's surface in Apollo 13.
- Miniature television monitors used within the spacecraft in Apollo 10, 11, 12 and 13 to help the astronauts focus and aim the color cameras.
- Four additional color cameras for future flights.

The color cameras used in the previous three flights were returned to earth while the black and white lunar camera was left mounted on its tripod on the moon. Two of the color cameras brought back were modified or refurbished for subsequent missions.

The Apollo 10 command module color camera was modified for NASA by the Westinghouse division for use on the lunar surface during Apollo 12. A lunar color camera is shown in Figure 1 during tests at



the Westinghouse division. The color camera used in the command module in Apollo 11 was refurbished by Westinghouse and used in the command module, also during the Apollo 12 mission.

#### Apollo 12 Camera Damage

The Apollo 12 color lunar camera operated for about 40 minutes before intense light damaged a sensitive part of the camera's image tube. The light in effect partially blinded the tube in its target which roughly corresponds to the retina of the eye.

When the tube was exposed to the high intensity light, the target was damaged by a combination of electrical and heat effects resulting in a tear in the upper portion of the target. Because of the way the target is constructed, the effect of the tear was to appear to the camera's circuitry as an area of very bright light. The camera's automatic light control therefore reduced the amount of light the tube could accept. This caused the picture to go completely dark in the region corresponding to the undamaged portion of the target.

The target of the camera tube is the portion where the image is recorded and converted electronically to a video signal that is subsequently amplified and transmitted. A few hundredths of an inch thick and about one-inch square, the target is a three-layer wafer in the second section of the tube. It augments the image presented to it as much as a hundredfold by a phenomenon physicists call secondary electron conduction or SEC. In addition to augmenting the image, the target records it electrically until it can be read out, or removed, by a scanning beam.





After being returned, the damaged camera was tested, dismantled and examined. The investigation by NASA and Westinghouse engineers showed that if the automatic light control circuit could have been disabled, a reasonably good image probably would have been present in the lower portion of the picture corresponding to the undamaged part of the tube's target.

Although press reports have indicated that the astronauts might have been able to disable the automatic light control, it would have been impractical to do so. Small hand tools were not available but even if they would have been, the astronauts could not have used them without considerable difficulty and some danger. The bulky gloves of the space suits make it hard for the astronauts to handle small items. In addition, there is always the danger of damaging a space suit by a tool slipping, by a burr left on a part by a tool, or by any of a number of other possibilities.

#### Apollo Television Cameras

The black and white and the color cameras are all small enough to be hand held. They have the sensitivity and automatic control necessary to consistently produce good pictures over a wide range of light levels and scene content. General characteristics of the cameras are given in Table I.

During the Apollo 10, 11 and 12 flights, color cameras provided real-time color scenes of the earth, the moon, spacecraft maneuvers and spacecraft interior scenes. These color cameras were built for use only within the spacecraft. They were used in conjunction with a miniature



television monitor, also built by Westinghouse, in the command module to help aim and focus the camera. The spacecraft camera and monitor are shown in Figure 2.

The steps taken to modify the color camera for lunar surface use were primarily improvements in its thermal characteristics. These were necessary because on the airless moon, there is no conduction of heat. In direct sunlight it is extremely hot and in shadow extremely cold. Excessive heat buildup or heat differential inside an electronic unit like a television camera can of course lead to damaged components.

Other changes made in the camera were the color wheel motor and gearing to reduce power consumption from 20 to 15 watts and to insure stability of operation in the vacuum environment.

The power reduction in turn reduced the amount of heat generated in the camera. The outside of the camera was coated with the same material used on top of the Apollo 11 lunar camera, Figure 3. This coating has high thermal emissivity (heat loss from the camera) and low thermal absorptivity (heat absorption due to the sun's radiant heating effect). In addition, the material resists changes due to ultraviolet radiation.

The black and white lunar TV camera, Figure 3, was designed and built for the vacuum and extreme thermal conditions found on the moon's surface. In the moon landing, the camera was stowed in the descent stage of the lunar module. As Astronaut Armstrong descended the ladder for the first moon walk, he pulled a lanyard which opened the compartment door on which the camera was mounted. When the door opened, the



camera pointed at the lunar module ladder and showed an astronaut step onto the moon for the first time.

After Armstrong's preliminary work, he set the television camera on a tripod some thirty feet from the lunar module. The camera televised the activities of the astronauts until they re-entered the lunar module. After jettisoning the equipment they no longer needed, the astronauts switched from a frequency-modulation to a phase-modulation mode of transmission from the lunar module which took the camera off the air. Television pictures could only be transmitted in the frequency-modulation mode.

As with all television cameras, the important part of the Apollo cameras is the image tube. Both the color and black and white cameras are equipped with a low-light-level tube, the SEC (secondary electron conduction) camera tube.

The SEC camera tube has been recognized for some time as being ideally suited for space applications because of its size, weight, power requirements, ruggedness, stability, and simplicity of operation. It has wide dynamic range, tolerance to high saturation levels, and an electrical gain mechanism. The two latter features are necessary for a portable camera, such as the Apollo cameras, with little or no operational control to handle changing or uncontrolled scene lighting. The SEC tube was invented at the Westinghouse Research Laboratories and is produced by the Company's Electronic Tube Division.

A recent Westinghouse innovation in the SEC tube is the addition of a wire mesh to the target of the tube which will prevent serious



damage in the event of overload of light. This may be used in future space cameras.

#### APOLLO BLACK AND WHITE LUNAR CAMERA

In several respects, a lunar camera is unique among the rest of the Apollo electronics equipment. It is one of the few items required to operate under all phases of mission environment from launch pad to the moon, on the moon's surface, and back to earth. More than 80 percent of its circuitry is in the form of molecular integrated devices. The SEC camera tube, enables the camera to operate under the low-light-level conditions encountered during the lunar landing.

To conserve transmission bandwidth, the scanning rate for the black and white lunar camera is slower than those of standard broadcast television. The pictures are converted on the ground to broadcast television rates for retransmission by commercial stations.

#### Operational Requirements

Mission environments and compatibility with other equipment placed numerous constraints on the camera design. As with all space equipment, highly reliable operation was a prime requirement.

Environmental conditions that the camera had to withstand were: vibration of 10 to 2000 cycles per second (up to 6 g) and shocks of more than 8 g during Apollo launch and lunar landing; pressure variation from sea level to  $10^{-14}$  mm Hg; temperature extremes on the moon's surface from +250 degrees F during the lunar day to -300 degrees F at night; acoustical noise of 130 dB (above  $0.0002 \text{ dynes/cm}^2$ ).

In a spacesuit, an astronaut's dexterity is reduced. Ease of handling, holding, pointing, changing lenses, connecting and





disconnecting, and storing placed many constraints on the design of the camera package. The final design of the camera left only two operations to the astronauts: changing lenses and switching scan modes. All other controls are automatic within the camera. Since the camera was to be hand held, it had to be small and lightweight.

Predicted scenes included views of astronauts on the moon, the lunar surface, and the lunar module on the moon. Light levels for just these scenes varied from partial earthshine on the moon to full sunlight, a range of 0.007 to 12,600 footlamberts.

Scanning parameters for the camera were selected by NASA to best fulfill the over-all mission. Several factors influenced the selection of the scan rates.

Motion rendition had to be preserved to avoid break up in pictures. Ten frames per second provide acceptable motion rendition. Although some motion break up could occur in normal scenes, the motion rendition during the Apollo 11 mission was satisfactory.

Ease of scan conversion to the standard rate of 60 frames per second (fps) was another factor in determining the lunar camera frame rate, since submultiples of 60 fps are most easily scan converted. Bandwidth and power for television transmission were severely limited. Since the camera had to share bandwidth with voice, biomedical, and other telemetry data, the camera was limited to a 500-kHz bandwidth.

A 320-line scan was chosen to obtain nearly equal horizontal and vertical resolution. Most home television sets reproduce about 300 TV lines from a 525-line scan and provide a pleasing picture. The 10-fps mode provided a picture of about 250 discernible lines which provides a satisfactory picture.



### Scan Conversion

In Apollo 11, video from the camera was sent over a 100-foot cable to the lunar module transmitter. Camera video was mixed with the voice subcarrier and telemetry prior to insertion into the transmitter. The S-band transmitter provides approximately 12 watts to the steerable antenna. Use of this antenna provided good signal-to-noise ratio reception on earth.

Earthbound receiving stations are located at Goldstone, Calif., Madrid, Spain, and Canberra, Australia. Each of these stations has a high-gain antenna and scan conversion equipment. Received video is separated from the carrier and must be converted to standard TV rates before it can be sent to commercial stations.

Scan conversion is accomplished through the use of a cathode ray tube, a vidicon camera, a disc recorder and a video encoder. A vidicon camera views the cathode ray tube which displays the 10-frame video. The camera operates at standard 30-frame rate but will read out only one field each time it is keyed. Each frame of the lunar camera video takes 100 milliseconds which is equivalent to six fields of standard television frame time. Fifteen milliseconds before the end of one frame on the cathode ray tube, the vidicon camera is keyed to scan one field. This allows it to be read out and ready to receive new information by the end of both scans.

This video is recorded on a magnetic disc recorder. Six fields of this video are read out of the recorder to provide three frames of standard rate signals. Every other field is delayed by one-half line time to simulate interlace. Correct sync is inserted into



the video to provide the correct format for broadcasting. When converted in this manner, the 10-frame flicker is no longer present.

### Optical Systems

Several lenses were required for different fields of view and the light level was expected to vary from 0.007 to 12,600 footlamberts. To cover both of these conditions, a set of four fixed-focus lenses, Figure 3, were chosen in preference to a zoom lens or a turret system, because either of the latter would have been heavier and less reliable.

The lenses are all a quick-disconnect type that can be changed by an astronaut in a spacesuit. They are listed with field of view and T-number in Table II. (T-number is the combination of f-number and effects of filtering.) T-numbers were chosen so that the photocathode illumination would be within the dynamic range of the camera tube for the various scenes.

Maintaining optical focus for all lenses under all environmental conditions required careful selection of mounting materials and methods. For example, the lenses are mounted directly to the tube assembly rather than to the camera case. This permitted closer mounting tolerances to be maintained.

### APOLLO COLOR CAMERAS

The cameras generate a field sequential color signal using a single image tube and a rotating filter wheel. A ground station color converter later changes the sequential color signal to a standard NTSC color signal. This approach is new in that a simple and reliable method is used in the camera where it is most important and relegates



the complexity of generating a compatible broadcast signal to the ground where it is readily handled.

The Apollo 11 spacecraft color television camera shown in Figure 2 is 17 inches long including the zoom lens, weighs only 13 pounds (weightless in space) and is completely self-contained. A small four-wire cable containing a single d-c input voltage and a composite video output suitable for modulating the transmitters was the only connection required. During the space flight a small viewfinder monitor (also shown in Figure 1) was used to assist the astronauts in aiming and focusing the camera.

Besides providing real-time communications useful to NASA ground personnel and the public, the camera provides another scientific feature. The calibrated color filter wheel could allow true color information to be obtained by proper data reduction of recorded video transmission.

#### Apollo Color TV System

A general diagram of the color television system is shown in Figure 5. The image is focused by the lens through the filter wheel onto the faceplate of the image tube. As the wheel positions a red filter in the field, the image tube stores the red information of the scene being viewed and then reads it out. This information is processed by the electronics of the camera and is sent to the miniature monitor and to the transmitter. The same is true for the green and blue filter.

In Apollo 10, 11 and 12, the field sequential color signals were sent to the earth by the command module S-band transmitter. The received signal was fed into two tape recorders to compensate for





doppler shift while presenting the information in real time. The doppler shift in frequency is caused by the motion of the spacecraft in relation to the earth. The correction is done by recording the information as it was received in the first unit and playing it back in the second unit. The second tape unit is driven by the subcarrier standard frequency located on the ground. Since the recorded frequency has the doppler shift, the speed of the second tape unit varies in accordance with the difference between doppler and ground standard frequency and thereby compensates for the frequency shift in the video. Due to the necessity for replaying at the compensated rate, there is, at the most, a delay of only about 10 seconds from input to output.

After doppler shift compensation, the sequential color information was put into the scan converter which is a storage and readout device. The converter holds two previous fields in memory and upon receiving a new field presents the three fields at the output. As the new field is placed into memory the oldest field is erased, updating the information at the field rate.

#### The Camera

A block diagram of the color camera is shown in Figure 6. Almost 70 percent of the functional blocks are integrated circuits exclusive of the power supplies.

The camera consists of three sections, the first being a monochrome camera with the addition of synchronization, pulse forming, and drive circuitry for the color adaptation. The second section is attached to this camera forming the housing for the transformer and motor, and finally, the section containing the motor, gearing, and filter wheel assembly which also serves as the mounting for the lens.



The camera input voltage is  $28 \pm 4$  volts dc using 15 watts nominally. Its output is a standard EIA format at color standard frequencies with the exception that it does not carry the color burst which is added on the ground. It is a black negative signal from -0.75 to +2.75 volts into 100 ohms constrained within 20 percent to prevent overdeviation of the transmitter.

The bandpass of the camera is 4.5 MHz with a 20 dB/octave roll-off, therefore having a theoretical limiting horizontal resolution of 360 television lines/vertical dimension. Due to the fact that the signal-to-noise ratio is high and that the roll-off is finite, more extensive calculations and experience have shown the resolution to be in excess of 425 TV lines/vertical dimension. The limiting vertical resolution fixed by the number of scan lines and Knell factor is approximately 350 TV lines/vertical dimension.

The system limiting horizontal resolution is set by the bandpass of the command module transmitter and is less than 2 MHz resulting in slightly more than 200 horizontal television lines referenced to the vertical dimensions, which again exceeds the theoretical limit because of an even higher signal-to-noise ratio and finite roll-off. Since the signal-to-noise ratio was high, approximately 40 dB for a broad scene, it was decided to include aperture correction to boost the image tube 200-TV-line response by 40 percent, which also improves the resolution.

The Apollo color camera controls are limited to one switch associated with the electronics and the common lens adjustments of focus, iris, and zoom. The switch is used to change the automatic



light control detector from an averaging type for "inside" scenes to a peak-detector type for "outside" scenes. A typical scene for the "outside" mode would be the earth subtending one-third of the vertical field of view.

The lens is a standard commercial unit that has been extensively modified. The most significant modifications were changing the format from a 12.7 mm to 25 mm and changes to qualify the lens for space use. The lens characteristics are shown in Table III.

#### Color Wheel and Motor

The color wheel has six sections comprised of two sets of red, green, and blue filters. This configuration is dictated by the speed of the motor, 1,798.2 r/min, and the gear ratio, 3:1. The color wheel then rotates at 599.4 r/min or 9.99 r/s to yield six fields per revolution at the standard vertical color frequency of 59.94 hertz.

Because of size limitations, it was necessary to use a three-inch color wheel. This necessitated a special filter segment design to obtain optimum size, transmission efficiency, and uniformity.

Interspersed between the filters are opaque regions which are necessary to give the tube time to complete forming an image. As a particular filter rotates past the image tube faceplate this light information is integrated by the target. The electron beam must move across the target, while scanning, in synchronization with the filter wheel. To prevent mixing with the next color, an opaque region is located on the color wheel between the color filters. The size and shape of the opaque regions are determined by the wheel size and stability of the scanning beam and wheel rotation.



The synchronization of the wheel position and the scanning electron beam position is accomplished by knowing the relative position of the wheel and using that information to set the scanning beam. This principle is shown in the block diagram. A pickup device senses the wheel position, the signal is amplified and sets the synchronizing generator which controls the sweep circuits and causes the beam to be in the right position.

The ability of this system to keep the scanning beam in the opaque region depends to a large extent upon the stability of the synchronous motor which is only as good as its input frequency. It is necessary to maintain a highly stable motor drive frequency.

As a result of frictional load shifts and motor hunting, the filter wheel has some unpredictable motion. To compensate for this, the size of the opaque region is increased.

The input power to the motor is approximately 11 watts at nominal input voltage. If a class A driver were used to drive it, the total power would have exceeded 30 watts; therefore, it was decided to drive it with a pulse input resulting in a total power consumption of approximately 12 watts.

The filters are dichroic depositions selected for maximum transmission and spectral response. When modified by the spectral response of the S20 photocathode and a daylight source their response closely matches that of the P22 phosphor. These filters are deposited on one piece of glass and sealed by another.





SEC CAMERA TUBE

The SEC camera tube consists of three main sections: image section, SEC target assembly, and hybrid gun. The scene is changed from light to electrical patterns on the photocathode which emits electrons. These electrons are accelerated by the high potential between the photocathode and the SEC target. This target, the unique feature of the SEC camera tube, consists of an aluminum oxide layer, a very thin layer of aluminum, and a low-density KCl film.

When the accelerated electrons strike the target, they pass through the aluminum layer and strike the KCl film. Secondary electrons released by the KCl film are collected by the signal plate and the wall screen leaving a charge pattern in the KCl film. Since the resistance of the film is high, it can hold the charge pattern for long periods until discharged by the reading beam.

The reading beam is supplied by a vidicon-type gun, a hybrid arrangement with electrostatic focus and magnetic deflection (electrostatic focusing permits simple external circuitry and has low power requirements). As the reading beam scans the target, the beam current discharges the KCl film back to cathode potential. This discharging action produces the video signal.

An important characteristic of the SEC target is that it is almost completely discharged by the beam, leaving negligible signal pattern for the next readout unless recharged by the scene. This eliminates the image smear problems that occur with vidicons and orthicons at low light levels. Of course, smear will occur if the image is moved within a frame period.



Electron gain of the SEC target provides target charge gains in excess of 100. With an S20 photocathode, the combined sensitivity of the image section and the SEC target is typically 10,000 A/lumen. Since target gain is a function of the accelerating potential, target gain is controlled by adjusting the accelerating potential (-2 kV to -8 kV).

#### FUTURE APPLICATIONS OF APOLLO-TYPE CAMERAS

##### Space Television

The utility of television aboard spacecraft and in manned planetary landings has been proved beyond all doubt. The amount of public interest in space television was shown in Apollo 11 to be significantly greater than anticipated. During the Apollo 10 and 11 flights the astronauts showed some other applications when they televised the crew, indicating their conditions, and the unusual condensation in the tunnel for ground support evaluation. There are a multitude of other applications, mostly in the area of remote viewing for inaccessible locations and hostile environments.

NASA is planning extensive use of closed-circuit television on future missions. In the larger spacecraft and areas such as the S IV-B workshop, television will be used for on-board monitoring. Many activities will be undertaken by one man and the other crew members can monitor his movements on television for routine observation and safety. Closed-circuit color television with higher resolution than commercial television is planned for much of the monitoring.

Some real-time television links are planned for transmission back to earth. Lunar roving vehicles may use television for guidance control and navigation.



### Low-Light-Level Television

The successful development of a hand-held low-light-level space-craft camera demonstrated that the low-light-level TV (LLTV) concept would find expanding use in other areas where the same low-light-level conditions were present. LLTV is primarily a military night vision tool.

By early 1967, a low-cost, standard-rate, LLTV compact camera was available. It weighed under 8 pounds, consumed less than 8 watts, and was housed in a 4x4x8-inch case. This type camera provided full automatic light control and automatic gain control functions that allowed unattended operation over a wide range of light levels. An image intensifier can be added to a compact camera configuration to provide an extremely sensitive camera with the same size and power advantages.

With refinement of known techniques and continuing improvement, LLTV will become an accepted basic airborne sensor. For example, in the early 70's, photocathodes having a very deep red response and a sensitivity of 400 A/lumen are expected to be available. Image tube targets of silicon which produce gains in the region of 1000 to 3000 will be available, and over-all performance will be substantially improved with a possible reduction in cost. Active television using gated covert illuminators will provide full resolution capability in extreme darkness. Wider spectral bandpass will be realized for application with covert active television. The utility of LLTV will also be increased through the use of a greater zoom capability in the sensor tubes.



### Underwater Cameras

Cameras for underwater use have been developed partly as a result of space and military camera work. As with the other types of cameras, reliability, compactness, automatic features, sensitivity, and a minimum power demand are important in underwater units. In addition, underwater cameras must provide suitable resolution under deep water light levels, respond rapidly to changing scenes without smear, be able to detect low scene contrast, and operate over a wide range of scene brightness.

A variety of underwater TV cameras have been developed by the Westinghouse Ocean Research and Engineering Center in conjunction with the Company's Aerospace and Electronic Systems Division. These cameras are for a variety of purposes. Units have been built both for use by divers and for unattended use on manned or unmanned underwater vehicles.

One of the cameras developed is shown in Figure 7. In the photo, a Westinghouse engineer is pointing at the section of the underwater camera that is the same as the basic imaging section of the Apollo color cameras. The unit at the left of the photo is a miniature TV monitor in a pressure-resistant housing. The monitor itself, without the housing, is the same as those carried by the astronauts in the Apollo command module to help them focus and adjust their color TV camera. At the right of the photo is the underwater camera's housing which is water-tight and resists water pressure at depths to 1000 feet. The electronic subassemblies are insulated from the housing. Remote focus and automatic aperture control circuitry and mechanical linkages can be seen just behind the lens. The aperture or iris is activated by a cadmium sulfide





(CdS) sensor much like that used in automatic film cameras. This "light meter" along with built-in automatic light level control allow the camera to provide maximum resolution over a 250,000 to 1 light level range.

The lens used in this camera has a 50 degree diagonal field of view in water with remote focusing from six inches to infinity.

The camera shown in Figure 4 is 22 inches long with a diameter of 6.8 inches. Its operating depth is 1000 feet.

Although the camera shown is for use in water, an alternate design with almost identical appearance has been developed for use under pressure in a helium atmosphere. Helium is the main constituent of breathing gas used in deep diving and in saturation diving. It is a very light element and causes a variety of problems under pressure. One effect is that TV camera tubes degrade very rapidly in a high-pressure helium atmosphere. The cause is a gradual infiltration of the helium through the glass from which the tube is made, especially the faceplate. Other electronic components also suffer.

To solve this problem, a camera for use in a helium atmosphere is put in a pressure housing much like that used for the underwater camera but with a special type of glass and metallic O-ring seals.

A WL-30691 SEC camera tube is used in the underwater camera. This tube, manufactured by the Westinghouse Electronic Tube Division, is coupled by a fiber optic faceplate to a 25-millimeter format image intensifier.

###

GLOSSY PRINTS AND TABLES ENCLOSED.

Figure 1 -- PRX-29688-24

Figure 2 -- PRX-29546-17



Figure 3 -- PR-28923

Figure 4

Figure 5

Figure 6

Figure 7 -- PRX-29920-29

TABLE I

TABLE II

TABLE III



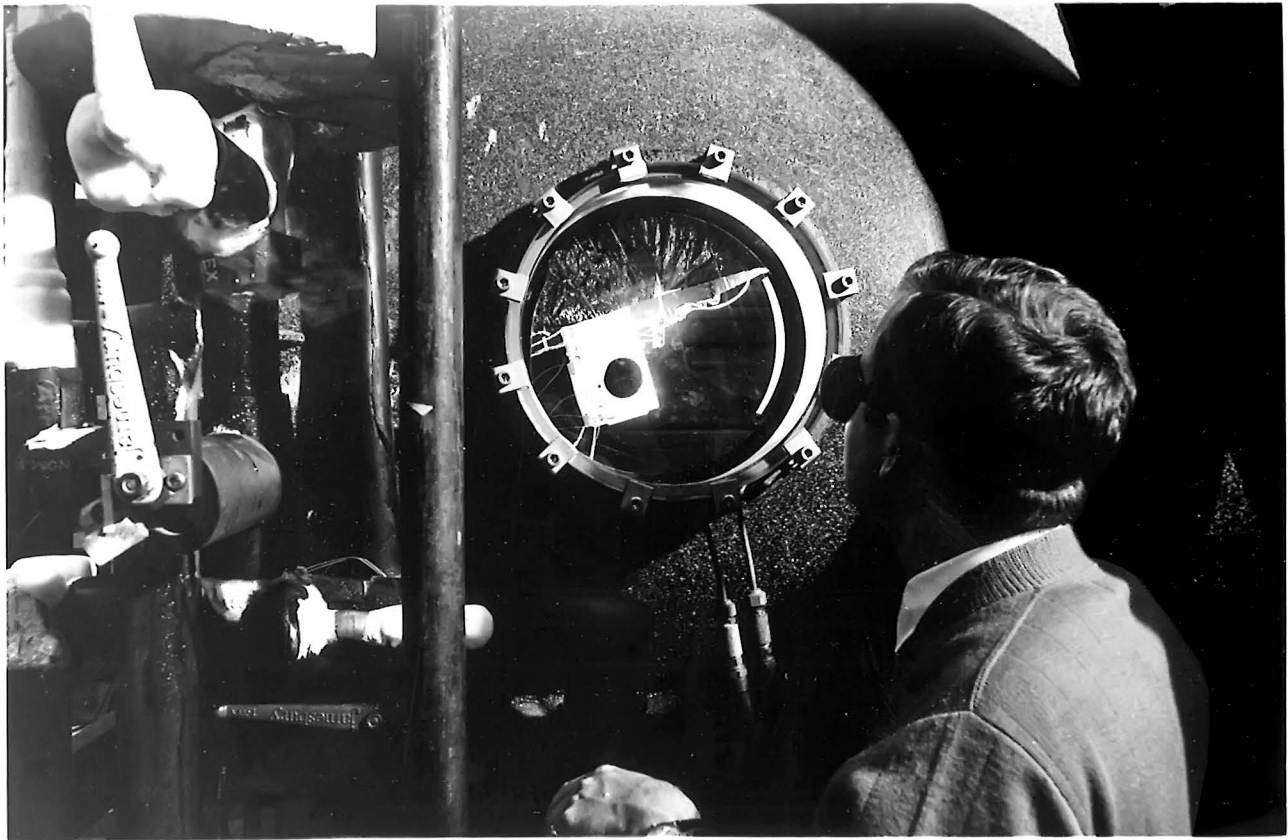


Figure 1.

Westinghouse Photo PRX-29688-24



Figure 2.

Westinghouse Photo PRX-29546-17



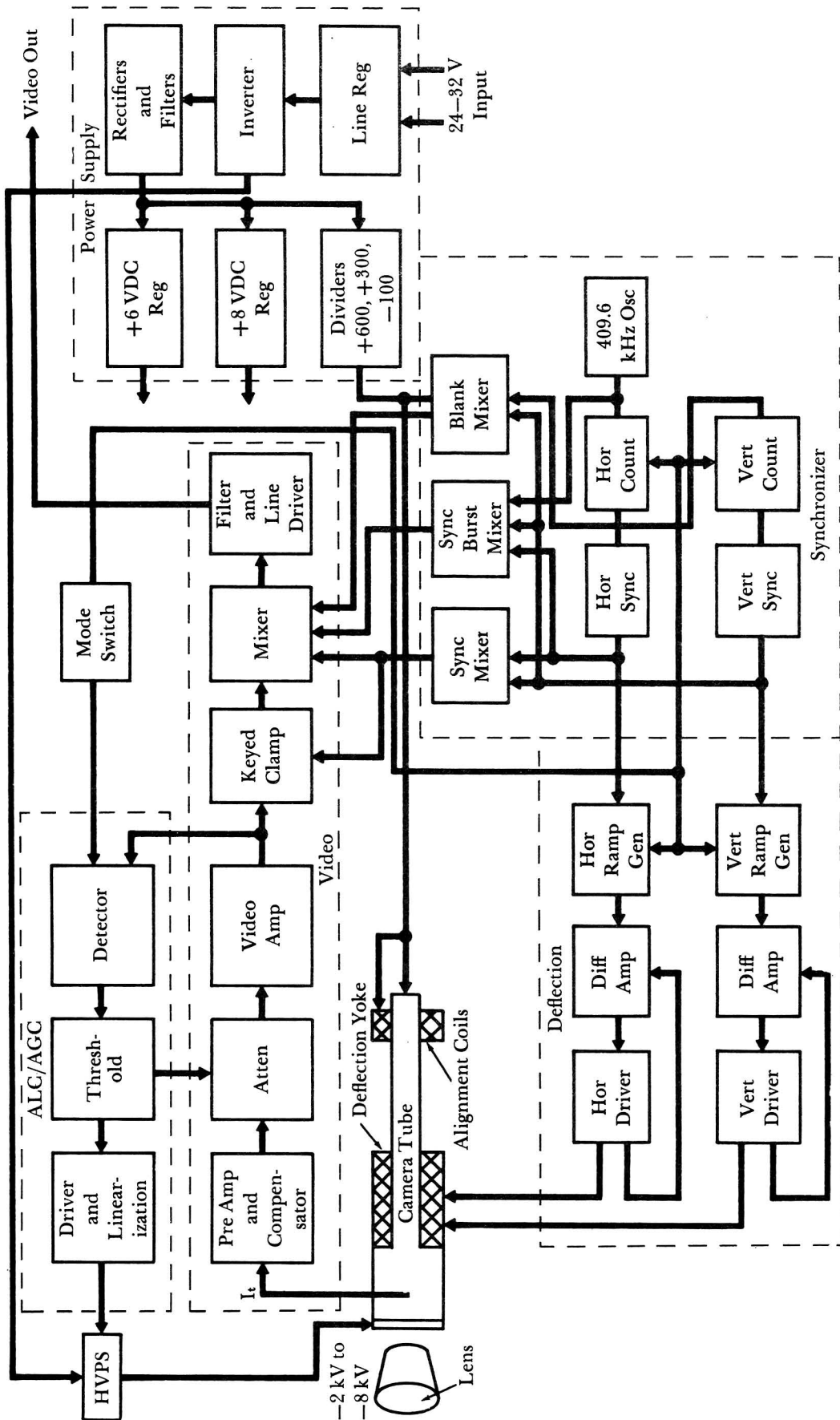
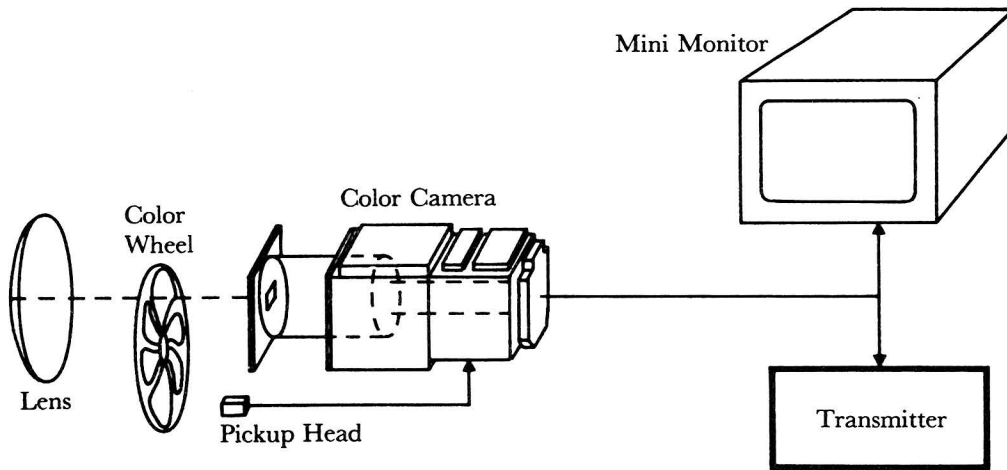


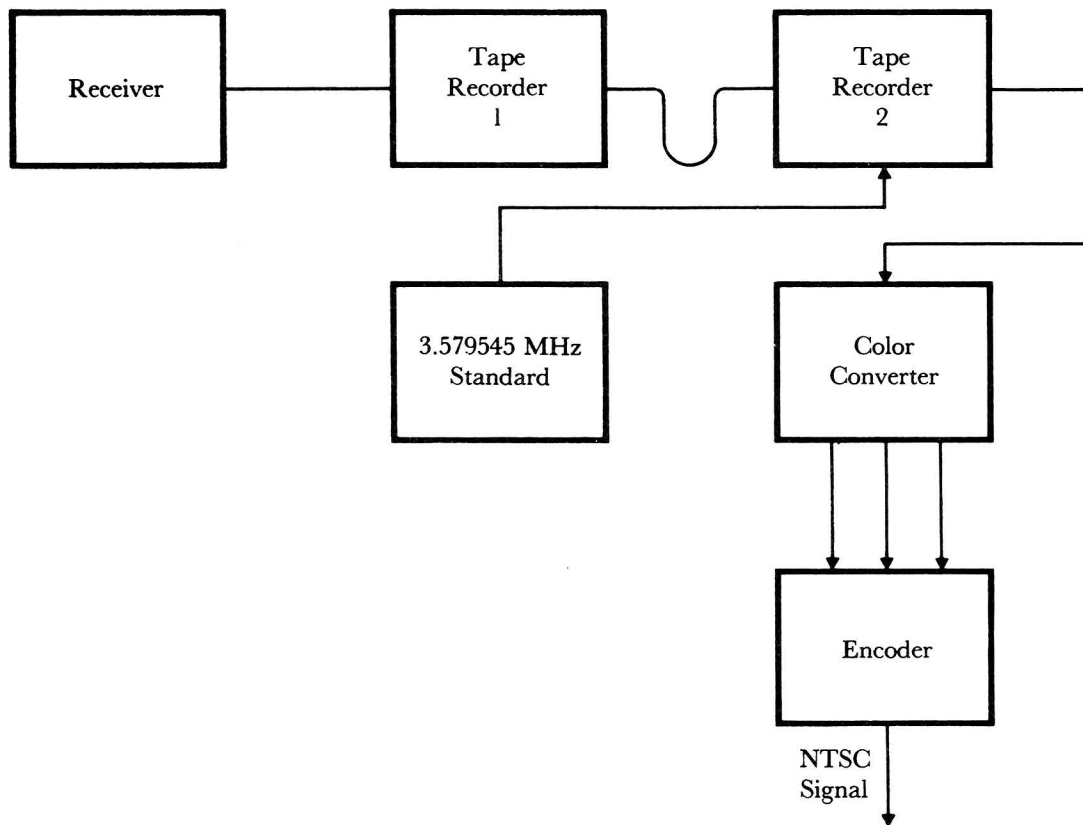
FIGURE 4







Spacecraft Equipment



Ground Equipment

FIGURE 5



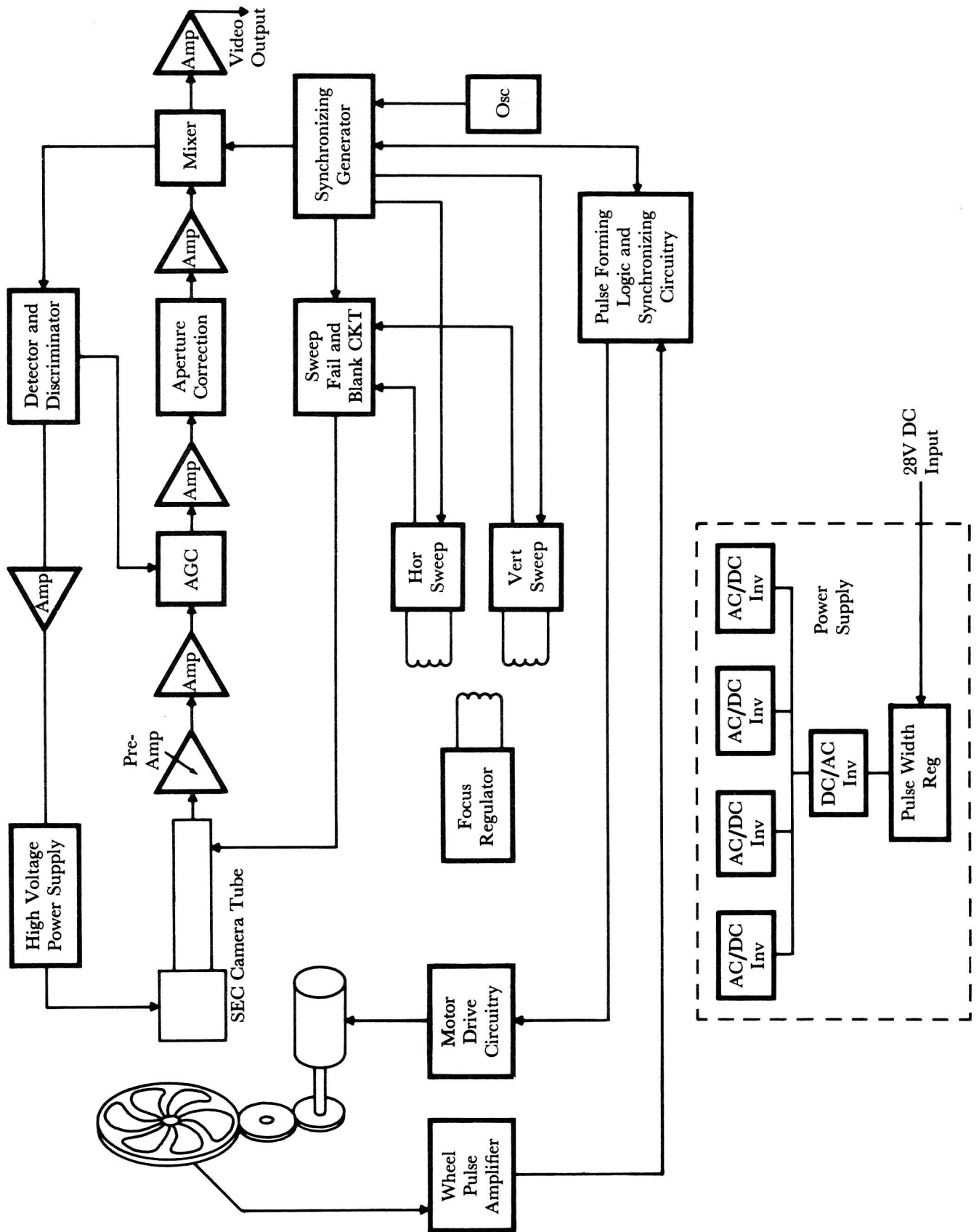


FIGURE 6





Figure 3.

Westinghouse Photo PR-28923



Figure 7.

Westinghouse Photo PRX-29920-29



TABLE I  
GENERAL CHARACTERISTICS OF THE APOLLO TV CAMERAS

	<u>Lunar Camera</u>	<u>Color Camera</u>
Scan Rate	10 fps 5/8 fps	30 fps
Minimum Signal-to-Noise Ratio	28 dB	32 dB
Resolution	320 lines (10 fps) 1280 lines (5/8 fps)	425 lines
Video Bandwidth	500 kHz	4.5 MHz
Electrical Requirements (nominal)	28 + 4 Vdc 6.5 W	28 + 4 Vdc 15 W
Minimum Light Range Ratio	1000:1	1000:1
Weight	7.5 lbs	13 lbs
Cooling	Radiation	Radiation





TABLE II  
BLACK AND WHITE LUNAR CAMERA LENS CHARACTERISTICS

<u>Scene</u>	<u>Light Level (footlamberts)</u>	<u>Lens Field of View (degrees)</u>	<u>Lens T-Number*</u>
Lunar Surface - Night	0.007-1.2	30	1.15
Lunar Surface - Day	20-12,600	30	60
Earth and Moon	20-12,600	7	60
Spacecraft Interior	0.5-300	80	5

\*T-number is the combination of f-number and the effects of filtering.



TABLE III

## COLOR CAMERA LENS CHARACTERISTICS

T-number		5:1
Zoom Ratio		6:1
Focal Length		25 mm to 150 mm
Field of View		
Wide Angle		43° horizontal
Narrow Angle		7° horizontal
-		
-		Near Focus f#
Wide Angle	20"	4.4
Wide Angle	1"	4.4
Narrow Angle	3"	4.4
Narrow Angle	2"	4.4

