X11.5
X1.8

M-ASTR-IN-63-6
February 25, 1963



# INTERNAL NOTE

## SATURN TELEVISION SYSTEM FOR SA-6

XI.8
XII.5

By

Carl T. Huggins

INSTRUMENTATION DEVELOPMENT BRANCH
ASTRIONICS DIVISION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

FOR INTERNAL USE ONLY

MSFC - Form 1094 (May 1961)

ASTRIONICS DIVISION

M-ASTR-IN-63-6

# SATURN TELEVISION SYSTEM FOR SA-6

By

Carl T. Huggins

## ABSTRACT

The Saturn television system is an instrumentation device intended to provide visual information on vehicle performance in real time. The system covers the entire problem from the original image presented to the television camera to the presentation of the finished photographs for analyses.

A brief history of the television instrumentation system is presented to chronicle the evolution of the system concepts and designs. The inflight television system and the ground receiving station are described, as used in the instrumentation of the Saturn SA-6 research vehicle test flight.

This modular system is highly adaptable to many various applications. It is available without additional R&D funding to other government agencies.

ASTRIONICS DIVISION

M-ASTR-IN-63-6

# SATURN TELEVISION SYSTEM FOR SA-6

By

Carl T. Huggins

VEHICLE COMMUNICATIONS UNIT
RF SYSTEMS SECTION
INSTRUMENTATION DEVELOPMENT BRANCH

ASTRIONICS DIVISION

M-ASTR-IN-63-6

# SATURN TELEVISION SYSTEM FOR SA-6

By

Carl T. Huggins

## SUMMARY

The Saturn television system provides real time display and permanent storage of pictures televised from the vehicle during test flight.

The system antedates all known research rocket television systems with inherent commercial television system compatibility, high picture resolution, and display-analysis features.

The Saturn television system is considered applicable to many other research projects where environments comparable to that of the Saturn are expected. The system is modular in form and, consequently, highly adapted to a wide variety of layout schemes. It is now available and offers a considerable savings to other users since little R&D funding should be required for many various applications.

## INTRODUCTION

The Saturn television system is an instrumentation device to provide visual vehicle performance information in real time. The system also makes a permanent record of the information. Information may be provided from any area inside, outside, or around the craft before, during, and after launch as well as information from areas remote to the craft. The entire problem from the original image before the TV camera to the finished photograph is covered by the system.

The transmitting equipment includes one to four cameras and camera control units, a master clock, a sequence coder, and a transmitter. Only two cameras are used in the SA-6 system. The master clock generates the horizontal and vertical drive signals for all cameras to insure that they maintain the same frame relationship. The sequence coder receives the outputs of the cameras used and feeds them in sequence to the wideband frequency modulated transmitter.

The receiving system consists basically of a parametric amplifier and a broadband receiver. The receiver output is fed through four distributing amplifiers to the display and recording systems.

## HISTORY

Responsibility for the design-development of an instrumentation television system for the Saturn research vehicles was assigned to the Radar and Communications Unit, RF Systems Section, Instrumentation Development Branch, Astrionics Division, MSFC, in early 1959. Since that time, this organizational segment has been engaged in evolving television systems for use between space vehicles and the earth; first, for instrumentation purposes to yield information useful in the development phase of the Saturn systems and second, with a view toward providing real-time operational data from the post-development vehicles while engaged in the navigation of space. A continuous study was made of the various instrumentation problems as they were presented in the course of the development of the Redstone, Jupiter, and Pershing missiles, both as they were related to vehicle system development and to space navigation as they were inferred.

The primary concern for the application of vehicle-borne television systems to the earlier programs implied relatively short flight times and operational ranges; a high picture rate was required with good resolution for the acquisition of as much information as could reasonably be recovered during the short times involved. Commercially available television subsystems were then providing a capability of 30 pictures per second with the desired resolution. On this and other considerations, a decision was made to concentrate, at least in the beginning, on a small, extremely rugged camera capable of withstanding the environmental extremes expected during powered flight and free space coasting of the test vehicles

The first complete system assembled included an entire flight system that consisted of a wideband transmitter featuring quasi-carrier frequency modulation and a miniaturized camera-chain capable of withstanding the least favorable launch environment expected, which was that of the Redstone booster at that time. The ground system consisted of a locally fabricated receiver, a broadband amplifier, and a specially-built kinescope recorder. The inhouse assembled ground station was operated by laboratory personnel because of their familiarity with the laboratory arrangement of the apparatti.

This system was the first to transmit real-time high-resolution television pictures at 30 frames-per-second speed, compatible with commercial television systems, from a ballistic missile operating outside the earth's atmosphere. It operated satisfactorily from liftoff to the optical horizon, a distance of more than 320 km, on the famed flight of the monkey "Ham" on the Mercury-Redstone vehicle, January 31, 1961.

The multiple-camera single-transmitter system concept was evolved and tested early in 1960, and a proposal including a system description along with the details of the test and an evaluation of the test results was subsequently submitted to Dr. Wernher von Braun in that same year. Extensive tests of the new camera and the lighting concepts for application, both on the test stand and inflight, continued until the fall of 1961, at which time it was considered operational for the 1.5 million pound thrust environment of the Saturn booster. It was then included as an instrumentation device in the instrumentation program for the Saturn system.

Pictures received from this system may be displayed on any standard television system such as the local commercial broadcast television stations or any of the major television networks, which must conform to the Federal Communications Commission's standards for the generation of synchronization signals. Recent single-camera, real-time pictures made of the deployment of the Echo I balloon demonstrate the excellent results that can be obtained with this type of system. These pictures were shown over the major commercial television networks.

## INFLIGHT EQUIPMENT

### 1. Transmitter

The Saturn television system employs a wideband frequency modulated transmitter utilizing quasi-carrier techniques. The transmitter modulation creates a quasi-carrier frequency in the presence of a modulating signal with the unmodulated frequency occurring at the lower limit of the assigned frequency band. The sync tip of the composite video signal is clamped to the lower limit of the carrier frequency. In the presence of modulation, the carrier deviates in an upward direction. Lower and upper side bands are generated with the center frequency at any given instant being dependent upon the average d.c. of the composite video signal. The center frequency varies with changes in the video of the composite video signal, while the lower side bands are limited by the transmitter bandwidth. The maximum deviation of the carrier will not exceed 20 MHz in an upward direction from the carrier frequency of 860 MHz.

If a modulation index of one is considered, a deviation factor of 80 lines per MHz is assumed, and it is desired to transmit a picture with a video bandwidth of 4.2 MHz (336 lines) using the second order side bands on the upper side of the quasi-carrier to yield the desired detail in the picture, an overall deviation of 4 x 4.2 or 16.8 MHz will be necessary. Therefore, a bandwidth of 20 MHz is allowed to permit a better-than-commercial quality picture to be transmitted over the system. Such modulation is considered to be optimum for operations through orbital ranges.

The present transmitter employs a cavity in the final stage consisting of three ceramic-triode electron tubes. The output of the transmitter is 5 watts with an input power of approximately 50 watts.

A power supply converts the 28 V d.c. vehicle power to the voltages required by the transmitter.

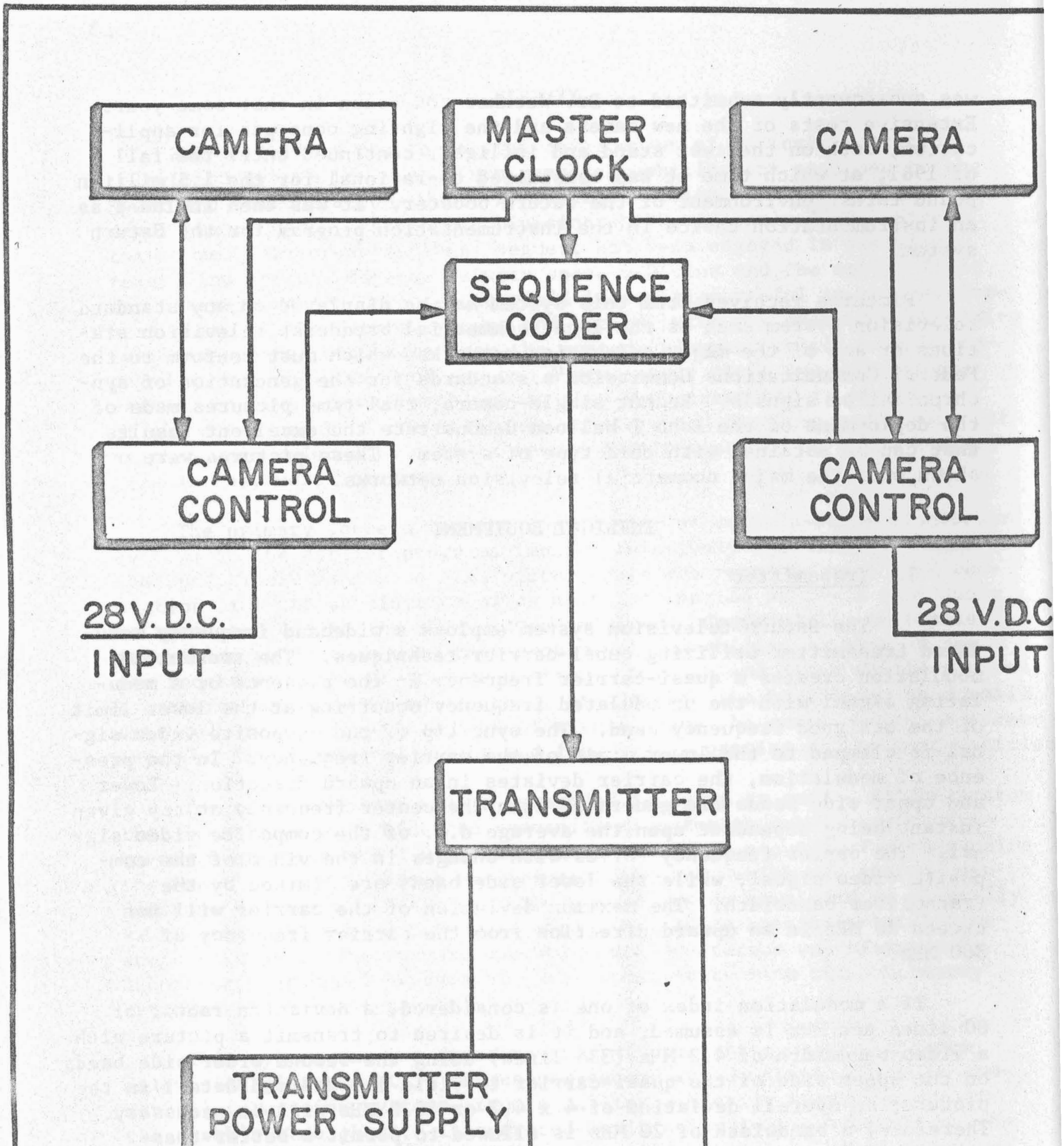


**Figure 1 Inflight Equipment**

2. Cameras

Two cameras are carried on SA-6 to view separate areas. The same transmitter is utilized to transmit the pictures to the ground station. This technique was adopted to conserve both primary power and carrier bandwidth while transmitting maximum information.

3. Master Clock

The master clock or synchronizing generator initiates the horizontal and vertical drive signals for both cameras to maintain the same frame relationship for both in switching from one camera image to the other. The horizontal drive signal is 15 750 Hz and the vertical drive signal is 60 Hz. This permits the necessary sweep generating circuits to be housed within the control unit associated with each camera.

As the basic frequency standard, the synchronizing generator uses a highly shock-resistant crystal. The crystal is encapsulated in a silastic compound to protect it from the highly adverse environmental conditions experienced during launch. The solid-state synchronizing circuits are housed in a canister along with its d.c. to d.c. converter and is operated from the common 28 V d.c. vehicle power. The synchronizer can be used to provide horizontal and vertical drive signals for as many as four cameras. Each output is isolated from the others so that failure of any one camera will not affect the output to the other cameras.

4. Sequence Coder

The sequence coder is capable of accepting the composite video input from four cameras simultaneously. The single output is applied to the modulator input of the transmitter. Vertical timing pulses are provided by the master timer for switching purposes.

Only two camera inputs are available on SA-6, although the four camera capability exists for two additional cameras. Each of these two inputs will be switched in turn to the input of the transmitter for two complete pictures. The switching takes place during the vertical interval preceding the two pictures.

The coder is capable of identifying the field beginning a frame or a picture, so the frame registry will be preserved when switching from one camera to another. During the vertical retrace interval preceding the first picture of a group of two, from camera number one, the coder will place a signal on the carrier indicating that transmission of camera number one is about to begin. The solid-state sequence coder contains its own d.c. to d.c. converter to use vehicle 28 V d.c. power for operation. The latest techniques in miniature transistors and modular construction are used to insure the maximum in efficiency and reliability.

The flight system consists of the transmitter assembly which includes the transmitter power supply, the master clock, and the sequence coder. These units may be mounted together as a package or separately for mounting convenience. The remainder of the flight system is the cameras and their respective control units.

## GROUND RECEIVING STATION

### 1. Parametric Amplifier

A parametric amplifier, located at any convenient point between the antenna and the receivers, provides the maximum of gain consistent with the lowest noise figure. The amplifier has a gain of approximately 20 db, with a noise figure of 1.35 db.

### 2. Receivers

Two wideband superheterodyne receivers convert the frequency modulated signal into the video signal and apply it to the signal processing and distributing amplifiers. The two receivers cover the same frequency band; however, only one of their outputs at a time is utilized by the ground station. The second receiver is constantly monitored to show picture condition in the event that the first receiver fails to perform properly. Switching between the receivers can be accomplished within the time period of approximately one frame of transmitted information. The receivers are existing microwave television receivers that have been modified to improve their gain, noise figure, linearity, and bandwidth characteristics. The acceptable threshold gain of each receiver is 85 db, with a noise figure of 12 db. The intermediate frequency is 44 MHz, with an IF bandwidth of 20 MHz flat to within 1 db. The video output of each receiver is set to 1 volt composite peak-to-peak with a negative going sync.

### 3. Distributing Amplifiers

The output of the receiver is fed into four signal distributing amplifiers in parallel. These amplifiers serve as buffers between the receiver and the other sections of the system. If any one section ceases to function during an operation, it has no effect on the remainder of the system. The video bandwidth of each amplifier is in excess of 8 MHz. The output levels are adjusted to 1 volt composite peak-to-peak. Each amplifier has four isolated outputs.

### 4. Video Tape Recorder

One output of distributing amplifier #1 is applied to an Ampex model 1001A video recorder. This video recorder has been modified to accept the resolution present in the French system of television transmission. It has a video bandwidth of 5.5 MHz at the tape speed of

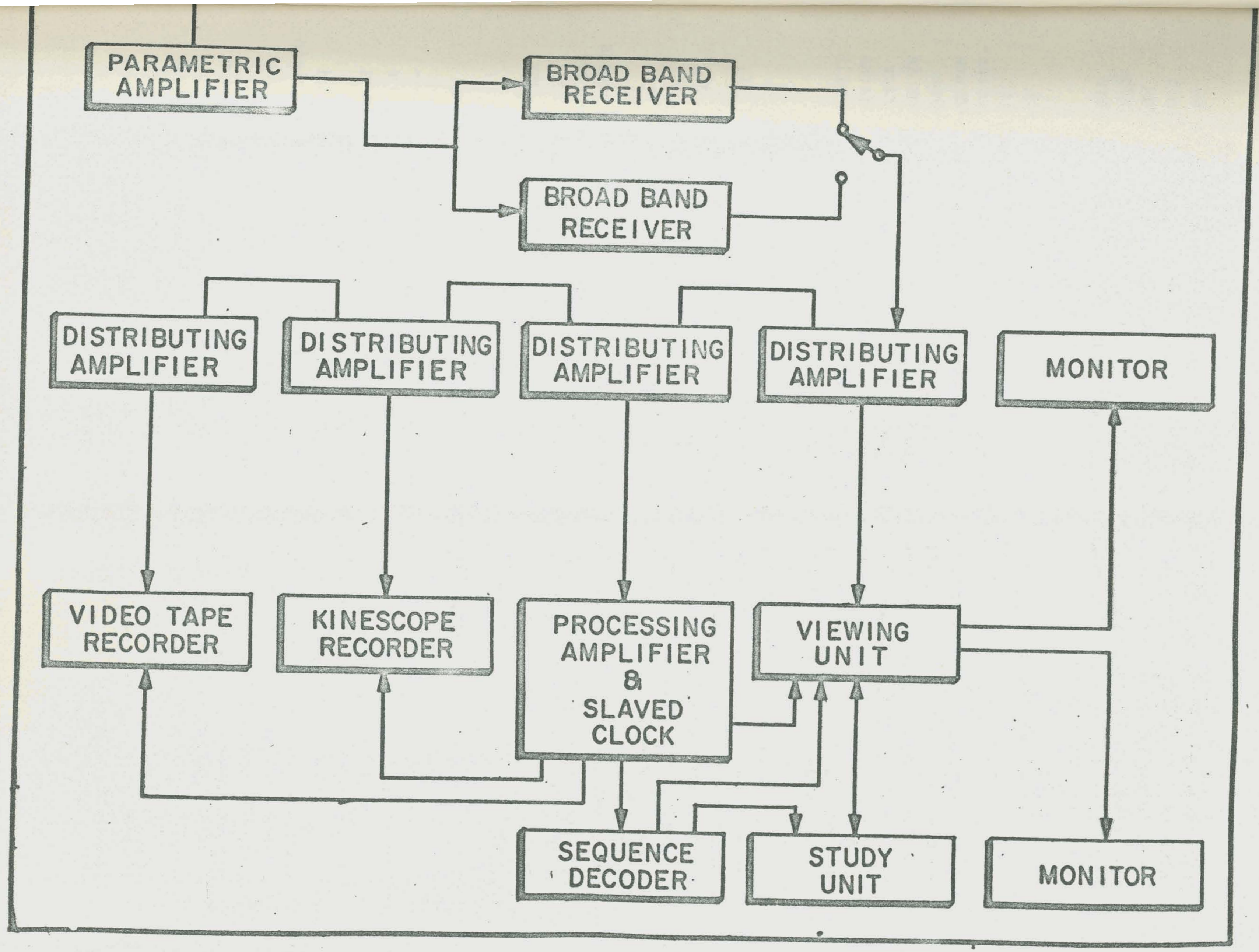


Figure 2 Ground Receiving Station

approximately 37 cm/s. The recording time of one reel of tape is 60 minutes. The video recorder accepts the 1 volt composite signal in a terminated input of 75 ohms, unbalanced. All video information from the receiver is recorded on the main video track of the recorder. The remaining two tracks, the main audio channel and the cue channel, are used for other data.

5. Kinescope Recorder

One output of distributing amplifier #2 is applied to the kinescope recorder. This recorder uses a Bach-Auricon 16 mm motion picture camera to photograph the face of a 20-cm standard wideband television monitor. All information supplied from the receiver to this monitor is recorded at 30 frames per second by the camera. The kinescope monitor tube is a whiteface type with a P-4 phosphor. The film capacity of the camera is 26 minutes. Each picture received by the ground station will be photographed independently on the film.

To identify an individual picture with respect to the camera of origin and to identify the picture in terms of vehicle time-of-flight, numbers are simultaneously photographed in the upper right and left corners of the picture. A single digit is recorded in the upper right corner that indicates the number of the camera of origin. A 3-digit number appears in the upper left corner. This number indicates the flight time (in seconds) of the vehicle from takeoff. When zero is reached in the countdown, the numbering system for these 3 digits begins to function. The 3 digits represent the time to the nearest second for each frame within the total-time capability of 999 seconds. A photograph of any single frame will have the vehicle time recorded for easy reference, beginning at launch time.

6. Processing Amplifier and Slaved Clock

One output of distributing amplifier #3 is applied to a processing amplifier which strips the video component of the signal from the synchronizing component for use in two parts of the ground-timing system. The synchronizing portion of the incoming signal, called "stripped sync," has all of the synchronizing information transmitted from the vehicle. This output from the processing amplifier is fed into a unit called "sync lock." The sync lock unit and the sync generator form the slaved clock which serves as a master timer for the entire ground station. The sync lock and sync generator are tied together in a servo loop which functions at a standard frequency in the absence of an incoming signal from the vehicle. This standard frequency is 60 Hz for the vertical frequency and 15 750 Hz for the horizontal frequency. The horizontal frequency is converted into an average d.c. voltage by the sync lock and fed to the sync generator.

The vertical sync signal is compared with the sync generator output or with incoming signals. As long as the correct phase is maintained, no correction voltage is applied to the sync generator that feeds both horizontal and vertical drive signals back to the sync lock unit to complete the servo loop.

When a signal is received from the vehicle via the processing amplifier, the horizontal sync frequency is compared with the sync generator horizontal frequency and an established d.c. level which may or may not be the same as the before-reception level of the airborne signal. If this frequency is different and therefore the voltage is different, the correction voltage fed from the sync lock to the sync generator begins to change the frequency of the horizontal oscillator. When the first vertical sync pulse of the received signal comes into the sync lock, it will be checked for phase against the vertical signal fed to the sync lock by the sync generator. If there is a phase difference, a correction voltage is fed to the vertical oscillator and, within the period of three frames, the ground sync generator will shift its frequency smoothly to that of the flight unit. Normal conditions permit a reduction of this time period to less than that of a single frame. All ground systems, locked to the sync generator for vertical and horizontal frequencies, have their frequencies shifted to correspond to the signal received from the vehicle. If there is a loss of received signal to the sync lock from the processing amplifier, the servo loop returns to the original standard reference frequencies, which are normally received from the flight unit. This insures that all ground equipment will continuously receive synchronizing or timing pulses and continue to function as if video information were being received from the vehicle.

The sync generator supplies composite sync to the video tape recorder, to the kinescope monitor, to the ground sequence decoder, and to the ground storage viewing unit.

7. Sequence Decoder

The sequence decoder is the counterpart of the sequence coder located in the flight unit. It accepts two types of inputs and accepts the output of the sync generator and uses this to operate its time clock. The time clock divides the vertical drive pulses by 4 to provide 15 pulses per second to a solid-state switch having four outputs. Only two of these outputs are used when the decoder is set for two cameras. The 15 pulses per second supplied to the solid-state switch cause it to move continuously from position one to position two and back again. It switches once every two complete pictures or frames of video. The switch opens a gate that passes one vertical blanking pulse which becomes a command pulse. One command pulse for every four vertical blanking pulses is passed through the gate operated by position one of the counter. Then this gate is closed and gate #2, controlled by position two of the switcher, opens to permit one command pulse to pass the gate during four pulse intervals. The command pulses go out on what are called command lines #1 and #2 and are fed to the storage and viewing units. These command pulses are required for the operation of the storing and viewing units.

The second output of the processing amplifier is the video portion of the received signal and contains no synchronizing information. It reclaims certain information required by the sequence decoder which will be discussed later.

The command pulses appearing at the output of each of the positions of the sequence decoder switch must be the correct four pulses associated with two consecutive frames or pictures from the same camera in the flight unit. If this condition does not exist, an absence of frame registry will occur. A single picture on a monitor could consist of one half of a picture from one camera and one half of a picture from another camera. If the switch in the ground station loses synchronization with the switch in the vehicle, the video tape recorder contains a circuit that can distinguish the first field or first half of any single frame and produces a pulse referred to as the edit pulse. This pulse occurs just prior to the beginning of the first field or first half of each picture. It is fed continuously into the portion of the divider chain that produces the 15 pulses per second which controls the command output switch. If the edit pulse arrives at a time when this portion of the divider is in the wrong state, it will cause the frame registry to be corrected as the command switch advances to the next position.

8. Storage and Viewing Unit

The storage and viewing unit contains special storage tubes and their associated circuits which allow standard monitors to receive 30 pictures per second at all times regardless of the input to the ground receiving system. There is one storage tube for each camera on board the vehicle.

When the ground station is receiving and recording the two pictures from camera #1 on the video tape and kinescope, the viewing and storage unit is performing the following functions:

The unit has storage tube #1 clear. The command pulse from command line #1 of the sequence decoder commands the viewing and storage unit to accept and store the next two fields, or one complete picture. The storage tube accepts and stores this picture, then closes its acceptance gate to prevent information from being accepted until the sequence decoder returns its command switch to position #1. While the picture is being stored, it is read out to monitor #1, the standard monitor. This monitor receives the original frame, as it is stored, and then receives three identical copies of this frame read from the storage tube. This includes one frame during storage, one frame while the second is transmitted from camera #1, plus two frames during the time that camera #2 is transmitting its two frames from the flight unit.

At the beginning of the next group of four frame intervals, the command pulse will completely erase the stored picture within one millisecond after the beginning of the vertical interval. The storage tube, then being prepared for storing, will cut off the erase circuit and activate the write circuit. Storage will commence at the trailing edge of the command pulse.

Only one command channel is open at any time; therefore, only one storage tube receives information at any given time. It is possible, however, for the video component (passed simultaneously to all of the write circuits of the storage tubes) to become displaced by one or more pictures or cameras because of signal fading or original turn-on of the system when the clock in the vehicle and the clock in the ground station are not in step. To correct this situation as quickly as possible, the separated video from the processor is passed through a narrow-band filter. The signal placed on the carrier in the sequence coder in the flight equipment to insure the correct orientation of the cameras during the first two or three lines following the vertical blanking period is removed by this filter. Normally at the top and bottom of the raster-scan, there are three or four lines scanned on the vidicon tube outside the image area. A narrow-band signal is placed in the area of these lines on the composite wave and is passed through the filter in the ground system while all other components are blocked. A pulse from the filter of approximately 50 microseconds duration occurs during each of the first two or three lines following the vertical blanking interval and is called the homing pulse. In normal operation, the homing pulse is applied to both sections of the divider in the sequence decoder as well as the first position of the solid-state switch. This resets all circuits in the solid-state switch to the #1 camera position, regardless of the state of the circuits prior to the receipt of the homing pulse. Resetting these circuits will not initate a store command since the store command pulse must pass through one of the gates which in turn must be operated by changing the position of the switch. The homing pulse simply resets the circuits so that the next vertical drive pulse coming through on channel #1 will pass, open the gate, and allow the command pulse to pass to the storage tube #2. Storage tube #2 then stores the picture from camera #2. Thus the picture from camera #2 would be the first one to return to camera registry as a result of the command pulse from the command switch in the sequence decoder.

It is possible to regain the signal following an outage immediately following the initiation of the homing pulse. That is, all cameras could be out of camera registry for one rotation of the command switch until the next homing pulse arrived from the vehicle to restore the normal conditions and return all monitors to normal registry. During this time, frame registry would be preserved by the edit pulse and one picture at the most could be on the wrong monitor. This is of negligible concern because the maximum time period is 1/15 of a second. The resolution of the storage tubes is 300 line-pairs, horizontal, with no noticeable decay of the picture under these operating conditions within the maximum storage time of 1/4 second.

The original signal from the receiver is routed to the video tape machine for recording. The two other tracks normally used for audio recording are used for other functions. The track normally used for commentary purposes, called the cue track, has a special purpose in this system for use after the recording is made. Circuits operated by the edit pulse produce a binary number from 1 to 99 999. The output is in serial form so that it may be recorded on the cue track. The beginning of the numbering is chosen at some point prior to the time of vehicle launch. When the numbering switch is thrown, these circuits immediately begin to place the binary numbers serially along the tape during each 1/30-second period, while the picture is being stored on the tape. Each picture has its own identifying number, which may be used later to relocate it, recorded simultaneously on the tape.

### 9. Study Unit

The study unit operates in conjunction with the viewing and storage unit. It consists of a standard monitor and one of the special storage tubes. After a flight or test has been recorded, the tape may be played back through distributing amplifiers #3 and #4, and the entire flight can be reviewed exactly as seen during the actual recording. If it is desired to study a single picture from one of the two cameras on this flight, a switch allows only the command pulses from the sequence decoder associated with this camera to be passed to the study unit. The video is fed from the same camera output of the viewing unit to the normal monitor mounted with the study unit, so that images from this one camera may be viewed as the tape recording is played back.

When the image of interest is located, pressing a store command button causes the study unit to pass the next command pulse associated with the camera being viewed to the circuitry of a special storage tube in the study unit. The next picture from this camera is stored on the storage tube. The writing gun is turned off and no more information is accepted in the storage circuitry. However, the normal monitor continues to show the pictures as long as the tape continues to run. The tape may be stopped to analyze the picture on the study storage tube. This picture will remain for 2 minutes, with no more than 20 percent degradation of resolution. Provisions are included for swinging a Polaroid camera over the storage monitor and making a 10-second print in the normal manner for record or for sending to a remote location for analysis.

At the same time that the store command button is pressed to allow a store command to go to the study unit storage tube, circuits associated with the numbering system, which placed the numbers on the tape originally for each picture, convert the number associated with the picture to be stored and viewed into a decimal number. Five "Nixie" readout tubes display the decimal identification number for this particular picture.

After 2 minutes, the picture on the storage tube will automatically disappear because normal degradation causes the picture to fall below an acceptable level for study. Should the same picture be required for study again, a set of rotary switches may be set to the number noted for that picture and the tape returned for a new search scan for the desired picture. A coincidence circuit is set up to compare the number set on the switches against the number continuously read from the tape for each passing picture. When the correct number has been received and compared, the picture identification command automatically is issued by the numbering system. This command causes the same picture to be stored on the storage tube as previously done when the store command button was pressed. The same decimal number appears immediately below the stored picture as the double-check that the proper picture is displayed. The capability exists for displaying any one of a possible 99 999 individual pictures.

For example, assume picture number 704 is viewed and the analyst decides to go back approximately one second in time and view the image from the same camera. At 30 frames per second the nearest multiples of four corresponding to 30 are 28 and 32. The analyst subtracts 28 from 704 and gets number 676. The analyst sets the switches for 676, backs up the tape, and plays it through again. The comparison circuitry of the picture identification system pulls out picture 676 and stores it on the study tube. The picture will be displayed for 2 minutes.

The picture may be erased from the study unit in either of two ways. Backing the tape and starting it forward again automatically causes the picture to disappear. No output will be issued by the picture identification system for comparison if all the switches associated with the readout tubes are set in the OFF position. The system with the study unit permits the analyst to retrieve any one of 99 999 pictures and to make a high resolution photograph within 5 minutes after the completion of the flight.

APPROVAL

THE SATURN TELEVISION SYSTEM FOR SA-6

By

Carl T. Huggins

T. A. Barr

T. A. BARR
Chief, RF Systems Development Section

for L B Bell

O. A. HOBERG
Chief, Instrumentation Development Branch

DISTRIBUTION

M-LVO-E
Mr. Sendler
Mr. Williams

M-LVO-EP
Mr. Collins

M-LVO-ER
Mr. McMath
Mr. Wheeler
Mr. Edwards
Mr. Byrnes

M-QUAL-PI
Mr. Brooks
Mr. Batte

M-P&VE-VG
Mr. McCollough

M-ASTR-DIR
Dr. Haeussermann
Miss Flowers

M-ASTR-I
Mr. Hoberg
Mr. Bell

M-ASTR-IM
Mr. Powell

M-ASTR-IR
Mr. Barr
Mr. Harper
Mr. Duggan
Mr. Huggins (50)
Mr. Malone
Mr. Gregory

M-ASTR-IP
Mr. Cox
Mr. Bratcher (10)

MSC-ASPO
Mr. Clyde Whittaker (2)

MSC-SEDD
Mr. Alfred Eickmeier (2)

M-ASTR-ADM
Reference File

M-MS-IP
Mr. Remer