UNCLASSIFIED

AD NUMBER
ADB008136
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; NOV 1975. Other requests shall be referred to Air Force Flight Test Center, Edwards AFB, CA.**
AUTHORITY
AFFTC ltr 20 Sep 1976

THIS PAGE IS UNCLASSIFIED

AFFTC-TR-75-40

AD B008136

DEVELOPMENT OF AN AIRBORNE HIGH RESOLUTION TV SYSTEM (AHRTS)

CONRAC CORPORATION
INSTRUMENT/CONTROLS DIVISION
1600 SOUTH MOUNTAIN AVENUE
DUARTE, CALIFORNIA 91010

NOVEMBER 1975

FINAL REPORT

DISTRIBUTION LIMITED TO U.S. GOVERNMENT AGENCIES ONLY (TEST AND EVALUATION) NOVEMBER 1975. OTHER REQUESTS FOR THIS DOCUMENT MUST BE REFERRED TO AFFTC/DOESD, EDWARDS AFB, CALIFORNIA 93523.

CONTROLLING OFFICE:

AFFTC/DOESD
EDWARDS AFB, CALIFORNIA 93523

PREPARED FOR:

AFFTC/DOESD
EDWARDS AFB, CALIFORNIA 93523

AFFTC

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

This report was submitted by the Conrac Corporation, Instrument/Controls Division, 1600 South Mountain Avenue, Duarte, California 91010, under Contract No. F04611-73-C-0054, Job Order No. FE2805521099807, with the Air Force Flight Test Center, Edwards AFB, California 93523. Michael Sakahara and Lester B. Merryman were the AFFTC Project Engineers for this effort.

Foreign announcement and dissemination by the Defense Documentation Center are not authorized because of technology restrictions of the U.S. Export Control Acts as implemented by AFR 400-10.

Publication of this technical report does not constitute Air Force approval of its findings or conclusions. It is published only as a record of the technical effort.

Prepared by:

Francis J. Dutton
Conrac Corporation, I/C Division
Project Engineer

This report has been reviewed and is approved for publication:
(25 November 1975)

Lester B. Merryman
Project Engineer

Paul J. Sehnert, Chief
Technical Development Branch

Qualified requesters may obtain copies of this report from the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314. Department of Defense contractors must be established for DDC services or have "need to know" certified by cognizant military agency of their project or contract.

DDC release to NTIS is not authorized

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsiblity nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or any other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

Do not return this copy; retain or destroy.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFFTC-TR-75-40	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): DEVELOPMENT OF AN AIRBORNE HIGH RESOLUTION TV SYSTEM (AHRTS)	5. TYPE OF REPORT & PERIOD COVERED: Final Report, Jan[redacted]973 — Jul[redacted]975
	6. PERFORMING ORG. REPORT NUMBER: ER-60002-05
7. AUTHOR(s): Francis J. Dutton	8. CONTRACT OR GRANT NUMBER(s): F04611-73-C-0054
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Conrac Corporation, Instrument/Controls Division, 1600 South Mountain Avenue, Duarte, California 91010 (Code 72737)	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: JON: SC6220, PEC: 65807F
11. CONTROLLING OFFICE NAME AND ADDRESS: AFFTC/DOESD, Edwards AFB, California 93523 (Code F07623)	12. REPORT DATE: Nov[redacted]975
	13. NUMBER OF PAGES: 29
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. government agencies only (test and evaluation) November 1975. Other requests for this document must be referred to AFFTC/DOESD.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Data Acquisition, Test:	TV System, Air/Ground
TV System:	Test Data Acquisition
TV System:	Airborne/Ground
Monitor/Record:	TV System Data Acquisition
Flight Test:	TV System Data Acquisition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides information on the development of an air vehicle/ground test data acquisition instrumentation high resolution TV system. The system allows real time television observation of air vehicle instrumentation and recording-reproduction of data generated during test program.

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

31p.

404 410

19. KEY WORDS (continued)

Video Record:	TV System, Data Acquisition
Real Time, Monitor:	TV System
Instrumentation:	TV System
Safety Instrumentation:	TV System, Data Acquisition

SUMMARY

This report documents the development of an Airborne High Resolution TV System. The System developed under this program provides real time television pictures of aircraft instrumentation from a camera mounted in the aircraft to a ground station. On board recording capabilities are also provided, as well as recording/reproducing capability at the ground station. A ground based scan converter provides stop action and zoom capabilities. A transmitter and receiver provide the link between the aircraft and ground station. The television signals are displayed on a monitor located at the ground station.

Maximum use of off-the-shelf equipment was utilized with modifications as required. Miniaturization and light weight of the airborne equipment was given high priority. The video tape recorders were modified and changed back to their original off-the-shelf design when the System was converted to an 875 line TV rate, single scan converter system. The camera was modified to operate at 875 line rate and is documented accordingly. The receiver was not modified; the transmitter was modified in an area that is proprietary to the manufacturer and is repairable by the manufacturer. Documentation for that proprietary area does not exist. The monitor was not modified. The remote control unit, junction box, antennas, and RF switches were documented as built.

PREFACE

This report is the final report on the Airborne High Resolution TV System prepared by the Instrument/Controls Division of Conrac Corporation, Duarte, California. The work was accomplished under the U.S. Air Force Contract No. F04611-73-C-0054 for U.S. Air Force Flight Test Center, Edwards Air Force Base, California 93523.

The report was written by Francis J. Dutton who was Project Engineer. The author acknowledges the assistance of Dean E. McDowell, Program Manager, and Lester Merryman, Project Engineer AFFTC/DOESD.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

THIS PAGE INTENTIONALLY BLANK

SECTION I

INTRODUCTION

This report presents the development and operation of an Airborne High Resolution TV System. The System developed under this program is to be used in helicopter and high performance aircraft to optimize flight safety during critical and hazardous test flights. In some cases, the TV System will be the source for primary data acquisition.

The System is separated into two subsystems; an Airborne Subsystem, and a Ground Subsystem. The Airborne Subsystem consists of a remote control box, video camera, camera control unit, junction box, and airborne video tape recorder, a transmitter, RF switch, and two aircraft antennas. The Ground-based Subsystem consists of a receiver, a video tape recorder/reproducer, a scan converter, and a display. A preflight monitor is also provided to permit check-out of the camera when installed on the aircraft.

SECTION II

TEST AND EVALUATION

2.1 INVESTIGATION

2.1.1 Airborne Subsystem

a. Requirements

The Airborne Subsystem of the Airborne High Resolution TV System provides video pictures of the instrument panel of an aircraft during critical or hazardous test flights. The video pictures are available for real time or quick look post flight analysis.

Instrument panel video pictures are obtained via a TV camera transmitting signals to a ground station in real time or video tape recording for later viewing and analysis.

The Airborne Subsystem consists of a TV camera and camera control unit, a radio frequency transmitter, a video tape recorder, a remote control unit, a junction box, and associated RF swtiches and antennas as shown in Figure 1.

The basic system requirement is that the TV System resolve 1/8-inch wide by 3/16-inch high characters on the instrument in a field of view 30-inches wide by 23-inches high. This requirement establishes performance characteristics for all system elements. The following sections review system requirements and characteristics available from existing equipment.

b. System Resolution

As previously noted, the Airborne High Resolution TV System must resolve and display 1/8-inch wide by 3/16-inch high characters in a 30-inch wide by 23-inch high aircraft instrument panel. This resolution requirement establishes the minimum performance required of all system elements. While resolution would seem to be a straightforward calculation, several factors are involved which make resolution a complex factor. These factors include evaluation by a subjective observer, scene content, and scene illumination.

A number of theoretical and empirical investigations have established practical approaches to the definition of system resolution. Generally and alphanumeric character is considered resolved if the character is subject to at least 7 scans per character height, and 5 scans per character width (Reference 1).

Assuming 7 scan lines per character height and .187-inch high characters in a 23-inch high scene, the vertical line rate is established at 861 lines. Since 875 lines is a common rate, 875 was used as the vertical line rate.

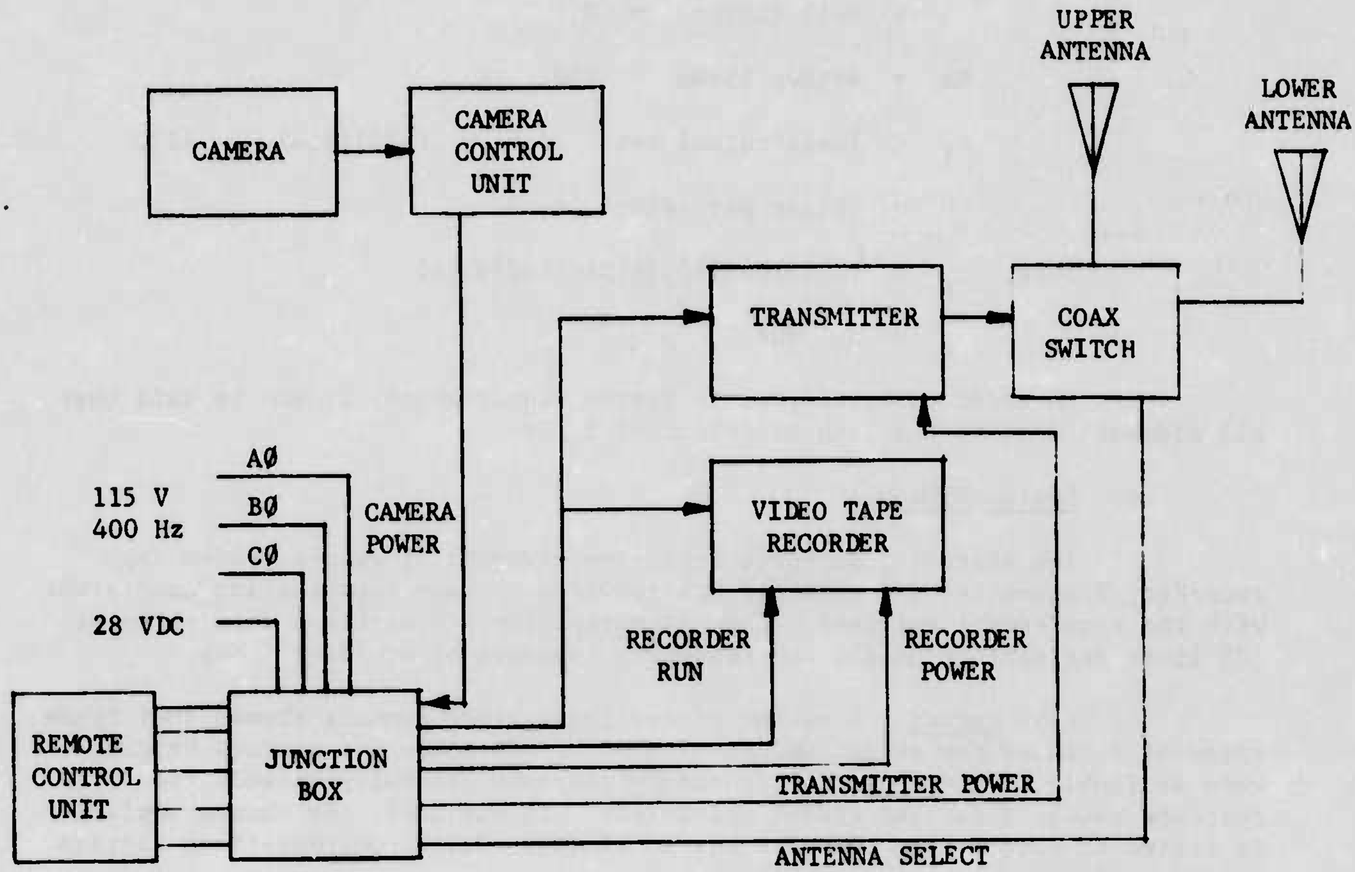

Figure 1. Airborne Subsystem Block Diagram

The next most important requirement is channel bandwidth, given by the following relationship (Reference 2):

$$f_e = .715 \rho k \, M_z \, R_1 \, N$$

Where ρ = aspect ratio = 4/3

k = Kell factor = 0.7

Ma = active lines = 814

R_1 = longitudinal resolution = (3/2)(814) = 1220

N = frames per second = 8

Thus, $f_e = (.715)(4/3)(.7)(814)(1220)(8)$

$f_e = 5.1 \text{ MHz}$

In order to satisfy basic system requirements, it can be said that all elements must have a 3 db bandwidth of 5 MHz.

c. System Elements

The essential Airborne Subsystem elements of camera, video tape recorder, transmitter and antennas are required to have capabilities consistent with the requirement outlined. That is capability for vertical scan rates of 875 lines per picture height and frequency response of at least 5 MHz.

(1) Camera. A review of available video cameras showed that frame rates of 8 frames per second and resolution of 875 lines per picture height were available. Camera circuit frequency response generally exceeds the response required for the stated resolution. In one case, the camera amplifier is stated to have a flat response out to 32 MHz. Noise considerations dictate rolling off the response somewhat.

The final selection of the camera was based on factors other than bandwidth. A survey was made of many camera suppliers to check availability of existing equipments or equipments which could be modified without extensive cost and development risk to meet the requirements of the program. Very few candidates could meet the total environment. Some candidates which could meet the environment were much too large for cockpit utilization and required heaters for low temperature operation. The equipment selected was the best possible trade-off of resolution, size, performance in the environment, development, risk and cost.

(2) Transmitter. The RF transmitter was required to transmit a frequency modulated signal proportional to the intensity modulated scene viewed by the video camera. The principal requirement of the transmitter is that the modulation capabilities be commensurate with the video bandwidth requirements. Several transmitters were available which satisfied the system requirements.

One typical transmitter has the following specification:

Output power:	20 watts minimum
Output frequency:	Factory preset to 1765 MHz
Output impedance:	50 ohms, will deliver specified power into load VSWR of 1.5:1
Modulation frequency response:	±1.5 db from 20 Hz to 6.5 MHz

It was concluded that the RF transmitter was not a limiting factor in system performance.

(3) Video Tape Recorder. The video tape recorder represented the most difficult element of the system in terms of satisfying system requirements. For a given tape reel size, bandwidth and recording time are inversely related. Also for a given tape speed, the signal to noise ratio will degrade somewhat as bandwidth is increased.

One flight qualified tape machine provided a reasonable compromise and was the leading candidate for use in the Airborne High Resolution TV System. The essential specifications for this machine are as follows:

Recording time:	30.6 minutes (8-inch reel, 2300 feet, 1.13 mil tape)
Tape speed:	15 IPS
Frequency response:	30 Hz to 4.25 MHz ±1 db Down 3 db maximum at 6.5 MHz
Signal to noise ratio:	38 db
Weight:	38 pounds

Another recorder considered provided the following performance:

Recording time:	48 minutes (10-1/2 inch reel, 3600 feet, 1 mil tape)
Tape speed:	15 IPS
Frequency response:	10 Hz to 5.5 MHz ±3 db
Signal to noise ratio:	38 db
Weight:	95 pounds plus tape

The greater weight and more limited frequency response of this machine more than offset the greater recording time advantage.

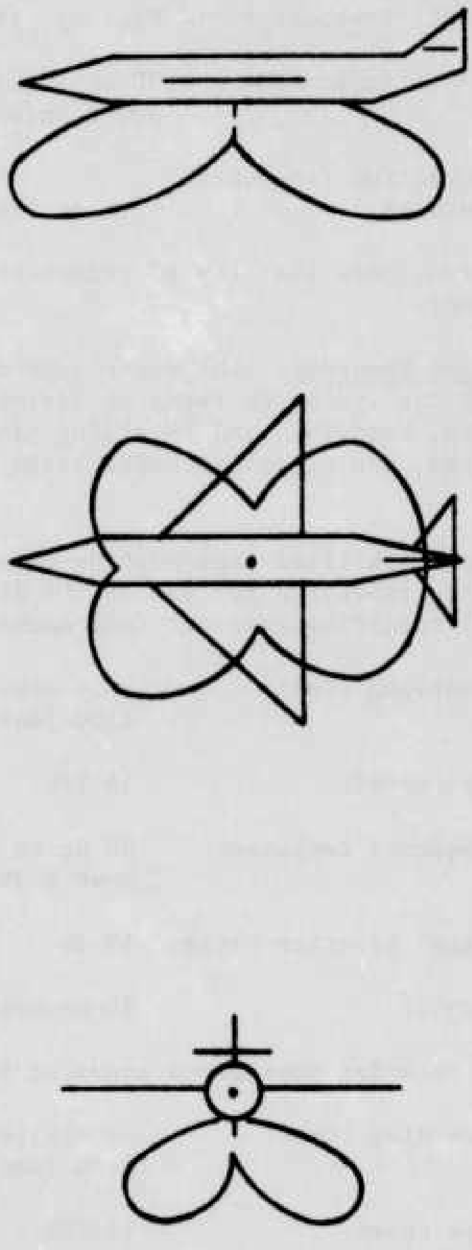

Figure 2. Typical Stub Antenna Patterns

(4) Transmitting Antennas. The transmitting antenna patterns were of considerable importance in establishing system performance under various conditions of range and aircraft attitude. The specified monopole antenna provides the best pattern coverage for a simple, easily installed antenna. The idealized pattern for a belly mounted monopole is shown in Figure 2. This idealized pattern is never realized in actual installations. Typical patterns in actual installations are subject to reflections from various aircraft structures such as flaps, other antennas, nacelles, etc. The result is multiple and deep lobing of the basic pattern (Reference 3). The pattern resulting from a similar stub mounted on the upper surface of the aircraft will be similar except for an additional large null aft due to the shadow cast by the vertical fin. Antenna patterns, and therefore gain, for specific installations can be accurately determined only by measurements of the exact configuration.

An approximation of transmitting antenna gain for use in system calculations can be made. The maximum gain to be expected from a monopole antenna under ideal conditions is approximately 5 db above an isotropic radiator. If one allows -6 db for operation off the maximum and -3 db for cross polarization effects, the airborne antenna should be considered to have a nominal gain of -4 db.

2.1.2 Ground Subsystem

a. Requirements

The Ground Subsystem of the Airborne High Resolution TV System provides signal processing and display of the instrument panel pictures acquired and transmitted by the Airborne Subsystem.

The Ground Subsystem consisted of an RF receiver, a video tape recorder/reproducer, scan converters, a display and associated video amplifiers and switches as shown in Figure 3.

The RF receiver accepted signals from a government furnished receiving antenna and provided outputs to the government furnished microwave relay link as indicated in Figure 3.

The video signals were then distributed to the video tape recorder and the scan conversion/display equipment.

The basic system requirement for the Ground Subsystem was that of providing adequate video frequency response and signal processing for the display of 1/8 inch by 3/16 inch instrument panel characters.

The video frequency response requirement was shown to be 5 MHz.

The flicker-free display was provided by the conversion of the scan rate from 8 frames per second to 30 frames per second.

The following sections describe these subsystem elements in greater detail.

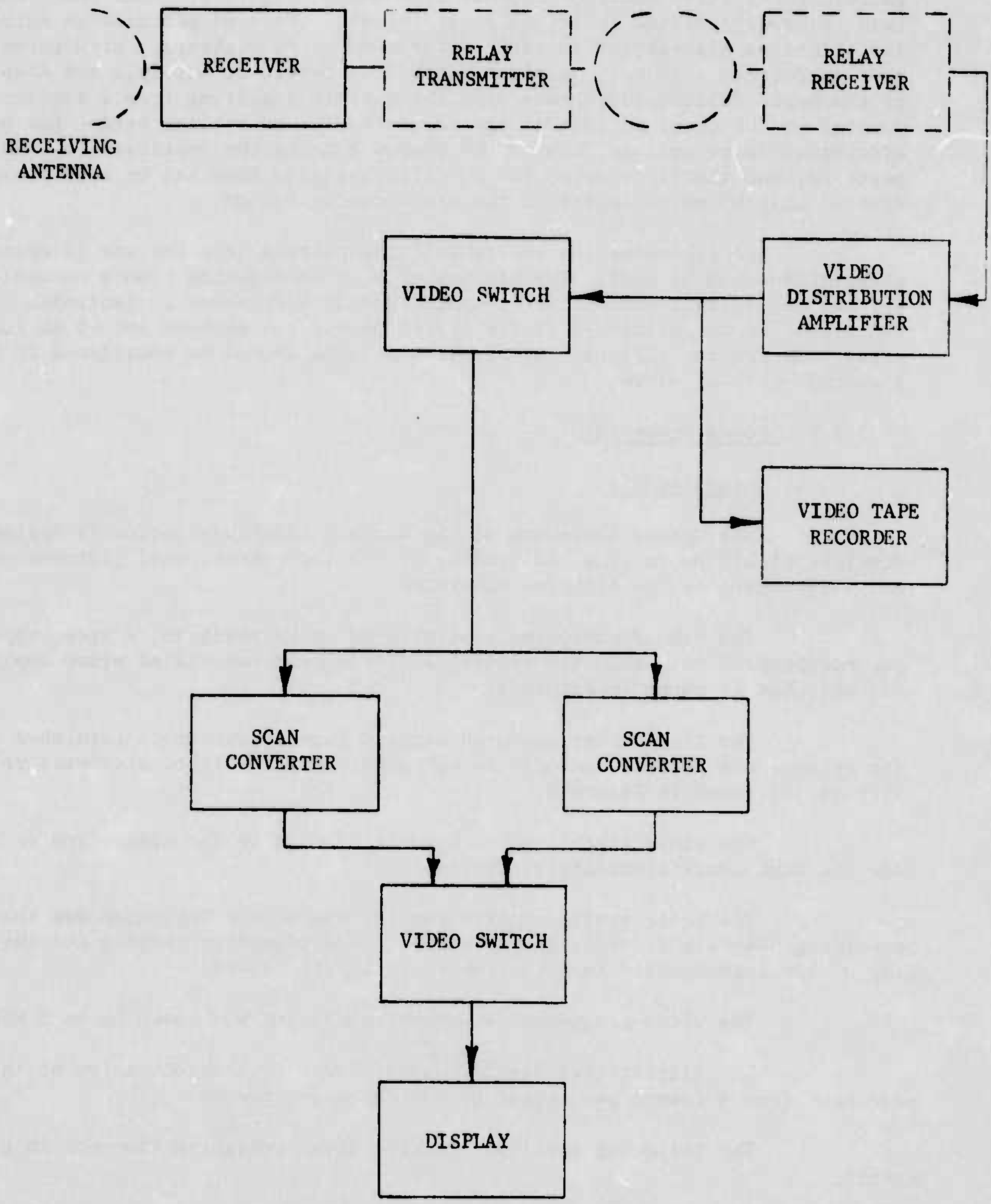

Figure 3. Ground Subsystem Block Diagram

b. RF System

While several elements of the RF System have been predefined, it was important to review the RF System to ensure that the desired performance was available.

The transmitter, operating frequency, transmitting antenna and microwave relay link have been defined. The maximum range and receiving antenna gain were unknown and were assumed. Only the TV System receiver was undefined.

Utilizing standard expressions for RF link performance, the requirements for the TV System receiver were established.

Given: $10 \log (P_T/P_N) = A_p + (S/N) + (nf) - G_T - G_R - (nif)$ (Ref. 4)

Where P_T = transmitter power = 20 watts

A_p = path attenuation (50 miles assumed at 1765 MHz)

= -136 db

S/N = 40 db (specified)

nf = to be determined

G_T = transmitting antenna gain = -4 db

G_R = receiving antenna gain (15 foot diameter assumed)

= 36 db

nif = noise improvement factor = $3\beta^2$

where β = modulation index $\Delta f/fm$

Δf = deviation = 10 MHz

fm = highest modulation frequency = 5 MHz

nif = 12

= 11 db

P_N = receiver noise power = k B T

where k = Boltzmann's constant = 1.38×10^{-23}

B = receiver bandwidth = 30×10^{6}

T = receiver temperature = 300°K

$\cong 10^{-13}$

Thus $$nf = \frac{P_T}{P_N} - A_p - S/N + G_T + G_R + nif$$

$$nf = 143 - 136 - 40 - 4 + 36 + 11$$

$$nf = 10 \text{ db}$$

The 10 db noise figure requirement was satisfied by a number of off-the-shelf receivers.

The microwave relay link was stated to have an IF bandwidth of 32 MHz and a video response of 20 Hz to 7.5 MHz. These characteristics were more than adequate to meet the transmitter deviation of ±10 MHz and the video bandwidth of 5 MHz.

c. Equipment

The major elements of the Ground Subsystem are described and characteristics compared to requirements.

(1) Receiver. As calculated above, the receiver was required to have a noise figure of 10 db. In addition, the IF bandwidth had to be 30 MHz and the video response extend beyond 5 MHz. The definition of required bandwidth was fairly complicated and was dependent on a variety of factors such as the modulating waveform. Even with sinewave modulation, the expression for a frequency modulated wave shows that theoretically an infinitely wide band was required.

Practically a variety of approximations were employed. One common approximation is "Carson's Rule" (Reference 5) which states that:

$$B = 2 (\Delta f + fm)$$

$$B = 2 (10 + 5) = 30 \text{ MHz}$$

At least one receiver was identified which met these requirements. This crystal controlled, fixed tuned receiver had an IF bandwidth of 30 MHz, and a video response extending to 6.5 MHz. The unit was suitable for unattended operation.

(2) Video Tape Recorder/Reproducer. Because of the need for compatible recording format, etc., the ground reproducer was obtained from the same manufacturer as the airborne recorder.

The ground recorder/reproducer had the same characteristics as the airborne unit except that up to 91 minutes of recording time was available.

(3) Scan Converter. Two scan conversion units were used in the Ground Subsystem to provide the functions of slow scan video conversion to 875 line 30/60 frame/field rate video, and for the stop-action function. This enabled use of a camera scanning rate of 8 frames/sec. as described below.

The two scan conversion units were used in a "ping-pong" fashion. The video inputs and outputs were selected by the video switches indicated in Figure 3. The conversion sequence was conducted as follows, starting from turn-on:

0-250 msec	Channel 1 will write 2 frames of the received video
250-500 msec	Channel 1 will store the video Output reads from Channel 1
500-750 msec	Channel 1 storing video Channel 2 writes 2 frames of new video Output reads stored video from Channel 1
750-1000 msec	Channel 2 erased Channel 2 stores new video Output switched to read Channel 2
1000-1250 msec	Channel 1 writes new video Channel 2 storing video Output reads Channel 2
1250-1500 msec	Channel 1 stores new video Channel 2 erased Output switched to read Channel 1

In this sequence, the output was switched with a period of 500 milliseconds to read alternately from Channel 1 and Channel 2 units. The slow scan input frequency of 8 frames/sec. allowed writing 2 frames during the write period with consequent enhancement of the signal to noise ratio. The conversion timing diagram is shown in Figure 4.

(a) Stop-action. The pair of scan converters was also utilized as a stop-action unit by causing the unit being read out to remain in the stored mode upon activation of a stop-action command signal.

The scan conversion unit featured resolution of greater than 1200 horizontal lines, video bandwidth to 30 MHz and the capability for reading the stored image for over 12 minutes. One additional useful feature was that an area of the scene may be selected and enlarged up to 36:1.

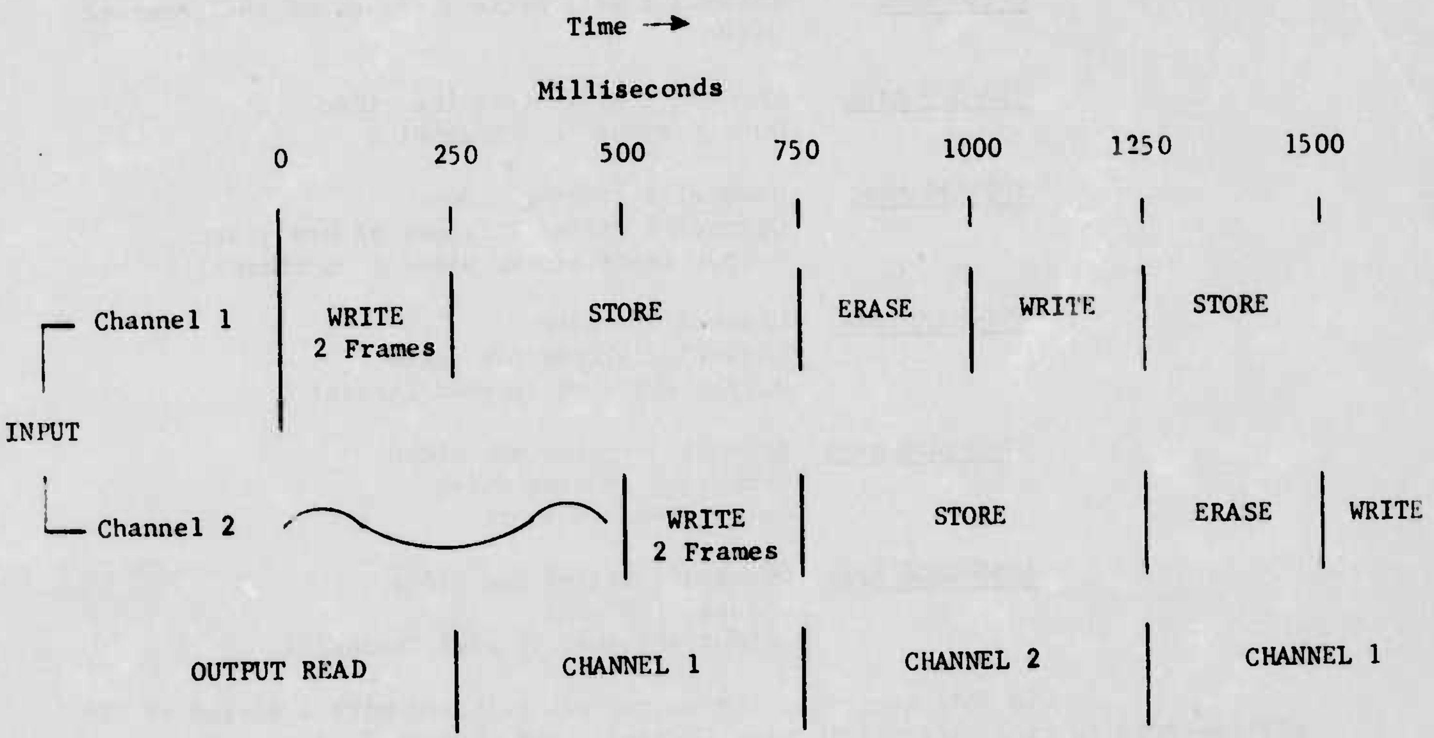

Figure 4. Video Scan Conversion Timing Diagram

(4) Display. Utilization of the scan converters permitted use of conventional displays for operator viewing, since the readout frame repetition rate was 30 frames/sec, interlaced 2:1.

The display can accomodate up to 4930 scan lines per frame and provides horizontal resolution of over 1200 lines. Video response extends to 30 MHz. Linearity is better than 1% of picture height.

2.2 INITIAL SYSTEM

2.2.1 Procurement. The initial system consisted of equipments from various manufacturers. The equipments and their manufacturers are listed:

TV SYSTEM (Reference Figures 5 and 6)

G/B Subsystem -	TV Monitor Unit	Conrac Corporation Duarte, California P/N 3064443
	Receiver Unit	Terracom San Diego, California TCM-601
	Remote Control Panel Unit	Conrac Corporation P/N 3064468
	Control Unit	Conrac Corporation P/N 3064474
	Scan Converter	Princeton Electronic Products New Brunswick, New Jersey PEP-400R
	VTR Unit	Echo Science Corporation Mountain View, California WRR-411
A/B Subsystem -	Camera Unit	Edo Western Salt Lake City, Utah Model 1430
	Camera Control Unit	Edo Western Series 140C
	Remote Control Panel Unit	Conrac Corporation P/N 3064430
	Distribution Panel Unit	Conrac Corporation P/N 3064420
	Transmitter Unit	AACOM, Inc. Concord, California AT3620L-V
	RF Coax Antenna Panel Unit	Deacon BH Co., Inc. Philadelphia, Pennsylvania Model 11200
	VTR Unit	Echo Science Corporation WR-202-04
	Antenna Unit	Deacon BH Co., Inc. 01-23-02760

A/B Test Equipment (same as G/B Subsystem TV Monitor Unit)

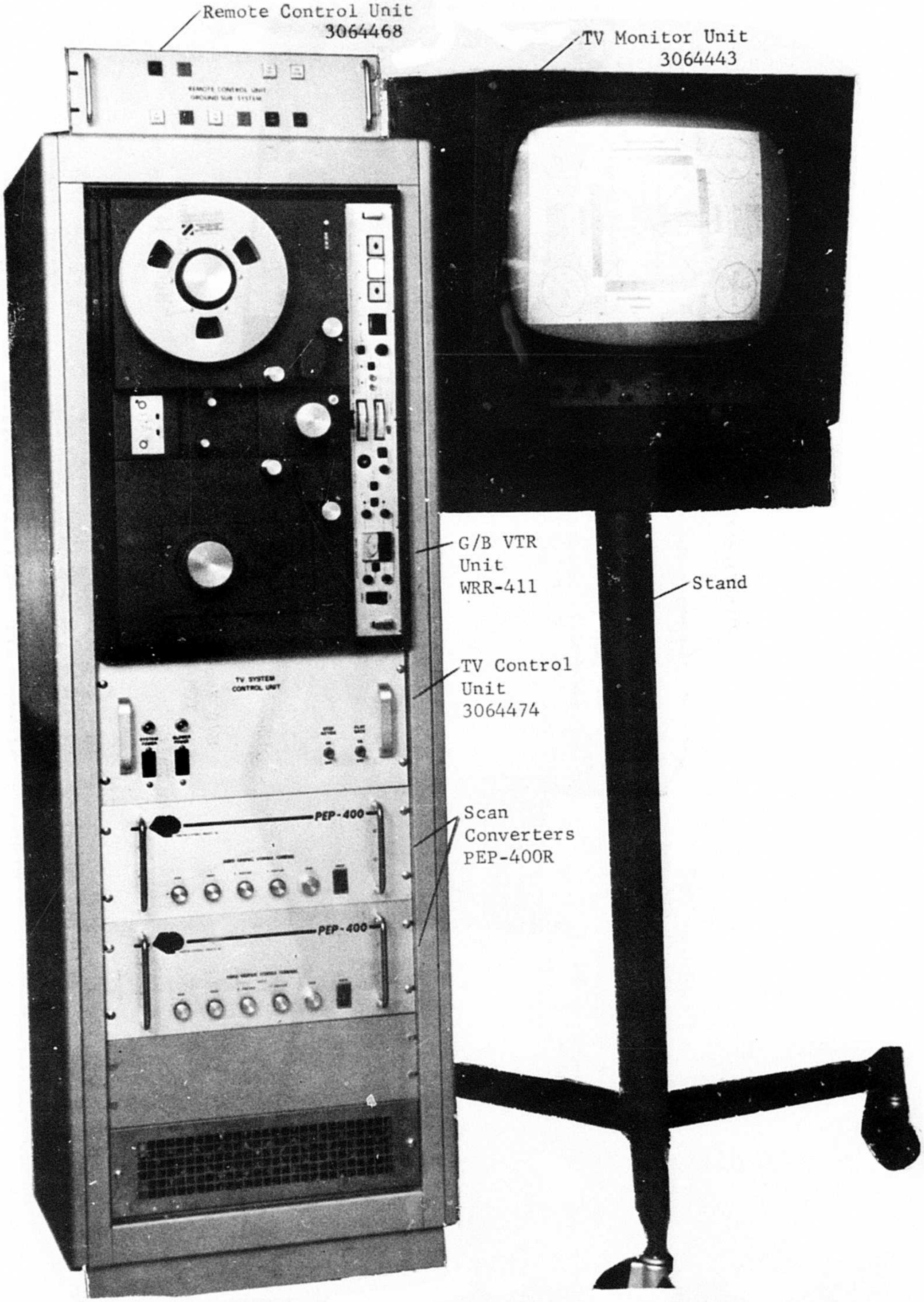

Figure 5. Airborne High Resolution TV System (G/B Subsystem)

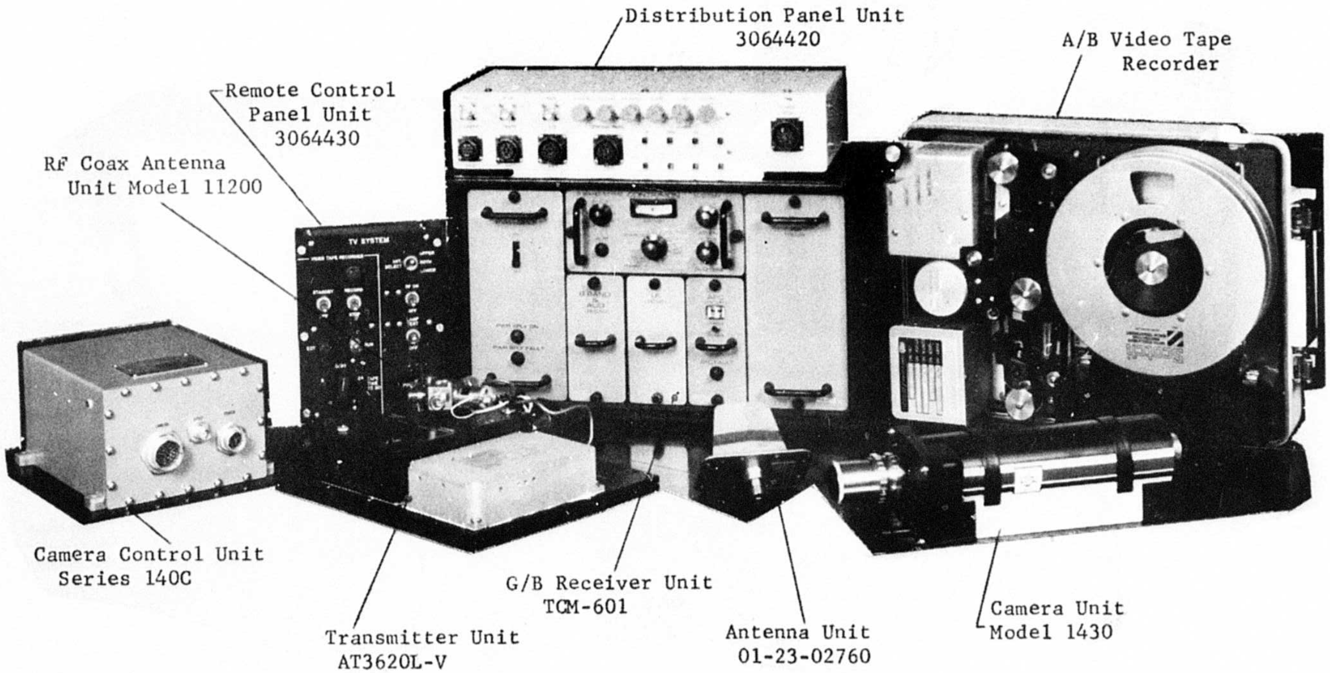

Figure 6. Airborne High Resolution TV System (A/B Subsystem)

2.2.2 Evaluation. Tests disclosed that the System performance was not adequate to accomplish its mission. General picture quality was poor and was not stable with time. The scan converters required excessive time to optimize for use in the "ping-pong" method of operation and within a day, performance had degraded. Registration of the picture as the System switched between the two scan converters was extremely difficult to maintain.

The Airborne High Resolution TV System was a development program to integrate as much off-the-shelf equipment as was commercially available to meet the Exhibit A requirements as a design goal. A number of units were designed and fabricated by Conrac and the minor developmental problems associated with these types of units did not warrant documentation in the monthly progress reports. However, a number of problems and more importantly, design trade-offs were encountered and were documented in the monthly progress reports, as well as discussed with the respective project engineers. A number of significant trade-offs and problems are reiterated here, referenced to the particular monthly report.

Monthly Report #2. After studying the requirement, it was not deemed feasible to include color video in this program. The leading candidate airborne video tape recorder did not satisfy the 40-minute record time specification.

Monthly Report #4. The most appropriate transmitter to meet the System requirements could not guarantee performance to spec below -30°C. The camera selected as most appropriate to meet the design requirements could not guarantee performance below -30°C. Inasmuch as a 50-inch field of view lens cost was 6 times that of the other lenses, it has been deleted as a requirement. It was determined that a power junction box with remote power switching will be required. A conceptual design includes one scan converter with a flight line display. The monitor being provided does not require vertical and horizontal hold controls and technically does not satisfy 4.3.4 of Exhibit A. The monitor will be provided with a P4 (white) phosphor rather than the originally proposed P31 (green) phosphor.

Monthly Report #5. A system junction box will definitely be included in the Airborne Subsystem.

Monthly Report #11. The camera had an apparent mechanical focus problem which was corrected after adjustment by the camera supplier.

Monthly Report #12. During the initial System tests, it became obvious that the specified resolution could not be met. After a review with the Program Office at Edwards, it was decided that an improvement can be effected by going to a wider bandwidth system utilizing only one scan converter. Lengthy adjustments of the scan converter required on a daily basis justified elimination of one of the scan converters from the design approach. The camera was returned to the vendor because of poor focusing, resolution, video tilting, and a sticking sun shutter. The resolution was improved somewhat and the other mentioned problems were corrected entirely. The camera frame rate was changed to 30/sec. The airborne and ground video tape recorders had their time bases changed back to the original off-the-shelf design. The transmitter was modified to meet expanded bandwidth.

Monthly Report #16. There was a circuit failure in the motor drive circuit of the ground tape recorder which was repaired. There was apparent intermittent failure in the camera which caused loss of video which was subsequently repaired by the camera manufacturer. There was a failure in the tape recorder tension servo and electrical time base assembly which was corrected by the manufacturer at Conrac.

Alternate methods were proposed to improve System performance. Of several possibilities, three alternatives were selected for consideration:

(a) Initial Approach. It was possible that the camera problems could be corrected and the System could be made to meet the objectives. In view of the past experience with the special camera, it was unlikely that the problems could be corrected within a resonable time. In addition, the extreme amount of maintenance required to keep the scan converters at peak performance made this approach impractical for field use. This alternative was therefore rejected.

(b) Digital Conversion. Other users of analog scan converters have reported similar problems to those noted above. In some cases, the analog converters have been replaced by digital scan converters. Digital converters with sufficient capacity to satisfy resolution requirements are available. Cost of such converters is in the range of $150,000 and up. It was felt that the cost was excessive for the present program. Digital scan conversion should be considered for future programs.

(c) Straight-Through Approach. The most practical method of satisfying system requirements was to change the camera frame rate from 8 to 30 frames per second (standard). This method eliminated the ping-pong scan converters and their attendant problems from the basic operation.

One scan converter was retained for the stop-action feature. Maintenance of a single converter is considerably less complicated than for the ping-pong units. The zoom function was available in a single converter whereas it was not available in the ping-pong units.

Some degradation in the resolution available from a 30 frame camera was experienced as the signal was passed through bandwidth limited devices such as the VTR or the ground microwave link.

Demonstrations were conducted that indicated this degradation was not as bad as one might expect from theory. Overall operation with this approach was demonstrably better than with the initial approach. Therefore, the "straight-through" alternative was recommended.

After review with AFFTC personnel, the straight-through approach was selected and approved.

2.3 REVISED SYSTEM

2.3.1 Modifications. Changes required to the system to modify it to the straight-through approach required the following:

(a) Conversion of the camera frame rate to 30 frames. Since this is a standard rate, the conversion should be easily accomplished by the vendor.

(b) Conversion of the VTR time base.

(c) Expansion of the transmitter video bandwidth.

(d) Addition of the zoom feature to the ping-pong scan converters.

2.3.2 Evaluation. System tests were performed after modification to the various equipments to operate at a conventional 875 line 30 frame rate. Bandwidth appeared to be the limiting factor with each equipment contributing somewhat in limiting the end item resolution. Resolution at the camera output was 600 TV lines but had dropped to 375 lines at the output of the receiver. The resolution at the output of the video tape recorder was on the order of 330 lines.

The scan converter was functional only in the stop action mode of operation and produced approximately the same resolution as in the real time or recorder playback.

System capability as relating to the performance requirements was demonstrated during an acceptance test prior to delivery. The requirement to resolve characters 1/8 inch wide by 3/16 inch high in a 30-inch wide by 23-inch high field of view could not be met. In a 30-inch by 23-inch field of view, the characters had to be 1/4 inch high. The field of view had to be decreased to 23 inches by 17.5 inches to resolve characters 3/16 inch high by 1/8 inch wide.

System performance other than a small loss in resolution was good. The ambient illumination was changed over a 3000:1 ratio with less than a 6 db change in the video signal at the camera output. The video tape recorders produced relatively the same display during playback as when recorded.

SECTION III

CONCLUSIONS

The object of the program was to develop an Airborne High Resolution TV System for use on helicopters and high performance aircraft.

The initial system which utilized two scan converters in a "ping-pong" method of operation did not meet the performance requirements. Picture quality and stability were not satisfactory. Registration of the two pictures could not be maintained to produce an acceptable display. Calibration was lengthy and had to be repeated frequently.

A modified straigth-through approach was developed which eliminated the scan converter except in the stop-action mode. The camera was changed to a conventional 875 line 30 frame system to be compatible with the monitor. The video bandwidth requirement did increase for this system, however, with the resolution of the System degraded somewhat. The improved picture quality and stability more than offset the decrease in resolution.

The resolution requirement was to resolve characters 3/16 inch high and 1/8 inch wide in a 30-inch wide by 23-inch high field of view. In a 30-inch by 23-inch field of view, the characters had to be 1/4 inch high to be resolved. To resolve characters 3/16 inch high by 1/8 inch wide, the field of view has to be decreased to 23 inches by 17.5 inches.

The balance of the System objectives were obtained. These are summarized as follows:

(a) The camera operated over the 3000:1 light change as required. A solar shutter was incorporated to protect the vidicon from damage from direct view of the sun.

(b) The FM transmitter produced a minimum output power of 20 watts.

(c) The video recording equipment produced a stable display in record and reproduce mode. The minimum recording time was 30 minutes.

(d) The receiver was pretuned and produced stable display over a wide range of input signal strength.

(e) The monitors were 21 inches minimum diagonal screen and were compatible with the video format of the Airborne and Ground Systems.

The specification compliance tabulation (Table 1) indicates extent of achievement of the goals of the program.

TABLE 1

SPECIFICATION COMPLIANCE

SPECIFICATION NO. Exhibit A to Contract Subline Item No. 0001AA, Contract F04611-73-C-0054

PARAGRAPH NO.	WILL COMPLY	WILL DEVIATE	NEEDS CLARIFICATION	REMARKS
2.1		X		System Resolution
				The resolution requirement was to resolve characters 3/16-inch high and 1/8-inch wide in a 30-inch wide by 23-inch high field of view. In a 30-inch by 23-inch field of view, the characters had to be 1/4-inch high to be resolved. To resolve characters 3/16-inch high by 1/8-inch wide, the field of view has to be decreased to 23 inches by 17.5 inches.
3.1	X			General
				The capability for recording voice was considered, but not implemented.
3.2.2	X			Frame Rate
3.2.3	X			Interlace Ratio
3.2.4	X			Geometric Distortion
3.2.5	X			S/N Ratio
				Not measured in ATP, but camera manufacturer indicated it was greater than 40 dB.
3.2.6	X			Auto Light Range
3.2.7	X			Sensitivity
				Resolution vs. illumination was fairly broad, but resolution of 2.1 was not achieved.
3.2.8	X			Gray Scale
3.2.9.1		X		Sunlight Glare
				This was studied, but no method for implementation was conceived.
3.2.9.2	X			Sunlight Protection
3.2.9.3	X			Lens
3.3.1	X			General
3.3.2		X		Recording Time
				31 minutes, 10 seconds
3.3.3	X			Video S/N
3.3.6	X			Start Time
3.3.7	X			Time Totalizer

TABLE 1

SPECIFICATION COMPLIANCE

SPECIFICATION NO. Exhibit A to Contract Subline Item No. 0001AA,
Contract F04611-73-C-0054

PARAGRAPH NO.	WILL COMPLY	WILL DEVIATE	NEEDS CLARIFICATION	REMARKS
3.4.1	X			General
3.4.2	X			Center Frequency
3.4.3	X			Power Output
3.4.4	X			Antennas
3.5.1	X			Controls
3.5.2	X			Indicator
4.2.2	X			Video Input Level
4.2.3	X			Input Impedance
4.2.5	X			Video S/N
4.2.7	X			Video Output
4.2.8	X			Output Impedance
4.2.9	X			Record Time
4.2.10	X			Start Time
4.2.11	X			Controls
4.2.12.1	X			Stop Action
4.2.12.2	X			Remote Control
4.3.2	X			Input Level
4.3.3	X			Screen Size
4.3.4	X			Controls
4.4	X			Time Totalizer
5.2.1	X			General Designed to meet this requirement, but environmental testing not performed.
5.3.1.1	X			Camera
5.3.1.2	X			Recording Equipment
5.3.1.3	X			Transmitter
5.3.1.4		X		Amplifier Replaced by Junction Box 3.5" high, 7" wide, 15" deep

TABLE 1

SPECIFICATION COMPLIANCE

SPECIFICATION NO. Exhibit A to Contract Subline Item No. 0001AA, Contract F04611-73-C-0054

PARAGRAPH NO.	WILL COMPLY	WILL DEVIATE	NEEDS CLARIFICATION	REMARKS
5.3.1.5	X			Miscellaneous
				Remote control unit complies with MS25212
5.3.2	X			Size
5.3.3	X			Weight
				Total weight is 56.6 pounds.
5.4.2.1	X			Airborne System
5.4.2.2	X			Ground System

SECTION IV

RECOMMENDATIONS

System resolution could be improved by obtaining equipments with greater bandwidth capabilities. The camera, transmitter, and receiver manufacturers have these capabilities available but in some cases extensive redesign would be required. Marginal improvement could be obtained with a modification to the video tape recorders. If the System were modified to bypass the VTR during real time viewing, an improvement in resolution could be realized. However, during playback, this improvement in resolution would be lost.

SECTION V

REFERENCES

1. "Fundamentals of Display System Design," Sherr
   Wiley-Interscience 1970

2. "Display Systems Engineering," Luxenberg and Kuehn
   McGraw-Hill 1968

3. "Antenna Engineering Handbook," Jasik
   McGraw-Hill 1961

4. Reference Data for Radio Engineers
   H. W. Sams & Co. 1970

5. "Signals-To-Noise Ratios For Television Transmission,"
   Collins, Massachusetts Institute of Technology, Technical
   Note #1969-12, March 1969

EQUIPMENT TECHNICAL PUBLICATIONS VOLUME REFERENCE

TD 60002-B1-	Conrac, Instrument/Controls Div.	Conrac Manual Designation
Volume I	Conrac, Instrument/Controls Div.	A/B TV System Tie-in
Volume II	Conrac, Instrument/Controls Div.	G/B Subsystem
Volume III	Conrac, Instrument/Controls Div.	A/B Subsystem
Volume IV	Edo Western Corporation	TV Camera and Control Unit
Volume V	Echo Science	G/B Video Tape Recorder
Volume VI	Princeton Electronic Products	G/B Scan Converter
Volume VII	Conrac, Instrument/Controls Div.	TV Monitor
Volume VIII	Echo Science	A/B Video Tape Recorder
Volume IX	Terracom	Receiver