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TELEVISION SYSTEM STUDY FOR NUCLEAR ACCIDENT RECOVERY Phase I

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U. S. ATOMIC
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NATIONAL
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Prepared by

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TELEVISION SYSTEM STUDY
FOR ACCIDENT RECOVERY
(Phase I)

by

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Prepared for
Idaho Operations Office
U. S. Atomic Energy Commission
AEC Idaho Operations P.O. No. 65-156

ABSTRACT

A previous study of equipment necessary for clean-up following a nuclear accident indicated a need for a portable television system capable of operating in hazardous environments during recovery operations. A system to accomplish this is described and justified in this study. Four television cameras will be used for coverage, with three radiation-tolerant and environmental-resistant cameras to be used in and around the source, and one standard environmental-resistant camera to be used for general area surveillance. All cameras will be controlled at a remote control monitor console located up to 2100 feet from the cameras. Further separation from the camera control units of from five to ten miles is possible through the use of lightweight, portable, one-way microwave systems. The standard camera may be used, hand-held, aboard airborne platforms and linked to the monitors by microwave. An intercom system will provide communications between wire-connected cameras and control area. Monitor viewing is provided for use at the camera, if necessary, and at the control area. A three-dimensional viewing adapter will permit the utilization of two radiation-tolerant cameras in a configuration that will provide a depth perception viewing capability. A video and audio tape recorder, plus still and motion picture cameras will be available for recording of scenes and intercom channel for real-time viewing or data storage. A vehicle is proposed to allow remote camera positioning from the control area, thereby eliminating the need for personnel in the hazardous environment. Design criteria, final system design and equipment lists are included.

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SECTION I

INTRODUCTION

This final report describes the Phase I work on a television system study as directed under modification No. 83, to contract No. AT(29-1)-1183, and transmitted to Edgerton, Germeshausen & Grier, Inc., on an AEC-Idaho Operations Purchase Order No. 65-156. EG&G was contracted to provide a study of a television system as outlined in Proposal LP-245, dated February 18, 1965.

A previous study of the equipment necessary for operations following a nuclear accident indicated a requirement for remote viewing equipment. Appendix A of this report discusses the relative advantages and disadvantages of available viewing systems. The results of the comparison indicate that a highly portable, radiation tolerant, flexible, closed circuit television system offered definite advantages in the area of personnel safety, operational use, and maximum viewing flexibility in the hazardous environment.

EG&G's approach to the television system study was to first determine what tasks the system must support and how the system would be used. These "Operational Requirements" are detailed in Section II. The "Functional and Safety Requirements", Section III describes the characteristics of a TV system which will meet the operational needs. During the generation of the Functional Requirements, separate investigations were made into the relative merits of high resolution systems versus standard resolution (Appendix C), the justification for selecting three dimensional camera chains for some applications (Appendix D), and a discussion of the advantages and disadvantages of color TV systems (Appendix E).

To insure that the Functional Requirements, which were established, did not specify equipment beyond the state of the art, an extensive

vendor search was initiated at the start of the study. A listing of the vendors contacted appears in Appendix F.

A television system design was then generated which met the operational and functional criteria. In addition to providing the reliability and quality as outlined in the criteria, the proposed system pays particular attention to flexibility, ease of operation, and compatibility with other commercial equipment.

Certain equipments are included as options to the system design. These options either provide for ease of operation and maintenance or expanded system capability. Appendix H describes a relatively simple remotely controlled vehicle for increasing camera mobility. The benefits of a television system control van are discussed in Appendix I. In addition to providing a more favorable environment for long term operation of the TV system, the van also provides a convenient place for storage of test equipment and preventive maintenance and repair of operational equipment.

Detailed specifications were prepared for the equipment described in the television system design. These specifications were prepared in sufficient detail to permit public advertisement and competitive bidding for the complete system. The detailed specifications are included in a separate volume (Phase II) of the system study report.

SECTION II

OPERATIONAL REQUIREMENTS

A. GENERAL

The operational requirements to be placed upon the TV system are derived from considerations of the geographical and physical locations, accident viewing areas, operating personnel, and general equipment usage.

1. Geographical and Physical

a. Storage

The necessary facilities, test equipment, and trained personnel will be available at the storage sites to operate and maintain the equipment.

The system may be operated at the storage sites during normal conditions. However, no special requirements will be placed on the system by the storage site operations.

b. Transportation

The size and weight of the shipping containers housing the equipment will be such that two men can handle the equipment.

The containers will be designed to protect the equipment from shock and vibration incurred during transportation to the accident site, and will meet the regulations of commercial airlines. A trailer may be utilized, reducing the need for shipping containers.

c. Environments

Equipment operated in unprotected areas may be subjected to a wide range of temperatures.

Equipment operated in unprotected areas may be subjected to 100% humidity.

Equipment in certain areas may be exposed to pressurized conditions experienced in containment vessels.

Equipment in unprotected areas may be operated in extreme precipitation conditions.

All equipment will be packaged to prevent damage occurring during transportation and handling.

Portions of the TV system must be able to withstand high radiation levels.

d. Power

Unregulated power for the TV system will normally be supplied from the primary power system serving the site. Where primary power is not available, an engine-generator set capable of operating the complete TV system will be supplied by the site.

2. Accident Viewing

a. Usable Areas

The TV cameras will provide visual instrumentation and shall be utilized inside and outside the site buildings and above the general accident area. It will be necessary to view more than a single area or article during accident assessment and disassembly.

b. Illumination

Artificial lighting will be provided independent of the existing facilities of the site.

c. Elevated Viewing

Viewing above the site may be accomplished by equipment housed in a helicopter or from remotely controlled TV equipment on a crane.

d. Field of View

Surveillance will be accomplished by remote controlled devices. These devices will permit viewing of 360° in the horizontal plane and a minimum of $\pm 90^{\circ}$ in the vertical plane. Depth of field will be varied by proper selection of remote controlled lens assemblies.

e. Object Resolution

The system resolution must be of the highest order without necessarily increasing size, weight and decreasing reliability.

3. Personnel

a. Operators

Qualified operators will be present during assembly, operation and disassembly.

b. Training

Extensive training in the theory of operation, maintenance, and trouble shooting of the system will be required for the main operator.

4. Equipment

a. Camera Platforms

Adequate platforms will be provided for land and airborne operations.

b. Size and Weight

The camera and lighting fixtures must be of size and weight capable of being carried and placed by one person, and of physical structure for use with crane or equivalent.

c. Environment Information

The TV system will provide an information link to the main monitor area to transmit the radiation and temperature environment at the camera.

d. Equipment Assembly

One camera/ monitor system will be capable of separate transportation and temporary assembly. Rapid assembly techniques and packaging will be necessary. The single camera system will be capable of four hour assembly and the entire system will be capable of 12 hour assembly.

e. Mounting Requirements

The monitor and control equipment may be placed and operated on the ground or an equivalent surface during temporary assembly. For extended utilization at an area, the monitor, control and recording equipment should be placed in an environmental controlled trailer or structure.

f. System Controls

Camera controls should be available at appropriate locations to permit multiple control. An audio link is necessary between these control points.

g. Monitors

Sufficient monitors will be available to provide viewing at multiple locations.

h. Recording

Video recording is required for data storage and future analysis.

i. Operating Distance

The camera control/ monitor will be located in an area considered safe for personnel and equipment while the camera is viewing the accident site.

j. Maintenance

After the initial accident assessment survey, a scheduled time will be allotted for preventative maintenance.

SECTION III

FUNCTIONAL REQUIREMENTS

A. EQUIPMENT

1. Introduction

The specification defines the functional and safety requirements for the TV visual instrumentation system. This system will consist of four television camera chains, a video switcher, distribution amplifiers, monitors, video recorders and ancillary equipment. Areas will be monitored to assess damage, view indicators, controls, victims, reactor containment and immediate site. The scenes will be viewed at the main control area on monitors which are selectable for the cameras. Outputs and equipment will be available to permit viewing at three other locations. See Functional Block Diagram, Figure 1.

2. Radiation Tolerant Camera Chains

a. Introduction

Three radiation and environmental resistant camera chains will be provided. Two chains shall be utilized for inside observation of indicators, controls, victims, damage and the other for reactor safing, cleanup, and control room. An accessory mounting device will be provided to allow any two of these chains to be combined in an appropriate configuration which will produce a three-dimensional picture.

The camera chains shall, under conditions defined, produce high resolution, interference free pictures in all respects to EIA Standard RS-170. Each camera chain shall be of identical construction and have identical electrical and mechanical specifications.

b. Electrical Requirements

A minimum resolution of 600 lines horizontal in the center and 450 lines in the corners, using a maximum of 10 MC bandwidth and 375 lines vertical, shall be provided.

Figure 1. Functional Block Diagram

A usable picture shall be produced at one footcandle illumination, using a lens aperture reference opening of $f/1.5$. It will reproduce all ten shades of gray while viewing an EIA test pattern with one footcandle highlight illumination on the vidicon face.

The combined geometric distortion and scan nonlinearity shall be within 2%.

To provide faithful reproduction for low light level gradations of a scene, which in essence aids in detail reproduction of dark corners or areas, a selector switch at the control unit will provide a contrast (Gamma) correction ratio of 0.7 from the normal ratio of 1.0.

To eliminate vidicon target damage in case of sweep or cable failure, a fail-safe, electronic circuit, sampling the deflection coils, shall be utilized to protect the vidicon. This circuit shall be located in the camera head or preamplifier.

To allow satisfactory camera operation in high radiation areas, it is advisable to maintain a minimum of electronic components within the camera head. This shall be accomplished by detaching the camera preamplifier and sweep circuits from the camera head and locating them in a separate enclosure. The present state of the art limits this distance to 100 feet. The preamplifier enclosure shall also contain provisions for permitting the Camera Control Unit and sync and generator to be located 2,000 feet away, without external boosters. The intercom/command system will also be placed within this enclosure. Lighting and camera cable integration for the 100 foot run to the camera head shall also take place in the preamplifier container.

Each Camera Control Unit shall be equipped with its own, high quality, sync generator. This provides complete camera redundancy allowing each camera chain to be separable. However, any sync

generator will have the capability of driving any or all of the camera chains. Each camera chain will be configured to permit external or internal sync generator operation. This then allows common sync timing for other cameras in cases where 3D operation is desired or when internal sync generator failure occurs. To insure picture stability and compatibility with other standard television systems, the synchronization shall be at the standard EIA scanning rate of 525 lines, 60 fields interlaced 2:1, and conform to the most recent EIA specification RS-170, paragraphs 2.6 and 3.3.

Normally, the master oscillator of the sync generator will be phase locked to the 60 cycle AC line, but in cases where rapid AC line frequency fluctuations might occur due to engine-generator or other difficulties, the master oscillator will be locked to an internal crystal which shall be switch selectable.

The operational controls for camera head and preamplifier shall be located at the Camera Control Unit so that adjustments may be made remotely from the camera, which might be in high radiation areas.

No change in performance characteristics shall occur during short or long term operation.

The camera shall be capable of operating from an input voltage of 105 to 130 volts AC, 60 cps. To maintain reasonable demands from the power source, the camera input requirements should be approximately 30 watts.

To insure high quality reproduction under long or short term fluctuating input power, all DC voltages shall be highly regulated to at least 1%.

To eliminate many separate cables between the camera head, accessories and preamplifier, a junction box shall be used at the camera to allow single cable routing of all functions from preamplifier.

Distribution to the camera head, lights, pan/ tilt, 3D accessory, headsets and speaker shall then originate from the junction box.

All connectors at the camera, accessories, junction box and preamplifier shall be environmental proof and of rapid disconnect/ connect type for reliability and quick operation. The appropriate camera, accessory and junction box connectors shall be radiation tolerant.

c. Mechanical Requirements

The camera head shall be compact and of cylindrical design for ease of handling, mounting and decontamination. The camera head and connector shall be waterproof and capable of submergence to depths of 100 feet. This is easily accomplished since most standard housings can withstand the pressure and only require waterproofing. This will also allow the camera to operate in pressures to 30 psig as may be encountered in reactor containment vessels. The housing shall be constructed so that accessories consisting of windshield wiper, defroster and sun shield could be attached if needed. The preamplifier enclosure shall be of minimum size, yet still perform satisfactorily since it will be necessary to place, and possibly drag it, along concrete floors.

The Camera Control Unit shall be constructed for mounting in a portable carry case or standard 19 inch rack.

The camera head enclosure and zoom lens shall not weigh more than 17 pounds.

The preamplifier shall not be more than 12 pounds, including intercom amplifier, but excluding external radiation shield. The external radiation shield shall not exceed 215 pounds. This allows for shielding factors discussed in Appendix K.

The Camera Control Unit shall not be more than 30 pounds.

The camera head shall be of aluminum construction with a purified fused-silica faceplate for radiation tolerance.

The preamplifier enclosure shall be of lightweight, rugged material since it may be subjected to rough usage.

The camera head shall have a heat reflecting, weather resistant, smooth finish.

To insure operation during shock or vibration, all circuit components, with exception of vidicon or possible nuvistors, shall be permanently attached by soldering to their associated circuitry. Solid-state circuitry shall be utilized wherever possible, excluding camera head, where no semiconductors shall be used.

To accomplish three-dimensional viewing, utilizing two of the three cameras, a suitable camera head mounting platform is necessary. The platform must mount the cameras side by side, remotely control their interocular distance (spacing), and be lightweight and as small as possible. The relative spacing between cameras should be adjustable from 5 inches to 32 inches to allow depth perception cues from 2 feet to more than 50 feet from the camera. (See Appendix D).

3. Standard Camera Chain

a. Introduction

One standard, self-contained camera chain will be provided for utilization as a general outside area monitor. It may be used on platforms such as helicopter, crane, boom or tripod. It may also be used for inside area monitoring under a low radiation environment. The camera chain, under the conditions defined, shall produce high resolution, interference free pictures in all respects to EIA Standard RS-170.

b. Electrical Requirements

A minimum resolution of 600 lines horizontal in the center, and 450 lines in the corners, using a maximum of 10 MC bandwidth, and 375 lines vertical, shall be provided.

A usable picture will be produced at one footcandle illumination, using a lens aperture reference opening of $f/1.5$. It will produce all ten shades of gray while viewing an EIA test pattern with 1 footcandle highlight illumination on the vidicon face.

The combined geometric distortion and scan nonlinearity shall be within 2%.

To provide faithful reproduction for low light level gradations of a scene, which in essence aids in detail reproduction of dark corners or areas, a selector switch at the Control Unit will provide a contrast (Gamma) correction ratio of 0.7 from the normal ratio of 1.0.

To eliminate vidicon target damage, in case of sweep or cable failure, a fail-safe electronic circuit, sampling the deflection coils, shall be utilized to protect the vidicon. This circuit shall be located close to the camera.

The camera setup functions, such as, beam, target, pedestal and electrical focus, shall be capable of being controlled at either the camera or a remote control unit located up to 2,000 feet away.

The camera shall be equipped with a high quality, self-contained sync generator. To insure picture stability and compatibility with other standard television systems, the synchronization shall be at the standard EIA scanning rate of 525 lines, 60 fields interlaced 2:1, and conform to the most recent EIA specification RS-170, paragraphs 2.6 and 3.3.

Normally, the master oscillator of the sync generator will be phase locked to the 60 cycle AC line, but in cases where rapid AC line frequency fluctuations might occur due to engine-generator or other difficulties, the master oscillator will be locked to an internal crystal which shall be switch selectable.

The operational controls shall be located at the rear of the camera unit and easily accessible, unless utilized as explained above.

No change in performance characteristics shall occur during short or long term operation.

The camera shall be capable of operating from an input voltage of 105 to 130 volts AC, 60 cps. To maintain reasonable demands from the power source, the camera input requirements should be approximately 30 watts. For portable, airborne use, the camera shall also be capable of operating from a 24-28 volt DC source. This scheme minimizes external components and is easily provided for in most camera systems.

To insure high quality reproduction under long or short term fluctuating input power, all DC voltages shall be regulated to at least 1%.

c. Mechanical Requirements

The camera head with self-contained control unit shall be of cylindrical design and minimum size for ease of handling.

The separate remote control unit shall be as small as possible and capable of mounting in standard 19 inch rack or portable case.

The total weight of self-contained camera and control unit should not exceed 10 pounds.

The remote control unit alone should not exceed 15 pounds.

The entire camera chain shall be constructed of durable, lightweight materials.

The camera head shall have a heat reflecting, weather resistant smooth finish.

All circuit components, with exception of vidicon or possible nuvistors, shall be permanently attached by soldering to their associated circuitry. Solid-state circuitry shall be utilized wherever possible.

4. Lenses

a. Introduction

The appropriate lenses are required to satisfy the wide range of viewing conditions which may be experienced. Zoom lenses offer the best flexibility by permitting various degrees of coverage from telephoto to wide angle, within a single lens assembly. A total of five zoom lenses, with attachments, shall be supplied, consisting of three radiation tolerant automatic zoom, one standard automatic zoom and one manual zoom lens.

Fixed lenses offer the advantage of extreme wide angle coverage beyond the capability of the zoom lens. Three radiation tolerant models shall be supplied for use on any of the four cameras. Telephoto requirements will be adequately covered by the zoom lenses and their attachments

b. Radiation Tolerant Zoom Lens

Three radiation tolerant automatic zoom lenses shall be utilized with cameras #1, 2 and 3. (Radiation levels listed in Environmental Section III, B2. They will be attached by way of standard "C" mount threads so that easy removal is possible.

The zoom lens controls of zoom, focus and iris shall be capable of up to 2,100 feet separation from the lens. Dual controls with master control override shall be provided to allow operation from the camera preamplifier enclosure location. This location might be used where camera head positioning by crane or boom was in process, and changes of viewing distances and field were necessary.

The resolution shall be at least 700 lines overall.

The lens shall be color corrected.

The flange focal length shall be the standard 0.690 inches.

The lens focal length shall be variable from 30 mm (1.2") to 300 mm (12").

The only available radiation tolerant lens for vidicon camera provides 30 mm (1.2") to 150 mm (6") with short lens converter and 60 mm (2.4") to 300 mm (12") with long lens converter, and these shall be supplied.

The focusing shall be variable from 6 feet to infinity. Three 2/3 diopter, radiation tolerant supplementary lenses shall be supplied to allow focusing to be variable from 3 to 6 feet.

The format for the vidicon faceplate shall be the standard 5/8" diagonal image circle or a full 1/2" by 3/8".

The lens speed shall be as "fast" as possible but as least f/2.7 to allow low light level viewing.

c. Standard Zoom Lens

The standard camera (#4) shall be supplied with one automatic and one manual zoom lens. The automatic zoom will be utilized whenever this camera is remotely located requiring remote operation of zoom, iris and focus, at distances up to 2,000 feet. The manual zoom will be needed whenever the camera is operated from a hand-held position, such as aboard aircraft for area surveillance, etc.

The automatic zoom lens shall provide a variable 15 mm (0.6") to 300 mm (12") focal length range. To accomplish this extremely wide range of focal lengths, the basic lens assembly shall be 15 mm (0.6") to 150 mm (6"). A lens converter shall be supplied to enable a variable focal length variation of 30 mm (6") to 300 mm (12"). The lens shall provide 700 line, overall resolution, be color corrected, have a flange focal length of 0.690 inches (vidicon standard), and be attached by way of standard "C" mount threads. Focusing range shall be variable from 5 feet to infinity. The lens shall provide standard vidicon format. The speed shall be as "fast" as possible to allow low light level viewing.

The manual zoom lens shall provide a manually variable focal length of approximately 25 mm (1") to 100 mm (4"). The lens shall be equipped with a "see-through-lens" eye-piece type viewfinder, to allow the camera operator to properly zoom, frame and focus the lens without the need for external video monitor. This also eliminates the need for a control box and wiring necessary with an automatic zoom lens. The lens shall provide 700 line overall resolution, be color corrected, have a flange focal length of 0.690 inches (vidicon standard), and be attached by standard "C" mount threads. Focusing range shall be variable from 5 feet to infinity. The lens shall provide standard vidicon format. The speed shall be as "fast" as possible to allow low light level viewing.

d. Fixed Lenses

Three radiation tolerant wide angle fixed lenses shall be provided for use with any of the four cameras, but supplied primarily for cameras #1, 2 and 3. (Levels listed in Section III, B2). They shall have a focal length of 13 mm (0.5") and be attached by way of standard "C" mount threads.

The resolution shall be at least 700 lines overall.

The lens shall be color corrected.

The flange focal length shall be the standard 0.690 inches.

The focusing range shall be from 1 foot to infinity.

The format shall be standard vidicon.

The lens speed shall be as "fast" as possible but at least $f/2.5$ for viewing in low light level areas.

5. Viewing Filters

Sun filters are needed to protect the vidicon from the direct rays of the sun and to permit direct viewing of extremely highly lighted scenes. The protection afforded by these filters allows for accidental viewing of the sun or other sources of extreme brilliance without permanent damage to the vidicon.

The filter transmission in visible spectrum should be approximately 70%.

The filter shall be radiation tolerant for levels as outlined in Section III, B2.

A total of 7 filters will be needed. Four for the zoom lenses and three for the wide angle lenses. The use of separate filters for the different types of lenses eliminates the need for filter adapters and reduces possible loss of these small adapters.

6. Illumination

a. Introduction

Lighting systems shall be included for indoor as well as underwater operations. All designs will be considered on a basis of no additional lighting being available. Each camera shall have two lights mounted at each side of the camera head to allow the maximum light intensity and shadow control.

b. Indoor Lighting

The minimum intensity of the incident (on the object) light should be about 40 footcandles.

The maximum field of view will be about 1,200 sq. ft. or 60 ft. horizontal and 20 ft. vertical for the wide angle lens. For the zoom lens, there will be about 860 sq. ft. or 43 ft. by 20 ft.

The maximum object to camera separation is expected to be about 50 ft., and the lamps shall be selected to provide sufficient intensity for satisfactory television reproduction.

Remote focusing of the light from a spot to a flood is desirable; however, this adds extra weight and requires radiation tolerant construction. Therefore, one spot and flood shall be used for each camera.

The lamps shall operate without degradation in radiation environments as listed in Section III, B2. (See Appendix K for radiation considerations).

The mean lifetime of a light should be about 1,000 hours. The average shutdown time for replacement of all lights should be about 5 minutes. There should be enough replacements on hand to last for 7 weeks (about 1,500 hours) of continuous operation.

The lamps shall withstand pressures of up to 30 psig without failure as may be encountered in reactor containment vessels.

The total weight of the lights should be less than 10 pounds.

The lights shall operate on 115 or 230 VAC at 60 cps, and for maximum conditions 5,000 watts of power. The 230 volt lamps will be used on the portable radiation tolerant cameras to reduce the size and weight of the long power cables. The 115 volt lamps will be used on portable light stands for area illumination where 115 volt power sources are available.

It shall be possible to individually turn each lamp on and off at the control point to aid in obtaining maximum lamp life and depth cue information.

The effect of shadow patterns caused by proper lighting to enhance objects during monocular viewing will provide a maximum of depth cues. A believable estimate of object depth and shape will then be possible on the basis of these patterns. To achieve this cue, a lamp shall be placed on each side of the camera consisting of one spot and one flood. They shall be located below the camera head and at the tilt pivot point of the pan/tilt unit to maintain a minimum of tilt table loading. Since each lamp is individually switchable, this will allow the selection of maximum depth cue shadow patterns.

c. Underwater Lighting

Underwater lighting may be necessary for use with the underwater camera accessory.

The light shall supply about 65,000 candlepower peak intensity. This should provide adequate illumination for camera operations at 100 feet depths.

The maximum object distance to camera shall be about 30 feet.

The mean time before failure should be about 1,000 hours.

The lamp shall be capable of up to 100 feet submersion.

Weight should be less than 10 pounds in air.

Power should be 500 to 1,000 watts operating on 240 VAC and 60 cycles.

7. Distribution

a. Introduction

A video distribution system shall consist of a video switcher capable of routing the desired camera video input to the appropriate viewing or recording device. All outputs to remote viewing areas shall be isolated through distribution amplifiers.

b. Video Switcher Electrical Requirements

The switcher shall accept six composite video input signals. The video source will be composed of four cameras, one video tape recorder, and one spare.

The switcher will provide four selectable composite video outputs. The outputs will feed the utility monitor, waveform monitor, video tape recorder and distribution amplifier #5. Each output shall be amplifier isolated to allow proper input/output bridging and isolation.

Input and output source impedance shall be 75 ohms, $\pm 5\%$ for proper coax cable matching.

Each input, when not selected, shall be terminated with its characteristic impedance to provide the proper coax cable load at all times.

Isolation between channels shall be at least 40 db down to reduce crosstalk.

The amplifiers shall be of solid-state design.

The four amplifiers shall be powered by one regulated power supply. This supply shall operate from an input power of 105 to 130 volts AC, 60 cps.

c. Video Switcher Mechanical Specifications

Reliable, lighted, mechanical pushbutton type switches shall be utilized.

The switcher shall be compact, self-contained and capable of mounting in a standard 19 inch rack.

d. Distribution Amplifier Electrical Requirements

The amplifier shall be of solid-state design.

The amplifier shall provide either a high impedance bridged looping or terminated input.

Input impedance, when terminated, shall be 75 ohms, $\pm 5\%$.

Frequency response shall be uniform to 10 MC ± 1.0 db.

Hum and noise shall be 60 db RMS below 1 volt p-p output.

Differential phase and gain shall be less than 1%.

The video gain shall be adjustable from approximately -10 db to + 20 db to permit the use of long video lines. The video gain will be necessary when feeding video to remote viewing areas.

A self-contained regulated power supply capable of stable operation from 105 to 130 volts AC, 60 cps shall be utilized. The supply shall be capable of powering four distribution amplifiers.

e. Distribution Amplifier Mechanical Requirements

The amplifiers shall be of modular construction, compact and designed so that all are self-contained, with power supplies, within one panel no larger than 5-1/4 inches x 19 inches. This compact arrangement allows easy handling and setup.

8. Monitoring

a. Introduction

Visual observation of the scenes being viewed shall be accomplished by the use of high quality television monitors. The main control/monitor location shall contain five, 14 inch and one, 17 inch utility monitor. Two of the 14 inch monitors shall be arranged such that a 3D presentation is possible by the addition of a mirror arrangement accessory (See Appendix D). Other viewing locations shall each contain one, 14 inch monitor. Two portable 9 inch monitors will be provided for use with the general outside area assessment camera or the other cameras.

b. Electrical Requirements

Frequency response shall be uniform (+ 1 db) to 10 MC.

The monitor shall provide either a high impedance bridged looping or terminated input.

Operation within specifications shall be possible with a negative video input signal of 0.3 volt p-p.

Input impedance, when terminated, shall be 75 ohms, $\pm 5\%$.

Linearity shall be within 1% of picture height.

Selectable D. C. restoration of either 100% or zero shall be provided by a built-in switch to provide constant video reference level under varying video signal amplitude.

The kinescope shall produce a high brightness picture capable of viewing under high ambient light conditions. The tube shall have a laminated safety shield.

Input power requirements shall be 105 to 130 volts, AC, 60 cps approximately 50 watts for 14 inch and 9 inch monitor and 180 watts for 17 inch monitor. The low voltage power supply shall be regulated to insure overall monitor stability.

With the exception of kinescope and possible high voltage rectifier, all circuitry shall be solid-state (14 and 19 inch monitors only).

c. Mechanical Requirements

The monitors shall be capable of being mounted in either a standard 19 inch rack or portable cabinet to permit a choice of ease of movement or semi-permanent installation. This will be accomplished by use of a rack mounting adapter and portable cabinet.

The size and weight of the monitor shall be as small as possible and lightweight to maximize ease of movement.

9. Recording

a. Introduction

Various types of recording equipment will be necessary to permit the storage of video and audio information. (Appendix G). The recording equipment shall consist of one compact, portable, video tape recorder, a motion picture camera suitable for video recording from a monitor, a still camera for producing regular film or polaroid stills, and one audio tape recorder for recording the intercom channel.

The video tape recorder shall also be capable of recording one channel of audio. This allows audio commentary coordination when video recording. The intercom control headset will be used for audio commentary by proper control panel switch selection.

b. Video Tape Recorder (VTR) Electrical Requirements

The recorder shall be a high quality, professional, portable tape recorder.

The VTR shall have a video frequency response of at least 10 cycles to 3.0 MC, ± 3 db which shall produce a minimum horizontal video resolution of 250 lines.

One track shall be available for audio recording with an audio frequency response of at least 100 cycles to 8 KC, ± 3 db.

Modular design and solid-state circuitry shall be utilized for ease of maintenance, reliability and compactness.

The recorder shall be capable of displaying a video frame in stop-motion. This may be useful in displaying a scene for specific picture examination.

Tape loading and threading shall be uncomplicated so that unskilled operators could easily accomplish it.

The video input shall be 75 ohms, terminated internally.

Signal input shall be negative sync, 0.8 to 1.2 volts p-p composite.

The video output shall be 75 ohms. The output signal shall be 0.9 to 1.1 volts p-p composite and capable of reproduction on any standard video monitor.

The audio input shall be 600 ohms, unbalanced or balanced, terminated internally, line (-1 dbm) or microphone level (-6 dbm). This will allow a direct microphone connection if desired.

The audio output shall be 600 ohms balanced or unbalanced at approximately + 4 db.

The recorder shall be capable of continuous recording of up to 5 hours. This eliminates the need for frequent tape changes and results in less tape bulk.

Input power shall be 105 to 130 volts AC, 60 cps, approximately 400 watts.

c. Video Tape Recorder Mechanical Requirements

The recorder shall accept standard SMPTE reels up to 12-1/2 inches in diameter.

A skew control on the recorder shall be provided to compensate for tape expansion or shrinkage during playback.

The head drum instantaneous speed shall be servo controlled to insure picture stability.

The recorder shall have a mechanical tape counter with digital readout which may be used to numerically reference any portion of the tape for replay purposes.

The counter shall have a push button reset.

The recorder shall be capable of mounting in a portable case or standard 19 inch rack. The dimensions shall not exceed 19 inches wide x 15 inches deep (total) x 34 inches high.

The weight of the recorder shall be approximately 100 pounds.

d. Video Motion Picture Film Recorder

The film recorder shall consist of a high quality, motor drive, 16 mm motion picture camera which has been modified for recording of video information displayed on the 17 inch utility monitor's screen. The camera shall be modified to enable it to record the video picture without shutter bar or flicker, yet maintain the standard 16 mm speed of 24 frames per second. This allows playback on any standard 16 mm projector.

The recorder shall be as small as possible and weigh approximately 17 pounds excluding film magazine.

Input motor drive power shall be 105 to 130 volts AC, 60 cps.

The camera shall accept either 600 or 1,200 feet magazines and one of each shall be supplied.

The camera shall be equipped with a lightweight, portable tripod for camera mounting and placement in front of monitor.

A camera to monitor accessory hood shall be provided for attachment to the 17 inch utility monitor, for light exclusion, distance and framing determination.

e. Still Camera

For recording of stills, a standard 4 x 5, "press type" camera shall be utilized. The camera will be mounted on a tripod (supplied with the film camera) and placed in front of the 17 inch utility monitor for recording.

The camera shall be capable of accommodating 4 x 5 film packs, 120 roll film or polaroid film.

A ground glass focusing method shall be provided for ease of setup.

The camera shall be small and lightweight.

The camera to monitor hood accessory for the movie camera shall also be used for the still camera.

f. Audio Tape Recorder

A dual track audio tape recorder shall be provided for recording either the intercom channel or a separate microphone input. One external microphone shall be provided. (This can also be used on Video Tape Recorder).

The input and output impedance shall be 600 ohms, balanced. A low impedance microphone input shall also be provided.

Audio frequency response shall be at least 100 cycles to 5,000 cycles, which is adequate for speech.

Standard 1/4" tape shall be employed.

It shall operate at selectable tape speeds of 3-3/4 inch or 7-1/2 inch per second.

The recorder shall accept standard audio tape reels of up to 7 inches in diameter.

10. Mechanical Mounts and Enclosures

a. Introduction

The following table depicts the camera mounting hardware which should be available for each camera:

Table B-1

MOUNTINGS AVAILABLE

Camera	Med Duty Pan/ Tilt Unit	Tripod and Dolly	H. D. Pan/ Tilt & Exp. Proof Housing	Univ Bracket	Modified Med Duty Pan/ Tilt For 3D	3D Mount
Radiation Tolerant #1	X	X	One Unit ↓	X	One Unit ↓	One Unit ↓
Radiation Tolerant #2	X	X		X		
Radiation Tolerant #3	X	X	↓	X	↓	↓
Standard #4	X	X	No	X	No	No

In addition, one remotely controlled mobile television vehicle capable of mounting camera and lights shall be provided.

b. Pan and Tilt Units

Four medium duty pan and tilt units shall be provided for use with any of the four cameras (#1-4). These will support the loads imposed by a single camera chain and accessories.

For the heavier two-camera 3D configuration, one modified medium duty pan and tilt unit shall be provided. This model, modified to handle the heavier loads, will require a sacrifice in tilt speed and total angle, but it allows the use of a lighter unit rather than a heavy duty unit with a 3 times increase in unit weight.

One heavy duty unit shall be furnished for use with cameras #1, 2, and 3 for the heavy loads imposed by accessories such as the explosion proof housing.

c. Pan and Tilt Unit Electrical Requirements

The pan and tilt mechanism shall be capable of operating up to a distance of 2,100 feet from its control unit. Dual controls with master control override shall be provided to allow operation from the camera preamplifier enclosure location.

The unit shall operate from 105 to 130 volts AC, 60 cps, single-phase, approximate input power of 150 watts for the medium duty unit and 200 watts for the heavy duty unit.

d. Pan and Tilt Unit Mechanical Requirements

The pan and tilt assembly shall be capable of panning in the horizontal plane from 0° through 350° , and $\pm 90^{\circ}$ from the level position for the medium duty unit. The modified medium duty and heavy duty pan and tilt units shall be capable of horizontal movement of 0° to 350° , and vertical movement of $\pm 45^{\circ}$ from the level position.

The units shall provide for a positive braking arrangement, and in the event of an AC power outage, the movable table shall remain locked in the last pan and tilt position without slippage.

The units shall be as small as possible. The weight of the medium duty assemblies shall be approximately 25 pounds. The heavy duty unit shall weigh approximately 70 pounds.

The medium duty pan and tilt unit shall be capable of accommodating a balanced load of 30 pounds. The modified (3D) medium duty unit shall accommodate a balanced load of approximately 65 pounds and the heavy duty unit shall accommodate a balanced load of approximately 82 pounds. The pan and tilt units mentioned above shall perform without degradation at the stated loads.

The pan and tilt units shall be suitable for mounting on tripod or universal mounting bracket.

All units shall operate satisfactorily in radiation environments as described in Section III, B2.

e. Tripod and Dolly

Four tripods shall be furnished and used for mounting any of the pan and tilt units.

Four sets of dollies (casters) shall be supplied for the tripods and shall be easily attached to the tripod. These could be used for ease of camera movement (manual) where the floor is smooth and obstruction free.

The tripod height shall be manually adjustable from approximately 35 to 72 inches. The total combined tripod/ dolly weight shall not exceed 30 pounds.

The assembly shall be capable of supporting loads to 165 pounds.

The tripod shall accept any of the pan and tilt units. A friction head will not be necessary.

The tripod shall be easily folded for transportation.

The dolly (casters) shall be easily attached and capable of free swiveling, straight line tracking or locked operation.

The tripod/ dolly shall be constructed of materials which are radiation tolerant to the levels listed in Section III, B2.

f. Camera Mounting Brackets

Circumstances could arise where the tripod would not be suitable for mounting the camera assembly. This could occur when reactor core viewing is necessary where a pipe or boom mount might be used; in locations where the camera assembly would be clamped to a roof beam for viewing along the roof structure and also the room below; and possibly be mounted on overhead pipes, etc.

Four mounting brackets shall be furnished for use with any of the four cameras (actually for pan and tilt mounting). Two of the brackets shall allow for mounting on vertical members and two for horizontal members.

The brackets shall have interchangeable and removable mounting feet which will allow the brackets to be clamped to girders, pipes, booms and cranes, and tables.

The brackets shall be capable of placement by a remotely controlled manipulator unit.

The bracket shall be as small as possible and lightweight.

It shall be capable of supporting loads up to 165 pounds.

It shall be constructed of materials which are radiation tolerant to the levels specified in Section III, B2.

In addition, four quick disconnect / connect camera and lights mounting bracket shall be supplied for rapid attachment or removal of these from the pan and tilt unit.

g. Underwater Operations

The existing camera housing will be capable of operating underwater at depths up to 100 feet. Underwater television operations may be needed in examining the core of a water moderator reactor.

A mounting clamp for attaching an underwater light shall be furnished.

The housing shall be equipped with a yoke type mounting bracket which can be quickly attached and removed from the enclosure. The yoke shall allow the camera to be easily tilted and locked in position, at the point of attachment. The yoke shall be equipped with a clamping device for attachment of cable or rope of up to 1/2 inch in diameter, used for lowering of housing. The yoke shall weigh at least 10 pounds to insure housing submergence to 100 feet.

The connector shall allow for lowering by camera cable if desired.

h. Explosion Proof Housings for Camera

One housing capable of mounting any one of the radiation tolerant cameras shall be provided. This housing shall be designed for use in areas which contain potentially explosive gases as outlined in Section III, G2.

The housing shall weigh approximately 32 pounds.

It shall be constructed of materials which are radiation tolerant to the levels specified in Section III, B2.

The housing shall be capable of being purged prior to use by nitrogen to a level of 3 psig.

i. Explosion Proof Housings for Lamps

Two explosion proof housings shall be provided to contain one quartz lamp each. This housing shall be designed for use in areas which contain potentially explosive gases as specified in Section III, G2.

The housing shall not weigh more than 5 pounds each.

It shall be constructed of materials which are radiation tolerant to the levels specified in Section III, B2.

The housing shall be capable of being purged prior to use by nitrogen to a level of 3 psig.

The housing shall have brackets for attaching to the explosion proof camera housing.

j. Three-Dimensional Camera Accessories

A 3D mounting accessory shall be supplied to allow depth perception viewing, using the method outlined in Appendix D, for both camera head and monitor.

The camera mount shall be capable of satisfactory operation in radiation levels as outlined in Section III, B2.

The camera mount shall weigh approximately 15 pounds and be as small as possible.

The camera mount shall provide for quartz lamp mounting above the camera head.

The camera cradles shall provide for remote adjustment of interocular spacing and manual adjustment of ocular angle. (See Appendix D).

The monitor viewing attachment shall be easily attached and removed.

k. Remote Controlled Camera Vehicle

It is desirable to provide a vehicle capable of remote camera movements, particularly in high radiation or other hazardous areas. See Appendix J for a complete vehicle discussion.

l. Motion Picture and Still Camera-to-Monitor Viewing Hood

A viewing hood for motion picture and still film camera positioning in front of the 17" Utility Monitor shall be provided. This hood shall be capable of easy attachment and removal.

11. Transmission

a. Introduction

Two methods which may be utilized for video transmission are coaxial cable and microwave relay. Transmission between the cameras and the control point will normally be accomplished by use of coaxial cable. In addition, coaxial cable shall be used for relaying the video from the control point to other viewing areas when the distances are within 2,000 feet. When viewing distances exceed this, it will be necessary to utilize microwave relay transmission. In addition, since one camera will have the capability of utilization upon elevated platforms, such as a helicopter, or at great distances from the control point, video

information from this source shall be transmitted by a microwave relay system utilizing an omnidirectional antenna for ease of alignment.

b. Transmission Paths

Transmission paths will encompass a variety of conditions. These may include mountains, rolling hills or flat terrain covered by forests, desert, barren areas, etc., under extremely varying atmospheric conditions.

c. Radiation Resistant Camera, Cable

The following table depicts the various cable assemblies necessary to transmit control, audio, temperature and radiation information between camera and control area:

Table B-2

<u>FUNCTION</u>	<u>APPROX. LENGTH</u>	<u>CONNEC- TION</u>	<u>CONNEC- TORS</u>	<u>USAGE</u>
Connects camera head to preamplifier	100'	Environmental, Rad. Resistant	Water-tight	Cam. control video-audio
Connects pan & tilt unit to preamplifier	100'	Environmental, Rad. resistant	Water-tight	Pan & tilt control
Connects preamplifier to control unit	2000'	Environmental, Neoprene jacket	Environ-mental	Cam. control video-audio pan/ tilt cont.
Camera mount to distribution box at camera preamplifier	100'	Environmental, Rad. resistant	Water-tight	Radiation and temp. monitor
Distribution box at pre-amplifier to control area	2000'	Environmental, Neoprene jacket	Environ-mental	Radiation and temp. monitor
Connects lights at camera to control area	2000' 100'rad. resis.	Environmental, Neoprene jacket	Water-tight	Illumination

d. Standard Camera Cable

The camera control unit may be connected to the camera through 2,000 feet of environmental resistant cable. The cable shall transmit camera control, video, audio and pan and tilt control signals. Environmental proof connectors shall be supplied. In addition, a cable will be provided for the transmission of temperature and/or radiation information.

e. Video Transmission Cable

Video transmission to other possible viewing areas within 2,000' shall be through low loss, environmental resistant, coaxial cable.

f. Microwave Relay System Electrical Requirements

Two, one-way, video only, portable microwave relay systems shall be provided for transmitting video information from the standard TV camera to the control point and/or control point to other remote viewing areas. This will provide extreme flexibility in camera placement and remote viewing. There is no point in providing a one way audio channel since communication will be maintained by two-way radio systems and the audio channel would reduce the video channel bandwidth.

The basic microwave relay system shall be capable of 10 mile line-of-sight range using 2 foot parabolic antennas and no external amplifiers, and 5 miles using omnidirectional antenna on one end and 2 foot parabolic on other end.

The video frequency response shall be approximately 8 MC, ± 1 db.

Input and output impedance shall be 75 ohms, $\pm 5\%$. Input shall be terminated by this impedance.

Video input signal shall be 1 volt p-p, composite ± 0.5 volt. Output signal shall be 1 volt p-p, composite ± 0.5 volt.

Frequency stability shall be at least 0.1% over a wide temperature range.

With the exception of possible transmitter tubes, all circuitry shall be of solid-state design.

Power requirements shall be either 105 to 130 volts AC, 60 cps or 24-28 volts DC at approximately 60 watts.

g. Microwave Relay System Mechanical Requirements

The system shall be as small as possible and mounted in a portable case.

The transmitter and receiver shall not exceed 20 and 30 pounds, respectively.

12. Power

a. Introduction

Power input to all systems with exception of that used aboard aircraft shall normally be supplied by the existing 115 volts AC, 60 cps, single phase circuits available at the site. When this is inadequate or not available, power will be supplied by a standby engine-generator. The standby power will be supplied by the site. The engine-generator should provide stable power and supply 105 to 125 volts AC, 60 cps, which is within the capability of most industrial type generators.

b. Distribution

A single input jack shall be supplied for obtaining input power from the power source to the distribution system.

Adequate receptacles and spares shall be provided for all equipment. Each receptacle shall be capable of supplying at least 15 amperes of current.

All wiring shall comply with the 1962 edition of the National Electrical Code (NFBU No. 70).

c. Load

The total load of all TV systems, lighting and ancillary equipment shall not exceed 10 KW.

d. Regulation

All power sources shall be stable, non-fluctuating and within 8% regulation.

e. Protection

Adequate protection by utilization of circuit breakers and/ or fuses shall be provided in compliance with the 1962 edition of the National Electrical Code (NFBU No. 70).

13. Intercom System

Intercom communications shall be provided between each camera location and the control console.

Headsets, with microphone attachment, shall be used at each location.

A command speaker with talk-back capabilities shall be capable of mounting at camera # 1-3 locations. The speaker amplifier circuitry for speaker drive and talk-back shall be solid-state and located at the preamplifier enclosure location. The speaker shall be capable of tolerating radiation levels listed in Section III, B2. This radiation requirement is not essential since the speakers will be considered expendable due to their low cost.

An intercom control panel shall be furnished to allow camera/ headset/ speaker, input-output selection. The panel shall provide switch selectable outputs to the video tape recorder, audio tape recorder and monitor speaker.

The control panel shall permit a minimum of two headset inputs.

The control panel shall have connectors for interconnecting with a minimum of 2, two-way radios. Push-to-talk switches shall be

furnished on the control panel for keying the two-way radios. (The two-way radios are not a part of these requirements and will be supplied by the site.)

Internal amplifiers of solid-state design shall be utilized for the necessary talk, listen, and speaker monitor audio power.

14. Environmental Information

a. Introduction

The prevailing environmental conditions of temperature and radiation at the camera location, when in an appropriate area, should be available at the control point. This will aid in decisions relating to personnel safety.

The temperature measuring system will consist of a radiation tolerant thermometer located on the camera mounting device and connected by cable to an indicating device at the control point.

b. Temperature Measurements

The thermometer shall be capable of remotely measuring ambient temperatures ranging from -50° to $+200^{\circ}\text{F}$.

The temperature sensing element (thermometer) shall be capable of radiation tolerance to levels specified in Section III, B2.

An indicator shall be provided at the control point for readout of the thermometer output.

The thermometer unit shall be capable of up to 2,100 foot separation from the indicator, using a minimum amount of cable pairs.

The thermometer shall be lightweight, compact, and capable of mounting on either the camera or tripod. The indicator shall be mounted in a portable type case and shall be as small as possible.

c. Radiation Measurements (See also Appendix K)

The radiation monitoring probe shall be capable of measuring gamma radiation levels from 10 mr/hr to 10^4 r/hr. The device shall

have a collimated pattern if possible; however, collimation will require heavy lead shielding.

An indicator shall be provided at the control point for data measurement from the probe.

The radiation probe shall be capable of up to 2,100 foot separation from the indicator, using a minimum amount of cable pairs.

The probe shall be lightweight, compact, and capable of mounting on either camera or tripod. The indicator shall be mounted in a portable type case and shall be as small as possible.

15. Test Equipment

a. Introduction

Adequate and portable test equipment, independent of any test equipment at the disaster site, shall be provided to adequately maintain all systems.

b. Equipment

The following equipment shall be the minimum required:

- 1) Waveform Monitor (For waveform analysis and camera setup)
- 2) Dot-Bar Generator (For monitor alignment)
- 3) Multimeter (For general equipment maintenance)
- 4) Diascope (For camera chain alignment when camera head is separated by long cable, and routine maintenance)
- 5) Oscilloscope (For general maintenance)
- 6) Transistor Checker (For general maintenance)

The test equipment shall be mounted in portable type cases, when possible.

B. ENVIRONMENTAL REQUIREMENTS

1. Introduction

All equipment may be subjected to environmental conditions as defined in this section during shipping, handling, storage and operation.

The equipment must be designed to survive any reasonable combination of these conditions. In accordance with reliability objectives, equipment design will assure an adequate safety margin such that demonstrative environmental testing of equipment shall in no way affect its after-test operation.

2. Nuclear Radiation

a. Introduction

The nuclear radiation levels experienced by the equipment at any particular location depends upon its proximity to the source and the attenuation produced by intermediate shielding materials. Radiation effects may range from temporary degradation of performance to permanent damage.

b. Neutron

No degradation of performance shall occur when the appropriate equipment is exposed to a radiation environment of 10^3 neutrons/cm²/sec., and a cumulative dosage of 10^{12} neutrons/cm².

c. Gamma

No degradation of performance shall occur when the appropriate equipment is exposed to a gamma radiation level of 10^4 roentgens/hour and a cumulative dosage of 10^8 roentgens.

3. Temperature

a. Storage

No deleterious effects shall occur to equipment in storage if subjected to temperatures ranging from -65° to $+150^{\circ}$ F.

b. Transportation

No deleterious effects shall occur to equipment in transportation if subjected to temperatures ranging from -65° to $+150^{\circ}$ F.

c. Operation

No degradation of performance shall occur when certain equipment is subjected to and operated at temperatures ranging from -50°F to $+150^{\circ}\text{F}$. Some equipment such as the camera head may be subjected to temperatures of up to $+200^{\circ}\text{F}$.

4. Altitude (Pressure)

a. Transportation

No deleterious effects shall occur to equipment when subjected to pressures ranging from 14.7 to 6.8 psi, corresponding to altitudes from sea level to 20,000 feet.

b. Operation

No degradation of performance shall occur to equipment subjected to and operated at pressures/ altitudes from 14.7 psi (sea level) to 10.1 psi (10,000) feet.

5. Humidity

a. Transportation

No deleterious effects shall occur to packaged equipment transported in carriers when subjected to an atmosphere containing a relative humidity of up to 100%, at temperatures up to $+150^{\circ}\text{F}$, with condensation in either the liquid or solid state.

b. Storage

No deleterious effects shall occur to packaged equipment in storage when subjected to an atmosphere containing 0 to 100% relative humidity.

c. Operation

No degradation of performance shall occur when certain equipment is subjected to and operated in an atmosphere containing 0 to 95% relative humidity at a temperature of $+120^{\circ}\text{F}$ for periods of up to 15 days.

6. Sunshine

All unprotected equipment may be exposed to and operated with a sunlight radiation exposure of 105 watts per square foot, total, with 50 to 84 watts per square foot of this radiation above 7800 angstroms and 4 to 8 watts per square foot below 3800 angstroms.

7. Precipitation

a. Transportation

No deleterious effects shall occur to equipment in transportation when subjected to a precipitation of approximately 4 inches/ hour for 2 hours.

b. Operation

No degradation of performance shall occur to unprotected equipment subjected to and operated in a maximum precipitation of approximately 4 inches/ hour for periods of 2 hours. This is limited to exposure and normal water runoff without flooding.

8. Sand and Dust

a. Transportation

No deleterious effects shall occur to packaged equipment in transportation if subjected to bombardment by sand and dust particles in winds up to 70 MPH, or settling dust.

b. Storage

No deleterious effects shall occur to protected equipment which is stored and subjected to bombardment by particles of sand and dust in winds up to 70 MPH, or settling dust.

c. Operation

No degradation of performance shall occur to certain equipment when subjected to and operated during bombardment by particles of sand and dust in winds to 35 MPH. The equipment shall be protected to withstand this condition for periods of 6 hours.

9. Mechanical Shock

a. Transportation

No deleterious effects shall occur to packaged equipment when subjected to shocks caused by transportation vehicles and accidental drops to a maximum of about 20 inches and when subjected to 18 impact shocks of 15g, each shock impulse having a time duration of 11 ± 1 milliseconds consisting of 3 shocks in opposite directions, along each of three mutually perpendicular axes. The maximum acceleration shall be reached in approximately 5.5 milliseconds.

b. Handling

Equipment subjected to bench servicing shall survive one-inch flat drops and 4-inch pivot drops onto a hard surface.

c. Operation

No degradation of performance shall occur when certain equipment is operated while being subjected to shocks caused by platform vehicles at levels of 18 impact shocks of 15 g, each shock impulse having a time duration of 11 ± 1 milliseconds consisting of 3 shocks in opposite directions, along each of three mutually perpendicular axes. The maximum acceleration shall be reached in approximately 5.5 milliseconds.

10. Vibration

a. Transportation

No deleterious effects shall occur to equipment in transportation when subjected to a peak force of 3.5 g, from 5 to 50 cps (limited to 0.4 inch double amplitude) and 1.5 g, from 50 to 300 cps for 30 minutes. Excitation will be in three mutually perpendicular coordinates, applied at equipment's point of mounting to shipping container.

b. Operation

The magnitude of vibration experienced by equipment at any particular location depends upon its proximity to a dynamic force and the response characteristics of the structure to which the equipment is attached. No degradation of performance shall occur when certain equipment has been subjected to vibrations at all frequencies between 5 to 50 cycles for 15 minutes at an applied double amplitude of 0.036 inch or an applied acceleration of ± 10 g, whichever is the lower value, along each of three mutually perpendicular axes.

11. Wild Life

Equipment cabling shall not be damaged by rodents and other wild life.

12. Atmosphere

a. Inert

Some equipment may be subjected to, and shall satisfactorily operate in an atmosphere which will be encountered in rooms or enclosures purged to prevent accumulation of explosive gases.

b. Explosive

Some protected and unprotected equipment may be subjected to and operated in an atmosphere which will be encountered in rooms or areas not purged with the resulting possibility of explosive gases. Equipment which is operated in a potentially explosive atmosphere shall have provisions to prevent ignition of this atmosphere.

c. Pressurized

No deleterious effects shall occur to certain equipment when subjected to pressures of 30 psig which will be encountered in reactor pressure containment vessels.

13. Underwater

Some camera equipment and lighting may be operated under conditions of complete water immersion. Enclosures shall be provided to allow operation of these at levels down to 100 feet.

14. Fungus

No deleterious effects shall occur if equipment is subjected to fungus growth on nutrient organic materials, including grease, oils, dust, etc., in an environment where the relative humidity and temperature exceeds 60% and 60°F.

15. Salt Spray

No deleterious effects shall occur when certain equipment is subjected to an atmosphere containing salt laden moisture for periods of seven days.

C. RELIABILITY AND QUALITY ASSURANCE

1. Reliability Requirement

Maximum system reliability under a wide range of operating conditions and environments shall be stressed. The equipment shall demonstrate a probability of success (P_s) of 0.90 for 1,000 hours of operation with a confidence limit of 90 percent.

2. Mean Time Between Failures (MTBF)

The nominal mean time between failures required for a probability of success (P_s) of 0.90 for 1,000 hours is approximately 9,500 hours.

3. Reliability Estimate

A reliability estimate including mean time between failures and probability of success for 1,000 hours of operation shall be furnished. The specific method of estimation should conform to an accepted part count method. An environmental multiplying factor of ten shall be utilized and derating by component shall be indicated.

4. Maintainability

The equipment layout and packaging shall be designed to allow maximum accessibility for calibration and maintenance. Periodic and specialized maintenance requirements shall be specified in the maintenance manual.

The equipment shall be capable of being maintained by skilled technicians unfamiliar with the equipment.

A recommended list of spare parts required to insure operational status of all equipment for one year shall be supplied.

A list of consumable material required for equipment maintenance shall be supplied. This should include recommended quantity and ordering information for items such as lubricants, adhesives, cleaning materials, preservatives, desiccants, protective coatings and finishes, gasket compounds and any other special consumable items peculiar to the equipment.

All controls which may require frequent adjustment shall be readily accessible and clearly marked.

Automatic fault detection and indication shall be incorporated where practicable.

Clearly defined and readily accessible test points monitoring important circuit parameters shall be included in all equipment to aid in fault localization.

All equipment shall be accompanied by maintenance manuals which include schematic diagrams for all circuits, standard measurements and tolerances at test points, essential test voltages, waveforms, typical performance limits, suggested maintenance routines, and a tabulation of common equipment malfunction symptoms related to probable causes and suggested repairs.

5. Time Change Items

Components requiring periodic replacement shall be specified in the maintenance manual.

6. Circuitry

Where possible, all circuitry shall utilize solid-state devices and be of modular construction. All transistor leads shall be permanently attached by soldering to their associated circuitry.

7. Interchangeability

Complete system, subsystem and component interchangeability shall be emphasized in all equipment through the use of standard hardware, components and tools. All specially selected, sorted or matched components shall be identified in the equipment and discussed in the maintenance manual.

D. EXPANDABILITY

1. Expansion Capability

The system shall be capable of expansion without difficulty. This will be accomplished, where possible, by utilization of components, video levels, connectors, cables, hardware, synchronization, etc., which are standard within the television industry and are in compliance with standards of good television engineering or EIA specifications.

2. Reconfiguration

The equipment shall contain components, hardware, connectors and cables which allow for flexibility in the re-arrangements of individual units within each camera chain, controls, monitors or between subsystems.

3. New Standards Conversion

The system shall be capable of conversion to new operational standards of synchronization, etc., by replacement of assemblies or subassemblies rather than replacement of the complete system or subsystem.

4. New Development Integration

The system shall be updated frequently as improvements and modifications are developed by the manufacturers of the various equipment utilized.

E. PORTABILITY

1. Introduction

It is essential that the television system and its equipment be properly packaged and contained to insure efficient transportation techniques and reliable operation.

The two methods of packaging available are the use of either individual packing cases or a trailer. These methods are fully discussed in Appendix I.

The functional requirements of each method are discussed here.

2. Packing Cases

a. Shipping Size

Equipment design and construction shall stress ease of assembly into small packages which are suitable for transportation by commercial, air-freight shipping.

b. Shipping Weight

Shipping containers for use with the television system shall be capable of being carried by two people; however, the maximum total container weight, with equipment, shall not exceed 250 pounds. This requirement shall not include cable and reels. These will be handled without containers due to their size, weight and durability.

c. Container

All equipment, with exception of large cable and reels, shall be packaged in containers for shipping.

The containers shall be lightweight, watertight, airtight, shockproof, heavy duty and reusable.

The performance characteristics of the containers shall comply with the environmental conditions of temperature, humidity, precipitation, sand, dust, shock, vibration, fungus, and salt spray, of Section III, B.

In addition, they shall withstand extremes of tumbling (at least 100 tumbles in a 14 foot test tumbling drum) and complete water immersion without leaking.

A pressure equalizer shall be installed for equalizing inside pressure when case lid opening is desired.

The container shall have flush, folding type, carrying handles, designed for convenient carrying by one, two, or more persons.

The shape of the containers shall allow a condition of stable equilibrium and provide for stable, easy stacking.

Some containers shall be provided with cable access doors and ventilation ports to permit equipment operation while contained within the case.

3. Trailer

a. Configuration

The trailer shall contain all the control monitor consoles necessary for mounting the camera controls, pan and tilt controls, monitors, recorders, switchers, microwave and other ancillary equipment.

Space shall be provided for storage of cameras, lights, tripods, as much cable as possible, and other system equipment.

All control and monitor equipment shall be mounted in the trailer racks/consoles such that they could be quickly removed and placed in cases for portable operation outside the trailer if necessary.

The trailer size shall be approximately 40 feet long and a maximum of 8 feet wide. This width permits highway transportation without special permits in most areas.

b. Transportation

The trailer shall be capable of easy transportation from the storage location to the desired location. This may be accomplished by tractor towing or military aircraft.

c. Air Conditioning

Heating and cooling shall be included to provide a controlled environment suitable for stable equipment operation and operating crew comfort.

F. OPERATORS/ TRAINING

1. Skills

At least one fully qualified, competent, television technician shall be permanently assigned the overall system technical responsibility. He should be thoroughly familiar with the system and able to direct the activities of other technicians during assembly/ disassembly and maintenance. He should also be capable of instructing other technicians on the system. He should be available to travel with the equipment to the desired locations.

Two additional technicians/ operators should be available for initial assembly, checkout and until stable operation is achieved. After stable and semi-permanent operation of the equipment is accomplished, local technicians/ operators may be utilized.

2. Human Engineering

Special attention to efficient placement of controls, indicators and adjustments shall be accomplished to aid in the operation of the system.

3. Manuals

A thorough maintenance manual shall accompany each unit of the system. The following shall be a guide of the minimum contents and suggested layout.

EXAMPLE OF MAINTENANCE MANUAL CONTENT AND LAYOUT

Chapter 1 - Introduction

Introduction (System)

Subsystem

Chapter 2 - General Description

General System Description

Physical Description

Power Requirements

Chapter 3 - Assembly/ Disassembly & Checkout Instructions

General

Subsystem Assembly and Checkout Instructions

System Assembly and Checkout Instructions

Controls and Indicators

System Disassembly Instruction and Packaging

Subsystem Disassembly Instructions and Packaging

Chapter 4 - Operation

System Operation

Subsystem Operation

Chapter 5 - Circuit Description

System Circuit Description

Subsystem Circuit Description

Functional Circuit Description

Chapter 6 - Maintenance

System Maintenance

Maintenance Instructions

Subsystem Troubleshooting

Unit Troubleshooting

Waveforms

Chapter 7 - Circuit Diagrams

Schematic Diagrams

Chapter 8 - Recommended Spare Parts

Recommended System Spare Parts

Recommended Subsystem Spare Parts

Appendix A - SPECIAL AND COMMERCIAL INSTRUCTION MANUALS

Appendix B - CROSS-REFERENCE INFORMATION

4. Operator Training

At least two weeks of training every year should be provided for each technician which may be assigned to the TV system during operation. The training should consist of practice in the rapid assembly, checkout and operation of the complete system.

G. SAFETY

1. Hazard Protection

The maximum convenience and safety to personnel in the installation, operation and maintenance of all equipment shall be provided. Guide lines, which follow, shall be adhered to wherever practical, to minimize the effects of hazard sources. When these guidelines are impractical, alternate provision may be incorporated if equivalent protection is provided.

a. Electrical Hazards

Provision shall be made in all equipment to prevent personnel from coming into contact with voltages in excess of 40 volts peak-to-ground.

When covers are removed for maintenance, personnel protection will be provided for voltages in excess of 500 volts, peak-to-ground. Guards or barriers may be used for protection from these voltages.

The design and construction of the equipment will insure that all external parts, with the possible exception of antennas, are at ground potential at all times. Electrical outlets and plugs will have provision for automatically grounding the equipment when the plug is mated with the receptacle.

Provisions will be made for a "power-off" mode of operation which will prevent operation of equipment from a remote station while the equipment is being repaired or adjusted.

b. Mechanical Hazards

Operating equipment which contains gears, fans, belts, etc., shall be supplied with suitable protective devices to prevent injury to personnel from these moving parts.

Doors, hinged and slide mounted, and heavy equipment which may injure personnel by pivoting or falling when moved from its normal position, shall be provided with suitable locking mechanisms and warning labels.

The length of projecting and overhanging edges shall be kept to a minimum, and if any, they shall be rounded.

Adequate working room shall be provided in and around equipment racks, if used. Adjustments and other often worked-on areas shall not be located near unprotected high voltage, moving or high temperature parts.

Protection to personnel from imploding devices such as kine-scopes shall be incorporated to protect personnel from injury.

Equipment design shall prevent incorrect assembly of chassis, parts, etc., where a personnel hazard may result from this incorrect assembly.

c. Fire Hazard

Wherever a fire hazard from either normal equipment operation or malfunction might exist, flammable materials shall not be utilized. Overheating by defects in equipment or overload shall be protected by devices such as fuses or circuit breakers.

d. Radiation Hazard

Radiation levels emitted by the equipment in a normally accessible area shall not exceed 0.01 watts/cm^2 of microwave radiation or 100 milliroentgen/ week of x-ray radiation.

e. High Temperature Hazard

The temperature of exposed parts or equipment enclosures shall not exceed 140°F. The temperature of equipment front panels and operating controls shall not exceed 105°F. Internal components above 175°F shall be clearly labeled or have a protective guard. All temperature extremes shall be measured at an ambient temperature of 77°F.

f. Guard Labeling

A label shall be attached to all protective devices or guards to indicate the hazard encountered if this protection is removed.

2. Area Requirements

a. Non-hazardous Areas

The safety requirements for equipment utilization in a non-hazardous area shall be in accordance with the 1962 edition of the National Electrical Code (NFBU No. 70) for General Occupancy, Industrial Areas.

b. Hazardous Areas

The safety requirements for equipment utilization in hazardous areas shall be in accordance with the 1962 edition of the National Electrical Code (NFBU No. 70) for Specific Occupancies and modifications which may be specified here. The applicable standards of this Code shall be Class I, Division 1 in locations containing Groups A, B and D atmospheres.

Illumination devices shall be contained within suitable vapor tight fixtures, purged if possible, protected from mechanical injury and be supplied with appropriate connectors.

Television cameras shall be mounted in a weather-proof, air-tight enclosure and purged, if required. Motors for pan and tilt devices shall be in an explosion proof container.

A speaker shall be provided which is mounted in a weather-proof, explosion proof container.

SECTION IV

SYSTEM DESIGN

A. INTRODUCTION

The television system is composed of three radiation tolerant camera chains, one standard camera chain, monitors, distribution equipment, recorders, intercom, lights and an assortment of mechanical mounts and enclosures. The three radiation tolerant camera chains are used for observation of indicators, controls, damage, reactor, etc. Two of the three chains may be combined to form a three-dimensional viewing system. The standard camera is used for general area observation by aerial or ground vehicles where radiation levels are low. It is a completely self-contained, lightweight camera permitting either hand-held operations or mounted on a mechanical mount. The other accessories such as recorders, monitors, etc., provide a complete and thorough system yet still portable for ease of movement. Outputs are provided for routing the video signal to other viewing areas.

B. CAMERA CHAINS

1. General

Each camera chain will be defined as containing the following basic subsystems:

- Camera Head
- Preamplifier (Preamp)
- Camera Control Unit (CCU)
- Synchronization Generator (Sync Gen)
- Junction Box (JB)
- Lens (See Section C)

Certain basic subsystems mentioned above may be integrated with each other in some of the chains. Other special accessories may be utilized with the camera chains and are discussed in this section.

2. Radiation Tolerant Cameras

The Radiation Tolerant Camera chains are interconnected as depicted in Figure 2. The camera is connected to the Junction Box (JB) by a short length of 19 conductor radiation tolerant camera cable. The cable conductor size may vary depending upon the camera vendor. This cable supplies the sweep, blanking, and camera voltage from the pre-amp to the head and feeds the camera head video output to the preamplifier. The camera head accepts standard 16 mm "C" mount zoom or fixed lens.

The specially fabricated Junction Box provides centralized cable distribution for the camera head and accessories. A single 35 conductor radiation tolerant camera cable of 100 feet in length interconnects this JB with the preamp. This single cable supplies all necessary signals and voltages from the preamp to the JB for the camera and its accessories which includes lens, pan/tilt, lights, 3D interocular adjustment drive motor, and intercom system.

The preamp receives the camera video and provides the amplification necessary to drive up to 2000 feet of cable. The preamp also contains the camera sweep generation and protection circuitry for the vidicon. Two Jacks mounted on the preamp case will supply intercom signals to a headset or speaker amplifier. See Section III-K for intercom discussion. Interconnection between preamp and CCU is provided by 30 conductor environmental resistant camera cable. Power cable for the lights connects to the preamp case and is combined with the cable run to the camera head. See Section III-I for cable discussion.

The Camera Control Unit (CCU) contains all the necessary circuitry to supply voltages, and drive pulses to the camera head, and process the noncomposite video from the preamp. Two outputs of composite video are then supplied for distribution at the standard level of 1 volt p-p video and 0.4 volts sync. Connectors for the intercom signal output, pan/tilt/lens

Figure 2.
Complete Television System

controls, and 3D camera spacing controls (CCU #1 only) are located on the CCU. The CCU provides all camera adjustments such as target, beam, electrical focus, etc.

Sync Generators are provided for each camera (three generators) as an internal part of the CCU. This combines all important camera supply voltages and timing generation within one compact unit eliminating any possibility of separation. This also reduces hookup time and allows the CCU to be located close to, or with, the preamp. For the normal setup of cameras #1, #2 or #3 the CCU is located up to 2000 feet from the preamplifier. The CCU's and sync generators are wired to allow any generator to be used as the master sync source for any or all of the other cameras.

When Cameras #1 and #2 or #1 and #3 are combined for 3D viewing, camera #1 sync generator will be used for the master timing. Cables will be routed from Camera #1 to #2 or #3 for supplying the sync pulses. The unused sync generator (#2 or #3) is then turned off.

Each camera and lens assembly is mounted in a lightweight aluminum cylindrical housing. This housing facilitates decontamination and protects the camera and lens. The housing and connector are waterproof allowing the camera to be used underwater at depths to 100 feet. The junction box will not be used underwater thereby eliminating the need for extensive junction box waterproofing. The underwater camera cable will be routed directly to the camera head. This approach simplifies the camera underwater capability. Most standard camera housings will easily withstand the pressures encountered at 100 foot depths. In addition, this will insure that the camera head can satisfactorily operate in containment vessels of 30 psig which may possibly be encountered at some reactor sites. The cables could be run through temporary, emergency fitted, stuffing boxes.

The container is sectionalized such that it is capable of accommodating the various lens options by use of three interchangeable front optical housings which enclose the lens. The camera assembly is mounted in the main (rear) container which also supports the cable connectors at the rear. The two sections are mated by a threaded captive screw so that either the zoom lens or fixed lens covers can be accommodated. This requires two front covers, one for each lens, utilizing non-browning glass faceplates. The cover for the zoom lens is of suitable size to contain either the long or short lens converters, and the container window will be sized to prevent lens "portholing" effects (see Lens). The container does not attach in any way to the lens, only to the back cylinder. Accessories are supplied that may be attached to the enclosure for operation under certain environments. These accessories are: (1) Windshield Wiper, (2) Defroster, and (3) Sun Shield.

The Functional Requirements delineates that equipment such as the camera head may be subjected to operating temperatures of -50°F to $+200^{\circ}\text{F}$. The camera head will require some external cooling device to permit operation at this temperature for extended periods.

At temperatures below approximately 0°F and down to the expected low of -50°F extreme vidicon image burn-in and increased lag can be expected. This condition is generally only temporary and will usually recover when the temperature is increased above 0°F . For prolonged exposures at temperatures below 0°F , heating must be supplied. This heating is easily provided by a small, thermostatically controlled heating element. About two watts of heat is generated by the nuvistor and vidicon tubes which provide a small amount of heat rise and the heating element will maintain the desired temperature of between 77° to 95°F .

Cooling of the camera head is normally required above 130°F to prevent vidicon loss of sensitivity. Some methods of cooling are:

1) Liquid coolant using the heat exchanger principle. This method requires a compressor which can either be combined with the evaporator or be separated. The self-contained method would increase the camera weight beyond the point of easy handling. If the compressor is separated, refrigerant interconnecting lines will be required and this would decrease the camera's portability and ease of handling.

2) Thermoelectric cooling modules using high currents and low voltages. Although these units are basically very small and lightweight, they require careful attention as to their mechanical configuration to permit adequate heat sinking. It is necessary to dissipate the heat generated by the module in order to attain the desired low temperature. These modules have been recently used as housings to cool television cameras in ambient temperatures of $+190^{\circ}\text{F}$ down to $+60^{\circ}\text{F}$ (inside cameras). The weight of the thermoelectric devices was only about five pounds including an aluminum enclosure. About 40 amperes of direct current at 5 volts was utilized and supplied by an external power supply, but higher voltage, lower current (18 volts at 10 amps) modules are available. The modules are composed mainly of Bismuth Telluride. Sufficient information to establish radiation tolerance is not available, however, from a cursory analysis of its elements and the nature of its use, it appears that the modules should satisfactorily operate in the specified radiation levels.

3) A gas-cooling, recycling, absorption type cooling system. This method utilizes either a low voltage or liquefied petroleum source to provide the heat necessary for recycling. Although this method can be easily adapted for camera head cooling, it has to be operated in a level position and within 5 to 10% of level which will severely restrict camera movement in the tilt direction.

4) Other methods of cooling such as liquid or solid coolant using a stored supply are possible, however, if operated for long periods of time in radiation areas, access to replenish the coolant would be inconvenient and hazardous. Any method requiring the pipe-fed supply would

make the system very cumbersome and difficult to set-up and move, particularly on a remotely controlled camera vehicle.

5) Use no cooling. This approach would be useful in temperature environments such that the vidicon faceplate temperature does not exceed 160°F. Continued use of the vidicon above this temperature would eventually result in permanent vidicon damage. The exact length of time before damage is unknown and depends upon the temperature, however, if rapid camera setup is necessary for a quick look, the tube could be operated until damaged and then removed. An estimate of tube operation at 200°F before damage and uselessness would be at least 30 minutes and quite possibly up to a couple of hours. Between 130° and 160°F extended operation is possible with no permanent damage; only temporary loss of picture sensitivity requiring increased illumination and occasional adjustment of target voltage.

It is expected that the camera head will not normally be subjected to temperatures above +150°F, however, in cases where such operation is needed an accessory cooling device is made available. This device will be lightweight, portable and able to accept any of the radiation tolerant cameras. A total of two will be available for use with two cameras.

The above cooling methods all require some trade-off between economics and performance but from a standpoint of effective system operation under the conditions imposed the thermoelectric cooling method (#2) appears to offer the best solution. The cooling enclosures capable of accepting the cameras will maintain the camera head at +86°F ±10% in ambient temperatures to 200°F for approximately \$2000 each. A remotely located power supply is used to supply the current (D. C.) of approximately 10 amperes at 18 volts and interconnected by two conductor radiation tolerant cable. The possible separation distance between the enclosure and power supply is dependent upon providing a sufficient sized

conductor to insure adequate voltage without excessive drop. Using #10 wire, a separation of 200 feet is possible and this assumes an approximate voltage drop of 20%. Therefore, for an output voltage of 18 volts the voltage from the power supply is 22 volts. The power supply will be powered by 220 or 110 volts AC, selectable at the supply. If central power distribution from the control area is necessary the supply will be through 1900 feet of environmental protected, #12 AWG cable, supplied in 3 pieces (see cable section).

3. Standard Cameras

The Standard Camera chain is interconnected as depicted in Figure 2. The camera head, preamp, control unit and sync generator are all contained within one compact enclosure. The camera head provides a standard 16 mm "C" mount for acceptance of zoom or fixed lens. Zoom electrical connections are routed directly into the camera head. One composite video output of up to 3 volts p-p is available for distribution to either microwave transmitter, or monitor. Another output is available for remote control of lens, target, beam, focus, pan/tilt, and other important camera set-up functions at a location up to 2000 feet from the camera by use of environmental resistant 23 conductor camera cable. The pan/tilt and lens control lines are routed through the Camera Unit.

4. Three-Dimensional Configuration

When the 3D configuration is utilized, radiation tolerant camera heads #1 and #2 or #1 and #3 are combined on the 3D mounting accessory (Figure 3). Except for the sync generator, no common electrical connection exists between the two camera chains, only the appropriate mechanical mounts and viewing mirror. See Appendix D for further discussion of 3D equipment (for Range Finder discussion see Section IV, H4).

Figure 3. Three Dimensional Viewing System

5. Interface

To allow complete flexibility and future additions, all video levels from the camera control units or distribution amplifier except for camera #4 are standard 1.4 volt composite. Camera #4 CCU video output is 3.0 volts p-p for driving the long transmission line, when the line is utilized. Coaxial cables are 75 ohms and terminate in BNC type connectors.

C. LENSES

1. Radiation Tolerant Cameras

Three radiation tolerant automatic zoom lens assemblies are provided for use on cameras #1-3. With short focal length converter (normal configuration), the lens provide a zoom range of 30 mm to 150 mm (1.2 to 6 inches) at a minimum aperture of f/2.7 to f/3.5. The addition of a long focal length lens converter provides a zoom range of 60 mm to 300 mm (2.4 to 12 inches) at a minimum aperture of f/5.4 to f/8. Figure 4 is a chart depicting the correct lens to employ for the particular field of view and object distance. The three lens are identical in all respects which allows random interchangeability between lens assemblies. The focusing range for the above configurations is 6 feet to infinity. Three 2/3 diopter (1.5 meters focal length) close up supplementary lenses, one for each camera, are provided for focusing range of 3 to 6 feet. The zoom lens attach to the camera through a standard "C" mounting arrangement and orienting ring. They mount directly to the camera when the short lens converter is used and thru an adapter which separates the camera and lens by 4.55 inches when the long lens converter is used. Operation of zoom, iris opening, and focus is accomplished at the control area at separation distance of up to 2100 feet. The lens assembly control cable is connected internally to the camera head through a 4 conductor shielded cable and connector. The control cable is then combined with the camera cable

for the feed to the control area. The remote zoom lens control module is combined on the same panel as the pan/tilt controls for each camera (Figure 2). Individual switches are provided for controlling zoom, iris, and focus along with a rate control for speed control of these functions. The speed control is desirable for fine focusing of lens, for detail reproduction and for slow pan of an area to allow viewing without smear. A cable between the camera control unit and control module routes the control voltages to the zoom lens through the camera cable. A second lens control located with the pan and tilt controls is provided for use at the preamplifier enclosure. A master override control is located on the main pan, tilt and lens control panel.

Three radiation tolerant, wide angle, fixed lens are available for use with cameras #1 through #4. These are f/2.5, 13 mm (1/2") focal length lenses that mount on the camera by standard "C" mount threads. They are manually adjusted and provide a wide viewing area. Figure 4 is a chart of distance versus viewing field for these lenses.

2. Standard Camera

Standard camera #4 is provided with a manually operated zoom lens for hand-held portable operation and an electrically operated (automatic) zoom lens for unattended remote operation.

The automatic zoom lens provide a 15 mm to 150 mm (0.6" to 6") focal length range and with lens converter it provides a focal length range of 30 mm to 300 mm (1.2" to 12"). The lenses mount on the camera by standard "C" mount threads. Control cables are routed into the camera head and a connector provides rapid connect/disconnect. Control of the automatic zoom lens consists of zoom, iris, and focus; and is controllable at the remote pan/tilt/lens control panel which may be located at a distance of up to 2000' from the camera.

The manual zoom lens with eye-piece viewfinder is necessary whenever the camera is hand-held. This eliminates the need for a video monitor which would be required for picture framing. Additionally, it allows extremely flexible camera operation as the operator can concentrate on the viewing scene rather than having to continually look at the monitor. The lens focal length is adjustable from 25 mm to 100 mm and is equipped with a see-through-lens viewfinder. It mounts on the camera using standard "C" mount threads.

D. ILLUMINATION

1. General

Suitable lighting is provided to illuminate an area, for each camera, of 43 to 60 feet wide and 20 feet high at a distance of 50 feet. They supply approximately 40 to 50 foot-candles of incident lighting to the scene at 50 feet. Most camera specifications indicate a light level of 1 foot-candle for minimum lighting; however, this assumes a lens speed of $f/1.5$. In the practical application of the camera system utilizing non-browning zoom lens at long focal lengths a more realistic figure of $f/8$ is utilized as reference. Therefore, the minimum lighting necessary becomes approximately 30 foot-candles incident.

Two spare lamps for each camera are furnished.

Due to the long transmission lines capability, it is necessary to utilize 230 volt lamps to reduce the current requirements and keep the cable size reasonable. (See Power, Section III-J.)

2. Radiation Tolerant Cameras

Two 230 volt quartz-type lamps are provided for each radiation tolerant camera chain (#1-3). These lamps draw 800 watts each (230 volts) and have a life span of up to 250 hours. Each camera (#1, 2 and #3) has one spot and one flood type reflector. This arrangement was selected over the utilization of one lamp with remote focusing capabilities because of the need for:

- 1) Weight reduction
- 2) Redundancy using two lamps.
- 3) No complicated control arrangements in the radiation environment

The lights are very lightweight (1-1/2 lbs each), rugged, and inherently radiation tolerant (See Appendix K). Longer life lamps are available, however, their light output is much lower which results in more lights and greater weight. The lights mount to the camera bracket by means of an easily attached strap. Power is supplied from the Junction Box through radiation resistant cable and connectors.

3. Standard Camera

Two 110 volts, 1000 watt, spot and flood lamps are available for mounting with Standard Camera #4. These lamps have no necessity for long power transmission lines since it is assumed that power is available at a closer distance and no, or very low, radiation levels are present. This eliminates the need for a step-up transformer. The lights are supplied with 100 feet of cable, and the control switches are located on each individual lamp.

4. Light Stands

Two portable light stands are furnished to accept any combinations of 110 volt lamps. These could be utilized if camera mounting is not desired or if an additional bank of lamps is necessary. Two 110 volt, 1000 watt, light banks are available for mounting on these stands and power is supplied by 100 feet of cable.

5. Underwater

Underwater illumination to depths of 100 feet is supplied by one 240 volt, 1000 watt, 65,000 candlepower quartz lamp. This provides sufficient lighting for object distances of at least 30 feet for average water conditions. The unit weighs 11 pounds in air and virtually none in the water. Power is supplied by 100 feet of waterproof cable capable of

interconnecting with the normal light source power cable which is removed from the preamplifier. The light cable will parallel both input power sources.

E. DISTRIBUTION

1. General

Video distribution is provided by RG-59U coax which is routed from the camera control units (CCU) or distribution amplifiers (DA) to the various monitors, distribution amplifiers, and switcher (Figure 2).

Video output #1 from camera control units #1, #2 and #3 are routed to the main 14 inch monitors (#1-3), looped through (bridged) these monitors and then routed to the video switcher where the inputs are terminated by 75 ohm resistors. Video output #2 from camera control units #1-3 are routed to DA's #1-3 for eventual re-distribution to portable monitors at remote camera locations, TV projector, etc.

2. Video Switcher

The video switcher provides four, amplifier isolated, outputs from the six inputs. The inputs include CCU #1-3, DA #4, video tape recorder (VTR), and one spare. Four rows of illuminated pushbuttons are located on the switcher with each row controlling one output. This allows the six inputs to be selectable by pushbuttons for each output. The four outputs are routed to the 17 inch utility monitor, DA #5, VTR, and waveform monitor.

3. Distribution Amplifiers

Five distribution amplifiers are provided to allow for remote camera video termination, remote monitor feed isolation, and multiple video outputs. Distribution amplifiers #1-3 serve a dual purpose. They are used for isolation and line drive to the portable monitors which may be located up to 2000 feet from the DA and serve as line termination

amplifiers when camera control units #1-3 are remotely located (Figure 2 illustrates an alternate camera arrangement). DA #4 receives and distribute the video from standard camera #4 by way of the microwave receiver or cable. The output from DA #4 is routed to the main 14 inch monitor and terminated at the video switcher. DA #5 receives and terminates an output from the switcher. It is capable of providing three video outputs for remote viewing areas by way of microwave or cable at levels of up to 3 volts p-p.

Video levels within the system are all 1.4 volts p-p except for long transmission distances which are 3.0 volts p-p.

All video coax connectors are of the BNC type.

F. MONITORS

1. Video Monitors

Four main 14 inch transistorized monitors (#1-4) provide for individual viewing of each camera chain. The video from the camera control units is looped through (bridged) the high impedance inputs of the monitors.

Monitor #1 and either #2 or #3 may be combined for a three dimensional presentation. The 3D mounting adapter is arranged such that monitors #2 or #3 are removed from their normal mounting position and placed at right angles to #1. A switch on monitors #2 and #3 for reversing the leads to the horizontal winding of the deflection yoke for image reversing is necessary for proper image construction after mirror reflectance. The polarized glass faceplates on monitors #2 and #3 are arranged with their axis of polarization positioned at 90° to the polarized faceplate of Monitor #1. A special viewing hood containing a half-silvered mirror at 45° to the monitors is attached to the face of the viewing monitors (Figure 3). Special polarized viewing glasses are provided with each lens polar plane rotated 90° to each other to allow each eye to receive a separate image from the monitors. This adapter will be fabricated to properly interface the 14 inch monitors.

The 17 inch utility monitor (#5) provides a video viewing source for the still or movie camera and also provides individual monitoring capabilities for cameras #2 or #3 when their monitors are mounted in the 3D configuration. The monitor provides a 75 ohm terminated video input impedance and receives this video from the video switcher. This allows the selection of any camera source to be displayed on the utility monitor. A special viewing hood accessory is provided for attachment to the monitor face to permit the movie and still camera to be accurately positioned.

The portable transistorized monitors (#6, #7 and #8) provide for viewing at remote viewing areas. These areas include the field at camera locations and at remote personnel viewing locations. Monitor #6 has a 14 inch screen and #7 and #8 have a 9 inch viewing screen.

Monitors #1 through #5 are rack mounted and #6 through #8 are mounted in portable cases.

Any monitor has the ability to either provide high impedance looping or terminated input video capabilities.

2. Waveform Monitor

One waveform monitor is used for video waveform set-up, analysis, and maintenance. The video input feed is from the switcher, which allows waveform analysis of any camera chain or video tape recorder. This monitor normally terminates the input video with 75 ohms. A high impedance input is also available.

3. Large Screen Projector

One large screen TV projector provides projection of television images of up to 8 feet wide at a throw distance of approximately 16 feet. Input video is provided by many sources such as the microwave links or distribution amplifiers.

G. RECORDERS

1. Video Tape Recorder

The video tape recorder (VTR) receives a video feed from the video switcher and an audio feed from the intercom control panel. Outputs are provided for routing playback video to the switcher for distribution to the monitors or DA #5 and audio to the intercom panel for distribution to the speaker. Video inputs are 1.4 volts p-p composite, 75 ohms, terminated. Audio inputs are 600 ohms at 1 milliwatt, terminated, and low impedance microphone input.

One low impedance microphone is furnished for use with the VTR or audio tape recorder for annotating or tape editing.

The VTR provides Video/Audio recording with instant playback availability. By use of the appropriate size reels, up to 5 hours recording is possible. The following chart depicts tape reel size versus approximate recording time.

<u>Reel Size</u>	<u>Recording Time</u>
6-1/2 "	40 minutes
8 "	1 hr, 28 min.
10-1/2 "	3 hrs, 15 min.
12-1/2 "	5 hrs

2. Video Motion Picture Film Recorder

The continuous recording of video information on film is accomplished by the placement of a high quality, motor drive, 16 mm motion picture camera in front of the 17 inch utility monitor and viewing hood accessory. The camera is modified to enable it to record the video monitor picture without shutter bar or flicker and at the standard 16 mm rate of 24 frames per second. This allows the films to be projected on any standard 16 mm projector. The film magazine contains 600 feet of film which provides up to 16-1/2 minutes of continuous recording. A magazine containing 1200 feet of film is also available, and this provides up to 33 minutes of continuous recording.

3. Still Camera

The recording of video information by a still film camera is accomplished by the placement of a 4 x 5 press type camera in front of the 17 inch utility monitor and viewing hood accessory. The camera shutter speed used for this purpose is limited to speeds of 1/10 second or slower. The lens aperture is determined by the film speed.

4. Audio Tape Recorder

The portable half track tape recorder provides for recording/playback of one channel of audio and receives its input from the intercom control panel switcher. The input-output impedance is 600 ohms, balanced, at a level of about 1 milliwatt. Its response, about 100 to 5000 cps, will be adequate for speech frequencies.

A low impedance microphone input is provided for tape editing or annotating. The microphone provided with the video tape recorder is also used for this recorder.

Standard 1/4-inch tape at speeds of 3-3/4 or 7-1/2 per second will provide a record/playback time of up to three hours using both tracks of 1 mil tape on 7 inch reels.

H. MECHANICAL MOUNTS AND ENCLOSURES

1. Introduction

The cameras and accessories such as lights, speaker, etc., all require suitable mounting and mechanical control capabilities as outlined in the Functional Requirements.

2. Pan and Tilt Units

Table H-1 lists the individual weights of the maximum amount of equipment that could be used and their effect on the mechanical mounts for radiation tolerant cameras #1-3. The table indicates the total weight of camera equipment (#1-3), (lens/light, mount/cable) is approximately 30 pounds for the normal television configuration. This requires that the

TABLE H-1

Camera Mounting Equipment Weights for Camera #1-3

<u>Qty.</u>	<u>Description</u>	<u>Wt. Lbs.</u>	<u>Tot. Lbs.</u>	<u>3D Use Wt-Lbs.</u>	<u>Tot-3D Wt-Lbs.</u>
1	Camera Head	3.5		(2) 7.0	
1	Zoom Lens	5.0		(2) 10.0	
1	Camera/lens enc.	8.5 (incl. acc.)		(2) 17.0	
2	Quartz Lamps	3.0		(2) 3.0	
1	Light/Camera Mount	3.0		(1) 15.0	
	Intercom Spkr/cable	<u>2.0</u>		<u>(1) 2.0</u>	
TOTAL CAM. EQ.			<u>25.0</u>		<u>54.0</u>
3'	Camera Cable (JB to head)	3.0		(6') 5.0	
1	Connector (head)	0.5		(2) 1.0	
10'	(2) lights cable (JB to lights)	<u>1.5</u>		<u>(10') 2.0</u>	
Total Cable			<u>5.0</u>		<u>8.0</u>
TOTAL CAM. & CABLE EQ.			<u>30.0</u>		<u>62.0</u>
1	Pin/tilt unit	25.0		25.0	
1	Junction Box	5.0		(2) 10.0	
6'	Camera Cable & Connector	7.0		(12') 14.0	
1	Tripod/Dolly	<u>30.0</u>		<u>30.0</u>	
Total pan/tilt/JB/cable			<u>67.0</u>		<u>79.0</u>
TOTAL CAM., CABLE, PAN/TILT			<u>97.0</u>		<u>141.0</u>

mounting device for the above be capable of supporting the weight. In the case of the 3D equipment, this weight increased to 62 pounds (total camera and cable). Therefore, three remote controlled medium duty pan and tilt units capable of supporting and operating the 30 pound weight of the usual camera configuration is provided. These units provide a pan of 0° to 350° (horizontal plane) at speeds from 0 to 5 degrees/second and tilt of $\pm 90^{\circ}$ (vertical plane) at speeds from 0 to 2 degrees/second. One medium duty remote controllable pan and tilt unit capable of supporting and operating the 62 pound weight of the 3D camera configuration is furnished. This pan/tilt unit will be capable of supporting the increased weight of the 3D configuration, however, it will tilt in the vertical plane $\pm 45^{\circ}$ rather than $\pm 90^{\circ}$. The tilt requirement is eased for the 3D configuration to allow a medium duty pan/tilt unit to be used with slight modification; thereby, maintaining the 25-pound pan/tilt unit weight. Otherwise, this would require special design and fabrication or the alternate of using a heavy duty pan/tilt unit which weighs 70 pounds in itself.

Table H-2 depicts the individual weights of the maximum amount of equipment that could be used and their effect on the mechanical mounts for Standard Camera #4. A medium duty pan/tilt unit is adequate to support and operate the 26 pound weight of the camera configuration. The overall weight of 89 pounds includes the entire camera, pan/tilt and tripod.

All of the above weights include the equipment necessary to operate in most environments excluding extremes of temperature and explosive atmospheres. For these environments special enclosures are necessary (see Section III-N). The use of the explosive resistant container for Cameras #1-3 adds approximately 32 pounds to the weight of the camera assembly, and the two explosion proof lamp containers (for two lights) adds approximately 20 pounds to the assembly. This requires the

TABLE H-2

Camera Mounting Equipment Weights for Camera #4

<u>Qty.</u>	<u>Description</u>	<u>Wt-Lbs.</u>	<u>Total Lbs.</u>
1	Camera Head	4.5	
1	Camera control unit	5.0	
1	Zoom lens	4.0	
2	Quartz lamps	3.0	
1	Light/camera mount	<u>6.0</u>	
	Total Cam. Eq.		<u>22.5</u>
10'	(2) lights	1.0	
5'	Camera Cable	2.0	
1	Connector	<u>0.5</u>	
	Total Cable		<u>3.5</u>
	TOTAL CAM. & CABLE EQ.		<u>26.0</u>
1	Pan/tilt unit	25.0	
1	Junction Box	5.0	
6'	Camera Cable & Conn	3.0	
1	Tripod	<u>30.0</u>	
	Total pan/tilt/JB/cable		<u>63.0</u>
	TOTAL CAM/CABLE, PAN/TILT, TRIPOD		<u>89.0</u>

use of one heavy duty, explosion proof, pan and tilt unit which weighs 70 pounds. Therefore, the total camera, cable lights, and pan/tilt assembly for cameras #1-3 now weighs 164 pounds (Table H-3).

TABLE H-3 <u>Weight for Environmental Enclosure on Cameras #1-3</u>	
Total Cam. & Cable Eq. (Table 8-1)	30.0 lbs
Environmental Enclosures (camera, 2-lights)	52.0
Heavy Duty Pan/tilt	70.0
Junction Box	5.0
6' Camera Cable & Connector	<u>7.0</u>
Total wt. Cam. enc. pan/tilt	164.0 lbs
Tripod/Dolly	<u>30.0</u>
GRAND TOTAL	<u><u>194.0 lbs</u></u>

All of the pan and tilt units are equipped with fully enclosed, dual motorized gear trains. Both pan and tilt functions incorporate dynamic braking to eliminate overshoot. The gear trains are arranged so that loss of control voltages will cause the pan and tilt table to remain locked in its last position. The pan/tilt control module is mounted on a panel at the Control Area, and consists of a joystick control which will control pan/tilt and speed functions dependent upon the movement of the joystick handle. Even though a joystick handle does have the disadvantage of being accidentally actuated by arm or coat sleeve, it is the most efficient method of controlling pan and tilt accurately and quickly. It is also available as an "off the shelf" item. Another control unit is available at the preamplifier location for use when the camera is boom or crane mounted and pan/tilt control is desired at the camera location. A master control override is provided. For Camera #4 the wiring is routed through the camera to the control module through up to 2000 feet of camera cable.

3. Camera/Lights Special Brackets

The mounting of lights, lens and camera to the pan and tilt unit is accomplished by either of two options: (1) The camera and lens are mounted directly to the pan and tilt unit by screw/nut fastener or; (2) the camera lens and lights are mounted to a special bracket. This bracket is then fastened to the pan and tilt unit by a quick engage-disengage feature for employment in hazardous areas where timely application is important (Figure 5).

Four of these brackets are provided for use with any of the four cameras.

4. Three-Dimensional Camera Adapter

The three-dimensional (3D) viewing adapter is composed of two camera/lens cradles mounted side by side and having a remotely controlled common worm drive for lateral adjustment. The lateral adjustment allows the ocular distance between cameras to be varied from 5 inches to 32 inches. This permits depth perception from approximately 2 feet to 50 feet or more, depending upon the ocular angle between the two cameras and lens focal length. The ocular angle is manually adjustable such that the angle may be set from 0° to 30° (Figures 3 and 5).

A range finding device could be incorporated into the 3D viewing system to provide a readout of interocular camera spacing, calibrated to read camera to object distance. A helipot could be coupled by gears to the camera spacing drive motor and by placing a voltage (D. C.) across it an analog voltage output would occur relating to camera spacing. This could be amplified and allowed to drive a meter or digital readout device. To get the range of an object from the cameras an operator at the 3D viewing monitors would, not using the polarized viewing glasses, adjust the camera spacing until both images were exactly coincident at the center of the viewing (half-silvered) mirror. The mirror would be inscribed

Figure 5. Mechanical Mounts

with a + at its geometric center to aid in image alignment, and both cameras carefully pre-aligned to eliminate geometric distortion and non-linearity. Prior to use as a range finder, each camera's zoom lens would be adjusted to provide a picture of identical size. Using the optimum camera ocular angle of 2° (Appendix C) the cameras would then give range finding information from 3 to 38 feet. A range of 6 to 76 feet could be provided by adjusting the ocular angle of one camera to 0° . Greater distances (up to infinity) could be read if one camera was placed at 0° and the other at some angle less than 2° and greater than 0° . Of course, the close-in range would also increase. Usually the cameras would be used for 3D viewing and most likely in a radiation environment, therefore, camera angle changes would be difficult unless a changing scheme is used. Remote camera angle adjustments would further complicate the 3D mount and increase its weight.

The amplifier could then be mounted with the readout device at the control area and interconnected to the helipot by three wires. Additional conductors would have to be provided in the camera cable increasing its weight and size.

Since the 3D viewing system would in itself give a measure of camera to object spacing using known shapes as reference, the availability of facility drawings indicating room size and equipment spacing, and the increase of system complexity, the range finding feature is not presented as a part of the overall television system. However, it could be eventually provided as an accessory and, to eliminate extra cable, it could be routed over unused cable conductors such as the pan/tilt wires (only one pan/tilt used for the two 3D cameras).

5. Tripods and Dollies

Four tripods and dollies are available for the mounting of the pan and tilt units. These tripods provide a stable platform for use with any combination of camera accessories. They are capable of supporting 165

pounds. The vertical height is adjustable from 35 to 72 inches. It weighs a total of 30 pounds with no load. Accessory lockable casters (dolly) are supplied for mounting, if needed.

6. Universal Mounting Brackets

Four Universal Mounting Brackets are provided to allow the pan and tilt units to be attached to various assorted locations such as girders, pipes, cranes, booms, tables, etc. This bracket has four individually hinged legs which are attached to the mounting plate on one end and mounting feet on the other end. Various mounting feet are available to provide maximum gripping power for the particular structure on which mounting is desired. Clamping action is gained by using a single right and left hand screw through adjacent legs (Figure 5). The brackets can be placed by a remotely controlled manipulator system. One manipulator can support the assembly while the another tightens the adjusting screw using a spanner wrench. Of course, the manipulator must be capable of supporting the weight of the bracket and camera assembly.

I. TRANSMISSION/INTERCONNECTION

1. Cable

The transmission and interconnection of all subsystems by cable, excluding primary AC wiring, is depicted in Figure 2. Due to the need for system flexibility such that the control equipment may be located at various distances up to 2000 feet from the camera preamp dictates the use of interchangeable cable assemblies in various lengths mounted on portable cable reels. Table I-1 indicates detailed information of cables used with the various subsystems. The number of conductors are indicated primarily as a guide to cable size and weight since various camera manufacturers may use different conductor configurations. All cables are shielded. Control Area AC power/light distribution cables are discussed

Used With	Function	*No of Conductors	Cable Diam (inches)	Each System Cable Length (ft.)	Cable Weight (lb. per. ft.)	Actual Cable Length (ft.)	Rad. Tol. Cable and Connectors	Total Cable Length(ft)	Total No. of Connector	Total No. of Reels	Single Empty Reel Weight (lbs.)	Total Empty Reel Weight (lbs.)	Total Cable and Connector Weight (lbs.)
Cameras #1, 2, 3	Junction box to preamp	35	1. 1	per cam. 100	0. 7	per cam. 100	yes	300	6	none	---	---	216
Cameras #1, 2, 3	Preamp to CCU	30	1. 0	per cam. 2, 000	0. 5	per cam. Four-500	no	6, 000	24	12	100	1, 200	3, 024
Cameras #1, 2, 3 Lights	Preamp to light control	4	0. 715	per cam. 2, 000	0. 4	per cam. Four-500	no	6, 000	24	12	70	840	2, 424
Remote controlled Camera vehicle	Vehicle to radiation/ stand- ard cable connector	10	0. 7	100	0. 4	100	yes	100	2	none	---	---	42
Remote controlled camera vehicle	Radiation/ standard cable connector to control unit	10	0. 7	2, 000	0. 4	Four-500	no	2, 000	8	4	75	300	808
Camera #4	CCU to microwave transmitter	RG-59 coax	0. 242	500	0. 036	500	no	500	2	1	5	5	18
Camera #4	JB#4 to remote pan/ tilt/ lens camera controls	23	0. 725	2, 000	0. 4	Four-500	no	2, 000	8	4	70	280	800
DA #1, 2, 3 or 5	DA's to remote viewing areas	RG-11 coax	0. 405	Total 6, 000	0. 089	Five-1, 000 Two-500	no	6, 000	14	7	5	35	540
Cameras #1, 2 or 3 Temp. Measurement	Camera to control area (100' rad. tol., 2, 000' stan.)	4	0. 02	2, 100	0. 08	2, 000 100	100'-"yes" 2000'-"no"	2, 100	4	1(for 2000'cab)	10	10	170
Cameras #1, 2 or 3 Rad. Measurement	Camera to control area (100'rad. tol., 2, 000' stan.)	8	0. 02	2, 100	0. 036	2, 000 100	100'-"yes" 2000'-"no"	2, 100	4	1 (for 2000' cab)	5	5	78
Cameras #1-3	Waterproof cable cameras #1-3 to remote controls	21	0. 7	100	0. 4	250	yes - water- proof also	100	2	none	---	---	50
Underwater Light	Light to power cable removed from preamp	2	0. 4	100	0. 1	100	yes - water- proof also	100	2	none	---	---	15
Cameras #1-3 Cooling housing	Power supply to cooling housing	2	0. 4	200	0. 1	200	yes	400	4	none	---	---	50
Cameras #1-3 Cooling housing	Power supply to control area	2	0. 3	1900	0. 1	Two-600 One-700	no	3800	12	6	10	60	440
Subtotals												2, 735	8, 675
Grand Total												11, 410 lbs.	

Table I-1
Table of Long Transmission Cables

*NOTE: All cables are shielded but shield not included in number of conductors column.

in Section IV-J. Table I-1 also depicts the long transmission lines and their characteristics. The camera to preamp cable of Radiation Tolerant Cameras #1, #2 and #3 contains sufficient conductors to transmit all functions necessary for the operation of the camera and its accessories. This eliminates many separate cables which would otherwise be needed with resulting complexity and handling difficulty.

Two long transmission cables between preamp and Camera Control Units (2000 feet) provide all functions necessary for camera and accessory operation (Figure 2). One cable contains 30 conductors pulse shields for camera, lens, pan/tilt, 3D control. The other cable contains 4 conductors plus shield for the transmission of quartz lamp voltage from the CCU to the preamp. This cable is kept separate due to the large size of conductors necessary to provide the required current with reasonable voltage drop over the 2000 feet of cable (see AC Power Distribution).

Remote temperature and radiation measurement cables each consist of 100 feet of radiation tolerant and 2000 feet of standard cable (see Special Devices).

The video interconnection of all units within the control area is accomplished by use of RG-59U coaxial cable. The cable is terminated in its characteristic impedance (75 ohms) when not looped thru the equipment.

The underwater capability of cameras #1-3 is provided by a total of 200 feet of radiation tolerant and waterproof cable for the camera and light (100 feet for each).

The camera cooling accessories (two) each have a total of 2100 feet of cable with 200 feet of radiation tolerant cable between power supply and cooling housing, and 1900 feet of standard cable between power supply and control area.

Cable reels are utilized for storage and transportation of the long transmission cables. All other cables are not mounted on reels since a savings in size and weight will be realized. All reels are constructed of solid aluminum or steel tube construction for portability. Cable payout and retraction is accomplished by the use of hand operated cranks with the reels mounted on portable base stands. The inside connector is accessible so that cable operation is possible without completely removing cable from the reel.

The weights of transmission cable and reels (Table I-1) will vary somewhat depending upon cables; however, the total weight of these is, as listed, approximately 11,410 pounds. This includes the 6000 feet of quartz lamp cables, cooling accessory cables, remote controlled camera vehicle and, of course, the necessary camera cables. This weight does not include the reel mounting stands which will, in any case, contribute very little to the total cable/reel poundage.

Table I-2 depicts the interconnection cable details. No reels are necessary since the proper coiling of cables will be satisfactory. The total weight here is approximately 101 pounds and this includes all possible interconnections as may be necessary for the system to include video coax feeds to the small remote monitors that could be located at a camera positioning device such as boom, crane, etc.

Sufficient cable and terminating resistors are available to allow many other configuration combinations that might be necessary in the course of operation. The changes are easily accomplished because of the use of standard BNC connectors and 75 ohm coaxial cable.

The radiation tolerant cables are constructed of materials to withstand the levels specified in Section III, B2 without failing and without becoming brittle or hard. The jacket is composed of a Hypalon compound which is radiation tolerant, environmental resistant and smooth, permitting them to be easily decontaminated.

Used With	Function	*No. of Conductors	Cable Diam. (inches)	Length (feet)	Cable Wt. (lb. per. ft.)	Radiation Tolerant	Total Cable Length (ft.)	Total No. of Connectors	Total Cable & Con. Wt. (lbs.)
Camera #1, 2, 3	JB #1, 2, 3 to pan/ tilt units	6	0.35	per cam. 2	0.09	yes	6	6	3.5
Camera #1, 2, 3	JB #1, 2, 3 to camera head	21	0.70	per cam. 4	0.3	yes	12	6	10.0
Camera #1, 2, 3	JB #1, 2, 3 to lights	4	0.33	per cam. 5	0.07	yes	15	6	1.5
Camera #1, 2, 3	JB #1, 2, 3 to speaker	2	0.2	per cam. 5	0.03	yes	15	6	0.5
Camera #1	JB #1 to 3D mounting adapter	2	0.2	4	0.03	yes	4	2	0.5
Camera #1, 2, 3	CCU #1, 2, 3 to main monitor, switcher (video #1)	RG-59U coax	0.242	per cam. 20	0.036	no	60	12	2.5
Camera #1, 2, 3	CCU #1, 2, 3 to DA #1, 2, 3 (video #2)	RG-59U coax	0.242	per cam. 20	0.036	no	60	6	2.5
Video Switcher	Video switcher to/ from various equip	RG-59U coax	0.242	total 100	0.036	no	100	10	4.0
Asst. Video Equip.	At remote viewing areas, etc.	RG-59U coax	0.242	total 200	0.036	no	200	10	8.0
Intercom/ audio	Intercom control panel to CCU,#1,2,3	3	0.200	per cam. 50	0.04	no	150	6	11.0
Intercom/ audio	Intercom control panel to/ from tape recorders, speaker amp.	2	0.170	250	0.02	no	250	6	5.0
Intercom/ audio	Speaker amp. to speaker	2	0.170	100	0.02	no	100	2	2.0
Camera #1, 2, 3	CCU #1, 2, 3 to pan/ tilt control	6	0.35	10	0.09	no	30	6	3.5
Camera #1, 2, 3	CCU #1, 2, 3 to lens control	4	0.33	10	0.07	no	30	6	3.0
Camera #4	JB #4 to P/ T #4	6	0.35	10	0.09	no	10	2	1.0
Camera #4	JB #4 to CCU #4	22	0.725	10	0.4	no	10	2	42.0
Total									100.5 lbs.

Table I-2
Table of Interconnecting
Cables

*NOTE: All of the cables are shielded and not included in number of conductors column.
No reels are utilized.

All cable connectors are standard, "off the shelf" type. Radiation tolerant connectors are supplied where needed, as listed in Table I-2. The connectors at the camera are of the quick disconnect type for rapid installation or removal and will be protected from environmental elements by rubber protective covers when in use, and metal waterproof caps when in storage and prior to use.

2. Microwave

The transmission of video over a distance of 10 miles line-of-sight is possible through the use of two complete one-way portable microwave relay links (Figure 6).

The input voltage requirements are 110 volts AC for normal use and 24-28 volts DC for aircraft or other portable use.

The microwave transmitter and receiver operates with an input or output video signal of 1.4 volts p-p composite, 75 ohm, using BNC connectors.

The antennas (4) are two feet in diameter and are connected to the transmitter or receiver by a ten-foot section of RG-9U coaxial cable with N-type connectors at each end. One omnidirectional antenna is provided for helicopter mounting when this camera platform is utilized.

J. AC POWER DISTRIBUTION

The following power distribution system provides all the necessary load distribution and protection for the television system. Since the quartz lamps on the radiation tolerant cameras require 230 volts, step-up transformers are provided to allow the entire system to be powered from a 110 volt AC source.

This distribution system permits a certain amount of flexibility in movement of connected equipment which is particularly useful when the packing case option is used. The system may also be utilized for the trailer option which in this case would be mounted in the equipment racks. The alternate camera #1-3 setup and camera #4 extension cords would not be trailer mounted but stored and used as needed.

Figure 6. Microwave Transmission System

If a situation should arise where the equipment might be setup using the convenience AC outlets of a facility, it would only be necessary to use the extension cords as distribution panels for the low power input equipment keeping in mind the convenience outlet's current limitations. The quartz lamps distribution cable is supplied with a convenience outlet mating connector accessory. Of course, each lamp circuit draws about 1600 watts and the total load of the three circuits (about 4800 watts) must be distributed to eliminate possible AC outlet circuit overload.

1. Total Load

The design for this subsystem assumes that the total load of all subsystems, with exception of trailer mounted air conditioning, lights, etc., is approximately 10 KW. See Figure 7 for the AC Power Distribution details.

2. Power Distribution Panel

The Power Distribution Panel has a capability of 14 circuits.

Twelve of these are used for distribution and four are spares.

On the side of the panel there are 12 receptacle housings, with spring doors, to which each output cable is connected by a male locking plug. The panel contains:

- 1) A main input circuit breaker of 100 amps.
- 2) Three quartz lamp (camera lighting) circuit breakers of 20 amps each.
- 3) A camera vehicle circuit breaker of 20 amps.
- 4) Camera control units and video tape recorder circuit breakers of 10 amps.
- 5) Four circuit breakers of 15 amps each for monitors; video switchers; microwave trans/rec; and all test equipment.
- 6) Two 5-amp circuit breakers at 220 volts for use with camera cooling accessories (see Camera Section).

Figure 7. AC Power Distribution

3. Input Cable

The input consists of 100 feet of #2 AWG, 3 conductor cable, the total weight being 136 lbs. There are 4 sections of 25 feet each. They are coupled together by locking action plugs and receptacles.

For connection into an existing power source, three 5 foot sections of #2 AWG, 3 conductor cable are provided.

On one end of each section there is a female locking action receptacle. The other end of each section contains a selection of terminal lugs, clamps, and bare leads for connection to engine-generator or other AC source.

4. Quartz Lamps (Camera Lighting) Distribution

Three 5 foot sections of #14 AWG, 3 conductor cable, the total weight being 3.3 pounds, is used to connect three step-up transformers, rated at 115/230 volt 1.7 KVA each, to the power distribution panel. Ten feet of #14 AWG--3 conductor cable, having a total weight of 6.6 pounds, is used to connect the output of each transformer to its own individual 2 circuit breaker panel. The 6 circuit breakers have a rating of 5 amps 230 volt each and individually control each lamp. There are three 1000 foot sections, the total weight being 930 pounds, and six 500 foot sections, having a total weight of 456 pounds of 10 AWG--4 conductor shielded cable.

One end of each section has a locking action receptacle, the other end a locking action plug. The maximum run for 1 pair of lamps is 2000 feet or one 1000 foot section and two 500 foot sections, the total weight being 462 pounds. The total weight of all lamp runs is 1386 pounds. The reason for using 230 volt quartz lamps is cable weight. Because of permissible line voltage drop, the minimum size cable for 115 volt operation is #4 AWG. The total weight for all lamp runs would then be 7500 pounds, and for 230 volt operation the total weight is 1386 pounds. As can be seen, this reduces cable weight by a factor of 5. Both breakers will be "on" for underwater light use.

5. Control Area Distribution

Four 50 foot lengths of #14 AWG--3 conductor cable connects to 4 panels containing eight 3-prong standard female receptacles. For optimum load distribution a pan/tilt unit; two 14 inch monitors; and a microwave trans/rec will be plugged into each panel. This leaves 4 other receptacles per panel for use with other equipment.

Ten feet of #14 AWG--3 conductor cable connects a constant voltage, frequency insensitive, transformer rated at 115/118 volts 1 KVA to the cameras and VTR power distribution panel. Fifty feet of #14 AWG--3 conductor cable connects the output of this transformer to a subsystem distribution panel, containing 5 circuit breakers. Four of these circuit breakers provide outputs for the CCU and are rated at 1 amp each. The remaining one has a rating of 5 amps and provides power thru 50 feet of #14 AWG--3 conductor cable, for use with the VTR. One end of this cable is a locking action plug, while the other end is a standard 3-prong receptacle.

6. Extension Cords

Four extension cords, each 50 feet in length, are available for use when the cameras are using normal convenience outlets, other local AC power sources or other general use. They are composed of 3 conductor #14 AWG, neoprene covered cable with a standard 20 amp NEMA 3-prong plug and an outlet panel of five 3 prong standard 20 amp female receptacle.

7. Airborne Equipment Distribution

One DC (28v) to AC (115v) converter rated at 200 VA is provided for use with the portable monitor.

8. Camera Vehicle Distribution

Fifty feet of #12 AWG--3 conductor cable is provided for connection between the Power Distribution Center and the Power Center.

The power center and associated control equipment is supplied as part of the vehicle.

K. INTERCOM SYSTEM

1. General

The Intercom System provides two-way communication between the control area and field for each of the radiation resistant cameras (Figures 8, 9, and 10).

At the camera location, two jacks are provided, one for a command speaker and one for a headset (Figure 8). The speaker has both listen and talk-back capabilities, and transmission is controlled at the control area. The normal switch position will be in the speaker listen (command) mode. The headset may be used instead of the speaker, in which case two-way communication is possible without having to use the push-to-talk circuit.

At the camera preamp a headset jack is provided to enable two-way communication over the same lines to the control area.

At the control area, jacks are provided for each of the three intercom lines to the cameras. Tape recorders will be used as needed to record audio from any of these intercom lines. Three headsets and three jacks are provided for multiple operator use, if needed.

The Standard Camera Chain does not have an intercom capability as it is primarily designed for self-contained, portable, hand-held or tripod mount operations in non-radiation areas with video transmission by microwave. However, two-way handie-talkies may be utilized, if available, for communication. The intercom control panel has a jack available for interfacing a two-way radio with the intercom system.

Figure 8. Intercom System, Block Diagram

2. Camera Speaker Amplifier

A Speaker Amplifier Unit is located at each of the preamp locations. It provides the amplification and DC control circuitry necessary for coupling the speaker and phone jacks to the control area equipment (Figure 9). Its major components are as follows:

The simplex unit allows audio and DC power to be transmitted over the same pair of wires.

The amplifier provides the necessary 1 watt audio for driving the speaker (at the camera location) or the simplex transformer, depending on the direction of transmission. It receives its power from the bridge rectifier contained in the amplifier.

The amplifier reversing circuit receives the DC control voltage (of either polarity) and converts it to constant polarity, providing power for driving the amplifier and the phone equipment.

The phone equipment consists of a retard coil, hybrid coil, and the phone jacks. This equipment provides power to the carbon microphones in the headsets and converts from three-wire operation to two-wire operation.

All transformers, inductors, and audio wires are shielded.

3. Control Panel

The Intercom Control Panel contains the necessary equipment for monitoring the intercom lines, for providing DC power to the speaker amplifier, for controlling direction of transmission of the speaker at the camera, and for net talking (Figure 10). Its components are as follows:

Five-conductor phone jacks are provided on the control panel. Two jacks are used for two-way radio connections and three jacks for headsets. A total of six headsets are provided.

The simplex equipment consists of three simplex units as previously described.

Figure 9. Speaker Amplifier Typical Unit

Figure 10. Intercom Control Panel

The push-to-talk switches provide for separating the three intercom lines or tying them together.

The recorder select switch determines which intercom line is to be recorded by both an audio channel of the video tape recorder and a channel of the audio tape recorder. An "off" position is also provided.

The speaker select switch determines which intercom line is to be monitored by the local speaker. The switch may also select either of the recorder outputs or may be placed in an "off" position.

The local speaker amplifier provides sufficient gain to drive the local speaker. A volume control is also included.

An additional headset is provided to annotate the recorders as necessary. This headset may be switched to either recorder or used for intercom communication.

The intercom control panel operates on 115 volts AC, 60 CPS, and is rack mounted.

All transformers, inductors, and audio wires are shielded.

L. EQUIPMENT PACKAGING

1. Introduction

Two methods of equipment packaging for storage, transportation and operation are available and the relative merits of each are discussed in Appendix I.

Since it is not certain at this time which method might be utilized, both approaches will be covered here, in the next section, and in the Equipment List.

2. Packing Cases

The packing cases are designed to comply with the environmental conditions outlined in the Functional Requirements. In addition, certain cases are designed to allow equipment operation without removal such that the cases become the operating containers.

The case and cover are constructed of seamless, one piece, drawn 6061, aluminum material. For shock protection and equipment support of cases which are not equipment operating containers, the support cushion is of polyurethane foam-type material or equivalent; and for cases which are also operating containers, the equipment support is flanged, with neoprene gaskets. Hinges are installed which allow cover and case separation. All latches are mounted on the cover so when operating containers are used without cover, the latch is not in the way. Spring loaded, rattle-proof, 90° carry, rubber-grip steel handles are mounted to allow ease of handling by one or two people. Four mounting feet per side are necessary and are determined by: (1) whether the container is used for operating or not; and (2) on the equipment configuration. An automatic or manual pressure equalizer is provided. Dimples are located on the container top for stacking purposes. The covers are equipped with an inner lid for storage of operating and maintenance manuals.

Most of the equipment which is operated within the cases have cable connectors installed on the back portion of their chassis. In this case, a cable access door is installed on the case at the appropriate location to allow rapid cable/connector mating.

3. Trailer

One control monitor trailer is provided to contain all of the control monitor equipment permanently mounted. The field equipment such as cameras, pan/tilt units, lights, lens, etc., are contained within storage bins or housings. An exception is the large cable reels since their weight dictates either a separate trailer or that they be shipped and handled separately.

The vehicle has a cross country capability, controlled environment, and is capable of being towed by standard tractors or transported by military aircraft.

All equipment is mounted in racks and arranged as discussed in Section III-M. Power distribution will be internal and one input connector will be installed on the trailer for mating with the cable from a power source. Additional power panels and increased input source will be necessary depending upon air conditioning, lights, etc.

The trailer size is largely dependent upon the final equipment configuration; however, with possible exception of large reels, a 40 foot long by 8 foot wide semi-trailer will satisfactorily house all equipment, provide adequate working areas, and yet be easily transportable. The trailer is completely insulated with cooling being provided by an air conditioner and heating by electric heat strips. The semi-trailer is superior to a house trailer because of its ruggedness and excellent rough road capability.

M. CONTROL MONITOR CONFIGURATION

1. Packing Cases

The equipment is transported in lightweight, reusable carrying cases. To provide for rapid set-up of the system, all the equipment may be operated in their containers and transferred to equipment racks if long term operation is necessary. The mounting arrangement for all of the equipment at the control areas is flexible in that no special configuration is necessary with exception of the 3D mounting adapter. This adapter allows either monitor #2 or #3 to be placed at right angles to monitor #1 (Figure 3).

The equipment is normally tailored to fit the operating conditions, area, and space available and is left to the discretion of the television supervisor. However, for ease of operation it is desirable to place the central control functions consisting of the camera, lens, and pan/tilt controls of each camera chain very close to each other and within close viewing distance of the main monitors. The video and audio switcher are also placed within reach of the above mentioned control and within viewing distance of the monitors. The waveform monitor is

placed close to the camera controls for waveform analysis and adjustment. The audio and video tape recorders are located within close proximity to the central control functions to allow reach of recorder operating controls. The utility monitor (#5) is separated from the central control position to allow the placing of still or movie camera in front of the monitor without disturbing the control operator (Figure 11).

2. Trailer

The control trailer has all of the control, monitoring and power equipment permanently mounted. However, they are installed so that if any camera control unit, monitor or pan/tilt/lens control unit is needed they can be quickly removed. This requires that all equipment be rack mounted and easily removable for mounting in portable cases. A set of portable cases are available to enable one complete camera chain and monitor to be enclosed for separate shipment capabilities.

For ease of operation the central control functions consisting of the camera, lens, and pan/tilt controls of each camera chain are placed very close to each other and within viewing distance of the monitors. The video and audio switcher are also located within arms reach of the central controls and within viewing distance of the monitors. The waveform monitor is placed close to the camera controls. The audio and video tape recorders are located within reach of their operating controls and close to the central controls. The utility monitor is separated from the control cluster to allow film or still camera placement in front of monitor without disturbing the operator (Figure 12).

N. SPECIAL DEVICES

1. Housings

Special camera housings are needed to allow viewing in areas which may be encountered and are beyond the capabilities of camera container described in Section I. There are designated as "Highly Explosive" and "Extreme Temperature," and are discussed under Functional Requirements.

Figure 11. Control Layout Using Packing Cases

Figure 12. Control Layout Using Trailer

a. Explosive Atmosphere

The radiation tolerant cameras (#1-3) may be subjected to highly explosive atmospheres as outlined in the Functional Requirements. To prevent ignition of this atmosphere, one explosion-proof housing is furnished to accommodate the cameras. The housing weighs approximately 32 pounds and when used is mounted on a heavy-duty pan and tilt unit.

The quartz lamps also require an explosion-proof container to prevent ignition of explosive atmospheres. Each housing is fabricated to accommodate one quartz lamp with capabilities for mounting on the above mentioned camera housing. Two housings are furnished, each weighing approximately 10 pounds.

The housings are capable of purging by connection to an appropriate air or inert atmosphere source through the use of 3/8 inch threaded connectors and valves. These connectors are installed, when needed, in threaded holes in the containers. The holes are plugged when not in use.

b. Extreme Temperature

Temperature excursions below the value of -50°F mentioned in the Functional Requirements are not anticipated but, if encountered, the internal camera heater should provide adequate temperature control to maintain operation.

Temperature excursions above $+150^{\circ}\text{F}$ would require special cooling devices or enclosures as discussed in Section IV, B2. No provisions for operation above $+150^{\circ}\text{F}$ are considered here.

2. Environmental Information Monitoring

a. Radiation Measurement

Radiation measurements at the camera location are accomplished by an appropriate detector/indicator unit. The detector will normally be non-collimated as the addition of approximately 125 pounds of lead

would be necessary for collimation to reduce the radiation at the undesired angles by approximately one decade. If collimation is desired, the detector would have to be mounted on a pedestal apart from the camera. The uncollimated probe weighs 4-1/2 pounds (includes 5 feet of cable) and may be strapped to the camera mounting pedestal. The radiation monitor will provide measurements over ⁶ adjacent decades up to a maximum of 10^6 R/hour and down to 1 mr/hour. Exposure to high radiation levels within or in excess of the range of the radiation monitor will not cause saturations or other effects that would result in a false indication of low radiation levels. Readout of levels are provided by a meter and indicator alarm light mounted on the control unit. Separation of up to the desired 2100 feet between probe and indicator is achieved by an 8 conductor shielded cable #22 wire (Cable, Section IV-I).

b. Temperature Measurements

Temperature measurements at the camera location are accomplished by an appropriate transducer/indicator unit. The transducer may be strapped to the camera tripod. The temperature monitor will provide measurements over a range of -50^oF to +300^oF. Readout of levels are provided by a meter on the control unit. Separation of up to 2100 feet between transducer and indicator is achieved by a 4 conductor shielded cable of #18 wire (Cable, Section IV-I). The transducer will withstand the radiation levels specified in the Functional Requirements.

O. TEST EQUIPMENT

The test equipment to adequately maintain the television equipment is defined in the Functional Requirements and detailed in the Equipment List. This is a minimum requirement and additional equipment may be necessary depending upon the particular television equipment manufacturer's requirements.

P. SYSTEM SETUP CONSIDERATIONS

The overall system contains a variety of pre-assembled cables, mounting accessories, cameras, as previously discussed, to provide flexibility in the multitude of operating conditions.

When called upon for use at a particular location, different equipment options are available for shipment to the site.

The entire system could be transported to the location. This would require some expenditure of time to accomplish.

One camera chain could be immediately transported to the site with eventual follow-up of the entire system. This could be accomplished rapidly.

If one chain is rapidly transported to a site, this allows cursory television analysis of desired areas. The equipment sent contains the minimum necessary subsystems for this chain to display the viewed scene on one monitor without the use of accessories such as recorders, intercom, etc. The following table (P-1) depicts this minimum system, including weight and number of pieces.

Table P-1 indicates a total weight of 2,064 pounds and 23 pieces for the initial system. This provides up to 1100 foot separation between camera and control unit. This distance has been suggested rather than the 2000 feet, (actually 2100 feet), to help lessen the cable weight. Of course, the entire 2000 feet of cable could be sent if necessary, and this would add about 1500 pounds to the weight which would then total about 3,564 pounds.

After the equipment arrives at the site, whether it be one chain or the entire system, the procedure for equipment setup is:

- 1) Unpack desired camera chains, depending upon number of chains needed.

- 2) Unpack and interconnect control area equipment. This includes the video switcher, intercom switcher, recorder, monitors, cables, etc.

TABLE P-1

List of Minimum Equipment Necessary for Cursory Area Examination

<u>Item #</u> <u>(Ref. Equip</u> <u>List)</u>	<u>Qty.</u>	<u>Description</u>	<u>Approx. Wt. -lbs.</u> <u>(Incl. packing case)</u>	<u># of</u> <u>Pieces</u>
1, 4, 10	1	Radiation Tolerant Cam- era w/ lens & vidicon	25	2
3	1	Camera Control Unit w/ Sync Generator	20	1
7	1	Junction Box	10	1
12	1	14" Monitor	80	1
19	1	Medium Duty Pan/Tilt Unit	35	1
23	1	Tripod/Dolly	40	1
24	1	Pan/Tilt/Lens Control Unit	10	1
29	1	Camera/Light Bracket	7	1
31	2	Quartz Lamps	7	1
38, 39	1	Power Distribution Pan- el, Lighting Panel & Transformer	200	2
47, 48	1	Coaxial & Multiconduc- tor Cable for Control Unit-to monitor & pan/ tilt lens control	10	2
42, 43, 49	100',	Camera Cable, Light	1600	5
50, 53, 54	1000'	Cable & Reels		
45, 51, 52	short lengths	Radiation Tolerant Mul- ticonductor Cable for Junction Box to pan/tilt, lens, camera, lights	20	4
TOTALS (approximate)			<u>2,064</u>	<u>23</u>

3) Assemble desired camera/mount configuration at staging area for placement on tripod, universal mounting bracket or remote vehicle. Couple camera/lights to the mounting device then place in areas to be viewed.

4) Reel out needed cable lengths and interconnect the camera head, preamp, intercom, control unit and light distribution system.

5) Finish with hookup of other accessories which might be needed such as remote monitors, 3D accessory, other viewing areas, etc.

All cable connectors are protected from environmental hazards by metal, waterproof covers to completely seal them when not in use; however, during interconnection, care must be exercised to eliminate any direct contact with snow, moisture, or dirt. After connector mating, flexible boots, which are on the cable end, will be positioned over the connectors to insure a watertight seal.

Care must also be exercised in assembling the cameras since extreme rough handling could be detrimental to internal components.

Placement of the camera within the many possible containment structures which might be encountered imposes special problems and considerations due to the possible radiation hazards present. Methods of placement are largely determined by the local conditions. Some of the methods are:

- 1) By personnel.
- 2) Remote controlled camera vehicle.
- 3) Boom, crane, fork lift.
- 4) Lower by cable through roof access.

SECTION V

EQUIPMENT LIST

The Equipment List contains the necessary components for providing the capabilities discussed in previous sections.

Potential vendors are listed to indicate possible sources of suppliers, however, a recommended vendor and model number is listed to indicate the source most capable of furnishing the equipment which will meet the conditions of this study.

All costs are from recent catalogs where available, with estimated costs provided when published prices were unavailable or special fabricated items are specified.

The following summary delineates equipment cost estimate totals for one complete system. The two equipment packaging options and remote vehicle are separated for clarity.

Equipment Items		\$117,706
Remote Controlled Camera Vehicle		40,000 (avg)
Packing Cases		14,400
or		
Trailer	(approx)	11,000

Item No.	Equipment Description	Function	Quan.	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs	Tot No. Pieces	Est. Cost		Remarks
										Unit	Tot.	
1	Radiation Tolerant Camera Head/Preamp, less lens & vidicon, for 95 ma vidicon in container.	Scene to video conversion for transmission to control area.	3	6 circuit boards	Pur.	Cohu (Kintel) Dage, Motorola	Cohu(Kintel) Model 2500	12.0	6	4000	12000	Capable of 100' camera head to preamp separation. Preamp circuit boards expendable
2	Camera Control Unit with Sync Generator, in portable case (for Item #1)	Process camera video supply camera voltages, provide two video outputs.	3	3 circuit boards	Pur.	Same as Item #1	Cohu, Model 3911	11.0	3	1600	4800	Must be compatible with Item#1.
3	Radiation Tolerant Vidicon (Same as Type 7263A)	Camera pickup tube for Item #1.	3	2	Pur.	RCA, GEC	RCA C74134	Negligible	5	700	4200	Two spares for the three camera desirable.
4	Radiation Tolerant Automatic Zoom "C" mount lens with converter & close up attachment (Less control box.)	Camera optics for Item #1 with total of 30-300 mm focal length.	3	0	Pur.	Wollensak	Wollensak TV Raptar, non-browning automatic zoom with converter and close-up attach.	5.0	9	1300	3900	Sole vendor
5	Radiation Tolerant Wide-Angle (1/2") Fixed Lens with "C" mount.	Camera optics for Item #1, with 1/2" (13 mm) focal length.	3	0	Pur.	Wollensak	Wollensak 1/2" non-browning lens.	0.5	3	250	750	Sole vendor.
6	Junction Box for Item #1	Distribute cables to various items such as lens, camera, pan/tilt, intercom.	3	0	Fab.	Same as Item#1	Cohu	5.0	3	200	600	Rapid disconnect connectors.
7	Standard Camera Chain includes self-contained control unit, sync generator. Capable of remote control.	Scene to video conversion. One video output.	1	0	Pur.	Cohu, Dage, Fairchild, GE and RCA	Cohu, Model 2000 w/2000-100 control unit	4.5	1	2700	2700	Cohu desirable for compatibility with Items #1 and 2.

Item No.	Equipment Description	Function	Quan	Spares	Fab or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs.	Tot. No. Pieces	Est. Cost		Remarks
										Unit	Tot	
8	7262A Vidicon	Camera pickup tube for Item #7.	1	1	Pur.	RCA, GE, GEC	RCA 7263A	Negligible	2	300	600	
9	Automatic zoom lens and extender with total focal length of 15mm to 300mm (Less control box)	Remote controlled camera optics for Item #7.	1	0	Pur.	Zoomar, Wollensak, Elget, Canon	Zoomar, Mark X-B with 2X extender	4.0	2	1300	1300	Zoomar lens-high resolution and dependable.
10	Manual Zoom lens with eye piece viewfinder (25 to 100 mm) for Item #7.	Camera optics when camera (Item#7) is hand-held during operation.	1	0	Pur.	Pan-Cinor, Angenieux	Pan-Cinor, Type A-2	2.5	1	500	500	Manual operated and low cost.
11	14" Monitor in Cabinet (Transistorized)	Remote Video Viewing	2	0	Pur.	Conrac, Miratel	Conrac RLB14/C	65	5	460	2300	Cabinet model must be special ordered.
12	9" Monitor in cabinet (Transistorized)	Remote video viewing	2	0	Pur.	Conrac, Miratel	Conrac RNB9/C	34	2	445	890	
13	17" Monitor in cabinet	Utility monitor for film recording, etc.	1	0	Pur.	Conrac, Miratel	Conrac CVA17C	67	1	350	350	Tube type monitor
14	Video switcher, 6 inputs/4 outputs, amplifier isolated, illuminated.	Video switching	1	0	Pur.	Dynair, RCA GE, Telemet	Dynair VS-6X4 CBL	10	1	1125	1125	
15	Distribution amplifier (4" self-contained unit) with high gain capabilities.	Video distribution	4(self-contained)	0	Pur.	Dynair, Telemet, International Nuclear	Dynair FR3000A Frame PS-3015B Power Supply, DA3062C Distribution amp.	8	1	4@ 190 1@ 150	910	Entire assembly self-contained.
16	Video Tape Recorder with microphone and 2 rolls of tape.	Video Storage	1	0	Pur.	Ampex, Precision Instrument, Sony.	Ampex 660	100	1	11600	11600	Reliable, compatible.

Item No.	Equipment Description	Function	Quan	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs.	Tot. No. Pieces	Est. Cost		Remarks
										Unit	Tot	
17	Portable Microwave Relay Link with 2' antenna(Dish & Cables) and omnidirectional antenna.	Video Transmission	2 links	0	Pur.	Microwave Assoc., RCA, Micro-Link, Raytheon, Motorola, ITT	Microwave Assoc., MA-ZTV	38	4	5500	11000	15 lbs-transmitter 23 lbs. receiver.
18	Medium Duty Pan & Tilt Unit, 0 to 350° horizontal, ± 90° vertical.	Remote pan/tilt for Item#1	3	0	Pur.	Pelco	Pelco PT550MX	25	3	580	1740	Not for 3D or environmental housing
19	Medium Duty Pan/Tilt Unit 0 to 350° horizontal, ± 45° vertical	Remote pan/tilt for Item#1 when 3D mounted.	1	0	Pur.	Pelco	Pelco PT550MX	25	1	580	580	For 3D
20	Heavy Duty Pan & Tilt Unit Explosion proof, 0 to 350° horizontal, ± 45° vertical	Remote pan/tilt for Item#1 when mounted in explosion proof housing.	1	0	Pur.	Pelco, Houston Feerless	Pelco PT1000LX	70	1	1750	1750	For environmental use.
21	Explosion proof, purgable environmental enclosure	For Item#1	1	0	Pur.	Pelco	Pelco EHX	32	1	500	500	
22	Portable tripod for loads to 165 pounds with built-in lockable dolly and low center of mass (without pan head).	Supports for camera	4	0	Pur.	Quick-set, Houston-Feerless, Baughman Davis&Sanford	Davis & Sanford Model HD	30	4	350	1400	Folds into compact package.
23	Pan/Tilt/Lens Control Unit mounted on panel	For Items #1, 18, 19, 20.	3	0	Pur.	Pelco, Cohu	Pelco Modular Controls PT-1500	2	3	390	1170	One panel contains pan/tilt/lens enclosure controls.
24	Remote camera & zoom lens controls.	For Item #7	1	0	Pur.	Same as Item #7	Cohu Model 2481	2	1	235	265	
25	Remote pan/tilt control	For Item #7	1	0	Pur.	Pelco	Pelco PT-1500 Rate Control	1	1	228	228	

Item No.	Equipment Description	Function	Quan	Spares	Fab or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs	Tot No. Pieces	Est. Cost		Remarks
										Unit	Tot	
26	Remote Pan/Tilt/Lens controls for Item #23	Used at preamp location.	3	0	Fab.	Pelco	Pelco	2	3	100	300	
27	3D Mounting Adapter for Item #1 and Item #11	Mount for 3D camera configuration & monitor.	1	0	Fab.	Same as Item #1	Cohu Elec.	25	2	600	600	
28	Camera/Lights Bracket with quick engage/disengage	Mount camera/lights to pan/tilt unit	4	0	Fab.	Same as Item #1	Cohu Elec.	3.0	4	100	400	
29	Universal Mounting Bracket with interchangeable grips	Attach pan/tilt or camera/lens to girders, cranes, booms, tables, etc.	4	0	Fab.	Same as Item #1	Cohu Elec.	20.0	12	200	800	
30	Quartz lamps-aluminum housing, 230VAC, 800 watts	Scene illumination for Item #1	6	6	Pur.	Colortran, Mole Richardson	Colortran, Model LQK/5 WYA	1.3	12	17	204	250 hour life-3 floods, 3 spots.
31	Quartz lamps-110VAC, 1000 watts	Scene illumination for Item #7 and light stand	6	4	Pur.	Colortran, Mole, Richardson	Colortran Model LQK/5 WYA	1.3	24	59	590	500 hour life
32	Lamp Stand (aluminum) Folding (height 37" to 112")	Support two of Item #31	2	0	Pur.	Colortran, Mole Richardson	Colortran Model 55G	5.3	2	24	48	
33	Intercom Control Panel with Speaker amplifier	Intercom line switching and distribution.	1	0	Fab.	Electrospace EG&G, ITT, RCA	EG&G	25	1	600	600	
34	Speaker amp. for preamp.	Field communication by headsets or speaker.	3	0	Fab.	Electrospace EG&G, ITT RCA	EG&G	3.0	3	200	300	

Item No.	Equipment Description	Function	Quan	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs	Tot No. Pieces	Est. Cost		Remarks
										Unit	Tot.	
35	Headset (with microphone) single headband with stretch cord.	Communication from field to control area	5	1	Pur.	Tele-sonic, Western Elec. Telex	Western Elec.	1	6	40	240	Expendable.
36	Speaker (in weatherproof container) (3 inch)	Communication at field and control area	4	4	Pur.	Utah, Jensen, Quam	Jensen	2.0	8	30	240	Expendable.
37	Audio Tape Recorder, Dual Track	Intercom, mike recording	1	0	Pur.	Ampex, Viking Magnecord	Ampex, 602	31	1	650	650	
38	Power Distribution Panel	Main AC power distribution	1	0	Fab.	GE, Square D, Westinghouse	GE	50	1	335	335	Includes cable.
39	Lighting distribution panel and step up transformer	Control and protection of remote quartz lamp, (Item #30)	1	0	Fab.	Same as Item #38	GE	120	3	440	440	Includes short cables
40	Camera and recorder power distribution panel with constant voltage transformer	Control and protection of camera controls & recorder	1	0	Fab.	Same as Item #38	GE	120	3	385	385	Includes cables. Transformer must be frequency insensitive
41	General Equip. power distribution panel	Control area equip.	4	0	Fab.	Same as Item #38	GE	14	8	200	800	Includes cables.
42	Radiation tolerant camera cable	Camera head (Item #1) to preamp	300'	100'	Fab.	Jefferson, Boston Elec. Specialty Co., Belden	Boston	0.7/ft	3	2.00 /ft	800	Hypalon jacket
43	Environmental Camera Cable	Preamp to camera control unit.	6000'	0	Pur.	Same as Item #42	Boston	0.5/ft	12	1.00/ft	6000	
44	Environmental Camera Cable	Camera to control area for Item #7	2000'	0	Pur.	Same as Item #42	Boston	0.4/ft	4	1.00 /ft	2000	

Item No.	Equipment Description	Function	Quan	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs	Tot. No Pieces	Est. Cost		Remarks
										Unit	Tot.	
45	Assorted radiation tolerant multiconductor and camera cable	Junction box to pan/tilt, lens, camera head lights, speaker, 3D adapter	64'	0	Pur.	Same as Item #42	Boston		16	05 /ft	30	Total weight is 18 lbs.
46	Coaxial cable RG-11A/U	Remote viewing areas	6000'	0	Pur.	Same as Item #42 plus Alpha	Belden RG11A/U	0.089/ft	7	93.80 /M	581	Meets MIL-C-17D
47	Coaxial cable RG 59B/U	Video routing	920'	0	Pur.	Same as Item #42 plus Alpha	Belden RG-59B/U	0.036/ft	approx 30	43.20 /M	40	Meets MIL-C-17D
48	Assorted audio and multiconductor control cable	Control area use	1200'	0	Pur.	Same as Item #42	Belden		approx. 20	25/M	25	Total weight is 94 lbs.
49	Multiconductor environmental cable	Quartz lamps for Item #1	6000'	0	Pur.	Same as Item #42	Belden	0.715/ft	12	720 /M	4320	
50	Camera connectors	For camera cable	22	4	Pur.	Same as Item #1	Cohu Elec.	0.5	23	20	520	
51	Assorted multiconductor connectors	Junction box to pan/tilt, lens, lights, 3D adapter. CCU to control units for above	45	0	Pur.	Same as Item #1	Cohu Elec.	0.25	45	5	225	
52	Coaxial connectors and crimper	For coaxial cable	70	20	Pur.	Amphenol, Cannon	Amphenol	0.1	150	1	90	Crimp type
53	Portable Camera Cable Reel (Hand operated)	For Item #42 (100' of camera cable)	3	0	Pur.	Indus. Elec. Reels, Ace Hose Reel Co. Aero Motive Mfg. Co.	Indus. Elec. Series 60	40	3	150	450	
54	Portable Camera Cable Reel (Hand operated)	For Item #43 (500') of camber cable/reel	12	0	Fab.	Same as Item #53	Indus Elec. Series 60	110	12	450	5400	

Item No.	Equipment Description	Function	Quan	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs	Tot No. Pieces	Est. Cost		Remarks
										Unit	Tot.	
55	Portable Camera Cable (Hand operated) Reel	For Item #44 (500' of camera cable/reel)	4	0	Fab.	Same as Item #53	Indus. Elec. Series 60	110	4	350	1400	
56	Portable multiconductor Cable Reel (Hand operated)	For Item #49 (500' of lamp power cable/reel)	12	0	Fab	Same as Item #53	Indus Elec. Series 60	110	12	350	4200	
57	Portable Coaxial Cable Reel	For Item #47 (500' of coaxial cable)	1	0	Pur.	Same as Item #53	Indus. Elec. Series 60	5	1	50	50	
58	Portable Coaxial Cable Reel	For Item #46 (1000' and 500' of cable/reel)	7	0	Pur.	Same as Item #53	Indus Elec.	5	7	50	350	
59	TV Projector	Project video on large screen	1	0	Pur.	Dalto, Philips (Norelco)	Dalto TS190/193	100	2	2000	2000	Images up to 8' in width
60	Projection Screen, approx. 4-1/2' x 5-1/2', lenticular.	For Item #59	1	0	Pur.	Radiant, Norelco	Norelco	20	1	80	80	For wall mounting
61	Underwater light with of cable.	Underwater applications	1	1	Pur.	Birns&Sawyer, Oceanographic Engr. Co.	Birns&Sawyer 5500	10.5	4	350	700	To 100' depth or more
62	Underwater camera mounting yoke and 100' cable.	Mount Item #1 underwater & rad. tolerant	1	0	Fab.	Cohu Elec.	Cohu Elec.	10	1	400	400	
63	Waveform Monitor in field case	Video analysis, camera video setup and monitoring	1	0	Pur.	Tektronix	Tektronix Spec. Type 529	50	1	1100	1100	
64	Portable Transistorized Oscilloscope	General TV system maintenance	1	0	Pur.	Tektronix	Tektronix 422	21	1	1750	1750	Rechargable battery or AC. Versatile, high quality.
65	Multimeter (comb. VTVM-VOM)	General purpose maintenance	1	0	Pur.	Triplett	Triplett 631	5	2	70	140	

Item No.	Equipment Description	Function	Quan	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. Per Unit-lbs.	Tot. No Pieces	Est. Cost		Remarks
										Unit	Tot	
66	Portable Optical Camera chain alignment system	Camera chain alignment useful in optimizing 3D	1	0	Pur.	Photo Research, Zolomatic Corp.	Zolomatic, Model 252 diaspope	3	1	495	495	Necessary for alignment of camera chain over the 2000'.
67	Portable Transistor checker	Equip. maintenance	1	0	Pur.	Hickock, Triplet	Hickock 890	8	1	140	140	
68	Dot Bar Generator	Equip maintenance	1	0	Pur.	Cohu, RCA	Cohu, DBG-1	5	1	500	500	
69	16mm movie camera with 600' magazine modified for video recording and lens.	Video to film recording from monitor.	1	0	Pur.	Auricon, Milliken, Palmer	Auricon PRO 600	20	2	2000	2000	
70	Still camera 4 x 5" press type" with lens and polaroid attachment with tripod.	Video to film stills from monitor	1	0	Pur.	Graflex	Graphlex Crown Graphic	8	3	450	450	Least expensive yet reliable.
71	Explosion Proof, purgable housing	For quartz lamps, Item #30	1	0	Fab.	Pelco	Pelco	10	2	300	600	
72	Temperature measurement system -50°F to 300°F with 100' of radiation tolerant and 2000' of standard cable (4 conductor shielded)	Remote temperature measuring	1	0	Pur.	Winsco	Winsco SRM 4116	180	5	530	530	Cable reel for 2000'. None for 100'. \$155. for cable.
73	Radiation Level Measurement Remote System. 1 mr/hr to 10 ⁶ R/hr with 100' of radiation tolerant and 2000' of standard cable (8 conductor shielded)	Remote gamma radiation measurement of 6 decades	1	0	Pur.	Victoreen	Victoreen 711/719	84	5	800	800	Cable reel for 2000'. None for 100'. \$130. for cable.
74	Portable multiconductor cable reel	For Items #71, 72	2	0	Pur.	Same as Item #53	Indus. Elec. Series 60	10	2	50	100	
75	Camera cooling enclosure, power supply	For radiation tolerant cameras	2	0	Pur.	Scientific-Columbus	Scientific-Columbus, Columbus, Ohio	15	4	2000	4000	Cool camera from 200°F to 100°F.
76	Cable for item #75	200' radiation tolerant, 1900' environmental	4200'	0	Pur.	Same as Item #42	Boston	0.1	8	.15/ft	630	
77	Portable reels	For Item #76	6	0	Pur.	Same as Item #53	Indus. Elec. Series 60	10	6	60	360	
TOTAL EQUIPMENT												<u>\$117,706</u>

Item No.	Equipment Description	Function	Quan.	Spares	Fab. or Pur.	Potential Vendors	Rec. Vendor & Mod. No.	Wt. per Unit-lbs.	Tot No. Pieces	Est. Cost		Remarks
										Unit	Tot.	
78	Remote controlled camera vehicle	Remote controlled camera platform	1	0	Fab.	PAR, FMC	FMC	250	2	(avg)	40K	FMC cost for one approximately \$35K - 45K, there after at much less cost. PaR unit cost approximately \$9.5K
TOTAL VEHICLE												<u>\$40,000.</u>
PACKING CASE/TRAILER OPTION												
79	Packing Cases	Equipment transportation and operation	34	0	Fab.	Zero, Halliburton, TA Mfg.	Zero military type cases.	(avg) 10	34	(avg) 250	8500	For Items 2, 11, 12, 13-17, 23, 24, 26, 33, 37-41, 63-65, 67, 68 (some of the above require more than one case.)
80	Packing Cases	Equipment transportation only.	59	0	Fab.	Same as Item #76	Same as Item #76	(avg) 15	59	100	5900	1-3, 7, 9, 10, 18-22, 27-32, 34-36, 48, 59-62, 66, 69-74. (Some of the above require more than one case.)
PACKING CASE TOTAL												<u>\$14,400.</u>
81	Trailer (40' x 8') outfitted with racks, storage bins and air conditioning	Control Monitor and storage center for the TV system.	1	0				TOTAL TRAILER (approx.)				<u>\$11,000.</u>
												Cost based upon use of surplus trailer.

SECTION VI
APPENDICES

A. MISSION ANALYSIS

1. Mission

a. Area Surveillance

After a nuclear accident, it is of prime importance to search the area for hazards, locate equipment, assess damage, and look for facility damage. Another important task is that of finding and removing any victim that may either be trapped in the facility or missing. Normal entrances and personnel passages may be damaged or destroyed. Coupled with this physical problem of entry will be the hazard of nuclear radiation. Personnel will be limited to the amount of time they can spend in an area and will be further handicapped by the protective clothing they must wear. Some areas may be completely off limits because of high radiation. Remotely operated vehicles, manipulator, and other mechanical contrivances will be required. But, to successfully operate these devices, a remote visual system must be provided.

Aerial surveillance may also be required and could greatly help in determining the amount of damage. For maximum use, the personnel directing operations on the ground should be able to see the view from the aircraft with no delay or communication problem. Another function of surveillance is that of monitoring people entering and leaving a dangerous area.

b. Inside Viewing

Inside viewing is necessary to look for personnel, equipment, hazards, internal damage, instrument readings, and identification of objects.

Radiation levels inside could well exclude humans from entering and much of the work would have to be done by remotely controlled devices. A remote viewing system would be required to control these devices.

Normal lighting would probably be disabled by the accident and special illumination would be required for the remote viewing system.

In some instances, objects under water would require examination, and some means of viewing would be required.

c. Disassembly

During disassembly operations, hardware would need to be identified, relative distances measured between points, access routes planned, and machinery positioned. Again, much of the work may have to be done by remote means and remote viewing equipment would be needed. The viewing equipment should be capable of providing 3D presentation.

2. Factors/Requirements

There are a number of factors and requirements which would be imposed on a remote viewing system when used around the aftermath of a nuclear accident. Some of the more important are listed:

a. Environments

Nuclear radiation of 10^4 R/hr gamma (measurements to 10^6 R/hr desirable for camera safety) and 10^3 neutrons/cm²/sec, or higher, could be present after an accident, with temperatures anywhere between -50°F and +200°F. Scene illumination could be anything from bright sunlight to almost total darkness. Humidity of 100%, pressurized containment vessels, and even the possibility of underwater use may be encountered. Components of the system exposed should withstand and operate in this environment with little or no degradation.

b. Field of View

The field of view must be as large as possible for quick searching, but when an object is found, it must be enlarged and the field narrowed.

c. Resolution

The system must have sufficient resolution to easily pick out details such as meter scales, dial settings, and nomenclature.

d. Operational Periods

The system should be capable of operating in the environments listed for 6 months or longer.

e. Reliability

The system's reliability should have a probability of success of 0.90 for 500 - 1,000 hours of operation with a confidence limit of 90 percent.

f. Maintenance/Servicing

Equipment layout and packaging should be such that maximum accessibility for maintenance and calibration is obtained. Skilled technicians unfamiliar with the equipment should be able to service and maintain the equipment.

g. Size

The equipment should be small and compact to facilitate transportation, set-up and operation. A design goal for each individual piece of equipment should be such that when housed in a packing case, the case could easily be carried by one or two men.

h. Recording

There will be views that will need to be studied and documented; therefore, a means of making permanent recordings should be included in the system.

i. Ease of Set-up

The system will be set-up under trying conditions where a state of emergency exists. It is very essential that the system can be easily set-up without delays or the use of extremely skilled people.

3. Viewing Systems

There are a number of different viewing systems which might be used for viewing a nuclear accident area.

These are:

Human - (binoculars and film camera)

Remotely operated film camera

TV

A brief evaluation of capabilities and limitations of each system is listed below:

a. Human

A human equipped with binoculars and film camera has some definite advantages over other systems. He has good perspective of the overall area and can pick out details and objects of interest very fast. His judgment for selecting the views is thus improved. Still pictures containing much information and resolution may be obtained. He is also mobile and can move about to improve the view.

There are some definite limitations on a human. He will not be able to enter areas if the radiation is too high, and in others, he can remain only for a short time. This means high manpower requirements if much information is to be gathered. The operation is non-continuous and time consuming. A human will have a poor retention of areas he didn't look at closely and may make mistakes in later describing a view he saw. When film is used, there is the delay of developing. This system is slow and requires a lot of manpower.

b. Remote Film Camera

A remotely operated film camera provides high resolution and a permanent record of what it sees and is very valuable for documenting important views. It would be used with a TV camera in low radiation areas with the TV camera used for aiming and surveillance. They could use a common optical system.

However, it has poor perspective and no feedback information is provided the operator. It can't be placed in high radiation fields without special shielding and requires placement and aiming to get the desired view. Film reloading is also a problem. It is a non-continuous operation and there is the delay of developing the films.

c. Television

A TV camera can operate in environments that a human or a film camera can't. Accumulative doses up to 10^8 R and 10^{12} neutrons/cm² are

possible before the picture becomes unusable. It will operate at temperature extremes of -50°F or $+150^{\circ}\text{F}$, while humans and film cameras would experience difficulties. Operation of 100% humidity, or even below water, is possible.

A distinct advantage of TV is that it presents a continuous display of the scene. There is no delay waiting for film to be developed, or for a man to return and report what he saw.

Another advantage is easy placement of the camera. Two men in a few minutes can place a TV camera and connect cables. No adjustments or aiming is necessary, as all the functions are done remotely. The TV camera requires no further attention until it is moved again. With a film camera, adjustments would need to be made and the camera aimed. Film reloading will also take time and manpower.

Since TV operates continuously, a recording can be made anytime as required. By use of a video tape recorder, immediate playback is possible for any scene. Film recording, either movie or stills, can also be obtained from TV.

With TV, many people can view the pictures at once and they can use their collective judgment on what action to take. Use of several monitors allows officials and dignitaries to watch, yet keeps these people from being in the way of those directing the operation. TV is very versatile and can be used in a number of ways. A camera mounted in a helicopter with a microwave transmission link could be very useful during rescue operations and initial assessment of facility damage. Cameras can be placed on remote controlled or shielded vehicles for looking into areas that personnel couldn't enter. Underwater views down to 250 feet is possible by using a suitable housing and lighting devices. Two cameras in a 3D configuration could be used to help speed disassembly operations. Camera placement depends on the circumstances encountered, equipment available, and the ingenuity of those using it.

Two disadvantages of TV is its relative poor resolution compared to film, and its lack of perspective. The resolution problem can often be improved upon by the use of zoom lenses and moving the camera closer to the object. Perspective can be improved by using more than one camera.

B. USES OF TV ON NUCLEAR ACCIDENTS

1. How the TV System Can Be Used

The system is designed to allow portions of the equipment to be used without assembling the complete system. The number of camera chains, the amount and type of monitoring and recording equipment, the need for RF transmission, and the mechanical mounts and lighting requirements are determined for a particular application.

It is contemplated that the equipment will be stored at a convenient geographical location and maintained in operational readiness. Upon notification of a need for radiation tolerant viewing equipment, one or two of the camera chains, with their associated control units, and monitors, can be rapidly transported and set up at the accident site. This chain would be inserted within the accident area where it would be used for an immediate inspection of the damage, monitor the conditions of control and indication consoles and to locate additional hazards. The camera chain would provide a direct feedback to personnel as an aid in the early planning for personnel recovery neutralization of hazards (Figures 13 and 14). The use of the specialized lighting equipment and remote control vehicle would depend upon the location and nature of the accident. The audio and video recording equipment could then be set up to provide a permanent record of the recovery and safing operation. The video recordings and still photographs would also be used for a more careful scrutiny of equipment location and damage.

If required, the portable camera chain (number 4) would then be utilized probably with the microwave transmission equipment to provide complete area surveillance.

Figure 13

Figure 14

If it then appears necessary to provide remote viewing equipment for follow on monitoring, recovery, safing, and clean up, the complete system including all four camera chains and monitoring equipment could be assembled, probably in the control van, for continued 24 hour 7 day a week use.

A typical configuration during a safing and clean up operation would be as follows: Radiation tolerant cameras 1 and 2, installed on the 3D mounting adapter, would be located inside the building where the accident occurred. This 3D camera chain would be used to direct remotely controlled equipment to enter the building and containment vessel for disassembly. The 3D system would allow an accurate, real time feedback of distance and depth information to the operators. Camera No. 3 (radiation tolerant) could be located on the remotely controlled device as a reference to the operator. Camera No. 4 (standard) would be located outside to view the general area both as an information feedback concerning the location of remotely controlled equipment and for general area surveillance and personnel control. The video tape recorder could record the selected outputs from the cameras and provide instant replay capabilities. The audio tape recorder would record all operations of the voice net. The additional microwave link could then be used to transmit a selected video signal to remote base of operations so that personnel could immediately determine the up-to-date operational situation without expending extensive travel time and risking unnecessary exposure to radiation.

The 3D camera chain could also be mounted directly on a remote manipulator for the more detailed mechanical disassembly and parts examination operations. If the remote controlled vehicle is used in

combination with a radiation tolerant camera chain and a zoom lens, a complete study of the interior of a building may be made. Still photographs could be taken from several perspectives, thus giving more detail concerning the shape and sizes and relative distances of various components within the building.

2. Use of TV on Past Accidents

Accident recovery operations conducted during recent accidents have been examined and a determination made of how TV could have been used.

a. WTR Fuel Melting, 1960

The WTR reactor (a pressurized water type) coolant water became contaminated with fission products and it was then necessary to raise the reactor head to aid in fuel element removal. A radiation tolerant TV camera mounted on a boom or a remote controlled vehicle could have allowed remote viewing for a longer time period since the core had to be replaced because of the radiation levels. A video tape recording could have been made for later core re-examination with still photos for use in discussions and meetings.

Facility cleanup was started after assurance that the reactor was and would remain subcritical. Radiation tolerant cameras, on tripod or booms, viewing the reactor controls and/or indicators, could have possibly reduced the waiting period through constant real time monitoring. A video tape recorder could have been used instead of having personnel continually watch the radiation level indicators. The tape would then be played back and the results observed.

b. SL-1 Accident, 1961

A considerable amount of surveillance and planning was required for the removal of two victims. Recovery planning could have been

greatly assisted using TV. Radiation tolerant cameras on a boom tripod or vehicle with video recording would have provided continuous information of existing conditions. The vehicle could have been used to move about the area for complete coverage. All this could have been recorded and later played back to detect additional hazards.

During reactor safing and disassembly two cameras mounted in a 3D configuration would have provided to the operator visual distance and depth information useful in directing remotely controlled safing and disassembly equipment.

The 3D camera configuration could also have been mounted on the boom using a universal mounting bracket. This boom was to inspect the reactor core after the accident, and the 3D viewing would have provided more information as to depth and distance. Recording of the core scene would also have been possible.

A camera, lighting and command speaker assembly could have aided in observing and directing personnel around the reactor or control rooms for safing operations and victim removal. The camera lights could have eliminated the need for personnel to carry lighting while in the reactor or control room.

c. EBR-1 Core II Meltdown, 1955

The highly radioactive core was removed by master-slave manipulators, overhead crane, tongs, saws and drills. Two radiation tolerant TV cameras in the 3D configuration could have helped in directing the handling of the core by the above equipment, resulting in a time and cost savings. Video recording would have provided a permanent record for future analysis of the operation.

d. Borax-I Deliberate Destruction, 1964

The explosion scattered radioactive debris, preventing reactor area access.

A radiation tolerant 3D TV camera assembly on a remotely controlled vehicle could have been used to locate some of the visible pieces of debris and direct remote manipulators to the proper locations. Video recording of the area would have provided the information available for recovery planning.

The Standard Camera could have been used for observing entrance ways and general area.

A microwave transmission link to a remote area of the cleanup operations would have provided current operational status information to many people without the need for travel.

e. NRDS Test Cell "C" Incident

Radioactive debris was scattered over a wide area preventing personnel access.

A standard TV camera mounted on a helicopter and transmitting, by microwave, information to a control point would have provided extensive area information as to the location of the large pieces of radioactive material. The video recorder could have stored this for analysis and planning. Still photos would have also aided in the planning.

A Radiation Tolerant 3D Camera configuration mounted on a remote vehicle would have greatly assisted in directing debris pickup vehicles or personnel to the desired area. In the case of personnel, exposure times could have been reduced by the strategic placement of TV cameras carrying the command speaker for use in personnel direction.

Microwave transmission back to the remote operations area would have provided current operational information and reduced the number of personnel at the hazardous area. This would have also reduced radiation exposure of personnel.

C. THE RELATIVE MERITS OF STANDARD AND HIGH RESOLUTION SYSTEMS

1. Standard TV System Parameters

- a. 525 line scan with 375 line vertical resolution
- b. 600 - 800 line horizontal resolution at 10 mc bandwidth
- c. Vidicon - 1"

2. High Resolution

- a. 567 - 1025 line scan with 390 - 850 vertical resolution
- b. 700 - 1000 line horizontal resolution at 20 - 30 mc bandwidth
- c. Vidicon - 1" or 1 - 1/2"

3. Summary Chart

<u>Item</u>	<u>Standard</u>	<u>High Resolution</u>
a. Standard components	Yes	No
b. Circuit reliability/complexity	Fair	Poor
c. Test Equipment	Standard	Special
d. Resolution	Fair	Good
e. Radiation tolerant	Available	Not developed
f. Adaptability to microwave	Standard	Special
g. Relative signal/noise	Better	
h. Relative cost	Cheaper	
i. Other	Longer cable lengths	Poor availability of spares

4. Discussion

a. Standard Components

For a high resolution system, special monitor and video distribution equipment are required. As yet, the industry has not standardized or defined high resolution.

b. Circuit Reliability/Complexity

The circuitry of a standard system is less critical and easier to align and adjust. If one chain of this system were high resolution, then the monitor, sync generator, and camera control panel could not be used in a standard chain and additional spares would be required. Because of the increased complexity and critical alignment required, reliability will suffer.

c. Test Equipment

Special 20 megacycle equipment is required for high resolution. A special oscilloscope and sweep generator is required for sweeping the system.

d. Resolution

The increased resolution is mostly vertical with little noticeable increase in horizontal. The increased vertical is not as great as one would think because of beam overlap in the kinescope and vidicon. This overlap is caused by present limitations of the beam focusing by deflection coils and tube elements.

e. Adaptability to Microwave

Portable microwave systems are available that will handle 4 - 6 mc bandwidth, but none exists for 20 mc; a semi-portable unit is available using tubes that has a bandwidth of 14 mc.

f. Radiation Tolerant Camera

In the present state of the art, only standard systems exist that are truly radiation tolerant. High resolution and radiation tolerance are conflicting requirements for a TV camera design. This is due to the preamplifier location and design.

g. Relative Signal/Noise

Increasing the bandwidth from 10 mc to 20 mc will decrease the signal to noise ratio by one-half. Long cable and poor operating equipment could easily reduce the resolution to that of a standard system.

h. Relative Cost

The standard system components are cheaper because less time is required at the factory to align and check the equipment. Also, in a wideband system, more circuitry is usually required to achieve the bandwidth.

i. Other

Longer cable runs may be used for a standard system before the signal begins to deteriorate. Availability of spares is a problem because of the many kinds of high resolution systems on the market.

5. Summary

The primary advantage of a high resolution TV system over a standard system, is, of course, its ability to reproduce fine detail while presenting a wider field of view, and this is accomplished mainly by an increase of vertical resolution.

The over-all television system response is the product of the response of all elements within the system and can be no better than the worst element. Therefore, the selection of either standard or high resolution systems must be related to a specific application; and consideration must be given to the response of various elements which effect the over-all system, such as excessive cable lengths, microwave relay transmission, radiation tolerant lens, etc.

With proper selection of lenses, a standard system will provide virtually the same detail response but at a narrower field of view.

A side-by-side comparison of these two systems was accomplished recently at the Kin-Tel factory. All of the previously mentioned effects were evident. Horizontal resolution of each system was virtually identical; the main difference being in vertical resolution and this increase in resolution was primarily evident while viewing alpha-numeric characters.

D. THE RELATIVE MERITS OF THREE AND TWO DIMENSIONAL VIEWING

1. Introduction

Three dimensional viewing of our eyes is often taken for granted and seldom noticed until one begins to manipulate objects remotely with vision limited to that supplied by a conventional TV system. Operations that would normally be quite easy to do become tedious and require considerable skill and experience when depth perception information is missing. A 3D television chain would be a valuable asset to any television system that is used to visually direct and control remote operations.

There are several ways to obtain 3D presentation from television equipment. Four methods are briefly described below.

2. Polarized Two Camera-Monitor

Two completely independent TV camera chains and monitors are time synchronized by a common sync generator to prevent flicker effects which might cause eye strain after long viewing periods. The viewing monitors are placed at right angles to each other. Polarized glass faceplates on the monitors are arranged such that their polar planes are 90° to each other. The images are then superimposed by the use of a half-silvered mirror which is at 45° to each monitor. The observer wears glasses with lenses polarized in a manner similar to the monitor faceplate. This results in each eye receiving a picture from each chain corresponding to the right and left camera.

In actual operation the ocular angles are adjusted for the proper depth effect at the range of viewing distances encountered. An angle of 2° (to each other) is an optimum value and coupled with the variable lens focal length provides depth perception of objects from approximately 2 feet to 50 feet or more from the cameras. This angle is manually adjustable since it is not necessary to change it unless a change of lens

is required. The ocular spacing is remotely adjustable to accommodate the various viewing angles encountered when the zoom lens focal length range is varied. By simply removing the mirror and polarizing glass, two standard 2D camera chains are available.

3. Orthogonal

Although it does not provide a true 3D presentation, it does provide the information. Two TV camera chains are used with each camera viewing the same scene at a different angle, the ideal angle being 90° . The monitors are mounted side by side.

A major advantage of this 3D system is the ability to provide depth perception of a remote viewing location to enable rapid and accurate remote manipulation of items by utilizing standard television equipment and relative simple camera, mounting, and monitoring arrangements. A disadvantage is that the operator is made uncomfortable by continually looking back and forth between each monitor and by the confusion of looking at two images.

The following table lists advantages and disadvantages between 2D, 3D, and orthogonal systems.

	<u>2D</u>	<u>3D</u>	<u>Orthogonal</u>
Simplicity	yes	yes	yes
Eye viewing comfort	yes	yes	no
Ease of alignment	yes	no	yes
3D presentation	no	yes	no
Ease of maintenance	yes	yes	yes
Over-all objective clarity	yes	no	yes

4. Stereotronics

This system called Stereotronics by its inventor uses one camera chain with a twin-lens view system such that two pictures are placed side by side on the camera tube. The monitor uses a mirror, polarized

filter and viewing glasses arrangement to achieve the picture to eye separation. The major drawbacks with this system are the excessive eye strain, loss of one-half the resolution, and narrow field of view.

5. Two Camera Color Monitor

Two individual camera chains are used with a single color monitor. One camera feeds the red electron gun and the other feeds the green electron gun in the color monitor picture tube. The observer wears glasses with a red and green lens to separate the red and green super-imposed pictures. The major drawbacks are excessive eye strain, lower resolution due to the color tube, and problems of maintaining picture tube color purity. The blue and green combination is not used because of its close relative spectrum relationship and resulting color filter separation problems.

The relative advantages and disadvantages of each 3D system are listed in the table below.

	<u>Polarized Two-Camera-Monitor</u>	<u>Stereotronics</u>	<u>Two-Camera Color Monitor</u>
Good resolution	yes	no	no
Eye viewing comfort	yes	no	no
Equipment stability	yes	yes	no

6. Summary

Three dimensional TV viewing is essential where objects must be manipulated remotely. One 3D system should definitely be included in an accident recovery type TV system. Of the four systems discussed, the Polarized Two Camera-Monitor System gives the best 3D picture. It is relatively simple, rugged, and requires only normal maintenance. Although not available off-the-shelf, it can be assembled from standard TV components and easily obtained materials with only a small amount of fabrication required.

E. COLOR CONSIDERATION

1. Introduction

Normal human vision perceives color and, because of this, there are definite advantages for viewing a TV scene in color.

a. Lifelike Scene

From the beginning of time man has been trying to record the pictures he sees in color. The eye is adapt to color and a scene viewed in color is much more pleasing to the eye than one made up of black and white with shades of gray.

b. Improved Contrast

Two objects which appear the same shade of gray in a black and white TV scene would in a color scene be easily distinguishable. However, proper lighting techniques can greatly affect the contrasts in a black and white system.

c. Improved Depth Perception

In black and white systems there is often little difference in shades of gray produced by an object and its shadows. In a color presentation the shadows would be quite evident and improve the depth perception.

There are three major types of color TV systems that could be used for closed circuit work. Each has certain disadvantages and limitations when compared with black and white systems.

2. Conventional Broadcast System

The most expensive and sophisticated, it uses dichroic mirrors and light filters to split the image into red, green, and blue with each of the three colors picked up by a separate tube. A special modulation technique is used to transmit the color and brightness information on one carrier. At the receiver end the signal is demodulated and decoded into three color signals that drive a three-gun color tube.

Some disadvantages:

a. More Costly

At present a color CCTV chain would cost about five times that of a black and white chain.

b. More Complex

A color system of this type is much more complex than a black and white system, which means more skilled operators and technicians will be required. Maintenance costs will be higher.

c. More Light Required

A black and white system using vidicons can provide an adequate picture with a minimum of 10 - 20 foot-candles of reflected light. A vidicon color system, depending on the type, could require 150 foot-candles of light. The color temperature of lighting is also more critical. The amount of lighting equipment required for good color would be prohibitive for a portable, field-type system.

d. Less Resolution

The inherent resolution for a color system is less. It should be remembered that for fine detail, color has little significance. As the colored surface area is decreased, five things happen in succession:

- 1) Blues become indistinguishable from grays of the same brightness.
- 2) Yellows become indistinguishable from grays. Browns are confused with crimsons, and blues with greens. In this range, reds are clearly distinct from blue green.
- 3) Blue greens become indistinguishable from grays.
- 4) Reds merge with grays of equivalent brightness.
- 5) For exceedingly small details, normal vision is devoid of all color sensation and only the brightness perception remains.

The previous statement can be verified by placing small colored dots on paper and viewing at arm's length. This means that a black and white system with 600 lines of horizontal resolution can provide far more detail than a color system limited to less than 400 lines of horizontal resolution. Even if a color system could transmit this fine detail, it would take on shades of gray and lose the identity when viewed by the eye.

e. Availability

Closed circuit color TV systems are not readily available off-the-shelf.

f. Not Radiation Resistant

Color cameras are not radiation resistant and many problems would need to be solved before a color camera could withstand high nuclear radiation.

3. Field Sequential System

This system uses a segmented three-color wheel in front of both the monitor and camera. Each wheel is divided into red, green, and blue segments and are synchronized to present the same color at the camera and monitor. The system presents very good color and is moderate in cost.

Some disadvantages:

1) All the disadvantages that were presented for the three pick-up tube system apply to the field sequential system.

2) The large color wheels needed for the monitor make the system bulky and cumbersome. The rotating wheels can create reliability and performance problems in the equipment due to vibration.

4. Stereotronics System

This is not a true color system but depends upon the physiological characteristics of the eye and brain to make up the colors not transmitted. At the camera, two lenses and color filters split the image into red and

green images with both images presented side-by-side on the vidicon face. A conventional transmitting link may be used. At the monitor, two polarized screens of opposite polarity are placed side-by-side over the monitor. Glasses of one red and one green lens are worn by the observer. The system can be added to any camera and monitor very easily and costs only about \$2,000.

Some disadvantages:

a. Color Presentation

Color presentation is poor. Imperfection in the observer's eyes greatly affects what he sees. Eye fatigue is a problem.

b. Narrow Field of View

The field of view is limited to about 16° .

c. Poor Resolution

The horizontal resolution is reduced to less than one half that of the system without the color adaptor.

5. Summary

Two advantages of a color system, good contrast and depth perception, can often be improved in a black and white system by the use of proper lighting techniques.

With the present state of the art, a color CCTV system would only compound the problems associated with a portable field type TV system. The problems of extra lighting equipment, complexity, cost, resolution, availability and lack of radiation tolerant cameras and filters rule out the use of color.

F. CAMERA QUANTITY JUSTIFICATION

A total of four camera chains have been selected as the optimum number to employ for a portable TV system. Three would be radiation and environmental resistant with the fourth being a general purpose non-radiation tolerant.

While more cameras might sometimes be used, problems such as transportation, weight, cost, and additional complexity become greater than the increased viewing coverage. Weight is a very real problem when one considers that over 3,000 pounds of cable are required for each camera. It is believed that up to four cameras are necessary under some circumstances and reasons for selecting that number are given below.

1) During initial investigations after an accident up to three cameras might be required to quickly view reactor and control rooms and other areas where a search and recovery operation for victims is required. Three cameras would also be useful to speed the assessment of damage and initial clean up operation.

The standard camera located away from the hazardous or high radiation area could be used to monitor personnel going to and from the accident area. It could also be mounted in a helicopter for aerial viewing of the accident.

2) During latter phases when disassembly operations are underway, two of the three cameras could be used in a 3D configuration, the third camera would be used to provide an over-all view along with the 3D view. The third camera would also serve as a back up should one of the 3D cameras fail.

3) If a remotely controlled vehicle were used with one camera on it, at least one and possibly two other cameras might be required to help direct its movements. Table F-1 provides a list of the major characteristics of each camera.

Table F-1 TV CAMERA SYSTEM

Camera number and purpose	Environment	Cable Length	Specifications	Camera Support	Radiation Resistant	Video transmission from camera
Camera No. 1 flexible inside monitor. Observation of indicators, controls, victims, damage. May be used as 1/2 of 3D configuration	Gamma radiation to 10^4 R/hr. 100% humidity. Condensation. -50°F to $+200^{\circ}\text{F}$. shock, vibration	100 feet from camera to pre-amp. 2000' from preamp to control unit	Resolution of 600 lines from 525 line scan and 8 mc bandwidth. Dual camera controls compact and lightweight so one person can carry. All camera control functions at remote locations	Universal bracket capable of mounting on pan & tilt pedestal. Can quickly be mounted to 3D adaptor.	Yes, to 10^8R and 10^{12} m/cm^2 total dose.	By portable microwave or cable
Camera No. 2 Reactor assessment. View re reactor, core, containment vessel for safing or disassembly may be used as 1/2 of 3D configuration	Gamma radiation to 10^4 R/hr. 100% humidity. condensation. -50°F to $+200^{\circ}\text{F}$ shock, vibration	100' from camera to preamp 2000' from pre-amp to control unit.	Resolution of 600 lines from 525 lines scan. Dual camera controls. Very small and light weight. All camera control functions at remote location.	Universal bracket capable of mounting on pan & tilt pedestal. Can quickly be mounted to 3D adapter.	Yes, to 10^8R and 10^{12} n/cm total dose.	By portable microwave or cable.
Camera No. 3 Control room viewing of gauges & meters. Supplements cameras no. 1 & 2	Gamma radiation to 10^4R/hr . 100% humidity. condensation. -50°F to $+200^{\circ}\text{F}$ shock, vibration	100' from camera to pre-amp 2000' from preamp to control unit.	Resolution of 600 lines from 525 line scan. Dual camera controls. Very small & light weight. All camera control functions at remote location.	Universal bracket capable of mounting on pan & tilt pedestal, can quickly be mounted to 3D adapter.	Yes, to 10^8 R and 10^{12} n/cm^2 total dose.	By portable microwave or cable.

TV CAMERA SYSTEM (Cont.)

Camera number and purpose	Environment	Cable Length	Specifications	Camera Support	Radiation Resistant	Video transmission from camera
Camera No. 4 All purpose and outside area monitor view immediate site area, inside area where low radiation exists	Gamma radiation less than 10^2 R/hr, under-water, condensation, -50°F to $+150^{\circ}\text{F}$ shock vibration, wind, sand/dirt, Fungus, salt spray	2000' from camera to control location	Self-contained camera unit capable of 2000' separation from remote control unit. Lightweight and compact resolution of 600 lines from 525 line scan environmental container for camera.	Hand held camera, universal bracket for crane boom. Capable of mounting on remote pan and tilt unit	No	By portable microwave or cable

G. THE NEED FOR RECORDERS IN THE TV SYSTEM

1. Introduction

Accident recovery operations usually involve many people and situations. It generally becomes necessary to provide an accurate record of the operations for further study, analysis, and evaluation. Frequently, written accounts, notes, and debriefings must be assembled into a logical and concise report, but difficulties may arise in obtaining the overall picture because of inaccurate notes, lack of specific information, and normal personnel retention capabilities.

Additionally, many decisions must be made as to reactor safing, damage clean up, etc. A pictorial representation of the accident and damage extent is necessary for close examination to aid in the proper decision. Radiation levels which may be present in the area causes difficulties in obtaining the desired pictures.

It then appears that the television system offers an ideal picture source readily capable of the various recording techniques available.

Audio commentaries are also very useful in explaining the various pictures being viewed and are particularly helpful in depicting the progression of events.

The equipment recommended for effectively assisting the overall operations is summarized as:

- a. Video Tape Recorder
- b. Video Motion Picture Film Camera Recorder
- c. Still Film Camera
- d. Audio Tape Recorder

The following paragraphs describe each method.

2. Video Tape Recorder (VTR)

The VTR (about \$12,000) is the most useful device in the recorder package in that it can record and immediately playback both video and audio information concurrently or separately. A stop-motion feature

allows a single frame (picture) to be displayed for examination or further recording by the still camera. The recorded tape can then be stored for future use. The tape permits easy editing; e. g. , the sound can be easily edited to more accurately reflect the concurrent picture information.

However, some major disadvantages exist with the present day portable tape recorders. These are (1) the capability of only about 300 lines (horizontal) picture resolution which is roughly a 50% reduction relative to the usual 600 lines of resolution for the television chain and (2) the video/audio information on the tape is not of form which can be easily played back at other locations since the tape will require an identical type machine, not normally available in most locations.

It is strongly recommended that only the best quality portable recorder be utilized (such as the Ampex 660) because much dependance is placed on the recorder once the operations are in full swing and field repairs are sometimes difficult and very time consuming.

3. Video Motion Picture Film Camera Recorder

A professional quality 16 mm film camera can be easily and quickly placed in front of a video monitor for video information recording. The camera will have to be modified for video recording, but most camera manufacturers provide this modification at a slight increase in overall cost (Total about \$2,000).

The film recording provides resolution capabilities which are better than the Video Tape Recorder but less than the actual monitor picture. It permits film playback on any standard 16 mm projector, a very important advantage if the film is shipped to other locations for viewing.

Film inconvenience and lack of instant playback capabilities are its major drawbacks.

It is not desirable to record "sound on film" concurrently with the video picture since recorder complexity and later film editing costs and time are increased due to the processing involved. The "sound on film" can be added by first using an audio tape recorder for the audio commentaries, editing this for synchronization with the picture, and then dubbing it on the film sound track.

4. Still Film Camera

The still camera becomes very useful where a scene, whether it be from the television cameras or video tape recorder, needs to be viewed by personnel for purposes of close and detailed scene examinations. This could be necessary in reaching decisions as to reactor safing, reactor condition, damage assessment, etc.

The picture is easily and quickly recorded from a video monitor. Polaroid film could be used for immediate pictures, or standard film packs could be used if processing time is available or if many prints are necessary.

5. Audio Tape Recorder

An audio tape recorder can be extremely helpful during and after accident recovery operations.

Among the possibilities are (1) commentaries relative to the overall operation for future use or documentation; (2) intercom channel conversation recording to permit future analysis of camera entry problems and comments on environmental conditions; (3) commentaries for later film dubbing; and (4) recording of debriefings, radiation area encounters, instructions, etc.

H. LARGE SCREEN TV PROJECTOR

An extremely useful accessory for the television system is a large screen television projector.

During accident recovery or related operations many responsible people not directly connected with operations will want to view the progress. These people should not be at the operating control point as they would contribute to traffic and security problems.

With television, a convenient remote viewing location could be setup very easily. This location, a theatre auditorium, hall or the like could provide viewing for a large number of people when equipped with a large screen television projector. The projector in size and weight is comparable to a standard TV monitor and is not difficult to transport. Operation and adjustments are no more difficult than for a monitor.

The projector provides a picture of up to 8 feet in width at a throw distance of approximately 16 feet. The resolution of the picture is about 80% of a video monitor. The highlight illumination of the picture at the screen is 3 to 4 foot-candles incident. The reflected illumination is determined by the gain of the viewing screen, which provides about a ten-fold increase in the reflected light.

The input signal is easily obtained from any 75 ohm video source, 1.4 volts p-p. This will be provided by either the microwave relay link or from a distribution amplifier through the use of coaxial cable.

I. PACKING CASES VERSUS TRAILER FOR SYSTEM MOUNTING

1. Introduction

Of prime importance is the overall system packaging technique. It is imperative that adequate protection is provided for all equipment during storage, transportation and operation as outlined in the Functional Requirements (also System Design).

The two methods available for accomplishing this task are (1) the use of packaging containers, each containing an individual item of equipment, or (2) the employment of a trailer containing all the equipment with possible exception of the large cable reels. The relative merits of each method are summarized as:

2. Summary of Relative Merits

<u>Condition</u>	<u>Packing Case</u>	<u>Trailer</u>
a. Transportation	Chance of loss, easily handled. Shipped rapidly by air freight.	Equipment together but needs tractor. Slow cross country movement.
b. Storage	Needs to be set up occasionally as check.	Ready to go for checking with some unpacking.
c. Set up Time	One system rapidly set up.	Control monitor equipment ready to go. One system hard to separate.
d. Environmental Proof in storage or transportation.	Good	Good
e. Environmental Proof during operation.	Will need cover.	Self-contained.
f. Equipment Reliability	Chance of rain, mud, heat, cold during operation.	Protected and controlled environment.

<u>Condition</u>	<u>Packing Case</u>	<u>Trailer</u>
g. Adaptability/ Flexibility	Excellent	Poor
h. Upkeep	None	Yes, on tires, bearings, air conditioning
i. Relative Cost	About the same.	

3. Discussion

a. Packing Cases

This approach has a major advantage in that complete flexibility is provided since one camera could be easily separated for use in areas apart from the main system and could be initially rushed to an accident site for use. The system could be assembled in stages, depending upon the equipment needed. At the accident site, each chain could be separated if it was desired to locate the Camera Control Unit near the preamplifier for microwave video transmission.

Some inconveniences would occur in assembling the cases for shipment and insuring that all arrive at their destination. The container cover and cable access door would be open during operation, which might expose some delicate equipment if not covered, to harmful environmental effects such as mud, snow, rain, etc. Complete environmental protection for operation of container mounted equipment would be very costly.

b. Trailer

All equipment would be mounted or stored in the trailer with possible exception of the large cable reels. Complete environmental protection would be provided which would help to increase reliability. It would provide shelter for the operator. Ease of system checkout during storage would be possible.

The trailer would be costly unless available through surplus. Some costs would be required to provide heat pump, equipment racks, and storage bins. It would be difficult to separate individual camera chains from the overall system if needed elsewhere. Maintenance would be required on the trailer in the form of tires, lubrication, etc. Cross country transportation would be slow. The heavy cable reels would still require either another trailer or separate shipment.

4. Summary

It appears that either method of packaging could be utilized successfully with the television system. Certain benefits are derived from each technique but the trailer does offer complete system protection at all times. However, the cable reels would still be handled separately. The packing cases offer extreme flexibility in handling, multiple location coverage and adaptability to new equipment.

J. REMOTE CONTROLLED CAMERA VEHICLE

1. Introduction

The movement and positioning of a television camera and its accessories for thorough investigation, within high radiation or other hazardous areas, can be safely accomplished by the use of a remotely controlled camera vehicle. The vehicle must have certain characteristics such as:

Lightweight so that a maximum of 4 men can carry
(about 400 pounds)

Able to roll through standard size doorways and
around sharp corners.

Operate satisfactorily in high radiation levels
(10^4 R/hr).

Electromechanically driven.

Able to roll over debris without stalling or over-
turning.

Able to climb 60% grade.

Able to support 120 pounds of camera/accessory
weight.

Able to raise and lower camera from approximately
40 inches to 70 inches.

Easy to wash down and decontaminate.

A search was conducted to determine the availability of a vehicle which would satisfy the above requirements. The results of this search follow below.

2. Programmed and Remote Systems Corporation (PaR)

This company manufactures the PaR-1 vehicle (sometimes called "Ranger"), a small track laying vehicle designed primarily as a remote handling system. It is available without manipulator arms for use as a camera vehicle. Its dimensions are 30 inches wide by 36 inches long and it weighs 800 pounds with telescoping mast and without manipulators or TV cameras. The weight of the unit makes its carrying capabilities by

three or four men virtually impossible; however, it was purposely made this way to allow sufficient traction for pulling or carrying a 100 foot, or more, length of cable. Its low slung design makes it difficult to negotiate debris. The ribbed rubber track, which is driven by a drive wheel, can cause maneuvering difficulty if debris becomes lodged between the track and wheel. Drive is accomplished by DC motors controlled from a power center and control box which can be located at 2,000 feet or more from the vehicle. The power center contains the motor magnetic amplifiers, relays, mounted in a caster-mounted cabinet, 24 inches wide, 22 inches deep and 61 inches high. The cost of the system is approximately \$9,000 to \$10,000, depending upon controls desired.

3. Thiokol Chemical Company (Logan Division)

This company has performed some investigation into small, remote controlled vehicles which could climb stairs; however, they are not interested in developing a workable model at this time, unless the need for production quantities exist.

4. FMC Corporation (Ordnance Division)

The FMC Corporation has proposed a vehicle which is lightweight and with relatively simple construction. The following is the proposal from FMC: (Figure 15)

To move a camera unit into a hazardous environment for observation purposes requires the simplest of vehicles that can be self-propelled and controlled from a safe remote point. It must be small to negotiate standard doorways, short so that it can negotiate a reasonable amount of debris without overturning. With pan, tilt and zoom capability, the need for camera positioning with respect to the vehicle itself is minimized to one of raising and lowering for proper attitudes.

The attached Figure depicts such a vehicle. It is small, able to go through doorways, can pivot turn about one side wheel or even rotate about the axle center, and is stable

Figure 15. Proposed Camera Vehicle.

on uneven terrain on its three-point suspension.

The camera boom can be raised through a considerable angle by relatively small travel of a linear actuator.

For the terrain most likely to be encountered, tracks are not considered to have any advantage. Because the vehicle is so small and narrow, tracks must be short, requiring small sprockets and idlers, and obstacle climbing capability is thus downgraded. Relatively large wheels are as aggressive as a small track, and have advantages in ease of steering and in climbing over reasonably large objects. The three-point suspension prevents vehicle teetering on uneven terrain, and the higher ground clearance possibility minimizes hanging up on obstacles.

As control distance is relatively long, an AC system should be used to minimize power loss. The vehicle drive motors are of series construction using a shunt circuit that provides variable speed capability and constant torque. Both motors will track together for straight ahead or reverse operation. The combination of worm gear and motor brake effectively locks one wheel, so power to the other wheel provides turning capability. Further control refinements, if desired, could produce any degree of turn capability rather than a simple turn about one wheel.

The basic structure is aluminum, to minimize the weight. At the same time, aluminum is less susceptible to residual contamination than is steel. The motors and drives make up the bulk of the weight, and thus the center of mass is approximately at axle height and between axles for maximum stability.

Normal operating direction is with the castored wheel forward. With camera boom lowered for maximum vehicle stability while in motion, the front of the vehicle is also seen by the camera, and serves as a reference point in driving the vehicle.

A total of 1-1/2 HP in the drive motors will develop all the tractive effort at 1 MPH that the weight of the vehicle can produce. This tractive effort obviously places a limit on the length of cable that can be dragged behind, but this is probably in excess of 100 feet.

A cable reel and slip rings on the vehicle are practical for the power supply, but extreme difficulties are encountered in transmitting the TV signal. At the same time, considerable weight would be added to the vehicle.

Power and control signal for the vehicle requires a number of wires in a multiple conductor cable. Pan, tilt, zoom, iris control and the TV signal can probably best be handled in a commercially available cable of their own. Thus two cables are trailed, rather than the one shown in the sketch. A single cable is possible, but would be quite stiff and heavy. Two more flexible cables, appear to provide increased range and maneuverability to the machine.

It is assumed the cables will be payed out while the machine advances, and will be pulled back when it returns. An identical machine, as a cable carrier, might be started out after the first as a means of increasing the range if necessary.

At the control console, vehicle control can be provided by a single joy stick. Motion forward or backward produces vehicle motion forward or back. Greater displacement provides greater speed. Right or left produce a right or left turn. Spring return of the joy stick provides fail safe stop with motor brakes locked. A rocker button provides for raising and lowering the camera boom.

Preliminary specifications for this vehicle are as follows:

Frame	Aluminum Tricycle type
Front wheel	Castored
Wheel diameter	18"
Wheel base	30"
Width	30"
Camera height-lowered	36"
Camera height-raised	72"
Drive	2 AC gear motors with brakes, series construction, shunt circuit, variable speed, constant torque

Weight	225 lbs. approximately, without camera equipment
Tractive effort	210 lbs. with gross weight of 300 lbs.

Many other possibilities exist for increasing the flexibility of the boom arrangement. For one, a manual or automatic boom extension capability would allow the camera to peer inside a window or opening. Another possibility is to provide a technique for swinging the boom 180° from its driving position (as pictured) for peering into openings or down a reactor opening.

All camera, lens and pan/tilt controls will be located in a separate unit to eliminate complicated interface problems, particularly with the 3D configuration. A budgetary cost figure for one vehicle has been estimated by FMC to be between \$35,000 and \$45,000.

Additional information received from FMC indicates that the total weight including camera is 300 pounds. Weight of the vehicle itself will be from 200 to 250 pounds and is capable of handling loads to 120 pounds. With 300 pound gross vehicle weight, the tractive effort on smooth floor will be approximately 70% of the total or 210 pounds. The cable handling problems with this vehicle may be somewhat resolved by careful driving techniques, although this does limit its range. However, since the vehicle is relatively lightweight and since the cable will be abrasion resistant (radiation tolerant), no deleterious effects to the cable will result if the vehicle rolls over it.

Based on the system mission, it appears that the FMC unit will provide the best operating configuration in a wide range of conditions such as travel over debris, sand and mud. It is easily handled by 3 or 4 people. Its simplicity allows ease of decontamination and insures reliable operation with a minimum of components.

Although the PaR unit is less expensive, its practical utilization is not possible under the wide range of operating conditions that may be encountered.

K. RADIATION ENVIRONMENT CONSIDERATIONS

1. Radiation Environments

The radiation environment to be tolerated by the TV System, without performance degradation, has been tentatively specified as consisting of:

Gamma:	10^4 roentgen/hr to an accumulated dose of 10^8 roentgen
Neutron:	10^3 n/cm ² -sec to an accumulated exposure of 10^{12} n/cm ²

2. Radiation Environment Acceptance Test

In "Functional Requirements", Section IIIB, "Environmental Requirements", it is stated that "equipment design will assure an adequate safety margin such that demonstrative environmental testing shall in no way affect its after-test operation". This requirement is relaxed in the case of the radiation environment, since exposure to the environment can produce irreversible permanent damage to certain critical components.

3. Radiation Sensitivity

For the specified radiation environments, the components and materials used in such a TV system are not significantly rate sensitive at these low rates. Therefore, radiation rate will not be the governing limitation. Instead, total radiation exposure is the criteria for component and system hardening specifications.

Compliance with the following remarks will, in general, result in a system capable of operating satisfactorily in the specified environment. Use of unapproved substitutes can result in marginal performance, excessive maintenance or lead to early failure.

4. TV Camera

This is one of the most radiation sensitive units in the entire TV system and will be among the closest to the radiation source. Because of the close proximity to the source, a special physical configuration is required to minimize the number of sensitive components in the radiation environment in order to achieve a radiation tolerant system.

The actual camera head is to contain the zoom lens, a vidicon of special construction with its deflection coils, no more than two electron tubes for signal conditioning between the vidicon and a remotely located preamplifier, and a minimum of passive circuit elements.

a. Optical System

Ordinary optical glasses exhibit excessive darkening or browning at gamma exposures as low as 10^5 roentgen gamma. The zoom lens for this camera must be constructed of non-browning type glasses. Some browning of a non-browning lens might be expected at 10^5 roentgen, however, it is felt to be correctable by the zoom lens iris control.

The three motors for zoom, focus and iris control, should use non-Teflon, high temperature insulating materials. The capacitors used for electrical noise suppression from the motors should be of ceramic construction. Other types of construction in the range of capacitance values required are inferior when in a radiation environment.

If excessive lens browning occurs, they may be "bleached" by aging or by controlled oven baking at 150°F to 200°F , which cuts the bleaching time in half. The lens should clear in several hours to several months, depending on the magnitude of browning.

b. Active Elements

Diodes, (used for blanking) if of the solid state type, must be germanium high frequency types. Signal conditioning amplifiers must use electron tubes of the nuvistor type. The vidicon of standard construction is incapable of withstanding the expected shock and vibration of transportation

and emplacement. Furthermore, the standard vidicon uses a glass in the faceplate which would exhibit excessive browning by gamma radiation. A vidicon of ruggedized construction and having a faceplate of pure fused silica (non-browning quartz) such as the RCA C74134 must be used.

c. Passive Elements

Resistors should be either carbon composition or wire wound. Metalized film resistors do not tolerate radiation environments as well as the above.

Dependent on required circuit values and in order of preference (radiation tolerance) capacitors should be ceramic, metalized Mylar (unoiled), tantalum, or 50% voltage derated dry electrolytics. Epoxy end seals are recommended over Teflon or boron-glass end seals.

d. Sun Filter

The sun filter should be a dichroic type filter with a base material of pure fused silica (non-browning quartz). Cemented gelatin or tinted glass filters are not recommended.

5. Lighting

The glasses used in conventional lamps for TV illumination purposes are unsuited for the specific radiation and vibration environments. Quartz bulbs must be used instead. In particular, a quartz-iodine lamp in a properly designed housing is well suited to this application, and is therefore specified. Should the quartz bulb show a slight amount of browning, it will be annealed out by the high operating temperature of the bulb when the lamp is turned on. The quartz-iodine lamp is also of rather rugged construction and should be able to withstand the expected shock and vibration.

6. Pan and Tilt Head

Motor and capacitor requirements as given above under Optical System are applicable to the motors and capacitors in the pan-and-tilt head. Many gear lubricants available show significant performance

degradation at 10^8 roentgen gamma exposure. Unsubstituted polyphenyl ethers and certain mineral- and glycol-based fluids with specific additives should be considered as substitute lubricants for the intended radiation environment.

7. Intercom Speakers

No specific information is currently available on radiation tolerance of intercom loudspeakers. It is known, however, that many installations exist using these devices, for example, KIWI and ROVER test stands at the Nevada Test Site. No difficulties have been sustained there requiring loudspeaker replacement due to radiation damage. The exposure levels experienced by these loudspeakers are not accurately known; however, the levels are known to be considerably greater than those specified for this TV system.

A loudspeaker of weatherproof type construction is recommended, and is felt to be more radiation resistant than one of ordinary construction.

8. Preamplifier

The preamplifier will consist of a large number of electronic components. In the interest of conservation of power consumption, the preamplifier is to use solid state components for the active devices. Solid state devices are extremely sensitive to radiation induced degradation. At present, there is little that can be done to radiation harden the solid state components for the environment specified. The alternative in this case is to use a combination of physical separation and radiation shielding to achieve a sufficiently low radiation environment which the preamplifier will tolerate. The tentative separation distance is to be 100 feet.

The material to be used for its fabrication is ordinary concrete. Reinforcing rods should be used in order to minimize risk of fracture during rough handling.

The recommended shield for the preamplifier is as follows:

Figure 16. Preamplifier Shield

To further minimize damage as well as an aid in decontamination procedures, the shield should be enclosed in a watertight heavy gauge sheet metal skin, preferably stainless steel, as shown in the figure.

For the shield thicknesses indicated, and for a 100 foot separation between radiation source and preamplifier, radiation exposure inside the shield will be limited to a total exposure of approximately 1×10^9 n/cm² and 1×10^5 roentgen.

The cutouts for the connectors should be large enough to pass the mating cable connector without interference.

The recommended use of the shield is as follows: The shield is placed open side up, 100 feet from the radiation source or 100 feet from point of closest approach by the camera head. If possible, the shield should be placed so that neither cable connector cutout faces the radiation source in order to minimize radiation streaming through the cutouts. The preamplifier is placed in the shield opening with the cable connectors already mated. The slab cover is then placed over the opening to complete the installation.

The approximate weight of the shield (empty) is 115 pounds, and the approximate weight of the cover is 88 pounds.

9. Remote Control Camera Vehicle

The comments and specifications made for motors, capacitors and lubricants apply to this unit as well. The type of material used on the wheels and/or track of the vehicle is not extremely critical; however, rubber components may harden somewhat at high radiation levels.

10. Connectors

Connectors with ceramic insulation for the pin inserts are known to be able to tolerate the specified radiation environment without degradation of insulation resistance and strength. Organic type insulations are not desirable, although a few types may be acceptable for this application.

11. Cables

Electrical and electronic signal cables of standard construction are susceptible to loss of flexibility, insulation resistance, hardening and subsequent brittleness of the insulation, when exposed to large amounts of radiation. Special radiation resistant cables are required between the camera and preamplifier, and for some distance from the zoom lens, lights, pan-and-tilt head and the vehicle. Since a preamplifier will be required at 100 feet from the camera, a cable junction box can be located here also. From this point forward to the units mentioned above, radiation tolerant cables must be used. From the preamplifier back to the control point, cables of standard construction can be used. Teflon or other fluorocarbon resins should be completely avoided.

12. Expendable Items

Certain items of equipment subject to radiation may be handled as expendable since their replacement costs are small and outweigh any special radiation hardening development costs. These items are:

- a. Command speakers
- b. Headsets
- c. Camera preamplifier circuit boards, if shielding is not utilized.
- d. Quartz lamps
- e. Sun filter

13. Lubricants

For radiation tolerance the following lubricants should be utilized:

- a. Viscosity SAE 10 to 20.
Calresearch (California Research Corporation) 59R-439, or equivalent.
- b. Viscosity SAE 60.
Calresearch 4P5E, or equivalent.

- c. Grease.
Calresearch 159, or equivalent.
- d. Dry-Film Lubricant.
Any of the commercially available dry-film lubricants having the following approximate composition: 71% MoS_2 , 70% graphite, 22% sodium silicate (or sodium phosphate or potassium silicate).

L. MARKET SURVEY

A market survey of television equipment and accessories was conducted to determine what was currently available on the market. Of prime interest was the availability of high quality, radiation tolerant camera systems. At the present time, only Cohu Electronics (Kin Tel Division) is producing cameras of proven radiation tolerance as an "off the shelf" item. Dage and ITT have discontinued their radiation tolerant models. Dage, ITT, GPL, GE, and others are producing cameras which can be modified for use in radiation environments; however no actual performance results and definitive data are available, except for GE.

The following is a list of vendors which were either contacted or for which information was available on file:

1. Ace Hose Reel Company, 3001 East 12th Street, Los Angeles, California
2. Adler Westrex Communications Div. , 1 LeFevre Lane, New Rochelle, New York
3. Admiral Corp. , Gov't Electronics Div. , 3800 West Cortland Street, Chicago, Illinois
4. Aero-Motive Manufacturing Company, P.O. Box 2678, Kalamazoo, Michigan 90023
5. Akutron Inc. , 8451 Standustrial, Stanton, California
6. Alpha Wire Corp. , 711 Lidgerwood Avenue, Elizabeth, New Jersey
7. Ameco, Inc. , P.O. Box 11326, Phoenix, Arizona
8. American Communications Corp. , 280 Broadway, New York, New York
9. Ampex Corp. , Southwest Region, 8467 Beverly Blvd. , Los Angeles, California
10. Amphenol Connector Division, Amphenol Corp. , 1830 South 54th Avenue, Chicago, Illinois

11. Automation Laboratories, Inc. , 179 Liberty Avenue, Mineola, New York
12. Avia Products Company, Inc. , 631-B South Walnut, La Habra, California
13. Bach Auricon, Inc. , 6950 Romaine Street, Hollywood, California
14. Baughman Company (E. J.), 1914 North Cogswell Road, El Monte, California
15. Belden Manufacturing Company, Box 5070-A, Chicago, Illinois
16. Benco Television Assoc. , Ltd. , 27 Taber Road, Rexdale, Ontario, Canada
17. Bendix Corp. , Bendix Radio Div. , East Joppa Road, Baltimore, Maryland
18. Bionic Instruments, Inc. , 221 Rock Hill Road, Bala Cynwyd, Pennsylvania
19. Birns & Sawyer, 6424 Santa Monica Blvd. , Hollywood, California
20. Blonder-Tongue Laboratories, Inc. , 9 Alling Street, Newark, New Jersey
21. Bludworth Marine Div. , States Electronics Corp. , 96 Gold Street, New York, New York
22. Boston Insulated Wire & Cable Company, 65 Bay Street, Dorchester, Massachusetts
23. C-Cor Electronics, Inc. , Box 824, State College, Pennsylvania
24. Camera Equipment Company, Inc. , 315 West 43rd Street, New York , New York
25. Cohu Electronics, Inc. , Kin Tel Division, 5725 Kearny Villa Road, San Diego, California
26. Collins Radio Company, Dallas, Texas
27. Colortran Industries, 630 South Flower Street, Burbank, California
28. Conrac, Div. of Giannini Controls Corp. , Glendora, California
29. Dage Television Company, 455 Sheridan Avenue, Michigan City, Indiana
30. Dalto Electronics Corp. , Oak Street, Norwood, New Jersey
31. Davis & Sanford Company, Inc. , 24 Pleasant Street, New Rochelle, New York 10802

32. D B M Research Corp. , Box 521, Cocoa Beach, Florida
33. Diamond Electronics, Box 415, Lancaster, Ohio
34. Dick, A. B. Company, 5700 West Touhy Avenue, Chicago, Illinois
35. Dynair Electronics, Inc. , 6360 Federal Blvd. , San Diego, California
36. Electrospace Corp. , 12 East Morris Avenue, Glen Cove, New York
37. Elgett Optical Company, Inc. , 303 Child Street, Rochester, New York
38. Entron, Inc. , 2141 Industrial Parkway, Silver Spring, Maryland
39. Fairchild Laboratories (Dumont), 750 Bloomfield Avenue, Clifton, New Jersey
40. FMC Corp. , Ordnance Div. , San Jose, California
41. GBC America Corp. , 89 Franklin Street, New York, New York
42. General Electric Company, Industrial Sales Div. , 1 River Road, Schenectady, New York (District Sales Manager, Suite 210, 232 North Lake Avenue, Pasadena, California)
43. General Electric Company, Lamp Div. , Cleveland, Ohio
44. General Electrodynamics Corp. , 4430 Forest Lane, Garland, Texas
45. General Instrument Corp. , Radio Receptor Div. , Andrews Road, Hicksville, New York
46. General Television Network, 901 Livernoise Avenue, Ferndale, Michigan
47. Giannini Controls Corp. , 1600 South Mountain Avenue, Duarte, California
48. Giannini Scientific Corp. , 185 Dixon, Amityville, New York
49. G P L Div. , General Precision, Inc. , 63 Bedford Road, Pleasantville, New York (Represented by McBride Associates, 3321 West Slauson, Culver City, California)
50. Graflex Inc. , Rochester, New York 14603
51. Halliburton Enterprises, Inc. , 4724 South Boyle Avenue, Los Angeles, California
52. Hickock Electrical Instrument Company, 10555 Dupont Avenue, Cleveland, Ohio 44108
53. Houston Fearless Corp. , 11801 West Olympic Blvd. , Los Angeles, California

54. Industrial Electric Reels, Inc., 1509 Chicago Street, Omaha, Nebraska 68102
55. International Nuclear Corp., 608 Norris Avenue, Nashville, Tennessee
56. ITT Cannon Electric Div., 3208 Humboldt Street, Los Angeles, California
57. ITT Industrial Products Div., (TV), International Telephone & Telegraph Corp., San Fernando, California
58. ITT Kellogg, Communication Systems, 500 North Pulaski Road, Chicago, Illinois
59. Jefferson Wire & Cable Corp., 181 Greenwood Street, Worchester, Massachusetts 01607
60. Jensen Manufacturing Company, 6601 South Laramie Avenue, Chicago, Illinois
61. Jerrold Electronics Corp., Industrial Products Div., 15th & LeHigh Avenue, Dept. ITE-138, Philadelphia, Pennsylvania
62. Kaiser Aerospace & Electronics Corp., Box 9098, Phoenix, Arizona
63. Lear Siegler, Inc., Hallamore 3171 South Bundy Drive, Santa Monica, California
64. LTV Continental Electronics Div., P. O. Box 17146, Dallas, Texas
65. LTV-Ling-Temco-Vought, Inc., Box 5003, Dallas, Texas
66. Magnecord, Midwestern Instruments, Box 7509, Tulsa, Oklahoma
67. Marconi Radio, Div. English Electrical Corp., 750 3rd Avenue, New York, New York
68. Micro-Link Corp., 1355 Marconi Blvd., Copiague, Long Island, New York
69. Microwave Associates, Inc., Burlington, Massachusetts
70. Milliken Company (D. B.), 131 North 5th Avenue, Arcadia, California 91006
71. Miratel Electronics, Inc., 3600 Richardson Street, St. Paul, Minnesota 55112
72. Mitchell Camera Corp., 666 West Harvard Street, Glendale, California
73. Mole-Richardson Company, 937 North Sycamore Avenue, Hollywood, California

74. Motorola Communications & Electronics Inc. , 222 West Osborn Road, Phoenix, Arizona
75. North America Philips Company, Inc. , (Philip's-Norelco), 100 East 42nd Street, New York, New York
76. Oceanographic Engineering Corp. , Box 1560, La Jolla, California
77. Packard-Bell Electronics Corp. , 12333 West Olympic Blvd. , Los Angeles, California
78. Palmer Films, Incorporated, (W. A.), 611 Howard Street, San Francisco, California
79. PAR (Programmed & Remote Systems Corp.), 899 West Highway, St. Paul, Minnesota
80. Pelco Sales, Inc. , 351 East Alondra Blvd. , Gardena, California
81. Philips Electrical Instruments, 750 South Fulton Avenue, Mt. Vernon, New York
82. Photo Research Corp. , 837 North Cahuenga Blvd, Hollywood, California
83. Pierpont Industries, Inc. , 77-15 25th Avenue, East Elmhurst, New York
84. Precision Instrument Company, Stanford Industrial Park, 3170 Porter Drive, Palo Alto, California
85. Quam-Nichols Company, Marquette Road at Prairie Avenue, Chicago, Illinois
86. Quick-Set Inc. , 8121 Central Avenue, Skokie, Illinois 60078
87. Radiant Manufacturing Corp. , 8230 North Austin Avenue, Morton Grove, Illinois
88. Radio Communication Company, 1020 East Land Place, Milwaukee, Wisconsin
89. Radio Corp. of America, Broadcast & Communication Products Div. , Front & Cooper Streets, Camden, New Jersey
90. Radio Corporation of America, Defense Electronic Products Div. , Front & Cooper Streets, Camden, New Jersey
91. Raytheon Company, Regional Commercial Sales, 12701 South Van Ness, Hawthorne, California 90250
92. Research Instruments Corp. , 16 South 12th Street, Richmond, Virginia

93. Riker Industries, Inc. , 875 East Jericho Turnpike, Huntington Station, New York
94. R. M. S. Association, Inc. , 102 East Sanford Blvd. , Mt. Vernon, New York
95. Sarkes Tarzian, Inc. , Semiconductor Div. , 415 North College, Bloomington, Indiana
96. Siemens America Inc. , 350 5th Avenue, New York, New York
97. Sony Corp. of America, Industrial Products Div. , 580 5th Avenue, New York, New York
98. Spectron, Inc. , 4216 Ponce De Leon, Coral Gables, Florida
99. Spencer-Kennedy Laboratories Inc. , 1320 Soldiers Field Road, Boston, Massachusetts
100. Square-D Company, P. O. Box 472, Milwaukee, Wisconsin
101. Surface Conduction Inc. , 1501 Broadway, New York, New York
102. Sylvania Electric Products Inc. , Home & Commercial Electronics Div. , 700 Ellicott Street, Batavia, New York
103. TA Manufacturing Corp. , 4607 Alger Street, Los Angeles, California 90039
104. Techniserv Corp. , 370 North Halstead Street, Pasadena, California
105. Tektronix Inc. , P. O. Box 500, Beaverton, Oregon 97005
106. Telectro Industries Corp. , 35-16 37th Street, Long Island City, New York
107. Telemet Company, 185 Dixon Avenue, Amityville, New York
108. Tele-Sonic Company, Reiman Enterprises, 663B South Indian Hill Blvd. , Claremont, California
109. Teletronics, Inc. , 7542 Park Avenue, Garden Grove, California
110. Television Utilities Corp. , 10-11 50th Avenue, Long Island City, New York
111. Telex/Acoustic Products, 3054 Excelsior Blvd. , Minneapolis, Minnesota
112. Triplett Electrical Instrument Company, 286 Harmon Road, Bluffton, Ohio 45817
113. Utah-American Corp. , 1124 East Franklin Street, Huntington, Indiana

114. Vare Industries Inc. , 128 West 1st Avenue, Roselle, New Jersey (Kinescope Recorders)
115. Victoreen Instrument Company, 5806 Hough Avenue, Cleveland, Ohio
116. Viking of Minneapolis Inc. , 9600 Aldrich Avenue, Minneapolis, Minnesota 55420
117. Vue-Tronics, Div. of Prescott Television Company, 920 North Citrus Avenue, Los Angeles, California
118. Westbury CATV Corp. , 212 South Fulton Avenue, Mt. Vernon, New York
119. Western Electric, Graybar Electric Corp. , 210 South Anderson Street, Los Angeles, California
120. Westinghouse Electric, Electronic Tube Div. , Box 284, Elmira, New York
121. Westinghouse Electric Corp. , Industrial Equipment Div. , P. O. Box 225, Buffalo, New York 14240
122. Winsco Instruments & Controls Company, 1533 26th Street, Santa Monica, California
123. Wollensak (Revere-Wollensak Div.), 3M Company, 850 Hudson Avenue, Rochester, New York 14621
124. Zero Manufacturing Company, 1121 Chestnut Street, Burbank, California
125. Zolomatics Corp. , 5875 Melrose Avenue, Hollywood, California
126. Zoomar Inc. , 55 Sea Cliff Avenue, Glen Cove, Long Island, New York

The following list contains the vendors which are a possible source of supply for the Television System. General comments are included, delineating the vendor's products and capabilities.

1. Ace Hose Reel Company
Cable reels, Special Order only.
2. Aero-Motive Manufacturing Company
Cable reels. Stock reels or Special Order.
3. Alpha Wire Corporation
Multiconductor and coaxial cable available and in stock.
4. Ampex Corporation
Market Marconi TV equipment and manufactures audio and video tape recorders. Marconi produces no radiation tolerant equipment.

Ampex Video Tape Recorders:

Model 660 (\$11,500 with stop-variable slow motion). A versatile, high quality, long play (5 hours), tape recorder which produces tapes that are reproducible on any other Ampex 660 tape recorder. This recorder has many outstanding features, such as skew adjustment, dynamic braking, etc., to insure high quality recordings. Uses 2" tape. Weighs 100 pounds.

Model 303 (\$4,000) A lower quality, short play (50 minutes) recorder for applications where limited resolution is suitable. Uses 1/4" tape.

Ampex Audio Tape Recorders:

Model 602 (\$625) Portable, broadcast quality, half-track, monophonic tape recorder.

5. Amphenol Corporation
Cable and coaxial (crimp or coaxial) connectors. Very large selection.

6. Bach Auricon, Incorporated
Film cameras for television video recording. For video recording, they require modification of shutter; costing about \$150; total cost about \$2,000.
7. Baughman Company
Tripods.
8. Belden Manufacturing Company
Standard camera and multiconductor cable available in stock.
Coaxial cable in stock.
9. Birns & Sawyer
Underwater quartz lighting systems.
10. Boston Insulated Wire & Cable Company
Radiation tolerant and standard camera cable in stock and special assemblies manufactured to specifications. Multiconductor cable in stock.
11. Cohu Electronics (Kin Tel Division)
Standard, high resolution, radiation tolerant camera systems and accessories.

 Radiation Tolerant Series 2500 High quality, lightweight, radiation tolerant camera system. Capable of 100 feet separation between camera head and preamp. 600 line center resolution. Proven to operate without picture degradation in gamma radiation total of 10^8 and neutron of $10^{12}/\text{cm}^2$. 2000' preamp to control separation available on order.

 Standard Series 2000 (\$2,700 complete) High quality, lightweight camera system. 700 line center resolution.
Other accessories such as lens, mechanical mounts, amplifiers, available through, but not necessarily manufactured by Cohu.

12. Colortran Industries
Illumination equipment and accessories. Quartz lamps. Complete line of small, lightweight, low-cost, high intensity lamps.
13. Conrac
A large selection of high quality television monitors are available. Transistorized 9" and 14" monitors with both low and high voltage regulation as a standard feature, are available.
14. Dage Television Company
High and standard resolution television systems, video tape recorder, television accessories. Radiation tolerant cameras were once manufactured by Dage, but have been discontinued.
15. Dalto Electronics Corporation
Large screen television projectors for black and white or color. Complete line of high quality, portable type of projector.
16. Davis & Sanford Company
Tripods, dollies. Lightweight, compact, high quality, low-cost units.
17. Dynair Electronics
Transistorized distribution amplifiers and switchers. High quality, low-cost equipment.
18. EG&G
Intercom systems.
19. Electrospace Corporation
Intercom systems.
20. Elgett Optical Company
Remote controlled zoom lens.
21. Fairchild Laboratories (Dumont)
Standard and high resolution television systems and accessories. No radiation tolerant systems.
Model TCS-950 (\$4, 500) High quality, transistorized, com-

pact, camera chain. Utilized integrated circuitry which is very radiation sensitive.

22. FMC Corporation

Remote controlled camera vehicle.

23. General Electric

Standard and high resolution, transistorized television systems and accessories. No specifically designed radiation tolerant systems are available. Their standard, transistorized, TE-15 camera was subjected to some limited radiation tests, however, the results were inconclusive. They claim that theoretical radiation tolerance calculations on the TE-15 camera place a limit of 10^7 rads total at a rate of 10^5 R/hr. This is questionable due to the extensive use of transistors within the camera head. Power distribution equipment and components.

24. General Electrodynamics Corporation

Miniature TV camers, slow scan TV systems, vidicon tubes.
No radiation tolerant systems.

25. GPL

Standard and high resolution television systems, underwater TV cameras, process pipe viewing camera (\$6,000), microwave relay links and accessories. No cameras specifically designed to be radiation resistant although their Model 800 camera has been utilized successfully with minor modifications in low radiation environments.

26. Halliburton Enterprises

Packing containers. Large selection of standard or mil spec type containers and special order for unusual sizes.

27. Hickock Electrical Instrument Company

Tube and transistor checkers.

28. Houston-Feerless Corporation
Tripods, dollies, pan/tilt units - mostly for extremely heavy loads and studio applications.
29. Industrial Electric Reels
Cable reels. Large selection in stock or special order.
30. International Nuclear Corporation
Transistorized distribution amplifiers.
31. ITT (Cannon)
Cable and coaxial connectors. Very large selection.
32. ITT, Industrial Products Division
Standard, tube-type television camera chains. Radiation tolerant cameras have been discontinued.
Model CM-20 (\$4,000) This tube-type camera has been utilized in radiation environments with some modifications, although no exact tolerance limits are known. It is not recommended for extended radiation area operation.
33. Jefferson Wire & Cable
Radiation tolerant and standard camera cable assemblies manufactured to specifications. Multiconductor cable in stock.
34. Jensen Manufacturing Company
Speakers.
35. Lear-Siegler, Incorporated (Hallamore)
Standard, slow scan, environmental television systems and accessories. No radiation tolerant camera systems.
36. Magnecord, Midwestern Instruments
Audio tape recorders.
37. Micro-Link Corporation
Portable microwave relay links, tube construction. (\$5,000 / one-way system). Wide-band (7 mc).

38. Microwave Associates
Lightweight, completely transistorized portable television, microwave relay links. The transmitter uses varactors rather than tubes, which greatly reduces size and weight. These are very reliable units. (\$5,000 / one-way system). Bandwidth - 4.5 mc.
39. Milliken Company
Excellent, high quality, film cameras for television video recording. (\$10,000).
40. Miratel Electronics
High quality, tube and transistorized television monitors.
41. Mole-Richardson Company
Illumination equipment and accessories. Quartz lamps. Various small, lightweight, low-cost, high intensity lamps.
42. Motorola Communications and Electronics
Radiation resistant and standard TV cameras. The radiation resistant camera is primarily designed for hospital x-ray areas and no specific tolerance levels are listed. It is designed for only 50 feet separation between camera head and control unit.
43. Oceanographic Engineering Corporation
Underwater TV cameras, lights and accessories. Underwater lights are mainly the mercury vapor type which have longer life and are less expensive than quartz lamps, but require higher operating voltages and produce less light output per input power.
44. Palmer Films, Incorporated
High quality film cameras for video recording. (\$7,000).
45. PaR
Remote controlled manipulator and TV vehicle.
46. Pelco Sales, Incorporated
Pan/tilt units, camera enclosures (underwater, environmental),

- and pan/tilt, lens, remote control boxes.
47. Photo Research Corporation
Optical test pattern camera chain alignment system called "Optoliner". (\$1,200). Requires AC power input source.
49. Precision Instrument Company
Video tape recorders.
Model PI-4V (\$11,800) New model, high quality, portable video tape recorder. Tapes interchangeable between recorders. This has just been offered by Precision Instrument.
50. Quam-Nichols Company
Speakers.
51. Quick-Set, Incorporated
Tripods, dollies of high quality.
52. Radiant Manufacturing Corporation
Projection screens.
53. Raytheon Company
Portable tube-type microwave relay links. Wide-bank (8 mc). (\$8,200 / one way system)
54. RCA
Standard and high resolution television systems. No radiation tolerant models available. Complete line of television accessories are available through RCA, although not necessarily manufactured by them.
55. Sony Corporation of America
Monitors, audio and video tape recorders and other accessories.
56. Square-D Company
Power distribution equipment and components.

- 57. TA Manufacturing Corporation
Packing containers. Standard or mil spec and special order for unusual sizes.
- 58. Tektronix, Incorporated
Oscilloscopes, television waveform monitors.
- 59. Telemet Company
Video distribution amplifiers, remote control TV system using tones.
- 60. Tele-Sonic Company
Headsets.
- 61. Telex/Acoustic Products
Headsets.
- 62. Triplett Electrical Instrument Company
Test equipment. Multimeters, tube checkers, transistor checkers.
- 63. Utah-American Corporation
Speakers.
- 64. Victoreen Instrument Company
Nuclear instrumentation equipment. Remote area radiation monitor systems.
- 65. Viking of Minneapolis
Audio tape recorders.
- 66. Western Electric (Graybar)
Headsets.
- 67. Westinghouse Electric Corporation
Power distribution equipment and components.
- 68. Winsco Instruments & Controls
Remote temperature indicators.

- 69. Wollensak (Revere-Wollensak Division)
Television, remote controlled, zoom and fixed lens which are radiation tolerant (non-browning).
- 70. Zero Manufacturing Company
Packing containers. Large selection of standard or mil spec type containers and special order for unusual sizes.
- 71. Zolomatics Corporation
Portable, battery operated, optical test pattern camera chain alignment system. (\$495).
- 72. Zoomar, Incorporated
High quality television remote controlled and manual zoom lens.