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A STUDY OF
COLUMBIA RIVER SURVEILLANCE
BY CLOSED CIRCUIT TELEVISION

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December 11, 1961

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HANFORD ATOMIC PRODUCTS OPERATION

GENERAL ELECTRIC

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A STUDY OF COLUMBIA RIVER SURVEILLANCE
BY CLOSED CIRCUIT TELEVISION

1.0 SUMMARY AND CONCLUSION

Surveillance of the Columbia River by closed circuit television does not appear to be economically practical under the conditions set forth in the Basis of Study (Section 2.0).

To observe a small boat 5000 feet away requires a 16 mm lens of 12 inch focal length. The angle of view of this lens is so small (approximately 2 degrees) that the river cannot be surveyed with it by simple panning alone. Also, panning speed with this lens must be very slow--approximately one revolution every 15 minutes--in order for an object to remain in the field of view for five seconds.

It would be technically possible to include an automatic search program involving fast and slow pan, fast and slow tilt, and lens change. Aside from the technical complexity of such a control, the time required to complete one search cycle would leave areas of the river unobserved for long periods of time. There is also the problem of getting the equipment synchronized with the automatic search program after it has been interrupted by manual operation.

The river can be surveyed by simple panning alone if the lens focal length is in the range of 1.5 inches. Due to the wide field of view of this lens, it cannot observe a small boat farther away than about 600 to possibly 1000 feet. Thus the remaining 4000 feet of the river would be beyond the resolving power of the system when it is scanning the river automatically.

River surveillance at night with television is not practical beyond 500 to 1000 feet because of the difficulty of providing adequate illumination. It seems practical to provide a searchlight beam capable of illuminating a boat at 500 to 1000 feet, however the searchlight beam would be only about 5 degrees wide. A 5 degree beam is not adequate for river surveillance by simple panning alone. It is approximately the same angle of view as that of a 6-inch lens.

Searchlights would be of no use in even moderate fog conditions because of light dispersion by water droplets.

Searchlights panning in synchronism with the camera would reveal to interested parties the direction in which the camera was aimed.

2.0 BASIS OF STUDY

2.1 General Description of Problem

- 2.1.1 Current Practice - A patrolman observes river traffic 24 hours a day, seven days a week, from a 50 foot enclosed tower located on the bank of the river. Under normal daylight conditions the opposite shore line and bluffs (2,000') and approximately three miles both up and down the river can be seen by naked eye with close up identification obtained through use of field glasses. For night time operation a manually operated searchlight is used to sweep the river for moving or floating objects. The searchlight now in use is a CROUSE-HINDS type G-40, 12 inch, DCX-12, Catalog #44082-A. It has a 500 watt G-40 spotlight bulb, beam candlepower of 434,000, lamp lumens of 10,100 and weighs 98 pounds. Indicated lumens and candlepower are based on G-40 spotlight with 200 hours life. A G-40 floodlight of 800 hours life yields a beam candlepower of only 360,000.
- 2.1.2 Proposal - To determine whether it is feasible to replace the patrolman in the river tower with a remotely controlled closed circuit television and searchlight system.

2.2 General Specifications

- 2.2.1 Camera - High resolution, lowest possible foot candle sensitivity to produce a usable picture; exposed to all types of weather: dust, rain, snow, sleet, ice, and temperature ranges from 20° to 130° Fahrenheit. Equipment for sun protection of vidicon tube is required.
- 2.2.2 Lens - Either a zoom lens or remotely controlled turret to obtain the best possible scanning of river along with ability to identify a type of boat and number of occupants of boat at a distance of 5,000 feet under normal daylight conditions.
- 2.2.3 Pan and tilt to operate both the camera and the searchlight in synchronism. The usual operating ranges of 10° to 350° pan and plus or minus 45° tilt are satisfactory.
- 2.2.4 All weather housing with window washer and wiper and heat strips for winter operation and fan cooling for summer operation.
- 2.2.5 The tower contains a weatherproof room with 120 V power available for the camera control unit.
- 2.2.6 Distance from tower to remote control station is 5,000 feet with poles already in place each 75 to 100 feet for the entire distance.
- 2.2.7 Monitor to be a minimum of 17".

2.2.8 Controls to be at a minimum for operation by patrolman.

- a. Contrast and brightness.
- b. "Joy stick" control of pan and tilt.
- c. Speed adjustment for pan and tilt.
- d. Control of either zoom or turret lens.
- e. Lens focus.
- f. Operation of window wipers and washers.
- g. Switch to turn searchlight on or off.

2.2.9 Continuous operation 24 hours a day - 365 days a year - never turned off.

3.0 VIDICON VERSUS IMAGE ORTHICON

A transistorized camera can remain stable without requiring readjustment for at least 100 hours, and probably much longer. A vacuum tube camera will age and drift faster than a transistorized unit. The camera should therefore be transistorized, except for the picture tube, of which there are no transistorized versions.

Both vidicon and image orthicon cameras are available transistorized.

The image orthicon camera has the sensitivity to produce an image of the river under bright night conditions without artificial light. The vidicon camera does not have this sensitivity. (One report indicates that a quality vidicon camera using the 7735A vidicon and an f:1.5 lens produced a relatively noise-free picture with scene brightness of one foot-lambert. The scene was a test chart.)

The cost of an image orthicon camera is about \$20,000. A quality vidicon camera costs about \$3,500.

An image orthicon camera requires 35-mm lenses, whereas the vidicon uses 16-mm lenses. For the same magnification and speed a 35-mm lens has twice the focal length and twice the diameter of the comparable 16-mm lens. To resolve a small boat at one mile requires a 24-inch 35-mm lens, or a 12-inch 16-mm lens.

Consultants advise that an image orthicon camera is very complex and requires frequent attention, possibly as often as several times a day.

One consultant advises that an image orthicon tube costs \$5,000 and is rated 1,000 hours. Another consultant advises that the cost of a sensitive image orthicon tube is about \$3,800 and that commercial broadcasters assume a 200 hour life for quality pictures. The annual replacement cost for the tube

alone will be \$45,000 to \$167,000 depending on which figures are accepted. Even at the lower figure the use of an image orthicon becomes economically unjustifiable for this application.

The writer has no knowledge of any image orthicon cameras in use at HAPC.

4.0 LENSES

4.1 Horizontal Viewing Requirements

Assume a 12-foot-long boat at 5,000 feet. Assume that the maintained horizontal resolution of the television system is at least 500 lines. Assume five lines required to recognize an object.

$$500 \text{ lines} \times \frac{4}{3} \text{ aspect ratio} = 667 \text{ horizontal lines per picture.}$$

$$\frac{5 \text{ lines}}{12 \text{ feet}} = \frac{667 \text{ lines}}{x \text{ feet}}$$

$$x = 1600 \text{ feet maximum horizontal field at 5000 feet}$$

The nearest equivalent lens is 2-inch and has a 1250 foot horizontal field of view at 5000 feet.

4.2 Vertical Viewing Requirements

Assume a 2-foot-high boat at 5000 feet. Assume that the maintained vertical resolution of the television system is 340 lines.

$$\frac{5 \text{ lines}}{2 \text{ feet}} = \frac{340 \text{ lines}}{x \text{ feet}}$$

$$x = 136 \text{ feet maximum vertical field at 5000 feet}$$

The nearest equivalent lens is 12-inch and has a 156 foot vertical field at 5000 feet.

Thus, the vertical viewing requirement is the most stringent and a 12-inch lens is required.

4.3 Vertical Resolving Power at 5,000 Feet With 12-Inch Lens

$$\frac{5 \text{ lines}}{x \text{ feet}} = \frac{340 \text{ lines}}{156 \text{ feet}}$$

$$x = 2.3 \text{ feet}$$

A 12-inch lens should be able to resolve an object which is at least 2.3 feet high and 5,000 feet away.

4.4 Horizontal Resolving Power at 5,000 Feet With 12-Inch Lens

The horizontal field of view of a 12-inch lens at 5,000 feet is 208 feet.

$$\frac{5 \text{ lines}}{x \text{ feet}} = \frac{667 \text{ lines}}{208 \text{ feet}}$$

$$x = 1.5 \text{ feet}$$

A 12-inch lens under the assumed conditions should be able to resolve an object which is at least 1.5 feet long and 5,000 feet away.

4.5 Focal Length Ratio

The design of lens turrets is such that the ratio of the longest to the shortest focal length lenses should not exceed 6 to 1 if the longer lens is to be kept out of the field of view of the shorter one.

This consideration indicates a 2-inch lens for the shortest one.

4.6 Vertical Resolving Power at 5,000 Feet With 2-Inch Lens

The vertical field of view of a 2-inch lens at 5,000 feet is about 937 feet.

$$\frac{5 \text{ lines}}{x \text{ feet}} = \frac{340 \text{ lines}}{937 \text{ feet}}$$

$$x = 13.8 \text{ feet}$$

A 2-inch lens should be able to resolve an object which is at least 13.8 feet high and 5,000 feet away. Thus the image of a 2-foot-high boat would be less than one scanning line on the monitor screen and would not exist. In other words, a 2-inch lens used for general automatic scanning cannot perceive a 2-foot-high boat at 5,000 feet.

4.7 Horizontal Resolving Power at 5,000 Feet With 2-Inch Lens

The horizontal field of view of a 2-inch lens at 5,000 feet is about 1250 feet.

$$\frac{5 \text{ lines}}{x \text{ feet}} = \frac{667 \text{ lines}}{1250 \text{ feet}}$$

$$x = 9.4 \text{ feet}$$

A 2-inch lens should be able to resolve an object which is at least 9.4 feet long and 5,000 feet away.

The minimum sizes derived in (4.6) and (4.7) are mutually independent. That is, the object must be at least 9.4 feet long and 13.8 feet high to be resolved by a 2-inch lens at 5,000 feet. However, if the object subtends perhaps 3 scanning lines an alert operator may notice that something is there that should be examined with a more powerful lens. This is a speculation and

depends heavily on the contrast of the object with its background, the alertness of the operator, the noise inherent in the TV system, and the weather conditions.

4.8 Intermediate Lenses

Four-lens turrets are available. With a 12-inch and a 2-inch lens established, there remain two intermediate lenses. There will be three intervals of magnification (2-x, x-y, y-12).

$$\frac{208 \text{ horizontal field of } 12'' \text{ lens}}{1250 \text{ horizontal field of } 2'' \text{ lens}} = \frac{1}{R^3}$$

$$R = 1.818$$

The ratio of the linear fields of view of adjacent lenses should be 1.818 to give equal changes of magnification.

$$208 \times R = 378 \text{ feet}$$

The required horizontal field of view of the second most powerful lens is 378 feet. The desired lens would have a focal length of 6.6 inches and the nearest standard lens is 6 inches.

$$208 \times R^2 = 688 \text{ feet}$$

The required horizontal field of view of the third most powerful lens is 688 feet. The desired lens would have a focal length of 3.6 inches and the nearest standard lens is 4 inches.

The tentative lens complement is thus four lenses of 12, 6, 4, and 2-inch focal lengths.

4.9 Lens Complement

A 2-4-6-12 inch lens complement will have magnification ratios of 2, 1.5, and 2 which are unequal and undesirable from a human engineering viewpoint.

It is desirable to be able to scribe a wax pencil line on the monitor tube and instruct the operator to change to a more powerful lens only when the object being viewed is within the indicated area. The lens complement must therefore have uniform magnification ratios. Suitable lenses are 1.5, 3, 6, and 12-inches, all available as standard, and having a magnification ratio of 2 between consecutive lenses.

The field of the 1.5-inch lens may be occluded to some extent by the barrel of the 12-inch lens. The quadrant containing the occlusion can be specified. The clear field will still be at least as great as that of a 2-inch lens.

4.10 Lens Fields of View and Limits of Resolving Power

The approximate horizontal and vertical fields of view of the recommended lenses are shown in the table below. Also shown is the maximum distance at which a 2-foot high boat can be resolved, based upon the assumption that five scanning lines are required to resolve the object.

<u>Lens</u>	<u>Field in feet at distance shown</u>			<u>Max. distance to resolve boat</u>
	<u>5000 ft.</u>	<u>1000 ft.</u>	<u>200 ft.</u>	
1.5"	1666 x 1250	334 x 250	66 x 50	550
3"	833 x 625	167 x 125	33 x 25	1100
6"	417 x 313	83 x 63	16 x 12	2200
12"	208 x 156	41 x 31	8 x 6	4400

This table indicates that it is impractical to survey the river by television and detect a small boat a mile upstream and downstream. The 1.5-inch or possibly the 3-inch lenses are the most powerful ones that can be used for general surveillance by automatic panning alone and still give a reasonable field of view at closer ranges. These two lenses cannot resolve a small boat beyond 600 to 1100 feet.

It is technically possible to incorporate a programmer which would program an elaborate search pattern involving both pan and tilt motions with lens changes and speed changes as required. However, the time required for a complete search cycle would leave some areas of the river unobserved for long periods of time. We have not worked out such a program, but suspect that a complete search cycle could require a half hour or longer. A further complication is the necessity of putting the camera equipment and the programmer back in step after the operator has stopped the automatic search and manipulated the equipment manually.

5.0 ASPECT RATIO

The results of (4.3) and (4.4) suggest that some improvement in resolving power for long low objects could be obtained if the normal aspect ratio of 4 wide to 3 high were changed to 3 wide and 4 high. In other words, the camera could be laid on its side and a special monitor used in which the picture tube and deflection yokes were turned 90 degrees. This would give an image 4 units high and 3 units wide.

During a visit to the camera site one can roughly mask out with his hands the fields of view encompassed by the two aspect ratios and observe that the standard 4 to 3 ratio seems best suited to the terrain.

In a 3 to 4 aspect ratio system the raster (scanning lines on the monitor) would run vertically. This arrangement could be irritating to an operator accustomed to viewing his home receiver in the normal pattern.

From (4.4) it can be seen that changing the aspect ratio will allow a small boat to be resolved about 33% farther away. Nevertheless, automatic scanning with a 1.5-inch or 3-inch lens would resolve a boat no farther away than 800 to 1400 feet respectively. The great majority of the one-mile range of river upstream and downstream still will not be under effective surveillance. Normal aspect ratio should be retained.

6.0 ZOOM LENS VERSUS LENS TURRET

A zoom lens is available with a focal length range from 2.4 to 12 inches and an aperture of f:5.4. This range approximates that of the 3, 6, and 12-inch lenses of a turret. The additional doubling of the linear field of view made possible with a 1.5-inch lens in a turret is a distinct advantage when viewing nearby scenes, and practically a requirement for automatic panning.

With a zoom lens the image will always be in the field of view during a change of power. If the operator sees that increasing the power is causing the image to move off the screen; he can correct with the pan and tilt movements. On the other hand, if a turret is used the requirement that the image must be within the prescribed area before the next higher powered lens is selected is a positive instruction to which an operator should easily adjust.

If a turret is used the image will be lost for 2 or 3 seconds during lens change. This disadvantage may not be serious. To cross the horizontal field of view of a 12 inch lens at 5000 feet in 3 seconds an object would have to be moving about 50 miles per hour.

The maximum aperture of the zoom lens is f:5.4. A 1.5-inch and 3-inch lens, which would be the only ones effective at night for general surveillance, can be obtained with aperture of f:1.5, which will pass 13 times more light than f:5.4. Even a 6-inch lens is available in f:1.8. These apertures are of lenses listed in reference data in the writer's files, and somewhat faster lenses may be available as standard items.

A turret has the further advantage that lenses can be replaced if some other focal length seems more desirable, or a faster lens becomes available. For example, there is a 15-inch f:4.5 lens and a 20-inch f:4.5 lens available. Also, extremely wide angle lenses (10 millimeter focal length) are available.

For the proposed application the turret appears to be the better choice.

7.0 MOUNTING OF PAN AND TILT UNIT

If the pan and tilt unit is mounted on a horizontal surface about 50 feet above the water, is tilted downward 8 degrees, and the 1.5-inch lens is in use, the 5000 foot horizon will be near the top of the monitor scene. When the camera is the panned to view directly across the river, the scene in view will extend from a near point of 150 feet to a far point of at least 5000 feet, unless the upward slope of the land foreshortens this range.

If a point nearer than 180 feet must be viewed during automatic panning, while keeping the 5000 foot range in view up and down river, the surface on which the pan and tilt unit is mounted will have to be inclined the required amount toward the river. This mounting will cause the entire scene on the monitor to be cocked to the left when viewing upriver, and to the right when viewing downstream. The apparent rocking motion of the scene during panning could be very annoying to the operator.

8.0 DOUSER

The environment is such that the camera can be turned directly into the sun during early morning and late evening. The camera must be equipped with a douser to prevent destroying the vidicon tube under these conditions. The douser should insert a sharp cutoff infrared filter in the optical circuit before the sun comes into the field of view of the widest angle lens.

The operation of this douser should be automatic and there should not be any provision for manual override, else the vidicon may be destroyed by operator error.

9.0 ILLUMINATION

9.1 Range of Searchlights

Factors which affect the range of searchlights are object brightness, color and brightness contrast of object with background, size of object, time of exposure, atmospheric conditions, and visual acuity of observer (or sensitivity of TV camera). The table below, from Crouse-Hinds, shows the approximate range in feet of searchlights for detecting with the eye a medium sized object such as a car or group of people.

<u>Beam Candlepower of Searchlight</u>	<u>Approximate Range in Feet Medium Sized Object</u>	
	<u>Clear</u>	<u>Light Haze</u>
250,000	575	540
500,000	800	750
1,000,000	1200	1150
2,000,000	1650	1450
3,000,000	2000	1750
5,000,000	2500	2100
7,000,000	3000	2400
10,000,000	3500	2700
15,000,000	4150	3300
25,000,000	5250	3750
50,000,000	7500	4800

This table is based on detection of the object in view. For recognition, from 2 to 10 times more light, contrast, size, or time will be required.

Position of the observer with respect to the searchlight is of prime importance. If the observer moves laterally away from the light, the useful range increases. Best conditions usually exist with the observer from 100 to 300 feet away from the searchlight.

Under moderate fog conditions a searchlight is of almost no value because of the scattering effect of water particles and the resultant halo.

9.2 Selection of Lamp

Lamps with the highest candlepower have the narrowest beam spread, shortest life, and are usually rated for 6, 12, or 32 volts. Projection type lamps are available rated at 120 volts but they also have a life of only about 50 hours. None of the incandescent lamps suitable for searchlight service are rated for longer than 800 hours. Where continuous duty is required, the lamps with longest life should be selected.

The approximate angles of view of the recommended lenses are shown in the table below.

<u>Focal Length of Lens</u>	<u>Angle of View</u>
1.5 inch	20 degrees
3 inch	10 degrees
6 inch	5 degrees
12 inch	2 degrees

A reasonably wide searchlight beam is particularly advantageous in spotting moving objects. The widest beams available in smaller searchlights are about five degrees and are obtained by using medium prefocus floodlight lamps. Of course, if several searchlights are used a wider beam can be obtained by careful aiming of the searchlights, but the beam candlepower will not be increased by this expedient.

Short life lamps are not desirable in searchlights operating continuously or when labor of replacement must be considered in the cost of operation.

These considerations dictate the selection of medium prefocus floodlight lamps, type G, rated 120 volts and 800 hours, if the lamps to be used are of the incandescent type.

9.3 Incandescent Versus Mercury Lamps

Searchlights can be arranged for use of mercury lamps and will produce about ten times the beam candlepower obtainable with incandescent lamps. These lamps require special ballasting and starting equipment. They have the further disadvantages of requiring a warmup time before reaching full brilliance, and

a cooling time before restriking in case they are turned off or power is interrupted. The cool and restrike time to full brilliance may run as long as 15 to 20 minutes.

Other gas discharge lamps would probably increase the beam candlepower by a factor of 10 or more also, provided searchlights can be arranged for such light sources.

Further information has been requested from Crouse-Hinds on mercury searchlights. In spite of their disadvantages they may be required if night viewing by television is to be reasonably practical.

9.4 Searchlights

Crouse-Hinds searchlight net weights and beam candlepowers when equipped with type G incandescent floodlamps are shown in the table below.

<u>Searchlight</u>	<u>List Price</u>	<u>Weight</u>	<u>Beam Candlepower</u>	<u>Candlepower Per Pound</u>
DSE-8	\$125	14 lbs.	97,000	6,900
DCE-12	\$250		360,000	
DCE-18	\$450		1,465,000	
SE-24	\$800		2,340,000	

Just to detect an automobile-sized object on a clear night at one mile, with the eye, requires 25 million beam candlepower. A cluster of units all precisely aimed at the same point would be required to obtain this candlepower. Any combination of searchlights listed in the table above would be too heavy for mounting on a pan and tilt unit. Further, the eye is much more sensitive than a vidicon television camera. Thus it seems impracticable to provide adequate beam candlepower mounted on a pan and tilt unit to permit a vidicon camera to resolve a small boat a mile away.

It would be possible to mount any required number of searchlights off the pan and tilt unit, preferably 100 to 300 feet away laterally. They would be fixed in direction and because of their narrow beam many units would be required to illuminate up and down the river. The cost of such an installation would be more than 10 thousand dollars for each 25 million candlepower 5 degree beam, if incandescent searchlights of 800 hour lamp life were used. Mercury vapor searchlights would probably reduce this cost considerably. Any floodlight installation would be useless under moderate fog conditions.

Carbon arc searchlights of the anti-aircraft type produce about 800 million beam candlepower but require operating personnel.

It would be practicable to provide a cluster of 8 DCE-8 searchlights on a heavy duty pan and tilt unit. The searchlights alone would weigh 112 pounds, cost \$1000, consume 2000 watts, and provide a combined 5 degree beam of only 776,000 candlepower. Two DCE-12 units would produce 720,000 beam candlepower, cost \$500, consume 1000 watts, and weigh almost 200 pounds. Either such weight would require a very heavy duty pan and tilt unit.

In either case a 700,000 candlepower beam is not of much value. Its beam would illuminate an object the size of a car for detection by eye at 1000 feet on a clear night, but a vidicon camera would be effective to a shorter distance because it is not as sensitive as the eye. Thus more than 80% of the daytime range of the system would be unobservable at night, even in clear weather.

It does not seem justifiable to spend the funds required for attaching searchlights to a pan and tilt unit when 80% or more of the river would still be unobservable. Furthermore, the movement of the lights as they were panned would reveal to an interested person the direction of view of the camera.

10.0 CONTROL

10.1 Functions Required

The following control functions are required:

1. Power on-off	10. Lens 1.5"
2. Pan left	11. Lens 3"
3. Pan right	12. Lens 6"
4. Tilt up	13. Lens 12"
5. Tilt down	14. Slow-Fast (Pan and Tilt Speed)
6. Iris open	15. Auto-manual panning
7. Iris close	16. Window wiper
8. Focus near	17. Window washer
9. Focus far	

10.2 Control Cable

The control functions require a cable with at least 18 wires. Several additional wires should be included for contingencies and future use, and for power to the distribution amplifier. A suitable cable is G.E. WCD-737, 24 conductors, No. 16 AWG. The list price of this cable is \$425 per thousand feet, or \$2125 for 5000 feet.

10.3 Auxiliary Relay Panel

Because of the distance between the control station and the controlled equipment the cable above will not be suitable for direct control of the equipment. The circuit resistance of No. 16 wire would be about 50 ohms. Even No. 12 wire has a resistance of about 20 ohms over this distance, and cable with No. 12 conductors would cost over \$5000.

The problem can be solved by use of an auxiliary relay control panel at the guard tower. Small, inexpensive relays will serve the purpose, and they can be of the plug-in type for ease of maintenance.

In the final design of the system it may be possible to choose relays and operating voltage such that No. 19 AWG control cable can be used with consequent savings of several hundred dollars in cable cost.

10.4 Wireless Versus Cabled Circuits

Complete wireless control and picture transmission is not economically feasible. Two transmitters and two receivers would be required and the cost would exceed \$30,000 for equipment alone.

The use of tone signal control over a spare telephone pair is possible, but we have no cost data at this time. A messenger cable must still be installed on the poles to carry the video cable. The specification should request a bid based on multiple conductor wired control, but should invite alternate proposals based on multiplexed control if they result in a lower installed cost. It should be noted that multiplexed control would add to the complexity of the system and thus increase maintenance costs, so it should not be considered unless the initial cost saving is substantial.

11.0 PAN AND TILT SPEEDS

11.1 Slow Speed Panning

Slow panning speed will be required when the longer focal length lenses are in use. The angle of view of the 12-inch lens is 2 degrees. If we assume that during panning an object should remain in the field of view for at least 5 seconds, then the maximum panning speed becomes

$$\frac{2 \text{ degrees}}{5 \text{ seconds}} = 0.4 \text{ degree per second, or 15 minutes per revolution.}$$

11.2 High Speed Panning

High speed panning will be required for automatic panning and when the shorter focal length lenses are in use. The angle of view of the 1.5-inch lens is 20 degrees.

$$\frac{20 \text{ degrees}}{5 \text{ seconds}} = 4 \text{ degrees per second, or 1.5 minutes per revolution}$$

Thus the high and low speed ratio becomes 10 to 1.

11.3 Tilting Speed

The vertical angle of view of the television system will be $3/4$ of the horizontal angle because of the 4:3 aspect ratio. For the 12-inch lens, then, the vertical field is only 1.5 degrees. Again assuming 5 seconds per field of view, the required tilt speed becomes

$$\frac{1.5 \text{ degrees}}{5 \text{ seconds}} = 0.3 \text{ degrees per second, or 20 minutes per revolution}$$

At this speed 2.5 minutes would be required to tilt the camera through an angle of 45 degrees, and this is too slow to be practical for viewing a nearby fast moving object. Two-speed tilting as well as panning will therefore be required, and with a ratio of 10 to 1 the high speed tilt would be 3 degrees per second.

11.4 Summary of Viewing Times

With the recommended panning and tilting speeds the seconds of viewing time will be the same in both the vertical and horizontal direction. These viewing times for the four lenses at each speed are summarized in the table below. "Seconds per field" refers to the time required for the image of a stationary object to cross the monitor screen during panning or tilting. An asterisk indicates that the viewing time is probably too fast or too slow for practical use.

<u>Lens</u>	<u>Seconds Per Field</u>	
	<u>Fast Speed</u>	<u>Slow Speed</u>
1.5 inch	5	50*
3 inch	2.5	25*
6 inch	1.2*	12
12 inch	0.5*	5

11.5 Aspect Ratio

If a 3 to 4 aspect ratio is chosen the recommended pan and tilt speeds must be interchanged.

12.0 COST ESTIMATE

12.1 Summary

Vendor's prime material and purchased parts	\$ 11,300
Vendor's labor to assemble and test system before shipment	500
Vendor's sub-contracted labor and material for installation and test of system	10,300
Vendor's design and field engineering and contract administration	<u>4,000</u>
Vendor's direct cost	\$ 26,100
Vendor's overhead at 20%	5,220
Vendor's profit at 10%	3,130
Packing and shipping	<u>550</u>
Estimated vendor's proposal price	\$ 35,000

12.2 Prime Material and Purchased Parts

The prime material and purchased parts estimate is itemized below to illustrate the type of equipment on which this estimate is based.

<u>Item</u>	<u>Estimated Vendor's Direct Cost</u>
a. Vidicon transistorized camera	\$ 2,900
b. Lens turret, selective (not sequential) type, for four lenses	420*
c. Lens 1.5" f:1.5	100
d. Lens 3" f:1.5	150
e. Lens 6" f:1.8	270
f. Lens 12" f:4.5	500
g. Special support for 12" lens	70*
h. Douser with infrared filter	230*
i. Weatherproof housing for camera and lens; includes heater, blower, washer and wiper	470
j. Pan and tilt unit, very heavy duty, to carry at least 200 pounds, with special two-speed pan and tilt speeds, weatherproof, automatic panning	2,800*
k. Searchlight assembly, eight Croco-fiducial units, with mounting platform and hardware	900
l. Remote control auxiliary relay and contactor panel with cabinet	500
m. Miscellaneous, weatherproof cable connectors, fittings and cable sets	220
n. Video distributor-amplifier with weatherproof housing	380
o. Monitor, 14 inch, rack mounted	350
p. Control station at monitor for control of all functions	340
q. Monitor rack assembly, power supplies, cables, connectors, etc.	700
TOTAL	\$ 11,300

* List price or other cost data not available. Estimate shown is tentative.

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END