

Section One: A SYSTEM FOR SIMULATING AERIAL OR ORBITAL  
TV OBSERVATIONS OF GEOGRAPHIC PATTERNS

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INTRODUCTION

The particular parameters of scale and image resolution needed for identifying and analyzing geographically-distributed phenomena is of concern to all earth scientists who use remote sensing imagery. When scan line rather than photographic imagery is utilized, these parameters become even more critical and provide rather decisive influences upon the interpretation process and the value of the data as a discriminator of patterns on the surface of the earth.

The geographer and the scan line sensor have one thing in common - they both intentionally generalize the reality of the almost infinite detail that can be observed in the environment. The scan line sensor does this by generating a signal which is a generalization resulting from the aggregate of the spacially-distributed phenomena it detects within the boundaries of its sensitive moving spot, which is usually making a linear traverse. The geographer does this by selecting the pattern he will analyze - such as vegetation, land use, or transportation phenomena; or he may seek to include all of these but at a certain hierarchical level of categorization. He might be satisfied to identify and discriminate the surface as merely one of four distributants - water, cropland, non-cropland, and urbanized landscape. Or at a larger scale of generalization he may wish to increase his information content by, for example, segregating the functional areas of the urbanized landscape into such categories as residential, commercial, industrial, institutional, and transportation uses. In the latter case of course a change in the scale of the analysis seems to be implied. The sensor changes its scale of detection by moving closer - either in actual distance or by optical adjustment - to the phenomena it is observing. And some scanners - such as television systems - may change the hierarchical-like level of their analysis by increasing their scan line rate (number of scan lines per unit area), and may at the same time narrow the aperture and hence the scan line width. This will increase the intensity of sampling the surface, and the resolution of the system in both television terms (number of lines discriminated) and optical terms (size of objects discriminated).

The possibility of using television as a remote sensor for the study of spacially-distributed earth phenomena was given little thought in the early years of the remote sensing activity. There are valid reasons for this neglect.

Following the First Symposium on the Remote Sensing of Environment in 1962, the attention of geographers and other earth scientists were drawn principally to the exciting perspectives unveiled by seeing the unseeable. The potentials of color infrared photography, thermal infrared scanning, imaging radar, and the less revealed but tantalizing potential of other electro-optical systems operating beyond the visual portion of the spectrum were the focus of attention. Also at that time the bulkiness of TV equipments, their large power requirements, and their insensitivity to lower light levels all combined to limit their portability and application to earth resource surveying. However, simply the fact that TV recorded in the visual spectrum, and did so with less resolution than familiar photographic systems, was probably the major reason it attracted little attention from earth scientists.

Tiros I had gone into orbit on April 1, 1960, and began its successful transmission of television pictures depicting clouds and incidental observations of the earth's more obvious landmarks. However, the observation of major earth surface features by this and later meteorological satellites attracted limited attention from those concerned with the study of patterns on the surface of the earth, since such gross scan line generalizations usually revealed what was already known about surface features, although they did help to locate more precisely some of these features. In July, 1964, the dramatic almost real time transmission of lunar landscape by the Ranger VII vehicle plunging toward the moon's surface provided the first decisive demonstration of television's potential as a tool for scientific investigation of surface features. Subsequently, the "soft-landed" and remotely controlled TV systems of Surveyor vehicles contributed significantly to lunar investigations, but still seemed of little value as an available tool for geography and earth scientists concerned with the earth's resources.

Images of the earth from orbit were taken by John Glenn in February, 1962, with a hand held 35-mm camera, and established the value of the synoptic view of the earth's surface. Subsequent photography by Gemini astronauts confirmed the value of orbital platforms for observing and analyzing earth surface features resulting from both natural and human processes. However, it was not until the Apollo was in orbit that TV cameras observed the earth from orbital altitudes, and these observations were incidental experiments with hand-held TV cameras peeking out of spacecraft windows. However in 1967, the Applications Technology Satellite III secured a dramatic color TV image of one full hemisphere of planet earth. The image was composed of 2400 scan lines with

an earth surface width for each line of approximately two nautical miles. This literally far out picture provided a dramatic demonstration of TV capabilities.

However, a systematic TV orbital observation of the earth's resources still has not been demonstrated by 1971, and apparently will not be until the first Earth Resources Technological Satellite is successfully launched in 1972. In order to simulate for study the nature and potential of TV observation of the earth's surface phenomena, with particular reference to its geographic aspects, this investigation devised a relatively uncomplicated method for generating images which would resemble those that can be expected from either aerial or orbital altitudes. It is the purpose of this report to describe and illustrate the system utilized.

## CONCEPTS AND CONSIDERATIONS FOR SIMULATING SCAN-LINE IMAGERY

The overriding control on all scale and resolution constants in scan line imagery is ultimately the design limitations of the instruments being employed and the remoteness of the device from the phenomena patterns being sensed. For example, any altitude might have been specified, but constant scale and resolution would result at that particular altitude unless changes in the instrumentation occur. In a TV system, the changes might be in the scan line rate, the aperture affecting the size of the scan line spot and hence line width, or the optical lens which cause scale changes before the phenomena is scanned on the face of the tube. Thus the design parameters of the sensor and its remoteness are irrefutable constraints on the utility of its imagery, and the capability of the system for recording or transmitting any specific geographic pattern.

Of equal importance but unfortunately not always recognized by earth scientists are the design parameters of the systems which are used to process and reconstitute the telemetered data originating from an orbital sensor. Although not functioning as the primary or initial constraint on the quality and utility of the final imagery data available for interpretation and analysis, the processing system is the final constraint. The telemetered imagery will have scale and resolution characteristics no better than those of the system which processes and reconstitutes it. Hence the fidelity of geographic patterns reproduced in the imagery is a function of the imaging and processing systems design parameters.

Since TV observations of earth surface resources are not readily available for study, but photographic imagery from both aircraft and orbital observations has been recorded, the latter data provides the essential approximation of reality needed for simulating TV observation of earth surfaces. Although the TV camera utilized will be monochromatic, since it is a black and white system which converts color variations into gray tone variations, only "natural" color imagery can be utilized to simulate the earth surface when the purpose is to obtain scanning signal values and monitor images which display observations within the normal TV visual spectrum. Should the imagery viewed be color infrared, it may be assumed that the

signals resulting may approximate those that could be obtained if the scanning tube had been specifically adapted and filtered to detect this "near infrared" portion of the spectrum. However, it is not likely to be a close approximation in signal values if only one camera is used to generate the signal.

The photographic imagery to be viewed by TV camera will already be a generalization, and will not possess the complete detail of the actual earth surface which would be observed by direct TV scanning of the phenomena. However, the optical resolution capabilities of high quality photographic systems are so much greater than the scan line resolution of a TV system at either aerial or orbital altitudes that significant differences in signal values should not result when observing geographic patterns.

The influences of sun angle, light level variations, and atmospheric attenuation will already be fixed as part of the photographic imagery characteristics. And the angle of sensor view, either vertical or otherwise, will also be established in the photography. Therefore to simulate television scanning under the conditions already established and "frozen" into the photograph available, the film transparency should be viewed at a ninety degree angle by the TV system. If it were desired to simulate other parameters - such as a different sun angle or atmospheric attenuation - photography which was taken under the desired conditions would be needed.

To simulate scale changes, however, the same photographic scene can be scanned, since the resolution in the photography is so much greater than that expected from the scanning system. By increasing or decreasing the distance between the TV camera and the image being viewed either as a transparency or a projected image on a screen, one can simulate changes in the altitude of the sensor or in the focal length of the device. When the image is being projected for viewing by the TV camera, changes in the distance between the projector and the screen or in the focal length of the projector can change the size of the screened image, and hence simulate scale changes which could be expected from changes in the altitude or optics of the sensor.

To simulate various resolution changes in TV imagery, it is also necessary to recognize the role played by the scan line rate. For example, an increase from 525 lines - the scan rate of standard American television - to 945 lines would greatly increase the number of lines

traversing the imagery pattern and hence increase sampling intensity. Although this alone would not increase resolution in an optical sense - the size of the smallest unit that can be discriminated - it would increase the detail available concerning the shape and size of units larger than the ground width of the scanning traverse. However, actually there will usually be also an increase in optical discrimination - size of smallest unit separately detected - because when scan lines are increased in number, related aperture adjustments are made which reduce the size of the scanning spot and the width of the scan line, hence increasing resolution capabilities. Consequently, the resolution capabilities of any system simulating TV observation of surface resources is affected by alternative choices in scan line rates as decisively as by the scale of the area being viewed.

## THE SIMULATION SYSTEM

### A. The Simulation of Earth Surface

The first requirement is to devise a means for displaying a photographic image of the earth's surface in a manner that permits the TV video tube to scan the displayed image; and in so doing to simulate a direct viewing of the surface phenomena recorded in the photograph. This requires that the color transparency either be viewed directly at close range, or be projected onto a screen with considerable effectiveness. Since it is also necessary that the TV camera observe the image from a ninety degree angle if it is to approximate the view of the original camera, it is recognized that any projected image could be viewed best via a rear view screen.

Significantly, the possibility of rear screen viewing creates a new range of options. It means that both the projector on one side of the screen and the TV camera on the opposite side can approach or retreat from the screen, and hence cause changes in the size of the image on the screen or the size of the area actually viewed by the TV system, and consequently the width of the "ground" traverse being made by a single scan line. It is also evident that if the screen itself is mobile so that it can either approach or withdraw from either the projector or the TV camera, the possibilities of simulating scale and resolution changes will be at least doubled in magnitude. Furthermore, if screen mobility also permits changes in the angle at which the image strikes the screen or is viewed by the TV, a simulation of various obliquity parameters become possible. It is indicated that if the rear view screen can be fixed in a light weight frame and mounted upon rolling and rotating casters, many valuable options become available in the parameters of display in the simulation system.

To implement the display system, a high quality Polacoat lenscreen measuring 4 feet X 6 feet X 1/4 inch was purchased and mounted in a frame composed of square aluminum tubing and designed by the Investigator and his research assistant in close collaboration with a local aluminum fabricator. Appendix A of this report presents the sketch designs from which the mobile viewing screen was made.

Projection equipments needed to throw the image upon the rear view screen are determined in part by the photographic format. Orbital imagery from Gemini and Apollo missions is usually available in either super-slide or 70 mm format. It may also be desired to project 35 mm slides. Initial experiments utilizing a popular slide projector utilized for instructional purposes revealed a considerable "hot spot" of light in the central image area which affected the fidelity of the simulation of real conditions and caused a pronounced fall off in signal strength of the TV scanning signal as it moved outward. This was overcome by securing a high quality Rollei-Honeywell projector adaptable to the above film size formats of space photography.

When film in the standard aerial 9 X 9 inch format is being utilized, two alternative display systems have been applied successfully. Figure 1 illustrates that with the use of a well illuminated glow box and other apparatus adjustments it is possible to aim the video camera directly at the roll film, while "Simulating TV Observation of Earth Surface Via Scanning of Aerial or Space Imagery". This technique is most effective when relatively large scale aerial imagery is used or when only highly generalized patterns from space imagery are desired, since magnification of the image being scanned is not feasible.

To project 9 X 9 inch frames of roll film onto the rear view screen a standard overhead projector may be used, but in order to hold the roll film in place an inverted "U" frame of aluminum was devised to fit over the projector. Horizontal bars welded to each side provided the mounting for standard film holders, and permit the film to be rolled across the viewing plate. It was also found that if the projector has a rotatable lens head, a band marking 360 degrees can be placed around the cylinder housing holding the lens. If the entire projector is placed on a rotatable projection stand, the rotating of the viewing plate, while the lens head points toward the rear-view screen, permits rotation of the image on the screen. If the TV system is scanning the screen with horizontal traverses, a study of azimuths and their influence in detecting phenomena is possible. Figure 2 displays this equipment.

If desired, motion pictures could also readily be projected upon the rear-view screen and scanned by the TV camera on the opposite side. Actually any type of image that can be projected could be thrown onto the screen with various degrees of enlargement or rotation or obliqueness; and viewed by the TV system or directly studied by human observers.

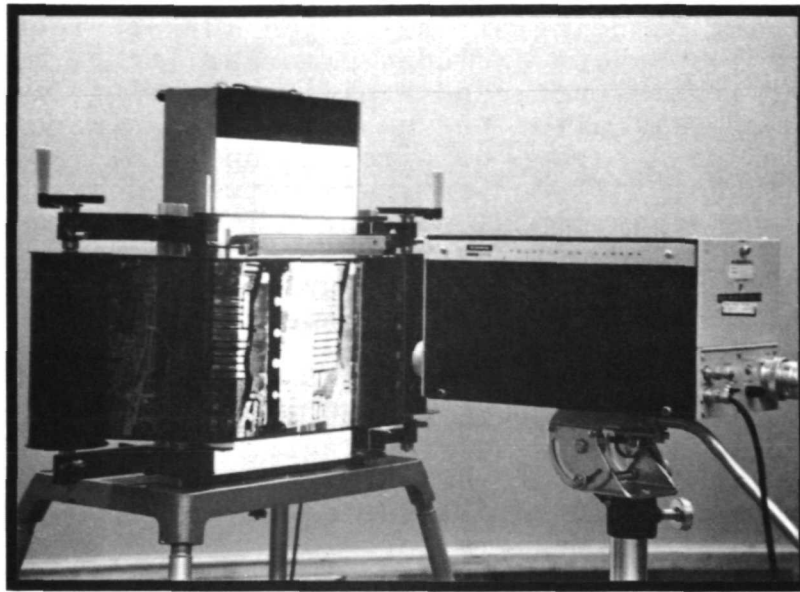


Figure 1. Direct TV scanning of 9 X 9 inch format aerial roll film via glow box device.

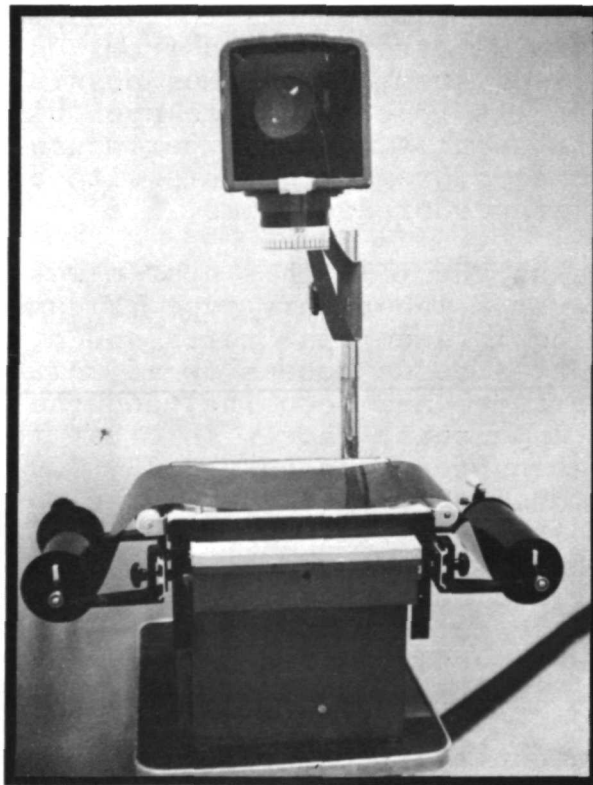


Figure 2. Projection of 9 X 9 inch format aerial film roll via device mounted on overhead projector.

## B. Television Scanning of the Imaged Surface

Television scanning of the imaged surface requires a laboratory room which excludes exterior light, minimizes the interior light level, and avoids reflecting light patterns which will alter the quality of the image being viewed either on a screen or directly on film. An interior room with a short corridor entryway between doors provides an appropriate experimental setting. It is not necessary to maintain complete blackout or darkroom conditions, but deviating very much from such an environment would significantly alter simulation effectiveness.

The choice of a closed circuit television system is related to the objectives of the investigation, the funds available, the engineering environment, and the instrumentation skills of the investigative team. It was the desire of this investigation to maximize the opportunities of geographers carrying out the experiment to alter such parameters as size (scale) of surface area scanned, location or proportion of image area scanned, azimuth of scan lines, and number of scan lines (scan line rate) utilized. It was also desired to minimize the dependence of the investigators upon engineering support for the experimental changing of such parameters. By limiting technical requirements to those readily developed after minimal training and from "on the job" experience with the system, it becomes possible for the non-engineer scientist to concentrate upon his research objectives and the results of his experimental fluctuation of the scanning system parameters with a minimal of technical assistance or down time.

It was found at the time this system was being developed that several laboratory type TV cameras could provide some choice in scan line rates and other variables. It was decided that a ready access to adjustable controls such as gain, aperture, and focusing, and the convenience of changing plug-in circuit panels in order to alter scan line rates among four choices - 525, 729, 853, and 945 - made the COHU 3200 series camera the most appropriate one for this investigation. The ease with which this modestly-sized camera could be manipulated when mounted upon a tripod mount was also helpful for the anticipated use. To further increase flexibility, two lenses of different focal lengths were purchased - one inch and one-half inch.

This tripod mounted TV camera is readily connected by a single coaxial cable to a video monitor or to a waveform analyzer. It can be moved freely and pointed in any direction, including horizontal and up or down

angles. The camera may be raised or lowered on a vertical pole mount without moving the tripod legs, and hence can look from close range at high or lower portions of a projected image. It may also be tilted downward to look directly at imagery as Figure 1 illustrated.

The inter-related equipment system developed to simulate television observation of earth surface phenomena is illustrated in Figure 3. The combination of projector, rear view screen, TV camera, video image monitor, and a waveform analyzer are shown in the most commonly used configuration. It is noticeable that distance relationships between projector and screen or between screen and TV camera are adjustable with a considerable variability of combinations. Focal length changes in the lens system of either the projector or the camera or of both also provide additional flexibility in the simulation system which can relate to changes in the relative positions of the sensor and the earth surface. Also, by changing sync generator circuit boards and aperture adjustments of the camera, it is possible to alter the scan line rate and consequently the "ground" width of the scanning traverse and the number of traverses sampling a given surface area.

Since the video camera is being utilized in close proximity and within view of the large video monitor which would display the image being generated for interpretation studies, there was no need to add to the camera the small viewing monitor available for cameraman viewing. It is more appropriate to view the large monitor face while making camera adjustments such as focusing or signal gain control. The ready access to controls on the rear of the camera or within its hinged rear access panel makes such operation feasible while tests are in progress or calibration is being accomplished.

The camera has optional bandwidth choices of 10 megahertz and 20 megahertz, and the substitution of a plug-in unit readily accessible converts the bandwidth from one choice to the other. For 525 and 729 scan line rates the 10 megahertz unit is used, and for 873 or 945 rates the camera is operated with 20 megahertz bandwidth.

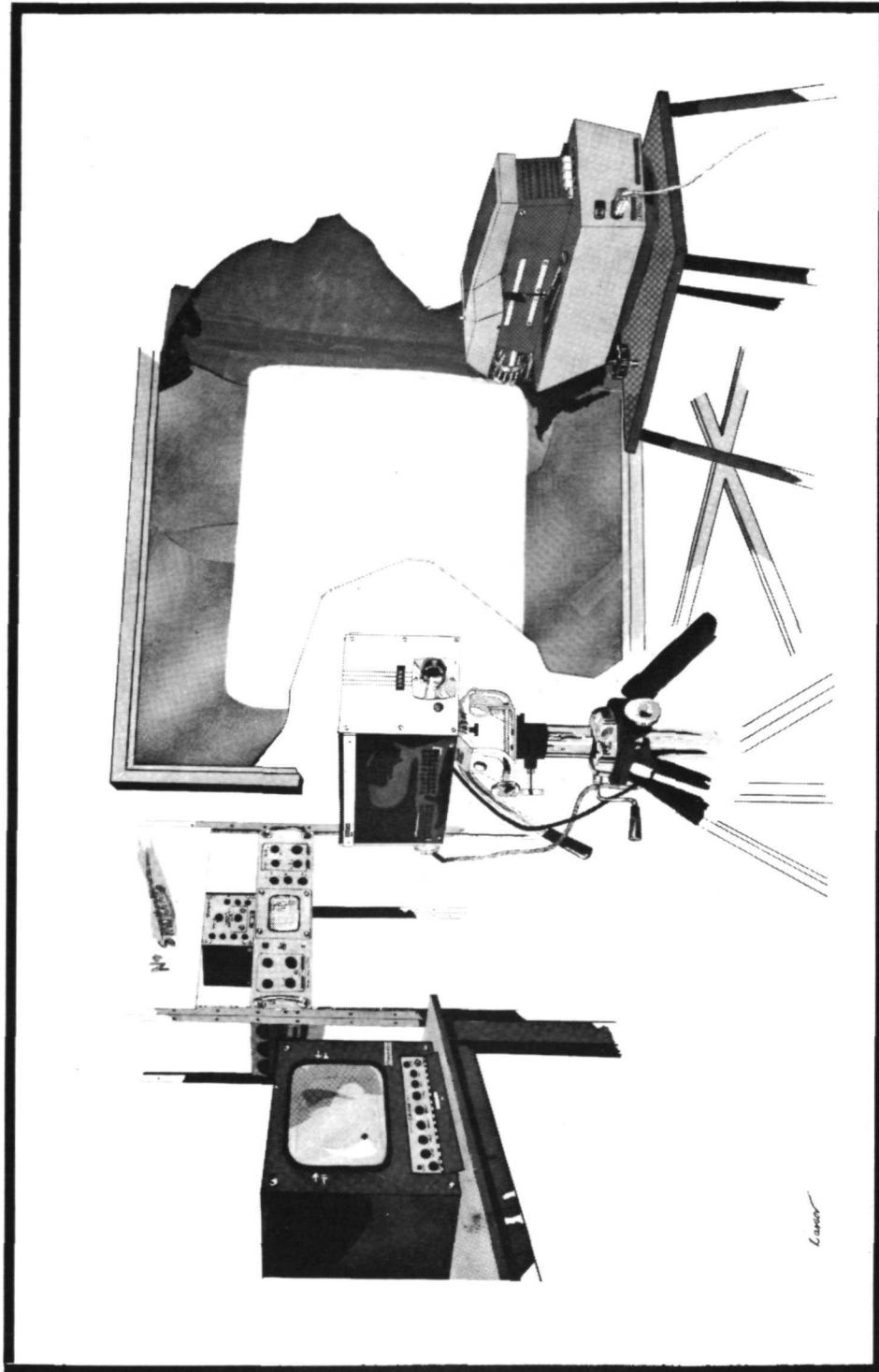


Figure 3. System for simulating T.V. observation of earth surface phenomena via projected imagery as developed by the Remote Sensing and Interpretation Laboratory at Florida Atlantic University.

### C. The Television Imaging of Geographic Patterns as Reconstituted from Scanning Traverses

To reconstitute the original patterns in the form of television scan line imagery, a separate video monitor is required for each of the four scan line rates that can be generated by the camera system. Fourteen inch Conrac monitors in standard laboratory cases are available for this purpose. A waveform analyzer is installed in the circuit between the television camera and the monitors. Coaxial cable connectors are easily moved from one monitor to the other as the camera is converted for scanning patterns selected from the rates available.

The monitors of course have the usual front mounted controls for brightness, contrast, and focusing. Both monitor controls and camera adjustments can be manipulated to secure the most effective scan line imagery possible. This adjustment process is carried out by visual observation of changes resulting from manual adjustments but can also be assisted by signal measurements displayed by the waveform analyzer which can indicate proper gain setting, blanking and also cable delay corrections. It also has other functions adaptable to geographic pattern analysis.

The specifications for the system's video camera promise a combined geometric distortion and scan non-linearity that will be within two percent. It is also possible that the original photography which is being used to simulate earth surface contained some geometric distortion due to lens factors or other parameters of the photo system. It can be assumed that some similar distortions will occur even when the TV system is directly scanning earth surface, and consequently the signals reaching the monitors may not be capable of contributing distortionless imagery on the tube face. However it is possible to determine the behavior of the scan line system of the monitor itself and verify its geometric characteristics and hence minimize the distortions in the reconstituted imagery. Such a goal is very significant for geographic research which is particularly concerned over the distribution relationships of the phenomena in the patterns.

A dot bar generator has been integrated into the system in order to verify that image size and shape characteristics are being satisfactorily produced by the monitor tube. It provides a choice of several patterns - such as systematically distributed dots, crosses, or lines - which can be used for testing the geometric characteristics of the display on the picture tube face,

and for observing the achievements of corrective procedures, as illustrated in Figure 4.

A useful technique for testing the geometric calibration of the complete TV camera and monitor system is illustrated in Figure 5. This calibration plate prepared on the 9 X 9 inch format of aerial film is scanned by the camera and used in conjunction with the signal dot generator to identify and then minimize any distortion tendencies of the total viewing and imagery display system. Also, the standard RTMA Linearity Chart is available for establishing electronic distortions, and the detailed adjustment processes are described in equipment manuals of the manufacturers of the equipments.

The projection of the reseau grid, shown in Figure 5, from the same viewing plate position that will be used for aerial or space imagery can also reveal any geometric distortion that may be present in the optics or positioning of the overhead projector. By inspection one can quickly confirm from the displayed pattern that the screen is at a 90 degree angle with the projection beam, and therefore displays the scene as it was originally observed by the camera.

In addition to obtaining a linear alignment throughout the system, it is appropriate to use resolution targets to determine the system's capability. Two targets readily available for such testing are: (1) Resolving Power Test Target (USAF1951), and (2) IEEE RETMA Resolution Chart 1956. The RPTT results can be computed by using a factor of  $\frac{6}{\sqrt{2}}$  when the smallest three bar group can be resolved and then converting to lines per millimeter. The resulting number is the system capability which can be compared with resolution of the aerial (or space)imagery being utilized. This can also be related through the electronic scanning and display system to give the equivalent photographic value of the target as displayed on the TV monitor. On the following page, Figure 6 displays the Revolving Power Test Target.

To determine the television resolution of the TV system, the IEEE RETMA Resolution Chart - 1956 can be used. Figure 7 illustrates the scanning of this target by the TV camera. Both horizontal and vertical TV resolution can be evaluated by determining the point on either axis at which line separation is no longer discernable.

Although the term "resolution" is also used in optical, photographic, and printing technology, the definition is quite different when one is referring to the measurement of

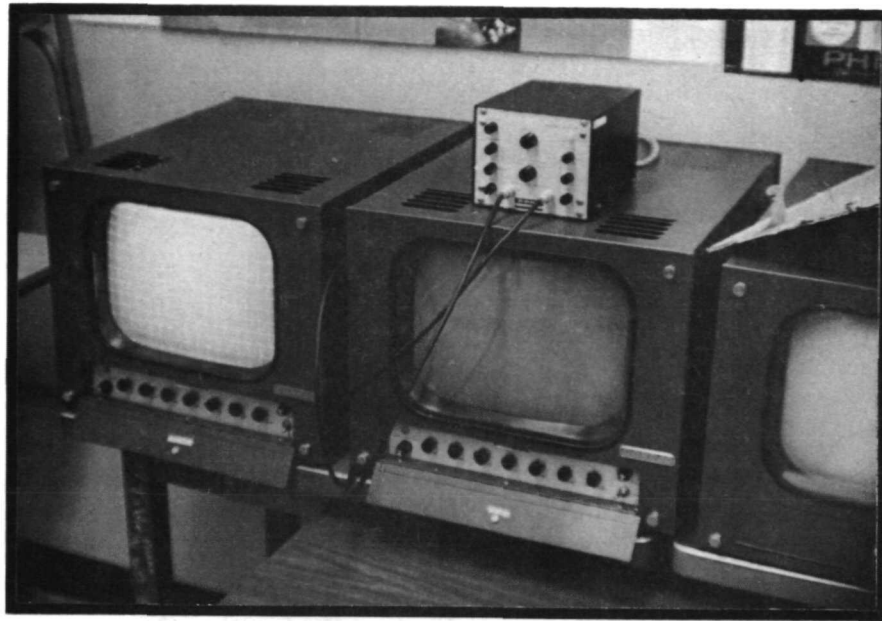


Figure 4. Dot bar generator for testing geometric characteristics of monitor image with a white cross-hatch pattern.

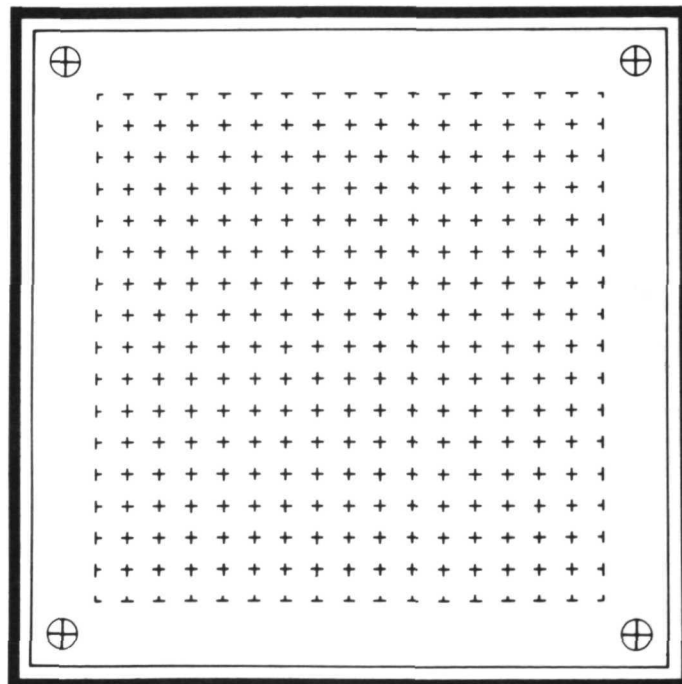


Figure 5. Calibration plate pattern for 9x9 inch format of aerial film scanned to test for and correct distortion tendencies from the T.V. camera and monitor display system.

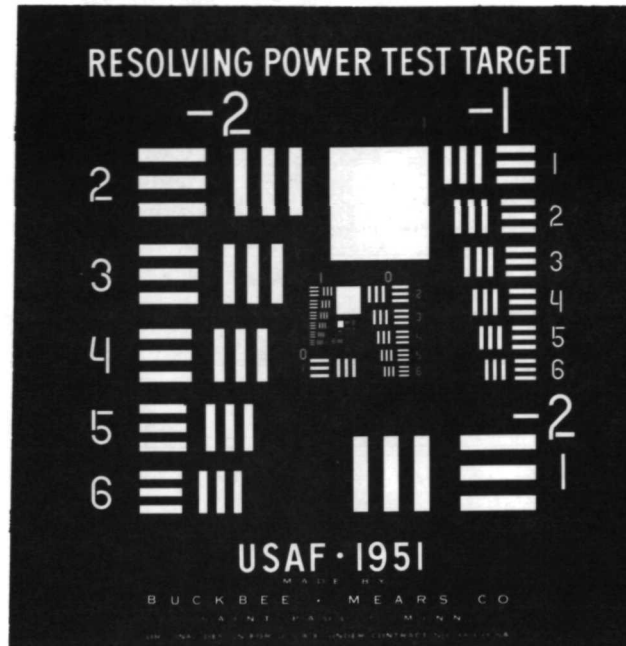


Figure 6. To determine the photographic (optical) resolution capabilities of either the image projection system or of the entire simulation and television imaging system, the Resolving Power Test Target can be utilized.

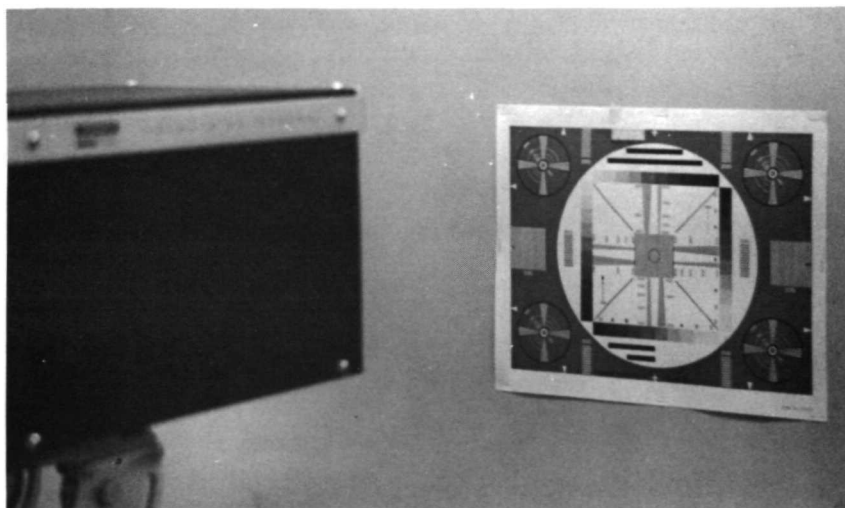


Figure 7. To determine the television resolution of a closed circuit T.V. system, the RETMA Resolution Chart (1956) can be used. Both horizontal and vertical resolution can be determined by locating the "point of no separation" on either axis.

resolving capability in a television system. Television resolution is determined primarily by bandwidth, scan rates, and aspect ratios. Although systems are usually designed to have equal horizontal and vertical resolution, the aspect ratio is generally 4:3 since it expresses picture width to height.

Horizontal TV resolution is the maximum number of both black and white vertical bars that can be resolved within the horizontal expanse of a raster equal to one picture height. Since horizontal width exceeds height by the 4:3 aspect ratio, the maximum horizontal resolution is the number of vertical bars resolved within 3/4ths of the raster width. Therefore, horizontal resolution is measured in terms of lines per picture height, and is primarily determined by the bandwidth, the active line time, and the aspect ratio. Horizontal resolution can be increased by use of additional channel bandwidth if available. The U. S. 525/60 system has a Horizontal Resolution Factor of 80 lines per MHz. With a standard bandwidth of 4.2 MHz, the nominal resolution is 340 lines. The 945/60 closed circuit system used more frequently in this research program has a Horizontal Resolution Factor of 40.5 and requires 15 MHz to provide 615 lines of horizontal resolution (Note: the camera used in this research provides an ample 20 MHz.)

Vertical TV resolution is defined as the maximum number of black and white horizontal bars that the system can resolve. It is also expressed in lines per picture height. It is determined by the number of active horizontal lines per frame (the total line count minus the number of lines in vertical blanking). The actual vertical resolution (for an interlaced system) equals the number of active lines per frame times 0.7 - the Kell factor which represents the relationship between the total number of active lines per frame and the actual resolving power determined in a visual manner. In a 525 scan rate system, about 40 lines are lost to vertical blanking time periods, hence when the Kell factor is applied the result will be a vertical resolution of 340 lines.

Resolution is measured visually while the system is reproducing a test pattern as shown in Figure 7. The upper central group of black and white lines is the resolution wedge. When the camera scans the full test pattern, line thickness and spacing at the top of the wedge equals 200 lines per picture height, and 400 at the bottom of the wedge.

The wedge immediately below that gives a test range of 300 to 800 lines. The resolution is determined at the point where the line pattern loses contrast, but individual lines are still discernable.

Television resolution measurements refer to the maximum number of discernable lines (black and white) that can be resolved within a dimension of one picture height. Optical resolution capability is generally accepted as the maximum number of line pairs per millimeter that can be visually resolved. Television resolution is relative to picture height and optical resolution to the millimeter, hence no direct conversion factor exists. The illustrated procedure presented on the following page as Figure No. 8 demonstrates both (1) The manner in which a projected resolution target can be used to determine the minimum size of objects as imaged in the film that can be resolved on the rear-view screen; and (2) The manner in which the resolution of objects in the photo image can be related to the minimum size of surface features that can be resolved in the projected image.

It should also be recognized that when any areally expressed unit is smaller than the width of the scanned path of a scan line, the lens of the TV system may discriminate the object, but the scanning of object by the internal electronic system will average the "density level" of this object with the density levels of any other phenomena also included in the total width of the scanning beam at that spot. Consequently, not the object but an average density value will be generated for that spot of scanning signal, and unless the object's density values are not significantly diluted by this averaging process, the object will not be represented in the gray-tones of the monitor image, and it cannot be resolved. However, if aperture adjustments reduce the size of the scanning spot and consequently the width of the scanning traverse, smaller objects can be resolved. If scan line rates are also increased, more sampling parallel scanning traverses will cross over larger units and hence yield more information concerning their size, shape and orientation. However, it must be recognized that resolving a photographed feature on the screen that simulates earth surface, does not mean it will be resolved by the scanning system, unless the feature is at least as large as the scanning line and dominates its width.

To determine the resolving power of a particular projection arrangement first locate from the projected image of the test pattern the smallest bar group which shows three separate and distinct bars and spaces on the screen. Then, to obtain a numerical resolving power factor for the system, divide by the enlargement factor the width of the line pair (bar and space) resolved.

EXAMPLE:

Measurements from the smallest resolved group of the pattern, as imaged on the screen.



If the enlargement factor is 10, then

$$(.05+.05) \div 10 = .01''$$

Therefore the projection system can resolve on the screen an object recorded on the film with a minimum dimension of .01".

If the scale of the photography is known, e.g.-- 1:10,000, then the smallest ground object that can be photographed and also resolved on the rear view screen with this particular projection arrangement would have a minimum ground size of 100 inches or 8.3 feet.

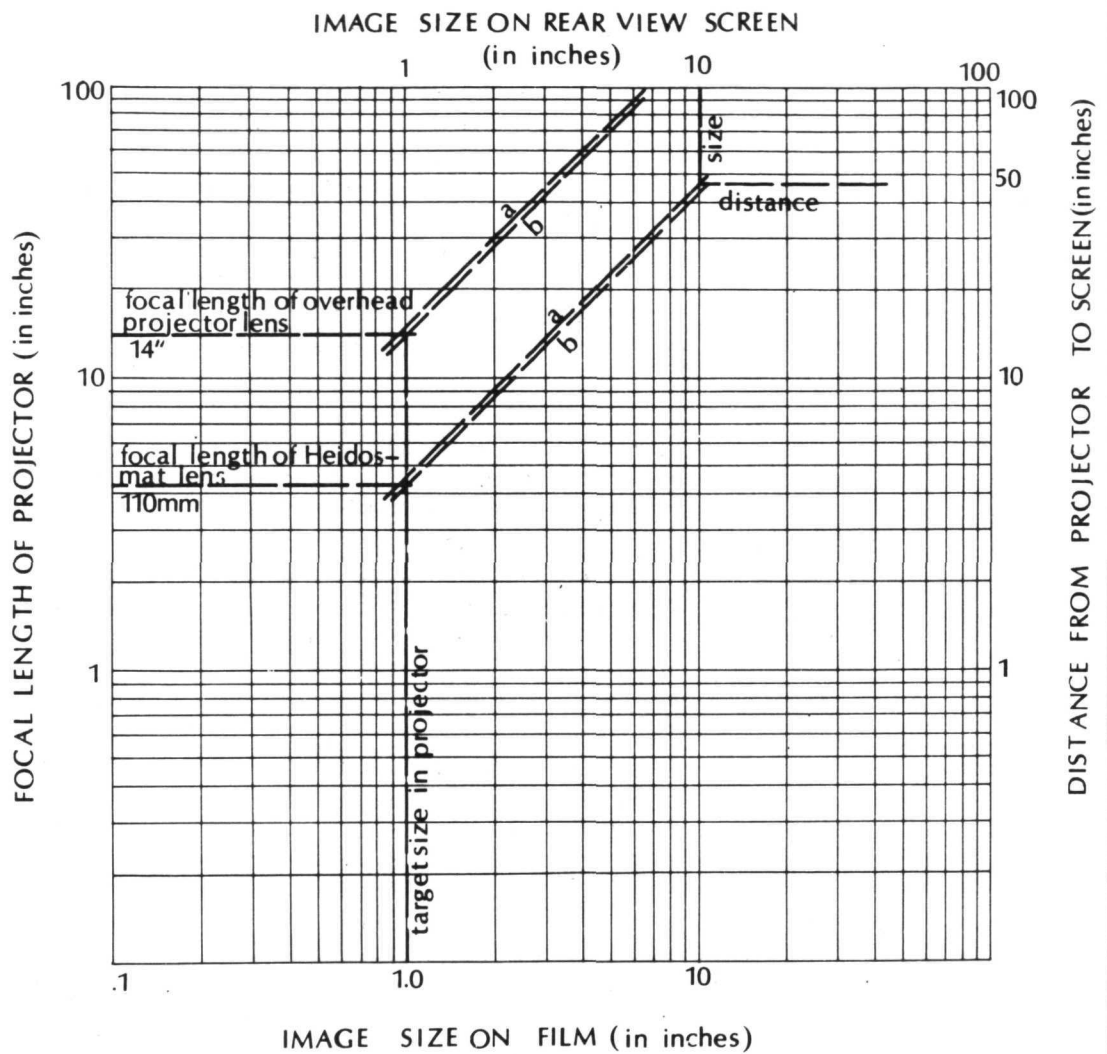
Figure 8. Illustration of Resolution Determination.

The size of the imaged objects on the rear-view screen will be a critical parameter which determines whether or not the objects are resolved ultimately in the television image. To assure that objects of particular interest are adequately represented on the laboratory screen which simulates the viewed earth surface, it is useful to know the relationships between the size of the imaged objects on the film, the focal length of the lens on the projector, and the distance from the projector lens to the screen. A chart which displays these relationships in the simulation system, and permits an estimate of the arrangement necessary to assure that all objects of interest will be adequately sized on the screen is presented as Figure 9 on the following page. Since any one of the four factors can be determined if any three are known, it is also possible to determine the size of an object in the film by measuring its dimensions on the screen.

For example, to determine the distance needed between projector and screen when one desires to enlarge a 1 inch object on the film to a 10 inch size on the screen, follow the line plotted as "a" on the graph. Starting with an image size on the film of 1 inch, first locate that point on the bottom scale. Then move upward to intersect the focal length of the projector lens being used. From this intersection point, then draw a 45 degree line until it intersects the line which descends from the desired 10 inch image size on the scale for the rear-view screen. From this intersection draw perpendicular to the descending 10 inch line a new line which will intersect the vertical scale on the right which indicates the distance from the projector to screen that is needed. In the case of this example "a," the needed distance is 46 inches.

Note however that one important factor must be determined before the chart is used. It is necessary to determine the focal point of the projector lens. In this chart which presents paths for both the Rollei slide projector and the Bessler overhead projector used for 9" X 9" aerial film, the measuring point varied. For the slide projector the measuring point was from the front of the lens, whereas for the overhead projector it was from the glass plate on the lens housing. Two lines are shown on the graph. Line "a" is that determined by measurement to be the focal point, and line "b" is the focal length of the lenses as annotated on the lens barrels.

# IMAGE SIZE ON REAR VIEW SCREEN RELATIVE TO IMAGE SIZE PROJECTED



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Figure 9.

Since the scale of the image on the TV Monitor will be determined not only by the scale of the image scanned on the rear-view screen but also by the focal length of the lens on the TV camera and the distance from that lens to the screen, a distance scale was developed to facilitate the positioning of the systems components. For example, in order to produce a 1:1 ratio on the monitor face when using a 25 mm. lens, the lens to screen distance is 56", and for a 2:1 ratio the scale is 45.4". Correct alignment is required to maintain correct geographic relationships in the image. Monitor brightness to contrast ratio can be adjusted subjectively but camera station adjustments can be made and observed on the waveform analyzer.

When it is desired that the screen image or the monitor image be at a certain scale, such as that which would match on existing map for compilation or comparison purposes, the image can be measured on the screen for the desired scale by using proportional dividers to relate map features to the image. Measurements are accomplished on the side of the screen facing the TV camera with a clean sheet of acetate film used to prevent damage to the screen. The projector or screen can be moved forward or back when a fixed projector focal length is used, or the zoom lens can yield ready changes if otherwise adequate. TV camera position can then be established by the techniques discussed above if one desires a 1:1 or other scale ratio on the monitor image.

To establish the limits of vertical detail that is useful in a TV image one must determine how many picture elements can be reproduced in a vertical array using a given number of scanning lines. However, typical picture content can be expected to have a non-uniform arrangement of elements. Some phenomena will fall directly on a scanning line while other distributants may straddle it. Since geographic phenomena is not usually randomly distributed but rather influenced by such factors as natural topography or cultural intervention, there are limits to the use of a concept such as the average number of elements that can be expected to fall directly on a scanning line. Yet, for purposes of analysis, engineers have suggest that - assuming a random distribution of light and dark picture elements - a "utilization ratio" representing the vertical detail to the total number of scanning lines ranges in experimental studies from 0.6 to 0.8 for different images with "typical" picture content.

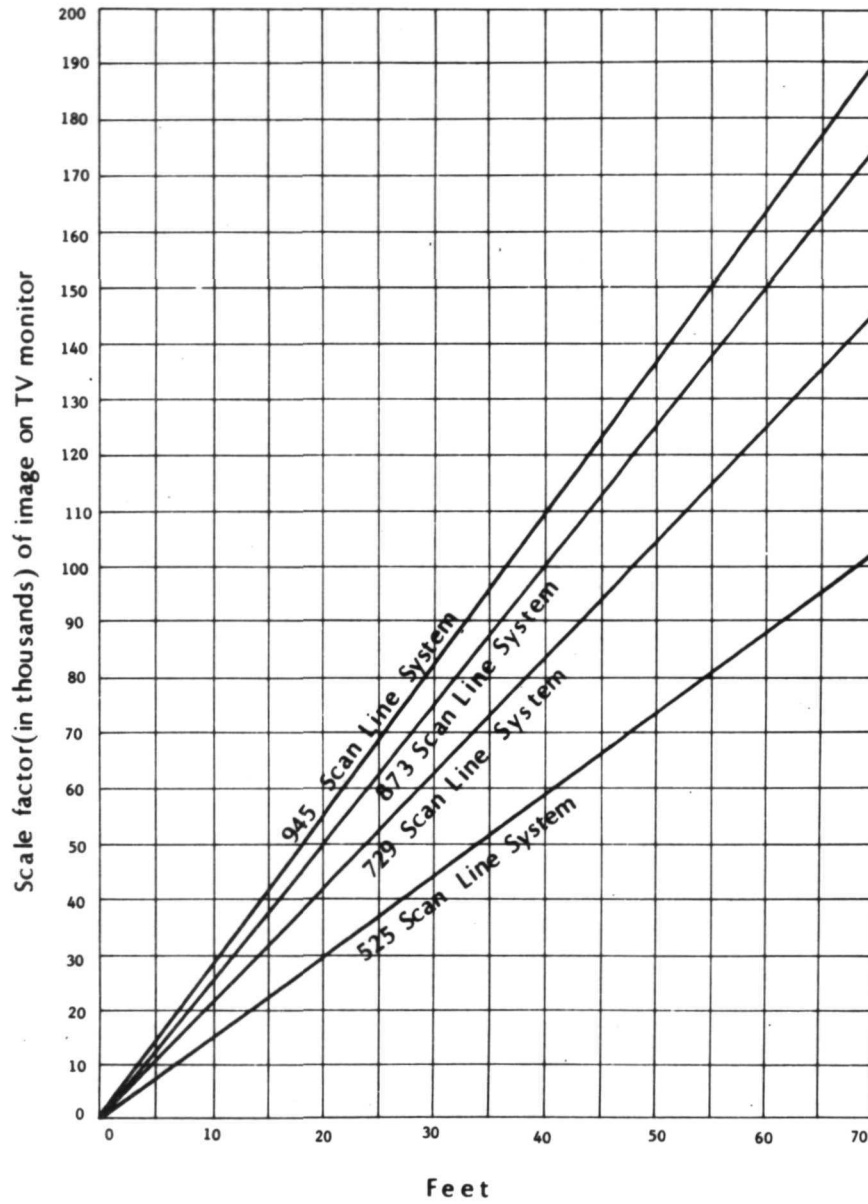
Hence, an average of 0.7 is used. Therefore it is suggested that the maximum number of vertical details that can be reproduced with 525 total scanning lines which reduce to about 493 visible lines due to vertical blanking is about 338, with the exact number depending on the particular utilization ratio. For geographers and others who utilize aerial or space television imagery, it is important to recognize these limitations. Not only is this a sampling system limited to a particular number of scanning traverses, but also the scanning traverses will not always be delivering resolvable data even when the phenomena has been within the scanning path.

Although the above limits upon vertical image details are present in TV imagery, an experimental study in our laboratory did permit a determination of the minimum size of objects scanned by the TV system that can be revealed by the vertical resolution of different scan rates as they adjust apertures for greater definition and present images on the monitor at different scales. If we assume that the system is scanning actual terrain - such as the projected image on the screen simulates - then the size referred to is the size of the surface feature being scanned. The scale of the image on the monitor would result from the altitude (distance) of the scanning system and the focal length of its optical system.

The experimental study measured the "ground" size of objects as they were imaged in the photography projected on the screen to simulate earth surface, and determine the ability of the monitor images at different scales to resolve them for visual interpretation. Each of the four scan line rates available were tested. When the results of all observations were plotted, they yielded the relationships indicated in the chart on the following page.

This chart in Figure No. 10 indicates that if the investigation can be carried out when the scanning system resolves surface phenomena that has a minimum dimension of 40 feet or more, then a 525 scan line rate system operating with an optical system and altitude that yields an image scale of 1:60,000 on the monitor can satisfy the requirements of the investigators. We also see on the chart that the needs of the investigation can be satisfied with a 945 scan line rate system operating with an optical system and altitude that yields a 1:110,000 scale image on the monitor. This may be the desirable alternative since it means that the scanner altitude could be much higher and also secure more synoptic imagery, thereby requiring fewer "flight lines" or "passes" and less time to secure the imagery resolution needed for the investigation.

MINIMUM GROUND DIMENSION IN FEET FOR  
 VERTICAL RESOLUTION OF SURFACE FEATURE  
 AS IMAGED ON TELEVISION MONITOR



REMOTE SENSING AND INTERP. LAB.  
 FLORIDA ATLANTIC UNIVERSITY

Figure 10.

Other alternative combinations are readily read from the chart for the scan line rates and monitor picture scales shown. Mission and system planning can be assisted by its utilization. Since greater bandwidth is required for the higher scanning rates, efficiencies or economies for recording or telemetry systems might be a consideration affecting the decision. It is obvious that an increase in scan line rate when all other factors are constant will yield more detailed imagery and a greater data potential, and probably increase the variety of investigations and disciplinary research fields that could be serviced with the same imagery. However, it would also be evident that information processing and distribution costs would increase. Probably time delays would be increased for some investigators who might have more efficiently pursued their objectives with less resolution or linear amounts of scan line data. Although most geographers might lean toward greater amounts and more discrimination of surface data due to their rather catholic interest in distributed phenomena, other investigators, such as geologists, might be satisfied with less detailed patterns of distribution.

#### D. Photographing Television Imagery

Although television imagery can of course be electronically recorded on video-tape or by other means, there was little reason for this investigation to do so. It was in fact more appropriate to photograph the monitor face, so that intensive interpretation studies of the images at various scales and scan line rates could then be independently studied by the interpreters to establish as objectively as possible the levels of geographic data in the various images. For a related investigation it was also appropriate to photograph the waveform signal and to relate its amplitude fluctuations to the surface features discernable along the scan line path that can be detected in the monitor image. The advantages of this simultaneous observation of waveform and monitor image can be observed in Figure No. 11 on the following page.

Although some Polaroid pictures were successfully taken of both monitor and the waveform analyzer, other camera systems were usually more appropriate for this investigation. Panchromatic film and speed settings of 1/30 second and 1/60 second, with proper aperture openings, have been used to record a full image on the monitor. To determine the proper aperture, a light meter adjusted to the proper film speed is used. A 35 mm. camera, sometimes with a zoom lens, is used to photograph just the waveform analyzer. The image on the TV monitor is recorded by a 2 1/4" X 3 1/4" press camera. The larger camera is usually used to photograph the monitor in order to obtain a negative that will minimize the enlargement factor, since it is often desirable to enlarge the photo print to equal the actual size of the 14" monitor tube. This was desired for interpretive studies since it reproduces the scan lines at the same size as they might be viewed on the monitor, and comes close to presenting the interpreter with the same capability of interpretation.

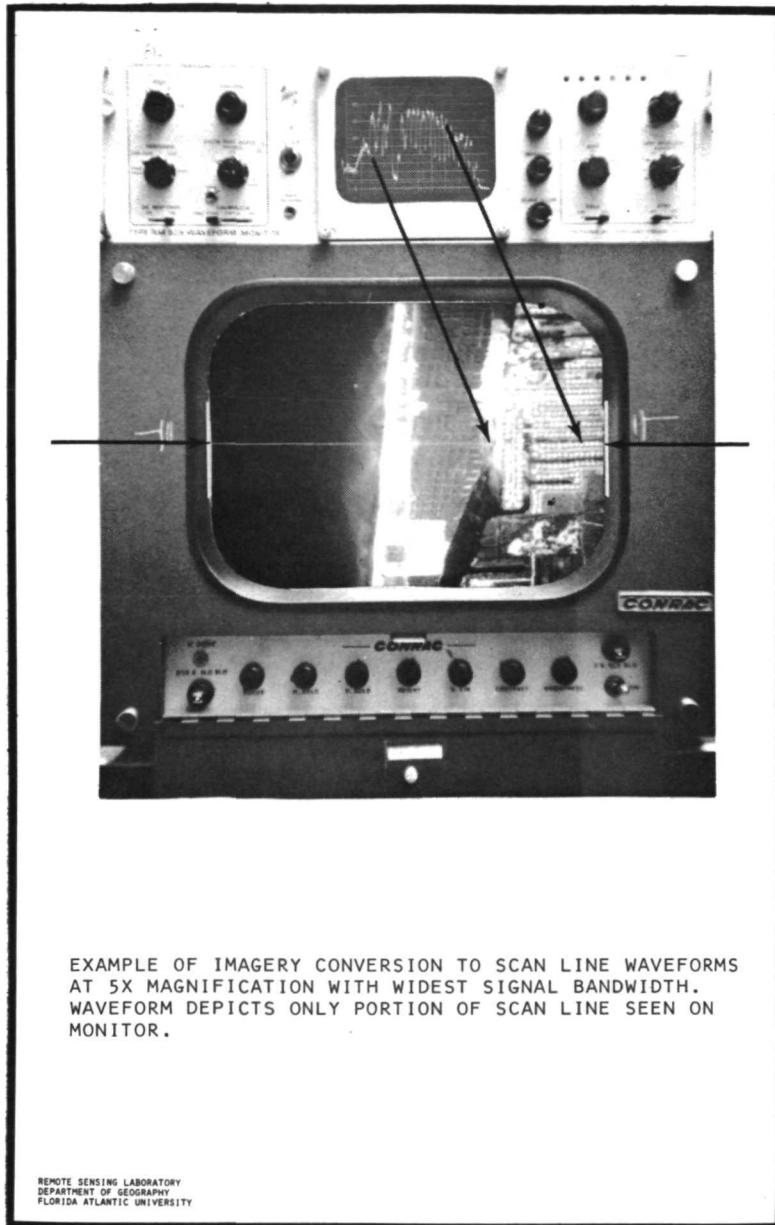


FIGURE 11.

## Section Two: INTERPRETATION STUDIES

In order to study the possibilities of geographic pattern discrimination in television imagery of earth resources from both aerial and orbital altitudes, this investigation has carried out a series of interpretation studies which are reported in the following pages, or presented in abstract in Section Three if a technical report has been published. In Section Four, the listing of some other papers, articles, or reports presenting interpretation studies may be found.

Since an earth orbiting television system designed to survey earth resources should be operational in the near future, our studies were particularly concerned with space imagery, or characteristics of aerial imagery which would contribute to the analysis of imagery from space-borne sensors. In this Section, Study A reports on an experimental program in which three interpreters with somewhat varied professional backgrounds carried out coordinated but independent interpretations of simulated TV imagery. The first phase of their study interpreted four selected images which depicted differing environments, and evaluated the degree to which geographic phenomena discrimination changed as changes in the television scan line rate were made in the imagery data. The second phase of this experiment concentrated upon vertical imagery of the East Central Florida area, and evaluated the degree to which discrimination of geographic phenomena patterns was improved by enlarging the scale of the simulated television image or by intensifying the scan line rate at a particular scale.

Study Two presents a concise description of how the signals resulting from television scanning can be interpreted by waveform and computer analysis in order to directly yield a print-out map of generalized land use. Study Three demonstrates that small scale - 1:60,000 - high altitude aerial imagery which resembles the resolution that we may later expect to get from orbital altitudes can be effectively interpreted to yield a geographic description and analysis of a rather large region, with particular emphasis upon the urban-rural interface zone. Study Four presents in summary form an example of the many evidences of environmental impact monitoring capability that the investigators noted in their interpretation studies.