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SIMULATING AND INTERPRETING AERIAL OR ORBITAL TV OBSERVATIONS OF GEOGRAPHIC PATTERNS TR-5

by

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Abstract

This report presents the methods, techniques, instrumentation systems, and concepts or analyses developed by an investigation of the possibilities, problems, and applications of interpreting the geographic patterns recorded by orbital television observations of earth resources and land use. To facilitate the study, a system for simulating orbital television imagery by scanning astronaut-acquired photography and converting it to a TV monitor image with alternative scales and scan line rates was developed. A study of this imagery by a team of interpreters determined the feasibility for extracting and mapping geographic data from the television images and analyzed how the capability varied with changes in scan line intensity or image scale.

Other studies established the feasibility of directly processing television signals with a waveform and computer analysis technique that produces a print-out category map of generalized land-use types. One study also demonstrates the possibility of using waveform signal analysis to quantify the geographic patterns of distribution and identify phenomena recorded in color or color infrared aerial imagery. Other studies demonstrate the use of very high altitude aerial photography to make a geographic region analysis or locate some pollution evidenced in the surface phenomena. Another interpretation study evaluated the amount and geographic relationships of unutilized land in a coastal urban region.

In the course of the investigation, six low, medium, or very high altitude missions were flown over NASA Earth Resources Test Site No. 164 centered on Boca Raton, Florida by multisensor aircraft. Ground survey was coordinated with each mission, and mission results were reported to the sponsoring groups--The Geographic Applications Office of the U. S. Geological Survey and the NASA Earth Resources Aircraft Program.

Principal Investigator James P. Latham, Director of the Remote Sensing and Interpretation Laboratory at Florida Atlantic University, was assisted in various stages of the investigation by research associates Richard H. Witmer, G. Lennis Berlin, L. Alan Eyre, Simon A. Baker, Nelson R. Nunnally, Clark I. Cross, and William H. Kuyper. Technical or research assistance was also provided by other graduate and undergraduate student assistants including Dillard Larson, Kenneth Smith, Sandra Harris, Ronald Senykoff, and some others.

Acknowledgements

This report includes instrumented techniques and interpretation experiments which have evolved in our Laboratory over several years of research activity. During that period many others have worked with the Investigator and contributed substantially to these concepts and procedures for analyzing geographic patterns in imagery via both traditional and inovative electronic and computer analysis systems. In most cases the nature of their contributions is suggested by their authorship of the studies or other documents included in this report. However, the Investigator wishes particularly to acknowledge the initiative contributed by research associates Richard E. Witmer and G. Lennis Berlin and by our Laboratory Technical Supervisor, William H. Kuyper. Kurtis Norling, Chief Television Engineer of the University, also contributed substantial technical support, as did William N. Watkins and other personnel of the University's Photo Laboratory and Computer Center.

Dr. Arch C. Gerlach with his staff at the Geographic Applications Program Office and numerous persons of the NASA Earth Observations Aircraft Program were generous in contributing to the success of our multi-sensor mission operations and other research support requirements.

James P. Latham
Principal Investigator
January 1972

T A B L E O F C O N T E N T S

INTRODUCTION

The particular parameters of scale and imagery resolution needed for identifying, bounding, and measuring specific types of geographic phenomena and their patterns of distribution which are detected by remote scanning sensors are of great concern. The principal controls on scale and resolution constants are:

1. Design limitations of the sensors being employed, such as: number of scanning lines, optical system, gray-tone discrimination, data recording systems, and some other factors, such as direction of scan traverse.

2. Efficiencies of transmittal systems (telemetry) which are constrained in part by considerations of bandwidth requirements, bit rates, transponders, etc.

3. Imagery reconstitution systems or signal analysis systems which permit the identification, qualitative or quantitative measurement, and comparison of geographic phenomena and their patterns of distribution.

4. Location of sensor, particularly in respect to altitude and sun angle.

5. Location of phenomenon: surface, sub-surface, atmospheric; and in relation to intervening restrictions, as cloud cover.

In the near future, the most systematic observation of the earth's geographic features on a synoptic scale will be carried out by unmanned orbiting remote sensors utilizing electronic scanning systems - such as television or infrared scanners. It is the purpose of this research to study some of the above system influences upon methods and techniques for geographic pattern analysis, with particular reference to tropical and sub-tropical environments.

Since 1962, the inter-disciplinary study of the application of remote sensors to the description and analysis of earth resources and their geographic patterns has been an expanding field of scientific investigation. The concurrent development of space sciences and the ability to place orbital remote sensors around the turning earth has created new perspectives for synoptic observation of the earth's surface patterns, and for the systematic study of the physical and cultural processes which cause these patterns to evolve and change. From the increased understanding of the total world environment so observed, major improvements in man's ability to efficiently operate in his environment seem assured.

However, the ability to extract, organize, and apply this new knowledge is dependent upon understanding the sensor systems, the data they record, and the limitations or particular advantages of each sensor. The development of instrumented methods for processing the geographic content of data in imagery form that is now being made available in great quantities has also become an essential requirement.

In 1959, this Investigator published a report on the Possible Application of Electronic Scanning and Computer Devices to the Analysis of Geographic Phenomena, and has since been continuously engaged in research applying electronic scanning devices to the analysis of geographic destributions as recorded in imagery or observed in the environment. Since the founding of Florida Atlantic University in 1964, a team of its geographers have applied electronic analysis to the task of extracting, measuring, and integrating the geographic content of imagery from both photographic and non-photographic sensors. In the process, an electronic imagery analysis laboratory - described in later pages - has been developed. In cooperation with the Bendix Corporation, overflights producing unclassified thermal-infrared imagery have been carried out. In cooperation with the U.S. Geological Survey and the NASA Earth Resources Aircraft Program, a test site has been established at Boca Raton,Belle Glade, and along the Southeastern sector of Florida. Multisensor imagery of this test site has been secured and studied. Other missions planned and executed by this research team have produced other imagery for a variety of studies, ranging from water pollution due to ocean outfalls to location of the mean high water line on the beach at Boca Raton.

Since the initiation of this U. S. Geological Survey project - Contract No. 14-08-0001-10936 - on July 1, 1967, studies have proceeded toward the goals of the program by accomplishing the following:

1. A system which simulates observation of the earth surface by aerial or orbiting television devices has been developed. By projecting color slides of photographs taken by aircraft and orbiting sensors upon a rear screen system, and altering scale of projected image, screen position, or TV camera position, it is possible to simulate alternatives of altitude, or optical systems. By altering scan line patterns in COHU 3200 series camera from 525 to 945 scan lines, it is possible to study implications of scan line resolution upon the detection and analysis of geographic patterns observed by orbiting TV systems.

2. Waveforms resulting from TV cameras are utilized to control and standardize monitor displays of imagery with the use of a Tektronix waveform analyzer. Waveform samples also provide statistical values for analyzing pattern variations present in imagery from either space or aircraft altitudes. Such data is proving more useful than densitometry traces for distinguishing land use regions revealed by texture differences in radar images, and has yielded "signatures" for some types of phenomena in other images, particularly when waveform characteristics from two or more sensors are combined. This suggests the possibility of extracting geographic information in "real time" directly from signals transmitted by orbiting devices.

3. Studies of the effects upon geographic pattern discrimination in TV imagery which relate to systems parameters affecting scale and resolution of images have been investigated in several studies.

    a. One study analyzed the need for a new strategy for developing land use classifications from imagery of different scales based upon the data actually present in the image and in a functional hierarchial order which permits the systematic integration of the classification at various levels of generalization.
    (See Technical Report No. 1.)

b. Interpretation of scan line imagery resulting from simulation of TV observation of the earth surface has been completed by three independent interpreters. Five images have been selected from the original set of 80 Gemini photographs. These five images have been scanned with both 525 and 945 scan line systems simulating orbital observation at various scales. From photographs of the monitor displays, interpreters are compiling three thematic maps from each image. The three maps are:

   1) Transportation patterns
   2) Other land use
   3) Physical regions

   The results from the three interpreters are compared, agreements noted and differences analyzed for cause such as (1) disagreement on identification of phenomenon; (2) visual acuity; (3) differences in interpretation techniques, or (4) differing professional backgrounds.

   Technical Report No. 2 summarized early findings and conclusions resulting which bear on instrumentation requirements and interpretation techniques.

4. A Test Site Program sponsored by NASA has been established. It includes coastal, urban, port, industrial, agricultural, and undeveloped swamp and everglades terrain typical of the tropical and sub-tropical region of south Florida. Independent aerial surveys carried out by this project, cooperative thermal infrared missions with the Bendix Aerospace Corporation, and a NASA multisensor mission at 5,000, 15,000, and 60,000 feet altitudes have produced a large data bank of imagery. Ground truth from selected sites, including the U.S. Department of Agriculture Experiment Station at Belle Glade, and areas of the Central and South Florida Flood Control District, as well as other agricultural and urban areas, provide experimental data for studying multisensor imagery, and relating it to space imagery covering the same area.

MISSION OPERATIONS - NASA EARTH RESOURCES AIRCRAFT PROGRAM

Test Site No. 164 - Boca Raton and Southeast Florida

Msn. No.	Dates Requested	Dates Flown	Altitudes and Imagery	% Coverage Achieved	Date Rec'd Imagery	Date 90 Day Report Mailed
66	Jan. 10, '68	Feb. 7, '68	5 & 15,000' CLR,CIR,TIR	100% of Test Site	March 15, 1968	June 13, 1968
79	Sept. 9-13, '68	Sept. 11, '68	5 & 15,000' CLR,CIR,TIR	100% of Test Site	Oct. 4, 1968	Dec. 11, 1968
85	Jan. 6-10, '69	Jan. 14, '69	5 & 15,000' CLR,CIR	50% of Test Site (Belle Glade Area)	Feb. 8, 1969	May 9, 1969
90	Jan. 6-10, '69	March 13,'69	5 & 15,000' CLR,CIR	50% of Test Site (Coastal Area)	May 19, 1969	June 5, 1969
92	Apr. 14-18, '69	Apr. 30, '69	15,000' CLR,CIR	100% of Test Site	July 24, 1969 (Less Reconofax)	Oct. 29,1969
			4,000'	50% of Test Site (coastal area only)	" " "	" " "
112	Sept. 14-15,'69 RB 57	Oct. 14-15 '69	60,000' CLR,CIR	100% of Test Site, and Southeast Sector of Florida	Feb. 15, '70	May 15, '70
147	Oct. 13-15 '70 RB 57	Nov. 19 & 23 1970	60,000' CLR,CIR AND Minus Blue	Flt. Line Nos. 1,2,3,4 Abort 5 & 6.	Feb. 16, '71	By ONR Tech Reps. July & Sept. '71

5. Urban applications of remote sensing imagery were studied in an experiment which applied traditional photo-interpretation techniques to color and color infrared aerial imagery. Since the spread of urban areas and the intensity of urban land use is expressed by a change of ground plots from vacant or unutilized land into developed sites and since plot sizes are large enough to be resolved easily from aerial altitudes and also should soon be resolvable from orbital altitudes, such vacancies represent an urban land-use characteristic that may usefully be studied as a phenomena related to the density and change in urban regions. Vacant land in southeastern Florida's coastal area was mapped, tabulated, and evaluated as recognizable pattern types which relate to particular geographic influences within the cities. Technical Report No. 3 points out these significant relationships.

6. Color and Color Infrared imagery from both aerial and orbital altitudes were investigated experimentally by television scanning and waveform analysis. It was determined that: (1) Geographic phenomena was not displayed so differently in the signals that automatic identification would be particularly advantaged by integrating the scanning values derived from the two film systems; (2) That since imagery from orbital altitudes yields more generalized pattern categories, it is quite feasible to apply computer analysis to the waveform signal values and secure a print out category map; and (3) That the television-waveform analysis system offers a means for quantified analysis of geographic distributions since signal values relate to the colors in which the phenomena are recorded, and fall within a limited range of values for a particular geographic phenomenon. Technical Report No. 4, which was also accepted as a Ph.D. dissertation in geography, reports in detail the results of this study.

N72-24410

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

by James P. Latham

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 discriminater 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 hierarchial 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 hierarchial - 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 earths 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 earths 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 colaboration 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 azmiths 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.

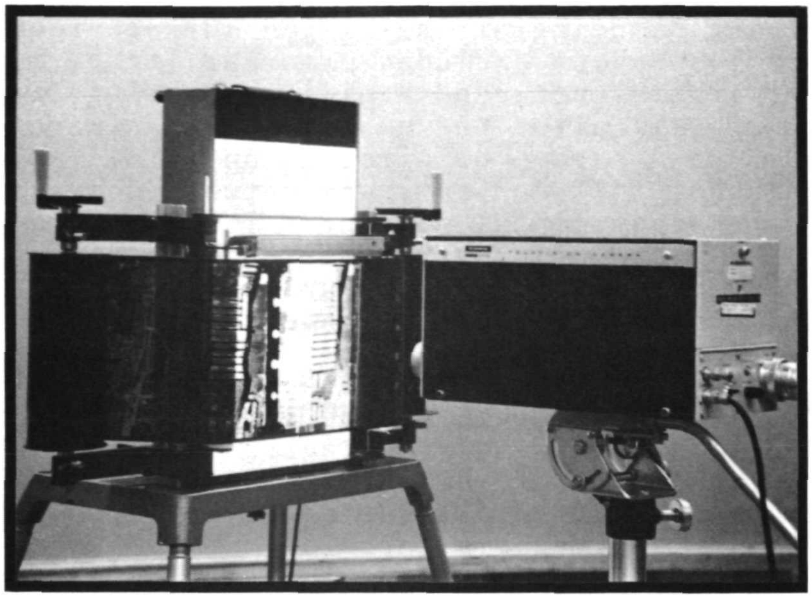

Figure 1. Direct TV scanning of 9 X 9 inch format aerial roll film via glow box device.

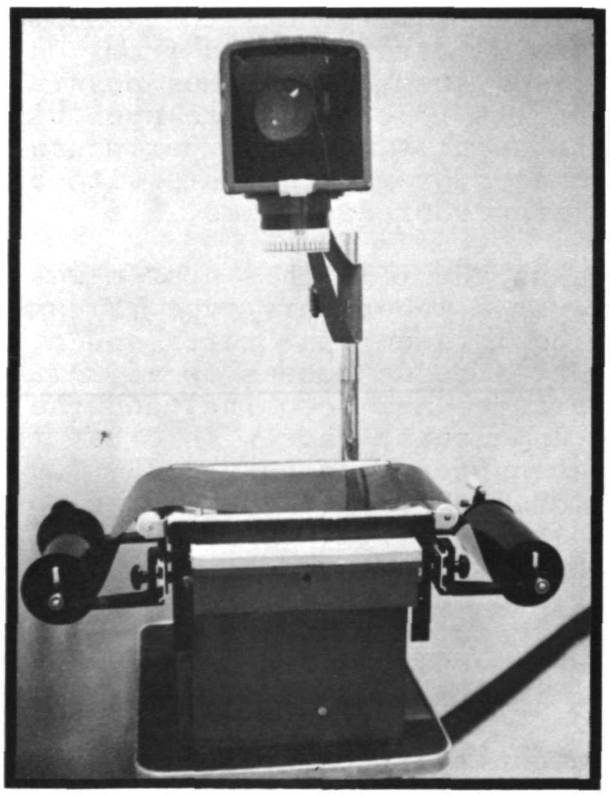

Figure 2. Projection of 9 X 9 inch format aerial film roll via device mounted on overhead projector.

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.

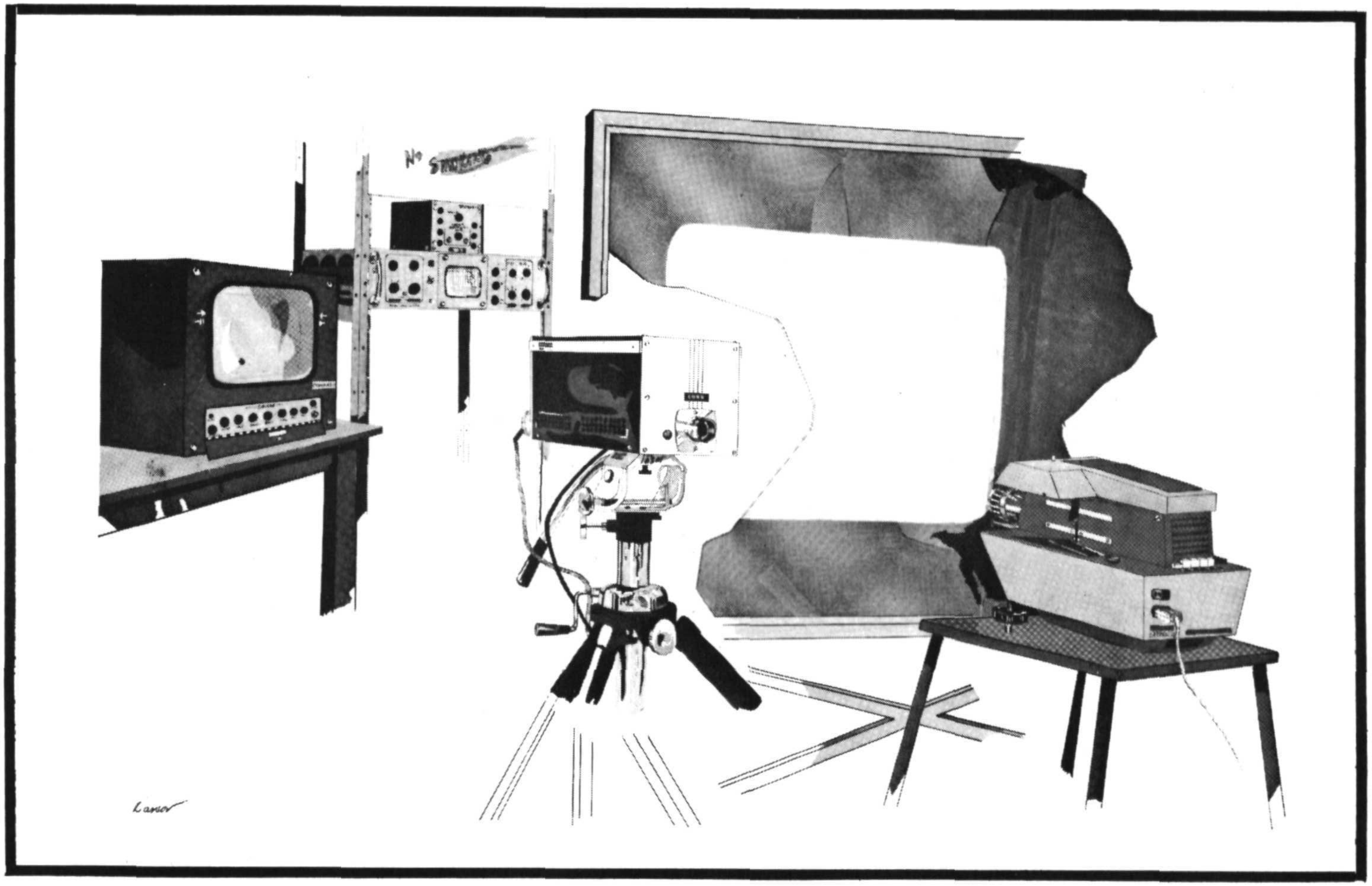

Figure 3. System for simulating T.V. observation of earth surface phenomena via projected imagery as developed by the Remote Sensing and Interpretation Laboratory at Florida Atlantic University.

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 $\sqrt[6]{2}$ 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 <u>television resolution</u> of the TV system, the <u>IEEE RETMA Resolution Chart - 1956</u> 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

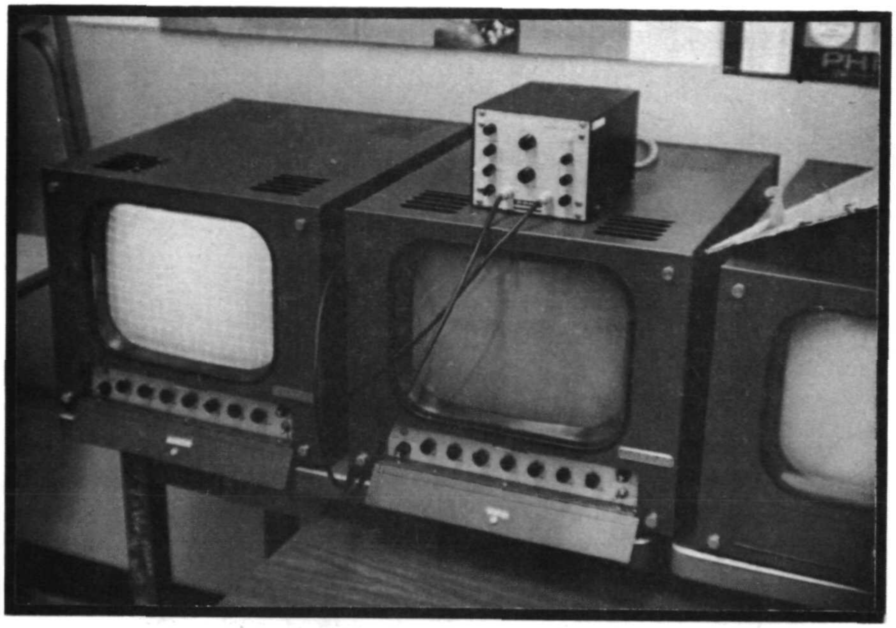

Figure 4. Dot bar generator for testing geometric characteristics of monitor image with a white cross-hatch pattern.

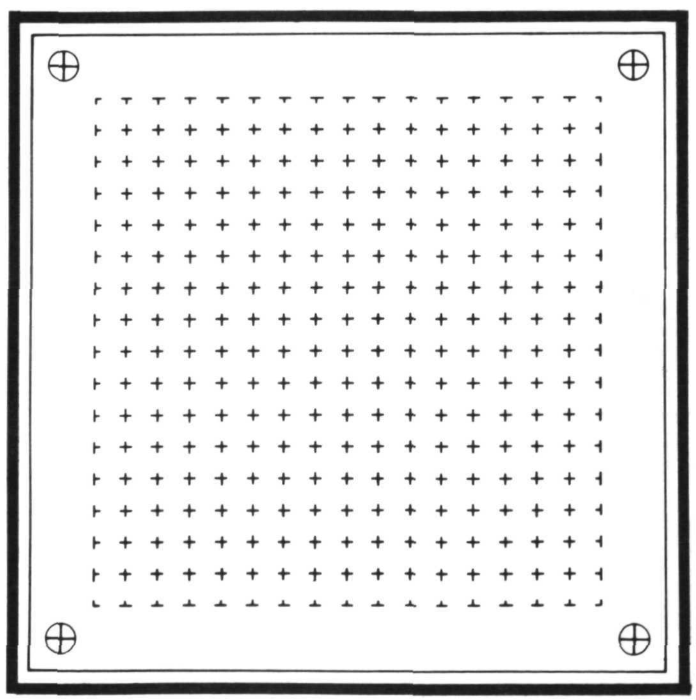

Figure 5. Calibration plate pattern for 9x9 inch format of aerial film scanned to test for and correct distortion tendencies from the T.V. camera and monitor display system.

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.

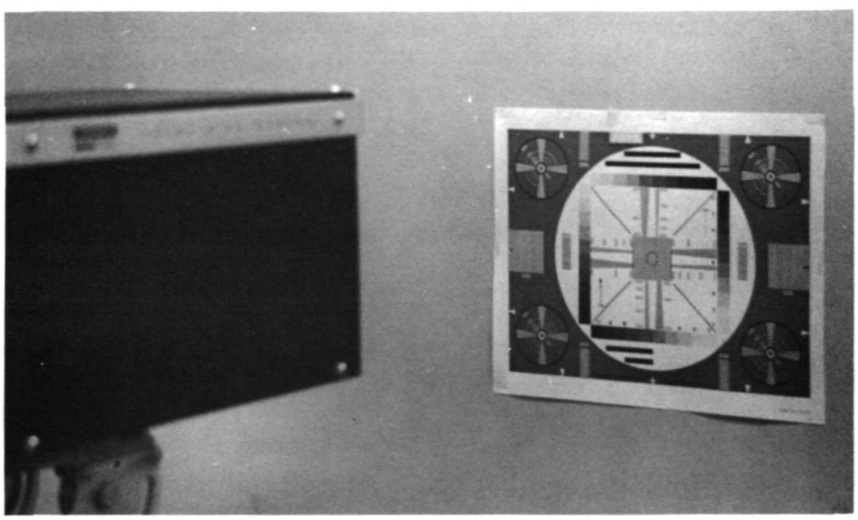

Figure 7. To determine the television resolution of a closed circuit T.V. system, the RETMA Resolution Chart (1956) can be used. Both horizontal and vertical resolution can be determined by locating the "point of no separation" on either axis.

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 <u>also</u> expressed in lines per picture height. It is determined by the number of <u>active</u> 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.

.05

.05

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.

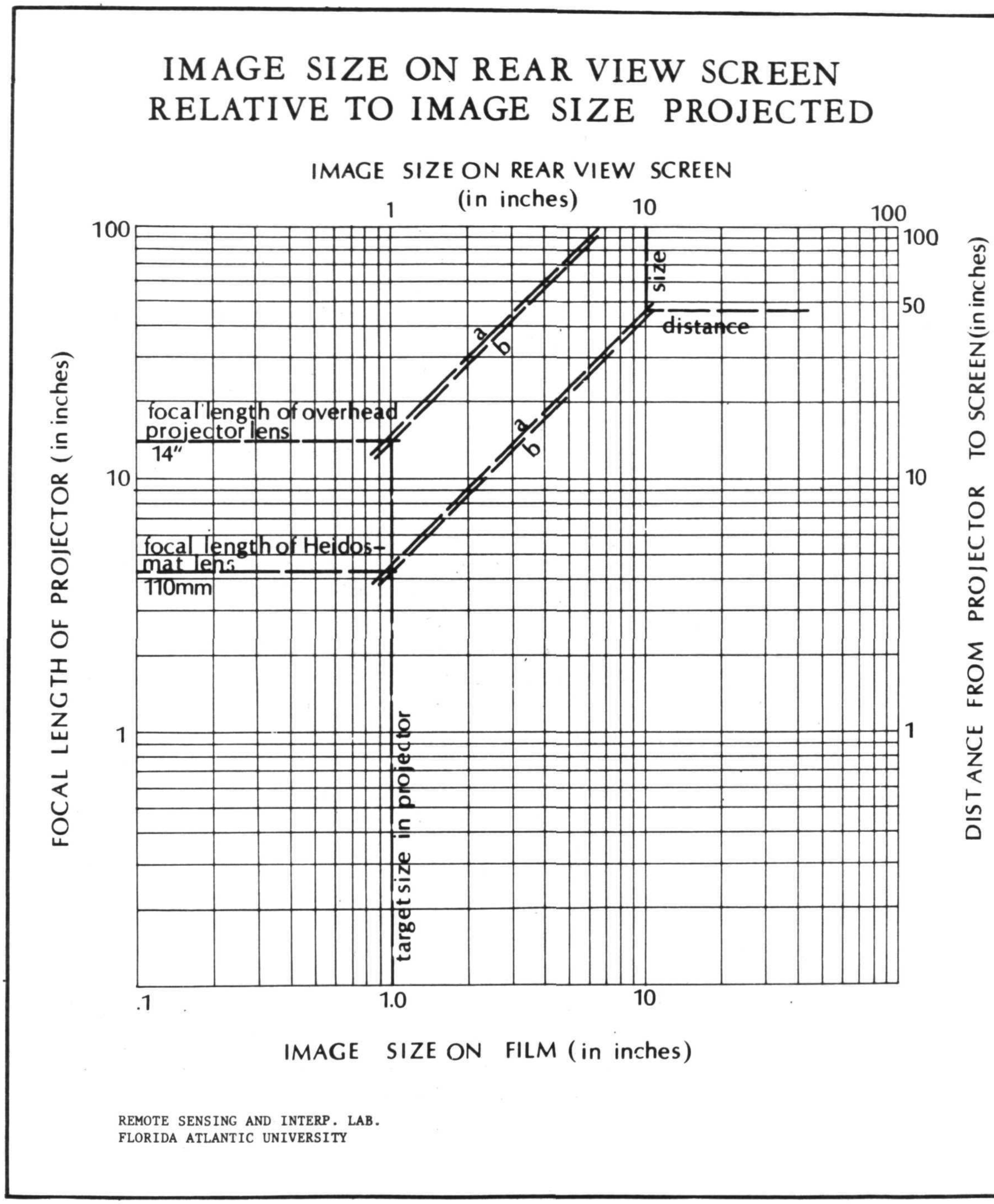

IMAGE SIZE ON REAR VIEW SCREEN
RELATIVE TO IMAGE SIZE PROJECTED
IMAGE SIZE ON REAR VIEW SCREEN
(in inches)
1
10
100
100
10
1
100
50
10
1
.1
1.0
10
FOCAL LENGTH OF PROJECTOR (in inches)
DISTANCE FROM PROJECTOR TO SCREEN (in inches)
focal length of overhead projector lens
14"
focal length of Heidos-mat lens
110mm
a
b
a
b
size
distance
target size in projector
IMAGE SIZE ON FILM (in inches)
REMOTE SENSING AND INTERP. LAB.
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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.

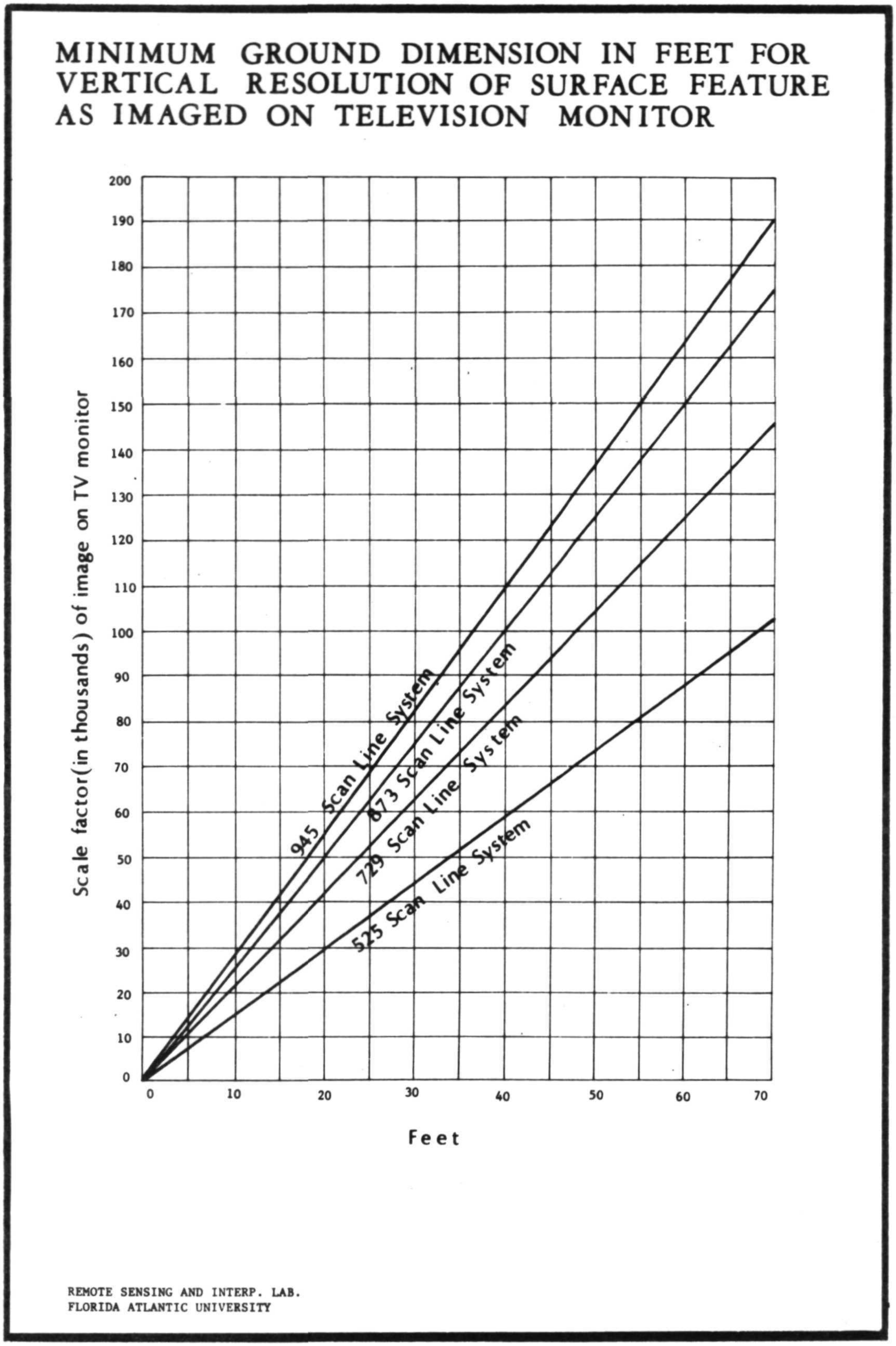
To establish the limits of vertical detail that is useful in a TV image one must determine how many picture elements can be reproduced in a vertical array using a given number of scanning lines. However, typical picture content can be expected to have a non-uniform arrangement of elements. Some phenomena 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 aperatures 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
Scale factor (in thousands) of image on TV monitor
Feet
945 Scan Line System
873 Scan Line System
729 Scan Line System
525 Scan Line System
REMOTE SENSING AND INTERP. LAB.
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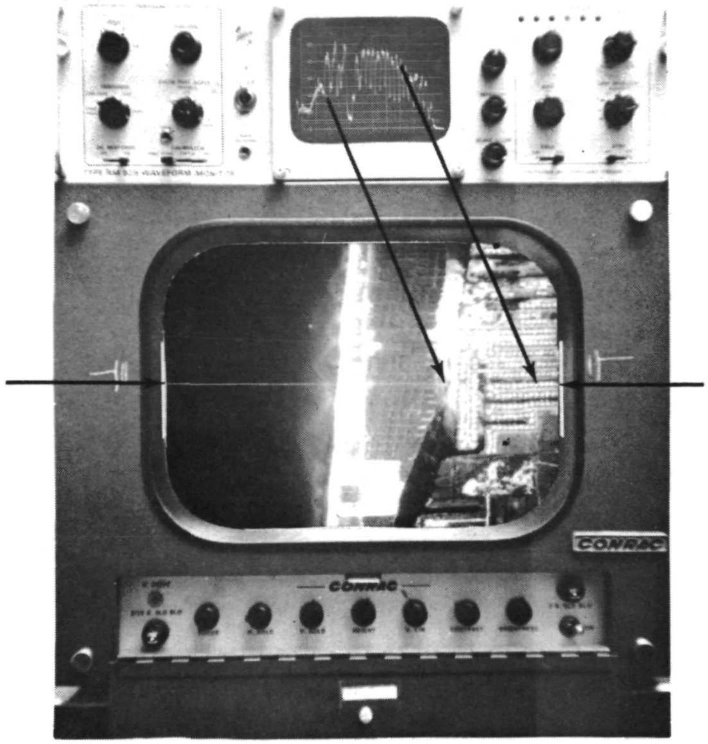
Figure 10.

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 interpretors 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.



EXAMPLE OF IMAGERY CONVERSION TO SCAN LINE WAVEFORMS AT 5X MAGNIFICATION WITH WIDEST SIGNAL BANDWIDTH. WAVEFORM DEPICTS ONLY PORTION OF SCAN LINE SEEN ON MONITOR.

REMOTE SENSING LABORATORY
DEPARTMENT OF GEOGRAPHY
FLORIDA ATLANTIC UNIVERSITY

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.

N72-22411

Section Two: Study A

INTERPRETATION OF GEOGRAPHIC PATTERNS IN SIMULATED ORBITAL TELEVISION IMAGERY OF EARTH RESOURCES

by

James P. Latham, with Interpretation and Analysis
by Clark I. Cross, William H. Kuyper,
and Richard E. Witmer

INTRODUCTION

The spatial variations and often complex inter-relationships that are displayed by geographic phenomena on earth surface always provide both a challenge and a partial answer to the interpreter of remote sensing imagery. The spatial variations of the patterns that are present in most regions increases the difficulty of the task when one desires to identify and isolate a particular geographic phenomenon. However, both detection and evaluation of the significance of a surface type or category may depend upon perceiving complex inter-relationships that are present in a synoptic image.

The photo-interpreter is both advantaged and disadvantaged by changes in the scale of the image acquisition program. Larger scale imagery may make it possible to interpret greater range of detail, but it also multiplies greatly the data which must be processed to extract specific elements of information. Consequently, for many purposes of geographic analysis the smallest possible scale which still resolves the patterns of interest should be preferred. This means that increasing the generalizing function by photographic scale reduction to the maximum permissible for the purpose of the investigation increases the efficiency of the interpretation process, and reduces the number of images that must be acquired and processed. Of course it also means that there is a limit placed on the minimum size of phenomena occurrances that can be resolved, and consequently some surface patterns will not be recorded.

Additional considerations are associated with the interpretation of scan-line imagery which is generated by television sensors. As emphasized in previous reports of this investigation, the scan line sensor is a sampling system and regardless of its resolving capability, it does not scan or record all of the surface within the area crossed by the pattern of scan lines. Also the degree to which details of the surface patterns are resolved now is dependent not only upon the scale of the imagery but also upon: (1) The number of systematic sampling scan lines that traverse the observed area; (2) the width of the individual scan lines that sense the patterns of phenomena perceived by the lens; and (3) the orientation of the parallel scan lines relative to the orientation of linear features in the mix of surface phenomena.

In order to better determine the effects of the above television imagery characteristics upon the interpretation of geographic patterns obtainable from orbital television sensors, and in order to better evaluate the influences of alternative sensor system parameters such as changes in orbital altitudes or scan line rates, this investigation designed the following experimental series of interpretation studies. A team of three professional interpreters independently mapped thematically the selected geographic phenomena that they could detect in orbital television imagery produced in the Remote Sensing and Interpretation Laboratory at Florida Atlantic University on a fourteen inch monitor and recorded photographically for analysis.

To minimize and test interpretation bias resulting from the differences among interpreters, three interpreters were used. The following two interpreters were geographers: Clark Cross who is particularly experienced with forestry photo-interpretation, and Richard Witmer, a physical geographer with interest in remote sensing. The third interpreter, research associate William Kuyper, has completed 23 years of photo-interpretation and research with the Air Force. Each interpreter was expected to have a general knowledge of the nature of the region but was also expected to avoid applying any specific knowledge not clearly discernible in the image. In each experiment, the smaller scale or grosser scan-line pattern was interpreted before viewing the next higher level of image refinement. The patterns separately interpreted included transportation routes, land use, and physical regions. Areas, imagery scale, and scan-line patterns were varied.

In selecting the photography to be used in simulating orbital television from the available images recorded by Gemini crews, the areas of consideration were limited to tropical or subtropical zones. Although the availability of good quality images were limited, particularly when a near vertical perspective was desired, sixteen images were secured in super-slide format from the NASA Applications Technology Center in New Mexico, and five were selected for this experiment. They are as follows:

CREW NO.	NASA/MCS NO	SCALE	LENS FOCAL LENGTH	ALTITUDE N.M.	LOCATION
VII	65-63806	1:2M	250mm	120	Cape Kennedy
VII	65-68807	1:2M	250mm	120	Cape Kennedy-DeLand
VII	65-82824	1:4M	80mm	120	Jacksonville
	65-45748	1:6M	80mm	140	Salton Sea
XII	66-63034	1:10M	38mm	140	Houston, Tex.

None of these photos were direct vertical views, although the Cape Kennedy image obliqueness was minor. No rectification of the images was attempted for this interpretation experiment, and the researchers were able to make some interesting evaluations of the influence of obliqueness upon the discrimination of phenomena. In estimating the scale of the images, a horizonal line through the mid-point of the slide was used as a basis for measurement. This estimated film scale is indicated on the thematic maps resulting from the interpretation studies.

The equipment system and procedures followed in simulating television observation of earth surfaces via means of the space photography have been described in the preceding Section One of this report. The resulting TV monitor image was carefully photographed by the most effective technique that resulted from a series of photographic systems test. The monitor image was then enlarged at actual size - 14 inches - and glossy prints on a medium weight paper were provided each of the interpreters.

To increase objectivity and maintain experimental controls, designed in part to reveal any differences in perception that might result from the previous experiences of the three scientists, the principal investigator established the following guidelines for the initial phase of the process:

1. No additional sources of data - such as maps or documented studies of the photo area- would be used by the interpreter.

2. Interpretation will proceed from the smallest to the largest scale imagery for an image series with a particular scan line rate, and changing image scale.

3. Interpretation will proceed from the least to the greatest scan line rate when image series are evaluated with different scan line intensities.

4. The interpreter may, as usual, draw upon his general background knowledge of physical geography, hydrology, agriculture, settlement patterns or other fields. His interpretation of the geographic patterns are expected to be rational assumptions based on his experience and understanding of the general character of the regions and the season of the photography. However, he should try to avoid prejudicing the process due to any specific knowledge of phenomena locations in the area based on other study or fieldwork. Decisions should be "read out" of the image.

5. Each interpreter should independently prepare a written summary of his observations on his interpretation experience and conclusions relative to the types of images processed as each phase of the study is completed.

PHASE I - INTERPRETING FOUR ENVIRONMENTS IMAGED AT VARIOUS SCALES AND TV SCAN LINE RATES

The interpretation studies were initiated with the evaluation of simulated imageries which were variously scaled on the monitor and presented with alternatives in scan line sampling intensity: either the 525 or 945 line systems. A famous view of the Imperial Valley, California-Mexico, was first interpreted, Figure 12 presents 525 scan line view of this area. The initial photography was taken with an 80 mm. lens from a relatively high orbit of 140 N.M. and at an oblique angle.

Figure 13 presents a thematic map of land use interpretation for the Salton Sea area which resulted from evaluation of the 525 image. In this and all the subsequent maps of this report, the scale of the map itself is indicated by the bar scale on the map. The term "Reference Scale" refers to the scale at which the region was viewed on the face of the TV monitor tube. The scale of the photography is indicated in two ways: (1) The scale of the film image which is being projected; and (2) the "projected image" scale as it appears on the rear view screen which simulates the earth surface viewed by the TV camera. This latter scale for a real orbital television system would be a function of the orbital altitude and the focal length of the camera lens.

In commenting upon interpretation of the 525 image, the following comments were made by the investigators: transportation patterns were not discernable - Airfield was annotated as I could see runway pattern - Agricultural patterns were pronounced in shape as sectional squares, but I could not identify types - I could not identify any particular portion of the urban area; only general outline- No linements (other than waterways) can be seen as transportation - Urban areas are differentiated from surrounding agricultural patterns by lighter tones and finer texture - Rudimentary suggestions of canal patterns seen.

Since all three interpreters agreed that the linear patterns associated with transportation routes were not evident - except for the airport runways - no attempt was

Figure 12. Simulated 525 scan line rate television image of Imperial Valley, California.

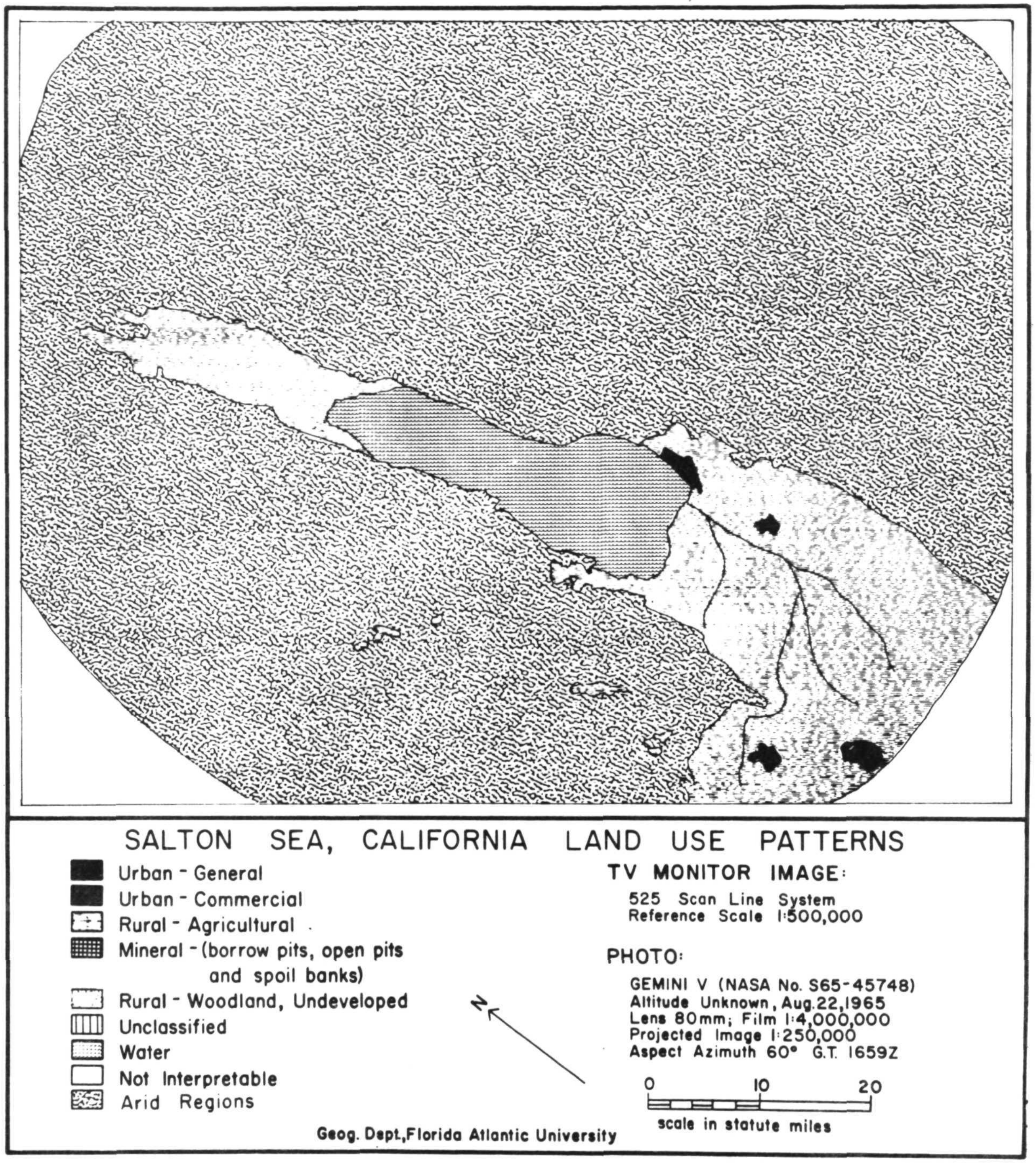

SALTON SEA, CALIFORNIA LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
Arid Regions
N
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:500,000
PHOTO:
GEMINI V (NASA No. S65-45748)
Altitude Unknown, Aug.22,1965
Lens 80mm; Film 1:4,000,000
Projected Image 1:250,000
Aspect Azimuth 60° G.T. 1659Z
0 10 20
scale in statute miles
Geog. Dept, Florida Atlantic University

Figure 13.

made to prepare a map of transportation for this area. It is apparent that both the scale of the imagery,and hence the resulting ground width for the scan lines,would make it impossible to resolve most routes. The obliqueness of the image may also contribute to the masking of roadways, since in irrigated areas they are apt to be lined with bushes or occasional trees. However, analyzing the 945 scan line rate image shown in Figure 14, one interpreter concluded that "increased resolution permits discrimination of several transportation lineaments.

As Figure 15 illustrates, the 945 image suggested only limited change in the land use patterns in this case; however, this map was not entirely representative. One geographer indicated that," It allows much greater detail to be interpreted concerning hydrologic patterns, especially surface streams and canals in the agricultural sections. Part of the image warranted an attempt to make large scale speculations concerning the patterns with light areas being considered land used for fruit and truck crops and the areas labeled as hay, pasture, and fallow." It is probable that some of the restriction upon the level of improvement from the increase to 945 scan lines is due to the fact that due to technical difficulties associated with the manufacture of the 945 monitor tube, it was yielding a "soft" image which reduced contrast and resolution. However the principal constraint upon the Imperial Valley television imagery was the considerable obliqueness in the photographic angle and the relatively high orbit.

Orbital television observation of the Houston-Galveston area of the East Coast of Texas was simulated with both the 525 and 945 scan line rates, but with the 525 system monitor scale at 1:350,000 while a smaller scale of 1:500,000 was studied with the 945 rate. The original photography was taken at the same 140 N.M. orbital altitude as the previous Salton Sea picture, but with a shorter focal length of 38mm. However, when the projected image viewed by the TV camera was at the same 1:500,000 scale as for the previously viewed image.

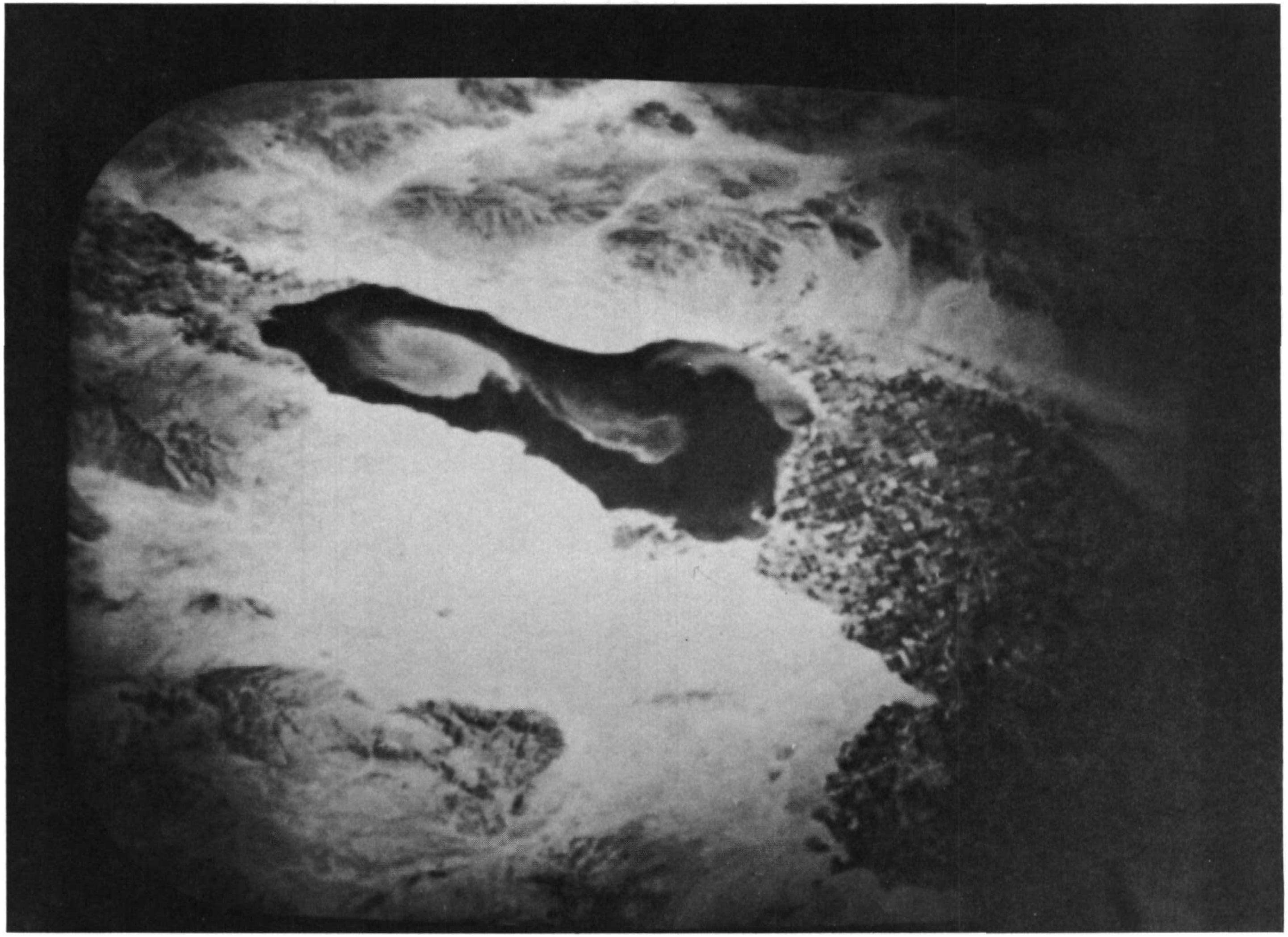


Figure 14. A 945 scan line rate simulated television image of Imperial Valley, California - Mexico - as imaged on 14 inch monitor.

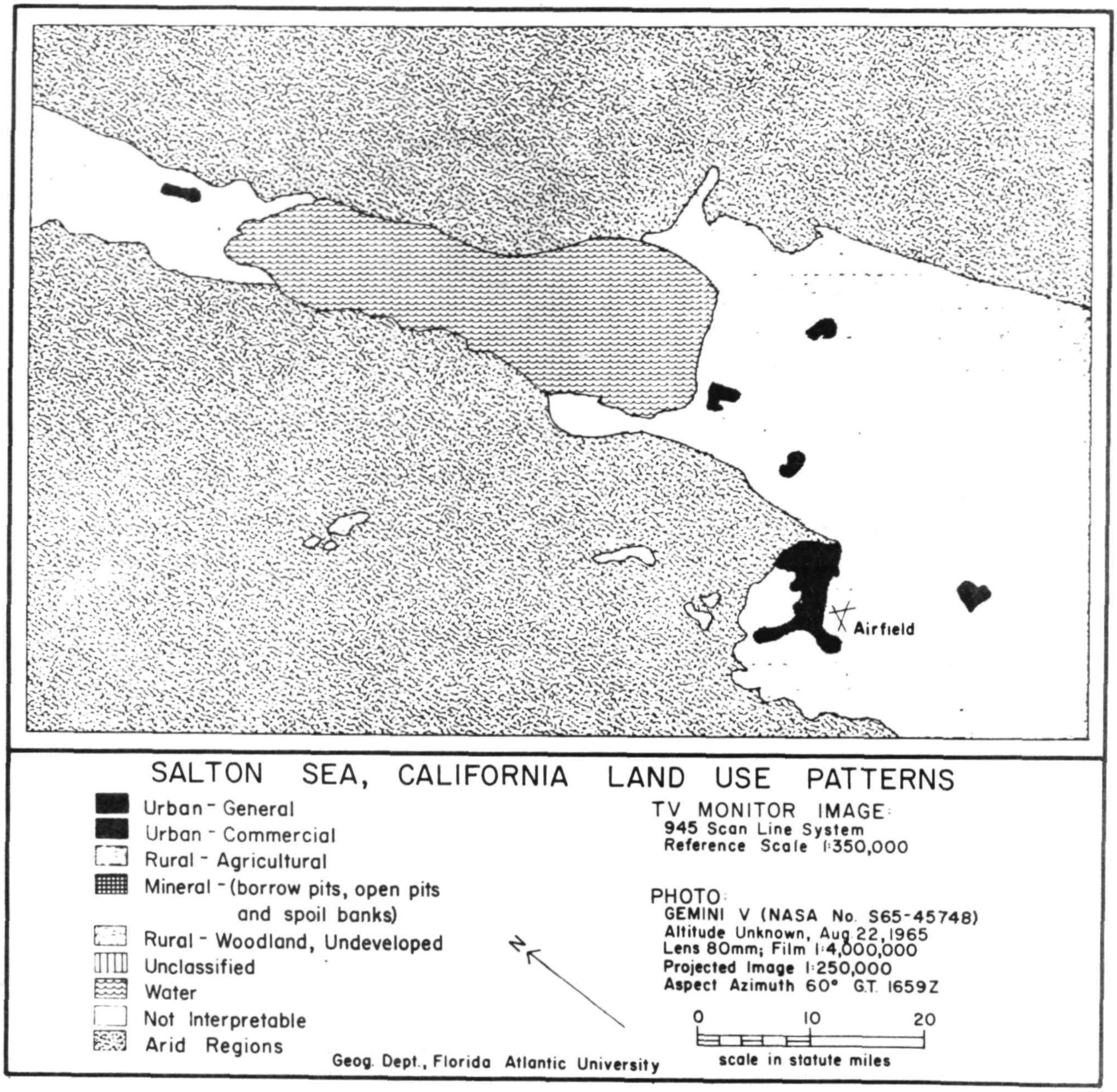

SALTON SEA, CALIFORNIA LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
Arid Regions
Airfield
N
TV MONITOR IMAGE:
945 Scan Line System
Reference Scale 1:350,000
PHOTO:
GEMINI V (NASA No. S65-45748)
Altitude Unknown, Aug 22, 1965
Lens 80mm; Film 1:4,000,000
Projected Image 1:250,000
Aspect Azimuth 60° G.T. 1659Z
0
10
20
scale in statute miles
Geog. Dept., Florida Atlantic University

Figure 15.

As Figure 16 indicates, significant elements of the transportation routes were discernable in the 1:350,000 image, even with only 525 lines, although only major route segments were seen by all three interpreters. The ship channel was interpreted by all since prominent spoil banks recorded strongly in even the TV image and a "darkened stripe" was "cutting almost striaght across the bay and exiting through the inlet."

Land use patterns are generalized into principal types in the Figure 17 map from the 525 line image interpretation. However, the analyst complained that in this image the "loss of information is tremendous and only very general patterns could be interpreted," consequently differentiations mapped were principally limited to a rural-urban difference and urban bounding was not very confident.Apparently this lack of definition is principally explained by the high orbit and short 38mm focal length for the orginal photography, and it demonstrates the disadvantages of short focal length for any imagery of earth resources.

Figure 18 images the Houston-Galveston area with 945 lines. The bright tones associated with urban area, beaches, and spoil banks are readily seen although this is a smaller scale image at 1:500,000 on the monitor. Figure 19 demonstrates that although monitor image scale has been reduced, the analysts discern more transportation pattern with this 945 line image, which has both more and narrower lines of scan. However, the increase in routes seen and agreed upon is not great, and may be limited by the fact that although scan line rate almost doubled, the imagery scale was reduced by more than one third. Similarly, the land use map of Figure 20 indicates a continuing inability to differentiate rural areas, which may reflect both the focal length limitations of the photography and the topography of the area. The 945 system however did encourage differentiating the "urban-commercial", since the lighter but coarser texture of the reflectance from congested structures of varying heights encouraged their separation from the other light gray urban tones.

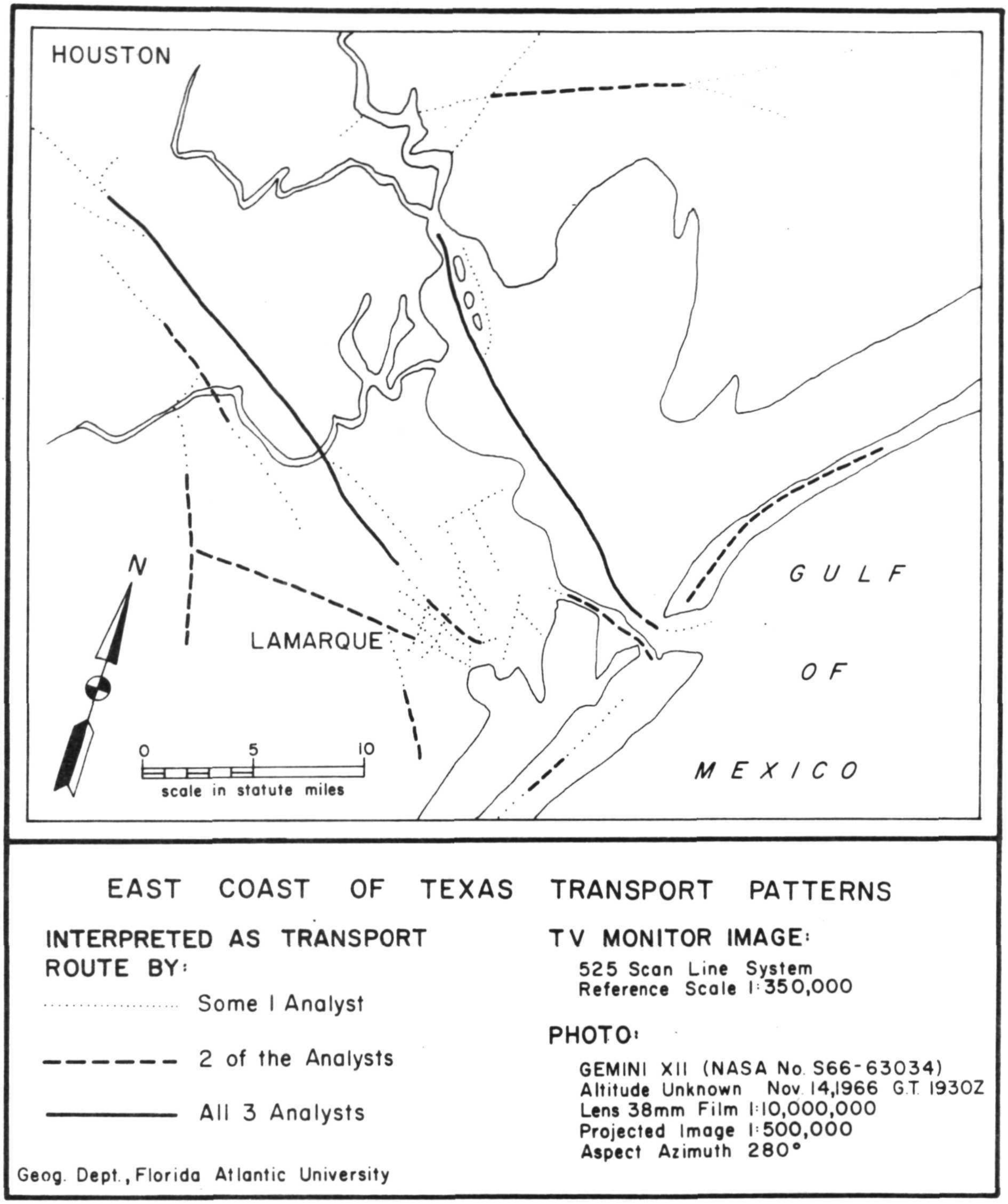

HOUSTON
LAMARQUE
N
0 5 10
scale in statute miles
G U L F
O F
M E X I C O
EAST COAST OF TEXAS TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY:
Some 1 Analyst
2 of the Analysts
All 3 Analysts
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:350,000
PHOTO:
GEMINI XII (NASA No. S66-63034)
Altitude Unknown Nov. 14,1966 G.T. 1930Z
Lens 38mm Film 1:10,000,000
Projected Image 1:500,000
Aspect Azimuth 280°
Geog. Dept., Florida Atlantic University

Figure 16.

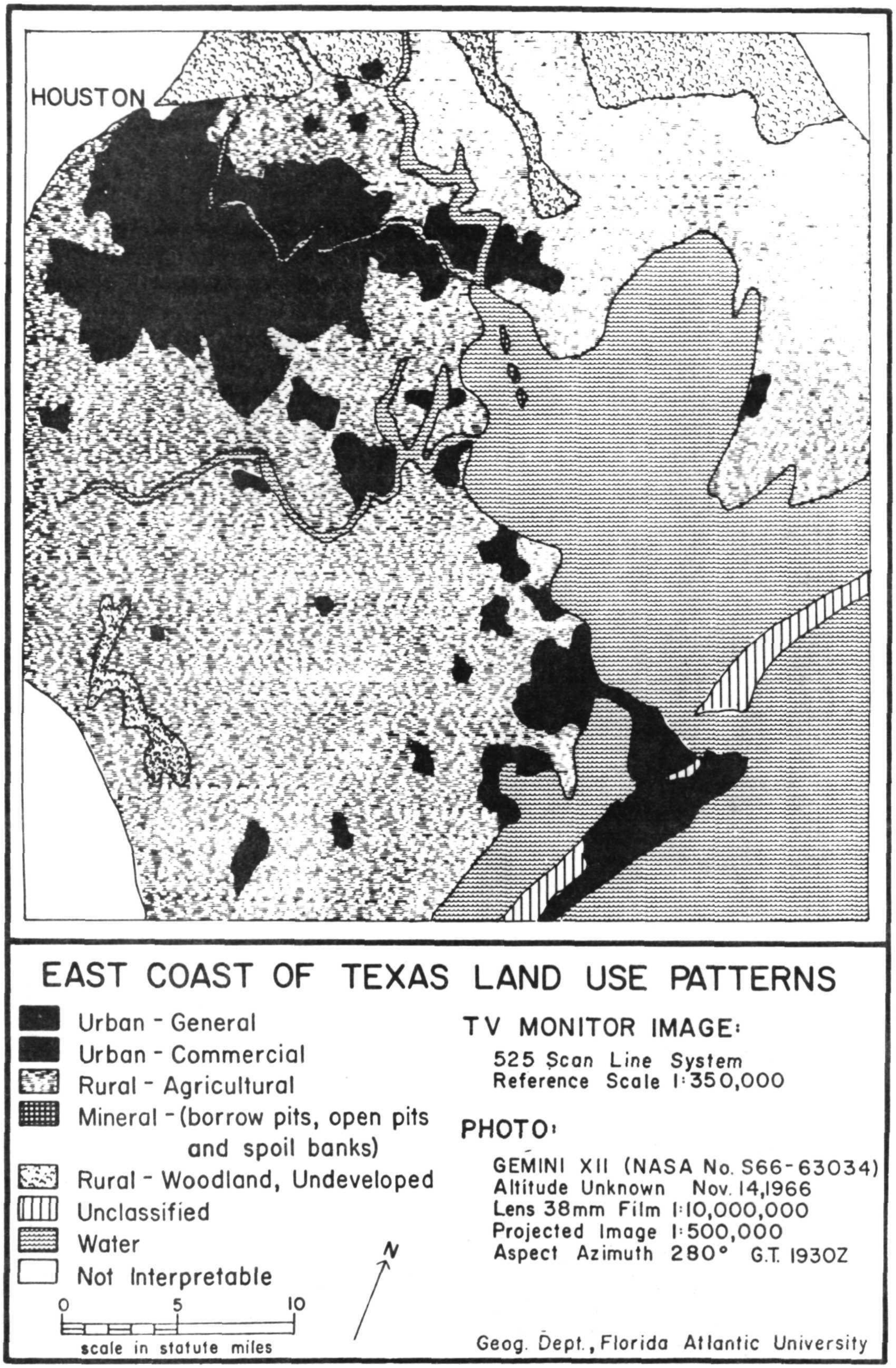

HOUSTON
EAST COAST OF TEXAS LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
0 5 10
scale in statute miles
N
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:350,000
PHOTO:
GEMINI XII (NASA No. S66-63034)
Altitude Unknown Nov. 14,1966
Lens 38mm Film 1:10,000,000
Projected Image 1:500,000
Aspect Azimuth 280° G.T. 1930Z
Geog. Dept., Florida Atlantic University

Figure 17.

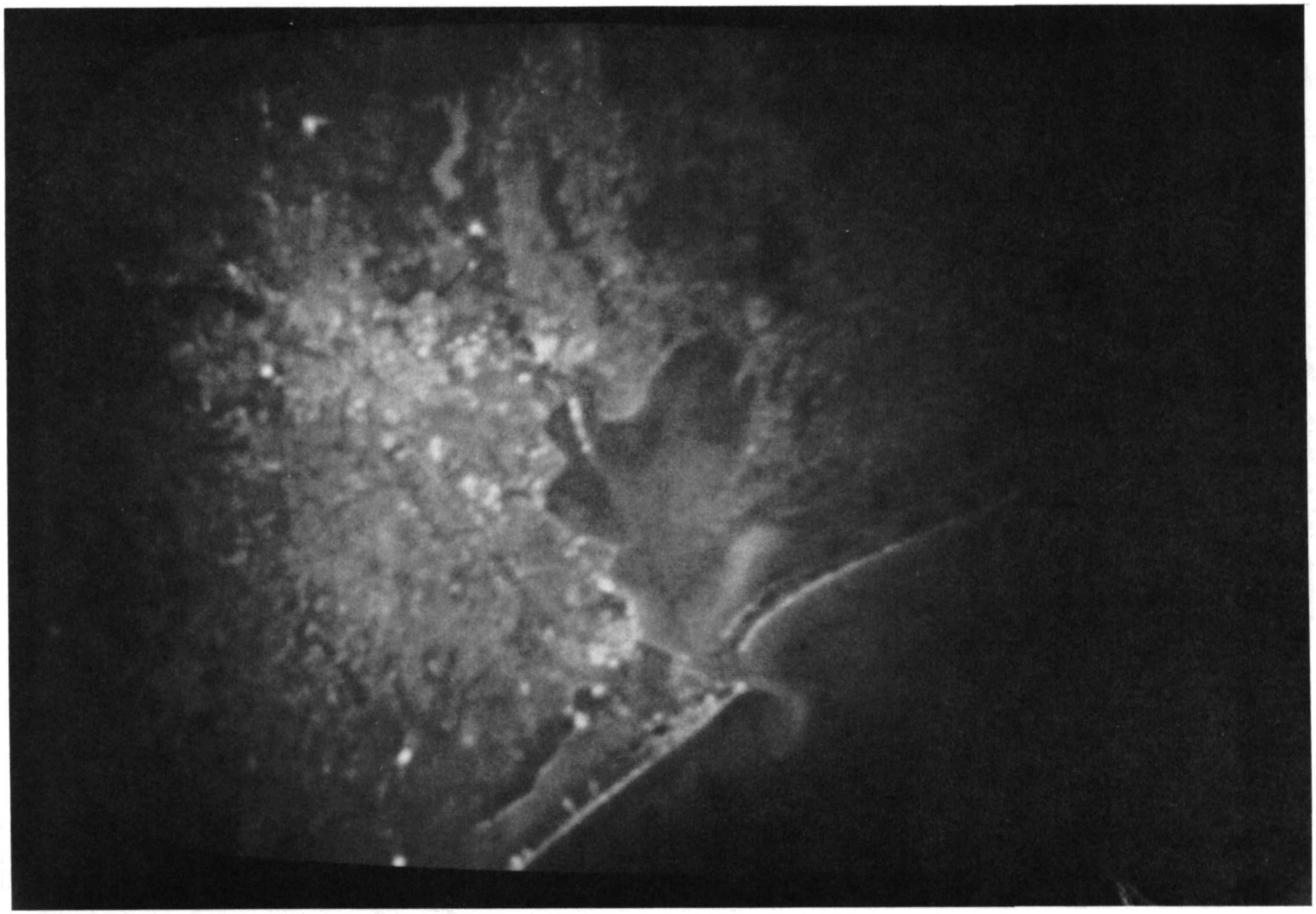


Figure 18. Simulated 945 scan line rate television image of the Houston-Galveston area of the East Coast of Texas, as imaged on the 14 inch monitor.

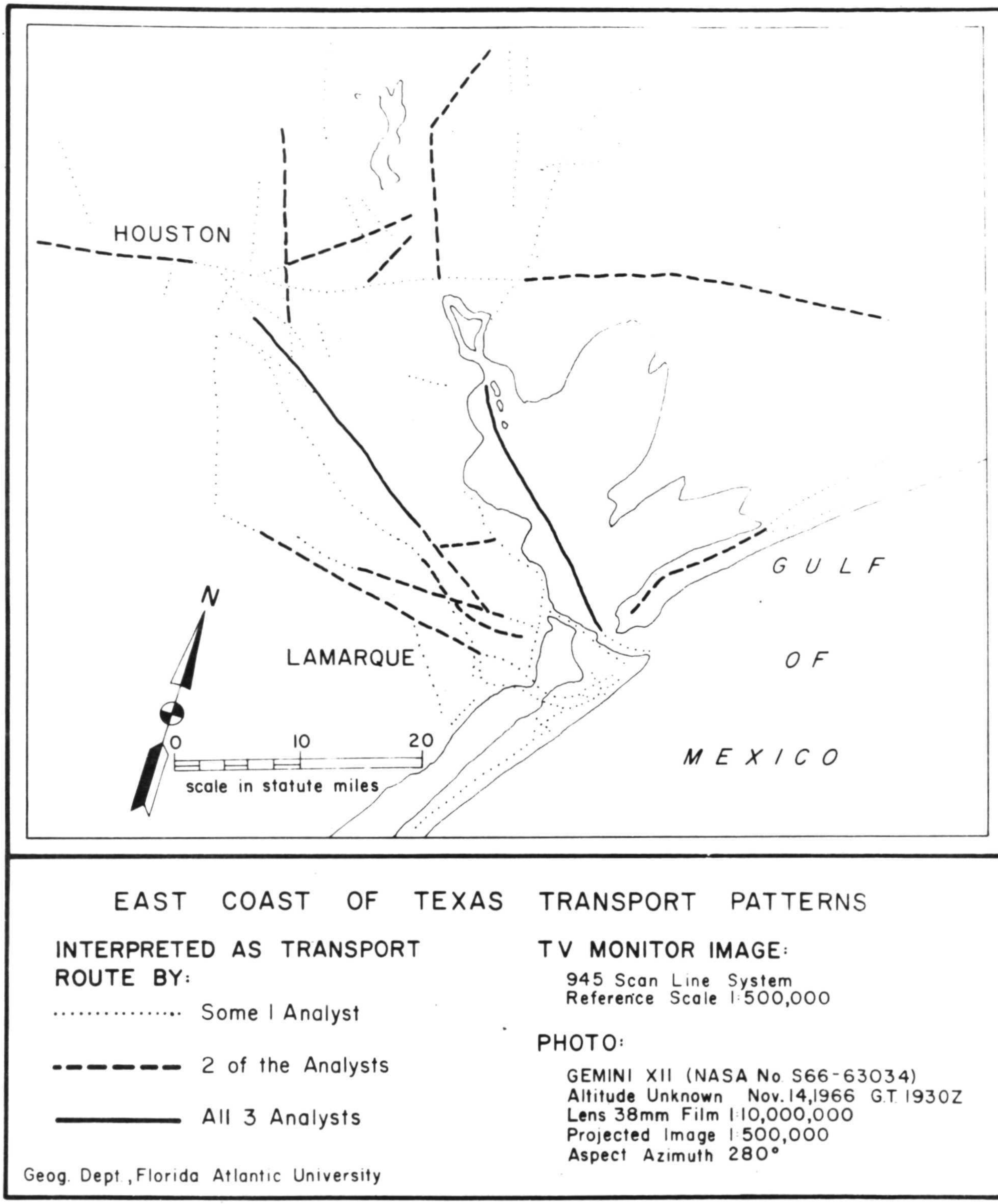

HOUSTON
LAMARQUE
GULF
OF
MEXICO
N
0
10
20
scale in statute miles
EAST COAST OF TEXAS TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY:
Some 1 Analyst
2 of the Analysts
All 3 Analysts
Geog. Dept., Florida Atlantic University
TV MONITOR IMAGE:
945 Scan Line System
Reference Scale 1:500,000
PHOTO:
GEMINI XII (NASA No. S66-63034)
Altitude Unknown Nov. 14, 1966 G.T. 1930Z
Lens 38mm Film 1:10,000,000
Projected Image 1:500,000
Aspect Azimuth 280°

Figure 19.

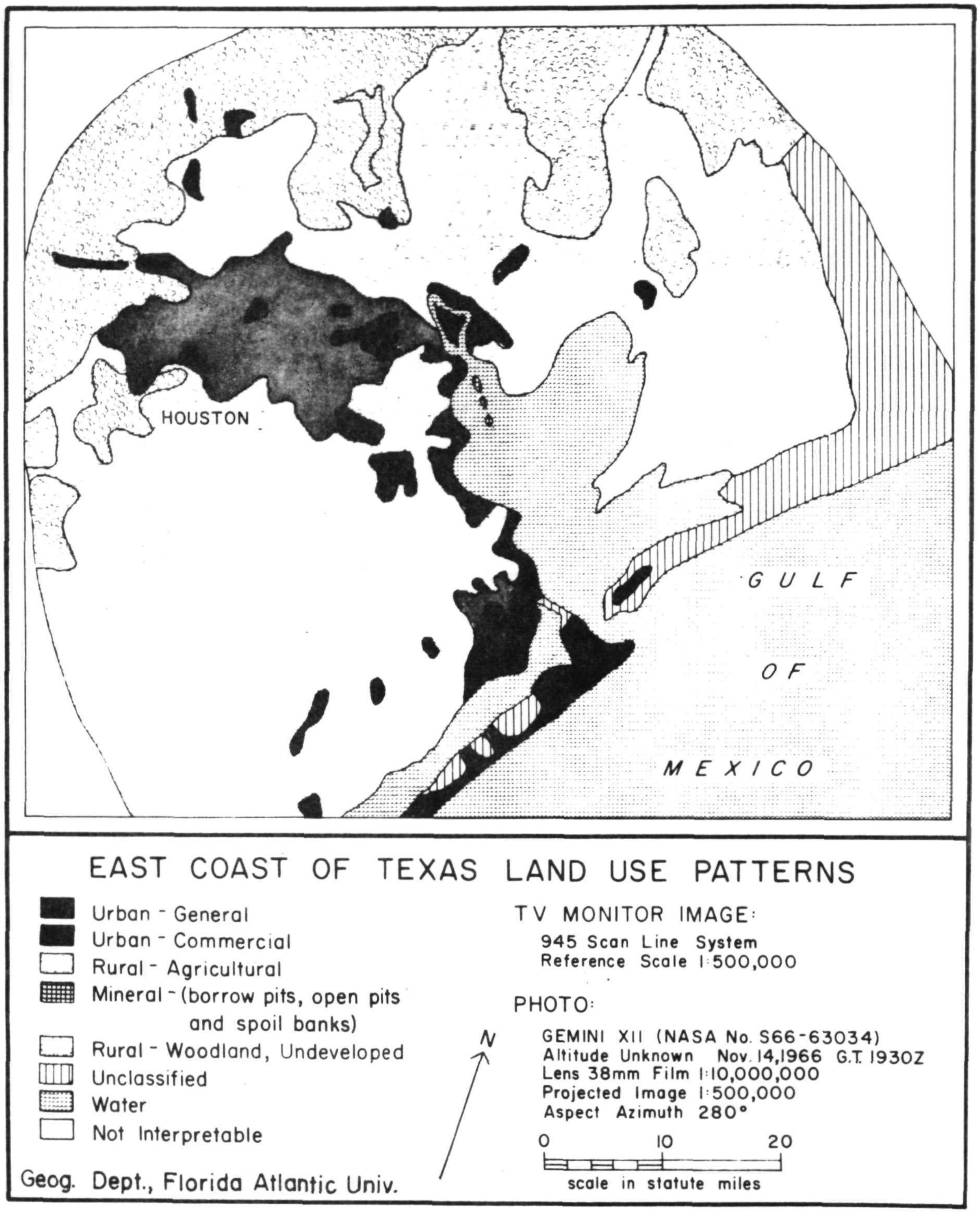

HOUSTON
G U L F
O F
M E X I C O
EAST COAST OF TEXAS LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
Geog. Dept., Florida Atlantic Univ.
N
TV MONITOR IMAGE:
945 Scan Line System
Reference Scale 1:500,000
PHOTO:
GEMINI XII (NASA No. S66-63034)
Altitude Unknown Nov. 14,1966 G.T. 1930Z
Lens 38mm Film 1:10,000,000
Projected Image 1:500,000
Aspect Azimuth 280°
0 10 20
scale in statute miles

Figure 20.

Northeast Florida's Jacksonville region is the third study area. Its mixed terrain types of woodland, fields, waterway, and urban uses provide an interesting pattern in Figure 21, which presents the 525 line image at a rather small 1:830,000 monitor scale. However, the original photograph was taken at almost a zero degree aspect azimuth from approximately 120 N.M. with an 80mm lens; and then scanned via a larger projected image scale of 1:400,000. It should be noted that the north-south orientation of the scan line pattern applied to this image relates closely to the overall orientation of both major natural features (e.g.: the coastline, beaches, and St. John River), and major cultural features (e.g.: highways and coastal settlements).

Although the monitor reference scale is smaller, the transportation mapping achieved in the 525 line interpretation presented as Figure 22 exhibits more detail than either of the preceding area studies. One interpreter explains that, "This image is somewhat of an anamoly. The fringe areas of the image are very dark and obscured, the central part of the image has a whitish obscured area, but the remainder is unusually clear and defined." There seems to be some evidence in this interpretation of linear features that the scan line azimuth adds significantly to the emphasizing of highways and other features with a comparable azimuth. Figure 23 maps land use patterns observed in the 525 line image. Separations of cropland and woodland were observed by the interpreters despite the small scale of the monitor image and the limits of the 525 line rate. However, they expressed some concern over the brightly generalized and exaggerated blooms that seem to show from the clearing of surface areas. In some cases these show a close relationship to highways and are probably large construction sites - as for the new shopping centers known to be developing south of the city. In other cases, they may be the open-pit mining of sands and other minerals that occurs here on old beach ridges.

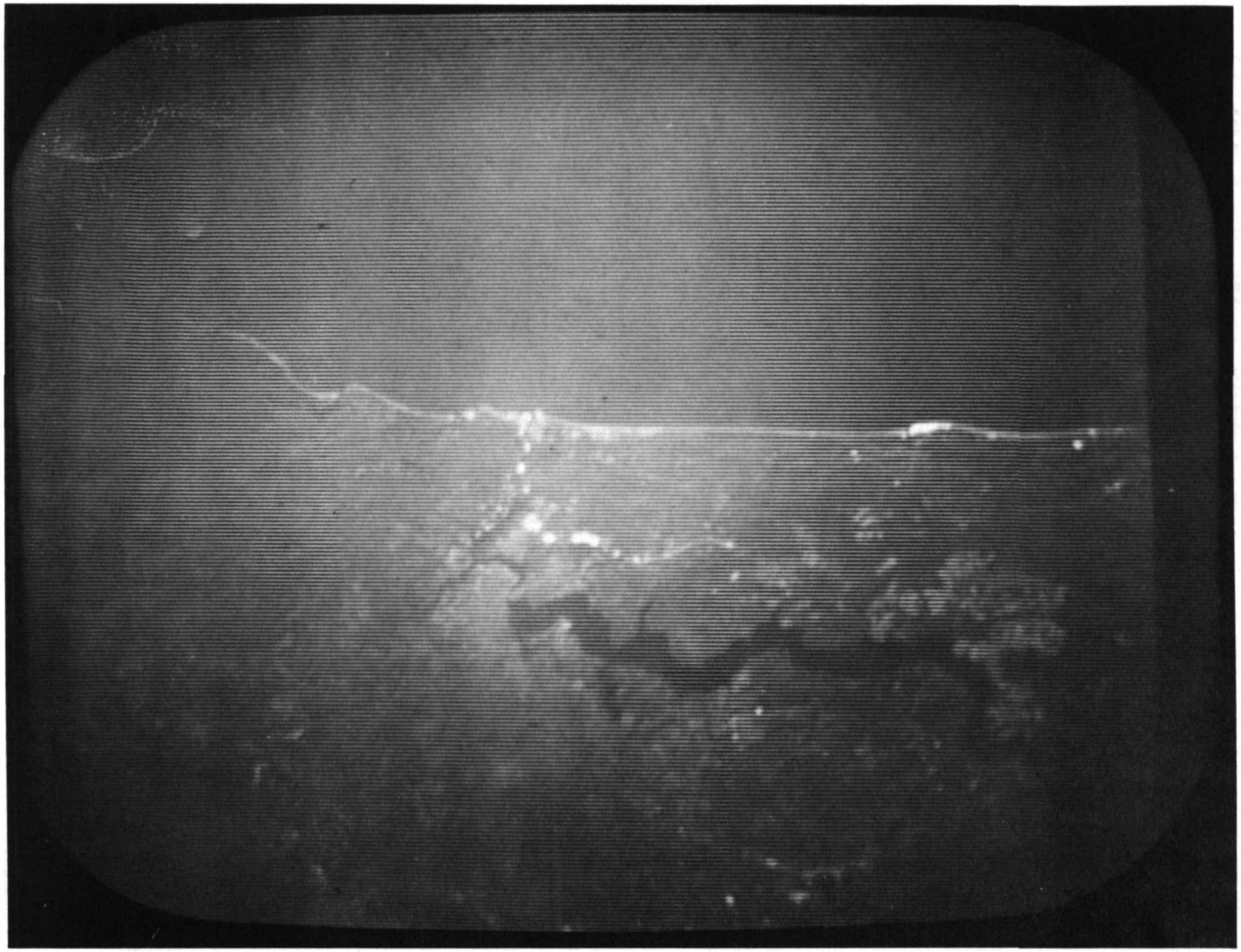


Figure 21. Simulated 525 scan line rate television image of Northeast Florida's Jacksonville area, as imaged on the 14 inch monitor.

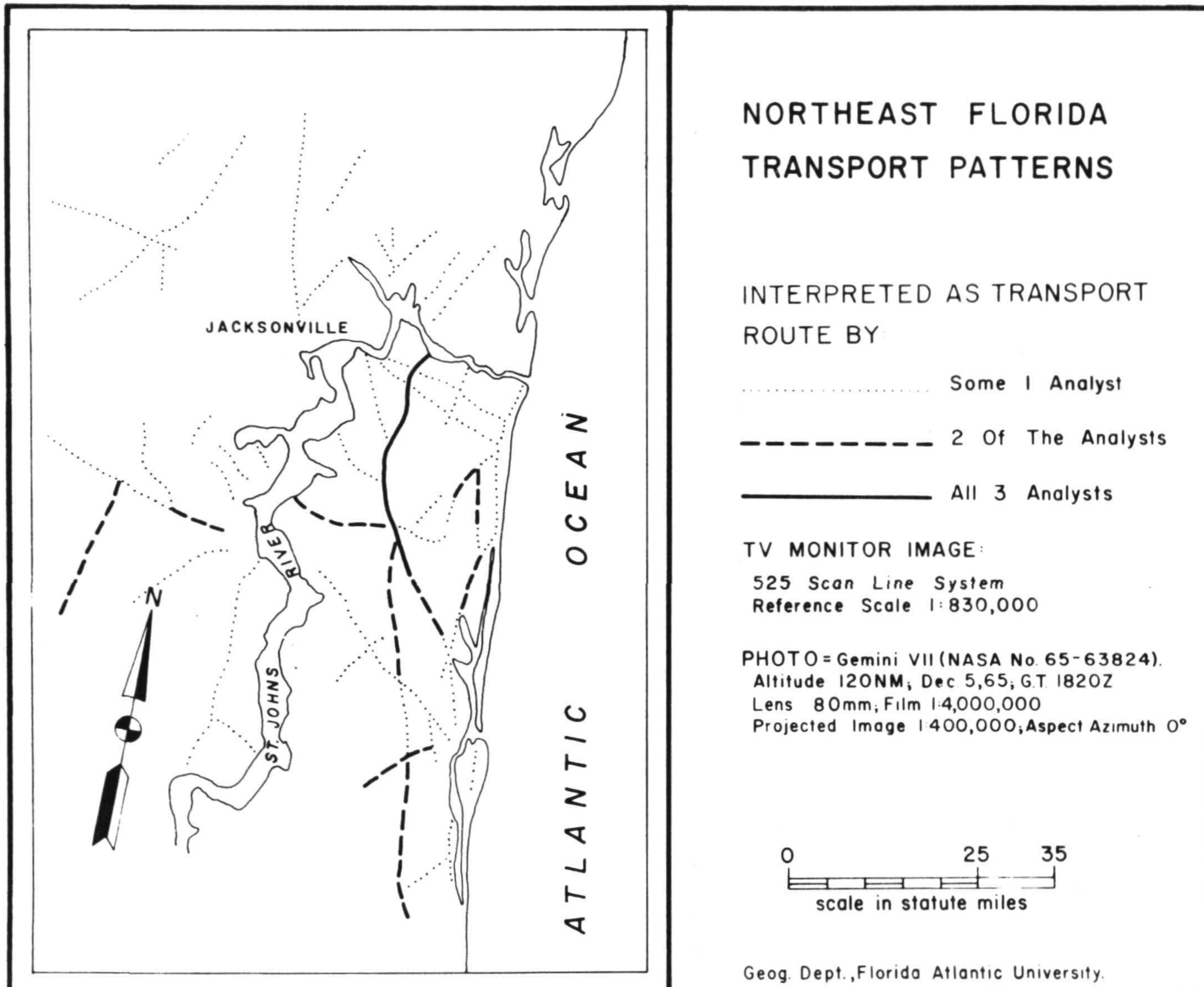

NORTHEAST FLORIDA
TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY
Some 1 Analyst
2 Of The Analysts
All 3 Analysts
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:830,000
PHOTO = Gemini VII (NASA No. 65-63824).
Altitude 120NM; Dec. 5,65; G.T. 1820Z
Lens 80mm; Film 1:4,000,000
Projected Image 1:400,000; Aspect Azimuth 0°
0
25
35
scale in statute miles
Geog. Dept., Florida Atlantic University.
JACKSONVILLE
ST. JOHNS RIVER
ATLANTIC OCEAN
N

Figure 22.

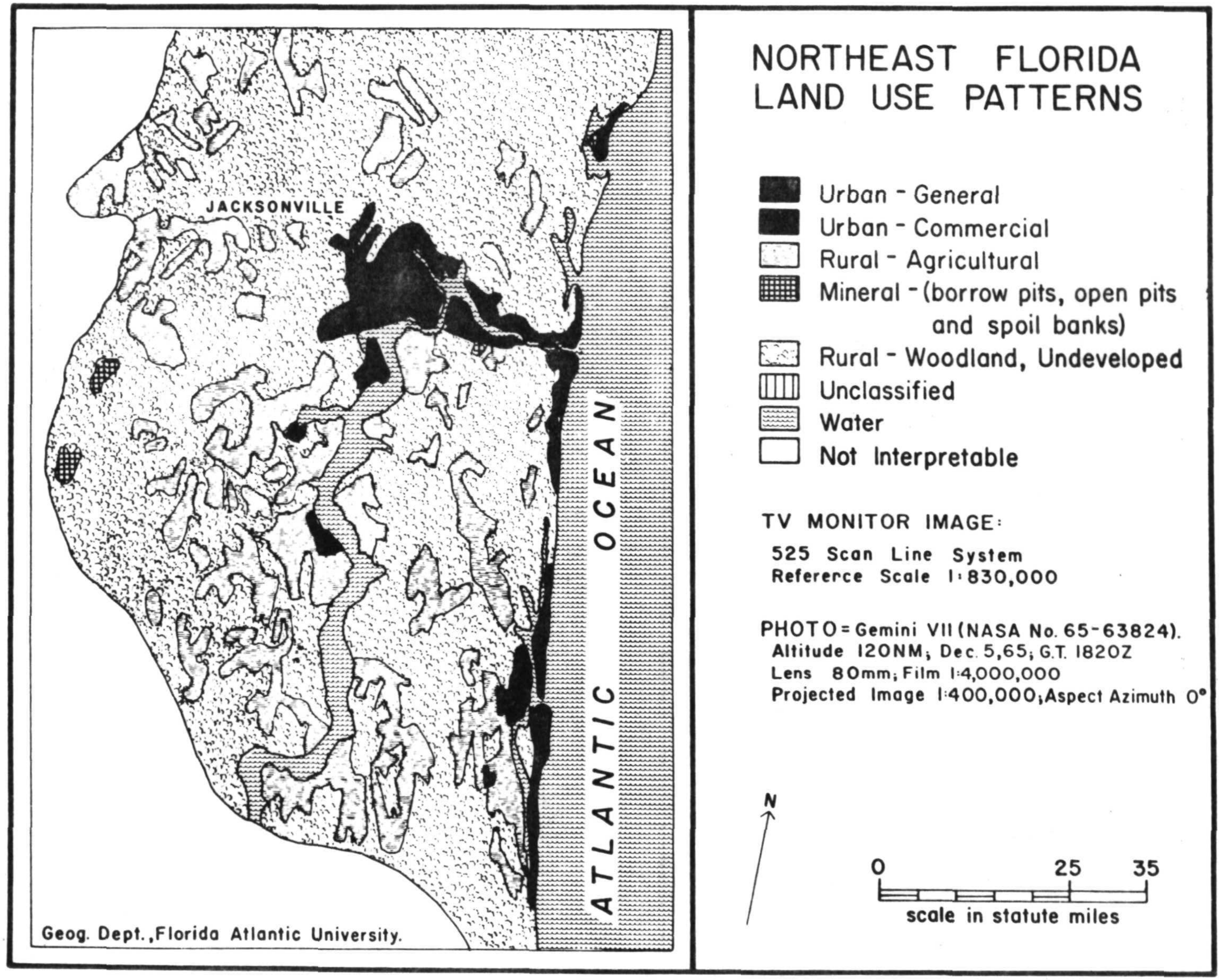

NORTHEAST FLORIDA
LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:830,000
PHOTO = Gemini VII (NASA No. 65-63824).
Altitude 120NM; Dec. 5,65; G.T. 1820Z
Lens 80mm; Film 1:4,000,000
Projected Image 1:400,000; Aspect Azimuth 0°
N
0
25
35
scale in statute miles
JACKSONVILLE
ATLANTIC OCEAN
Geog. Dept., Florida Atlantic University.

Figure 23.

Figure 24 displays the 945 line image at a larger 1:500,000 scale on the monitor image. Since the original photography was partially covered by a slight haze, it represented a limitation that will be commonly experienced in orbital imagery of sub-tropical humid regions. The interpreter's remarks quoted in the above paragraph pointed out how this may create uneven definition of surface areas within one frame. It is noticeable in this monitor image that adjusting brightness to improve monitor sharpness in the area of principal interest may drop out imagery content from the monitor's other areas. Figure 25 presents the transportation patterns discerned on the 945 line tube face. There is a significant gain in detail, particularly as one moves further from image center. However, no interpreter claimed that the type of transport route could actually be interpreted from the scan line image. On flat terrain such as prevails here, one is deprived of clues that might separate roads from railroads, since the roads go as straight and are usually as gently curved as the railroads. Land use patterns determined with the 945 line image display somewhat more variety and precision in Figure 26. Both the larger reference scale and the increase in scan lines while decreasing scan line width contribute to this. Both urban and cleared agricultural areas were discriminated by their lighter tones in contrast to the general woodland background. Bright "blooms" earlier discussed were now often being classified as "Mineral". It is interesting that airports known to be in the area were not located by the interpreters in any of the Jacksonville imagery.

The physical geographer of the team also prepared a physical regions interpretation which is not illustrated here. He commented that, "The detail of the image was first interpreted for geomorphic and physiographic sub-regionalization, and categories arrayed in an inland (east to west) direction - i.e.: beach ridge, backwater, beach remnants, etc. The tonal and textural features which permit this sort of differentiation are, in this author's judgement, some of the most salient features to be found in imagery of this type.

Figure 24. Simulated 945 scan line rate television image of Northeastern Florida's Jacksonville area, as imaged on 14 inch monitor.

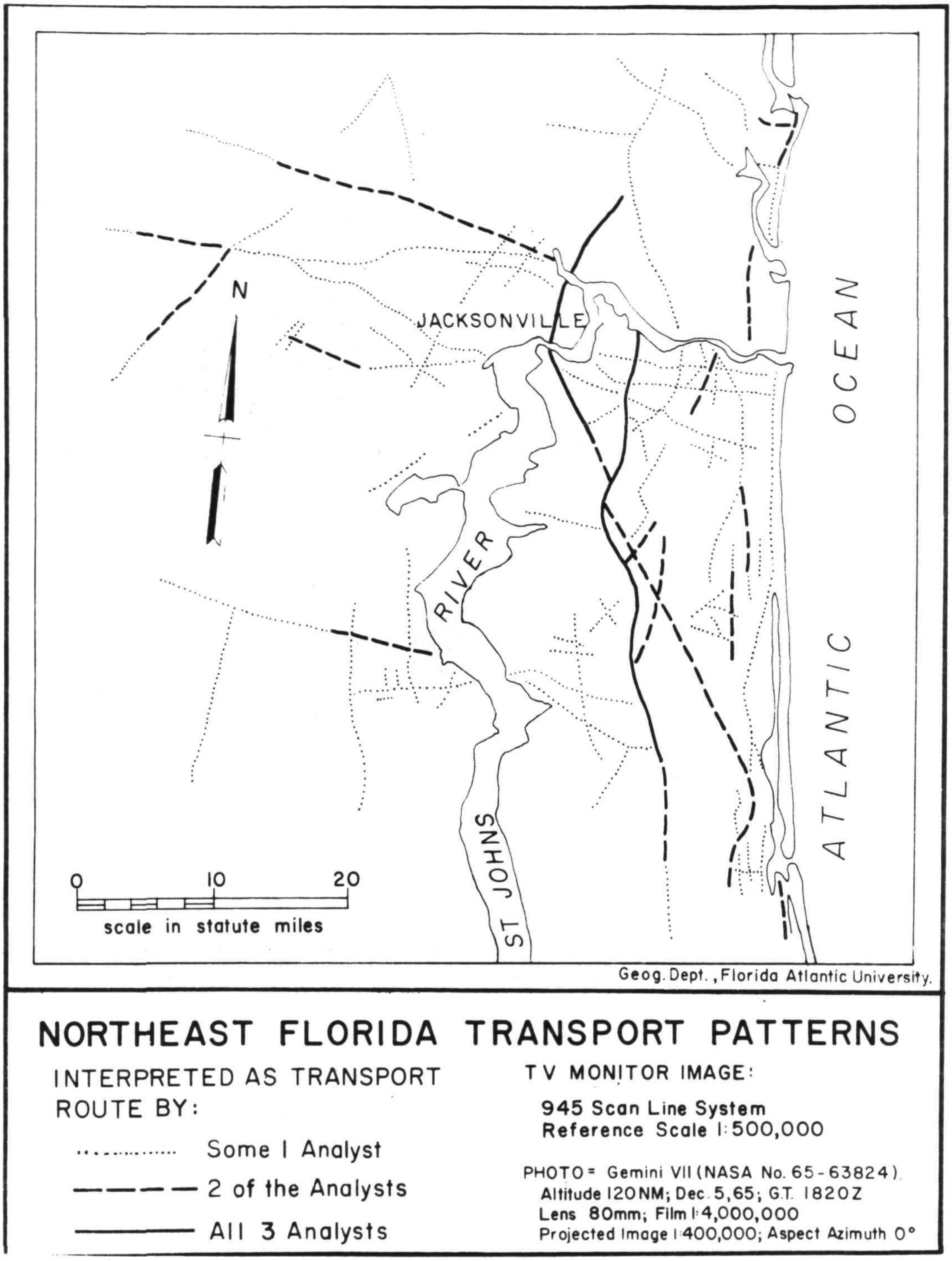

N
JACKSONVILLE
ST JOHNS
RIVER
ATLANTIC
OCEAN
0
10
20
scale in statute miles
Geog. Dept., Florida Atlantic University.
NORTHEAST FLORIDA TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY:
Some 1 Analyst
2 of the Analysts
All 3 Analysts
TV MONITOR IMAGE:
945 Scan Line System
Reference Scale 1:500,000
PHOTO = Gemini VII (NASA No. 65-63824).
Altitude 120NM; Dec. 5,65; G.T. 1820Z
Lens 80mm; Film 1:4,000,000
Projected Image 1:400,000; Aspect Azimuth 0°

Figure 25.

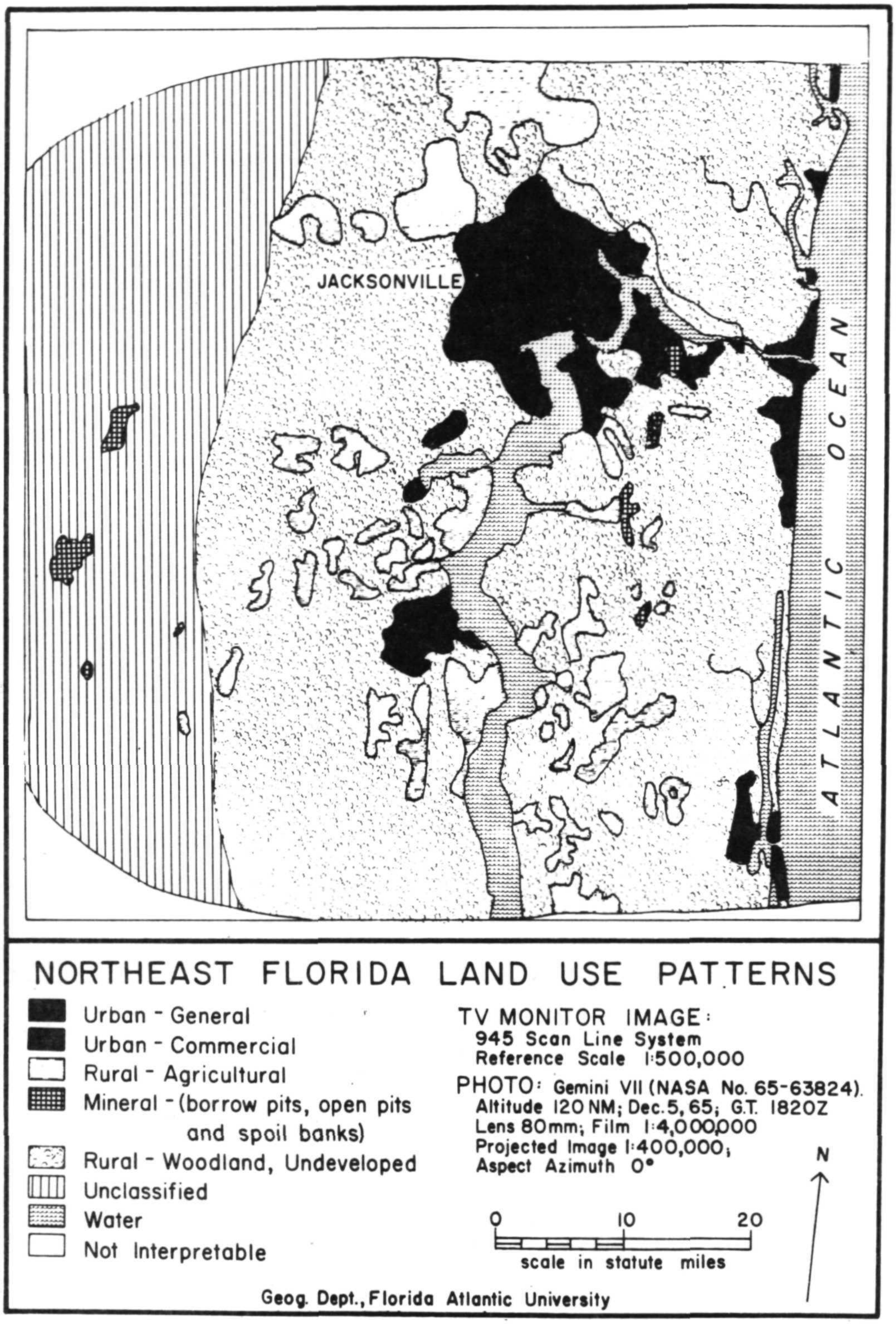

JACKSONVILLE
ATLANTIC OCEAN
NORTHEAST FLORIDA LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
TV MONITOR IMAGE:
945 Scan Line System
Reference Scale 1:500,000
PHOTO: Gemini VII (NASA No. 65-63824).
Altitude 120 NM; Dec. 5, 65; G.T. 1820Z
Lens 80mm; Film 1:4,000,000
Projected Image 1:400,000;
Aspect Azimuth 0°
N
0 10 20
scale in statute miles
Geog. Dept., Florida Atlantic University

Figure 26.

East Central Florida from Titusville to the Sanford and DeLand interior area was photographed with an oblique angle similar to the Imperial Valley scene, but this image was taken with the longer 250mm lens system and from a lower 120 N.M. orbit. Lines of transportation were more easily detected, as Figure 27 indicates for the analysis of 525 line imagery; and interpreters felt confident in actually identifying them as highways. It is interesting to note evidence that the oblique angle which centers the lens aspect angle on the Sanford-Deland region increases the road net detected in that area relative to the nearer Titusville area. Figure 28 indicates an interesting destribution of land use patterns but it is displayed on a background largely "unclassified" by the analyst working with the 525 line imagery. Once again the haze factor which inhibits humid coastal imagery is present, as indicated in the almost opaqueness that is generated as one moves toward Cape Kennedy.

Figure 29 makes the haze problem clear in this 945 line monitor image. It contributes to the difficulty of differentiating rural terrain types, and this image is also handicapped somewhat by the "soft" aspect of the 945 monitor tube. However, as Figure 30 displays, the longer lens and lower orbit did permit the interpreters to detect an interesting detail in transportation patterns with this 945 system, with a considerable network of roadways particularly observed in the Sanford vicinity. However, the 945 image still provides little basis for discriminating rural land use types, as Figure 31 indicates, although most of the previously "unidentified" category for the 525 image has now been generalized as "Rural-Woodland, Undeveloped." Near the coast some evidence of beach ridge and paralleling wet swales were observed in the pattern but their exact use was not clear.

All interpretation of the imaged environments analyzed above was accomplished without the use of any magnifying equipment on prints from photographs of the 14 inch television monitor tube which were at the same size as the monitor. Imagery resolution seemed to range between 100 to 200 feet at best with no individual buildings identifiable but linear features such as roads and bridges were detectable. Scale selection was extended to 1:250,000 on the screen if the imagery permitted enlargement to that scale. The Houston image was enlarged only to 350,000 because the scan line picture on the TV monitor actually lost detail at a larger reference scale.

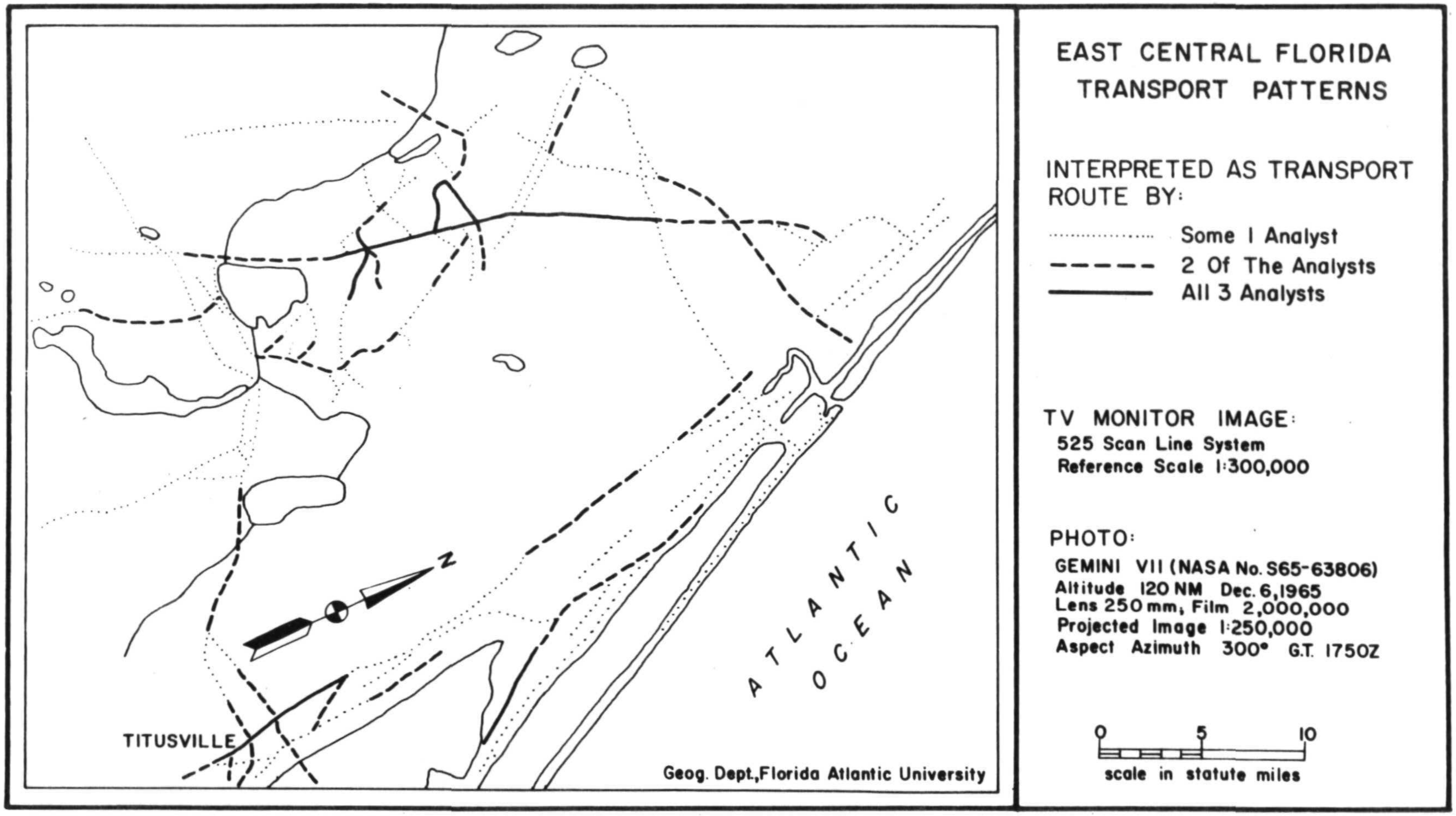

EAST CENTRAL FLORIDA
TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY:
Some 1 Analyst
2 Of The Analysts
All 3 Analysts
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:300,000
PHOTO:
GEMINI VII (NASA No. S65-63806)
Altitude 120 NM Dec. 6, 1965
Lens 250 mm; Film 2,000,000
Projected Image 1:250,000
Aspect Azimuth 300° G.T. 1750Z
0 5 10
scale in statute miles
N
TITUSVILLE
ATLANTIC
OCEAN
Geog. Dept., Florida Atlantic University

Figure 27.

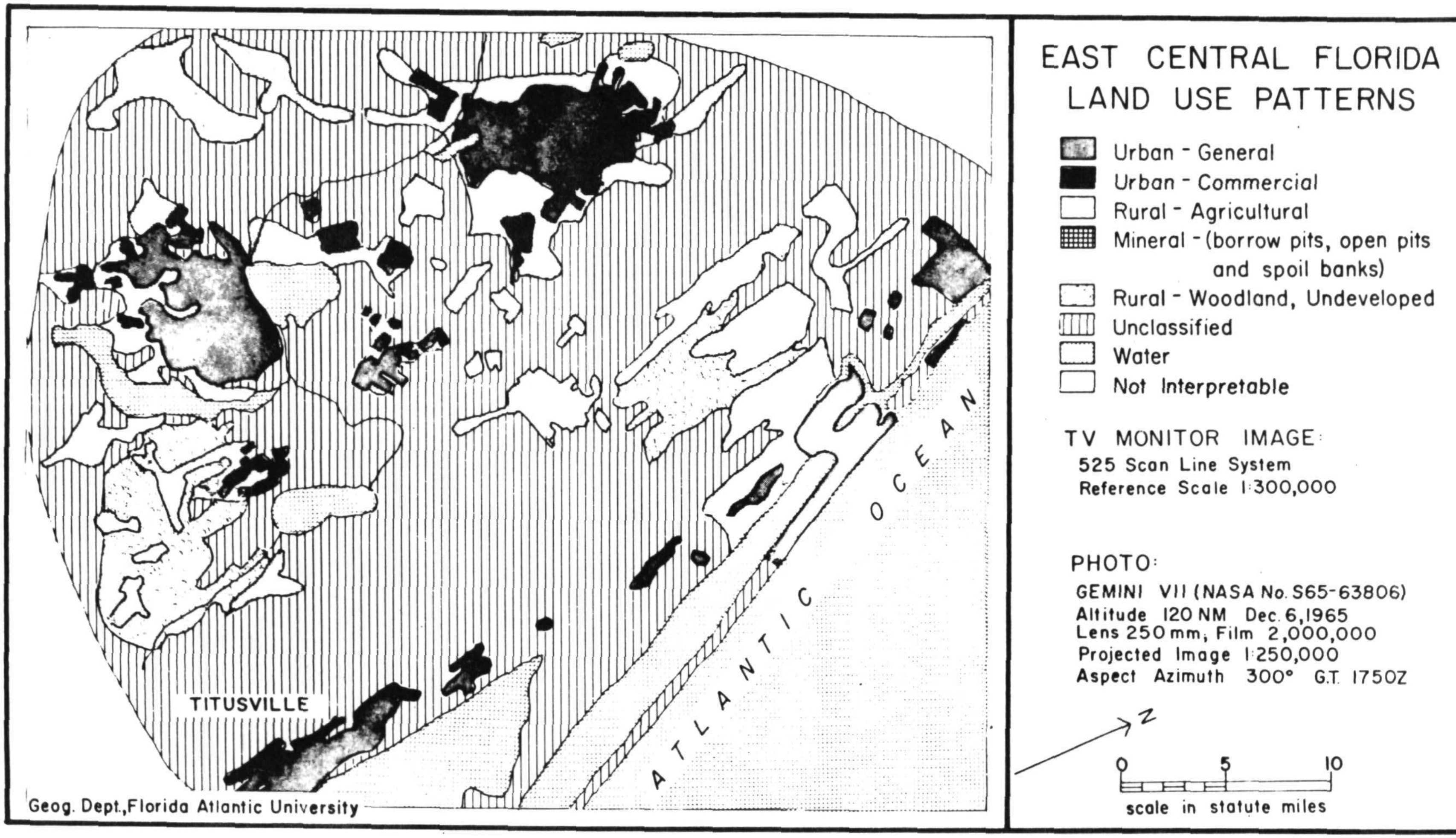

EAST CENTRAL FLORIDA
LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
TV MONITOR IMAGE:
525 Scan Line System
Reference Scale 1:300,000
PHOTO:
GEMINI VII (NASA No. S65-63806)
Altitude 120 NM Dec. 6, 1965
Lens 250 mm; Film 2,000,000
Projected Image 1:250,000
Aspect Azimuth 300° G.T. 1750Z
N
0 5 10
scale in statute miles
TITUSVILLE
ATLANTIC OCEAN
Geog. Dept., Florida Atlantic University

Figure 28

Figure 29. Simulated 945 scan line rate television image of the East Central Florida area from Titusville to the Sanford-DeLand region as photographed from a 14 inch monitor.

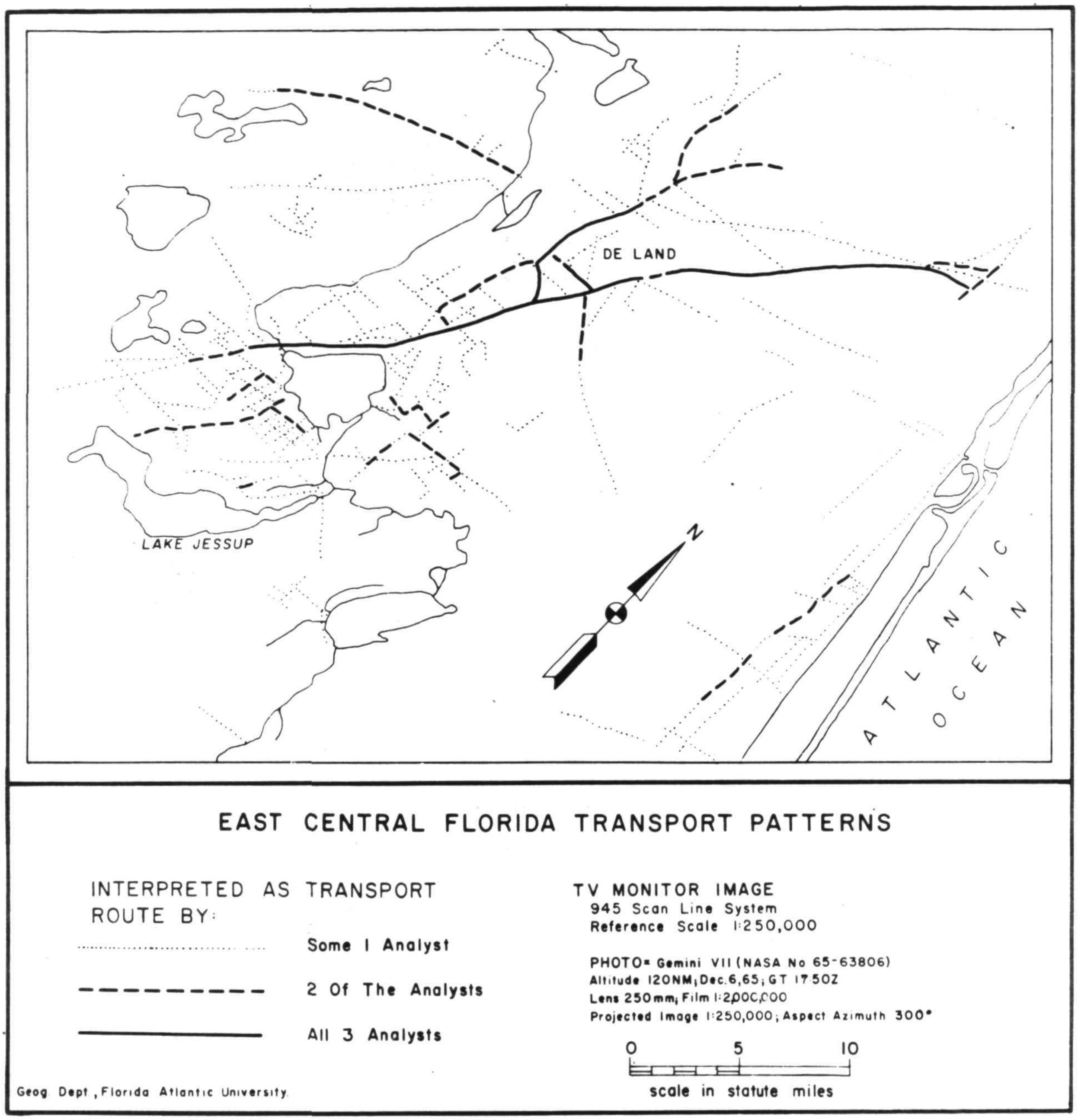

DE LAND
LAKE JESSUP
N
ATLANTIC OCEAN
EAST CENTRAL FLORIDA TRANSPORT PATTERNS
INTERPRETED AS TRANSPORT ROUTE BY:
Some I Analyst
2 Of The Analysts
All 3 Analysts
TV MONITOR IMAGE
945 Scan Line System
Reference Scale 1:250,000
PHOTO= Gemini VII (NASA No 65-63806)
Altitude 120NM; Dec.6,65; GT 17 50Z
Lens 250mm; Film 1:2,000,000
Projected Image 1:250,000; Aspect Azimuth 300°
0 5 10
scale in statute miles
Geog. Dept., Florida Atlantic University.

Figure 30.

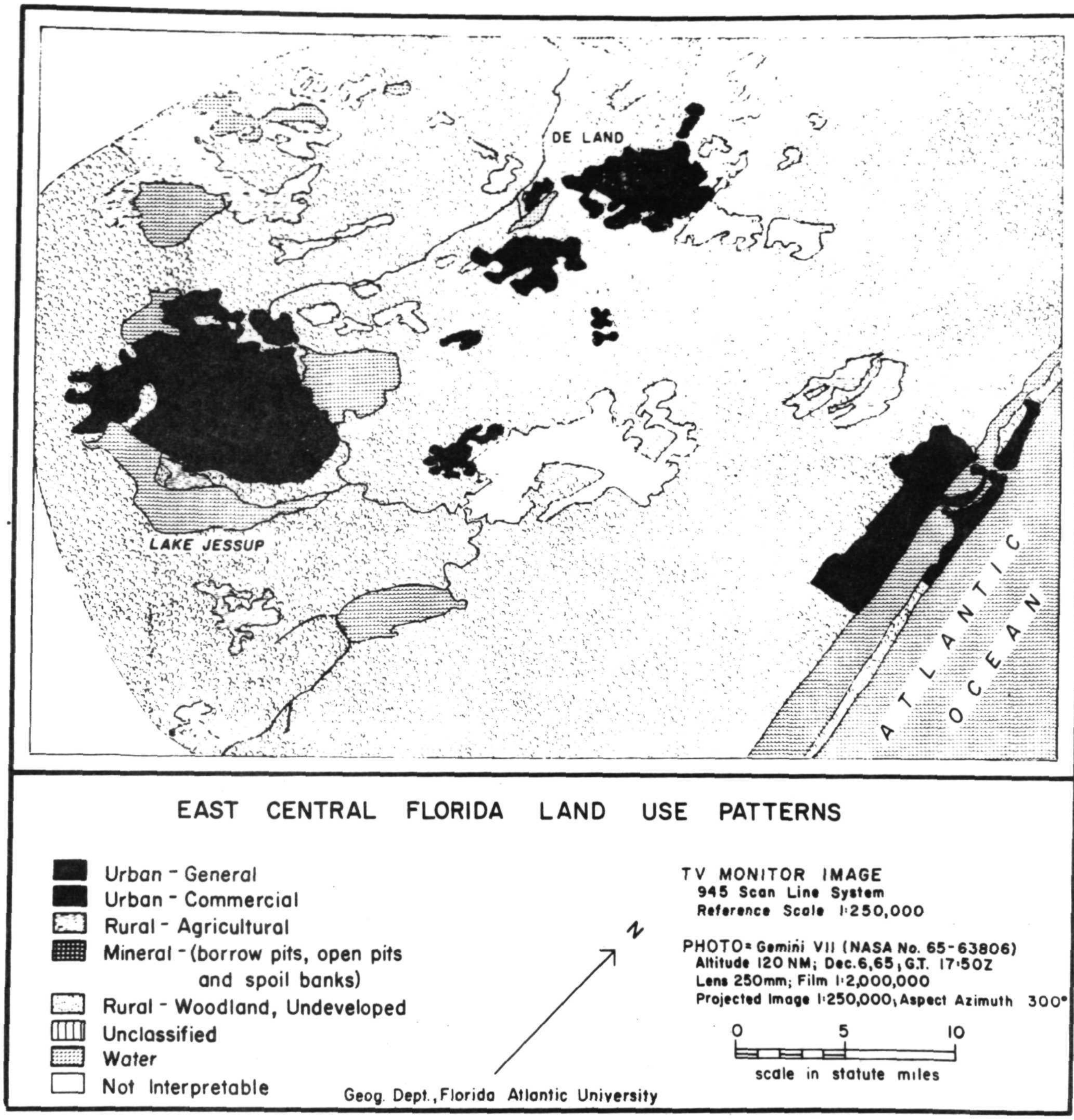

DE LAND
LAKE JESSUP
ATLANTIC
OCEAN
EAST CENTRAL FLORIDA LAND USE PATTERNS
Urban - General
Urban - Commercial
Rural - Agricultural
Mineral - (borrow pits, open pits
and spoil banks)
Rural - Woodland, Undeveloped
Unclassified
Water
Not Interpretable
N
Geog. Dept., Florida Atlantic University
TV MONITOR IMAGE
945 Scan Line System
Reference Scale 1:250,000
PHOTO = Gemini VII (NASA No. 65-63806)
Altitude 120 NM; Dec.6,65; G.T. 17:50Z
Lens 250mm; Film 1:2,000,000
Projected Image 1:250,000; Aspect Azimuth 300°
0
5
10
scale in statute miles

Figure 31

PHASE II- INTERPRETING FOUR SCALE ALTERNATIVES IN SIMULATED TV IMAGERY WITH EITHER A 525 OR 945 SCAN LINE RATE

On the basis of the experience and perception gained in Phase I, the Principal Investigator and the three Interpretation Associates initiated a controlled experiment to more precisely evaluate how changes in the scale of television images, such as those that might result from alternate choices in orbital altitudes or optical focal length, would influence the detection and thematic mapping of transportation and land use patterns. The near vertical image of the Titusville area west of Cape Kennedy was chosen for the study since it was judged the best available at that time. It was taken with the 250mm. lens from an orbital altitude of 120 N.M. and contained good resolution and pattern definition. It included the partial cloud and haze attenuation that is typical in the humid coastal region, however this was a serious handicap only over the Cape area, and did not seriously handicap the mainland Titusville region in which the researchers were interested. Technical problems which the image attenuation presented when scanned in order to generate a television image with a good gray tone balance were present but manageable.

It was determined that systematic hierarchial scale changes in the television monitor image would be studied with the following scales examined in the sequence given: 1:1,000,000, 1:500,000, 1:250,000 and 1:125,000. Only the area which would be bounded by the full size monitor view at the 1:125,000 reference scale would be interpreted at each scale, even though the monitor image would contain more area at the smaller scales. To provide some uniformity among interpreters, a time limit of two weeks was placed on their interpretation of each set of four images provided.

The first set of four 525 scan line rate images were provided, with mylar overlays bounding the area to be interpreted, and the interpreter analyzed the alternate scales in ascending scale order. After completing the transportation and land use analysis on this set, he was provided similarly with a set of four 945 scan line rate photoprints of the monitor face. All prints were made at actual monitor size. It was assumed that all three interpreters knew the location of the area and the nature of its region. They were instructed to maximize the detail of the interpretation that could be based on the actual imagery patterns. Each man processed his assignment independent of the other interpreters. No maps or written materials on the area were to be used by the interpreters.

Figure 32 displays the 525 scan line rate image as displayed on the 14 inch monitor at the maximum 1:125,000 scale. It bounds the entire area to be evaluated by the researchers at any scale. Of course the glossy monitor-sized prints from which the interpreters worked were much better renditions of the actual monitor image than this reduced size report print. The reference scale on the monitor tube did of course vary with the four alternatives but original film scale, estimated at 1:2,000,000 for this image, was always projected on the rear view screen at the 1:250,000 ratio for viewing by the TV camera.

Figure 33 presents the transportation patterns interpreted from the 525 image at 1:1,000,000. In view of the fact that this image encompasses only about 50 scan lines each of which have considerable ground width at this scale, a rather surprising amount of information could be interpreted. The major turnpike route was observable, although this was undoubtably assisted by the recency of construction and the "bloom" effect of a cleared sandy surface, and might not be so obvious with a later more vegetated pathway. Major coastal waterways were seen, and several possible interior highways.

With the increase to the 1:500,000 scale mapped in Figure 34, much more detail is available. Many roadways are seen by the interpreters and the coastal waterways are seen as well as the bridges or causeways spaning them. Interpreters commented they could be confused in urban areas with a tone response from buildings but in the open country they could be interpreted with confidence.

The most noticeable increase is the amount of data that can be mapped occurs as one moves from the previous scale to the 1:250,000 presentation of Figure 35. Agreement among interpreters has increased as well as the number of routes each has discerned. In the words of one interpreter, "At this scale, faint photo traces appeared which could be interpreted as roads. At the scale previous, these traces were not evident. The better road net made delineation of the urban complex easier."

At the largest scale of 1:125,000 routes of transportation are quite extensive within the 525 raster scan lines image compiled in Figure 36. One analyst commented that, "Several more roads are visible on this image, but land/water contacts are poorly represented outside the central area." Another one concluded that, "at this scale road patterns will not be interpreted with appreciably greater accuracy than at the scale of 1:250,000."

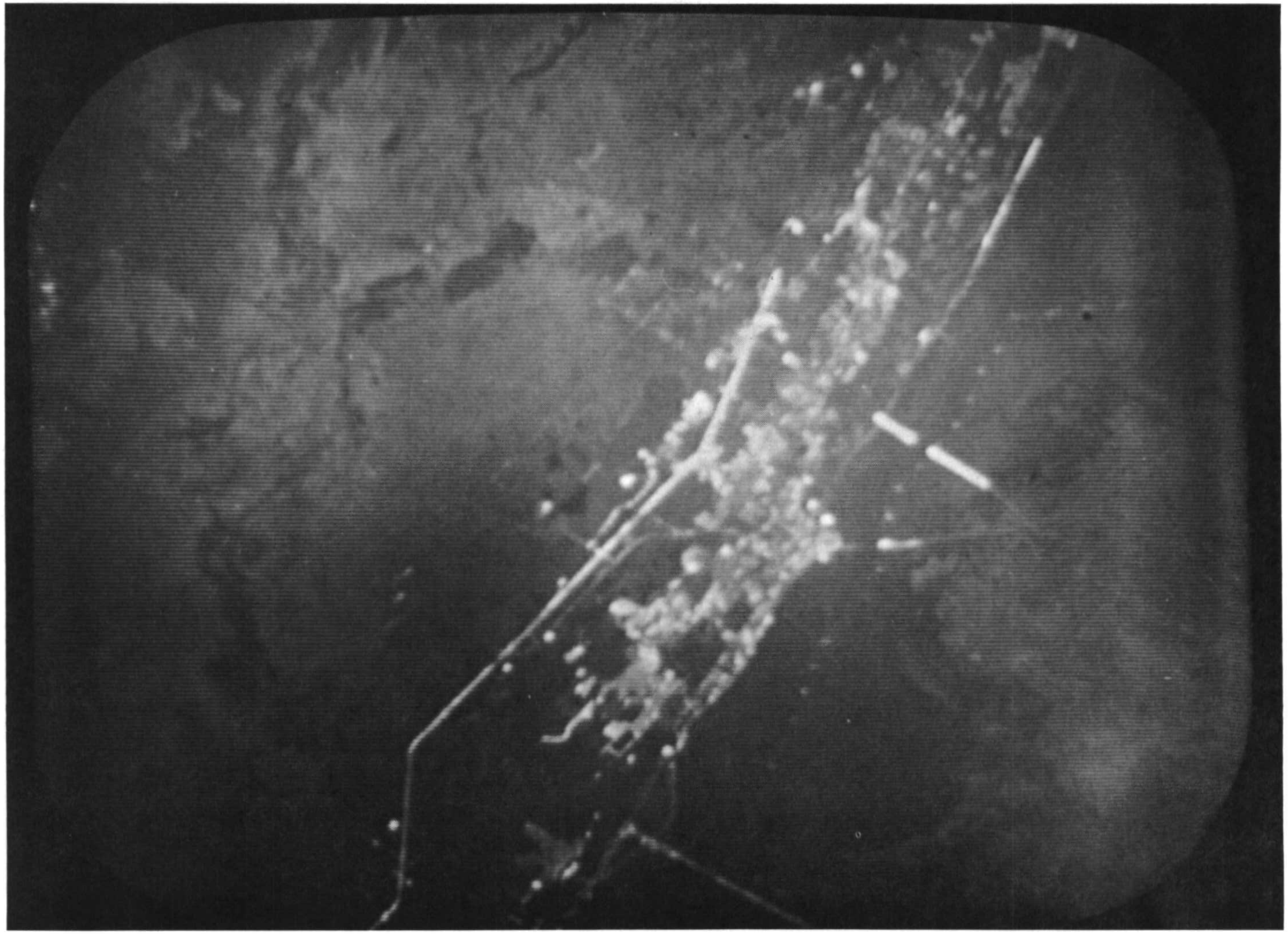


Figure 32. A 525 scan line rate simulated television image of the East Coast Florida Titusville area as displayed on a 14 inch monitor at a scale of 1:125,000.

EAST CENTRAL FLORIDA TRANSPORTATION PATTERNS

REFERENCE SCALE 1:1,000,000

INTERPRETED AS TRANSPORTATION ROUTE BY:

.... Some 1 Analyst
– – – 2 Of The Analysts
——— All 3 Analysts

TV MONITOR IMAGE

525 Scan Line System
Scale as Above

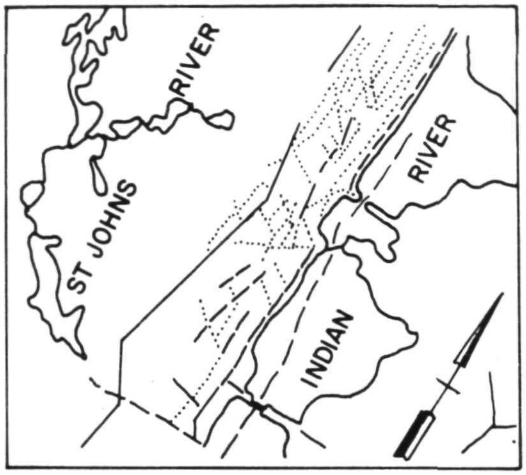
PHOTO= GEMINI VII (NASA No. 65-63806)
Altitude 120NM Dec 6, 1965
Lens 250mm, Film Scale=1:2,000,000
Projected Image Scale= 1:250,000
Aspect Azimuth 300° GT 1750Z

0 5 10 15 30

scale in statue miles

Geog. Dept., Florida Atlantic Univ.

Figure 33.



EAST CENTRAL FLORIDA TRANSPORTATION PATTERNS

REFERENCE SCALE 1:500,000

INTERPRETED AS TRANSPORTATION ROUTE BY

.... Some 1 Analyst
— — — 2 Of The Analysts
———— All 3 Analysts

TV MONITOR IMAGE

525 Scan Line System
Scale as Above

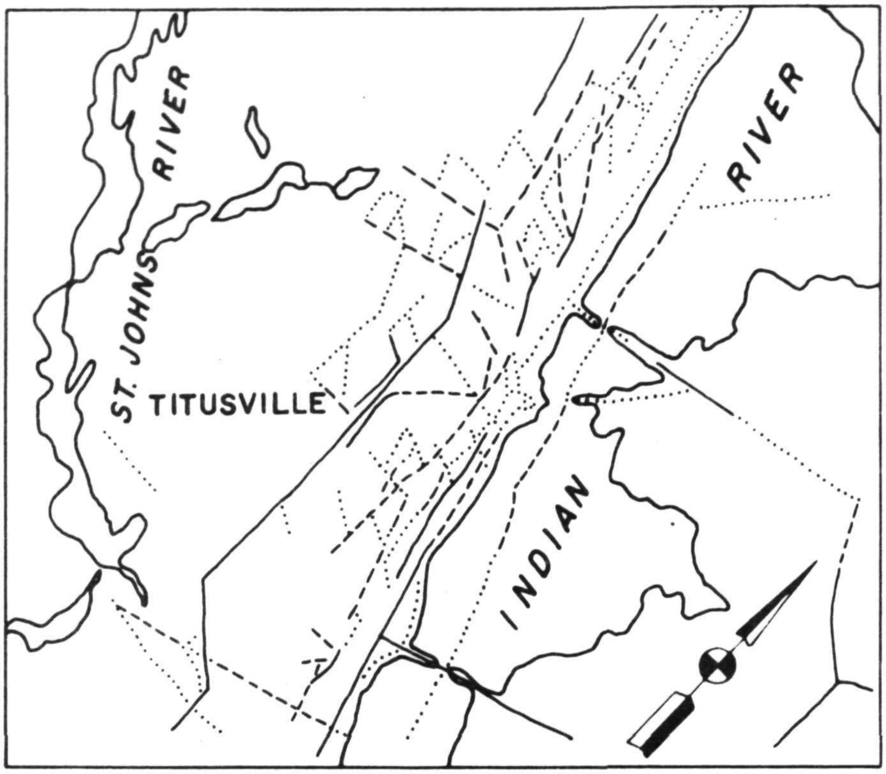
PHOTO = GEMINI VII (NASA No. 65-63806)
Altitude 120 NM Dec 6, 1965
Lens 250mm, Film Scale 1:2,000,000
Projected Image Scale 1: 250,000
Aspect Azimuth 300° GT 1750 Z

0 5 10 15 20 25

scale in statute miles

Geog. Dept., Florida Atlantic University

Figure 34.



EAST CENTRAL FLORIDA TRANSPORT PATTERNS
REFERENCE SCALE 1:250,000

INTERPRETED AS TRANSPORTATION ROUTE BY:

.... Some 1 Analyst
– – – – 2 Of The Analysts
———— All 3 Analysts

TV MONITOR IMAGE
525 Scan Line System
Scale as Above

PHOTO= GEMINI VII (NASA No. 65-63806)
Altitude 120 NM Dec 6, 1965
Lens 250mm Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z

0 4 8 12 16
scale in statute miles

Geog. Dept., Florida Atlantic Univ.

Figure 35.

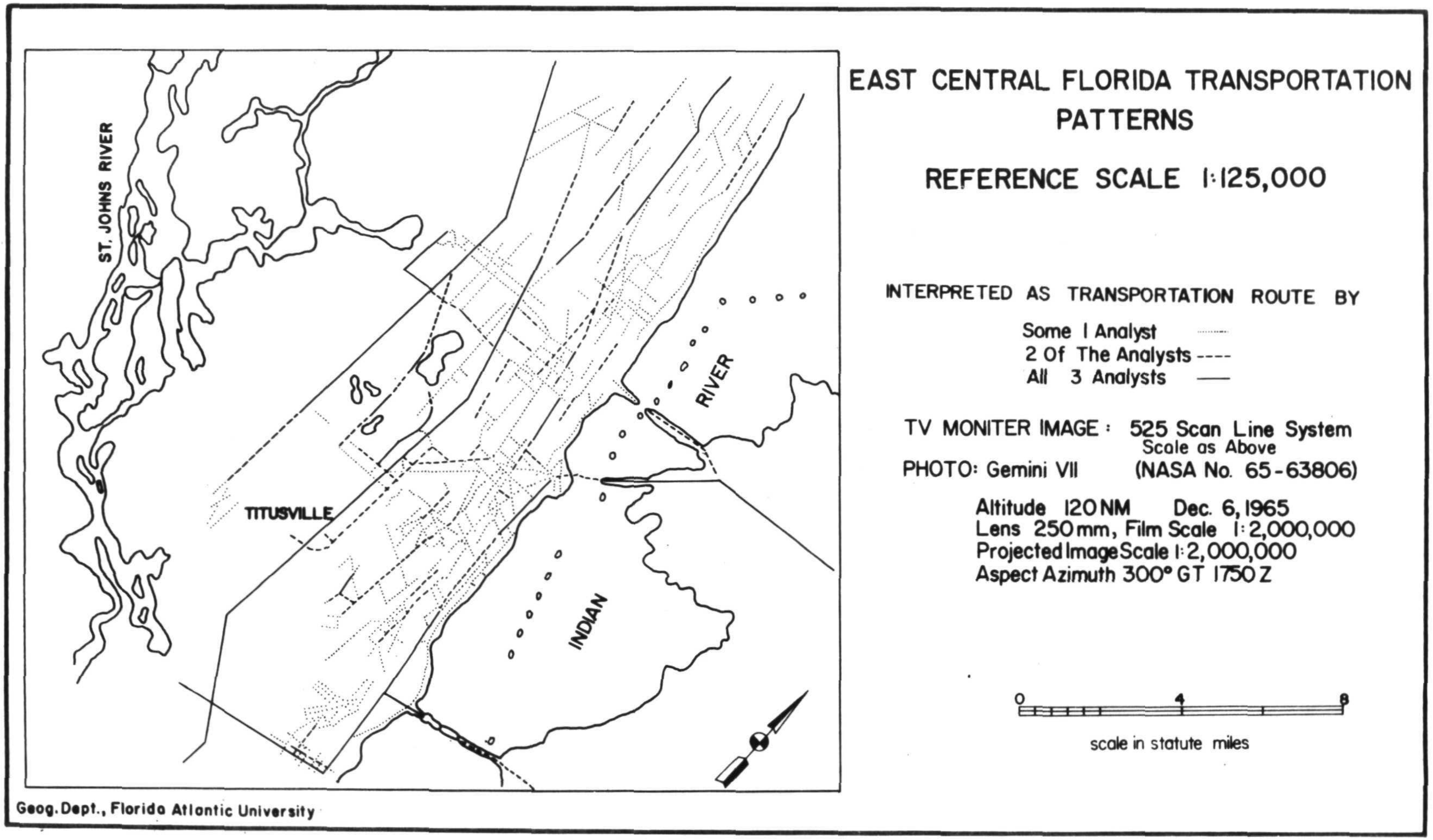

EAST CENTRAL FLORIDA TRANSPORTATION PATTERNS
REFERENCE SCALE 1:125,000
INTERPRETED AS TRANSPORTATION ROUTE BY
Some 1 Analyst
2 Of The Analysts
All 3 Analysts
TV MONITER IMAGE: 525 Scan Line System
Scale as Above
PHOTO: Gemini VII (NASA No. 65-63806)
Altitude 120 NM Dec. 6, 1965
Lens 250 mm, Film Scale 1:2,000,000
Projected Image Scale 1:2,000,000
Aspect Azimuth 300° GT 1750 Z
0
4
8
scale in statute miles
ST. JOHNS RIVER
TITUSVILLE
INDIAN
RIVER
Geog. Dept., Florida Atlantic University

Figure 36.

The 945 scan line rate image of the Titusville area of East Central Florida is displayed in Figure 37 as it appeared on the monitor at the 1:125,000 scale which bounds the region under study. When the transportation route net information that was compiled from it is observed in Figure 38, it is evident that it compares closely to that secured also at the small 1:1,000,000 scale from the less intense 525 line image. Apparently the scan line change is not significant enough to overcome the scale factor which still displays only the major pattern aspects. However, major features are seen, and one interpreter speculated that this degree of generalization might be very useful for imaging a larger region, like south Florida. It was observed that it seemed that a greater area was adversely affected by cloud tones now, although the same slide was projected. It may be that the increase in scan lines tends to exaggerate bright tonal responses, and reduce interpretability of haze-attenuated images.

The transportation patterns from the 945 scan line rate mapped in Figure 39 closely resemble those mapped for the 525 line image at the same 1:500,000 rate. One interpreter commented that, "The transportation pattern showed through the cloud blur that rendered the 1:1,000,000 photo so difficult to interpret. Road alignments rather than precise road locations are probably what is interpreted at this scale." When Figure 40 is compared with Figure 35, it is notable that the former interpretation from the 945 line image does display a significant increase over the detailing of routes in the lower scan image. It is also notable that although both are at the 1:250,000 monitor scale, the 945 seems to bring out more agreement among the interpreters. At the 1:125,000 scale images from both scan line rates are similar, with Figure 41 from this more intense system resembling its previous 525 counterparts high degree of network pattern. It seems to display superiority in the more distant western portion of the image, however and one interpreter classifies the 945 system as"somewhat superior." He also says, "At this scale, and scanline density, I have doubts as to the correctness of road location. For new construction the tone is a continuous straight line without irregularities in width. However in downtown Titusville what must be highly reflective surfaces like parking lots or large expanses of coated roafing disrupt the linear pattern of roads. I believe that the road is in such instances the darker line trace between brighter blobs."

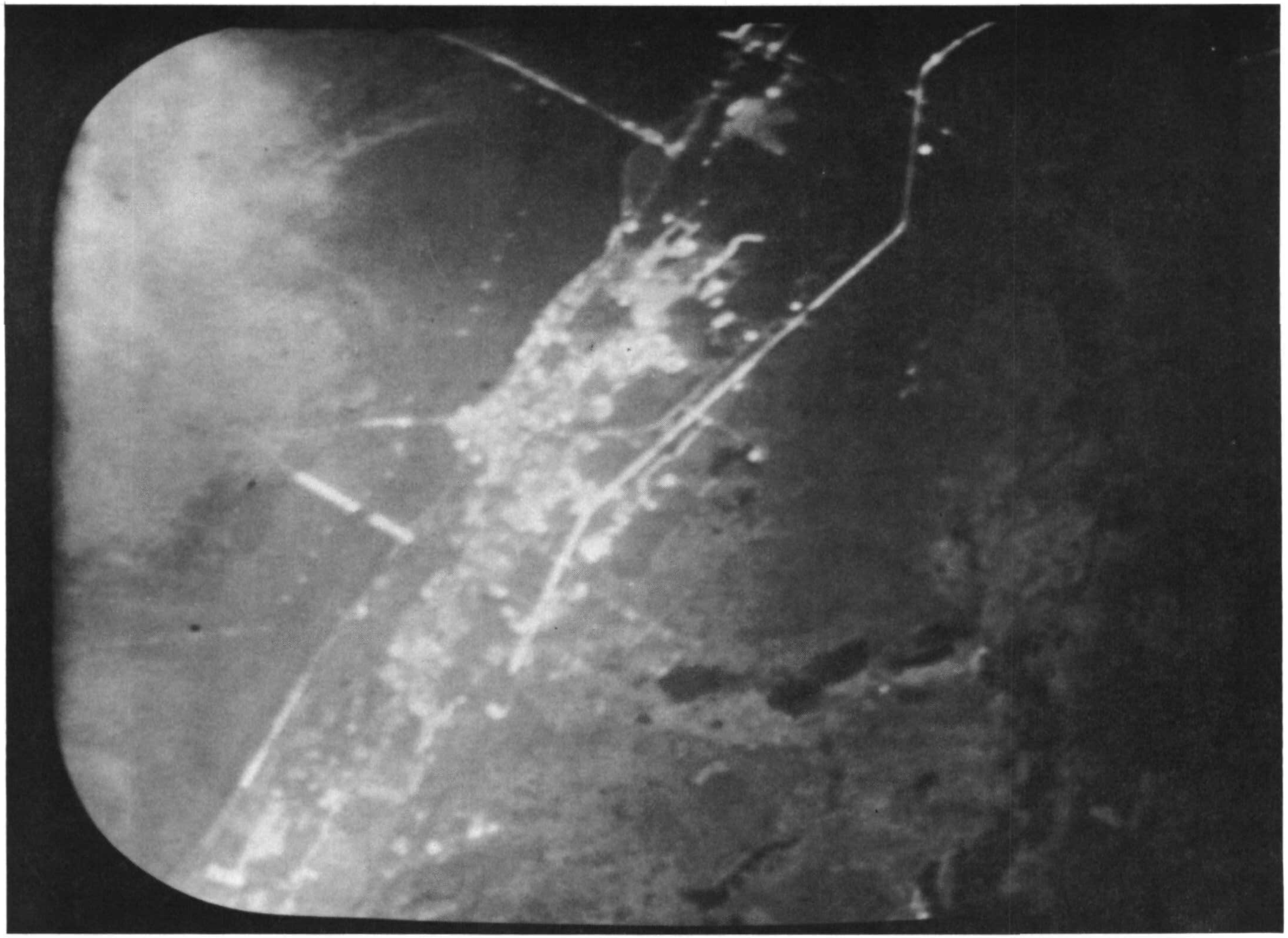
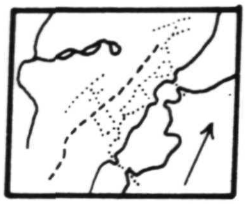


Figure 37. A 945 scan line rate simulated television image of the Titusville area of East Coast Florida as displayed on a 14 inch monitor at a scale of 1:125,000.



EAST CENTRAL FLORIDA TRANSPORTATION PATTERNS

REFERENCE SCALE 1:1,000,000

INTERPRETED AS TRANSPORTATION ROUTE BY:

....	Some 1 Analyst
- - - -	2 Of The Analysts
———	All 3 Analysts

TV MONITOR IMAGE

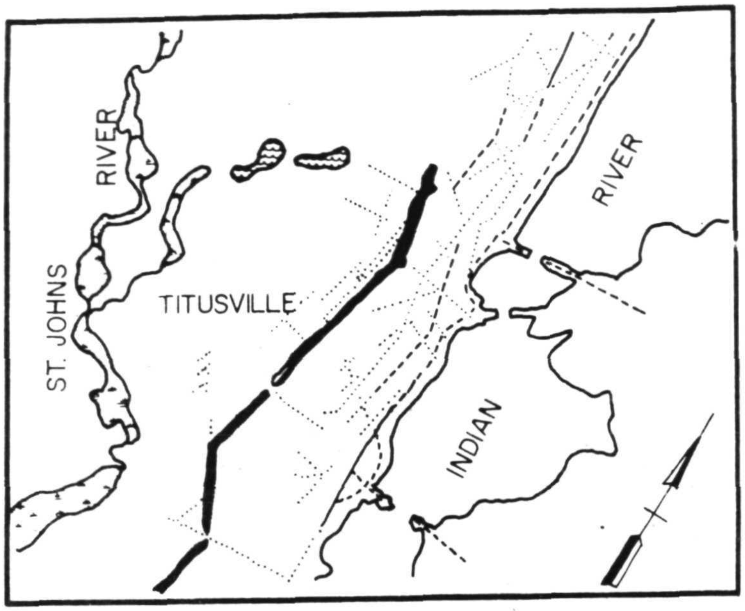
945 Scan Line System

Scale as Above

PHOTO = GEMINI VII (NASA No. 65-63806)
Altitude 120NM Dec 6, 1965
Lens 250mm Film Scale = 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z

Geog Dept., Florida Atlantic Univ

Figure 38.



EAST CENTRAL FLORIDA TRANSPORTATION PATTERNS

REFERENCE SCALE 1:500,000

INTERPRETED AS TRANSPORTATION ROUTE BY

- ········ Some 1 Analyst
- ---- 2 Of The Analysts
- All 3 Analysts:
- ——— Existing Route
- Major Construction

TV MONITOR IMAGE

945 Scan Line System
Scale as Above

PHOTO = GEMINI VII (NASA No. 65-63806)
Altitude 120NM Dec 6, 1965
Lens 250mm Film Scale = 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z

0 5 10 15
scale in statute miles

Geog. Dept., Florida Atlantic University

Figure 39.

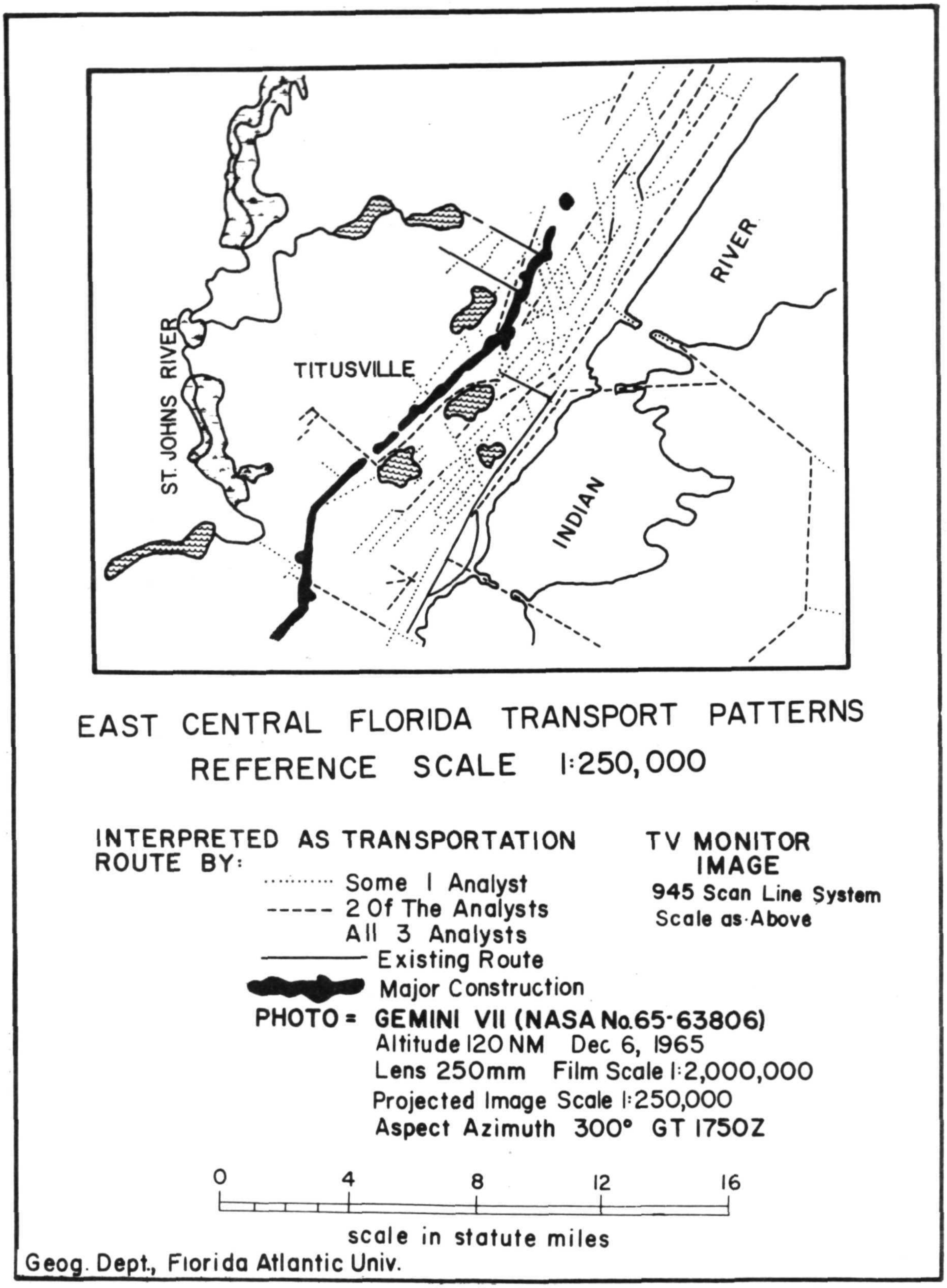

ST. JOHNS RIVER
TITUSVILLE
INDIAN
RIVER
EAST CENTRAL FLORIDA TRANSPORT PATTERNS
REFERENCE SCALE 1:250,000
INTERPRETED AS TRANSPORTATION ROUTE BY:
Some 1 Analyst
2 Of The Analysts
All 3 Analysts
Existing Route
Major Construction
TV MONITOR IMAGE
945 Scan Line System
Scale as Above
PHOTO = GEMINI VII (NASA No.65-63806)
Altitude 120 NM Dec 6, 1965
Lens 250mm Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z
0
4
8
12
16
scale in statute miles
Geog. Dept., Florida Atlantic Univ.

Figure 40.

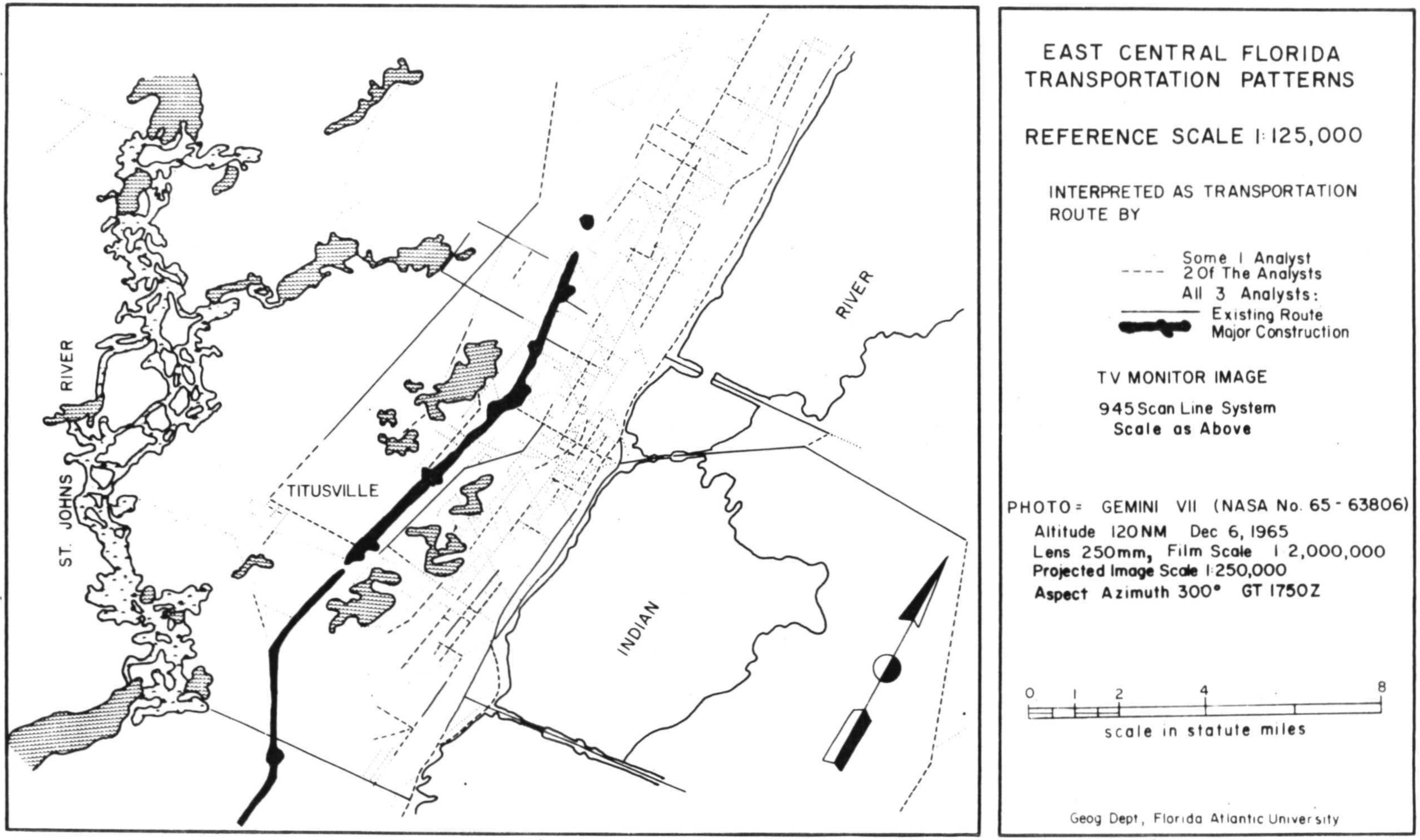

ST. JOHNS RIVER
TITUSVILLE
INDIAN RIVER
EAST CENTRAL FLORIDA
TRANSPORTATION PATTERNS
REFERENCE SCALE 1:125,000
INTERPRETED AS TRANSPORTATION ROUTE BY
Some 1 Analyst
2 Of The Analysts
All 3 Analysts:
Existing Route
Major Construction
TV MONITOR IMAGE
945 Scan Line System
Scale as Above
PHOTO = GEMINI VII (NASA No. 65-63806)
Altitude 120 NM Dec 6, 1965
Lens 250mm, Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z
0 1 2 4 8
scale in statute miles
Geog Dept, Florida Atlantic University

Figure 41.

Land use interpretation of the same four scale alternates for the simulated orbital television images of the Titusville area were also completed by the three interpreters for each of the two scan line rates being studied. This report will include only the maps which resulted from the superior 945 line scan, but the discussion will include some comparative evaluation of the 525 line use evaluations made by the investigators. The 525 maps were compiled first for all scales before the analysts mapped the discernable categories from the 945 line imagery.

The smallest 1:1,000,000 scale imagery is generalizing the test area with less than 50 scan lines for the 525 rate and with less than 85 for the 945 rate, hence it can be expected that land use identification will suffer because of a lack of resolution and a lack of gray tone discrimination. Only land, large water surfaces, and well developed or cleared surface lands versus undeveloped land may be reliably interpreted. Recently cleared transport routes involving extensive land usage will also be seen, and perhaps confused with urban lineaments. Figure 42 presents a good example of the patterns perceived. Although this may be a useful generalization for a large area it is not a very informative categorization or as discriminating as one might desire at the 1:1,000,000 scale.

At the 1:500,000 scale illustrated in Figure 42, interpreters report that even with the less intense 525 line imagery, urban fringes can be approximated quite well. Wetland and open bodies of water can be outlined, and rural land use, except pasture, is just beginning to "show up." There are few patterns of tonal difference discernable in the non-urban areas but there are probably few cropland occurrances in this area and it is "speculated that larger cropland units could be discernable at this scale in either scan rate. However, interpreters felt confident in locating the St. John River lowland area where cypress and other swamp vegetation fringe the watercourses and marsh grass extends toward dryer soils.

The interpreters expressed a belief that the most "optimum scale for interpretation of the TV scan line imagery lay within the range from 1;250,000 to something greater than 1:500,000. They speculate that this is a function of the pattern discrimination associated with the distance between scan lines - which helps to determine the boundary contrasts between gray tones. Figure 44 presents the 1:250,000 land use map which demonstrates once again the sharp rise in interpreted data at this level. This scale also permitted a more confident outlining and internal deliniation of urban area. A lack of defineable rectangular field patterns continued to discourage "rural agricultrual" classification except in the northwest corner, although a plowed field over 2 acres in size should be readily seen.

EAST CENTRAL FLORIDA LAND USE PATTERNS
REFERENCE SCALE 1:1,000,000

TV MONITOR IMAGE
945 Scan Line System
Scale as Above

URBAN GENERAL

NOT INTERPRETABLE

WATER

PHOTO = GEMINI VII (NASA No. 65- 63806)
Altitude 120 NM Dec 6, 1965
Lens 250 mm, Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750 Z

0 5 10 15 30

scale in statue miles

Geog. Dept., Florida Atlantic Univ.

Figure 42.

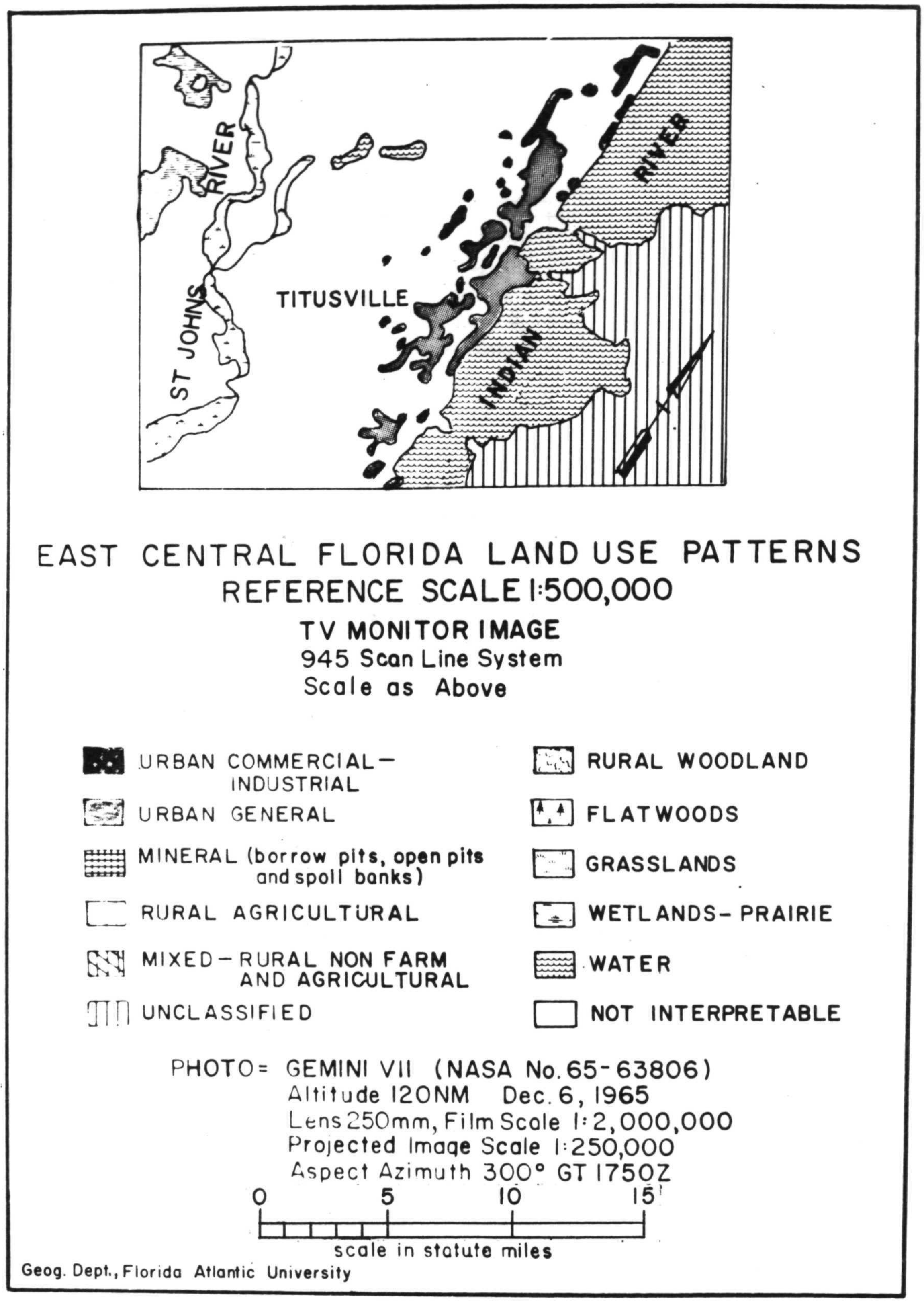

RIVER
ST JOHNS
TITUSVILLE
INDIAN
RIVER
EAST CENTRAL FLORIDA LAND USE PATTERNS
REFERENCE SCALE 1:500,000
TV MONITOR IMAGE
945 Scan Line System
Scale as Above
URBAN COMMERCIAL-INDUSTRIAL
URBAN GENERAL
MINERAL (borrow pits, open pits and spoil banks)
RURAL AGRICULTURAL
MIXED-RURAL NON FARM AND AGRICULTURAL
UNCLASSIFIED
RURAL WOODLAND
FLATWOODS
GRASSLANDS
WETLANDS-PRAIRIE
WATER
NOT INTERPRETABLE
PHOTO= GEMINI VII (NASA No.65-63806)
Altitude 120NM Dec. 6, 1965
Lens 250mm, Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z
0
5
10
15
scale in statute miles
Geog. Dept., Florida Atlantic University

Figure 43.

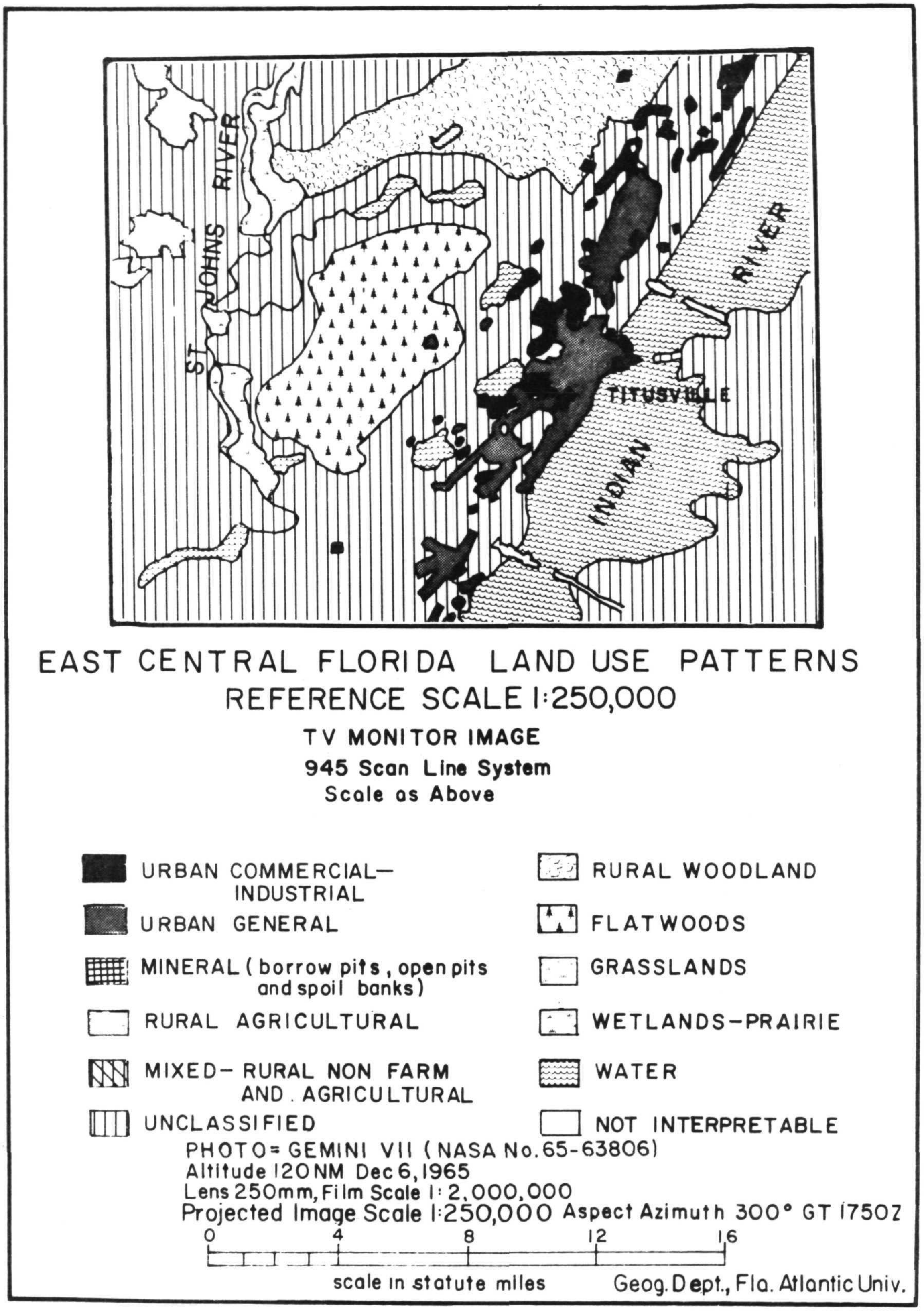

ST. JOHNS RIVER
TITUSVILLE
INDIAN RIVER
EAST CENTRAL FLORIDA LAND USE PATTERNS
REFERENCE SCALE 1:250,000
TV MONITOR IMAGE
945 Scan Line System
Scale as Above
URBAN COMMERCIAL–INDUSTRIAL
URBAN GENERAL
MINERAL (borrow pits, open pits and spoil banks)
RURAL AGRICULTURAL
MIXED– RURAL NON FARM AND AGRICULTURAL
UNCLASSIFIED
RURAL WOODLAND
FLATWOODS
GRASSLANDS
WETLANDS–PRAIRIE
WATER
NOT INTERPRETABLE
PHOTO= GEMINI VII (NASA No. 65-63806)
Altitude 120 NM Dec 6, 1965
Lens 250mm, Film Scale 1:2,000,000
Projected Image Scale 1:250,000 Aspect Azimuth 300° GT 1750Z
0 4 8 12 16
scale in statute miles
Geog. Dept., Fla. Atlantic Univ.

Figure 44.

At the 1:125,000 scale of TV scan line imagery, an "ultimate" in data extraction for land use category mapping is being approached for both the 525 and the 945 line systems. Although Figure 45 includes some portions still "unclassified," not all our interpreters agreed with that cautious approach. Detailed patterning and bounding of categories are now mapped, and internal differentiation of principal urban areas is possible. All categories in the map legend are now interpreted in some portion of this area.

This map has been compared with similarly scaled land use category maps generated by the laborious ground surveys, photo interpretation and compiling methods usually followed by planning agencies. The patterns in this map compare well with those produced in such a time consuming fashion. And this map could be produced in a few days or less if orbital television imagery was available.

CONCLUSIONS

Many interpretive insights are noted in the preceding pages of this study of stimulated orbital TV imagery, but it seems useful to concisely summarize here some of the conclusions of the Principal Investigator:

1. It is feasible to thematically map transportation and land use category patterns from orbital television imagery with less than a thousand scan lines in a system operating under two hundred miles above the earth, even with only a black and white image.

2. Monitor image scales between 1:250,000 and 1:125,000 are desirable, for general category or transport route analyses. Larger scales up to 1:50,000 seem quite feasible, with optical modifications, as a means of further refining the categorization but they will obviously yield less synoptic images with less coverage per image, on the 14 inch monitor display.

3. Aerial platforms with black and white television systems are capable of securing valuable imagery for surveying and mapping land use or other surface patterns.

4. Although higher scan line rates are helpful, they are not essential at lower orbital altitudes and consequent savings in transmission bandwidth and data processing or storage requirements are possible.

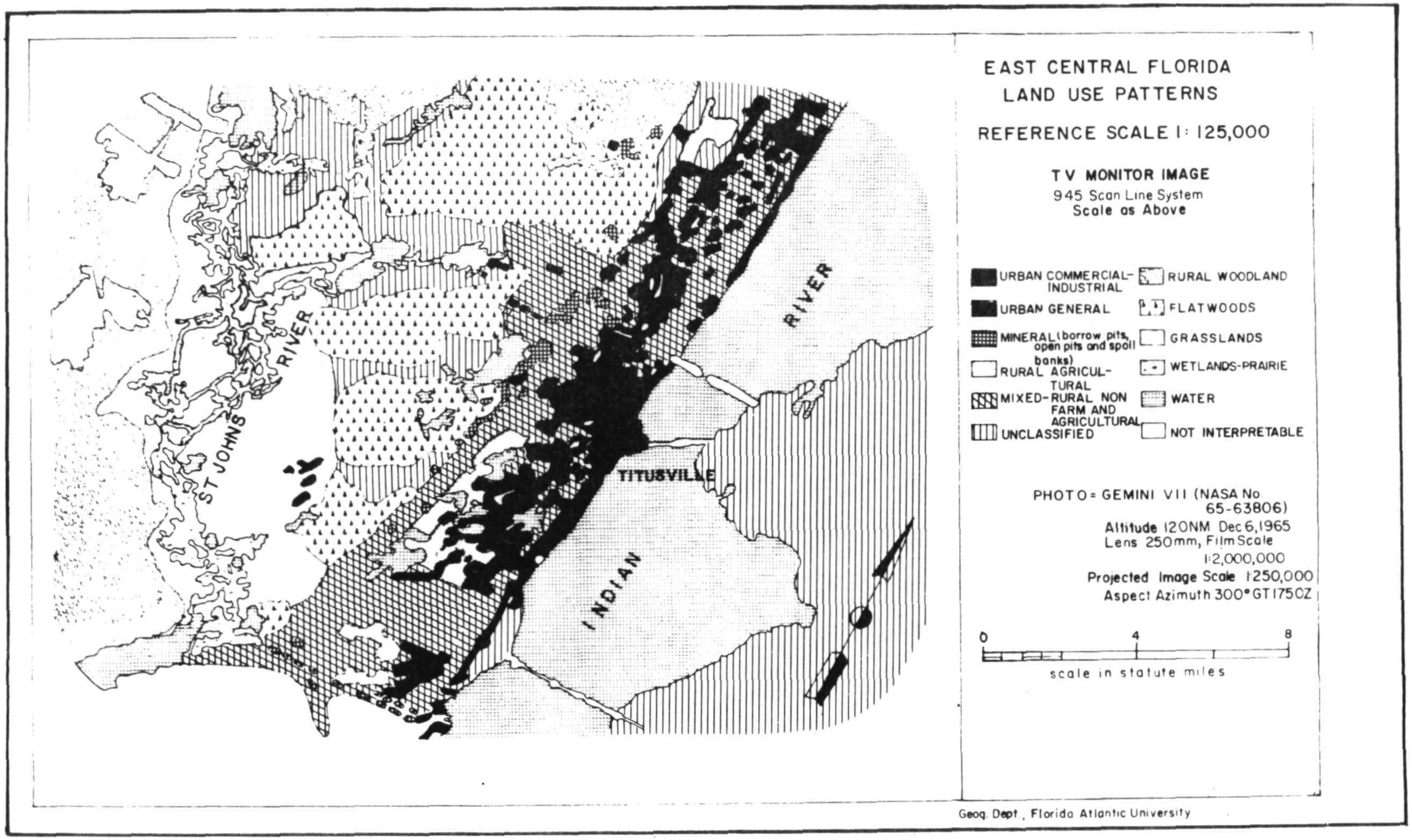

EAST CENTRAL FLORIDA
LAND USE PATTERNS
REFERENCE SCALE 1: 125,000
T V MONITOR IMAGE
945 Scan Line System
Scale as Above
URBAN COMMERCIAL-INDUSTRIAL
URBAN GENERAL
MINERAL (borrow pits, open pits and spoil banks)
RURAL AGRICULTURAL
MIXED-RURAL NON FARM AND AGRICULTURAL
UNCLASSIFIED
RURAL WOODLAND
FLATWOODS
GRASSLANDS
WETLANDS-PRAIRIE
WATER
NOT INTERPRETABLE
PHOTO = GEMINI VII (NASA No 65-63806)
Altitude 120NM Dec 6, 1965
Lens 250mm, Film Scale 1:2,000,000
Projected Image Scale 1:250,000
Aspect Azimuth 300° GT 1750Z
0
4
8
scale in statute miles
ST JOHNS RIVER
INDIAN RIVER
TITUSVILLE
Geog. Dept., Florida Atlantic University

Figure 45.

5. As higher scan line rates and narrower scan lines are integrated into a sensor system it may use higher orbits and acquire comparable imagery for a wider path of coverage.

6. It is feasible to economically simulate orbital television imagery of earth surface in a laboratory for training or experimental purposes.

7. Larger monitor faces which increase the scale of imagery display but do not contain additional scan line data are not an advantage for interpretation, since pattern perception and recognition with scan line imagery requires the interpreter to integrate the patterns separated by the blank spacing between scan line paths.

N72-24412

COMPUTER LAND USE MAPPING VIA TV WAVEFORM ANALYSIS OF SPACE PHOTOGRAPHY*

by

G. Lennis Berlin**

and

James P. Latham

A literature review indicates that orbital color photography offers a potential in geographic problem solving because such imagery records spatial patterns representing physical and cultural phenomena. However, as photo banks rapidly increase some form of automation is needed with the capability that will contribute to a method whereby the vast quantities of spatial data can be processed and integrated into geographic analyses. This paper describes an instrumentation and computer system which offers the potential for analyzing photo geographic distributions.

To satisfy the requirement for computer acceptance, a television and waveform system was developed to transpose pictorial or iconic photo forms to the analytic. A video conversion was accomplished, and each pattern visible on the original photography was represented by a certain range of percentages. With spatial occurrences in digital form, a computer program was developed that could identify, analyze, and map geographic inputs.

Earlier research by Principal Investigator James P. Latham demonstrated that a television camera and waveform analyzer converted various image types (e.g., panchromatic, thermal infrared, color infrared, and color) into graphically expressed electronic waveforms. A black and white TV camera extracted density characteristics in a form convertible to graytone percentages. With color and color infrared imagery, the television system

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* Abstract of this paper published in Journal of the Arizona Academy of Science, Vol. VI (April, 1970) p. 53.

** Dr. Berlin was a Research Associate at Florida Atlantic University and is now an Assistant Professor at Northern Arizona University.

detected tone variations present in photographic hues since graytones are one of the three coordinates or dimensions of color.

When using the television-waveform technique, the arrangement of equipment was similar to that of a normal television scan, but major emphasis was placed on the waveform analyzer rather than a receiving monitor. Because a televised image is constructed of parallel scan lines, the image can be electronically dissected, line by line, utilizing the waveform analyzer. The instrument simply provided a graphic display of how a pattern of spatially distributed phenomena were being intercepted in TV monitors.

A television camera differs from some other scanning devices because it has the capability to produce graytones signal which may be measured as either relative or absolute percentages. There are major drawbacks in using the latter form in instrumented photo-interpretation because such values fail to compensate for the many factors that vary on photographs (e.g., light and sun conditions, atmospheric environment, length of exposure, and processing variations). Television-waveform analysis largely reduced the limitations of these parameters because percentages were adjusted to reflect the density range in each particular image.

Data from such a system permitted a statistical comparison of various imagery patterns and provided the means for instrumentation interpretation which reliably identified many land use and land type categories. Identifications were made from 5,000 foot, 15,000 foot, and orbital color photographs. Therefore, the basic problem was solved for computer applications; and the iconic forms of the original photography were converted into an analytic substitution - graytone percentages. The following describes how a computer was used to process the waveform analysis of orbital color photography.

To evaluate computer analysis and mapping experiments, digital data in the form of graytone percentages were visually lifted from the waveform analysis of a portion of the orbital photograph depicting the lower Nile Valley. The waveform analyzer portrayed graytone percentages as one dimensional for a single scan line, but two dimensions resulted when percentages were extracted from traverses which were equally spaced from a predetermined line. Once the initial scan line was selected, graytone percentages were recorded every centimeter along the Y-axis. When completed the horizontal scan was moved eight lines along the X-axis and the process repeated.

A total of 22 lines were used, and along each line 20 graytone percentage readings were made.

A vertical scan movement of eight lines on a 945 line monitor (normal TV utilizes 525 lines) corresponded to one horizontal reading every centimeter on the waveform analyzer. These distances insured a square field of coverage and eliminated distortion problems. The graytone percentages represented a transformation of a land surface area to an array of numbers holding a direct position relationship.

The graytone percentages were placed on punch cards along with a Fortran IV language program that was designed especially for this type of digital analysis. The data was ordered into an IBM computer, and the program instructed the computer to perform the following:

1. Transform graytone percentages to letter equivalents. Percentage ranges for each land type were placed on a series of punch cards, and each graytone occurrence was classified when contacted in the digital search. Double letter codes were used to equalize the graytone conversions.
2. Map graytone distributions. Once the digital data were categorized, the computer was programmed to print the letters in map form, both as to a composite land type map and individual distribution maps.
3. Estimate the area of each graytone distribution. The computer counted the number of occurrences corresponding to each land type, and based upon a scale of 1:600,000 calculated the square mile and percentage coverage of each distribution.

The computer technique developed for processing the waveform analysis of imagery proved very successful. As evidenced in Illustration which follows, the computer converted graytone percentages to letter codes, mapped graytone distributions, and quantitatively analyzed the distributions.

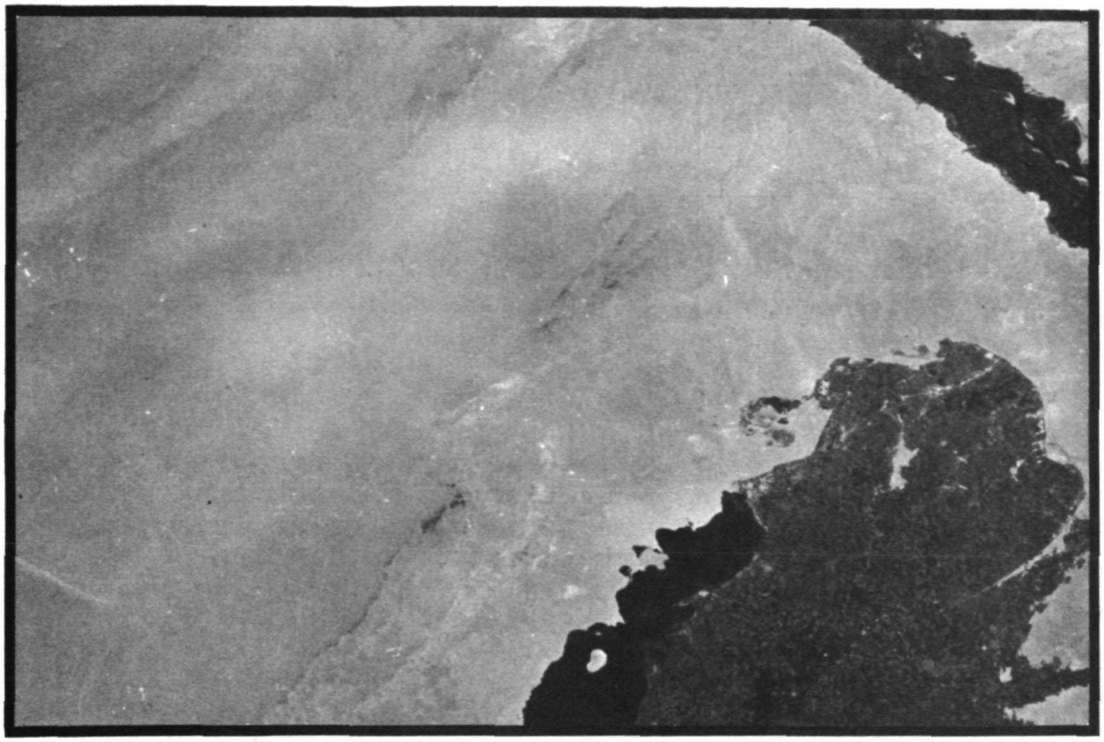
At this point it should be emphasized that the computer method did not constitute a closed system. Establishing graytone ranges for land types had to be performed manually. Then based upon the parameter of these ranges the computer decided to which category graytone occurrences belonged. Since only a minimal amount of time was required to establish range levels, the manual phase did not hinder the total analysis technique. Computation time for the Nile Valley example was less than 20 seconds. Total computer time was approximately 2.6 seconds.

The phase of manually recording graytone percentages onto punch cards can now be automated because of the success of previous tests. A strip chart recorder is planned to become an integral part of the instrumentation system at Florida Atlantic University's Remote Sensing and Interpretation Laboratory. Such an instrument is capable of (1) constructing waveform profiles and (2) accurately recording graytone percentages onto paper or magnetic tape.

Recorders are available that can record a maximum of 1200 readings per inch. In other words if a waveform had a length of 5 inches, a strip chart recorder could extract 6,000 graytone percentages. The number of readings recorded could vary with the (1) scale of the photography, (2) detail desired, and (3) particular arrangement of ground phenomena. With support from the Office of Naval Research and the U.S. Geological Survey the above instrument can be rigorously tested.

Investigational results have indicated that computer mapping and analysis via the TV-waveform analysis of orbital color photography may aid in geographic problem solving. A primary purpose of the technique would be to analyze distributions found on remote sensor imagery, with the resulting quantitative data and maps supplementing the total analysis package.

Waveform and computer analysis should go hand-in-hand with visual photo-interpretation. It goes without question that the latter is necessary to initially identify distributions and judge their significance. The instrumentation system can then extend the procedure by quantitatively analyzing and mapping the spatial patterns. It is hoped that the instrumentation system will help geographers better analyze the distribution of phenomena.



```
LAND TYPES

***************************************************************
* AA AA AA AA AA AA AA AA AA AA AA AA AA II II WW II    AA AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA    II II II II AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA II II       *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA II II II *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA II *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA II II    AA *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA II II II II II II *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA    II II II II II *
* AA AA AA AA AA AA AA AA AA AA AA AA AA AA II II    II II II *
* AA AA AA AA AA AA AA AA AA AA AA AA II II II II II II II II *
* AA AA AA AA AA AA AA AA AA AA AA II II II II II II II II II *
* AA AA AA AA AA AA AA AA AA II WW WW II II II II II II II II *
* AA AA AA AA AA AA AA AA AA    WW II II II II II II II II II *
* AA AA AA AA AA AA AA AA    WW II II II II II II II II II II *
* AA AA AA AA AA AA II WW WW II II II II WW    II II    II II *
* AA AA AA AA AA AA    II    II II II WW WW II II    II II II *
* AA AA AA AA AA II WW WW WW II II II WW WW WW       WW WW II *
* AA AA AA AA AA AA       WW II II II II WW    II       WW WW *
***************************************************************




APPROXIMATE AREAS


DESERT               AA            4562. SQUARE MILES      66.6 PERCENT OF TOTAL AREA
WATER                WW             343. SQUARE MILES       5.0 PERCENT OF TOTAL AREA
IRRIGATED LAND       II            1619. SQUARE MILES      23.6 PERCENT OF TOTAL AREA
```

Figure A. Illustration of computer mapping of land use from TV-waveform analysis of space imagery of Nile Delta area.

N72-24413

HIGH ALTITUDE COLOR PHOTOGRAPHY AS A TOOL FOR REGIONAL* ANALYSIS: AS DEMONSTRATED FOR SOUTHEASTERN FLORIDA

L. Alan Eyre
Laboratory Research Associate

By 1969, high altitude aerial photography of the United States had become available, and the opportunity thus opened for more general utilization of this type of imagery. In October of that year a NASA RB-57 overflight at approximately 18 km. altitude was flown over a large area of Southeastern Florida to support Earth Resources Test Site No. 164 at Boca Raton, where the Remote Sensing and Interpretation Laboratory directed by Dr. James P. Latham of Florida Atlantic University's Geography Department is located. The photography included color and color infrared of the tri-county region of southeast Florida: Palm Beach, Broward and Dade counties.

This region has experienced exceptionally far reaching changes in recent years. It includes one of the most rapidly growing urbanized areas in North America, concentrated along the "Gold Coast" but also extending increasingly inland. At the same time it is almost the only region which has undergone very substantial agricultural development on land never before used for this purpose. South Florida, in fact, is virtually the last humid area in the nation to undertake massive development on a regional scale. The availability of high altitude imagery made it feasible to evaluate its potential for quantifying the dimensions of regional change.

The imagery is in the form of 228 mm. by 228 mm. duplicate positive transparencies, which were projected by a Bessler Overhead Projector which was modified for aerial roll film use, and viewed on a rear view screen. Closer examination was accomplished with magnification using a florescent daylight tube illumination system made in the laboratory. Under ideal laboratory conditions, resolution of these color and color infrared transparencies is in the range of 4 meters. Each transparency covers an area of 22.5 km.^{2} at a scale of 1:60,000. (Zeiss RMK 30/23 Aerial Mapping Camera was used to record the imagery.)

*For published article see L. Alan Eyre, "High-Altitude Color Photos", Photogrammetric Engineering, Vol. XXXVII, No. 11, November 1971.

Attention has been focused upon three main aspects of change in the region, which in fact overlap. These are

(1) the transformation of the southeast Florida wetlands, popularly though not entirely accurately known as the "Everglades",

(2) the expansion of agriculture,

(3) the growth of the urbanized area.

The limits of all these three elements in the regional pattern were known from U.S. Geological Survey data obtained in 1956, which used both photogrammetry and the ground surveys for U.S. Corps of Engineers 1:25,000 quadrangles. The development analyzed therefore covered the period of thirteen years from 1956 to 1969.

In 1956 there were 9750 km.^{2} of undrained wetlands within the tri-county region. During the thirteen years the drainage and water regulation work of the U.S. Corps of Engineers and the operations of the Central and Southern Florida Flood Control District with headquarters at West Palm Beach have reduced this by 2600 km.^{2} to 7150 km.^{2}. Of this newly drained area, 6 percent has been built over, 68 percent has been developed for agriculture and 2 percent has been put to all other uses (airfields, mining, recreation, etc.); 24 percent was undeveloped as of October 1969 (Table 1).

The remaining 7150 km.^{2} of undrained wetlands are not homogeneous in character, and the color infrared transparencies were very useful in distinguishing various subtypes. Very striking is the pattern formed by the three Water Conservation Areas (Figure A). These are very large bodies of shallow freshwater, totalling 3275 km.^{2} in all, impounded by leaves, and are used to control the natural flow of water from Lake Okeechobee southwards to the Gulf of Mexico, Florida Bay and the Atlantic Ocean, mainly to prevent flooding. Sawgrass and algae, the vigorous growths of which occur throughout the Water Conservation Areas, can be noted by characteristic streaks and blotches of red on the color infrared. (Figure A) Variations in depth can also be detected where stretches of open water occur.

A second division of existing undrained wetland comprises 2122 km.^{2} of reserved areas under various authorities. These include that portion of the Everglades National Park within Dade County, that part of the Seminole Indian Reservation outside the levee of Water Conservation Area No. 3, the West Palm Beach Water Retention Area and the Corbelt Wildlife Area. The third division comprises those wetland areas not utilized for specific purposes in October 1969. The boundaries between the reserved areas and the undeveloped

TABLE 1

REGIONAL ANALYSIS OF DADE, BROWARD AND PALM BEACH COUNTIES, FLORIDA, USING 18 KM. COLOR AND COLOR INFRARED PHOTOGRAPHY

Major Changes 1956-1969

				km^2
Undrained wetlands, 1956				9750
Drained 1956-1969				2600
(a)	Utilized for:	1.	Sugar Cane	1207
		2.	Truck farming (So. Dade)	85
		3.	Grassland	273
		4.	Citrus and undifferentiated	205
	Total:		Agriculture	1770
		5.	Sand and Gravel Quarries	41
		6.	Urban expansion	153
		7.	Military, recreation utilities	22
(b)	Unutilized or undifferentiated			614
Undrained wetlands, 1969				7150
(a)	Water Conservation Areas			1772
(b)	Everglades National Park (Dade Co.)			1659
(c)	Indian Reservation			212
(d)	Corbett Wildlife Area			212
(e)	West Palm Beach Water Retention Area			39
(f)	Unreserved wetlands			1752
Urban built-up area, 1956				374
Expansion 1956-1969				1032
Urban built-up area, 1969				1406

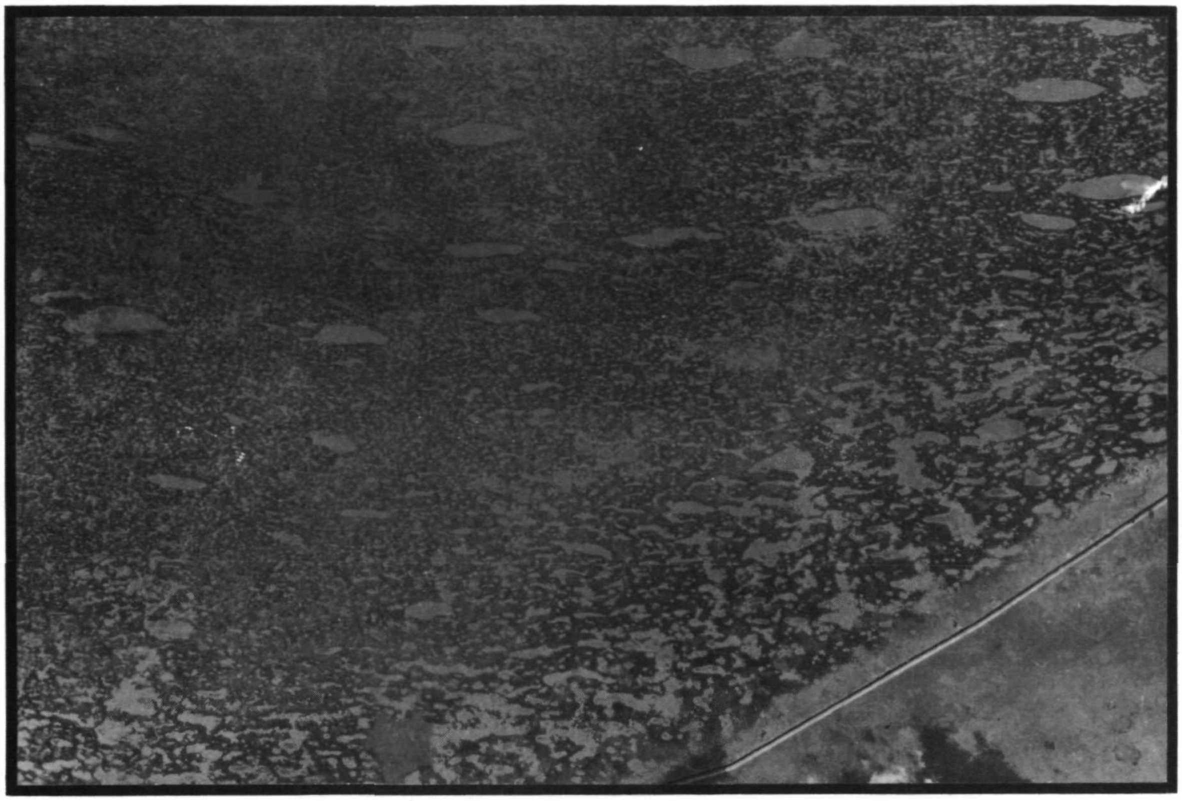


Figure A. - Sawgrass and Algae patterns in water conservation area.

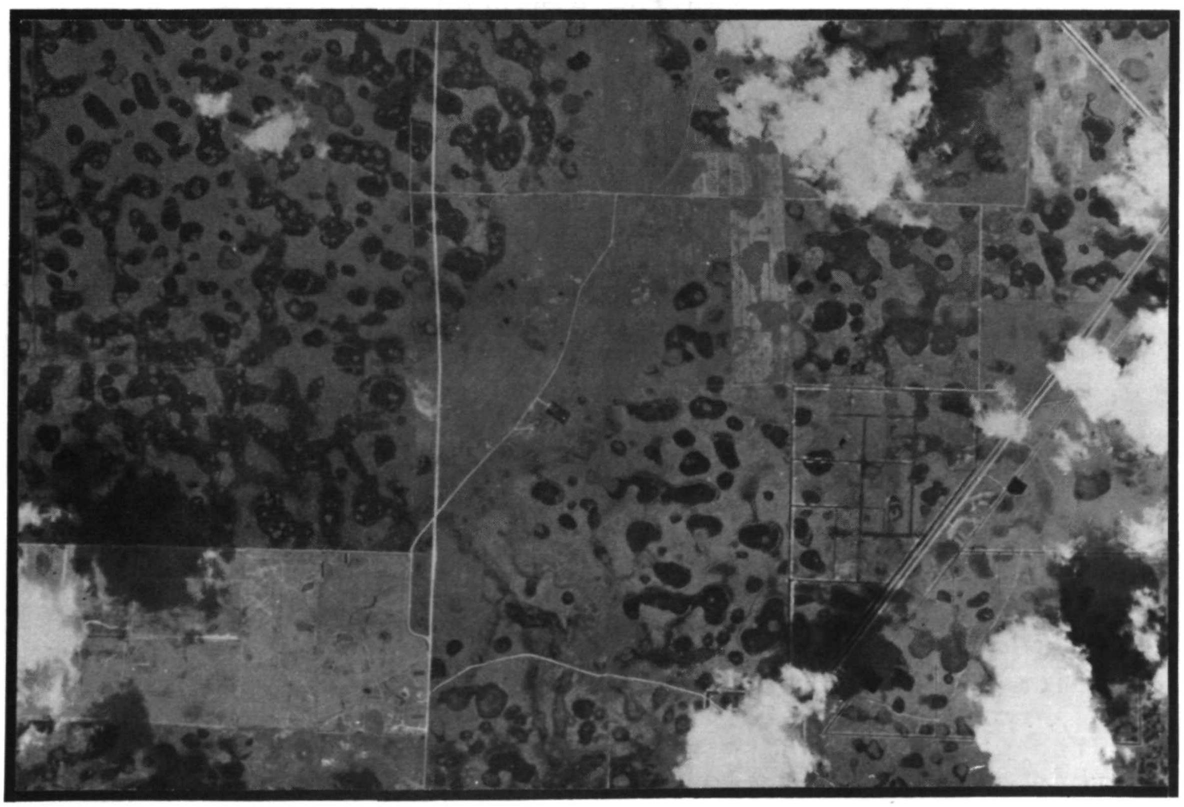


Figure B. - Circular solution features in karst-associated marshland topography.

lands are often quite distinct on the imagery even where their physiographic characteristics are similar.

When the color and color infrared photography are used together, a very detailed picture of this semi-aquatic environment can be obtained, as well as the broad regional physiographic changes from north to south and from the dry coastal ridge inland. This unique environment ranges from marine and brackish mangrove swamp in the extreme south and southeast, through sawgrass with slightly elevated tree hammocks and intervening sloughs, to the so-called "Florida karst" in the north. This last is a curious marshland topography with many low, circular solution features, the details of which are far more apparent from the high altitude photography than on the ground (Figure B).

The expansion of agriculture, almost all by occupance of drained wetland, can be interpreted at a macro level. Four principal types of development can be detected. These are:

(1) Sugar cane
(2) Vegetable and truck farming
(3) Citrus
(4) Grassland

The signatures of the first two on the photography are very distinctive and the expanded acreages of each easily calculated. Between 1956 and 1969 the area under sugar cane increased by 1207 km.^{2}, all of it "reclaimed" from drained Everglades muckland. This expansion is the direct result of the Cuban situation, when sugar supplies to the United States were curtailed after 1959. The industry is highly mechanized, although both domestic migrant and West Indian labor plays a significant role. Major citrus development - also in the forms of large scale enterprises - has entered the area, mainly in Palm Beach Co., since 1956 on drained wetland underlain by the Florida karst topography. Some citrus developments in a very early stage were difficult to differentiate from some other possible land uses. For this reason citrus had to be included with an undifferentiated category in Table 1. The truck farming is primarily in South Dade Co. Here, although 85 km.^{2} was taken in from the wetlands, 212 km.^{2} were lost to urban development, a trend which is continuing.

The fourth category, grassland, posed a difficult problem of interpretation. There are three types of grass cover in this region, all derived from drainage of the wetland. These are pasture, sod and "natural" herbaceous cover developing from former wetland now drained but unutilized. In the dry season the last category would probably be distinguishable, but in October the rains give an almost uniform red to all grasses on the color infrared. The pasture is used as open, but improved, range for cattle, and the presence of faint tracks and watering points sometimes can give indication of this land use. Large sod farms cultivate St. Augustine grass for trucking to gardens in nearby urban areas: from 18 km., however, this specialty is not easily distinguishable from improved pasture or fodder crops. In the case of the drained but unutilized areas, the semi-aquatic sawgrass vegetation quickly gives way to a variety of seasonal scrub and bunch grasses and low ligneous plants, with the gradual invasion of larger shrubs and palmetto. Most of the unutilized areas are being held as speculation in anticipation of large scale urban development. Even immediately adjoining the Everglades National Park, thirty-eight miles from Miami and eight miles beyond the present limit of suburbia in Dade Co., land is being subdivided for sale as homesites. On some lands of this type an extensive type of low-density livestock rearing is practised as a temporary utilization. There were a little over 600 km.^{2} of drained former wetlands not visibly utilized in October 1969.

The expansion of the urban area has been in two directions: a linear development which has linked all the coastal townships along a ninety-mile section of the Atlantic shoreline into one continuous conurbation, and a westward expansion into the drained wetlands. The latter movement is particularly characteristic of Dade and Broward counties. With lower altitude photography such as the NASA 1.5 km. and 4.5 km. coverage of Test Site 164 considerable potential for infilling of small plots of vacant land can be observed*, but on the high altitude imagery the limits and extension of the urbanization is very sharply defined. The type and density of the development can also be estimated within reasonable limits. From a 1956 area of 374 km.^{2}, the Dade-Broward-Palm Beach urban complex has exploded 280 percent in thirteen years to occupy a total land area in 1969 of aver 1400 km.^{2}.

One trend is of particular interest: the tendency for middle-income residential development (identified by lot size and subdivision design on the photography)

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*See L. Alan Eyre, <u>An Investigation by Remote Sensing of Vacant and Unutilized Land in an Urbanized Coastal Area of Southeastern Florida</u>, contract No. 14-08-0001-10936, Technical Report No. 3, Florida Atlantic University, 1969.

to expand westwards in Broward Co. into former wetland drained by the U.S. Corps of Engineers as far as the levee of the Water Conservation Areas 1 and 2. (Figure C) The continuous eighty-mile long eastern levee of the Conservation Areas forms a unique barrier to expansion of a major metropolitan region. With the Everglades National Park blocking expansion to the south, and the ocean on the east, this "island" of development is hemmed in on all sides except at a ten-mile wide neck near Boynton Beach.

Expansion is "open" only from this point northwards. Under these conditions it is apparent that enormous demographic and economic pressures will be built-up during the 1970's upon the remaining agricultural areas of the tri-county region and westward into Collier Co. beyond the Conservation Areas. More seriously, they will also be brought to bear upon large undeveloped but ecologically vital tracts of the Everglades National Park.

Since water is particularly emphasized on the color infrared, it is possible to identify the principal features of the complex hydraulic system operated by the Flood Control District. This vast system, which extends from Orlando, Fla. to the Keys and includes hundreds of miles of canals with associated sluices, pumping stations and spillways, maintains more or less effective control over the entire water regime of a shallow basin 50,000 $km.^2$ in extent. From the high altitude photography, the effects of pollution can be observed upon this enormous, slow-moving mass of water at several places. Particularly evident are the vivid red of water hyacinth infestations, excessive algal growth in semi-stagnant areas and several major pollution features in Lake Okeechobee. At some localities specific effects of canalization such as silt transportation and deposition can be noted.

In the kind of regional overview obtainable from imagery at this scale, it is possible to recognize by characteristic signatures unusual features which occur at widely separated localities and calculate the area they occupy. In the case of the region under discussion such features include drilling rigs, missile launch sites, commercial nurseries, sand and gravel quarries, golf courses and junk yards. Gravel pits and golf courses both occupy an unusually large area in the tri-county region (Figure D).

With this October 1969 photography covering both an urbanized region of two million people and one of the few major agricultural developments of the past decade,

Figure C. Residential expansion into former wetlands.

Figure D. Functional mixed land use changes.

its potential for detailed spatial analysis of the April 1970 Census of Population is considerable. It appears from the imagery that the great expansion of agricultural land in Palm Beach Co. has not been accompanied by any corresponding dispersal of rural settlement. Not only is the development capital intensive and associated with very large land holdings, but the universal availability of road transportation has enabled almost all the increased population to be accommodated in and around the existing centers such as Belle Glade and West Palm Beach.

This evaluation is of a preliminary nature, and only on the broadest scale. It is obviously possible to analyze landscape with this type of photography at a much more detailed level than that reported in this particular study. However, almost the only comparable tool up to the present for providing a broad synoptic picture for regional analysis by photogrammetry has been the black and white photo-mosaics prepared by the U.S. Department of Agriculture. Results using this new 18 km. photography are clearly superior because of the degree of resolution, the combined power of color and color infrared interpretation, and the large area covered by each frame. However, the greatest advantage of this high altitude imagery is undoubtedly the time-saving element, since it is possible to delineate and identify major geographic patterns over thousands of km^2 very rapidly.

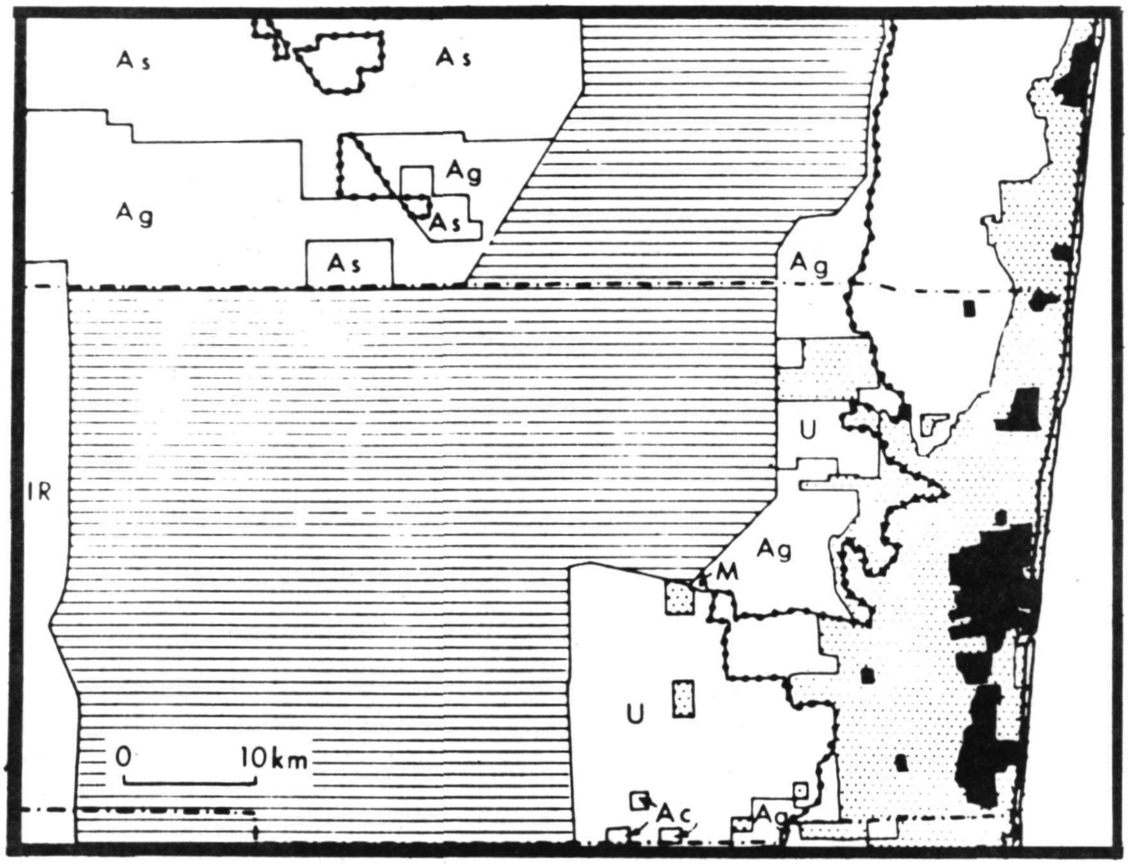

Figure E. A portion of the regional analysis made of Dade, Broward, and Palm Beach counties, Florida, from 18-k photography at the Remote Sensing Laboratory, Florida Atlantic University. Heavy dotted line indicates limits of drained area in 1956, with built up area solid black. Stippled, built up area 1969; hatched, water storage; utilization of land drained since 1956 is shown, - As, sugar cane; Ag, grassland; Ac, citrus; U, unutilized; M, Mining and quarrying.

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Section Two: Study D

REMOTE SENSING OF ENVIRONMENTAL DISTURBANCE*

James P. Latham

In October 1969 and November 1970, a NASA RB57 remote sensing aircraft at an altitude of 60,000 feet over the Boca Raton and Southeast Florida Earth Resources Test Site recorded simultaneously in Color, Color Infrared, and Minus-blue films nine different types of photographic images of the geographic patterns on the surface. The entire area can be overflown in less than four hours. Focal lengths varying from 40 to 250 millimeters were used on the nest of six Hasselblad cameras, 6 inch lens were used on two RC-8 cameras, and a 12 inch lens was used on the Zeiss mapping camera.

An analysis of the 1 to 60,000 scale color infrared imagery of the Miami area includes the Turkey Point shoreline of south Biscayne Bay. It shows cooling canal which runs southward toward its future warm rendezvous with the Bay. The synoptic view obtain also displays land use patterns which include the Homestead Air Force Base. The urban patterns of southeastern Miami, which include undeveloped bayfront lands currently proposed for an ambitious and disputed conversion to residential and recreational use, can be studied in this imagery. The strong red tones show the extent of mangrove fringe areas which many consider vital to the ecology of the Bay. But this synoptic view also indicates the nearness of this phenomena to the expanding population of south Miami. At somewhat smaller scale, one sees the Palm Beach environment with Peanut Island, the Port, and part of a proposed state recreation park on Singer Island - all current focal points of environmental change and pollution or land use disputes.

In Apollo 9 imagery, the recently re-aligned path of the Kissimmee River can be seen moving toward Lake Okeechobee in a now rather business-like manner. At 60,000 feet, the 40 millimeter lens of a Hasselblad camera demonstrates that the River is indeed now hard

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*Paper presented at the Annual Meeting of the Southeast Division, Association of American Geographers, Columbia, South Caroline, November 23, 1970.

at work, with its increased velocity busily transporting a flow of natural and culturally-generated sediments into the Lake. The 80 millimeter lens provides a closer but less synoptic look. Some recent reports indicate that algae is being formed in the Lake from the excess amounts of fertilizer carried into the basin. However, a July 1970 interim report from a U.S. Geological Survey team assures us that massive eutrophication is not yet indicated. The view with a 250 millimeter lens should discourage complacency, as Figure A demonstrates.

Meanwhile, on the other side of the Lake, Belle Glade peacefully nestles amidst its reassuringly prosperous field patterns, as detected from 15,000 feet with Ektakrome imagery. It is noticeable that there is some discrepancy in the reflectance characteristics of the water in the two borrow pits that are side-by-side at the left center exit of the transverse canal. In a color infrared view, the second pit is more obvious and it is clear there is a considerable disturbance between it and the canal.

At 5,000 feet, a color view reinforces the previous impression that the second pit's waters do indeed seem different, and a same altitude but further enlarged color infrared image, as seen in Figure B, confirms a growing impression that all is not sweet in the land of sugar cane. The sewerage treatment plant is to the east, but more interesting is the unhealthy billious yellow mass floating on the water, and the reddish hook reaching into it.

But of course our "ground truth" team is under the aircraft, and provides firm, flag waving evidence of the nature of the colorful mass floating at the south end of the borrow pit. As Figure C demonstrates, radishes, squash, and other field crop debris look less attractive in Color infrared.

There is some evidence that this health store cocktail is finding its way into the nearby canal, and subsequently may reach the Hillsboro Canal, which enters the Alantic Ocean via the lovely Boca Raton Inlet. From 1,000 feet, a low oblique color slide displays an informative pattern. But a recent experiment with the new Minus-blue film, does suggest that it's capacity for penatrating water surfaces may be particularly useful, and indications are that when used in the vertical axis a greater water penetration is achieved, as demonstrated in an image which provides some detail of the first underwater reef off the north Boca Raton Beach.

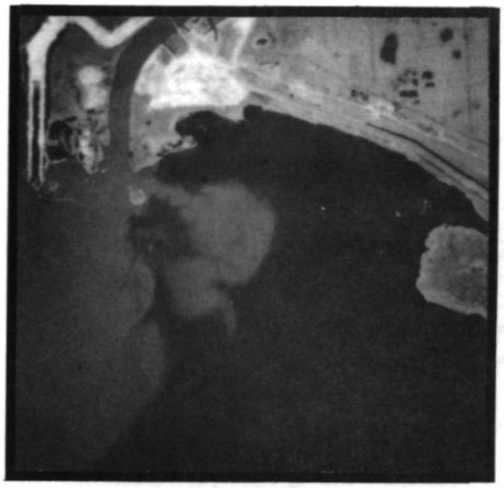

Figure A.

Black and White prints from Color Infrared photographs discussed in text.

Figure B.

Figure C.

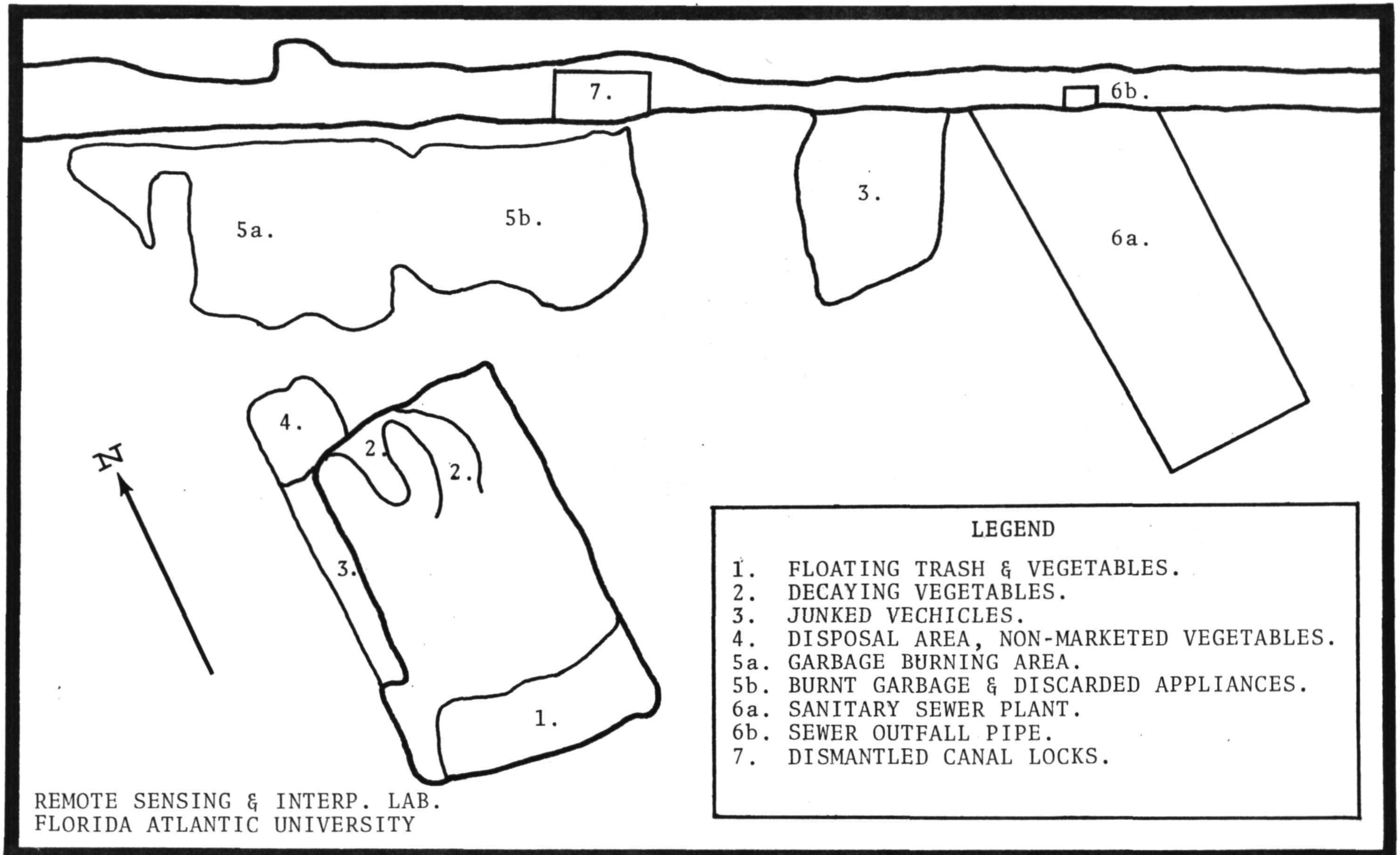

Figure D. Location map from imagery illustrating water pollution from agricultural waste.

Section Three: Technical Report No. 1, February, 1968

A STRATEGY FOR DEVELOPING CLASSIFICATION OF LAND USE AS INTERPRETED FROM REMOTE SENSOR IMAGERY

by Nelson R. Nunnally
and Richard E. Witmer

Abstract

A brief examination of classification theory and land use classification systems reveals that most land use classifications are derived through logical division; and, that they are not generally useful for classifying land use data interpreted from photos. Because of this and other disadvantages associated with logical division an alternative method of classifying land use from imagery is advocated. The method consists of interpreting detailed land use from images and recording this in map form; establish hierarchial categories by grouping similar or related uses; and, using a uniform point sampling technique for tabulating data by categories for generalized studies such as small scale mapping.

Section Three : Technical Report No. 2, September, 1968

INSTRUMENTATION OF IMAGE ANALYSIS AND TELEVISION SIMULATION TECHNIQUES *

by James P. Latham

Abstract

By utilizing simultaneous multisensor imagery acquired from low and medium altitude missions over NASA Earth Resources Test Site No. 164 focused on Boca Raton and Belle Glade, Florida, and with color imagery acquired by Gemini orbital missions, the investigators at the Remote Sensing and Interpretation Laboratory at Florida Atlantic University have developed methods for instrumenting the analysis of imagery and for simulating the observation of earth surface phenomena with television systems.

Selected images are scanned by a variable scan rate television camera and the scanning traverses are converted by waveform analysis to signals which indicate, by amplitude fluctuations, the gray-tone value of the densities in the image of distribution patterns along the sampling traverses. The analyzer is calibrated to express the values as percentages of the total range of gray-tone in the entire image, and the signals are magnified 5 X or 25 X to assist in observing and measuring the variations. Experimental programs have established the feasibility of utilizing the density values to compare and integrate the data in imagery resulting from two different sensing systems which simultaneously record the same surface area. It has also been demonstrated that it is feasible to utilize the values to convert the imagery into a matrix of values which provide a catalogue of land use patterns. When an unknown surface is scanned and converted into a matrix of values, it is then possible for a computer to identify the catalogue land use type that the unknown most closely resembles by a "least difference" statistical technique.

* This complete report was published under the same title in Earth Resources Aircraft Program Status Review, Volume I-Geology, Geography, and Sensor Studies, Houston: NASA Manned Spacecraft Center, 1969, pp. 9-1 to 9-29.

A simulation system which converts photographic imagery acquired by Gemini missions into television imagery representing an orbital television view of the earth's surface has been developed. Images simulating various TV scan line rates and scales of presentation such as those that would result from various orbital altitudes have been produced. Interpretation studies of these alternative images have studied the changes in their capability for geographic pattern discrimination, and produced thematic maps of the land use and transportation patterns that result from each of the alternative scale and scan line rate systems.

Section Three: Technical Report No. 3, August, 1969

AN INVESTIGATION BY REMOTE SENSING OF VACANT AND UNUTILIZED LAND IN AN URBANIZED COASTAL AREA OF SOUTHEAST FLORIDA

by L. Alan Eyre

Abstract

Ektachrome and Color Infrared aerial imagery of September 1968, is utilized to evaluate the distribution and characteristics of vacant and unutilized land in an urbanized coastal strip of southeast Florida extending one mile inland from the ocean from Port Everglades in Broward County to Boynton Inlet in Palm Beach County, a distance of thirty miles. This strip, administered by sixteen local government authorities, is divided into 538 quarter-mile grid squares. The proportion of vacant land is tabulated and mapped, and the distribution of vacant house lots in serviced subdivisions is also presented. Results show that the average percentage of vacant land in September 1968 was 34% with an average of 32% for 126 squares adjoining the ocean. Four types of vacant and unutilized land possess recognizable spatial patterns on the imagery: blocks of undeveloped land; commercially-zoned land awaiting development; vacant lots in existing serviced subdivisions; and vacant areas in and around negro residential neighborhoods. Over two hundred million dollars worth of vacant land still survives within a mile of the ocean, including more than five thousand vacant lots in residential subdivisions. Utilization of land zoned for commercial purposes has lagged behind residential development.

Section Three: Technical Report No. 4, September, 1969*

WAVEFORM AND COMPUTER ANALYSIS OF GEOGRAPHIC PHENOMENA RECORDED ON COLOR AND COLOR INFRARED MULTISPECTRAL IMAGERY FROM AERIAL AND ORBITAL ALTITUDES

by G. Lennis Berlin

Abstract

This investigation is a part of a continuing research program studying the potential of television-waveform instrumentation in identifying, analyzing, and mapping geographic phenomena recorded in aerial and space imagery. Research objectives included: (1) Effectiveness of converting aerial color and color infrared imagery to electronic scanning returns with an ultimate goal of providing a graphic and quantitative method for analyzing the geographic data recorded on the above two imagery types; (2)Effectiveness of manually transposing waveform information recorded from a systematic sampling by scan traverse lines into representative numbers (expressed as percentages) that reveal geographic phenomena and developing a computer program to manipulate the geographic data in several ways; and (3) To reveal new facets of research that could be an outgrowth of this investigation, and to evaluate the study as a contribution to geography.

Results indicated that the television-waveform system offers positive potential for the quantitative analysis of geographic distributions found on aerial color and color infrared photography. Phenomena colors were segregated on both the above film types, but identifying waveforms extracted from the former type offered optimum results. Waveform results from high altitude (15,000 feet) and orbital color photography also indicated positive results in the identification of geographic distributants. A direct correlation, however does exist - as the scale of the photography decreases the degree of categorization becomes more generalized.

With geographic information in the form of digits (graytone percentages) a computer program was developed to identify, analyze, and map the coded information. Computer analysis of graytone digital data revealed very positive findings. Additional discussion noted equipment additions which could be incorporated into the television-waveform system to more fully automate computer input information.

*Note: This report was accepted as a doctoral dissertation by the University of Tennessee, which awarded a Ph.D. in Geography to G. Lennis Berlin in January 1970.

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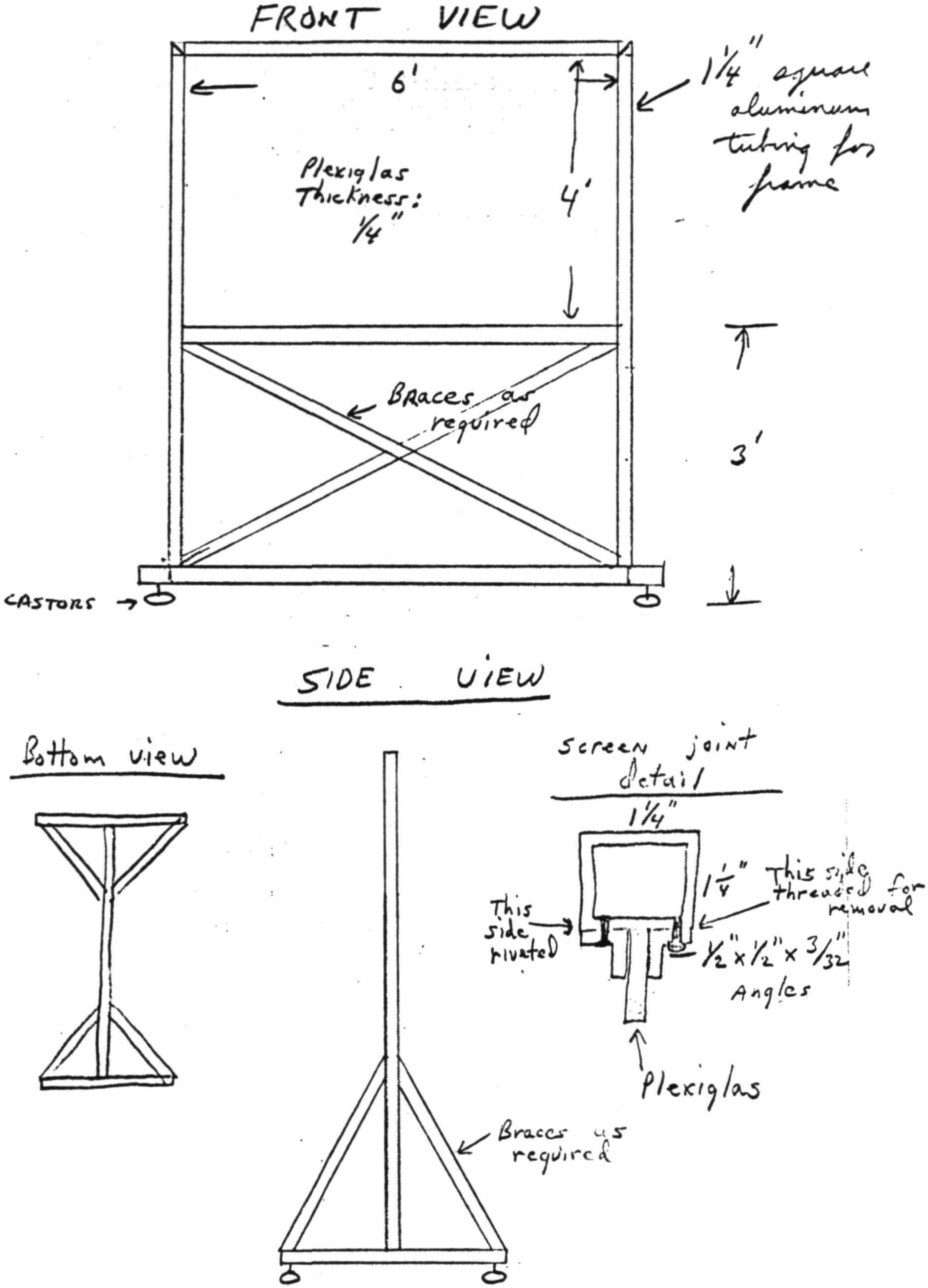

Dimensional sketch for fabricating rear view mobile screen mounting.

APPENDIX B

An itemized listing of equipment used in the Remote Sensing Television Simulation System:

1. Slide Projector, Rollei-Honeywell, with 110mm, 160mm and 110-160mm zoom lenses.

2. Rear view Polacoat screen, Pola Coat Inc. 4' X 6' mounted in an aluminum frame with rollers. (This specific item was designed and manufactured under the guide lines established by members of the research team).

3. Television Camera, Cohu Electronics Inc., Series 3200 with 4.25mm and 12.5mm lens; sync generators for 525, 729, 873 and 945 scan line systems.

4. Waveform Monitor, Tektronix Inc., Type RM 529 for the 525 scan line systems.

5. Waveform Monitor, Tektronix Inc., Type RM 529 modified for the 525, 729, 873, 945, 1029 and 1201 scan line systems.

6. Television Monitor, Conrac Corp., 14" Screen, 525 scan line rate.

7. Television Monitor, Conrac Corp., 14" Screen 729 scan line rate.

8. Television Monitor, Conrac Corp., 14" Screen, 873 scan line rate.

9. Television Monitor, Conrac Corp., 14" Screen, 945 scan line rate.

10. Camera, Graphic Century, Graflex Inc., film size 2 1/4" X 3 1/4", f3.5, 103mm lens, and roll film (120) adapter back.

11. Camera, Nikkorex, Nippon Kogaku, film size 35mm, 46-86mm f3.5 zoom lens.

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16. Abstracts This report presents the methods, techniques, instrumentation systems, and concepts or analyses developed by an investigation of the possibilities, problems, and applications of interpreting the geographic patterns recorded by orbital television observations of earth resources and land use. A system for simulating orbital television imagery by scanning astronaut-acquired photography and converting it to a TV monitor image with alternative scales and scan line rates was developed. Study of this television imagery determined the feasibility for extracting and mapping geographic data and analyzed how the capability varied with changes in scan line intensity or image scale. Other studies established the feasibility of directly processing television signals with a waveform and computer analysis technique that produces a print-out category map of generalized land-use types. One study demonstrated the possibility of using waveform signal analysis to quantify the geographic patterns and identify phenomena recorded in color or color infrared aerial imagery. Other studies demonstrated the use of very high altitude aerial photography to make a geographic region analysis or locate some pollution

17. Key Words and Document Analysis. (a). Descriptors
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17b. Identifiers/Open-Ended Terms

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