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PRELIMINARY TECHNICAL REPORT

PHOTOGRAPHIC IMAGE ENHANCEMENT AND PROCESSING

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PHOTOGRAPHIC IMAGE ENHANCEMENT AND PROCESSING

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INTRODUCTION

Investigators working with aerial imagery obtained from either aircraft or spacecraft mounted cameras may require that the original image be enhanced or processed for a variety of reasons. This enhancement is currently being accomplished at many government installations, universities and by large corporations, typically utilizing digital data recorded by an onboard scanner in magnetic tape format. LANDSAT data is frequently processed in this manner.

The purposes served by this image processing may include:

- Determination of percent area cover of a subject.
- Identification of subjects with common spectral signatures.
- Production of special images for use as map overlays.
- Production of thematic maps.
- Determination of changes in a scene with time. (multi-temporal studies.)

Photographic scientists at NASA's Johnson Space Center have been working with investigators associated with the Earth Resources Aircraft Program (ERAP) to accomplish image processing using photographic rather than digital techniques. Some investigators do not have access to the sophisticated digital processing facilities which require a huge capital outlay for scanning and computing equipment and associated software. These same investigators frequently desire some image processing, therefore, analogous photographic techniques have been designed to fill this need. These are characterized by:

- Relatively low capital investment. (1000 to 3000 dollars)
- Readily available facilities. (photo darkroom)
- High resolution results. (photograph)

In most instances the photographic image processing techniques adapt known laboratory techniques, therefore no complicated training exercise is necessary. The available techniques include:

- Contrast enhancement
- Color separation
- Scale change
- Registration
- Masking
- Spectral filtering

Using appropriate combinations of black-and-white and color duplication materials, photographic printing techniques and a knowledge of the characteristics of printing materials and filtration, an investigator may easily utilize these techniques.

The purpose here is to briefly describe the variety of image processing techniques (computer and photographic) which are used within the JSC Photographic Technology Division. Two purely photographic techniques used for specific subject isolation are discussed in detail. Sample imagery is included.

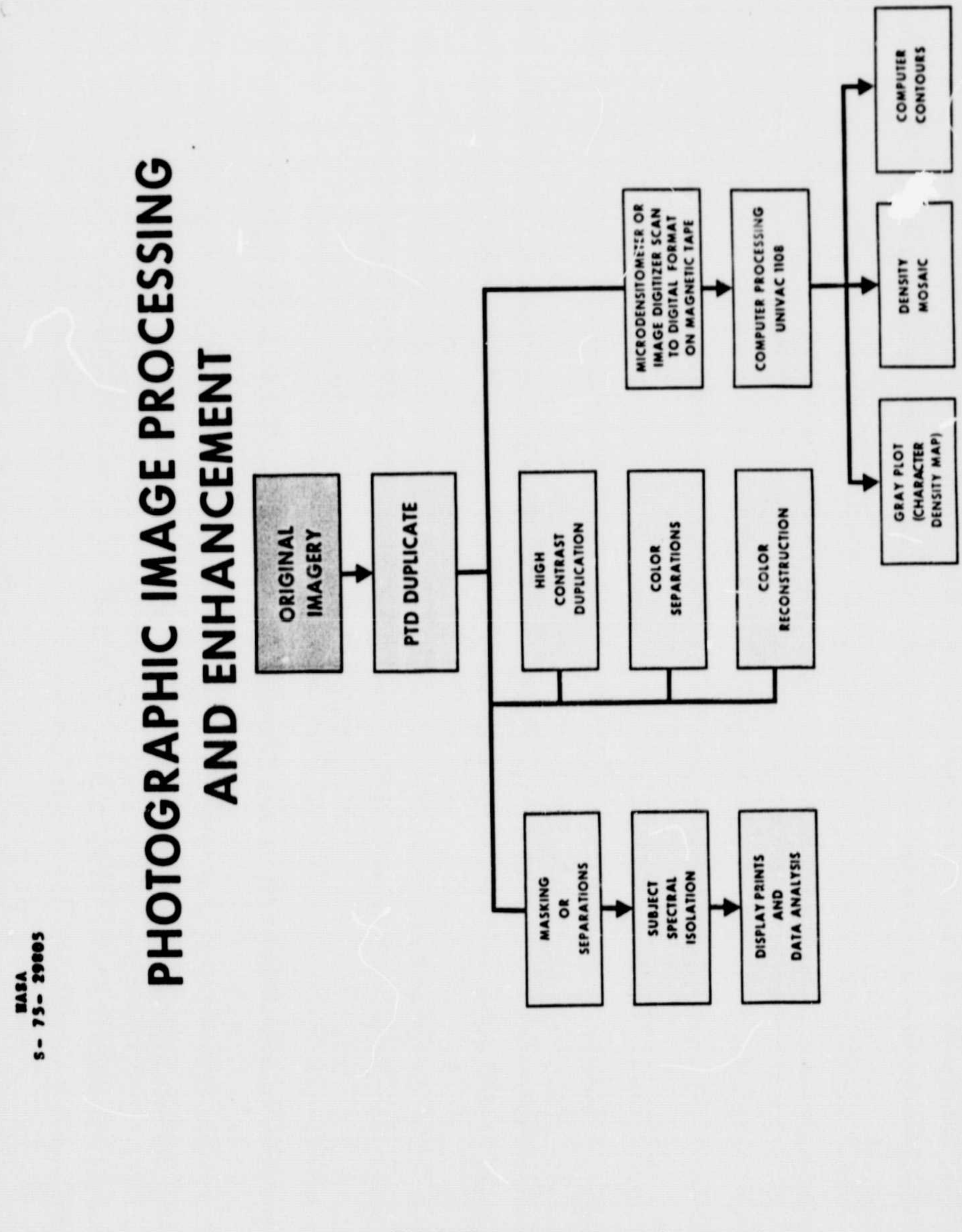

FIGURE 1 Image Processing Techniques in Current Use in NASA Photographic Technology Division.

OVERVIEW

Figure one shows the techniques in current use in the photographic division. Generally, these techniques fall into two groups, the first requiring digitization with subsequent computer processing, the second utilizing techniques available in the photographic laboratory.

Briefly the techniques requiring digitization include:

- Grayplot; Image densities are grouped into equal density increments with each increment assigned an appropriate graphic code and the result is printed. The codes are printed in correct geometric relationship such that the relative location density isolated subjects may be determined.
- Density Mosaic; Image densities are recorded and printed in correct geometric relationship, such that a digital density map is produced.
- Contours; Image densities are selected to produce a series of equal density contours at 0.20 density increments beginning and ending at specified levels. A two-dimensional topographic map of image densities is printed.
- Related Data: Data produced using the above techniques may be used to provide density histograms and to isolate subjects characterized by specific color or density. Information

which can be derived from this data might include percent cover per area of a selected subject, number of plants or subjects per area or relative locations of a given subject.

The image processing and enhancement available from the photographic laboratory include:

- Subject Isolation; Equal spectral signatures of relatively wide spectral band image hues; i.e., red-green-blue-etc. are isolated and a print of those image areas produced.

- Subject Isolation; (Ratioing); Equal spectral signatures of relatively narrow spectral band image hues; i.e. red-magenta, blue-cyan are isolated and a print of those image areas produced.

- Contours; Image densities are selected to produce a series of equal density contours of 0.08 to 0.30 density increments. The contours may be color coded and displayed as a color photograph.

- Related Data; The isolation images may be used to achieve information including percent cover per area of a selected subject, number of plants or subjects per area or relative locations of a given subject.

DIGITIZED DATA

The prerequisites for production of digitized data are (1) a device for scanning photographic imagery to obtain density values in digital format (2) a computer for processing the density data and (3) appropriate programs to manipulate the data and produce a usable result. These prerequisites are costly and not readily available to all users of aerial imagery.

JSC has these facilities and they have been employed by the photographic division to accomplish image processing for aerial imagery and other scientific applications. The programs used here were designed for use in analyzing astronomical imagery obtained on the Skylab program. The PTD hardware includes an Optronics International Specscan 3000, an automatic scanning microdensitometer with mini-computer located in the photo division facilities. The computer for data processing is centrally located to service all of JSC.

JSC, of course, has other digital image processing systems in use at locations other than PTD including a General Electric Image 100 and a number of specially designed image processors.

To accomplish digital processing from an original photograph the image is scanned using the microdensitometer (figure 2) and the image densities digitized using a wide selection of scanning apertures, filtrations and

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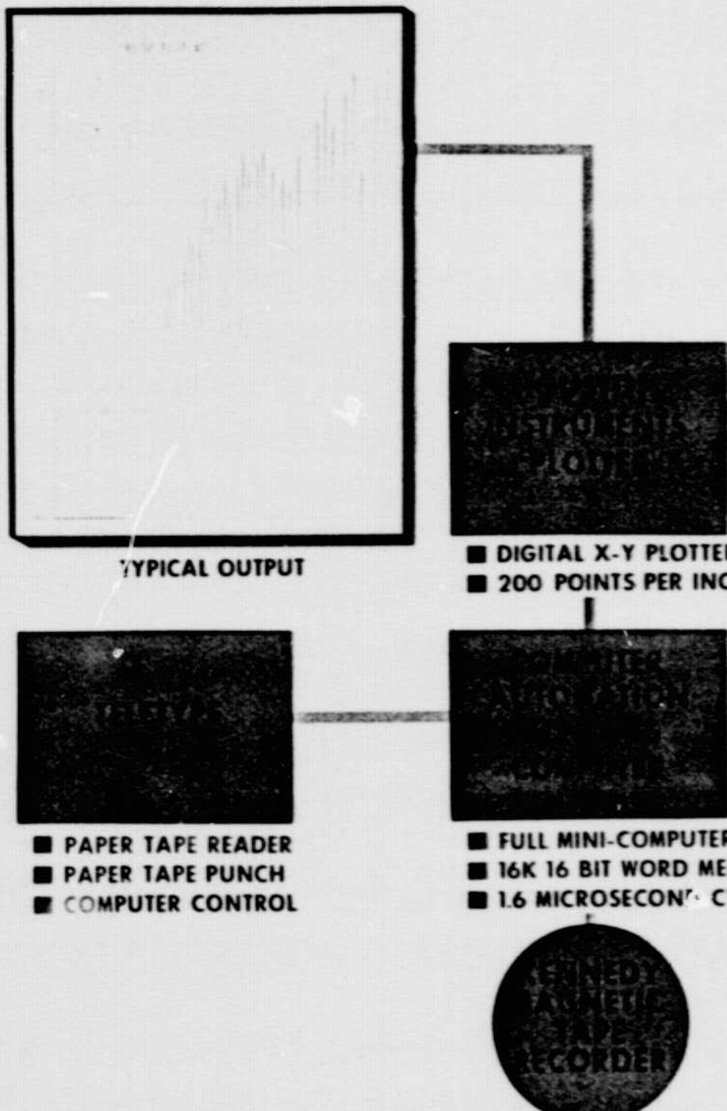
PTD SCANNING MICRODENSITOMETER SYSTEM

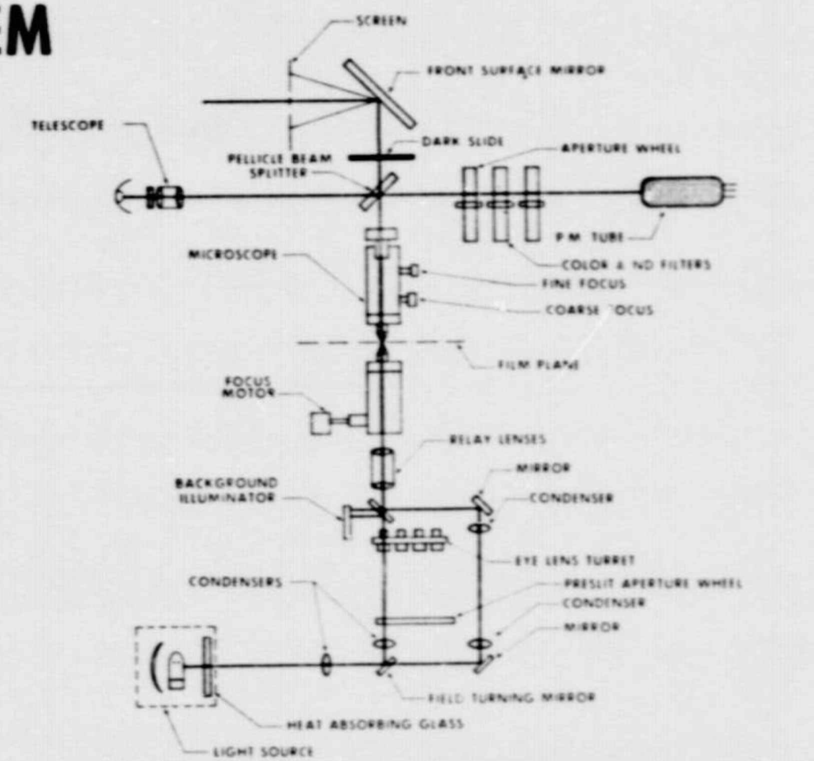


- DIGITAL X-Y PLOTTER
- 200 POINTS PER INCH

- PAPER TAPE READER
- PAPER TAPE PUNCH
- COMPUTER CONTROL

- FULL MINI-COMPUTER
- 16K 16 BIT WORD MEMORY
- 1.6 MICROSECOND CYCLE TIME

- 7 TRACK TAPE
- 200; 556; OR 800 BITS PER INCH
- 37.5 INCHES PER SECOND



PTD SCANNING MICRODENSITOMETER SYSTEM

SPECSCAN OPTRONICS INTERNATIONAL S-3000

- MEASURES DENSITY FROM 0.00 TO 4.00 IN COLOR OR BLACK & WHITE
- READS THROUGH RED, GREEN, BLUE OR NO FILTER
- READS RASTER SIZE UP TO 9 INCHES SQUARE
- SPOT SIZE IS 2 TO 800 MICRON CIRCLE
- SLIT SIZE VARIES TO 100 MICRON SQUARE
- SAMPLE RATE TO 2000 SAMPLES PER SECOND
- RESOLUTION TO 250 LINES PER MM AT 50% MODULATION

FIGURE 2 Scanning Microdensitometer Used to Digitize Photographic Imagery.

scanning rates varied to accommodate the data. Selection of operating parameters will be influenced by resolution requirements, time required to scan an image and precision required. The Optronics International Specscan 3000 is capable of scanning at a rate of 2000 samples per second but with sacrifice in resolution. A typical example: Scanning at 200 points per second a 1 x 1-1/2 inch area may be scanned with a 25 micron circular aperture in 3 to 4 hours. If less resolution can be tolerated, larger apertures may be used. For example, by increasing the scanning aperture to 255 microns, the scan time is reduced by 100X to about 20 minutes for a 1 x 1-1/2 inch format. A 70mm frame would require about a one hour scan time.

°Gray Plot

With this background, figure 3 shows the data flow for the gray plot technique. A sample site 84,000 x 63,000 microns (about 3 x 2 1/2 inches) was scanned with no filter and with a red filter using a 255 micron scanning aperture and 255 micron sampling intervals producing 2 full raster scans.

A density range of 0.50, from 0.80, to 1.30 density units, was specified for incrementing and coding into 32 equal density levels during data processing. The gray plot with graphic codes was printed on 35mm black-and-white microfilm. The microfilm was printed in the photographic laboratory to produce the results shown.

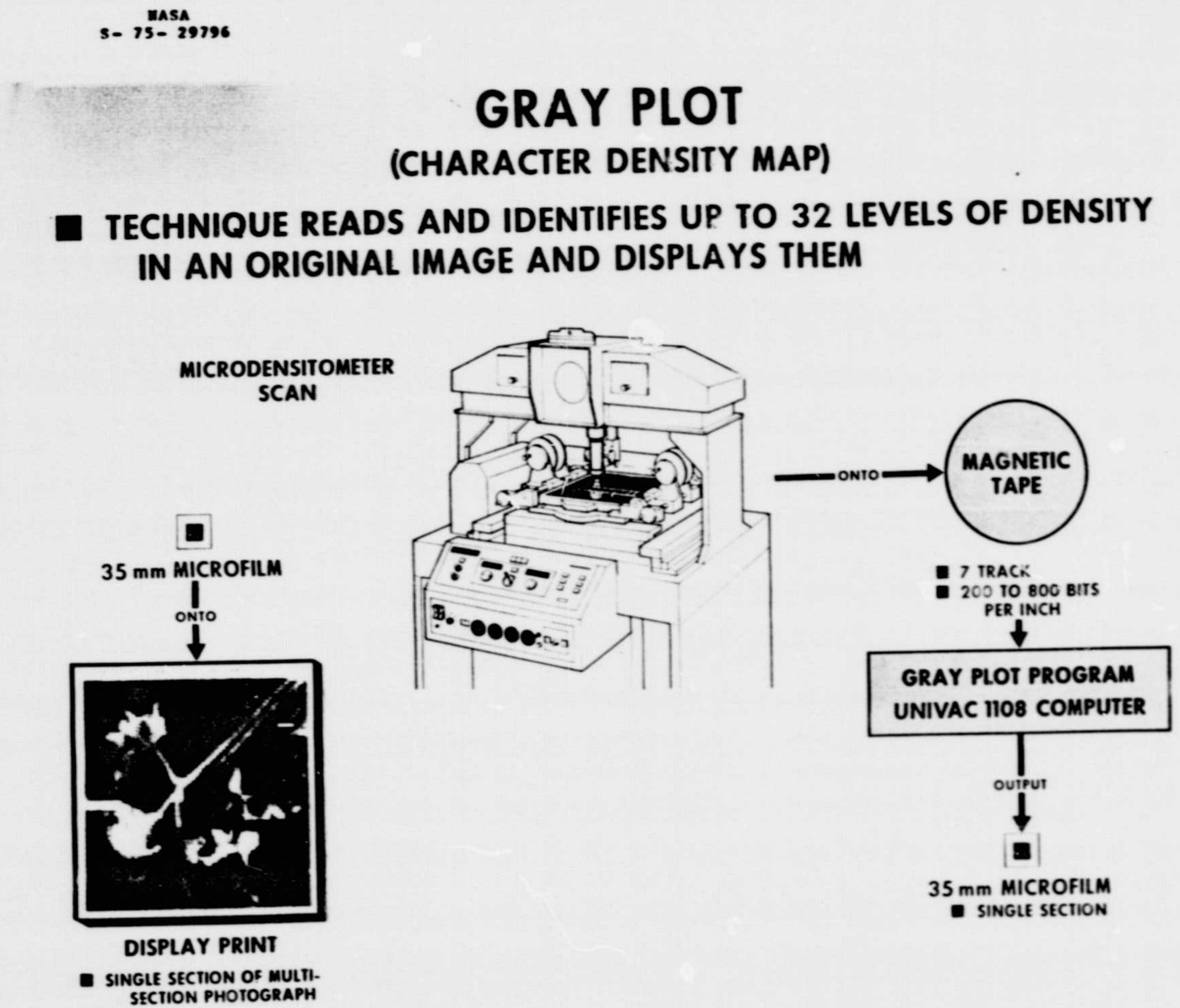


FIGURE 3 Gray Plot Technique for Producing Character Density Maps.

Any number of increments up to 32 may be selected. The selection criteria for number of increments would include the number of spectral signatures of interest and the ability of the densitometer to resolve each increment considering film granularity and scanning aperture size.

A brightness mask may be incorporated into the procedure before scanning aerial imagery. As explained below a brightness mask is effective in reducing error due to varying brightness of a subject characterized by a single color within a given scene. A duplicate of the brightness masked original which displays a selected subject as a single brightness hue rather than a variety of brightnesses makes density discrimination easier during scanning.

The data from the microdensitometer scan used for the gray plot can also be used to produce a density mosaic for the same 3 x 2 1/2 inch area. Figure 4 is a flow chart showing the microdensitometer scan, the data tape, and the computer program.

The density mosaic is simply a computer printout of all the densities in correct geometric relationship, read and recorded by the microdensitometer system. A total of 54 pages were required to produce the mosaic for this sample area. Each page is coded such that the data may be oriented and studied to ascertain areas of equal density.

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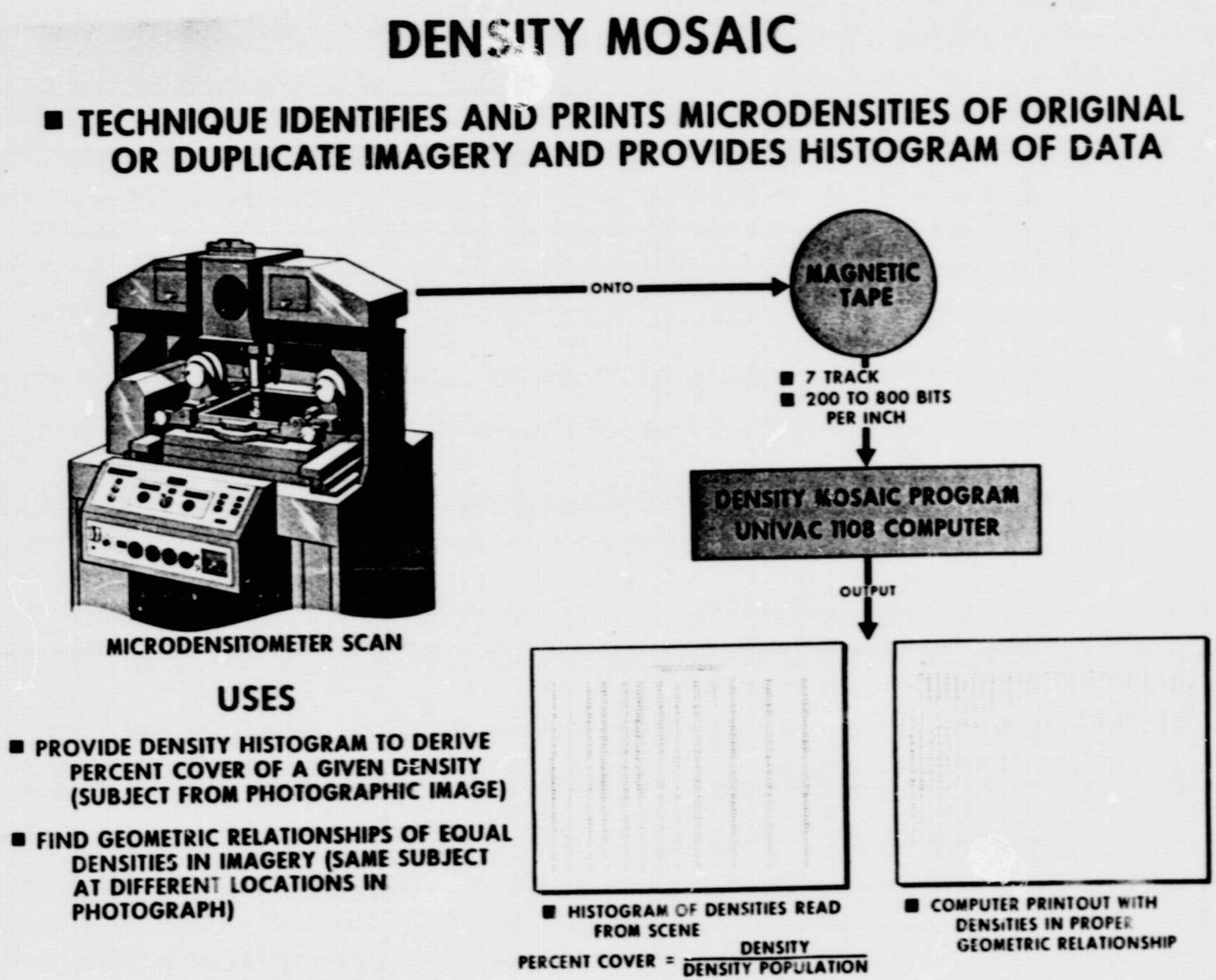

FIGURE 4 Density Mosaic Technique for Determining Percent Cover.

Perhaps the most valuable adjunct to this program is a histogram of densities. The histogram may be used to determine percent cover of a given density or subject in the image. The density mosaic may also serve as a useful tool for debugging data and checking the characteristics of the scanning instrument including linearity and orthogonality.

°CONTOURS

Again the same data sample was used for illustrative purposes here. Figure 5 shows the flow repeating the microdensitometer scan and recording system used in the Photographic Technology Division.

The program was instructed to produce four sets of contours with equal density increments of 0.20 density.

Set one, had a contour at a minimum density of 0.0 then incremented 0.20 density to produce contours at 0.20, 0.40, 0.60, etc. to a density of 3.00. Set two started contouring at minimum density 0.05, set three at 0.10 and set four at 0.15. All sets incremented at 0.20 resulting in a full set of contours at density intervals of 0.05 upon recombination.

Each of the four sets of contours is printed on microfilm by the computer system. These microfilms are then color coded and enlarged on color duplicating film using an I^2S additive color viewer available in the photographic division (Figure 6).

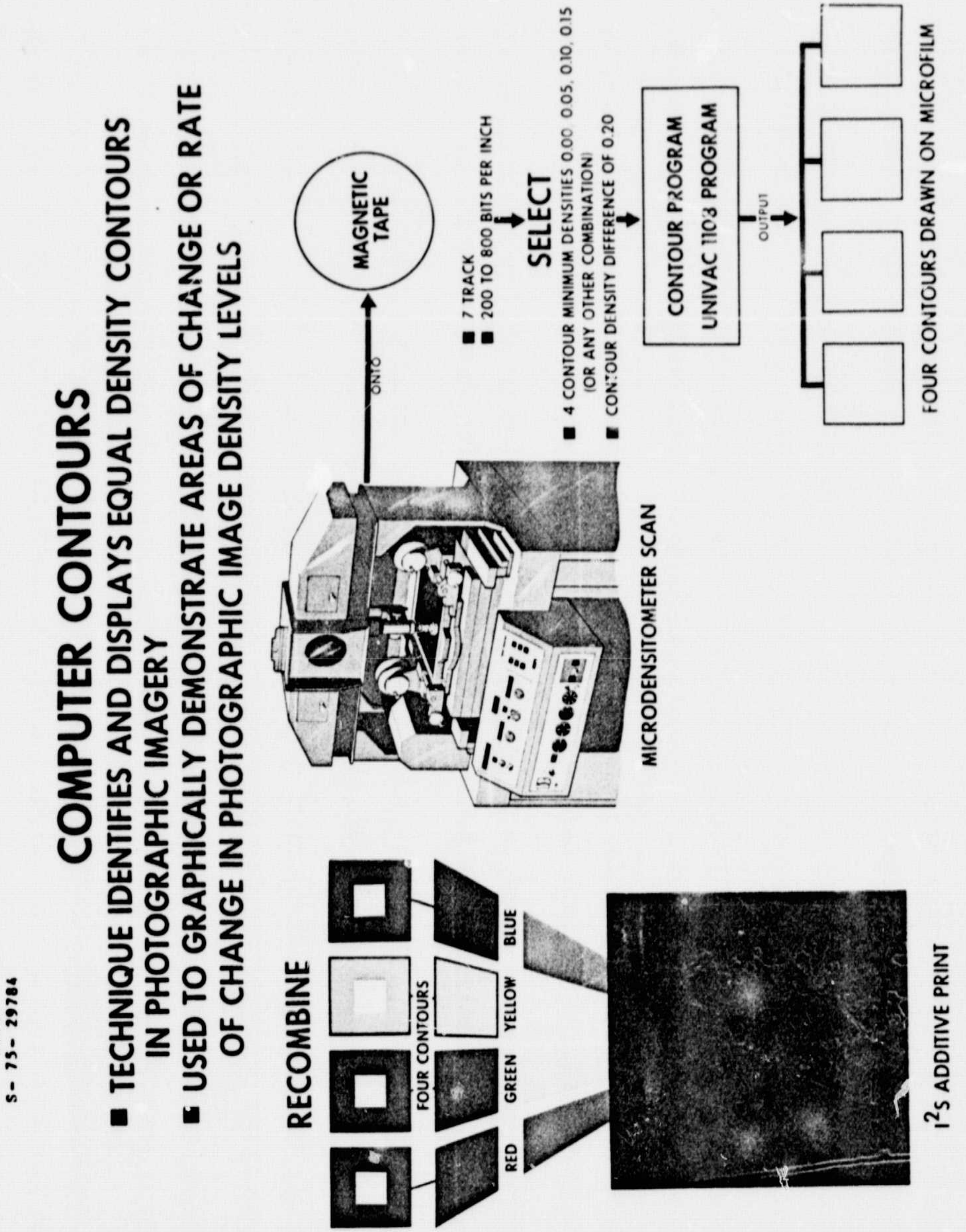

FIGURE 5 Computer Contours for Studying Density Changes in Imagery.

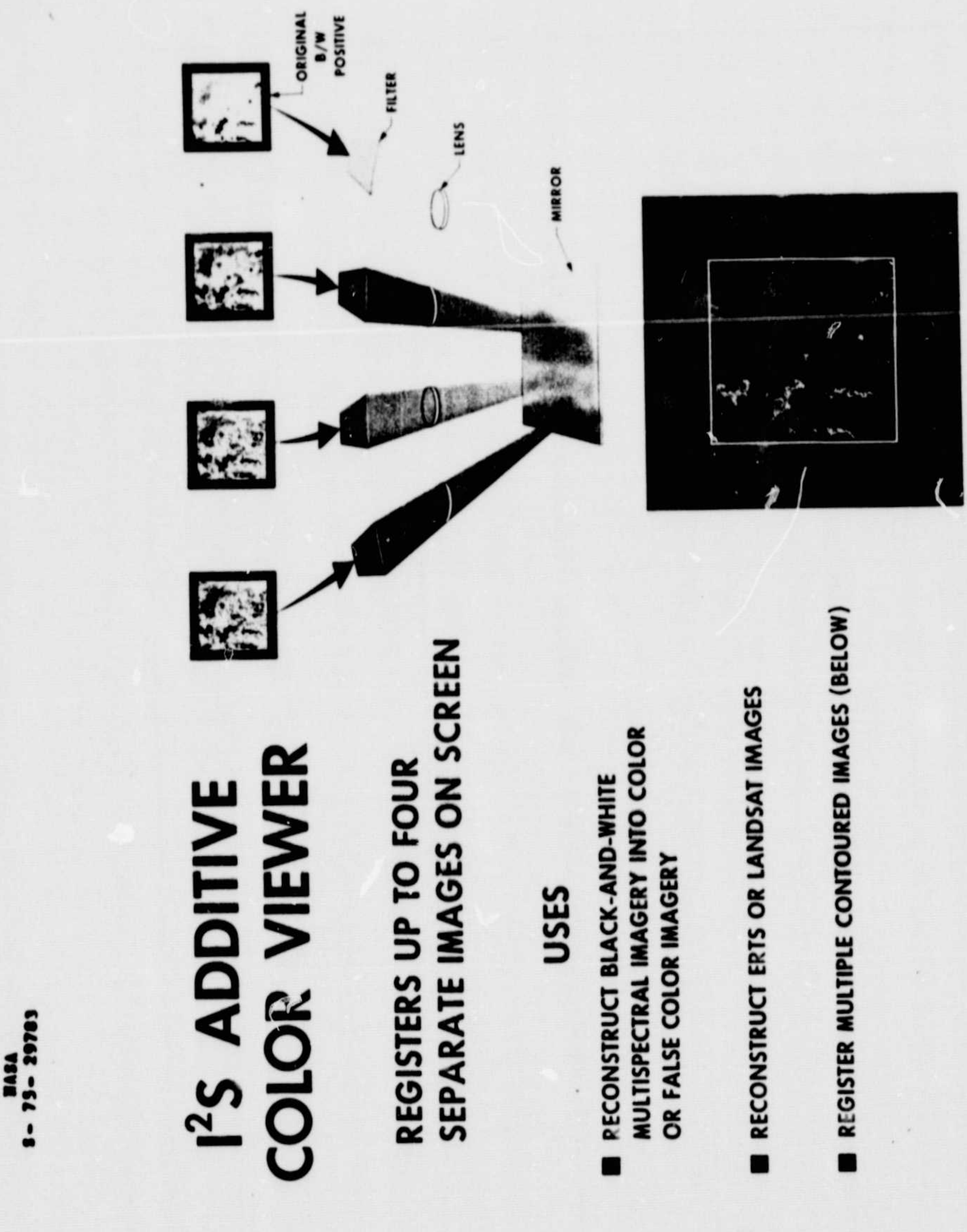

FIGURE 6a. I^2S Additive Color Viewer.

The usefulness of this technique is limited to applications where changes in density or rates of change in density across an image are important.

This series of processing techniques are used for a variety of projects. A major limiting consideration for applying any one of these techniques to a problem is not only the scanning and computing hardware availability but also the time required for photographically printing the computer outputs.

An advantage of these techniques is that the same data may be used to produce results in numerous formats.

PHOTOGRAPHIC IMAGE PROCESSING

The prerequisites for accomplishment of image processing utilizing photographic techniques are (1) a photographic darkroom equipped with a registration printer and/or an enlarger with a suitable light source (2) a set of spectral filters and (3) printing materials. The capital outlay for accomplishing this type of processing is significantly less than for digital processing.

Numerous techniques, all routinely available and well documented for photographic darkroom use are applied to the specialized processing of imagery using photographic facilities. The results are characterized not only by low cost but also by relatively high resolution.

Described here are two techniques employed at JSC for isolating areas with equal spectral signatures from a photographic image. In this case, the subject was a forest area with differing tree types and less than full area cover.

° WIDE BAND ISOLATION

This image processing technique called subject isolation shown in figure 7 is used to isolate hues which occur in relatively wide spectral bands; red versus green, for example. A nominal spectral band width would

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SUBJECT ISOLATION

- TECHNIQUE IDENTIFIES AND ISOLATES NARROW SPECTRAL BANDS IN PHOTOGRAPHIC IMAGERY
- USED TO ISOLATE AND QUANTIFY OBJECTS IN PHOTOGRAPH WHICH HAVE UNIQUE SPECTRAL SIGNATURES; USUALLY WITH CLEARLY DEFINED COLOR

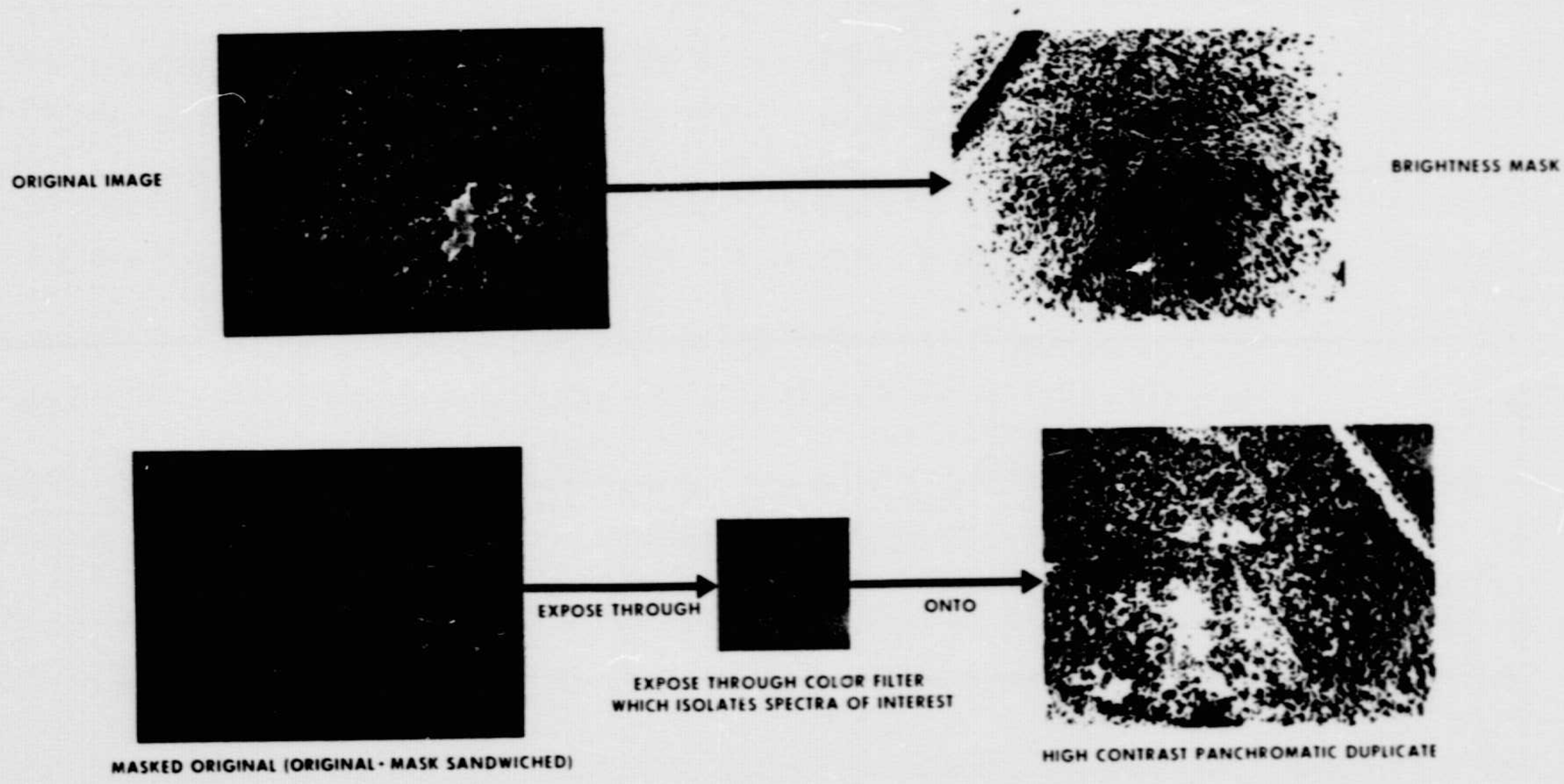

FIGURE 7a. Subject Isolation Technique for Separating Wide Band Hues

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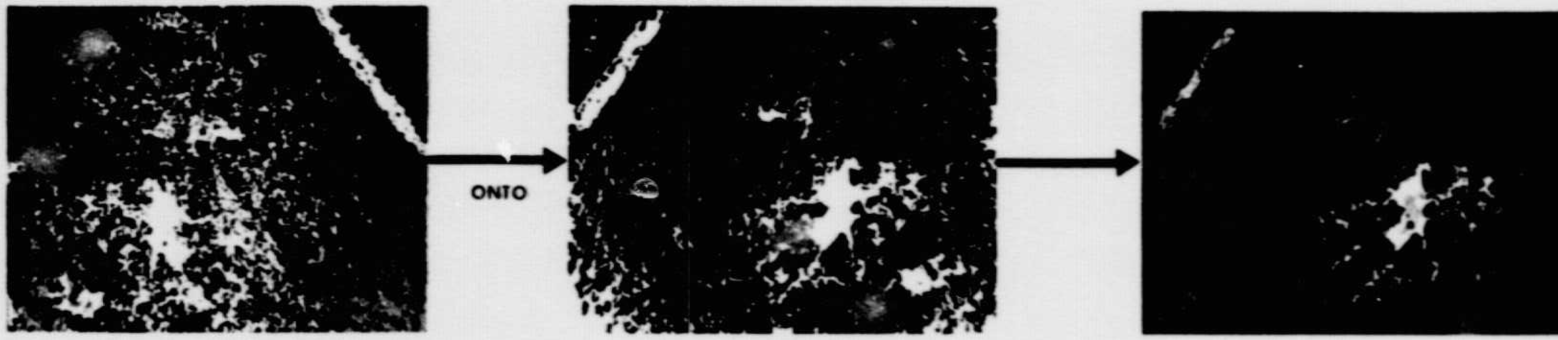

- POSITIVE OR NEGATIVE B & W PRINT
- POSITIVE OR NEGATIVE B & W TRANSPARENCY
- POSITIVE OR NEGATIVE COLOR TRANSPARENCY

USES

- ISOLATE SPECIFIC SUBJECT TO DETERMINE LOCATION FOR MAPPING.
- ISOLATE SPECIFIC SUBJECT FOR COMMUNICATION AND ILLUSTRATION OF DATA.
- ISOLATE VEGETATION, WATER, CROPS, ROADS, ETC. TO CALCULATE PERCENT GROUND COVER.

FIGURE 7b.

be 20 to 40 nanometers. In this illustration, the purpose of the isolation was to determine the relative amounts of tree cover to non-tree cover in the image. Non-tree cover is generally green in the image while tree cover was generally red or red related when recorded on a typical infrared film.

The initial step in the process is to equalize brightness occurring in the image. Aerial images typically vary in brightness across the frame for many reasons. Sun glint caused by the relationship of the sun and the camera characteristically results in a bright area in the image,vignetting caused by falloff in illumination from image center to edge at the camera image plane, and shadowing caused in the image.

These brightness variations can be eliminated to some degree, depending on the color balance characteristics of the original image (the tri-color curves need to be approximately the same gamma) and the linear range (straight line portion of the density versus log exposure curve) of a suitable black- and-white duplicating stock. Corrections for an image density range of 2.0 are easily achieved. Figure 8 shows the effect of a negative brightness mask made to equalize brightness in the image.

To make the mask a black-and-white panchromatic negative of the original is exposed and processed to a gamma of 1.0; i.e. a change in log exposure produces an equal change in negative density. Where the original image is bright, the mask will have heavy density and where the original is dark as in the shadows or near the image edge, the mask will be light. Upon registration of this mask with the original an equal density sandwich results as shown in figure 8.

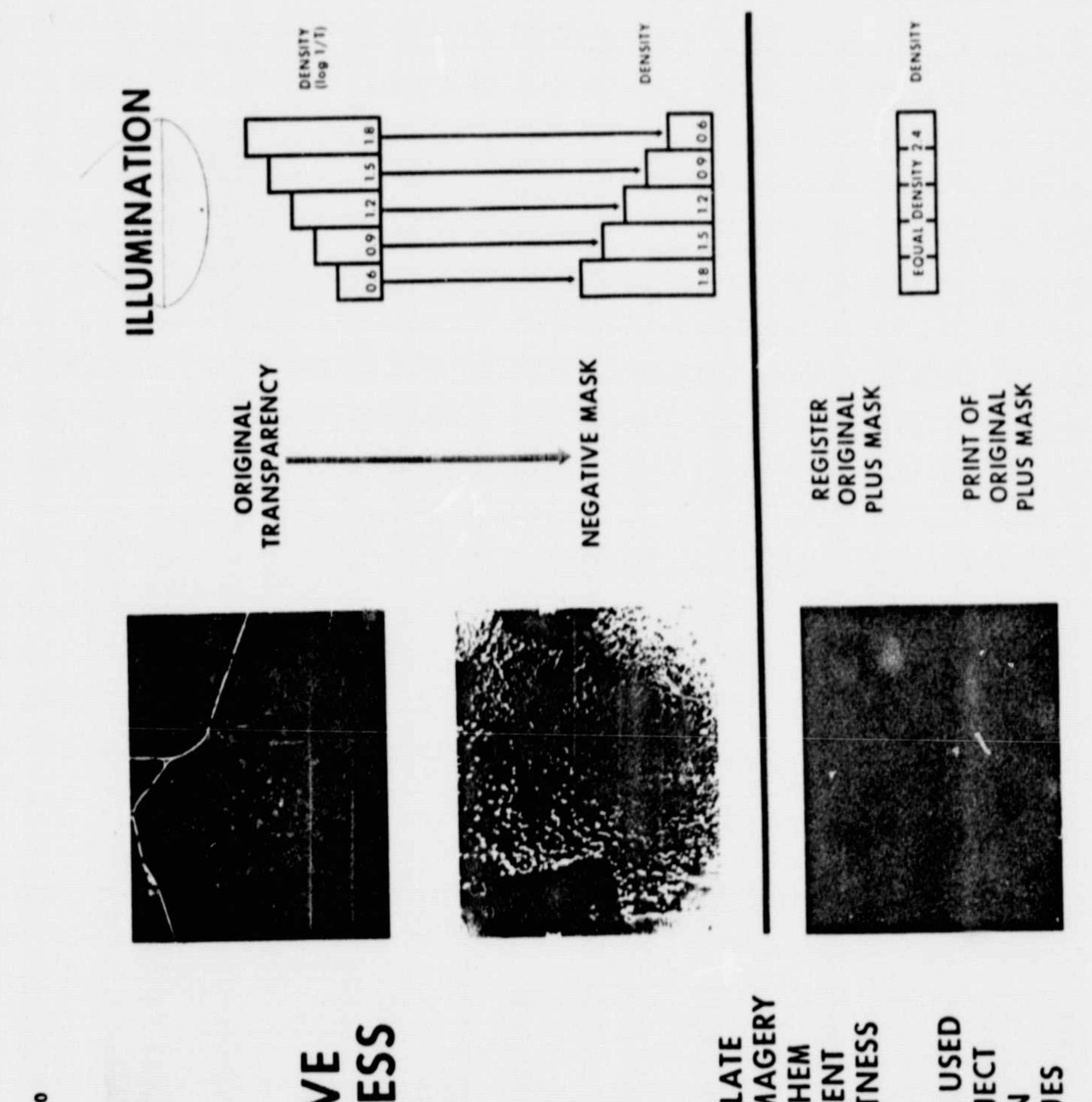

FIGURE 8. Negative Brightness Mask Used to Eliminate Brightness Variations in Color Imagery.

This masked original is then used as shown in figure 7. A filter is selected which isolates the hue of interest. In this example the subject of interest, trees, on this color infrared image was all non-green therefore, a green filter could have been used to isolate non-trees or a red filter could have been used to isolate the trees which were all various red-related hues; i.e. red, magenta, brown. A print of the sandwich was made onto a high contrast black-and- white material using the filter selected.

The high contrast panchromatic material is useful in providing a large density difference between the filtered hues in the sandwich. An objective for isolation is to make all hues of interest either very high or very low density. Frequently this high contrast print on black-and- white transparency material will be sufficient to meet the needs of the project.

Should additional density isolation be required, Agfa-Contour film, Kodalith or other high contrast printing materials may be used. Agfa-Contour film was used in this demonstration as shown in figure 7 to produce a larger density range.

Agfa-Contour film is a special photographic film which incorporates both a positive and a negative emulsion on the same film base. By selecting exposure time and filtration, this film may be used to isolate any density level from an original as shown in figure 9. Inherent with the Agfa-Contour film is a gamma of 7 or 8 making this a useful tool for density contouring or isolation. In some imagery where large density differences are already apparent in the image, Agfa-Contour film may be used directly with the original.

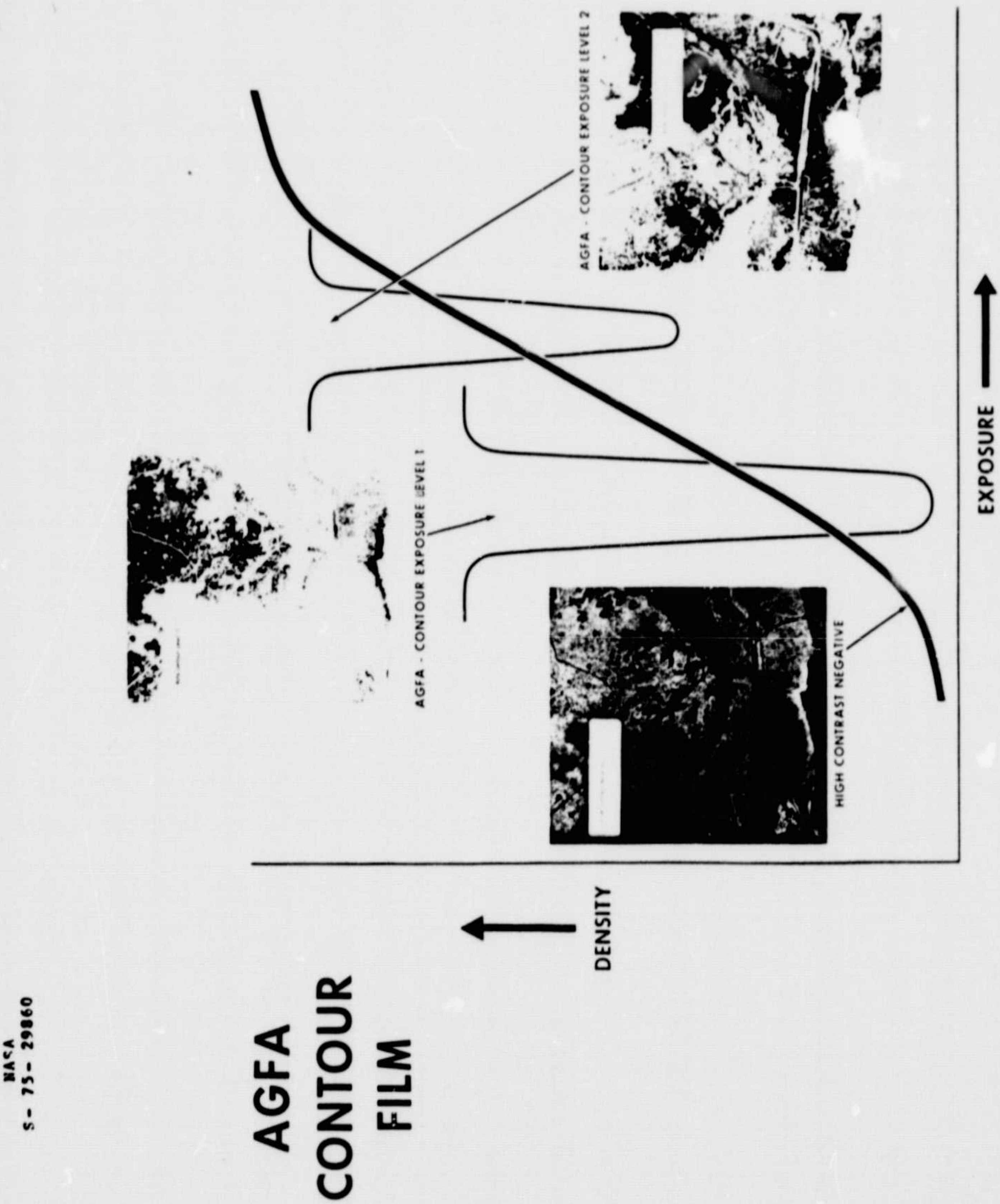

FIGURE 9. Agfa-Contour Film for Isolating Density Levels in Original Photographs on High Contrast Film Stock.

The final step is the production of a suitable display print. Typically, the choices include an overlay made with the original imagery for demonstration purposes, a black-and-white print made for field use or a black-and-white transparency made for percent cover determinations.

This isolation technique is easily adaptable to an entire roll of imagery taken over an area of similar subject matter, a forest land, for example. If the imagery was obtained at about the same time of day and of similar subjects the treatment of individual frames should remain constant from roll end-to-end.

°NARROW BAND ISOLATION (RATIOING)

A photographic image processing technique entitled subject isolation-ratio analysis shown in figure 10 is useful where the image hue to be isolated is closely related to a second hue; e.g. red and magenta or red and yellow.

Photographic production of this ratio involves the isolation of a single narrow color band using a combination of spectral filtration and masking of the original imagery.

Initially, an assessment is made of the hue to be isolated by viewing the original color transparency. In the example shown, the magenta trees required isolation from other trees characterized by a variety of colors; browns, reds, etc. A red to blue ratio was selected because all the trees have red comprising part of their hues and the blue ratio was selected because the trees of interest were magenta which has a low red to blue ratio or high blue content compared to the red or brown trees which have little blue content.

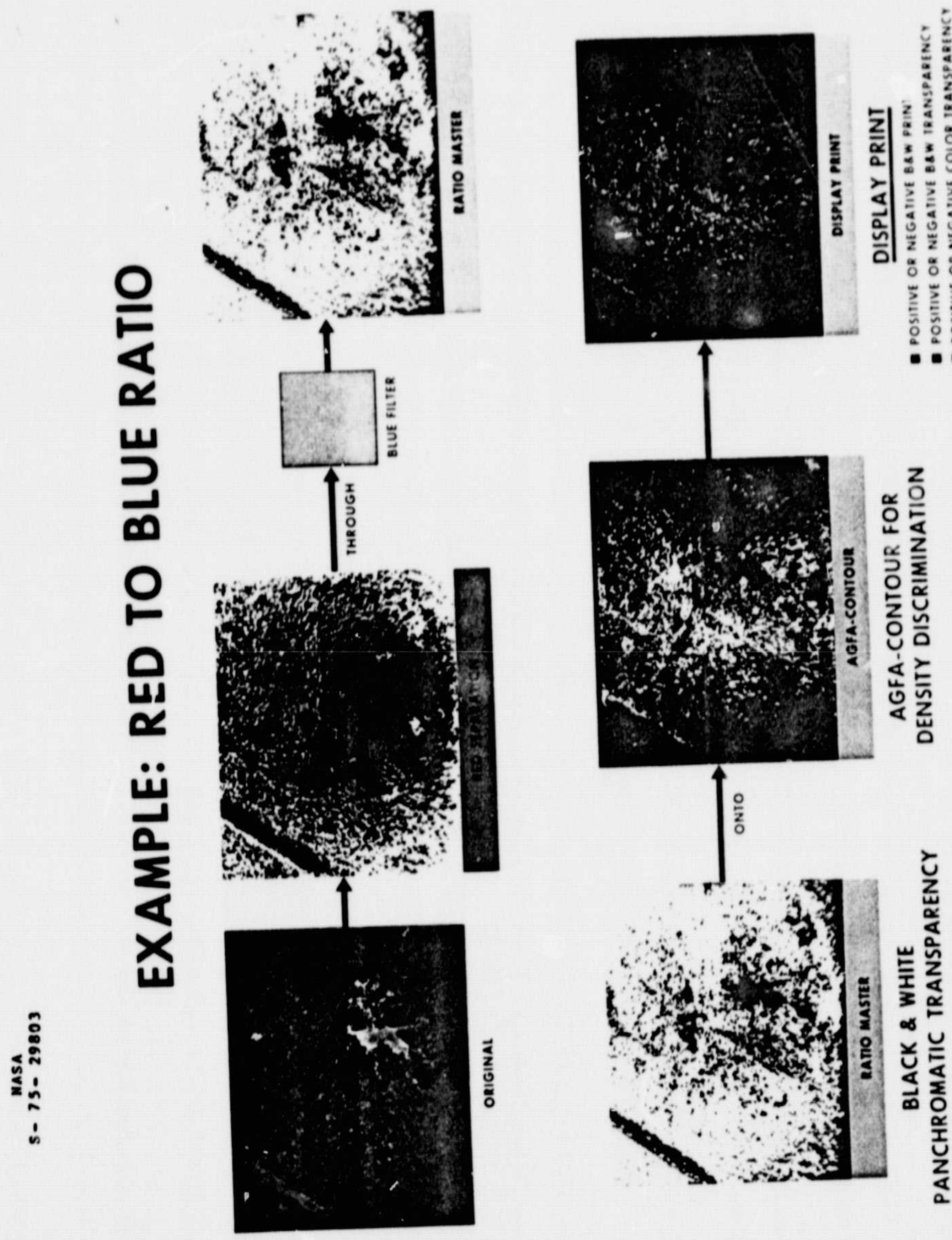

FIGURE 10a. Color Ratioing Technique for Narrow Band Hue Isolation.

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SUBJECT ISOLATION
(RATIO ANALYSIS)

- TECHNIQUE IS USED TO ISOLATE AND QUANTIFY SUBJECTS FROM PHOTOGRAPHIC IMAGERY OF CLOSELY RELATED HUES
- EXAMPLE: RED, ORANGE AND MAGENTA MAY BE ISOLATED FROM A SINGLE PHOTOGRAPH

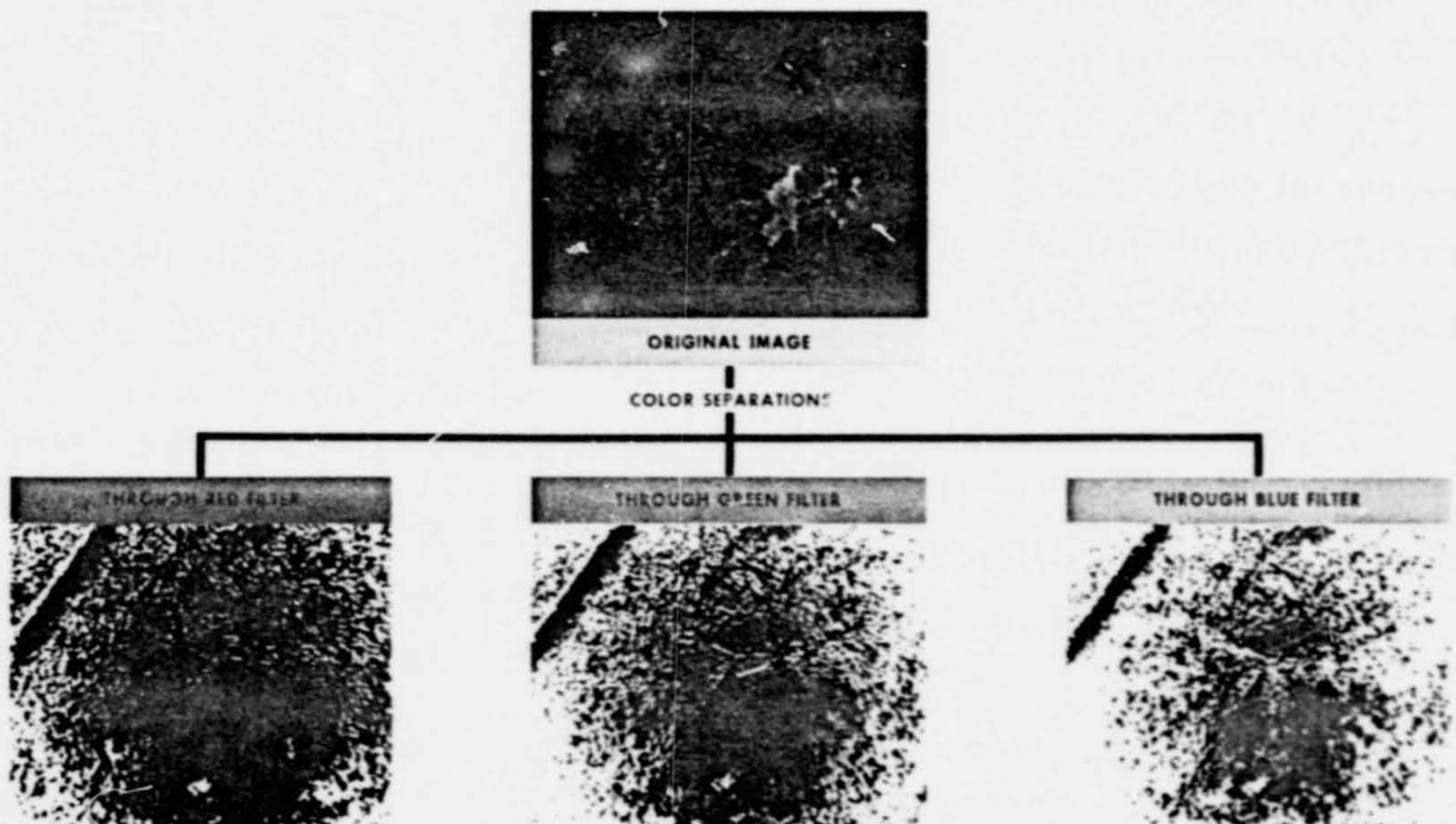

FIGURE 10b.

A separation negative was made using a red filter, Typically, wratten 70 (Red), 98 (Blue) or 99 (Green) filters are used to produce color separations from original imagery. This separation negative must be made such that the brightness range in the original transparency is imaged on the linear or straight line area of the black-and-white panchromatic negative stock. The process gamma of this separation negative must be 1.0 to maintain the desired density-log exposure relationship when the separation is registered with the original transparency. Additionally, when making the separation, a diffusion sheet should be interleaved between the original and the material to be exposed. This 0.003 inch thickness sheet diffuses the image, making the edges unsharp, thus preventing undesirable edge effects in the registration.

The separation negative is registered with the original transparency and the "sandwich" is printed through the appropriate spectral filter to achieve the color ratio. In this case, a blue filter would be used to complete the red to blue ratio. The material for duplication at this step should be a high contrast panchromatic stock. A high contrast stock will result in maximum density separation of each color in the image.

This image, the ratio master, may be adequate for the isolation being considered. Should additional separation be required, Agfa-Contour film as shown in figure 10 may be used.

END PRODUCTS

The end product of this subject isolation processing will be a very high contrast photographic image. The image tones will be black and clear with few, if any, midtones. The choice of format will depend upon the application.

If the image is to be overlayed on a map the best method is to display as clear the largest area. Remembering that the image densities will be either black or white with few middle densities, the larger clear area will make map referencing easier.

If the image is to be overlayed on the original, the clear area should overlay the area or subject of interest.

If the area is to be quantified, it should make little difference which part of the subject is displayed as black or white. One possible consideration to be made regards the flare characteristics of the device used to read the film. Large clear areas can produce excessive flare and erroneous data.

QUANTIFICATION

The JSC photographic division has used two methods for quantifying data to determine percent cover of a subject relative to a specified area.

Figure 11 shows an automatic image digitizer recently acquired from Photo Digitizing Systems, Inc. in Burbank, California. This device scans and stores density data at rates varying from about 300 to 100K points per second. The optical system for scanning large images has an effective

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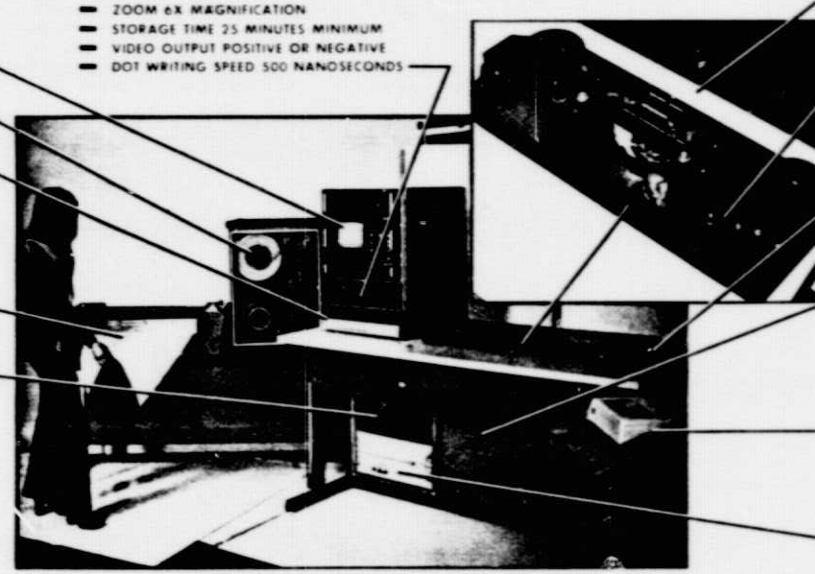
PTD AUTOMATIC IMAGE DIGITIZER SYSTEM

- RAPIDLY SCANS PHOTOGRAPHIC FILM IN FORMATS UP TO 9 1/2 INCHES SQUARE PROVIDING DIGITAL DENSITY DATA ON A POINT-BY-POINT BASIS

- REMOTE MONITOR
  - VIDEO OUTPUT
  - 9 INCH DIAGONAL DISPLAY
- DATA GENERAL MAGNETIC TAPE UNIT
  - 9 TRACK 1/2 INCH TAPE
- DATA GENERAL DATA PROCESSOR
  - NOVA 210 16 BIT 24 K MINI-COMPUTER
  - SCANS 100 000 POINTS PER SECOND
  - 256 LEVEL GRAY SCALE DENSITY RANGE
  - X-Y ORTHOGONALITY + 1/2
  - RASTER SCAN RATES UP TO 1 FRAME PER SECOND
- HOUSTON INSTRUMENTS PLOTTER
  - DIGITAL AND GRAPHIC OUTPUT
- FILM TRANSPORT CONTROL UNIT

- SCAN CONVERTER
  - ZOOM 6X MAGNIFICATION
  - STORAGE TIME 25 MINUTES MINIMUM
  - VIDEO OUTPUT POSITIVE OR NEGATIVE
  - DOT WRITING SPEED 500 NANOSECONDS



- COLD CATHODE LIGHT SOURCE
- FILM TRANSPORT SYSTEM
  - TRANSPORTS ROLL FILMS TO 9 1/2 INCHES WIDE
  - HOLDS SHEET FILMS
  - TRANSPORTS AUTOMATICALLY
- FILM TRANSPORT CONTROLS
  - AUTOMATIC FILM ADVANCE
  - INCH OR CREEP RATE
  - CONTROL FILM ADVANCE RATE
- DIGITIZING CAMERA
  - S-20 RESPONSE
  - 1.5 INCH IMAGE DISSECTOR PHOTO TUBE
  - 3 LENSES AVAILABLE
  - RASTERS FROM 32 X 32 TO 4000 X 4000 POINTS
- TELETYPE
  - PAPER TAPE READER
  - PAPER TAPE PUNCH
  - MANUAL INPUT/OUTPUT FOR SYSTEM
- POWER SUPPLY
  - 115 VOLTS 50/60 Hz 750 WATTS

SAMPLE OUTPUT

USES

- DETERMINE PRINTING AND TONE REPRODUCTION SPECIFICATIONS FOR ORIGINAL IMAGERY BY PROVIDING DENSITY DISTRIBUTION DATA FROM THE ORIGINAL IMAGERY
- DETERMINE PERCENT COVER IN A PHOTOGRAPHIC IMAGE OF A GIVEN SUBJECT; FOR EXAMPLE, FOREST CANOPY VERSUS CLEARED AREAS
- PROVIDE DIGITAL INPUT DATA FOR IMAGE PROCESSING AND ENHANCEMENT COMPUTER PROGRAMS

FIGURE 11. Photo Digitizing System.

scanning aperture of 2.4 mm. A 7 1/2 x 7 1/2 inch frame is scanned in a 128 x 128 matrix in a time of about 25 seconds. A roll of imagery of 200 frames can be automatically scanned giving a histogram of densities either frame-by-frame or in summary. Percent cover would be easily determined at a rapid rate. A 200 square mile area of forest land would be inventoried by the scanner in about 2 hours.

A second method requires a photometric measurement of each backlighted frame. A radiometer or photometer which integrates the light within a range of about 40 to 1 would be sufficient to give accuracies of better than 5%. Each processed frame is either black or essentially clear. Assuming the black area transmits no light, the area measurement is the relationship of the clear image transmission to a calibrated all clear image transmission. In tree count estimations, for example, the percent cover, the area covered in the frame of imagery, and average tree crown dimensions would be required to quantify the image. The percent cover would result after the tree subjects were isolated, the area covered would be available from camera-aircraft flight data and tree crown would be available from ground truth or other available data.

CONCLUSIONS

Photographic image processing may be accomplished where spectral or density discrimination is an experimental or project requirement.

Precise image processing can be accomplished without the use of digital equipment which may not be available for the investigation.

Many of the techniques used for digital processing are relatively easily adaptable to photographic processing.