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FUTURE TRENDS IN IMAGE PROCESSING SOFTWARE AND HARDWARE

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ABSTRACT

The image processing applications in which JPL's Image Processing Laboratory is active range from planetary exploration and earth applications to biomedical applications, astronomy, and scene analysis for the robotic vehicles of the future. There are several common trends that are apparent that are common to each of these applications areas, and these trends are discussed in this paper. The trends include requirements for improved adaptive search and interrogation of large image data bases, increasing utilization of graphics data in conjunction with imagery, improved techniques for display of multispectral imagery recorded in a large number of spectral channels, methods for merging data acquired by a variety of sensors, and development of custom Large Scale Integrated (LSI) chips for image processing applications to support intelligent remote user stations and future pipeline production processors.

II. INTRODUCTION

JPL's Image Processing Laboratory (IPL) is active in a variety of applications areas. For the past fifteen years, IPL's technology evolved around the requirements imposed by the NASA planetary program[1-7]; the planetary program is currently still a large and important activity within the IPL, as the recently acquired imagery of Jupiter and its moons will testify. More recently, IPL has become involved in the earth applications area[8-11], and has extended early efforts in biomedical image processing[12] and scene analysis technique development for application to future robotics vehicles[13]. This broad range of applications is characterized by common technology development trends, and several current trends are discussed in this paper.

II. ADAPTIVE INTERROGATION OF LARGE IMAGE DATA BASES

Computerized cataloging, search and retrieval of large image data bases has been important at IPL ever since the Mariner 9 spacecraft returned over 7000 images of Mars in 1971; prior planetary spacecraft had returned only a small number of images (only 200 images were returned from Mars by the Mariner 6 and 7 flyby spacecraft in 1969, for example), and a notebook could be used to store and retrieve all images returned prior to Mariner 9.

IPL has developed a variety of techniques for interrogating large image bases. "Picture Catalogs" are constructed that contain several hundred parameters that characterize the planetary images returned from NASA spacecraft. These parameters can be divided into several categories as follows:

<u>Engineering, Spacecraft and Footprint Data</u>

Examples:

Spacecraft Position and Orientation
Camera Filter Position
Solar Elevation Angle
Image Footprint (Longitude and Latitude)

<u>Location of Digital and Film Versions</u>

Examples:

Tape and File Number of Raw Image
Roll and Frame Number for Film Products
Microfiche Card Position
Dataset Name on Disk

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Processing History

Examples:

Real Time System Processing and Enhancement History
Second Order Processing Record (Program names and parameters used for subsequent processing)

It is possible to interrogate this catalog using the Informatics MARK IV data base management system, and both batch and interactive interrogation and report generation are possible. It is thus possible to sit at a terminal and initiate the following query:

"Provide the tape and file location, the image identification, the shutter speed and range to the planet for all images taken after 3:00 p.m. local Mars time on the Mariner 9 mission after day 100 of the mission through a violet filter that have been high pass filtered."

The appropriate report is printed at the user station; the selected images can be viewed from microfiche card, or directly from magnetic disk or tape via digital display systems, and can be accessed digitally for further processing.

The trend for the future in this area will probably be toward providing remote users of a central computing facility with low cost analog display equipment (e.g. video disk) that can be driven to display the appropriate images that are selected by interrogating the picture catalog located at the central facility. Currently, the Regional Planetary Image Facility at JPL utilizes microfiche display equipment as the low cost analog display equipment, and the other Planetary Image Facilities around the country are also acquiring this capability; the current JPL-based system is shown in Figure 1. The future video disk technology should remove the restrictions on the number of images that can be stored (our current microfiche system can store 40,000 images per carrousel).

The low cost analog storage system can, of course, only serve as a browse file; the remote user will ultimately want to process the digital versions of one or more selected images that are located through his search procedure, but the remote low-cost analog image storage device will provide him with a browse capability when connected to the central facility and its cataloging and query capability.

III. UTILIZATION OF GRAPHICS DATA WITH IMAGERY

Graphics data is becoming increasingly important in image processing applications. IPL is increasingly becoming involved in "information extraction" applications, where the results derived from image analysis are displayed as graphics, rather than image, data. In addition, it is becoming increasingly important to merge existing data bases represented in graphics format with digital imagery.

Figures 2, 3 and 4 illustrate these two trends. Figure 2 shows a pair of Voyager 1 images taken before the spacecraft encounter with Jupiter. One of the scientific objectives of the Voyager mission is the study of the atmospheric dynamics of Jupiter; that analysis is performed by tracking features in sequential imagery[14] and then generating a velocity field at a grid of longitude-latitude points across the planet. The resulting velocity field is further processed to yield other statistics; Figure 3 shows a contour plot of vorticity derived from the image pair. Figure 4 shows the registration of United States Census tract boundaries with a Landsat image, performed using the capabilities of JPL's Image Based Information System (IBIS)[15]. It is becoming increasingly important to correlate remotely sensed imagery with existing geographically coded data bases, which are normally represented in graphics format. Clearly, the ability to manipulate graphics data will become an important component of image processing systems of the future.

IV. DISPLAY OF MULTISPECTRAL IMAGERY

The future trend in remote sensing will be towards sensors that record the same scene in many spectral channels. Current techniques utilizing color for display of three or four channel imagery acquired by Landsat multispectral scanners will be inadequate for presenting data recorded in, say, fifteen or fifty spectral channels. Principal Component techniques[16] offer one possible solution to this information display problem. These techniques enable extraction of various degrees of redundancy or lack of correlation present in a multispectral image. One simple example is shown in Figures 5 and 6[17]. The original astronomical plates were exposed in four different spectral regions. Figure 5 shows the image data that is highly correlated across all four regions, while Figure 6 shows the fourth principal component, which basically illustrates the highly uncorrelated image data within the multispectral images. Techniques like this will be required in order to extract the information present in the large number of spectral channels recorded by future sensor systems.

V. MERGING OF DATA TAKEN BY A VARIETY OF SENSORS

The earth applications programs of the future will feature a variety of sensors orbiting the earth, each recording the earth's signature in a variety of domains. In order to extract scientifically useful information, it will be necessary to develop techniques to register data recorded by a variety of sensors to a common geometric base and to develop new techniques for classification employing a variety of data types. Examples of current efforts include attempts to register aircraft and Seasat synthetic aperture radar (SAR) imagery with Landsat and aircraft multispectral imagery, and attempts to merge heat capacity data acquired by the Heat Capacity Mapping Mission (HCMM) with remotely sensed imagery. It will be necessary to develop new techniques for merging disparate data types, because the earth's signature is different when acquired in different parts of the frequency spectrum. One recent attempt at IPL in registering radar with Landsat imagery is shown in Figure 7, and research is currently underway at JPL and other organizations directed toward improving the current registration techniques.

VI. USE OF CUSTOM LSI FOR IMAGE PROCESSING APPLICATIONS

Current efforts in the electronics industry have resulted in development of fabrication techniques that make it possible to design and fabricate single chips that can contain many thousands of transistors. It is now possible, using design techniques being developed at Caltech[18] and other institutions and commercial organizations, to design customized LSI chips that will execute a particular image processing algorithm at extremely high speed. One recent effort at IPL has been the design of a custom LSI chip that performs edge detection on real-time video data acquired by stereo cameras located on the JPL Robotics vehicle. The chip, when fabricated, will perform edge detection on a full video image (512x480 pixels) in the 1/30 second frame time of the video system.

It is clear that very high speed specialized chips will form the basis for flexible high speed intelligent image processing user stations that can operate in stand-alone mode or as remote terminals to central computer and data base storage facilities. It is also clear that this technology will form the basis for custom high-speed pipeline and/or parallel image processing systems. The only current obstacle is the tedious design effort currently required to design a complex chip. Future computer-aided techniques will alleviate that difficulty within the next decade, and the image processors of the future will be able to fabricate their own low cost high speed systems for image processing applications.

VII. SUMMARY

This paper has presented a brief overview of some future trends that appear important in current applications at JPL's Image Processing Laboratory. We are sure that the dynamic community of image processing institutions has many more examples to offer, and at this point only one thing is certain: the field of image processing will continue to evolve dynamically to meet future applications that are not now perceived.

VIII. ACKNOWLEDGEMENTS

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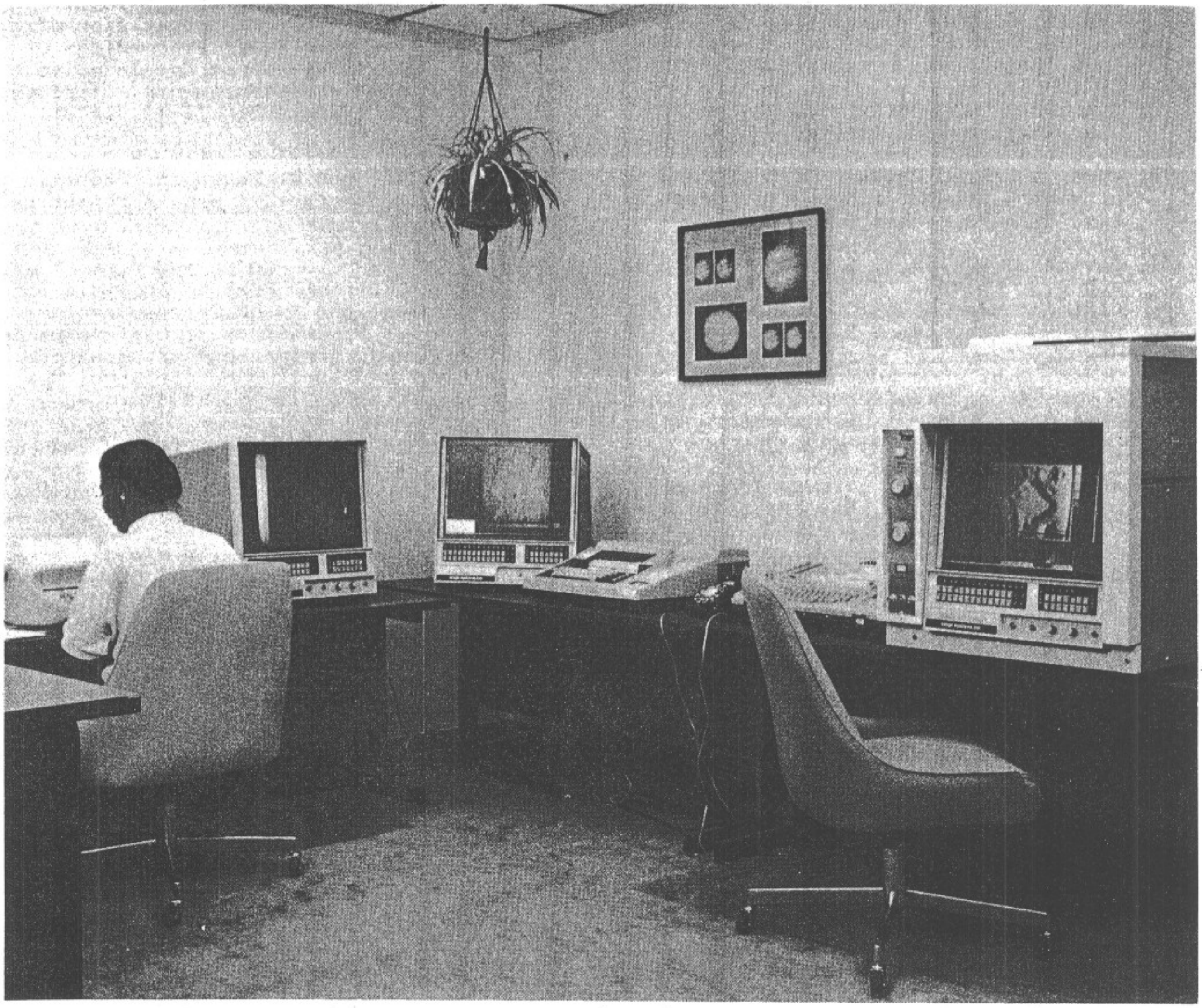

Figure 1. The NASA Regional Planetary Image Facility operated by JPL, showing the computer-controlled microfiche viewers used to display the planetary imaging data base.

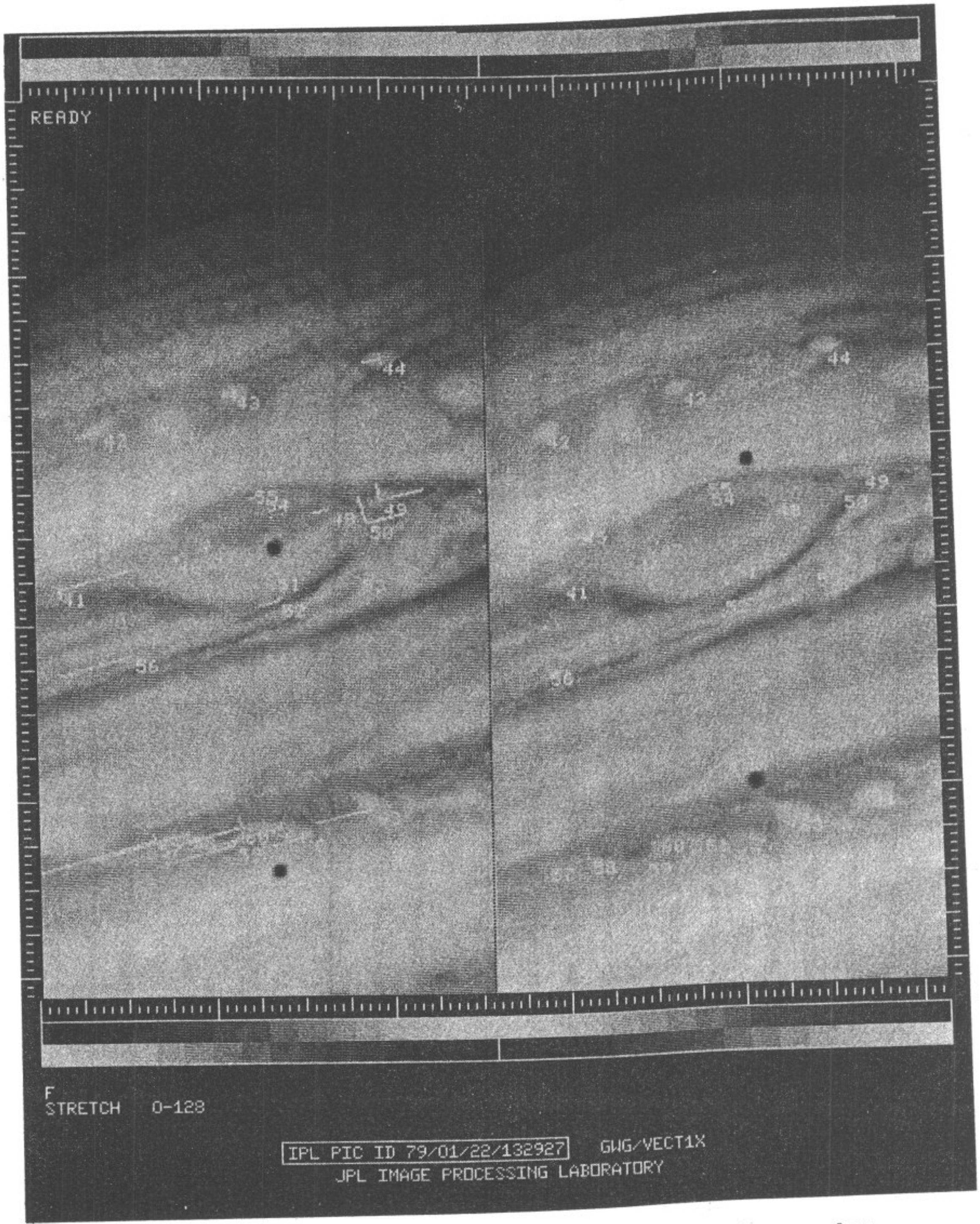

Figure 2. Two Voyager 1 pre-encounter images, with graphics overlay indicating relative displacement of atmospheric features that occurred between the two exposures.

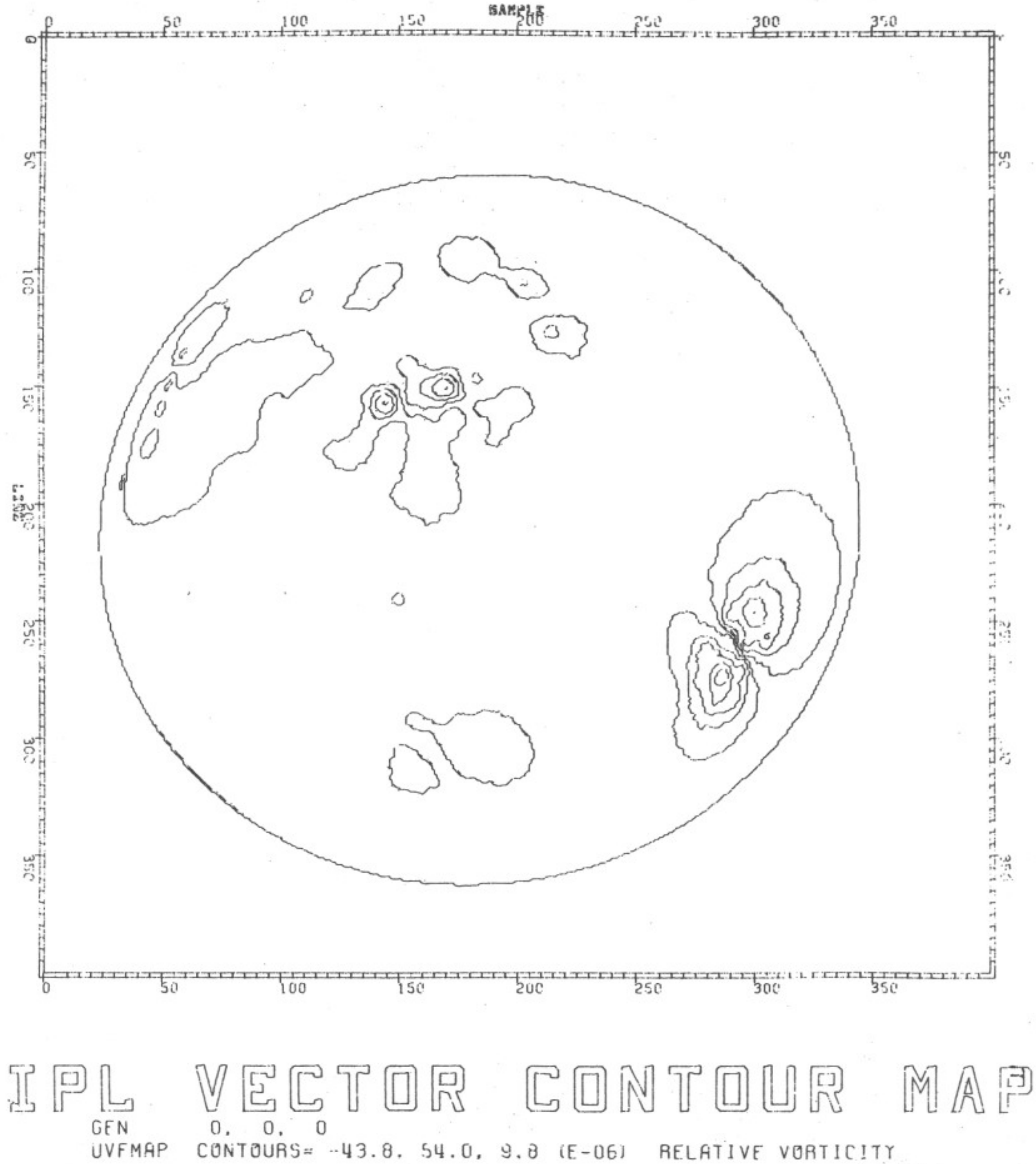

Figure 3. Contour display of vorticity, computed using velocity vector data obtained from analysis of the two pre-encounter Voyager 1 images shown in Figure 2.

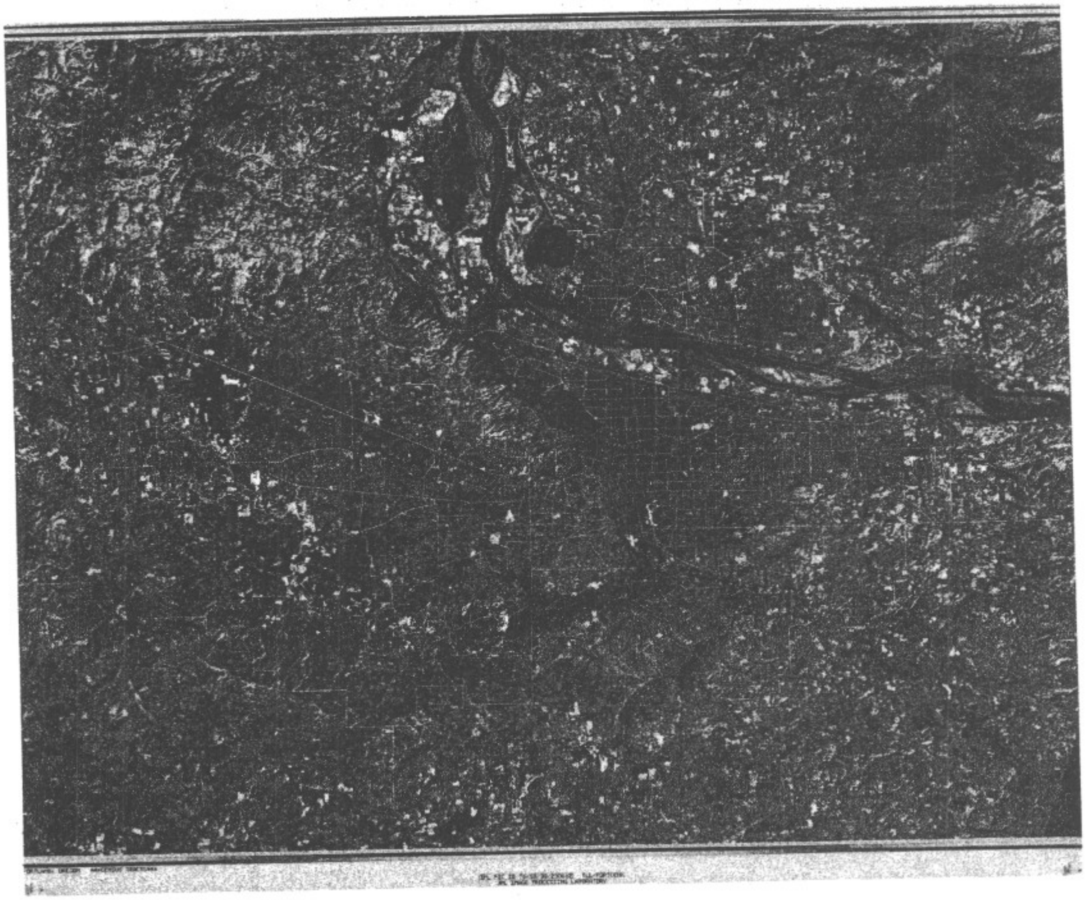

Figure 4. One spectral channel of a Landsat image of Portland, Oregon, showing the graphics overlay of census tract boundaries that has been geometrically registered to the digital image data.

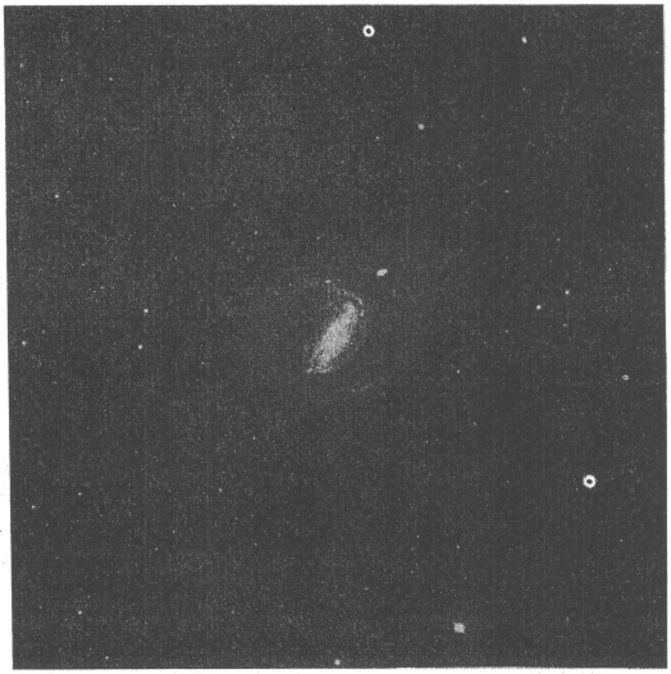

Figure 5. The logarithm of the highest ranked principal component, derived from a multispectral image of NGC 1097; this component contains information that is highly correlated across all four component images used in the analysis.

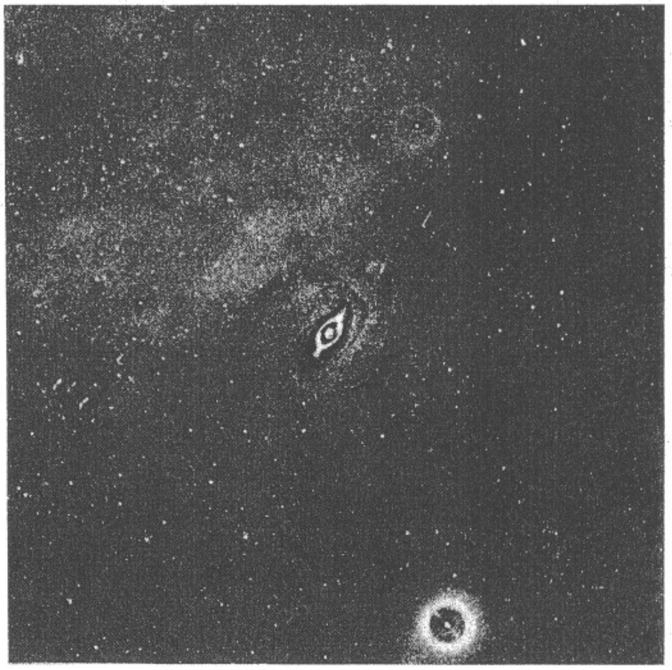

Figure 6. The fourth component obtained from the multispectral image of NGC 1097. Note that the detail in this component represents uncorrelated data across the four original bands (e.g. noise present on only one of the four component images).

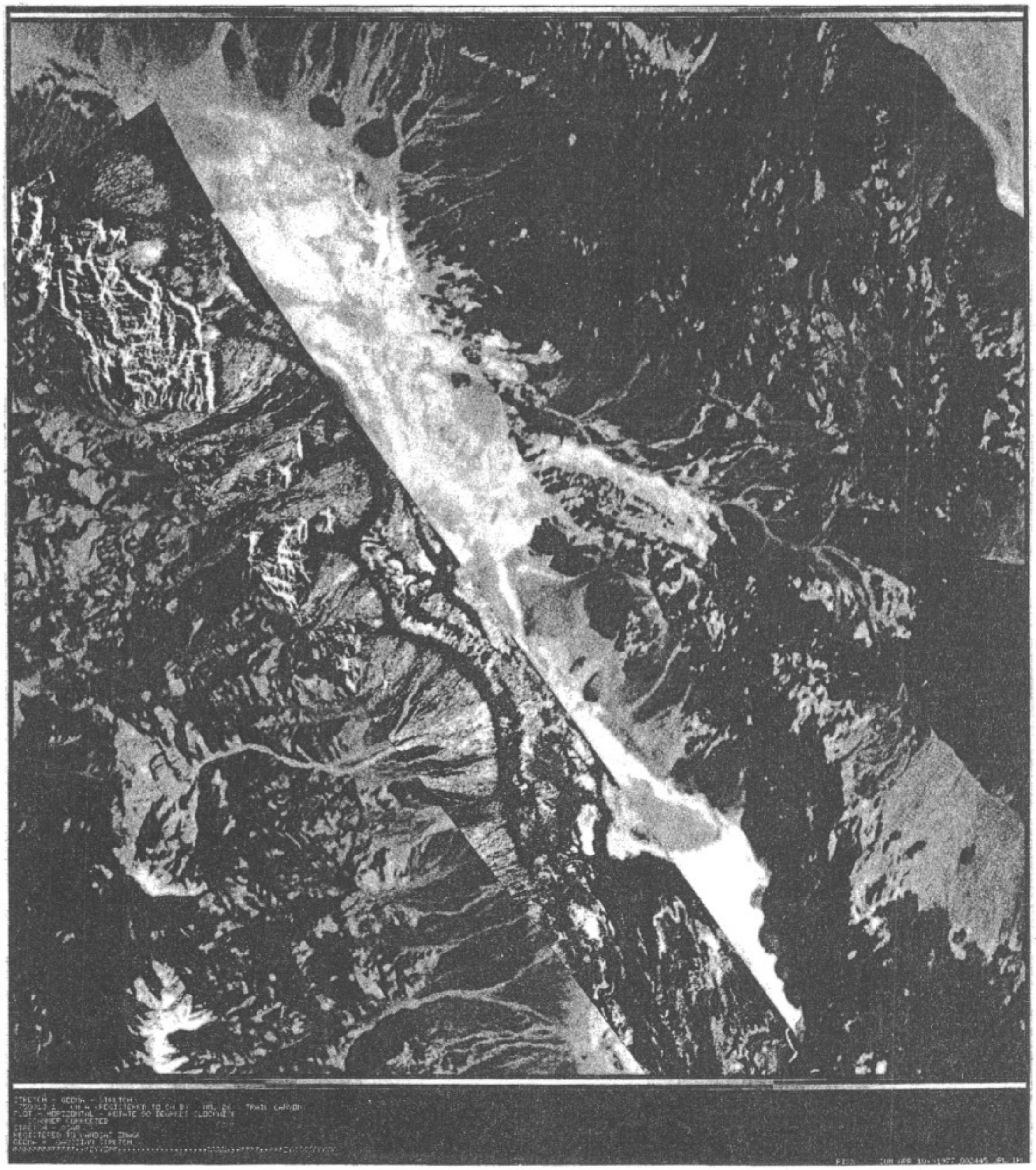

Figure 7. Registration of one swath of L-band Synthetic Aperture Radar imagery acquired by an aircraft-borne radar system with imaging data acquired by Landsat in the Death Valley area of California. One spectral band of the Landsat imagery is displayed.

Mr. Green is manager of JPL's Science Data Analysis Section. He received a BS in Applied Physics and an MS in Nuclear Engineering, both from UCLA. Prior to joining JPL in 1970, he was employed by Douglas Aircraft, North American Rockwell, and EG&G, where he performed analysis of the effects of atmospheric turbulence on the propagation of optical signals through the atmosphere. His section at JPL includes the Image Processing Laboratory. Current activities include processing of planetary imagery returned by the Viking and Voyager spacecraft, astronomical and biomedical image processing, and earth applications activities (including geology applications, land use studies and environmental quality tasks.) Mr. Green has taught digital image processing at California State University, Northridge and George Washington University. He is a member of the Optical Society of America.