

Ranger's Legacy

The benefit potential of aerospace spinoff is exemplified by the lengthening list of Earth uses for the space-developed art of image processing

You've seen the fascinating pictures of Jupiter, Saturn and Uranus, sent to Earth from distances up to two billion miles. No doubt you've also seen colorized versions of old black-and-white films, or *Titanic* at the bottom of the sea, or interior views of the human body taken by advanced diagnostic equipment, or images of Earth scenes showing details that could not be seen by the human eye nor captured by ordinary cameras.

They are all products of a common technology known as digital image processing, which involves the use of computers to convert sensor data into informative images. The term "processing" embraces not only the basic image creation but also a variety of computer techniques to correct sensor errors, change contrast, emphasize certain features, make measurements, clarify a point of particular interest, generally to improve and amplify the information that can be extracted from the image.

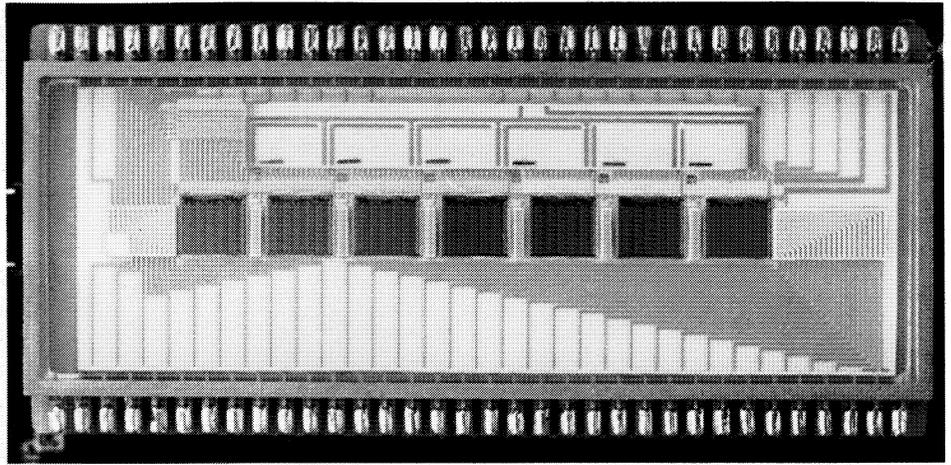
Although experimental work in computerized picture processing predated the start of the U.S. space program, it was a space requirement that propelled image processing from a collection of undeveloped ideas to a burgeoning technology in the early 1960s. Since then, NASA centers—in particular Jet Propulsion Laboratory—have led the way in developing the art of digital imaging processing and the companion technology of image enhancement.

It started with the Ranger program, a preliminary to the Apollo lunar landing missions. Ranger was an unmanned spacecraft designed to make a comprehensive photographic reconnaissance of the moon. Although the first six spacecraft were not successful, Rangers 7, 8 and 9, flown in 1964-65, achieved their objectives and re-



turned some 17,000 high resolution images. Composed of six TV cameras, the Ranger imaging system worked this way: Behind each shutter was a coated vidicon tube not unlike those of the commercial TV cameras of that day. When the shutter clicked, a moon image formed on the tube's face plate. The image was then rapidly scanned by a beam of electrons and converted to FM signals, then telemetered to JPL, where the picture was reassembled.

Ranger's camera systems, though the best available at the time, were subject to a variety of distortions—lopsided, stretched, too light, too dark images—and to contamination by the noise of the spacecraft's electronic equipment. Distortion correction and noise removal could have been accomplished—as the Soviets had done—by conventional photographic techniques, but JPL image data engineer Dr. Robert Nathan had a better idea: convert the Ranger analog signals to digital signals and use a computer for enhancing the images. Accordingly, he began developing what became the first operational digital image processing software.



At Jet Propulsion Laboratory (JPL), analysts are employing advanced computer techniques to enhance images sent to Earth in digital form by distant spacecraft. JPL's pioneering work in digital image processing laid the cornerstone for what is now an expanding industry.

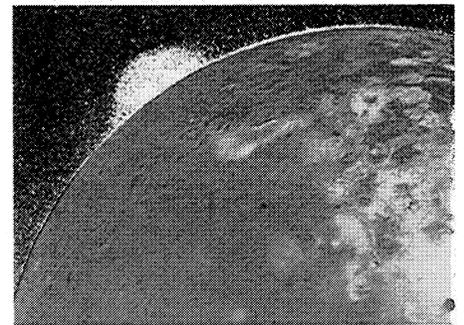
This is a hybrid "pipeline filter," composed of seven VLSI (Very Large Scale Integration) chips, for digital image processing. A new JPL development, the filter enhances images up to 200 times faster than earlier-used systems.

There was also a hardware need, a means of recording both analog video and digital images on film. No suitable commercial hardware existed, so JPL's Fred Billingsley designed a system called the Video Film Converter (VFC). Built under NASA contract by Link General Precision, the VFC was installed at JPL in 1963; much modified, updated and otherwise improved, it was used into the 1970s for digital image playback of the striking pictures returned by the unmanned planetary missions of the Mariner spacecraft. Thus, in terms of both hardware and software, JPL's work on the Ranger program was the cornerstone of what has become the sophisticated technology of digital image processing.

Over the years, there has been a steady stream of advances in digital image processing, necessitated by the advent of ever more sophisticated spacecraft sending immense volumes of image data from distances farther

and farther from Earth. When the sheer mass of incoming data threatened to overwhelm computer capacity, JPL developed a method of performing simultaneous—rather than step-by-step—image processing operations through application of VLSI (Very Large Scale Integration) circuitry. This "pipeline filter," first used to process Voyager 2's Uranus images in 1986, enhances images 50 to 200 times faster. Concurrent with the explosive growth of commercial computer capacity in the 1970s and 1980s, there were many parallel advancements in spaceborne imaging systems and in processing software, all combining to effect enormous gains in speed, efficiency and enhancement capability.

Inevitably, and with substantial assistance from JPL and other NASA centers, digital imaging technology began to spin off in new directions: to the field of medicine, which has been particularly receptive to space technology transfer; to the new art of Earth resources survey by remote sensing; to enhancement of motion pictures; to quality control systems in industrial plants; and to a variety of



When the Voyager spacecraft passed near Jupiter, its thermal mapping data revealed a heat source on the surface of the moon Io. Advanced image processing techniques developed by 3M Comtal enabled analysts to assemble this picture of the heat source and its "halo," a volcanic eruption spewing matter several miles.

other applications, some demonstrably practicable, some purely experimental, some promising but none yet fully commercialized.

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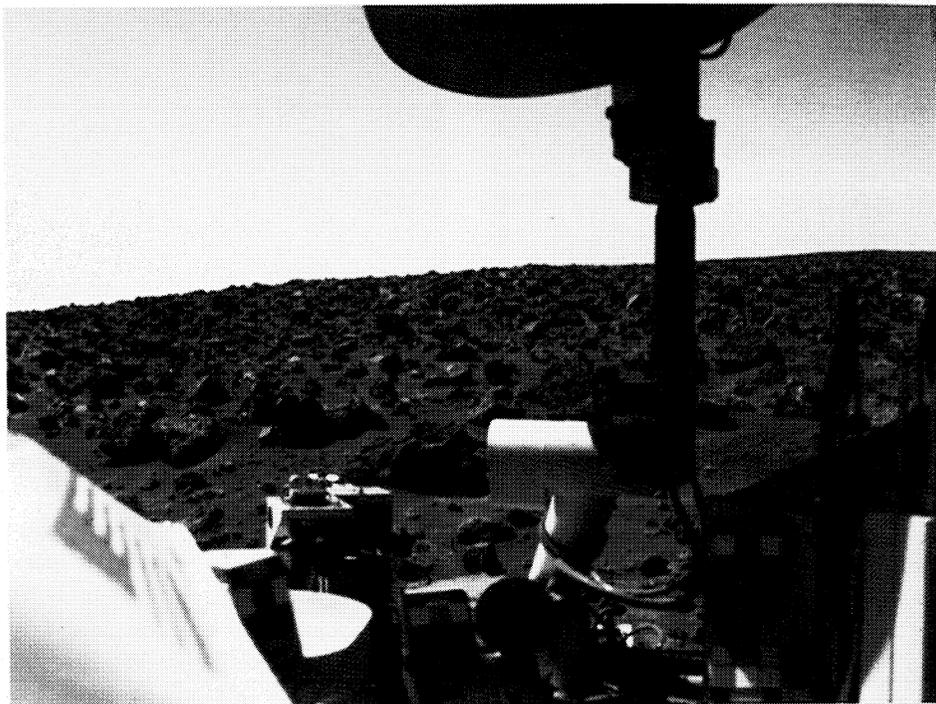
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The field of medicine proved to be highly receptive to transfer of image processing technology. And once again, it was Jet Propulsion Laboratory that pointed the way.

In the 1960s, JPL's Drs. Robert Nathan, Robert Selzer and Kenneth Castleman pioneered use of space-derived digital image processing techniques to enhance electron microscope, x-ray and light microscope images. This work sparked experimental medical applications by other organizations and emergence of a growing industry providing hardware, software and services for non-aero-space uses of image processing technology. Some of the companies were old-line firms that had worked with NASA from the earliest days. Others were new firms specially formed to commercialize the technology, many of them founded by former employees of NASA or space image processing contractors.

An example is Perceptive Systems Inc. (PSI), Houston, Texas, which was founded by Dr. Kenneth Castleman, who had worked on image processing at JPL for 15 years, and Don Winkler, who had served the same length of time at Johnson Space Center's Cell Image Laboratory. Many of the other PSI employees are former NASA image processing specialists.

The company's initial technology development was an extension of work in computerized chromosome analysis Castleman and others had started at JPL. The product of that technology is PSI's Genetiscan digital karyotyping system, a valuable aid to the cytogenetics laboratory. Cytogenetics is the science that deals with the relation of human cells—and the



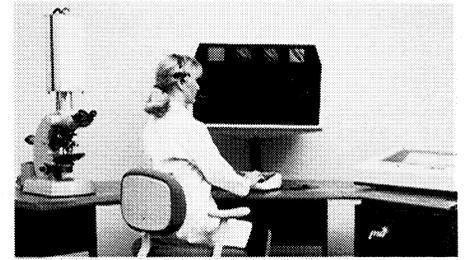
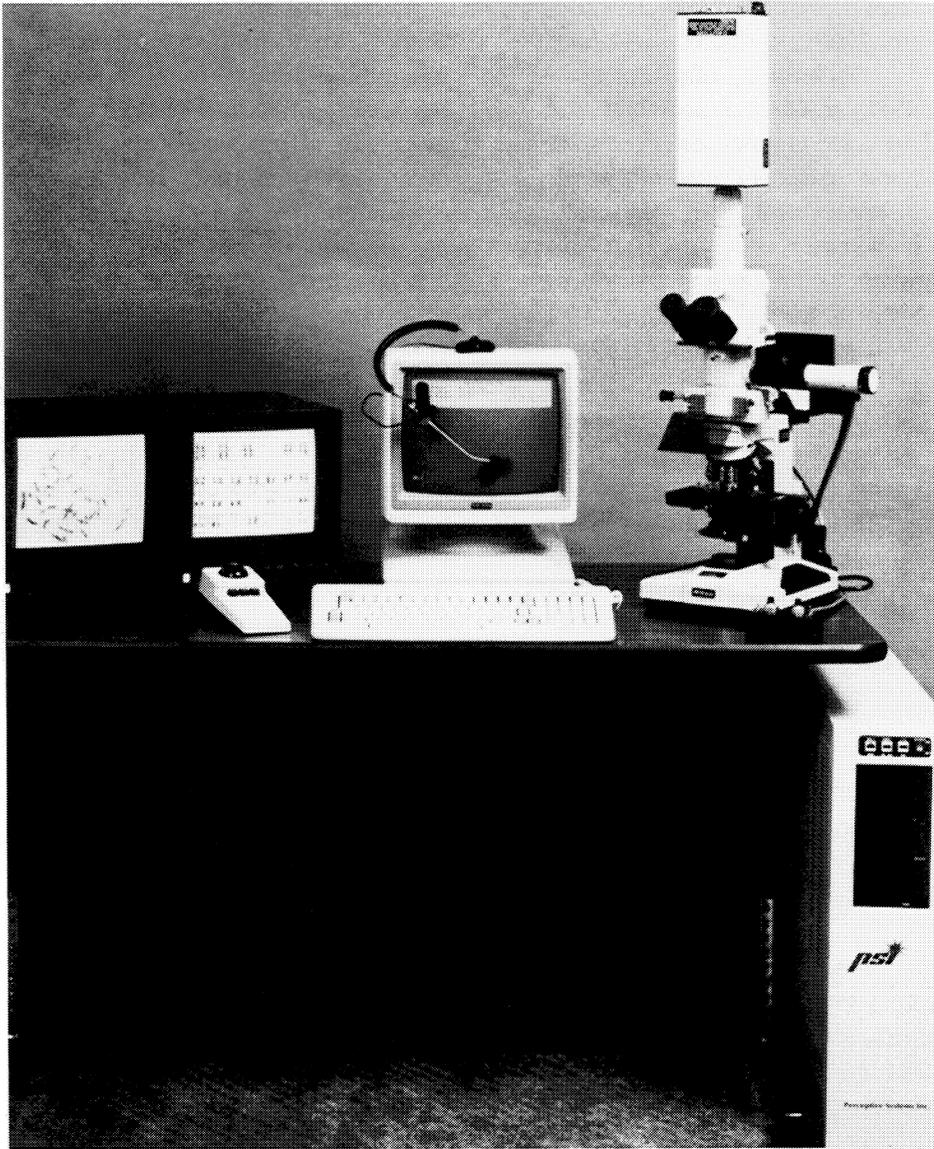
constituents of cells—to heredity. Such laboratories face a time-consuming bottleneck in the process called karyotyping, which involves analysis and classification of a set of chromosomes, the bodies within a cell which carry the genes that determine heredity. While the amount of information that can be interpreted from a karyotype has increased dramatically in the past 20 years, the method of preparing the karyotype has not. It consists of photographing the chromosomes through a microscope, then manually cutting and pasting the images to put together the karyotype classification.

The Genetiscan system eliminates the need for photography, including the hours of darkroom time, and the tedious manual assembly of karyotypes. It employs a video camera mounted on a microscope to capture chromosome images, which are then converted to digital form for processing. Genetiscan offers the ability to improve image quality; it can enhance

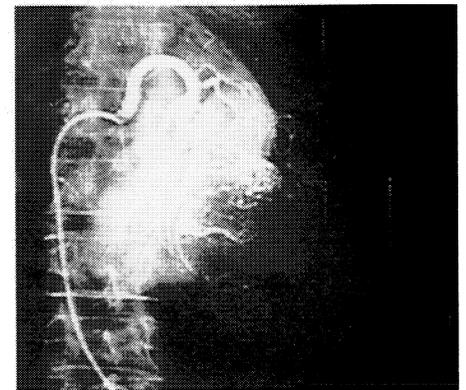
A famous view from space, a Viking Lander's "self portrait" against a backdrop of the bleak Martian surface. Note the color samples at center and right of the spacecraft; 3M Comtal image processing computers were able to balance the colors in the images they produced with the true values of the sample colors, thus providing an accurate coloration of Mars' surface.

the contrast of chromosomes, correct for shading in the microscope, and perform several proprietary PSI image enhancement operations. According to PSI, an experienced operator can produce a finished karyotype in less than 10 minutes. A big advancement that helps lower costs and increase productivity in the cytogenetics lab, Genetiscan is sold as a complete package that includes hardware, software and operator training. PSI also produces the PSICOM line of quantitative digital imaging systems (*see photo*) for industrial, scientific and clinical applications.

PSI is one of a growing number of companies producing image processing systems for an expanding range of medical uses. Among medical applications are computerized tomography



Perceptive Systems Inc. employed NASA technology in developing the Genetiscan system (left), a laboratory aid for study of heredity-related chromosomes. Genetiscan automatically processes a microphoto view of the chromosomes into a finished classification by size, shape, arrangement or other characteristics, providing big time savings. Shown above is the same company's PSICOM 327, a general purpose image processing system for medical, scientific and industrial uses.



(CAT) scanning, diagnostic radiography, brain or cardiac angiography, sonar body imaging, monitoring surgery and diagnostic nuclear magnetic resonance, a relatively new body scanning technique.

A special application of interest is the mobile diagnostic laboratory built by Remote Imaging Systems, a division of Portable X-Ray Labs Inc., Anaheim, California. Contained in a van equipped with a variety of processing equipment, the remote imaging lab is

dispatched to a site where an x-ray, ultrasound, electrocardiographic or other type of examination is required. The information acquired on film or hardcopy is digitized and sent over standard telephone lines to a diagnostic center, where a physician interprets the data, provides a written diagnosis and transmits it back to a computer printer in the lab—all within minutes. The system can transfer images between hospitals, clinics or other physician locations and it can be used to communicate with specialists for a second opinion.

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This is a view of a human kidney made clearer by an image processing technique known as digital subtraction, in which surrounding body tissues are removed from the image. The image can be further processed to isolate or highlight a region of special interest.

™ SDCIPS is a trademark of Unisys Defense Systems.

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With its Landsat satellites, development of sensors and advancement of processing techniques, NASA provided the initial technology base for another Earth-benefit application of image processing: Earth resources survey by means of remote sensing. The exceptional utility of this technology stems from the ability of sensitive detectors aboard satellites and aircraft to pick up radiations—light and heat waves—emanating from Earth objects. Since each object has its own unique “signature,” it is possible to distinguish among surface features and to generate computer-processed imagery identifying specific features of importance to resource managers. This capability offers practical application in such areas as agricultural crop forecasting, rangeland and forest management, land use planning, mineral and petroleum exploration, mapmaking, water quality evaluation and disaster assessment.

The major users of the technology have been federal, state and local governments, but it is making its way into commercial operations—for example, resource exploration companies looking for oil, gas and mineral sources and timber production firms seeking more efficient treeland management. Supporting both government and private users is a small industry composed of companies offering image analysis services and companies producing the processing hardware software. As is the case in the medical application, many of these companies are direct offspring of NASA's work.

An example is 3M Comtal, Pasadena, California, a subsidiary of 3M Company, which traces its lineage to

image processing research of the latter 1960s conducted by National Space Technology Laboratories (NSTL), a NASA center. NSTL was then—and is now—engaged in demonstrating the potential of remote sensing technology in a national interest effort to broaden the user base of space-acquired imagery. Among NSTL's needs was a processing system for an imaging spectrometer; such a system was developed for NSTL by Aerojet General Corporation.

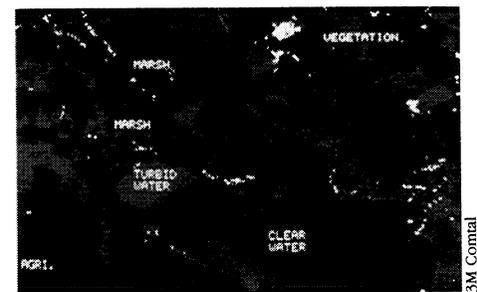
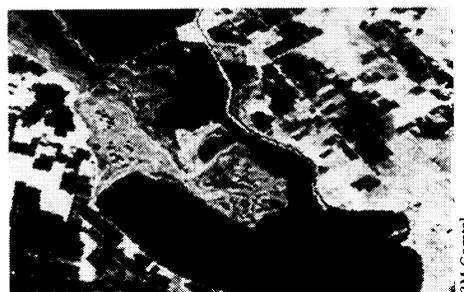
Aerojet, however, later decided not to put the system into production. John Tahl, who had worked for Aerojet on the development project, believed in the potential of the system and he left Aerojet to form a new company for further development and commercialization of the technology. Ever since, Comtal has had a strong supplier/codeveloper relationship with NSTL and, since 1975, a similar relationship with JPL.

These NASA relationships during the formative years of image processing technology gave 3M Comtal an early opportunity to establish a technology foundation, analyze the advancements that would be needed, and improve the capabilities of its systems. Today, 3M Comtal, whose equipment processed the exciting views of Viking on Mars and the Voy-

ager transmissions from Jupiter, is one of the leading companies in digital image processing. It is still serving the NASA centers and additionally producing image processing equipment used by customers in military, medical, resources management and meteorological applications.

Among other spinoff examples are cases where individual products, rather than whole companies, derived from NASA technology. System Development Group of Unisys Defense Systems, Camarillo, California has developed an image processing software package called SDCIPS™. The software has been applied in such diverse applications as military command and control, document image processing, geographic information systems and U.S. Postal Service video encoding research. SDCIPS consists of some 150 modules capable of performing digital filtering, contrast enhancement, surface illumination and contouring, image-to-image combining, color-space transformations and a variety of other operations. It is a direct spinoff of techniques developed by JPL for medical image processing.

The few companies mentioned are representative of a broader industry that bids to become significantly larger as new computer uses emerge and new applications of

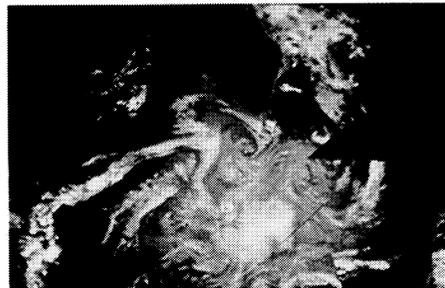


The unprocessed image of Matagorda Bay, Texas (left) shows little except where the land ends and the sea begins. But image processing through several stages produced the classification map above, identifying, in different false colors, the various types of land cover and water characterization.

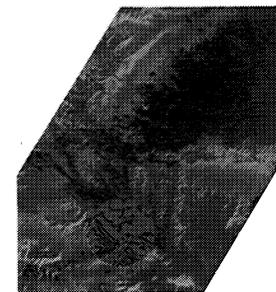
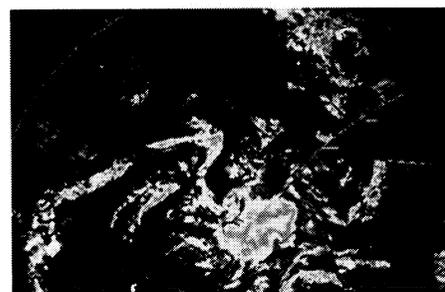
digital image processing become cost-effective. In addition to the uses described, image processing has applications in defense equipment, chemistry, cartography, manufacture of printed circuitry, metallurgy, ultrasonics and seismography.

The image processing story is an excellent example of the aerospace spinoff process. NASA development of the technology in two different but parallel directions—for planetary and Earth resources imaging—resulted in establishment of a new industry of impressive growth and exceptional potential, with attendant benefit to the Gross National Product and to job creation. Spinoffs like this one, whose benefits are valued in the millions, are not uncommon. In other cases, spinoffs generate only moderate economic gain but provide significant public benefit in other ways, ranging from simple conveniences to important advances in medical and industrial technology.

For more than a quarter century, under its Technology Utilization Program, NASA has been actively engaged in encouraging the secondary application of aerospace technology. During that time, literally tens of thousands of aerospace originated innovations have found their way into everyday use. Collectively, these spinoffs represent a substantial return on the aerospace research investment in terms of economic gain, improved industrial efficiency and productivity, lifestyle enhancement and solutions to problems of public concern. ▲



One of the latest advances in image processing technology is 3M Comtal's Visionlab II, for use with personal computers. Its advanced design provides capabilities and speed once available only on larger, costlier systems.



The satellite view of a hurricane at top gave meteorologists information as to the storm's size, strength and direction. But temperatures within the storm, obtained by processing infrared photography data to create the color-coded image in the lower photo, provided a clearer understanding of the storm.

A spinoff software package called SDCIPS combined satellite radar data with digital terrain data through a color-space transformation to produce this composite image in which the circular area highlights topographic contours.