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Stardust on the Bar: Space Fallout in Criminalistics

Gravity began to slacken its hold on man fifteen years ago, when Sputnik and Explorer 1 first succeeded in loosening the Promethean bonds that had been inviolate for perhaps five billion years. In orbiting and escaping Earth, we have again demonstrated the validity of the great physical laws of Kepler, of Newton, of Einstein. And, inevitably, we have also generated much new knowledge as we have launched satellites around our planet and flown men to the Moon and instruments to Venus and Mars.

Now that some of the technology developed in the wake of the solar wind has drifted back to Earth, we can begin to see traces of that fallout settling on the works of man, including the forensic sciences. But before we look at that technology, let us consider for a few minutes some of our accomplishments in space during the last one and one-half decades.

Certainly we have learned to work with awesome forces in penetrating beyond the immediate terrestrial environment. We have learned to build large rockets and to control the enormous thrust of millions of horsepower in accelerating payloads to orbit the Earth or to escape entirely the gravitational field of our planet. We have developed techniques to navigate these spacecraft to rendezvous with other bodies in the solar system at precise points in space. We have learned to design and build microelectronic circuits and computerized control systems of the highest order of reliability. We have also developed the capability for communicating with our spacecraft, to control their flight and to recover scientific and engineering data, out to millions of kilometres.

Following launch of the first instrumented Earth satellites in the late 1950's, we soon orbited men about the Earth in the Mercury and Gemini vehicles. It was intriguing to prove that men could survive the stresses of launch and the weightlessness of orbital flight. Meanwhile, the Earth was revealed from a perspective that had never before fallen within the view of man. The exhilaration of scientific achievement drew the peoples of the world closer together as they shared the unprecedented excitement of man in space.

In 1962, we were able to fly the first spacecraft to the vicinity of another planet when Mariner 2 approached within 34,000 kilometres of Venus and made three instrumented scans of the planet during a 42-minute encounter. Mariner found no measurable magnetic field or belts of trapped radiation. The clouds seemed to be cool and had no apparent breaks. The surface measured a lead-melting 800°F, probably a result of the "greenhouse effect" of the heavy carbon dioxide content in the clouds, which trapped the intense solar radiation.

Venus was revealed to be totally inhospitable to man with its exposure to solar energy, crushing pressure at the surface up to 100 times that at Earth's sea level, and a highly

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toxic atmosphere. These findings were largely verified by Mariner 5 in 1967, when it encountered the planet at 4000 km in altitude, some 80 million kilometres communication distance from Earth.

We began to look closely at Mars in 1964 and 1965, when Mariner 4 flew to the red planet. Like Venus, no radiation belts, magnetic fields, or trapped particles were found. The spacecraft took the first closeup pictures of another planet—22 photographs that covered about one percent of the surface. These pictures seemed to show an ancient plain heavily cratered, much like the Moon.

Mars was revisited in 1969 when Mariners 6 and 7 took over 200 photographs of the surface and gathered data that supported and extended the data of Mariner 4. The photographs revealed three types of terrain: heavily cratered Moon-like regions, unusual featureless areas in the desert of Hellas, and a type of wildly chaotic slumped topography never seen on Earth.

Meanwhile, the manned lunar exploration programs achieved the ultimate triumph when astronaut Neil Armstrong set foot on the lunar surface. This dramatic achievement captured the attention of the entire world unlike any other scientific event in history. Men on the Moon converted legend to fact, and added a note of credibility to Jules Verne. Certainly the benchmark dates of history must make room for 16 July 1969, when Apollo 11 touched down in the Sea of Tranquillity.

Five other Apollo missions landed on the Moon, culminating in Apollo 17, the last of the series, in December 1972. This was the third mission to carry a roving vehicle that enabled the astronauts to traverse several kilometres beyond the landing site of the mother craft.

How can we evaluate the true worth of Apollo? The six missions returned hundreds of pounds of lunar rocks and soil to Earth; the crews left a battery of on-surface instruments that will monitor and transmit lunar environment data of inestimable value in reconstructing the formation and development of the Moon, the Earth, and the entire solar system. But even more than the intrinsic value and scientific worth of the specimens brought back from the Moon, Apollo has demonstrated man's capability to dedicate himself to achieving the impossible in a project whose full value cannot even be properly assessed in this century.

With the termination of the Apollo program, man's adventures beyond Earth orbit have come to an end, perhaps not to be resumed with planetary visits until another decade, even another century. The emphasis for manned flight during the balance of this decade and that of the 1980's will involve the Skylab and Space Shutttle projects, which will demonstrate man's ability to accomplish sophisticated scientific missions in orbit. The Shuttle will significantly reduce the cost of orbital travel and will provide a base for future flights to the near planets.

Meanwhile, the unmanned mission of Mariner 9 to Mars in 1971–1972 raised the science of instrumented, automated planetary exploration to a new level. Whereas the 1964 and 1969 missions to Mars had been flyby encounters of very limited duration, the 1971 spacecraft was orbited around the planet and, during nearly a full year of operations, photographically surveyed the entire surface and made spectral measurements in the infrared and ultraviolet regimes. In addition, a continuing series of occultation experiments enabled scientists to refine highly the atmospheric model of Mars.

Mariner 9 was launched on 30 May 1971, and was placed into Mars orbit 167 days later. During its 349 days of operation, it orbited the planet 698 times and returned over 7300 pictures to Earth.

The mission of Mariner 9 has given us a new concept of Mars, one which summarily rejects the romantic notions of Schiaparelli and Lowell regarding the existence of structured canals and the works of a master race of intelligent Martian inhabitants. While we cannot categorically reject the idea of some type of life on the planet without landing on its surface, Mariner 9 shows us conditions that are, at best, inimical to the existence of terrestrial life forms.

Mars is also indicated by the data to be a live, dynamic planet, perhaps like Earth, with a molten core—one in which volcanic activity has been clearly evident in the recent geological past. Water vapor is identified at the polar regions and the planet is shown to have distinct traces of continents, what look like ancient ocean basins, and dried-up riverbeds. Vast stretches of canyons bear testimony to tectonic and erosional processes in past ages. One enormous canyon stretches a distance greater than the width of the U.S. and would dwarf our Grand Canyon on Earth.

Mariner 9, when it first arrived at Mars, encountered a global dust storm of a magnitude and wind velocity almost inconceivable on Earth. Although it was feared that the dust might ruin the photographic mission, it cleared in a few weeks and we had a completely successful mission.

Mariner also photographed Phobos and Deimos, the two satellites of Mars, named for the grooms of the war god. These two small moons orbit the planet at 6400 and 19,300 km, respectively, and have been heavily battered by impact collisions. Never before have the satellites of another planet been photographed by man-made instruments at close range.

Closer to Earth, space technology has been applied through the weather and communications satellites, and the new Earth Resources Technology Satellite (ERTS) program. Weather forecasting and communications techniques have made quantum jumps over the horizon since the inception of these orbital programs in the mid-1960's. ERTS holds spectacular promise as a tool for the surveying and inventorying of agricultural crops, animal herds, schools of fish, forest reserves, and the status of the world's natural resources—all through infrared photography and complex sensing instruments. These satellites will enable man to learn more about his own planet in the next decade than in all of his earlier history.

Although science and technology have been very active in space for the past 15 years, where do we see the impact in the forensic sciences? Most of the work up to the present of applying space related technology to forensics has occurred in criminalistics, with some in toxicology and medicine. Much work has been performed at the Jet Propulsion Laboratory (JPL) in Pasadena, where we have been actively engaged in seeking to transfer what we have learned in space to the civil sector during the past five years.

In the case of forensic science, the transfer process has involved both the introduction of new technologies for investigative purposes, and the development of techniques to increase the efficiency of the laboratory in its existing activities. Most of the new systems are computer based, not only for data storage and retrieval, but also for analysis and system control. Let us look at some of these techniques we are working on at JPL.

Thermoluminescence, presented at the 1972 Meeting of the American Academy of Forensic Sciences, is a new tool for determining the commonality of origin of evidence materials. It should be useful as a supplement to other methods of identification. The phenomenon involves light emission by certain materials when heated to temperatures below incandescence after exposure to ionizing radiation under controlled conditions. At high temperatures, it is observed in such nonmetallic materials as soils, minerals, salts, glass, ceramics, and plastics. At low temperatures, it can be seen in ice, frozen solutions, and organic compounds.

Thermoluminescence can be plotted in terms of temperature-versus-light intensity to yield glow curves of a piece of evidence from the scene of the crime for comparison with an exemplar to determine the degree of match. The glow curve can be digitized and the data entered directly into a computer, where they can be quantitatively compared with curve data from other samples.

One of the more spectacular spinoffs from space technology, as applied to photographic surveillance, has been the use of film scanning and digital computer processing techniques to improve the geometry, photometry, contrast, and resolution of pictures of the Moon and Mars returned to Earth by Ranger, Surveyor, and Mariner spacecraft systems.

These techniques have also been applied to the enhancement of medical X-ray films and biological microphotographs, often yielding dramatic improvement for diagnosis and identification. There is strong evidence that enhancement techniques can be adapted to improve the quality of photographic evidence, including such images as latent or poorly inked fingerprints, document alterations, and surveillance camera pictures.

A 1969 JPL study demonstrated computer methods to bring out latent images and to enhance the quality of poorly inked fingerprints submitted as evidence. A slope detection routine was described that could readily recognize the successive ridge-and-valley structure and the minutia information that is inherent in all fingerprints.

These image enhancement techniques could be of considerable use in criminalistics as their methodology is improved and their admissibility as evidence is more widely accepted.

Work to improve the efficiency of laboratories is typified by a system with the capability of automated examination and characterization of bullets for firearms identification, a field in which there has been little measurable technical growth. No current universal factual basis was found for establishing the identity of a firearm. This project investigated the reproducibility of most of the class characteristics and striations of bullets fired from the same firearm and some of the problems with methods used to obtain a profile. For example, scanning electron microscope examination showed that surface profiler measurement techniques seriously deform the bullet surface.

Certain class characteristics of bullets can be acquired by appropriated digital techniques. In the proposed automated system, these characteristics would be processed and encoded for search purposes. Comparison of these characteristics and of the striations would be done by computer match.

One of the most pressing problems now facing the criminalist has been that of identification of narcotics and drugs in blood and urine samples. The requirements for such a system were reported to this Academy at the 1971 meeting, and we are continuing to work on a fully automated drug identification system.

Another dimension in the improvement of efficiency would be provision for a continuing interchange between crime laboratories and centers of high technology in an educational sense.

In 1969, the Academy and the California Association of Criminalists recognized the need for training in analytical techniques and familiarization with newly developed instrumentation and methods. Accordingly, a three-day seminar in May 1970 addressed the primary objective of providing forensic scientists and technicians with knowledge of the potential value of advanced analytical instrumentation and techniques, as developed and applied in the space programs.

The seminar program covered a wide range of subjects: X-ray diffraction and fluorescence as analytical tools, use of the electron probe for qualitative analysis, nuclear magnetic resonance as applied to barbiturates, thermal techniques in identifying and characterizing materials, application of gas chromatography and mass spectrometry to criminalistics, advances in ultraviolet and infrared spectrometry, potential of the scanning electron microscope in criminalistics, potential of the computer in forensics, and image enhancement through application of the computer to fingerprint analysis.

In a 1971 case involving the murder of a teen-age girl in the Antelope Valley in California, computer analysis was instrumental in placing a second suspect at the scene of the crime. The suspect had claimed that, although at the scene, he had not been closer than 12 ft from the site of the struggle. The discovery of a second shoe print, distinctly different from the size 9½ shoe worn by the already convicted murderer of the girl, had reopened the case. The problem was to accurately determine the relationship of the print to the suspect's shoes.

Working with a photograph of the prints, it was possible to construct a curve for the imprint. Using shoes of similar style, but varying in manufacture and size, a series of coordinate readouts was obtained to produce a corresponding curve for each. A computer then compared the information for each shoe against the unknown shoe print, enabling the prosecution to conclusively place the suspect close enough to the crime to have participated in it. He was found guilty of voluntary manslaughter and sentenced to 15 years in a state prison.

Work in the application of these techniques to criminalistics has not been limited to space laboratories. The principal contributions of the space program have been implementing reliable, miniaturized, field-worthy instruments, and in using computers extensively for data processing and instrument control.

We have looked at some of the potentialities for the transfer of techniques and instrumentation involving high technology to the more effective application of the forensic sciences, particularly in criminalistics. But, spectacular as are these achievements, even in their formative years, I would suggest that space and its defense counterparts offer another discipline that may be even more important over the years in the continuing development of the forensic sciences: the techniques of systems management.

In order to better understand the importance of the systems approach, we must look back to the 1940's, at the onset of World War II, to the establishment of a supreme national effort to develop an atomic bomb capability, and to design and manufacture the materiel of war on a scale never before approached.

This management technique required the melding of many, often diverse, technical and professional disciplines, and their integration into a smoothly functioning team to achieve a common goal. This approach usually involved projects of overriding national importance, expending massive resources against an inflexible time schedule. Implementation of such demanding tasks required the merging of the broad, interdisciplinary talents of scientists, engineers, and managers in the theoretical, experimental, and applied sciences, with the skills required to integrate, control, and schedule project activities so as to meet the objectives.

Through such an approach, we were able to build an atom bomb, manufacture vast quantities of airplanes, tanks, and submarines, and land men on the Moon before the end of the decade of the 1960's. The performance was truly impressive in the accomplishment of national objectives under heavy stress.

But, how does all this relate to the forensic sciences? I should like to suggest that there is a very real corollary with the techniques of systems management. The disciplines represented by the different sections of this Academy would seem to have few areas of commonality, other than their application in the courtroom. In that, they very much resemble the many dissimilar capabilities required to launch Saturn 5 from Cape Kennedy.

Like aerospace, the forensic sciences combine multiform disciplines, each of which discharges a function of great importance when called upon to establish the truth before the bar. Like aerospace, forensics offers an excellent opportunity for the application of systems techniques.

There are two ways in which this approach may be useful to the forensic sciences. One is within a specific discipline, such as criminalistics, where, for example, there are undoubtedly benefits that can be achieved through organizing for common goals, such as standardization of procedures and reports, commonality of data bases, mutual interchange of information, and development of educational training programs. The second would be an effective interchange among the different disciplines represented in the Academy, involving the organization and direction of diverse talents and capabilities so that each provides that which is necessary to bring a case to investigation and trial, and no more.

As a matter of fact, the systems approach should be applied to the criminal problem on a much larger scale than the forensic sciences. Viewed in this light, the forensic sciences are a subsystem in the total criminal system. If I may make an analogy with the Apollo program, the forensic sciences are equivalent to the data collection and analysis subsystem. This is an essential subsystem, but one which must be integrated into the total system. Unless it is so integrated, it is little more than an academic exercise.

It seems to me that if we are really to take advantage of this space developed systems approach to problem solving, we must recognize that the criminal system includes at least five other subsystems: the criminal as an individual, the courts, the correction system, the law, and society as a whole. An attack on the problem would require participation of all of these subsystems in an integrated team activity. I recognize that this is easier said than done, and that the Apollo problem, involving primarily physical hardware, was a much easier problem than the criminal problem which involves primarily human beings. However, I believe that the nation will make progress in this and other social problems when it takes seriously the statement: "We can go to the Moon, why can't we solve this or that problem?."

Now, let us return to the more limited problem of the forensic sciences. We have talked at some length about the transfer of the considerable body of new technology that has originated in space research and its integration into the component sciences and professions of forensics. The germane question is: Just how do we go about effecting this transfer with the greatest benefit to the forensic disciplines?

The transfer must be a two-way process; it requires a determined and organized effort by those who have acquired that experience, as well as a receptive posture among those elements of the forensic community who stand to profit the most. In other words, there must be a strong and continuing commitment on both sides of the equation.

Forensic scientists must put aside today's fire drills and find time to worry about tomorrow's floods. Although they must learn to work together to achieve common goals, they cannot accomplish these goals as individuals. Only a disciplined organization can take a firm stance in the achievement of a meaningful goal.

So organized, the Academy can look to the development of nation-wide, joint-venture laboratories that would help to promote standardization and accessibility of uniform data bases, the capability for remote analysis, and improved education and training. Commensurate with this would be the ability to support resource centers which could provide the facilities for higher order analysis.

It is conceivable that, by bringing to bear all of the impressive resources of the forensic sciences in an organized environment—one receptive to the technology transfer process, particularly the general introduction of the computer into the laboratory—the judicial process can be significantly improved in a society where the statistics of crime are increasingly appalling.

Space fallout on the bar then becomes more than mere stardust. It becomes a meaningful body of innovative technology against which the forensic sciences can construct a dynamic future for the profession in the application of the law to a troubled scociety.