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MANAGEMENT SERVICES OFFICE

OUR INVESTMENT IN SPACE TO BRING MANIFOLD RETURNS

By

Science and Technology Section
Space Systems Information Branch

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I. INTRODUCTION

Recent critics tend to reduce the practical values, benefits, and by-products of space exploration to cigar sorting machines and filament wound brassiere supports. Although such by-products are comparatively trivial, and some of the examples contained in this document are rather trivial if separated from their context, they are nevertheless good evidence of the far-flung ways in which missile and space technology influences our lives.

A report by the Denver Research Institute at the University of Denver documented 185 carefully screened examples of such by-products, including the two mentioned above.* Actually, however, the new or improved produce is only a small, a very small, part of the over-all benefits of the space program. The by-product, perhaps, is frequently used in speeches and in mass communication media to illustrate the benefits of space exploration simply because it is comprehended more readily than the technical advances in, for instance, magnetohydrodynamics. In addition, it is far too early in the space program to estimate the worth of the by-product; it is difficult even to identify the by-products because a time lag exists between innovation and production and from production to commercial importance. According to the Denver Research Institute report, S. Colum Gilfillan, author of The Sociology of Invention, studied a group of 19 inventions that were selected in 1913 as the most useful ones of the preceding quarter century. He found that the geometric mean interval between the year during which the invention was first proposed and the year during which the first model or patent appeared was 176 years; that the geometric mean interval between the first model to the first commercial use was 24 years; from the first commercial use to commercial success, 14 years; from commercial success to important use, 12 years. Clearly, it is far too early to evaluate the by-products of space research, although Gilfillan's time lags have probably been shortened in recent years. The best that can be done at present is to give examples of such by-products.

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*Allied Research Associates, Inc., by making use of knowledge of solid state physics and printed circuitry gained in missile and space programs, developed a colorimeter that automatically sorts cigars for uniformity of color; a similar device will be used to monitor the color of cloth during dying processes. Lamtex Industries, Inc., developed the filament wound brassiere support as a by-product of missile and space filament winding work; the supports are used by many manufacturers to replace conventional metal supports.

The transfer, or diffusion, of missile and space technology to industrial applications is possibly more important to the economy than all of the specific by-products, although this process is extremely complex, broad, indirect, and difficult to identify. This aspect of the benefits of space research is discussed briefly in several of the sections that follow, in relation to particular topics.

As Hugh L. Dryden wrote in The National Significance of the Augmented Program of Space Exploration, "While the technological developments offer the earliest contributions to economic development, in the long run the contributions from the scientific knowledge obtained in the great unknown environment of the celestial bodies and interplanetary space may bring much greater returns. Today not only the prestige of a nation but also its true greatness and strength depend upon mastery and control of man's physical environment; and the extension and perfection of scientific knowledge is fundamental to that mastery and control. What benefits the new knowledge of the universe may ultimately bring to mankind no one today can predict. Judging from past experience, advances in scientific knowledge are the foundation of advances in technology and advances in technology are a key factor in economic development."

In the same document, Mr. Dryden stated, "Because of the newness of the space age, it is difficult to give specific examples [of benefits] at this early date. It is easier to recognize this process in relation to the automotive age, the air age, and the nuclear age. For example, the development of the automobile has brought us the concept of simplification for the operator through complication of design, a concept now widely applied in the operation of a modern steel mill or oil refinery and in such modern consumer products as automatic washers and ovens, where automatic controls program the entire operation. The automobile is largely responsible for the development of alloy steels, new fuels, synthetic rubber, quick drying finishes, and other new materials."

It is useful to ask here, "What was responsible for the automotive age?" Of course, the development of the internal combustion engine was necessary. But, ultimately, to what innovation can the internal combustion engine be traced? To the discovery of gun powder, the first "high energy" fuel, would probably be a good answer. The cannon, which can be traced as far back as 1327, is really a simple one-cylinder internal combustion engine. Leonardo da Vinci was the first to substitute a piston for a cannon ball. Leonardo's engine used gun powder for fuel, and so did a similar device that was patented in 1661, and so did other similar devices on down until the nineteenth century, when liquid fuels were substituted for powdered fuels. Which "innovation" deserves credit for the millions of automobiles that are now almost necessary in our daily lives? If the truth were known, Henry Ford might deserve as much credit as anyone else, not because of technical innovations, but because of an economic manuever. He had the insight, and the guts, to pull his company out of an economic slump not by raising the price of his product, but by lowering the price and thereby reaching a much larger market. The automobile would have come in full force sooner or later, but Ford's economic manuever greatly accelerated its mass production.

What Ford did for the automobile industry, the space program is doing for a number of other industries. It is providing a market for many products and materials that were previously not economically feasible for use in general industrial applications; as the space program provides a market, the manufacturer can take advantage of mass production to lower the price, thereby enabling his product to reach a much larger market. The cryogenics industry, which is discussed in Section II. G, is a good example of this aspect of the economic stimulus of the space program.

Even if all other scientific, technological, and economic benefits of space research are disregarded, the performance of our weather and communications satellites is pretty good evidence that our investment in space will pay off. The discussions of the benefits made possible by satellites (Sections II. A and II. B) were originally published in Space Information Digest, and no attempt has been made to bring the articles up to date because discussions of this nature will probably always be behind latest accomplishments. These articles do not reflect the accomplishments of Nimbus or Syncom III, which is expected to televise the Olympics from Japan to the world. Since the communications article was first published, Comsat Corporation has become a legal entity. In June, 1964, common shares were offered to the public through the over-the-counter market. In September, 1964, Comsat was listed on the New York Stock Exchange. Comsat hopes to have its two-satellite, 480-channel Early Bird communications system in operation during 1965.

The influence of the space program on selected topics or general technological areas is discussed in Section II, and brief historical perspective has been attempted. The principal sources of the material presented are cited at the end of each discussion. Because the topics that are discussed have been selected almost at random, a list is provided of topics that could have been treated. Selectivity has been required even in the list. Archaeology, for instance, has not been listed, although it is believed that archaeology will benefit from topographical studies of Earth made by satellites. To include all such topics would require a very long list, for almost every aspect of human endeavor will be influenced in one way or another by space exploration.

II. THE INFLUENCE OF SPACE EXPLORATION ON WIDESPREAD TECHNOLOGY

A. WEATHER FORECASTING

Only one-fifth of the globe is covered by conventional weather observational systems. There are extensive areas in which undetected hurricanes and typhoons can begin and grow. Meteorological satellites are filling the gaps in the weatherman's chart. Tiros satellites have spotted hurricanes whose existence and early formation could not have been detected by any other weather observation means.

On September 10, 1961, Tiros III, the "Hurricane Hunter," detected Hurricane Esther as it was forming in the mid-Atlantic. Information from Tiros III gave warning of Hurricane Carla in time to make possible the largest mass evacuation ever to take place in the United States; more than 350,000 people were able to flee from the path of the storm. Subsequently, a relatively small number of deaths were attributable to Carla. In the Atlantic, Tiros III photographed five hurricanes and one tropical storm; in the Pacific, two hurricanes, one tropical storm, and nine typhoons. More recently, the unusual Hurricane Flora was discovered in the nick of time by a Tiros satellite. Flora struck the island of Tobago barely 3 hours after it was reported.

Savings from meteorological satellites have been large, not only in human life, but in dollars and cents. In the future these savings will be even greater. President Lyndon Johnson, former chairman of the National Aeronautics and Space Council, has cited the following estimated annual savings that would be realized from the accurate prediction of the weather only 5 days in advance:

$2.5 billion to agriculture

$45 million to the lumber industry

$100 million to surface transportation

$75 million to retail marketing

$4 billion in water resources management.

The cost of orbiting meteorological satellites that make such benefits possible is not unreasonable when the area they cover is considered. A weather ship of the type currently used in the North Pacific can observe an area of about a 30-mile maximum radius. Such ships cost about a million dollars yearly to be maintained and operated, and this does not include their initial cost. A weather satellite and its launch operation cost about 4.5 million dollars. This is extremely economical, considering the fact that a weather satellite can observe, in each photograph it takes, an area of approximately 640,000 square miles and that it can photograph many areas of Earth each day.

The first step toward an operational satellite weather observation system was made with the launching of Tiros I on April 1, 1960. Within 60 hours after Tiros I orbited, its reports were being applied to day-to-day weather forecasting. Since 1960, seven Tiros satellites have been launched, and several more are planned.

The Nimbus series of satellites is next in NASA's weather programs. Although the Weather Bureau has recently dropped Nimbus because of its short operating time in orbit, NASA will continue the program on a research and development basis. Nimbus will be launched into a north-south polar orbit, thereby allowing it to observe almost every spot on Earth once every 12 hours.

The Aeros satellite will follow Nimbus. Tentatively scheduled for 1966, Aeros satellites will be placed into "stationary" equatorial orbits. Because they will appear to be fixed with respect to a point on Earth, Aeros satellites will be able to scan both hemispheres constantly. Dr. Fred Singer, Director of Satellite Programs for the Weather Bureau, has pointed out some possibilities of weather satellites that offer great promise. For example, photographs of the ice in the St. Lawrence Seaway obtained by Tiros satellites have demonstrated that it is feasible to make large-scale surveys of ice fields. Such surveys could result in great savings in the efficient use of ice reconnaissance aircraft and icebreaker vessels. A joint study made by the US Weather Bureau and Canada indicates that accurate satellite observation of the ice field in the Gulf of St. Lawrence alone offers potential savings of $1.7 million a year. Dr. Singer explained that if the satellite photographs show that the ice is completely fast and not breaking up, or if it has cleared out, there is obviously no reason to send reconnaissance craft or icebreakers. One of the most unusual applications of weather satellites was reported by the London headquarters of the Desert Locust Information Service. Information from Tiros satellites has made it possible for meteorologists to project with great accuracy the course and direction of insect swarms over wide areas in Africa and Asia, where insects are a great threat to crops.

In addition to immediate practical benefits from weather satellites, weather programs are providing data that will help man to understand Earth's atmosphere and the relationship of atmospheric phenomena. After man fully understands the weather, he may be able to control it. Even limited control of rainfall, storms, and tradewinds would bring inestimable benefits to mankind.

(Principal Sources: Civilian Dividends from Space Research, Edward Gottlieb and Associates; NASA News Release, September 26, 1963; NASA-Industry Program Plans Conference, February 11-12, 1963.)

B. COMMUNICATIONS

"It would be a mistake to minimize the technical problems of establishing a communications satellite system . . . but equally great are the incentives to get the job done," said Leonard Jaffe, Director of Communications Systems, Office of Applications, NASA. "Short wave radio circuits across the oceans depend on radio reflection from the ionosphere and are of extremely poor quality. These sometimes fail completely. Submarine cables are greatly superior in quality, but lack the broad band or large capacity of the future."

In 1960, there were over 3 million overseas telephone calls, and it is expected that there will be over 21 million in 1970. Existing and planned undersea cables and high-frequency radio installations will not expedite the heavy communications traffic of the future, and current overseas communications facilities have no capability for transmitting television.

In May 1946, Project RAND recommended design of an "experimental world-circling spaceship" that could serve as a communications relay station. Since then, the use of satellites in communications has received international enthusiasm. Auditory, visual, and "instant mail" communications between all parts of Earth promises to be one of the greatest of all benefits from space research.

Two types of communications satellites are possible. One type is passive: it acts as a radio mirror to reflect signals transmitted by one ground station to another ground station. The other type is active: it contains electronic equipment to receive, amplify, and retransmit signals. NASA communications programs include both active and passive satellites.

The first passive communications satellite was Echo I, a 100-foot metalized balloon launched by NASA in August 1960. Many successful transcontinental and transoceanic experiments and demonstrations were conducted with Echo I. Because its inflating gas has escaped, however, Echo I has lost much of its effectiveness as a radio reflector, and its surface has become wrinkled. NASA is developing a larger passive reflector satellite, Echo II, which is 135 feet in diameter and is made of a heavier, stiffer material so that it will retain its shape and its reflecting capability even after the inflating gas has escaped.

The era of active communications satellites began in 1958, when the SCORE satellite transmitted to the world a Christmas message from President Eisenhower. In 1960, the United States launched its second active satellite, Courier, a "delayed repeater" satellite that received a message from one ground station and later retransmitted it to another.

The third active repeater satellite, Telstar I, was built by AT&T and launched by NASA in July 1962. Telstar I enabled US and European television networks to exchange live programs for the first time. Telstar I was used for numerous engineering tests and public demonstrations, but radiation damaged its command circuits after 6 months of operation.

Telstar II was launched on May 13, 1963. It differed from Telstar I in that some of its electronic equipment was redesigned for greater resistance to radiation damage, its instrumentation and telemetry were expanded and changed, and its orbit had a greater maximum altitude.

On December 13, 1962, NASA launched the Relay satellite. The broad international interest in communications satellites is illustrated by the extent to which other countries are willing to fund ground facilities for experimental purposes. Stations in the United States, England, France, Italy, and Brazil are operational. Stations in Germany and Japan should be operating in 1964. Several other nations, including the Scandinavian countries, Canada, and India, have indicated interest in providing ground stations for communications satellites.

NASA's most ambitious undertaking in active satellites is Project Syncom, a program to place active repeater satellites in synchronous orbits. There are two principal advantages of a synchronous satellite system: (1) simpler ground stations, despite ground stations, despite the satellite's greater distance from Earth, and (2) the ability to cover most of Earth's surface with three satellites.

Syncom I was launched from Cape Canaveral on February 14, 1963. The launch was nearly perfect, and the satellite was placed in an elliptical orbit having a peak altitude of about 22,300 miles. At that point, the on-board rocket was fired, adding enough velocity to keep the satellite at the synchronous altitude. During the 5 hours it took for Syncom I to reach the 22,300-mile altitude, the communications equipment was checked out with satisfactory results. Approximately 20 seconds after the on-board rocket was fired, however, all signals from the spacecraft ceased, and Syncom I has remained silent since then. It has been established through telescopic observations that Syncom I is in an orbit with a period of nearly 24 hours.

Syncom II was placed in a near-synchronous orbit on July 26, 1963. The spacecraft's performance was excellent, and the communication system is performing as expected.

NASA is conducting preliminary studies on a more advanced version of Syncom, which would be a truly equatorial or "motionless" satellite. It would also have capability for simultaneous use by a fairly large number of independent ground stations without mutual interference. A multiple access capability would make possible the participation of a larger number of ground stations in a single communications satellite system.

In 10 or 15 years, it will probably be practical for broadcast satellites to retransmit radio or television programs directly to individual home receivers. Not only television and radio but all modes of communication will benefit from satellites. For instance, on August 22, 1962, the International Edition of New York Times contained articles (about 5000 words) that were transmitted from New York to Paris via Telstar I, and, on April 25, 1963, Relay satellite was used to transmit electroencephalograms from Bristol, England, to Minneapolis, Minnesota.

The exploitation of the laser as a communications transmitter is receiving much attention. Theoretically, one beam from a laser can carry as much information as 25,000 of our present television channels. The use of helium-neon gas lasers for transmitting television pictures was demonstrated recently at North American Aviation's Space and Information System Division. The new system is reported to have the potential of sending television pictures from deep in space.

It is probable that communications satellite technology will provide communications to are not served by other means, either because of their isolation or because their volume of communication does not justify economically conventional communications service. As President Kennedy said in a public statement, "There is no more important field at the present time than communications, and we must grasp the advantages presented to us by the communications satellite to use this medium wisely and effectively to insure greater understanding among the peoples of the world."

(Principal Sources: NASA-Inudstry Program Plans Conference, February 11-12, 1963; Proceedings of the Second National Conference on the Peaceful Uses of Space, May 8-10, 1962; Communications Satellites, Presented by Leonard Jaffe at First World Conference on World Peace Through Law, June 30-July 7, 1963; A Chronology on Communications Satellites, Comment Edition, NASA, May 1, 1963.)

C. TRANSPORTATION

General James H. Doolittle predicted that in the not too distant future we can fly from Los Angeles to New York in half an hour, or from Los Angeles to Paris in one hour.

Space research has given tremendous impetus to aeronautics. The high performance and reliability demanded by spacecraft will result in vast improvements in many flight components, including the instruments and radar equipment of commercial aircraft.

Now in the proposal stage are new supersonic transports that are based partly on the results of X-15 research planes and other advanced aerospace craft. The influence of space research will become even greater in the future. "Aircraft manufacturers," said J. R. Dempsey of General Dynamics/Astronautics, "are already beginning to think of boosters and launch vehicles as the trucks of space. In the next few years, improved air traffic, navigation, and control devices will also be developed, and these will be based in large degree on navigation satellites and on radio and inertial guidance systems originally built for missiles."

NASA is devoting considerable effort to supersonic transport, hypersonic aircraft, and V/STOL research. Last year, NASA allocated approximately $ 45 million specifically for aeronautics studies, plus additional sums for more fundamental research applicable to both space and aeronautics.

Two forthcoming aircraft, one civil and one military, show the importance of NASA's aeronautical studies. NASA's work on variable sweep wings made an important contribution to the development of the F-III (TFX) tactical fighter to be used by the Navy and Air Force. NASA's work on Mach 3 aircraft (including studies NASA sponsored with aerospace companies) is a major reason why the Federal Aviation Agency asked industry for proposals on a supersonie transport for airline use in the 1970s. Other examples of NASA's research in Aeronautics include the testing of new concepts for vertical and short takeoff and landing aircraft, studies of possibly better aviation fuels, and studies to lessen the noise made by jet-powered aircraft.

An outgrowth of aerospace research is the Posifix Rescue System, which was developed by the Douglas Aircraft Co. This system uses radio signals to fix accurately the location of downed pilots up to a distance of 150 miles.

The Minneapolis-Honeywell Regulator Co. announced a new pushbutton autopilot for light business aircraft. The system, based on principles derived from research in control of space vehicles, makes it possible for an inexperienced pilot to fly as smoothly and safely as a professional. The feature of the autopilot, as applied in the hypersonic X-15, is a computer than adapts automatically to compensate for such flight conditions as speed, altitude, weight, and wind gusts.

Navigation will be revolutionized. The Transit program has proven the feasibility of precise navigation at sea via satellite, even when the stars are obscured completely by clouds.

A plan for joint use of the Transit system for military and civilian services was announced on March 9, 1963, by the Department of Defense and NASA. Four satellites will be launched to provide navigational information to ships. NASA will be responsible for determining the civilian uses of Navy-developed equipment, and, with Navy help, will design additional devices to meet purely civilian needs.

Such a satellite system can operate day or night and in fair or four weather. Four satellites will permit determination of any position at any place on Earth every hour and a half. Ships of all nations could take advantage of the satellite system.

It has been predicted that in a few years navigators on ships or planes will no longer need sextants or radio beam finders. To get a "fix" on their position, they will "tune in" on a satellite 400 miles overhead. The navigational information will be fed into a simple computer that will pinpoint their position within five-tenths of a mile.

Automobile transportation will also be improved by space research. The power plants of tomorrow's automobiles, burning new fuels with much greater efficiency, may be no larger than coffee cans. According to the Aerojet-Corp., a new brushless generator, now being used in various space programs, may be used in automobiles. From space telemetry could come a system for the automatic changing of road signs as the weather changes.

Transportation will be safer in the future. A frangible tube that was developed to absorb the impact of the landing of the Apollo capsule can be used to minimize damage to automobiles in collisions. Flying will be safer, too. According to the International Telephone and Telegraph Corp., navigation equipment and techniques are being applied to solve the increasingly severe problems of air traffic control.

(Principal Sources: Civilian Dividends from Space Research, Edward Gottlieb & Associates; NASA-Industry Program Plans Conference, February 11-12, 1963; The Commercial Applications of Missile/Space Technology, Denver Research Institute, September 1963.)

D. MEDICAL TECHNOLOGY

Our effort to place a man in space has necessitated an evaluation of man's capabilities. The Mercury program led to new evaluative techniques and to a new methodology of physical examination. The requirements for physical performance monitoring in space missions, along with instrument miniaturization and telemetry, have brought about innovations in medical electronics.

Sensors that were developed to measure heatbeat, blood pressure, breathing rate, and brain waves of astronauts are currently being attached to hospital patients so that they can be watched by remote control. Such telemetering systems are used in Lafayette Clinic, Detroit, Michigan, and the North Carolina School of Medicine. A new electrostatic camera, developed for space vehicles, produces moving or still "instant pictures" without any processing; such a camera, when focused on a patient in a critical condition, could keep vital photographic records instantly available for doctors. Transducer-transmitters that relay intestinal data are currently in use, and doctors now foresee a battery-powered television system small enough to be swallowed, that will transmit an on-the-spot pictorial report from a patient's stomach.

At General Electric's Space Sciences Laboratories, electric power to operate a 500-kilocycle transmitter was drawn from the body of a living rat. The ability to use the bioelectric potential of the body, together with recent advances in microelectronic circuitry, will have important applications for medicine. For instance, electronic devices implanted in the body to regulate its functions or to report on physiological reactions could operate without batteries and could broadcast data without the hindrance of power wires from external connections.

The nation's 600,000 near-blind can benefit from new glasses that have multidirectional lenses. The principle of alternating panoramic fixation, used in satellite camera and lens systems, was applied in the development of the new glasses. General Data Corp., which develops instruments for spacecraft, is engaged in a study of an electronic sight aid for the blind. Eye surgery with a pinpoint of intense light from a laser has been accomplished successfully, and Kollsman Instrument Corp. indicated that the laser can be used in eye tumor removal, retinal welding, and brain surgery.

Pressurized space suits, developed by General Electric are making it possible for bedridden stroke victims to be ambulatory; such cases have been reported from Los Angeles and Santa Monica, California. An Illinois farmer, who was afflicted with a rare disease that affected his blood pressure, was an invalid for years; pressurized space suit trousers helped him walk and work again. At Northwestern University during a study to obtain data about the kind and the degree of head shock received by football players, an electronically rigged helmet was used in practice; the apparatus in the crown of the helmet resembled that used in telemetering critical data from our astronauts.

Pinpoint-sized ball bearings, developed for satellite equipment, make it possible for dentists to have almost painless, ultra-fast dental drills, and miniature transmitters have been attached to teeth to facilitate studies of night grinding or gritting. X-ray equipment being used by Aerojet-General Corp. to examine rocket motors can produce X-ray pictures at only 1/30 of the radiation exposure required with conventional X-ray equipment.

NASA's Direcotrate of Biotechnology and Human Research currently is performing studies in biotelemetry to identify the physical, emotional, and psychological state of man in space flight. This approach is not influenced by conventional medical practice, and the data that will be required cannot be obtained through the use of conventional electrocardiographic or other available methods. A wealth of information pertaining to physical and mental evaluation is certain to accrue. Better methods of detecting and treating diseases will follow. It is expected that within the next ten years clinicians will have tests to spot incipient diseases in patients before actual disease conditions arise.

(Principal Sources: Civilian Dividendends from Space Research, Edward Gottlieb & Associates; The Commercial Applications of Missile/Space Technology, Denver Research Institute, University of Denver, September 1963; NASA Industry Program Plans Conference, February 11-12, 1963.)

E. NEW MATERIALS

The practical application of space research by-products appears to be endless. According to the Brookings Institute, "The development of new materials, including among them many synthetics and composites of synthetics and metals, reflects a concentrated effort to meet the special and unique requirements of space flight. Fabrics to be used must be light in weight, high in strength, resistant to temperature extremes, noncorrosive and tolerant of multiple acceleration.

"Reinforced plastics are being considered for increasingly wide use in missiles and other space vehicles. Silicones, polyesters, epoxy resins, and phenolics reinforced with a variety of materials -- asbestos, quartz fibers, graphite cloth, glass fiber, etc. -- show mechanical strengths far exceeding most common construction materials . . .

"Various plastics and new metal alloys could replace traditional fabricating metals, if the costs of the new materials should prove to be competitive with the costs of steel, aluminum and the like . . . the long life of products utilizing these new materials would substantially lower replacement requirements."

New metals, alloys, fabrics, and compounds that were created or developed by space research are already being produced commercially. For instance, Packard Bell Electronics developed a ceramic insulation material, PSC-Durock, to withstand the extreme heat of exotic fuels, and this material is currently being used in high-temperature applications in the civilian atomic energy program; space-proof materials are being used to make nearly indestructible refrigerators and other appliances; dry lubricants, developed to meet space requirements, are being used on Earth; and fluxless aluminum soldering, an outgrowth of space research, is currently being marketed. Space research has stimulated the improvement of commercially useful aluminum alloy; research and experimentation on pyrolitic graphite with commercial potential; and the development of honeycomb structural material that is being used on boats, buildings, and aircraft. Today, better coffee is possible, thanks to a new Teflon-coated cloth filter developed for use in space research.

The near future will bring many other benefits from space research. For instance, Sundstrand Aviation has developed a photochromic material for space use which might lead to adaptable sunglasses and anti-glare windows. The Aluminum Company of America made an ultra-thin aluminum foil for project Echo; the company believes that this material has potential in the pharmaceutical industry and in freeze-dried products. A finely woven stainless steel cloth designed for parachuting spaceships back to Earth might be used in such important industrial applications as inflatable buildings. A nonflamable hydraulic fluid developed for use in launching systems will probably be used widely in aviation and industry. Temperature-control coatings for spacecraft might be used in paints and building materials, increasing the efficiency of heating and cooling systems, and it is possible that the house paint of the future might not ever require renewing.

Even our future clothing could be affected by space research; improved protective clothing, plastic fabrics, and ventilated garments for astronauts are constantly being developed. An aerospace company has predicted that tomorrow's best-dressed man can control his temperature by a tiny dial attached like a lapel stud to his coat. The prediction was suggested by a new thermoelectric weave developed by the company as a thermal generator for use in satellites.

In addition to new materials, space research is providing us with improved manufacturing processes. Rocket fuels and engines used as drills are now making it possible to shear ore and rock at very great depths; jet drilling is recovering iron from previously uneconomical taconite (very hard rock) ores. An infrared horizon sensor developed for NASA's Nimbus weather satellite is being used to measure the thickness of steel plates and rods in steel rolling mills; previously the sheet or rod had to be stopped, cooled, and hand measured. Filament winding techniques for making light, sturdy rocket cases have been used in fabricating auto parts and chemical vats.

(Principal Sources: Civilian Dividends from Space Research, Edward Gottlieb & Associates; The Commercial Applications of Missile/Space Technology, Denver Research Institute, University of Denver, September 1963; NASA News Release, September 26, 1963.)

F. ENERGY SOURCES

What will happen when Earth's supply of coal and oil dwindles? Along with atomic energy, by-products from space research and development could provide the answer. The automobile industry is already investigating the possibility of using fuel cells instead of gasoline, and energy from the Sun will provide homes and buildings with built-in heating, cooling, and lighting systems. In addition to supplying the energy for our basic needs of transportation, heating, and lighting, energy sources developed by space research, will fulfill unique applications. For instance, batteries that were developed for satellites can be sewn into a heart patient's body to overcome cardiac defects; Hoffman Electronics Corp. manufactures a solar-powered radio that stems from Vanguard satellite solar cells; and a commercial wrist watch is powered by a mercury battery that was developed to operate a timing mechanism for an Explorer satellite.

Although solar cells, in which the Sun's radiation is converted directly into electricity, were produced in the early 1950's, research for space applications significantly reduced their production cost, making commercial use feasible. Solar cells have been used as power sources for radios, an emergency call system on a Los Angeles freeway, and a telephone system in South Africa. The ultimate life-time of solar cells has not been determined; and they require no vast distribution system, no fuel, and no maintenance.

Since the 1890's, the fuel cell has been recognized as a highly desirable energy source because of its potential for converting externally supplied fuel and oxidant directly into electrical energy, thereby eliminating the requirement for machinery or moving parts. A large amount of fuel cell research has been conducted in space programs. In addition to supplying electrical energy to operate spacecraft radios and computers, a fuel cell, using a mixture of hydrogen and oxygen, is expected to provide astronauts drinking water. The commercial use of the fuel cell is almost unlimited. It is possible that the fuel cell will be used to provide electrical energy in remote areas, to power automobiles and trucks, and to replace the conventional battery.

The possibility of power conversion by thermoelectric devices was known in the late 1930's. Space research has been very active in the field of thermionic and thermoelectric power conversion, with emphasis being placed on lightweight portable units. Thermoelectric conversion generators are being used currently in an automatic meteorological data transmitting radio station, and other uses are being developed.

The production of electric current as a result of a conducting fluid that moves relative to a magnetic field was attempted 50 years ago. Space propulsion problems required studies of the high temperature properties of gases and the interaction of conductive gases with electrical and magnetic fields. At present, a magnetohydrodynamic generator for a central power station is under development, and its thermal efficiency is expected to be good.

Rocket motors are capable of providing large amounts of electrical or mechanical energy for short periods of time. Retrobraking systems and hydraulic systems actuated by rocket motors are being investigated for use on heavy trucks and trains.

In addition to developing new energy sources, space research is providing new means of energy conservation. Insulation developed in space research makes it possible to more molten aluminum without the necessity of putting it in ingot form and then remelting it. Temperature control coatings developed for spacecraft will be used in roofing materials, paints, and window coatings, thereby providing substantial gains in heating and air-conditioning efficiency.

In short, new and better methods of energy production and conservation developed in space programs will make daily living -- on Earth -- more pleasant, safer, and more economical.

(Principal Sources: The Commercial Application of Missiles/Space Technology, Denver Research Institute, University of Denver, September 1963; Civilian Dividends from Space Research, Edward Gottlieb & Associates; Proceedings of the Second National Conference on the Peaceful Uses of Space, National Aeronautics and Space Administration, November 1962.)

G. CRYOGENICS

Cryogenic experiments began in 1862 when Joule demonstrated that it is possible to cool a gas by expansion through a porous plug. Using this principle about thirty years later, Linde invented a machine for the liquefaction of air. By 1930, manufacturing, handling, and trucking of liquid oxygen (LOX) were common. Today, the steel and chemical industries use large quantities of cryogenics, and the third largest user is the missile and space program.

The transportation and storage of cryogenics is an important consideration in launch site operations. Because a vehicle might stand for some time on the launch pad, it would be impractical to store LOX in its tanks because of vaporization losses and the freezing of control valves. Tons of propellant must be loaded for launch with utmost speed. Because of this requirement, cryogenic instrumentation, materials, insulation, and fluid transfer techniques have been improved, and these technological advances are being adapted to commercial practices.

For instance, the launch facility requirements for a suitable cryogenic insulation have brought about the development of a special insulation grade of expanded perlite. Tennessee Products and Chemical Corp. helped to develop an expanded perlite to be used in the insulation of ground-support equipment storage tanks, primarily for the storage of LOX and liquid hydrogen. This improved insulation is now used in the fabrication of tanks and equipment for the industrial handling of cryogenics by such firms as Air Products and Chemicals, Inc., and Chicago Bridge and Iron Co.

Dewars, double-walled vessels with intermediate insulation, were small and expensive laboratory type equipment before the aerospace age. Missile and space requirements have necessitated the development of large dewar units to store large quantities of liquefied gases. Stearns-Roger Manufacturing Co., for example, designs, manufactures, and tests dewars for aerospace applications. The company is currently conducting studies for the natural gas industry to determine the feasibility of using these vessels for shipment of liquefied methane and other hydrocarbons. Other potential uses for large dewars include bulk storage of LOX for improvement of steel production, storage of nitrogen for freezing perishables, and storage of liquefied gases for medical use. Also, space related research at Arthur D. Little, Inc., has made it possible to transport liquid methane gas overseas. Union Carbide's Linde Div. has developed a semitrailer that has a capacity of 13,200 gallons of cryogenic fluid and that limits normal evaporation loss to less than 0.4 percent of capacity per day.

In missile and space applications, very exacting requirements for cryogenic system cleanliness are necessary because small foreign particles could seriously impair rocket engine performance. LOX tanks must be cleaned with extreme care; any trace of organic matter or other readily oxidizable substance could cause an explosion. Also, any traces of water or other liquid or vapor that can freeze at cryogenic temperature must be eliminated to prevent plugged openings, jammed valves, etc. Graver Tank and Manufacturing Co. developed a chemical cleaning technique to meet the cleanliness and particle size requirements of aerospace cryogenic applications. Similar techniques are now used in cleaning cryogenic vessels for commercial use.

Cryogenic fluid transfer requirements in launch site operations and the unique problems of vehicle propellant systems have brought about improved cryogenic pumps, valves, and seals. For instance, to meet the requirements in delivering LOX to rocket engines, North American Aviation, Inc., developed an improved pump seal that is effective at very low temperatures. Increased use of this seal is expected throughout the cryogenic industry and will have many non-aerospace applications.

Perhaps the most important influence of the space program on cryogenic technology has been economic. Missile and space programs have provided the market needed by commercial cryogenic producers to lower the prices of some liquefied gases. As a result, more commercial applications of cryogenics, such as truck refrigeration systems, have become economical. The production of LOX and other cryogenics is now an important facet of US industry.

Superconductivity is an application of cryogenics to which space research has made contributions. In brief, some metals have almost no resistance to the flow of electricity at cryogenic temperatures. Extremely fast switches, called cryotrons, and extremely powerful magnetic fields are possible because of the phenomenon of superconductivity. Cryogenic gyroscopes, called cryogyros, are being developed in which a light, spinning sphere of metal is suspended in a magnetic field, thus virtually eliminating friction. There is little doubt that these and other studies of superconductivity will increase the future commercial applications of liquefied gases and will contribute to cryogenic technology in general.

(Principal Sources: The Commercial Applications of Missiles/Space Technology, Denver Research Institute, University of Denver, September 1963; Missiles and Rockets, April 13, 1964.)

H. THE PLASMA JET

A gas in an extremely hot, ionized state is called a plasma. The term was first applied to ionized gas in 1928 by Irving Langmuir, although patent applications and technical papers describing the phenomenon can be traced as far back as 1900. Interest in plasma increased mildly during the 1930's and 1940's, then mounted rapidly during the 1950's because of the impetus of missile and space research.

The plasma, if ejected from a "gun" in the form of a jet, can deliver large amounts of heat per unit time and can achieve very high temperatures. For these reasons, the plasma jet was developed to facilitate the testing of high-temperature materials for nose cones and to meet a requirement for simulating reentry conditions.

The plasma jet's principle of operation can be understood better by first considering the electric arc. A large voltage potential between two electrodes across a gas-filled gap will cause a few of the electrons at the negative electrode to break away and be accelerated across the gap. Most of these electrons will collide with gas atoms or molecules, causing some ionization of the gas.

As ionization takes place, more electrons can flow across the gap. Soon the gas in the space between the electrodes is quite ionized and quite conductive, with electrons flowing across the gap in one direction and positive ions flowing across in the other. Heating takes place as the colliding electrons, ions, and atoms give up some of their kinetic energy in the form of heat energy. Temperatures near 7500° F can be attained by this process.

Merely increasing the electrical current through the gap will increase the volume of heated gas, but will not appreciably increase the temperature. But increasing the density of the gas, thereby increasing the probability of collision, will tend to increase the temperature. In the plasma jet, this increase in density takes place because of the "pinch" effect, which has two aspects.

The first, or thermal, pinch effect was discovered because of the need to cool the chamber in which the plasma jet operates. Cooling tends to decrease the ionization, and the conductivity, of the outer layers of gas. The current flow then tends to concentrate in the center of the discharge, causing increased current density and more heating.

The second, or magnetic, pinch effect is a result of the tendency of two parallel conductors, each conducting in the same direction, to be attached to each other by their own self-induced magnetic fields. Similarly, the charged particles flowing between electrodes are routed together by their own self-induced magnetic field. This causes the density of the gas in the discharge to increase, which in turn causes more heating.

In practical operation, the gas is usually forced through a gun that contains the electrodes in such a manner that the heated plasma is ejected in the form of a jet. Plasma jets that can produce temperatures of 30,000° F have been built; for the sake of comparison, it might be stated that the hottest temperature that can be achieved by a chemical flame is about 10,000° F.

Although the original applications of the plasma jet were mostly in hyperthermal wind tunnels for reentry studies, many additional aerospace and commercial applications have been developed.

At temperatures above 10,000° F, even the most refractory materials are vaporized. With the introduction of a powered refractory metal or ceramic into the plasma, the plasma jet can be used to spray a protective coating onto another material, much like the spraying of paint. The oil refining and chemical industries make use of this technique. For example, protective refractory materials are sprayed on parts of catalytic cracking systems that are exposed to destructively high temperatures; and relatively inactive materials can be sprayed on piping that is exposed to especially corrosive agents in a chemical process. Similar applications include plasma spraying in the paper, machine tool, small engine, and electronics industries to provide resistant coatings, conductive coatings, and dielectric coatings. With the plasma temperature reduced, plastics can be sprayed on electronic components to protect them from vibration and moisture.

The plasma jet can be used as a torch to make extremely clean cuts through thick metals, and it has also been used commercially in the welding of difficult materials.

One of the latest applications of the plasma jet is its use as a high-intensity light source. The extreme temperature of the plasma provides both brightness and total radiation levels several times those achieved by other man-made, controllable sources of light.

(Principal Sources: The Commercial Application of Missile/Space Technology, Denver Research Institute, The University of Denver, September 1963; Merle L. Thorpe, "The Plasma Jet and Its Uses," Research/Development, January 1960.)

I. COMPUTER TECHNOLOGY

Computers are not new, and no claim to innovation can be made on behalf of missile and space research. But the influence of missile and space research on advanced computer technology has been very significant, although diffuse and difficult to pinpoint.

In 1642. Blaise Pascal, a teenager working in his father's tax office, made a gear-dirven computer that would add and subtract. In 1694, Leibnitz constructed a similar machine that would not only add and subtract but would also multiply and divide. In 1822, Charles Babbage, an English scientist, designed a semiautomatic machine that would calculate functions, and he suggested the use of punched cards to feed data to computers. This "difference engine," based on the difference tables of the squares of numbers, contained hundreds of gears and shafts, many of which Babbage had to build himself because of the rather crude metalworking techniques of his time. (Incidentally, "spinoff" from Babbage's research greatly advanced metalworking technology.)

In 1937, Howard Aiken of Harvard University began designing a computer that had a memory and could store numbers; his machine, called Mark I, was built by IBM in 1944. The first electronic digital computer was built at the University of Pennsylvania in 1946 under US Army sponsorship, and all of its operations except input-output were performed by vacuum tube circuits. The use of magnetic tape, both as a storage and input device, was perfected in the early 1950's, thereby reducing input duration from 50 to 75 times. Multiple magnetic disc memories, developed in 1956, provided random access to five million characters of information. By 1957, several small transistorized computers had been built, and most large computers in commercial use today are transistorized.

The contributions made by the missile and space effort to computer technology have been primarily in miniaturization, increased reliability, input-output techniques, and in computational speed. Further, missile and space requirements are forcing the development of microelectronic circuitry for computer use. The trend toward high-speed, lightweight computers has been greatly accelerated by space exploration. Because spacecraft impose severe requirements in size and weight, the giant electronic brain of the 1950's is fast becoming small enough to fit into a briefcase.

In the beginning, microelectronic circuitry will be used almost exclusively in spacecraft and missile computers. But once the initial cost of development is overcome, it is very probable that microelectronic circuitry will be used widely in commercial computers, just as semiconductor circuits have largely replaced vacuum tube circuits in commercial computers. Microelectronic circuits eliminate 90 percent of the bulk, most of the wiring, and 90 percent of the solder connections of conventional circuits.

Because they reduce the wiring and eliminate most of the soldered connections that are required by conventional circuits, microelectronic circuits will increase the reliability of computers. Reliability is of prime importance in such systems-oriented computer applications as missile guidance, air defense, manned spacecraft, and industrial process control. Reliability can be achieved through duplication of equipment. Duplication, however, creates a weight problem in spacecraft or missile guidance packages, and duplication is expensive in other applications. Advances in reliability with a minimum of duplication for spacecraft and missile applications will be a tremendous benefit to process control applications where reliability is necessary but duplication is costly. In addition to added reliability, microelectronic circuits, which are compatible with mass production techniques, could greatly decrease the production cost of computers.

Computer input-output techniques and speed of computation are also being improved through knowledge gained in missile and spacecraft technology. For instance, computers for the guidance and tracking of missiles and satellites must have extremely fast computational speeds, and often data must be converted and reconverted automatically. These applications are analogous to process control in which physical data must be converted to a form that can be monitored by a computer. The California Research Corp. , for example, has helped develop a computer system that rapidly scans a large amount of data, converts it to digital form, processes it in a digital computer, and makes automatic process adjustments. Such systems are used in petroleum refining processes. Missile and space technology has contributed substantially to the development and availability of this type of equipment, in addition to lowering its cost by providing a larger market for it.

Missile and space technology has also instigated commercial applications for computers. The Astro-Electronics Div. of the Radio Corp. of America was instrumental in developing a computer system to catalog pictures from Tiros satellites. As a by-product, the company developed a system for the National Broadcasting Co. that displays, edits, and splices television pictures.

The Aeronautical Div. of Minneapolis-Honeywell Regulator Co. performed research and development on an adaptive flight-control computer system for the X-15 and X-20 craft. They developed a computer system that adapted automatically to compensate for such flight conditions as speed, altitude, weight, and wind gusts. A direct transfer of technology from the X-15 and X-20 research and development was the H-14 adaptive autopilot for twin-engine aircraft. Several manufacturers are recommending that the H-14 autopilot be used in their twin-engine business aircraft.

The Librascope Div. of General Precision's Information Systems Group builds both commercial and aerospace computers. Partly because of power limitations in space, their computers have been designed to operate in terms of milliwatts rather than watts; and reducing the power requirements by a factor of 1000 has enabled the firm to eliminate the bulky air-conditioning systems that are required in older computer systems.

According to the Autonetics Div. of North American Aviation, Inc., the transfer of technology from aerospace programs contributed to the development of their RECOMP series of desk-sized, all transistorized digital computers. These computers are used primarily for computation and industrial process control by petroleum firms, electronics manufacturers, scientific research institutions, optical equipment manufacturers, and many government agencies.

In addition, Autonetics Div. has developed card or tape programmed computer-type machines that check out a vehicle's electronic circuitry before firing. Through this development work, Autonetics Div. has acquired the technical knowledge that will enable them to design automatic check-out equipment for any electronic system. They expect that automatic check-out equipment and devices will have widespread applications in testing complex industrial electronic circuitry. They have developed neon-indicating functional test equipment that will perform high-speed continuity checks of wiring in telephone centrals, computers, and other complex circuitry. They have also developed a voltage and phase indicator that will test and check out transformers, gyros, and other components with high accuracy.

The use of printed circuits with semiconductor devices permits a degree of automation in computer fabrication. Thr Remington Rand Univac Div. of Sperry Rand Corp. indicated that further development of this fabrication technique could be very important in the construction of future commercial computers.

Univac Div. introduced its Microtronic computer in 1963. This unit, constructed mostly of microelectronic semiconductor circuits, was designed primarily to meet the increasing requirement of vehicle-borne computers without a corresponding increase in weight. One model of the Microtronic computer has less than 17 lbm and it has a memory of 4600 words, which can be expanded to 14,000 words if necessary. The Microtronic computer might well be a prototype of small, high-speed commercial computers.

Thin-film memory systems, which have been developed over the past 15 years, are currently being used in some aerospace computers. At present, thin-film memories are about ten times more expensive than magnetic core memories, but improved technology and a larger market could reduce their cost. Tunnel diodes and cryotrons (in which a current in a super-conductive material is controlled by a magnetic field induced in an adjacent conductor) are potentially useful as memory systems because they have fast switching times and because they can be made in miniature arrays.

Extremely fast printing equipment has been developed in the last few years because of the relative slowness of computer input-output equipment. Some of this equipment will be used commercially. Radiation Inc. has developed a printer that has a maximum rating of 62,500 alphanumeric characters per second. Data are printed a line at a time on 12-inch wide electrosensitive paper. Each line can contain 120 characters, and the machine can print 31,250 lines per minute.

(Principal Sources: The Commercial Application of Missile/Space Technology, Denver Research Institute, University of Denver, September 1963; Civilian Dividends from Space Research, Edward Gottlieb & Associates; Missiles and Rockets, July 1, 1963.)

J. ANALOG-TO-DIGITAL CONVERSION

The preceding section showed the influence of space research programs on computer technology. A major problem in a systems-oriented computer is the conversion of analog data into digital input form. This section gives examples of how commercial analog-to-digital techniques have been improved as a result of aerospace research and development.

Most present industrial automation techniques still make use of pneumatic or electro-mechanical relay equipment. Gulton Industries, Inc., believes that during the next four or five years the transfer of solid-state digital control techniques from space programs will help replace the pneumatic and electro-mechanical equipment, thereby lowering costs and increasing reliability. Gulton Industries provides digital equipment for several aerospace programs, including Apollo and the S-17 Solar Observatory Satellite. New digital data acquisition and handling techniques that were acquired in these programs have been applied in unmanned control stations for natural gas storage and distribution.

Engine tests at North American Aviation, Inc., Rocketdyne Div., are facilitated by a high-speed electronic analog-to-digital converter. They call it IDIOT, an acronym for Instrumentation Digital On-Line Transcriber. IDIOT will sample 100 input channels at a rate of 10,000 measurements per second. Licensing arrangements for IDIOT commercial sales were negotiated in late 1963.

Epsco, Inc., developed a portable data collection system that was based on techniques acquired or perfected through work on various aerospace programs. The system is contained in two carrying cases, each of which has about 65 lbm. The company believes that this portable system is an economical solution to the problem of collecting and recording analog data for direct input to a digital computer; they expect the system to find wide use in measuring and analyzing the efficiency of process control in the petroleum, chemical, and electrical power generation industries. The system, which measures such variables as temperature, viscosity, and weight, can be of value to research groups in the evaluation of complex flow or mixing operations. In the petroleum industry, the portable system could be applied to the collection of data concerning oil well production.

Epsco's solid-state analog-to-digital converter is another improvement that can be traced to the rigid requirements of aerospace equipment. The company modified the design of existing components so that they would operate in aerospace environments; these components are now being sold commercially to companies that require rugged equipment.

In 1952, Genisco, Inc., built an analog-to-digital converter for a device called Icono Log, which was used for converting information from photographic theodolite film to punch card data for computing a missile's flight path. This converter was an electro-mechanical device for taking a pair of measurements (a pair of cross hairs, for example) and converting the position to an electrical signal. This unit has been made obsolete by high-speed equipment. But Genisco now manufactures a second generation analog-input-to-digital-output system, which is finding wide application in automatic weather stations and processing plants.

The aerospace programs have created a demand for a contactless shaft-to-digital encoder that General Precision, Inc., has built. Because these encoders operate without mechanical contacts, they are more reliable and last longer than encoders that operate on a mechanical contact principle. They generate a signal optically, capacitatively, or magnetically. In addition to aerospace use, contactless encoders are being used in the chemical industry, where corrosive chemicals shorten the life of mechanical contact controls. The high cost of the device has limited commercial applications, but the firm believes that contactless encoders will find a large commercial market as soon as increased production lowers their cost.

For vehicle launching operations, Fairchild Camera and Instrument Corp. has built programmers that incorporate a new kind of punched tape. The tape is an aluminized plastic. Optical holes are made in the tape, not by physical punching, but by evaporation of the aluminum coating. This process allows higher density information storage. The firm stated that the tape is no more expensive than standard paper tape, and that it is cheaper when its information capacity is considered. This principle is applicable to commercial computers, but no commercial market has been reported yet.

Although digitizing of analog data is performed frequently in many engineering and research applications, analog computers must not be discounted. In missile guidance or process control, analog computers can be used to make computations without converting the data to digital form. But analog computation is still too inaccurate for many applications. The accuracy of analog computers, however, has been greatly improved during the past four or five years, probably with much impetus from space programs.

(Principal Sources: Civilian Dividends from Space Research, Edward Gottlieb & Associates; The Commercial Application of Missile/Space Technology, Denver Institute, University of Denver, September 1963.)

K. PACKAGING AND SHIPPING

The packaging of missile and space vehicle components presents unique problems. Usually, these components have a high value per pound and are easily damaged. Further, they are usually handled several times by subcontractors, the prime contractor, and government agencies. Frequent handling increases the probability of damage, and constant packing and unpacking increases over-all costs. Kudl-Pak, developed by Navan Products, Inc., of El Segundo, California, is one of several devices that have been developed to alleviate these problems.

The outside of the Kudl-Pak container is a plastic case that hinges on one side and snaps shut on the other. The inside is filled with a polyurethane flexible cushion that adapts itself to the shape of the item being packaged, thereby eliminating custom nesting. Kudl-Paks are being sold in volume to producers of electronic equipment, precision machined parts, and similar products; and the range of uses is rapidly increasing. Although Navan does not expect that Kudl-Pak containers will replace egg cartons, a firm is contemplating their use to package expensive "100 percent disease-free" eggs to laboratories.

Navan Products, Inc., also developed the Klimp to facilitate spaceage packaging. A Klimp is an L-shaped spring wire clamp that replaces a nail in fastening a packing box. The Klimp is initially more expensive than the nail, but, according to the firm, it is cheaper in the long run. The unpacking operation is accelerated because of the Klimp's ease of removal. The packing material can be used repeatedly because neither the Klimp nor the box is damaged during packing and unpacking. Modular panel construction permits a wide variety of boxes to be made from a few basic panel sizes, and disassembled panels can be stored in one-fifth the space required to store conventional boxes.

Large quantities of Klimps are currently being used by the automotive, rubber, furniture moving, and food industries. The US General Services Administration has made Klimp fasteners a stock item, and the National Wooden Box Association is now sponsoring a federal commercial specification for Klimp fasteners.

A variation, called Klimp Celery Clamp, is in the final stages of approval for sale to the food industry. The Klimp Celery Clamp will hold vegetable packing boxes together, thereby preventing inshipment damage resulting from load shifting.

Pomona Div. of General Dynamics/Electronics developed a missile shipping container called Shock Master. It is a low-cost, mechanical device that indicates when predetermined shock levels have been exceeded. It automatically reports rough handling, thereby preventing undetected and potentially damaging shocks to sensitive components during transit. The Shock Master can be installed in containers, boxes, and crates, or it can be attached to vehicles or cargo. In either use, it can provide the shipper, the manufacturer, or the customer with a record of shock. Various models are now available commercially with shock readings from 5 to 50 G.

The Shock Master can also be used for the evaluation of container design, packaging techniques, carrier performance, and handling methods.

Sometimes unpacking can be a problem. According to a recent NASA Tech Brief (one or two page publications issued by NASA's Technology Utilization Div. to acquaint industry with innovations derived from the space program), large, heavy-duty staples are difficult to extract with commercially available staple removers. A hand tool that requires only one simple operation to extract a staple has been designed at Jet Propulsion Laboratory. The device easily removes round-headed staples from packing crates and staples from thick reports.

Under a contract to Jet Propulsion Laboratory, Hughes Aircraft Co. has developed a quick release mechanism that holds two objects together securely and releases them on demand. Commercial use of this device is being encouraged by the Technology Utilization Div.; some suggested applications are in coupling devices for load-carrying carts or trucks, hooks or pickup attachments for cranes, and quick-release mechanisms for remotely controlled manipulators. Also, the Technology Utilization Div. is currently processing information concerning a silent chain friction drive and air bearings that can carry heavy loads with minimum friction, both of which are expected to be used in industrial materials handling operations.

Broader aspects of the influence of the space program on shipping and transportation in general were discussed in a previous article in this series. It should be stated, however, that the transport and handling of the Saturn vehicle are bound to influence packaging, shipping, materials handling, and transportation methods.

(Principal Sources: NASA Tech Brief 63-10420; NASA Tech Brief 63-10292; Steel, December 23, 1963; The Commercial Applications of Missile/Space Technology, Denver Research Institute, University of Denver, September 1963; data and pigeon eggs provided by Navan Products, Inc.; data provided by General Dynamics.)

L. MANAGEMENT AND CONTROL

Large space and military missile programs -- which often involve several government agencies, hundreds of prime and subcontractors, and thousands of people -- have brought about unprecedented problems in management and control. New methods have been developed to help solve these problems, and these methods are being used more and more by industry for the management and control of non-government projects.

The most widely known of these methods is PERT, an acronym for Program Evaluation and Review Technique. It is an outgrowth of the sheer complexity of the Navy's Polaris program. Numerous management tools, both old and new, were applied to the Polaris program. A single page format, called Program Management Plan, was used to show milestones, schedules, task responsibility, supporting responsibility, and monitoring responsibility; variations of Gantt charts were used to depict schedules and progress; and line-of-balance charts were used to analyze the mix of effort going into the production of a particular item. But the standard measure -- money spent -- did not necessarily correlate to progress.

A new method was needed to predict the probability of meeting objectives on time. A team that was comprised of Naval and civil service personnel, consultants from Booz, Allen & Hamilton, and specialists from Lockheed's Missiles and Space Div. was organized. Because of the urgency of the Polaris program, and because cost is often dependent on time, the team devised a control scheme that used time as a common denominator.

PERT, then, is based on a time sequence flow diagram. Milestones, important events in the project, are linked graphically with arrows to portray interdependencies. Actual work activity is represented by the arrows that join the milestones. Times necessary to complete each task between events are estimated in such a way as to give an approximate measure of uncertainty. The "most likely time," "optimistic time," and "pessimistic time" are obtained from the person who is responsible for the completion of a particular activity or task. An average or expected time is calculated, giving the time for which there is a 50-percent chance of completing the activity. When the program is complex, a computer is used to determine the critical path, to set the date for the end objective, to calculate the latest date by which each activity must be finished if the program is to be completed on time, and to calculate the uncertainty involved in reaching each milestone.

Other techniques have been developed in space, military, and industrial programs. MCX (Minimum Cost Expediting) is a parametric linear technique used to determine the minimum cost of a project as a function of its duration. CPM (Critical Path Method) developed from MCX and borrowed from PERT. Many techniques similar to PERT and CPM have emerged, each with its variations and name.

CPM is often confused with, and even called, PERT, and vice versa. But there are several basic differences between them. First, PERT is a system that evaluates existing schedules; CPM generates plans and schedules. With PERT, job durations are random variables, probabilities that are assigned to the length of activities; with CPM, job durations are known fairly precisely. PERT, as originally used, did not include cost; CPM did. (A new system called PERT/Cost does take cost into account.) PERT generates one set of schedule limits; CPM can generate a spectrum of schedules with a minimum cost for each. In general, PERT is more suited to space programs, defense programs, and large research projects; CPM is more suited to civilian construction and maintenance. But the one is confused with the other, and each has borrowed from the other, until they should be thought of not as well-defined techniques but rather as new ways of managerial thinking.

The success of PERT (it was credited with saving two years over original estimates) has significantly accelerated the diffusion of such systems throughout industry. The American Management Association, Management Systems Corp., Service Bureau Corp., Mauchly Associates, and several other organizations offer courses in PERT, CPM, or both. Once one is familiar with PERT or CPM through a class or a government contract, he can evaluate other scheduling problems in terms of flow network and critical path. Here, then, is another way that large missile and space programs have lent impetus to the industrial use of critical path techniques in general. The General Electric Co., for instance, was introduced to PERT through government-funded work; since then, GE has adopted either PERT or CPM in all its divisions.

Possible applications of these program control methods are widespread. For example, PERT was used to keep track of the production of the Broadway play, Morgana. A hybrid of PERT and CPM was used at the Southwest Research Institute to help schedule the construction of a $20,000 shock tube. Both PERT and CPM have been used in constructing office buildings, moving plant facilities, designing new products, changing over from pilot plant to full production, and installing computers.

According to a recent report by Booz, Allen & Hamilton, a member of the team that created PERT, there is a marked increase in nongovernment applications of these new management and control techniques. In 1959, 81 percent of the firms using PERT applied it exclusively or partly to government-funded work. By the end of 1963, 50 percent of the companies that were surveyed used PERT only for commercial work, and another 35 percent used it for both commercial and government work.

(Principal Sources: The Commercial Application of Missiles/Space Technology, Denver Research Institute, University of Denver, September 1963; Missiles and Rockets, April 6, 1964.)

M. A LIST OF TOPICS NOT DISCUSSED

The following is a list of topics that are being influenced by space research, but which are not treated at length in this document. In some technological areas, sub-topics have been provided.

FABRICATION TECHNIQUES

- Explosive Forming
- Chemical Milling
- Magnetic Pulse Forming
- Welding, Soldering
- Solid State Bonding
- Filament Winding

TELEMETRY

MASERS AND LASERS

VIBRATIONAL TESTING

FLUID TRANSFER AND HYDRAULICS

INSTRUMENTATION

- Temperature and Pressure Measurement
- Infrared Instrumentation
- Strain Gages
- Instrumentation Amplifiers
- Blackbody References
- Optical Measuring Devices

GYROSCOPES AND INERTIAL GUIDANCE

THERMOELECTRIC REFRIGERATION

ELECTRONICS

- Microsystems Electronics
- Semiconductors
- Printed Circuits, Cables, Connectors

PHOTOGRAPHY

DISPLAY SYSTEMS (systems for presenting information visually)

MAP MAKING

BIOLOGICAL SCIENCES

ENVIRONMENTAL SIMULATION AND CLEANROOMS

MACHINE TOOLS

SOCIAL SCIENCES

EDUCATION

INTERNATIONAL RELATIONS

LAW AND ETHICS

METALLURGY AND CHEMISTRY

QUALITY CONTROL

AGRICULTURE AND FOOD PROCESSING

III. THE TECHNOLOGY UTILIZATION PROGRAM

At the Second National Conference on the Peaceful Uses of Space, James E. Webb said, "Each of the great scientific and technological revolutions of the past has produced countless new methods, ideas, and materials which have altered the course of our existence. In some instances these were totally new ideas and concepts discovered in the course of research devoted toward other goals. In other instances, ideas and methods long known suddenly became applicable to practical, everyday purposes because further development work, designed for other purposes, rendered them suitable for mass production at costs within the public reach."

It is commonly known that modern chemistry has developed from alchemy, and that many great scientific discoveries occurred by accident. By incidental observation Priestly discovered oxygen; Goodyear, the vulcanization process; Roentgen, the X-ray; and Becquerel, radioactivity. But NASA is not depending on mere accident or incidental observation to discover potential benefits from space research. As Mr. Webb said, "Rather, we hope to seek out and identify results of space research which can have practical applications, and to make this knowledge available now to those with the capability to develop and utilize it for the benefit of every citizen."

Through its Technology Utilization Program, NASA gathers, evaluates, and disseminates information about space innovations that have possible commercial uses. Eleven NASA centers, NASA prime contractors, and thousands of subcontractors report on new technology being developed in the various programs. A technology utilization officer at each center reports these findings to NASA Headquarters in Washington. So far, NASA centers have discovered over 850 innovations that are believed to have industrial potential.

Any industry or contractor in the Huntsville area that desires more detailed information about innovations mentioned in this document, or any other innovations derived from the space program, should contact:

Technology Utilization Office
Building 4200
George C. Marshall Space Flight Center
Phone: 876-1514

Further, any person working at George C. Marshall Space Flight Center, or with any local contractor, who knows of innovations that may have commercial applications should contact the same office.

The information is spread to industry in several ways. NASA Headquarters sends technical releases to the trade press, prepares films and exhibits, and sponsors conferences. The Office of Technology Utilization publishes material in five forms: (1) the Tech Brief, a one- or two-page bulletin above innovations; (2) the Technology Utilization Note, a compilation of new or improved techniques on a particular subject; (3) the Technology Utilization Report, a detailed description of an innovation that has a high industrial potential; (4) the Technology Survey, a summary that identifies NASA's contributions; and (5) the Technology Handbook, a detailed data compilation and reference book.

As a pilot program, NASA has contracted with Midwest Research Institute to aid Midwestern firms. Information is disseminated to industry primarily through seminars, and the institute also publishes a series of reports that are based on information from NASA centers and contractors.

Another pilot program, the Aerospace Research Applications Center at Indiana University, acts as the middleman between NASA and member companies. This program has been so successful that a research institute in the Southwest and a university in the Northeast have expressed interest in setting up similar programs. Also, the University of Maryland has a regional program in cooperation with NASA's Goddard Space Flight Center.

As was pointed out in the Introduction, a time lag usually exists between an innovation and its commercial or practical application. For instance, the ancient Chinese knew the mechanical principle of the crank for 19 centuries before any use was found for it. The median time lag between the first working model and commercial success of the 75 most important inventions of the early twentieth century was 33 years. Similarly, a time lag exists between some aerospace innovations and their commercial application. A survey has shown that from 5 to 10 years is usually the period required to develop and market a product by incorporating technology transferred from aerospace programs. It is highly probable, then, that most of the commercial benefits of space research are yet to come. As Mr. Webb said at the Second Conference on the Peaceful Uses of Space, "Space research is already producing spinoff . . . yet we have scarcely scratched the surface as far as these benefits are concerned."

(Principal Sources: Proceedings of the Second National Conference on the Peaceful Uses of Space, NASA SP-8; Steel, December 23, 1963; An Improved Precision Height Gage, Technology Utilization Report, NASA SP-5001; Technology Utilization Program, National Aeronautics and Space Administration.)