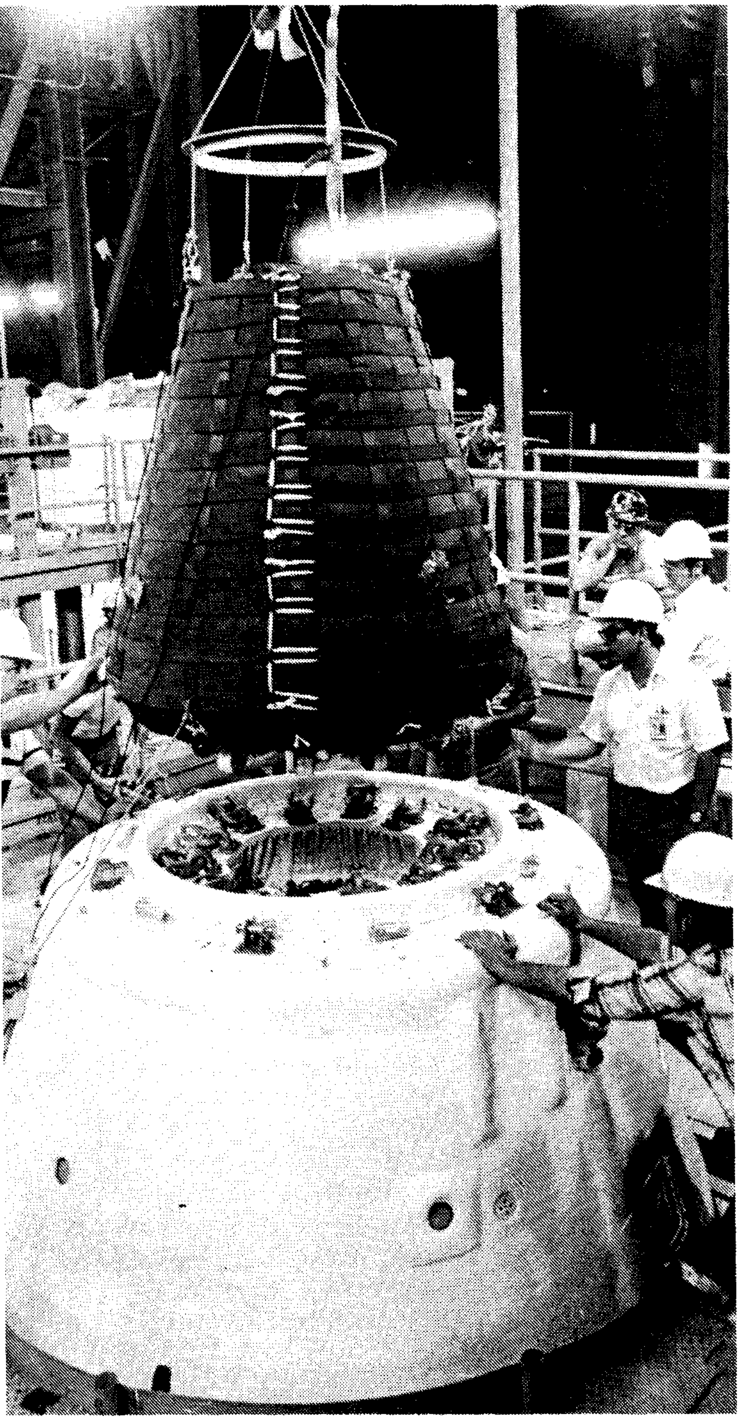
NASA paved the way for fusion



When Cong. Mike McCormack characterized the goals of his fusion energy legislation as "the nearest thing to landing man on the moon that this country has undertaken since the Apollo program," he called attention to the full implications of the fusion commitment. The U.S. National Aeronautics and Space Administration (NASA) program of the 1960s involved the mobilization of scientific manpower and supporting educational, technological, and industrial capacity. To succeed, the fusion effort will have to pick up where NASA left off.

To most Americans the word NASA is associated with the Apollo program to put a man on the moon—a program that succeeded in 1969. While NASA still exists as an agency, it has been scaled down to the point that even its space shuttle program, undertaken in concert with the Europeans, is three years behind schedule. NASA would appear to be a relic of the past, a relic that many Americans have been convinced may not have been that useful after all.

Yet NASA has already paid for itself many times over—and that doesn't even count the hundreds of technologies that U.S. desertion of the nuclear energy path have left unused.

The economic impact of the approximately $20 billion spent by NASA on the Apollo program included the creation of over 400,000 jobs; hundreds of new industries and companies; tens of thousands of scientists and engineers; and major increases in productivity through its focused impact on high-technology innovation. A study by Chase Econometrics has concluded that for every $1 spent in NASA, $14 was returned to the economy.

NASA created new cities around new laboratories, upgraded education on every level, and even did $11 million worth of improvement construction on the Mississippi River system so it could ship large equipment to its space centers. Basic heavy industries, technologically obsolescent since the war, were infused with new production techniques and new product lines.

The Chase study also showed that the spending of federal dollars on NASA research and development was four times more effective than other R&D spending, and that the application of technological breakthroughs developed in the NASA program were visible in two years, and they peaked about five years after the initial expenditure—compared to much longer "lag times" for private industry.

In 1968 NASA's Office of Technology Utilization collected reports on new technologies that NASA had developed with its contractors in order to computerize and index them for further use. One half million were catalogued at that time, and new technologies were coming in at the rate of 6,000 per month!

Installation of recovery parachute for NASA's Enterprise shuttle orbiter at Kennedy Space Center, 1979. Photo: Tiziou/Sygma

While it is extremely difficult to directly quantify the impact NASA technologies had on the productivity of the economy, the decisive decline in productivity of the U.S. economy measured by the LaRouche-Riemann model correlates with the time frame in which NASA technologies were being cut back. NASA research and development funding began to stagnate and then decline in absolute dollars in 1965. Two years later there was a distinct leveling off of energy flux density and energy efficiency in the U.S. economy. The sharp decline in productivity undergone in 1971-72—corresponding precisely to NASA "lag times"—was part of the longer-range impact.

Electronics

In 1975 the United States exported $3.8 billion worth of electronic equipment and telecommunications apparatus. This, more than two-thirds of the world market for microelectronic components, has been maintained by continually advancing both the capability and speed of the equipment and the state-of-the-art production technology, a process which took off with NASA.

In 1964 NASA established a reliability program and standards for microelectronic products for their own needs. Production lines that made components for NASA hardware were certified by NASA procurement. These standards and procedures were adopted by the Defense Department and by the industry as a whole. Producing components to meet NASA-formulated standards led to an increase in yield of 20 percent for the industry as a whole.

In addition to production techniques for electronics, both the computer hardware and software developed for space systems have been applied to manufacturing and research.

NASA also invested $2 million to develop an ultrasonic nondestructive testing technique. This technique is now an industry with annual sales of about $50 million in testing equipment being used for quality control in steel, railroad, aircraft, nuclear reactor, automotive and tubular production. Hundreds of materials themselves have been transferred from the space program to industry, including high-temperature resistive alloys and ceramics, and radiation-shielding materials for either space or nuclear radiation protection.

High-powered, reliable analysis had to be developed by NASA for computer-assisted determination of how physical systems would perform under unique circumstances. NASTRAN, or computer-assisted structural analysis, was developed as a computer software package for analyzing the behavior of elastic structures under a wide range of conditions. It was developed at the Goddard Center between 1965-1970 at a cost of $3 billion—a cost which no individual firm could afford—and released for public use in November 1970. It is now being used in aircraft and auto production, bridge construction and power plant modeling studies.

Agriculture and medicine

The economic benefit to agriculture from NASA-funded projects is incalculable. From satellite remote-sensing alone, farmers can determine the extent and geography of crop damage and disease, the ice accumulation in the winter to predict spring water run-off, the spread of pests, and the quality of the soil before planting. Accurate weather forecasting and the advance of the science of meterorology has allowed farmers time to prepare for, and avert, disaster. Global spot-checking of the growth of specific crops will one day help farmers plant what they know will be lacking in the next season by how it is growing in the opposite hemisphere the season before. The World Meteorological Organization has estimated that such worldwide planting coordination could save $15 billion per year.

NASA imaging technology, designed to develop pictures taken by satellites and planet fly-bys from thousands of miles, are now used for medical x-ray development. The applications of space-age technology to medicine are almost endless. They include the development of artificial limbs from the remote handling technology developed by NASA and the Atomic Energy Commission for nuclear plants, the implantation of flexible electrodes and remote sensors to monitor either healthy astronauts or gravely ill patients.

Scientific frontiers

No one in 1962 dreamed that after Apollo the United States would not choose to continue the manned quest of the rest of the solar system. To go farther than the moon, NASA would need propulsion systems that did not rely on chemical propellants, but on advanced nuclear and plasma systems. To provide the on-board electricity for long-duration space laboratories, or planetary flights too far from the sun, or to the dark side of the moon, systems to replace solar collectors would have to be developed. In 1963 NASA began a joint Nuclear Rocket Program with the Atomic Energy Commission to develop an in-flight nuclear reactor, termed the ROVER project, and a Nuclear Engine, Rocket Vehicle Application Program (NERVA) to develop an engine.

The program was canceled in 1972—even though sufficient work had shown that difficult problems could be overcome to make such a system operable in space—because no long-range plans had been made for continued manned space exploration. But both programs had important spin-offs for the ground-based research in the nuclear industry.

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Work done on compact, high-temperature nuclear fuel arrays led to the development of composite fuel elements which have been used in safety experiments in the liquid metal fast breeder program. Advanced reactors in the NERVA program incorporated "beaded" fuel particles—highly enriched uranium cores coated with pyrolytic graphite—embedded in a graphite structure. This approach has been applied to use in high-temperature gas-cooled nuclear reactors.

Analytical techniques developed under the constraints of high reliability and safety in space have been applied to the breeder development program. When the NERVA program was discontinued in 1972, many of the 450 people from Westinghouse who had worked on the program transferred what they had learned in analytic techniques to the Clinch River breeder program, for which Westinghouse was the lead manufacturer.

From the beginning of the space program, NASA scientists were interested and involved in the development of plasma-based systems for space propulsion and direct conversion systems for on-board electric power and propulsion. Plasma propulsion conferences sponsored by NASA through the 1960s drew together scientists from fusion, magnetohydrodynamics, and related fields to work on the applications of plasma processes to space.

The progress in both the fusion and MHD programs has had significant input from NASA conferences and the work of scientists in NASA laboratories. MHD, which is a process for converting a hot, ionized gas from fossil fuels, nuclear energy, or fusion to electricity, has used actual rocket engines for testing components.

NASA's Lewis Research Lab has been the Department of Energy agency doing experimental research on liquid metal MHD systems, and all of the MHD experiments have benefited from high-temperature materials developed for space. In addition, NASA's management skills have been applied to the MHD program—NASA Lewis is managing the next-step Engineering Test Facility for the DOE program.

In other energy areas, all solar technology in photovoltaic cells and collectors of all kinds have been developed by the space program and have been used in space for two decades. Gas turbine engines for increased efficiency in generating electric power have been under NASA development and have been transferred to the commercial market. NASA's requirement for minimal weight and maximal energy density have moved energy technology toward higher temperature processes and greater efficiency.

The single most important effort of the space program, the one with the least measurable but most long-term effect, was the creation of new generations of scientists.

NASA's science education programs changed the lives of students from kindergarten to doctoral candidates. Many of the scientists working today on all types of research got their education through NASA.

In 1962 NASA set up its Sustaining University program. The focus of the program was to help pay for graduate training for young scientists and engineers, to build new research facilities, or improve existing ones, at colleges and universities, and to distribute research funds to support NASA space science research.

Entirely new departments in space sciences, astrophysics and related fields were set up at institutions where they did not previously exist. At its height, over 200 educational institutions were receiving money for space research. In 1967, 1,500 faculty members and more than 2,000 graduate students in the sciences were engaged in space science and technology research.

In 1959 NASA gave out grants totaling $3 million for research in colleges; in 1968 this figure was $128 million. Between 1959 and 1969, NASA distributed over $700 million to university programs. Of this about $500 million was for work in direct support of specific space science projects and $200 million were grants for students or for upgrading teaching facilities.

By 1964 NASA was spending $20 million per year just for pre-doctoral training programs, and 3,600 students working on space-related problems in 30 academic disciplines were under NASA sponsorship. At the same time that the Sustaining University program was paying for the education of thousands of scientists and engineers, and giving them the opportunity to work on needed research in the process of earning their degrees, NASA worked closely with the National Science Teachers Association to improve public and parochial school science curricula.

There is no question but that adequate preparation of the United States for establishing a fusion-based economy will demand a total overhaul of the educational system and the conceptual orientation of scientific research. Among the first steps of such a program: The Office of Fusion Energy, under the impetus of the recent fusion review by the Department of Energy's Energy Research Advisory Board, has already begun plans for a graduate educational support program reminiscent of the NASA effort.

The additional $100 million put into the fusion laboratories around the country will also be an important contribution in the direction of preparing trained manpower. It will immediately allow the expansion of the personnel involved in the magnetic fusion engineering programs, including involvement from industry.

There are many industries that will be transformed

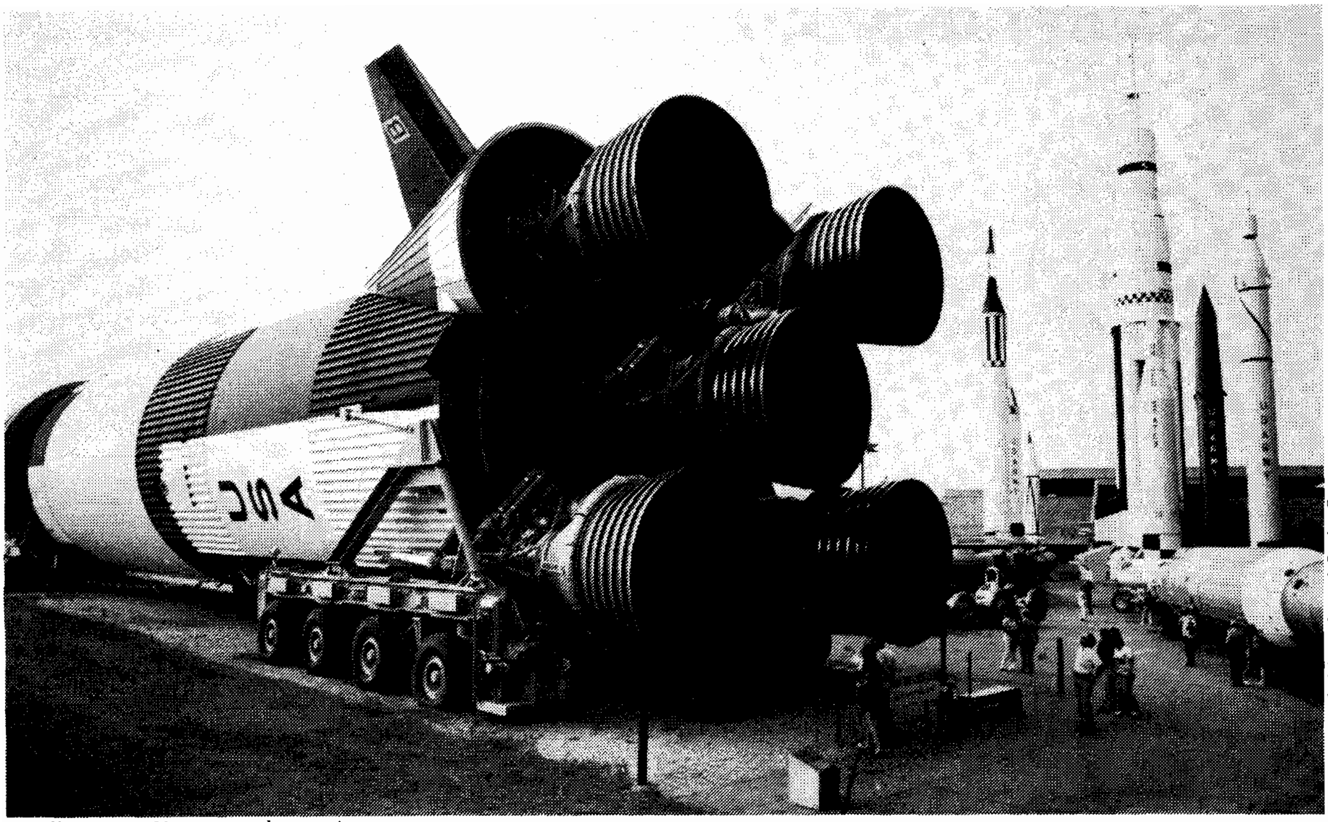
Photo courtesy of Alabama Space & Rocket Center

Apollo Saturn V moon rocket engines.

under the fusion energy economy. The fusion torch is an application of plasma in which, by isolating the hot ionized gas in a region separate from its source, it becomes possible to feed in any solid material, reduce it to its basic elements, and recombine them to form useful materials. With a fusion torch, it has been estimated, municipal waste could become the immediate source of 27,000 tons of new raw materials. Low-grade ore bodies not economically exploitable by conventional methods would become viable resources, and eventually, whole sections of the earth's crust would become a source of raw materials.

New industries

Not only will fusion power give rise to many industries, but the achievement of fusion power requires the prior creation of several wholly new industries, based primarily on skilled manpower.

To take one example, commercial scale magnetic fusion reactors will be a utility-based energy technology which will require superconducting magnets. Such magnets, made of materials which are kept at a few degrees above absolute zero, operate with virtually no energy losses through electrical resistance; they are used today only in scientific experiments.

Since there has been no large-scale demand for such equipment, no mass production industry has developed to provide it. The special wire for superconducting magnets is fabricated on a made-to-order basis and the magnets are wound by hand. With commercial fusion power plants on the horizon, a series of superconducting industries will be required.

Such industries will fabricate superconducting wire and cable, produce the cryogenic equipment to store and transport the liquid helium needed to keep the magnet cold, develop the insulation required for all parts of the technology, and integrate and control this very delicate technology. They will not only make large-scale production of magnets economical, but will allow the revolutionizing of all aspects of power production, transport, conditioning, handling, and distribution by making superconductivity commercially available. Superconducting power transmission systems, laid in underground cables and cryogenically cooled, could eliminate the up to 10 percent loss of electricity now common in electrical transmission lines.

Applications of superconductivity have been under development in industry and government laboratories for years. What is needed is the "push" from a government-sponsored research program that is going to pay for an accelerated R&D effort, the way NASA did in the fields of computers and electronics.