Spinoff from Space Fuel

Expanding civil use of liquid hydrogen, in applications ranging from fertilizer production to food processing, typifies the aerospace technology transfer process

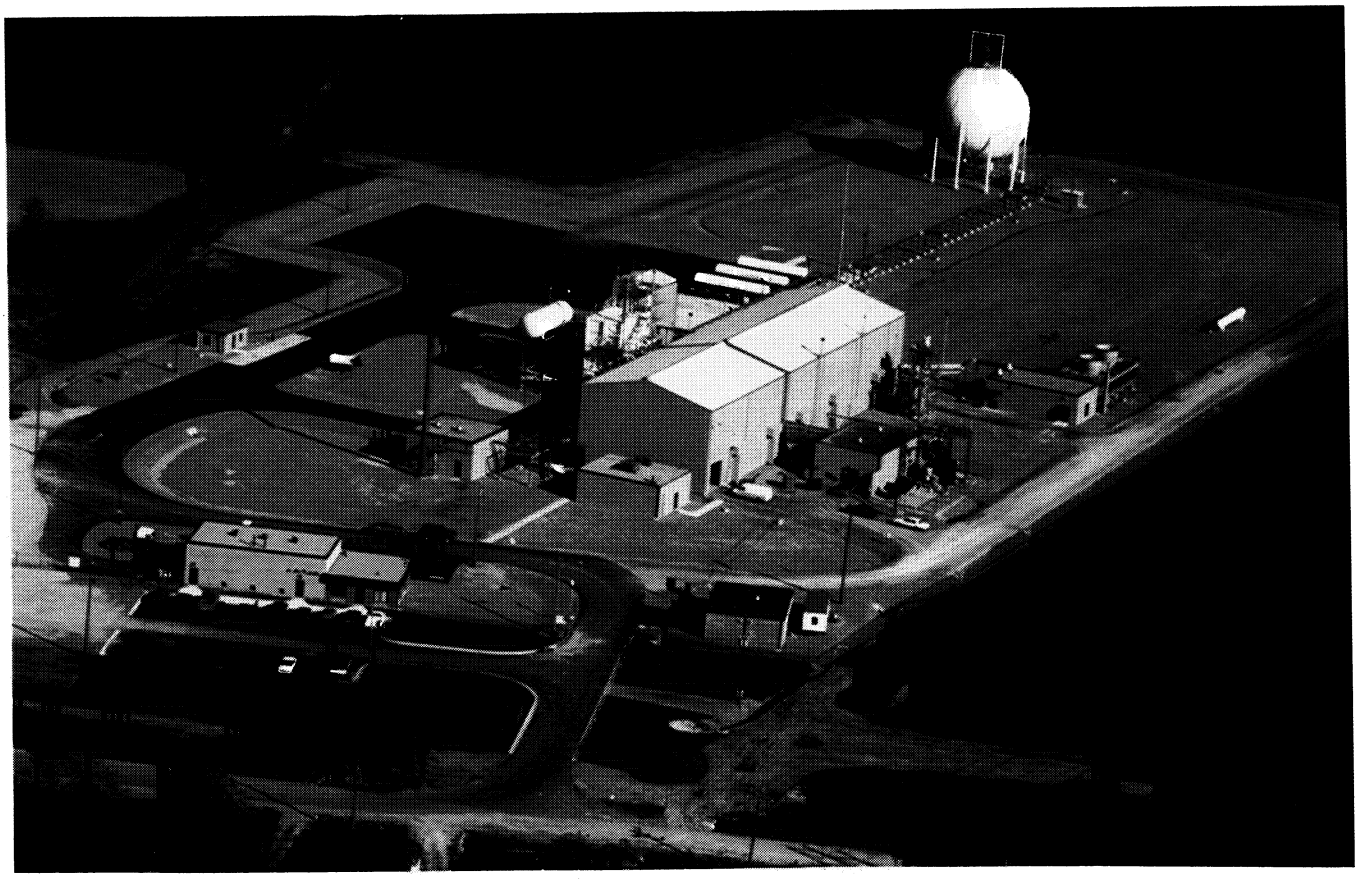
On a Space Shuttle launch, the Orbiter's three main engines burn for about eight minutes and in that brief time consume some 380,000 gallons of fuel. The fuel is liquid hydrogen, which was also used in the Saturn V launch vehicle that sent Apollo astronauts to the moon. NASA selected hydrogen for these heavy-lift space vehicles because it is very light yet produces far more energy per pound than other rocket propellants. The company that supplied liquid hydrogen for Apollo and continues to produce it for the Space Shuttle program is Air Products and Chemicals, Inc., Allentown, Pennsylvania.

Last October, Air Products opened a new plant in Sarnia, Ontario, a landmark development in that it is the company's first liquid hydrogen facility dedicated solely to supplying the needs of non-government users. Sarnia produces 15 tons of liquid hydrogen daily and the plant is designed for double that output, an indication of mounting growth in commercial usage. Air Products' experience in government research, development and production of liquid hydrogen served as the springboard for a broad variety of practical, Earth-use applications.

Today, liquid hydrogen is widely used by petroleum refineries in sulfur-removal processes and in gasoline production; by chemical and pharmaceutical firms in manufacture of fertilizers and drugs; by food processors, who use it to make margarine and to keep oils fresh; by metals industries for heat-treating operations which harden and strengthen metal alloys; by electronics companies in growing crystals for electronic systems; by electric utilities for cooling large generators, motors and frequency changers. And new commercial applications are growing at the rate of about 10 percent a year.

"These applications would not exist today," says Edward Donley, Air Products' chairman, "had it not been for our government experience. Our work on government contracts gave us the technological know-how for large-scale production of liquid

Opened last October, Air Products' Sarnia, Ontario plant is the company's first facility for production of liquid hydrogen dedicated solely to the needs of non-government customers, an indication of growing civil use of the same substance that fuels Space Shuttle engines.

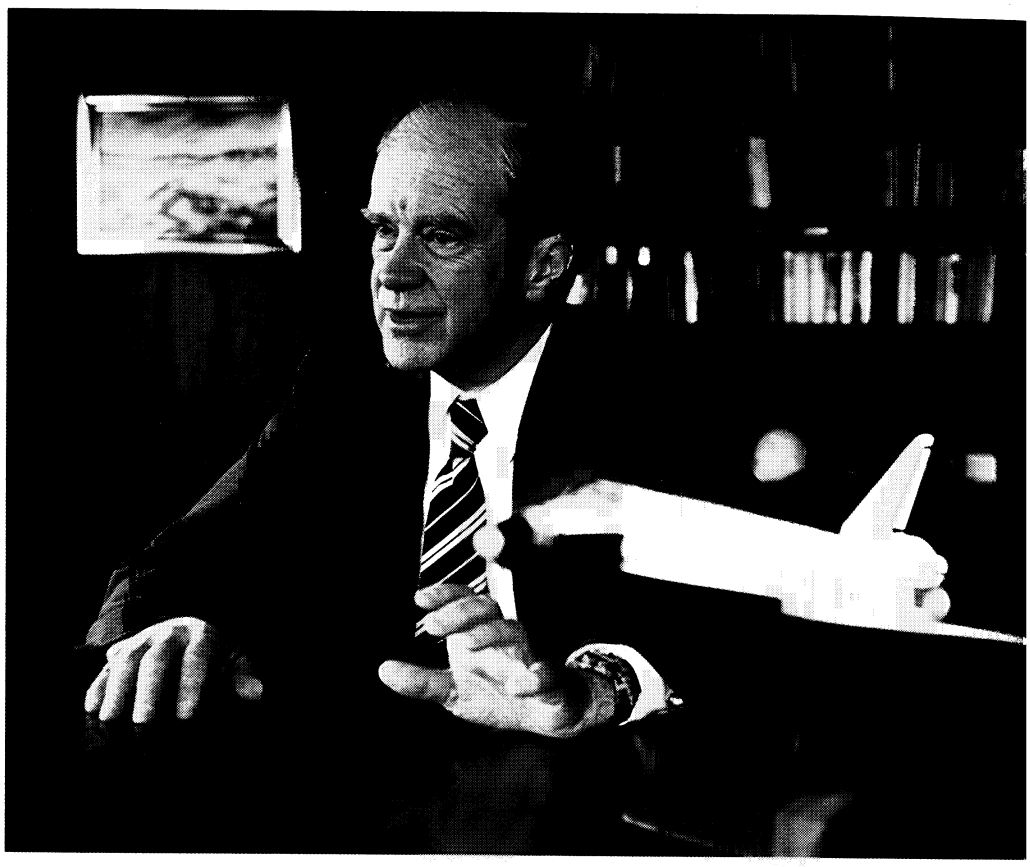


hydrogen, enabling cost reductions through economies of scale. That paved the way for expanded private sector use."

Air Products entered the picture in the mid-1950s when liquid hydrogen was little more than a laboratory experiment. NASA did not then exist, but the U.S. Air Force was studying hydrogen for both missile and space applications. Hydrogen's high-energy characteristics were known, but in gaseous form the element was not suitable for use in flight vehicles because of the very large volume of gas required. USAF research resulted in a process for liquefying hydrogen to reduce the volume, but another problem remained: liquid hydrogen was available only in laboratory-use amounts measured in hundreds of pounds per day, but extensive ground testing of rocket engines would demand production in tens of tons daily. Air Products, then an established producer of liquid oxygen, liquid nitrogen and other industrial gases and chemicals, was assigned the difficult job of pioneering tonnage production of liquid hydrogen.

Under USAF contract, the company built three plants from 1957 to 1959, the largest turning out 30 tons a day. About that time, a new and even larger requirement appeared when NASA began development of the Saturn V moonbooster, whose upper stages were powered by a high-thrust, hydrogen-burning rocket engine called the J-2. Years of exhaustive J-2 ground testing, coupled with the fuel needs for Apollo missions, created soaring demand for liquid hydrogen. In 1963, under contract with NASA, Air Products built a 32½ ton-a-day plant at Long Beach, California to supply West Coast rocket test facilities. In 1966, the company completed another 30 ton-a-day plant near New Orleans, Louisiana to serve NASA's Kennedy Space Center, Marshall Space Flight Center and the Mississippi Test Facility, where large rocket engines are test-fired. The advent of the Space Shuttle program further boosted NASA's liquid hydrogen needs; in 1977, Air Products added a 30 ton-a-day plant at the New Orleans site.

Over a quarter-century of government contract work, Air Products has acquired an enormous amount of technological know-how in all fields related to liquid hydrogen. The company pioneered safety measures for handling the potentially volatile substance and

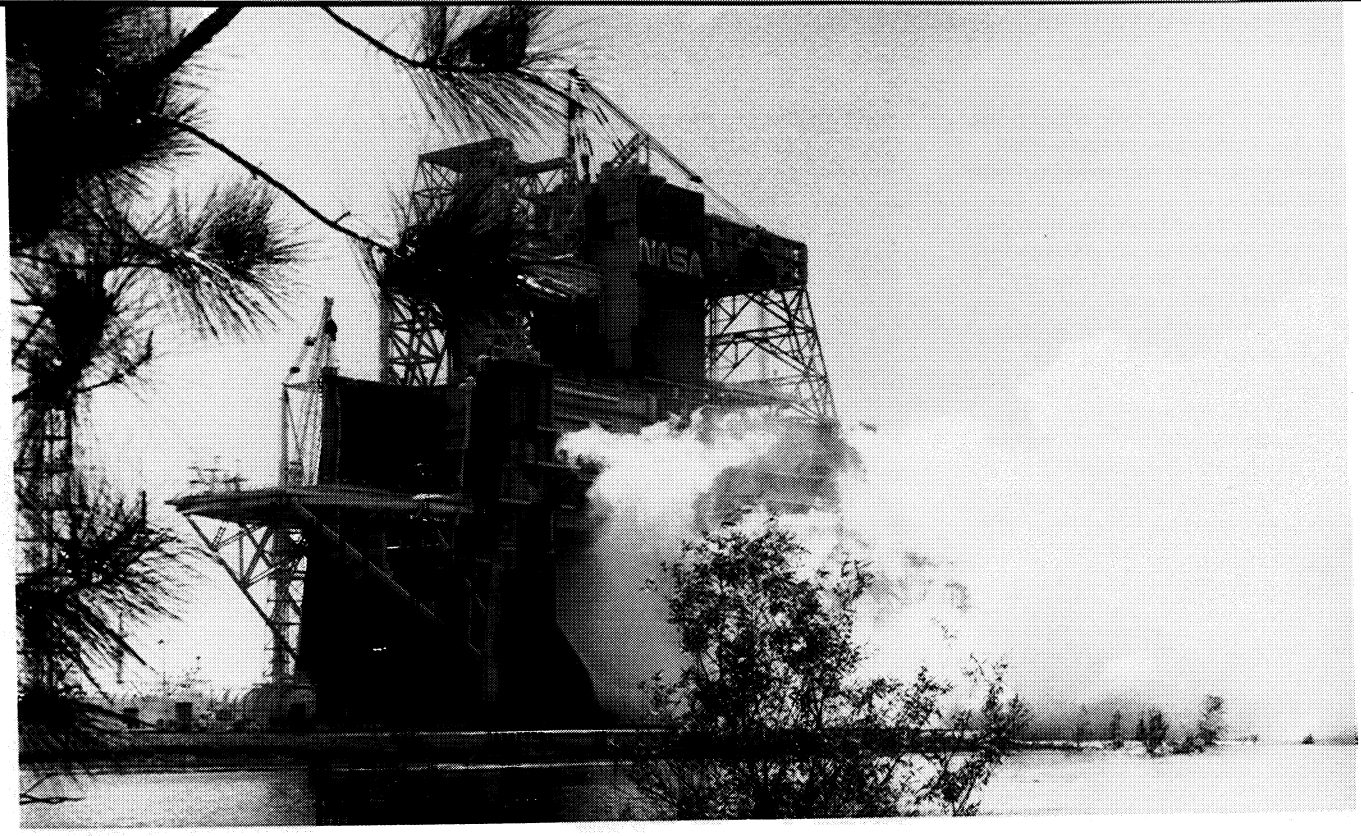


Edward Donley, chairman of Air Products and Chemicals, Inc.: "Our work on government contracts gave us the technological know-how for large-scale production of liquid hydrogen . . . that paved the way for expanded private sector use."

disseminated its information to other producers. It developed design and construction techniques for high-quantity production, storage and transfer, including the world's only transfer system for loading barges from liquid hydrogen storage tanks. For overland distribution of the product, which must be maintained at the supercold temperature of minus 400 degrees Fahrenheit, the company built a fleet of specially-designed semitrailer tankers which boasts an impressive record in many million miles of road hauling. Most importantly, Air Products developed a number of processes for producing liquid hydrogen more efficiently, effecting cost reductions that inspired broader commercial use. Input from government research, Air Products' own technology development, and the large space program requirement combined to make the company the prime manufacturer of liquid hydrogen; its four plants turn out more than the total output of all other producers in the free world.

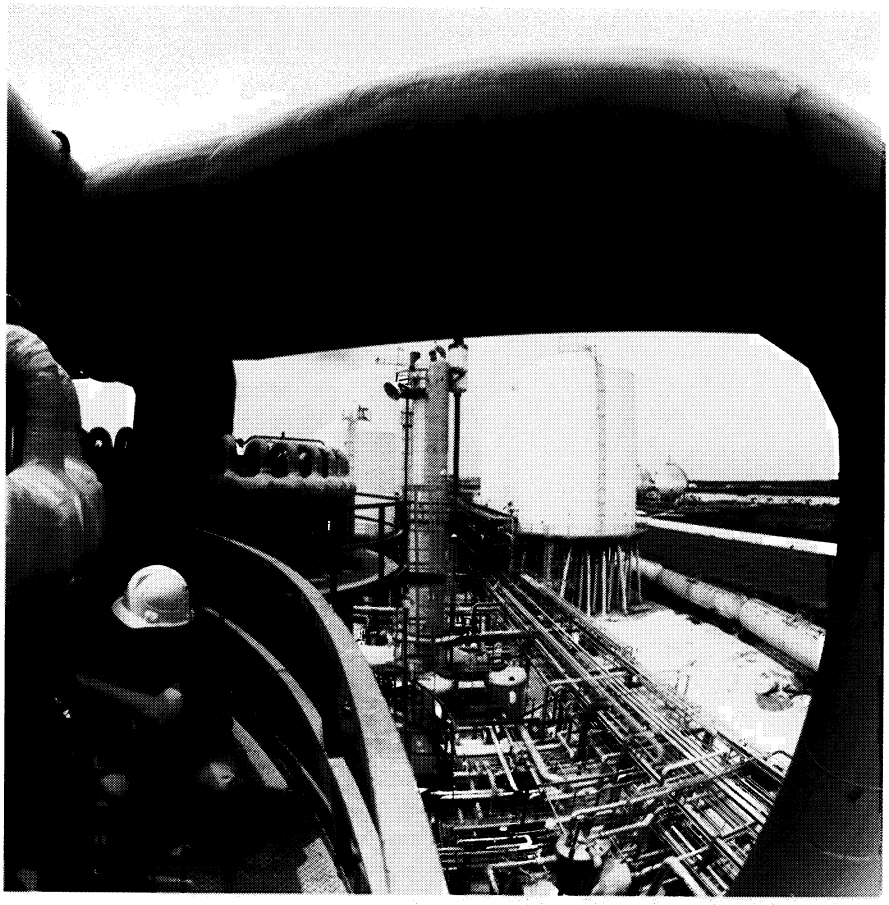
The Air Products story exemplifies the aerospace spinoff process. In this case, space needs created a large market for a new product; the NASA requirement, and the technology development necessary to its fulfillment, provided a base for company expansion into many non-government applications, with attendant benefit to the nation's Gross National Product and job creation. In other instances, the spinoff is government-developed technology rather than the growth and advancement spurred by a government requirement; once developed, technology can be reapplied in many avenues of everyday existence, often in ways surprisingly remote from the original application. Spinoff benefits valued in many millions of dollars are not unusual; in other spinoffs, the economic gain is only of moderate order, but the public benefits in other ways—from the introduction of new processes and products ranging from simple conveniences to significant developments in industrial and medical technology.

Through its Technology Utilization Program, NASA has actively promoted the secondary use of aerospace technology for two decades, during which thousands of aerospace-originated spinoffs have emerged. Collectively, they represent a substantial return on the aerospace investment.



Above, a Space Shuttle engine is being tested at NASA's Mississippi Test Facility, Bay St. Louis, Mississippi. The Shuttle's main engines burn liquid hydrogen fuel supplied by Air Products and Chemicals, Inc. On a full-duration test, the engines may consume hundreds of tons of liquid hydrogen. High volume production for NASA and other government requirements gave Air Products a technology base for expansion into a variety of civil applications of liquid hydrogen.

Liquid hydrogen is a "cryogenic" fuel, meaning that it must be maintained at extremely low temperatures. To distribute the product from plants to users, Air Products built its own fleet of specially-designed cryogenic transport trailers, one of which is shown at left.



At its chemical complex near New Orleans, Louisiana, Air Products operates two plants which supply liquid hydrogen to NASA's Mississippi Test Facility and Kennedy Space Center. The plants have a combined output of 60 tons daily. The original plant was built in 1966 to meet the fuel needs of the Apollo program; the second facility was added in 1977 when Space Shuttle engine testing began. In addition to the New Orleans complex, Air Products operates liquid hydrogen plants at Long Beach, California and Sarnia, Ontario.