

THE ENERGY MISSION

An Aerospace Perspective

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

THE ENERGY MISSION An Aerospace Perspective

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JULY 1979

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The mission of the Aerospace Research Center is to engage in research, analyses and advanced studies designed to bring perspective to the issues, problems and policies which affect the industry and, due to its broad involvement in our society, affect the nation itself. The objectives of the Center's studies are to improve understanding of complex subject matter, to contribute to the search for more effective governmentindustry relationships and to expand knowledge of aerospace capabilities that contribute to the social, technological and economic well being of the nation.

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PREFACE

Among national goals, a secure and adequate energy supply continues to be of highest priority. This report reviews some facts critical to the nation's energy policy and it highlights several important programs underway in the aerospace industry to develop new energy technology and to improve conservation and conversion efficiency. It examines some of the difficulties the industry and the nation face in bringing new technologies to market and offers some recommendations for improving prospects for a smooth transition to a new era of energy sufficiency.

SUMMARY AND RECOMMENDATIONS

The "energy crisis" is very much a reality. The late 1978 shutdown of oil fields in Iran, the world's second largest oil exporter, once again highlighted and intensified the problem. Moreover, oil importing nations must still nervously await the outcome of the OPEC cartel's periodic meetings on petroleum prices and production rates.

Following the basic course toward energy selfsufficiency, as outlined in the National Energy Plan (1977), has become even more imperative for the United States. Rapid development and commercialization of alternative energy technologies, while continuing conservation efforts and increasing production and use of coal and generation of nuclear power, must be pursued.

The aerospace industry has already assumed an important role in the quest for energy sufficiency by applying a broad array of skills to new energy technologies and more efficient fossil fuel use. Typical of all highly innovative endeavors, these activities involve significant risk for private investment. Consequently, government funding through the Department of Energy (DOE) has been helpful.

Since private enterprise will be responsible for sustaining new energy systems in the competitive marketplace, government can best assist by creating a more favorable environment for technology development, particularly by lessening regulatory disincentives which stifle industrial innovation. A smooth transition to the new energy era depends on government and industry ability to put America's technological genius to the test.

It is therefore recommended that:

GOVERNMENT

• Recognizing that the "energy crisis" is no less severe than in April of 1977, when President Carter submitted his first National Energy Plan to Congress, the Administration directed the Department of Energy to take more aggressive action to inform the public (1) of the erosive economic effects of relying so heavily on imported petroleum, (2) that continued U.S. economic growth is possible with a reduced energy consumption rate, thus the continuing requirement to support energy conservation, (3) of the need to more vigorously pursue renewable energy technologies which have the potential for sustaining a new era of cheap and abundant energy;

• DOE adopt a comprehensive systems approach to planning R&D programs, similar to proven DoD and NASA practice, which will (1) ensure that all aspects of new technologies are adequately developed and tested to maximize potential commercial success and (2) enable DOE to make stable, long term funding commitments to specific programs;

• In carrying out national energy policy, DOE seek to bring its regulations and practices into line with the principle of relying to the maximum extent possible on the vast technological and managerial capability of the private sector. Specifically, patent policy, conflict of interests rules, cost sharing and other procurement mechanisms be adopted which stimulate, rather than inhibit, private enterprise's creative potential.

INDUSTRY

• Industry make a strong effort to develop the kind of productive relationship with DOE that exists with DoD and NASA: in other words, a non-adversarial partnership which elicits the strengths of both the public and private sectors toward achieving national goals. Industry should take advantage of all opportunities to offer aerospace technical and managerial expertise to DOE planners and decision makers.

• Recognizing (1) that more favorable government R&D policies and procurement regulations can reduce but cannot eliminate the risk to business of investing in long term research and development and (2) that in business profits are generally commensurate with risks, industry be more willing to take the necessary risks associated with energy research and development, risks which are inherent to the industry as a leader in developing new technology.

THE ENERGY DILEMMA

The first National Energy Plan issued by President Carter in April 1977 states three objectives:

- "as an immediate objective that will become even more important in the future, to reduce dependence on foreign oil and vulnerability to supply interruptions;
- in the medium term, to keep U.S. imports sufficiently low to weather the period when world oil production approaches its capacity limitations; and
- in the long term to have renewable and essentially inexhaustible sources of energy for sustained economic growth."

The basic strategy outlined for accomplishing these objectives combines conservation, increased use of coal and other abundant fuels, rational pricing and production policies, reasonable certainty and stability in government policies and a vigorous energy research and development program.

The Plan's original urgency was supported by a Central Intelligence Agency (CIA) study published in 1977 which predicted a shortfall in world oil supply before the end of the 1980's. By the summer of 1978, however, the world was experiencing an oil surplus and some experts were predicting that an imbalance between supply and demand would not occur until well into the 1990's. The announcement of greatly expanded estimates of Mexican oil reserves further supported this prediction. But by the end of 1978, a cutoff of Iranian oil, followed by a 14.5 percent Organization of Petroleum Exporting Countries (OPEC) price increase, brought a renewed sense of urgency to the energy dilemma. In March 1979, 21 major industrial nations of the world hurriedly signed an agreement to cut back five percent on their oil consumption to compensate for the Iranian loss. It remains uncertain whether Iranian exports can or will be raised to the former level of 5 million barrels per day (MBD).

The basic logic and objectives of the National Energy Plan still remain valid. The finite supply of fossil fuels assures that a shortfall between supply and demand will eventually occur, and most all studies predict the final peak of world petroleum production before the year 2000, just twenty-one years away. Most agree that world energy demand will continue to grow.

Figure 1 summarizes world energy consumption growth rates since 1965 and gives an estimate through 1990 of the rate of growth of future demand. The rate has decreased, but the curve is still decidedly upward. The continuing U.S. dependence on foreign oil and consequent vulnerability to supply interruptions and excessive price hikes cannot be denied. Figure 2 shows that by 1977, U.S. oil imports were about 38 percent greater than the pre-embargo level of 1973. The 1978 level was down slightly from 1977 due to conservation efforts and an increased Alaskan oil flow.

The adverse economic effects of relying so heavily on imported energy are a matter of record. The 1973-74 Arab oil embargo and subsequent four-fold price increase contributed to a worldwide economic recession. Higher energy costs continue to have a strong inflationary impact. According to Chase Econometrics Associates Inc., the December 1978 OPEC price increase will result in an increase of 0.7 percentage points in the U.S. consumer price index. It has also been estimated that the OPEC increase will cost the U.S. \$5.4 billion annually.

The Energy Plan's basic strategy is sound. Increased use of coal and greater energy conservation are prudent near term alternatives. Both, however, present real challenges.

Although there are huge coal reserves in the U.S. (the demonstrated coal reserve base is estimated at over 400 billion tons, the environmental, health and safety regulations associated with coal mining and combustion may be barriers to reaching the production goal of 1.2 billion tons a year in 1985. Alternative technologies for extracting energy from coal, more efficiently and cleaner and in more convenient form, such as fluidized bed combustion, coal gasification and liquefaction, and magnetohydrodynamics will will have to be vigorously pursued.

Conservation has already demonstrated its effectiveness for easing the energy dilemma. From 1975 to the present, the relationship between growth in energy demand and Gross National Product (GNP) has dropped from approximately one to one, to about



0.7 to one. Industrial conservation is an excellent example. In 1977, overall U.S. industrial production was nine percent higher than in 1973, while industrial consumption of energy was actually five percent lower. Optimizing conservation will most likely require the development of improved conservation technology and more energy efficient devices. Computerized energy management systems, and combined cycle systems are two promising examples.

The President's National Energy Plan also called for modestly increasing electricity generation through the proven technology of the nuclear light water reactor and for deferring U.S. commitment to breeder reactors. Perceived safety, environmental and waste management and proliferation risks have weakened the very large potential role of nuclear fission, at one time predicted to be the key to energy self-sufficiency. The actual safety record of nuclear power plants has been extremely good over many years of operation. The recent serious incident at Three Mile Island is stimulating renewed efforts to further improve reactor safety. Despite heightened concern, it seems certain that nuclear fission will continue to contribute an increasing share of the U.S. and world energy supply. Nuclear plants generated 12 percent of total U.S. electrical utility output in 1977.



FY 1980 Budget Authority \$3,583 Million Hydro 18 Other 106 Geothermal 111 Basic Energy Research 276 Environment 278 Fusion 364 Other Ocean Biomass 156 35 58 67 130 121 Solar Applications Wind Photovoltaic Solarthermal 597 Other 663 57 64 **Fossil Fuels** Oil Gas Coal 796 Spent - fuel storage 84 104 199 590 Fission 20 40 Uranium **Commercial Waste** Converter Breeder Reactor 1,037 Management Resource Reactor Advanced nuclear systems 240 720 480 960 1200 Millions of Dollars

FIGURE 3 DOE ENERGY TECHNOLOGY DEVELOPMENT

Petroleum and natural gas will continue to be important sources of energy for many years. Rational pricing and production policies, with primary reliance on the market system, can stimulate greater conservation and additional exploration and production of these fossil fuels.

For long term energy security, the Energy Plan recognizes the fundamental importance of rapid development and commercialization of alternative energy technologies. Technologies which today contribute only a small fraction of the total supply, or which have not yet been commercially developed or in some cases even proved or demonstrated in the laboratory, will become increasingly important and ultimately assume the major burden of energy supply.

The Ninety-fifth Congress finally passed the Na-

tional Energy Act nearly eighteen months after the President's Plan was presented. The Act consists of conservation and coal conversion programs, utility rate and natural gas pricing reform and energy tax credits for business and consumers. It falls far short of the Plan's objectives. According to the Administration, the original Plan would have saved 4.5 MBD of petroleum by 1985 while Congress's version is predicted to save only between 2.5 to 3 MBD by then (1977 acutal U.S. demand was 18.5 MBD of which 8.7 MBD were imported). Although the Energy Act can have a significant impact on reducing U.S. energy imports, clearly it does not eliminate U.S. dependence on foreign supplies. Only when the nation can begin to rely on alternatives to petroleum will we regain control of our energy future. New technology

is the key to many of these alternatives.

The primary responsibility for spurring development of new energy technology now lies with DOE. DOE is currently conducting a broad range of research and development (R&D) programs involving fossil fuels, and technologies such as solar, wind and biomass. In recognition of the large amounts of capital investment, the high risks and long development time associated with the introduction of new energy technology, DOE's budget allots substantial funds for these programs. (See Figure 3)

No one can be certain how much time and how much money will be required to develop new energy technologies to the point where they can make a significant contribution to energy demand.

Figure 4, from a study done for the former Energy Research and Development Administration (ERDA) in 1976, gives an indication of the time and relative investment needed to commercialize a typical complex new technology. It takes nearly twenty years from concept to mature technology and there is no guarantee that a given concept will make it to successful commercialization. The capital needed to develop a given technology is enormous and the return on investment is negative until very late in the commercialization cycle. It is ironic that industry's ability to accumulate the necessary capital has been weakened by the very problem that the capital is needed to solve. Energy induced inflation is an acknowledged contributor to present capital formation problems.

Pursuing new technologies which can become competitive options for meeting future energy needs requires a concerted effort by all technological wellsprings: universities, private industry, government, nonprofit research organizations and others.

The remainder of this report focuses on the aerospace industry's role as a source of new energy technology.





Throughout the basic research, applied research, and development phases of the commercialization process, the private firm is subject to a high degree of financial/capital exposure (ROI is negative).

Source: Introduction to the Analysis of Commercialization Conditions, Booz, Allen & Hamilton, Inc., for ERDA, July, 1976.

AEROSPACE INDUSTRY CAPABILITY IN ENERGY TECHNOLOGY DEVELOPMENT

Efficient energy conservation, use and storage have long had a high priority for designers of aircraft and space systems. Powered flight, itself, is a critical exercise in energy management. For instance, the more useful power that an aircraft jet engine can derive from a given amount of fuel, the less range, payload or performance need be sacrificed to the weight of fuel load. This fact has driven the evolution of fuel efficient engine technology to the point where today's commercial aircraft engines are 35-40 percent more efficient than the jet engines of the late 1950's.

Energy management became an even greater challenge as man sought to extend flight beyond earth's atmosphere. The aerospace community again responded, this time with powerful rocket engines based on advanced technology and new fuels. Complex, long term space missions created a demand for highly reliable on-board systems for generating electric power, precisely managing its consumption and providing for its storage. Photovoltaic cells, fuel cells, and light weight, high capacity batteries were developed by NASA and aerospace companies to meet these needs. Advanced power and propulsion systems for future space missions are under continual development.

Some of the energy technologies now being funded by the government are direct outgrowths of classic aerospace technology. Others employ techniques and technology closely related to aerospace disciplines or developed as part of the space program. In fact, in FY 1978, NASA performed or managed over \$175 million worth of reimbursable energy research and development for the DOE.

Aerospace companies hold DOE contracts in nearly every emerging energy technology. They are leaders in several of the most innovative, such as solar thermal electric, ocean thermal electric, space solar power and magnetohydrodynamics. This breadth of involvement reflects the industry's diversity of experience, the broad applicability of aerospace expertise and the industry's neutrality in the "hard vs. soft" technology debate. The industry is not concentrating solely on large, centralized power generating systems or on decentralized "appropriate" technology. The skills to develop a complex multigigawatt solar power satellite system and to optimize an elegantly simple, home solar heating/cooling system are within the realm of aerospace technological capability.

The unique character of the industry suggests that its potential for solving energy problems is just beginning to be tapped. Aerospace companies have played a central part in maintaining national security since the early days of aviation. They have pioneered mankind's expansion into space. They have repeatedly accomplished complex missions in the national interest. These experiences have molded a high technology industry with particular attributes for successfully pursuing the goal of assured national energy sufficiency:

• Management of complex long term projects Single aerospace programs have often run into billions of dollars and have taken more than ten years from concept to completion. Effective management of these programs has honed the dynamic management skills of the industry skills which are directly applicable to the many programs and projects DOE is pursuing.

• Strong government/industry relationship Long-term, joint pursuit of national defense and aerospace goals has developed an effective planning and policy making relationship between the industry and the government. This ability to successfully work together on government funded programs is essential for solution of energy problems.

Research laboratories

The continuing development of more advanced weapons systems and space vehicles requires the industry to push forward many state-of-theart technologies. In many of its products, revolutionary advances in performance and capability are required. To meet this demand, the industry maintains many high quality research laboratories which have a proven record of giving birth to and developing new technology. The diverse technical disciplines and the capability of these labs are critical to the solution of many technological energy problems.

Systems analysis and engineering

Analyzing complex scientific and technological problems, involving many interrelated factors, and then engineering and implementing solutions which guarantee the desired result is a capability for which the aerospace industry is renowned. The Apollo program is perhaps the best known example. The Mars Viking mission, ballistic missiles, wide-body jets, Skylab and the Space Shuttle are but a few of the many others.

It must be pointed out, however, that basically the aerospace industry consists of those industrial firms that produce aircraft, missiles, space vehicles and their related engines, parts and systems. Although the non-aerospace, non-government portion of total sales is growing, the principal industry customers remain the federal government and the airlines. Hence, most companies currently do not have the commercial infrastructure, the product marketing, distribution and servicing network necessary to support commercial energy products. The aerospace companies that are part of large diversified corporations with substantial non-government markets are in the best position to transfer aerospace know-how to marketable energy products. Companies that must develop the necessary commercial network probably face a much greater investment and risk.

Further, aerospace companies will have to carve out a niche in an energy market where there already exist firmly entrenched companies. Although petroleum companies generally continue to put most of their R&D money into fossil fuel research areas, they are heavily involved in the uranium industry and are increasing R&D in solar, geothermal and fuel cells. The suppliers of energy equipment such as turbines and steam generators, mining hardware, and energy transmission and distribution systems are also branching into new technologies. The market for energy systems, however, is huge. The annual capital expenditures of the electric utilities alone are expected to increase from \$31 billion in 1978 to \$88 billion in 1995.

In the following pages an overview of the aerospace industry's "energy mission" is presented. This review is necessarily broad brush for it cannot cover all the individual initiatives of the industry. It does highlight some of the many areas where aerospace has contributed and continues to advance the state-of-theart of energy technologies.

The technologies discussed are in stages of evolution from concept verification to early commercialization. For many, there are technological and economic hurdles yet to be surmounted. Continued strong research, development and demonstration programs are needed to advance and sustain them. Their eventual contribution to overall energy supply, however, will be determined by a combination of technological, economic, environmental, social and political factors.

NON-FOSSIL FUEL TECHNOLOGIES

SOLAR

The Solar Energy Domestic Policy Review ordered by President Carter reported in September 1978 on possible solar scenarios for the year 2000. One scenario which represents "the maximum solar impact that could be accomplished within the framework of traditional Federal intervention" (and which assumes the cost of petroleum to then be \$25 a barrel) foresees the various solar technologies supplying 12.5 percent of total U.S. energy demand. A second scenario, which represents a "technical limit" with economic and market mechanisms playing a decidedly secondary role to national goals, could increase that figure to about 19 percent.

Aerospace companies have become leaders in developing a variety of solar technologies which will help maximize this technical limit. Some of these technologies are:

Photovoltaics

For almost twenty years, arrays of photovoltaic cells have been used to provide electrical power for satellites and other spacecraft. The ability of these simple semiconductor devices to convert incident sunlight directly to electricity makes them ideal solutions to the problem of providing reliable, long term electrical power with a minimum weight penalty. Aerospace companies working with NASA pioneered their development and continue to improve the technology. Current efforts focusing on increasing their energy conversion efficiency and reducing manufacturing costs may make solar cells cost competitive for a wide variety of small and large scale electrical needs. The Ninety-fifth Congress strongly endorsed photovoltaics by approving in its final days a 10 year. \$1.5 billion photovoltaic R&D program.

Solar Thermal Electric

The solar thermal concept entails using the energy of the sun to heat fluids which drive electricity generating machinery such as turbines, or which provide heat for energy intensive industrial processes. The technical or engineering feasibility of such systems should be proven in several DOE sponsored experimental projects. One of these, a solar power tower concept developed by aerospace companies, employs computer controlled sun-tracking mirrors to concentrate heat onto a central receiver/boiler, the power "tower". The resulting steam drives a turbine to produce electricity. The pilot plant, to be completed by 1981, will generate 10 megawatts of power and will be the world's largest application of solar thermal technology in which electrical energy is produced for the utilities. Aerospace contractors have been selected for design and construction of the collector mirrors and for system management of the program.

Another project employs large hemispherical bowllike distributed collectors to provide steam for electrical generators. The goal is construction of a five megawatt plant in the mid 1980's. Aerospace companies are also engaged in the development of these solar collector systems.

Solar Heating and Cooling

High altitude air travel and space travel posed difficult problems for aerospace engineers responsible for providing safe and comfortable cabin environments for passengers and crew. Skills gained in solving these environmental problems, combined with skills in development and use of advanced materials, thermodynamic design, systems integration and other areas of aerospace expertise are enabling aerospace firms to make a significant contribution to solar heating and cooling technology. All buildings—residential, commercial and industrial—are potential markets. High efficiency solar collectors, advanced solar heat pumps, and innovative "total systems" are being developed by aerospace companies, either independently or for DOE.

Wind Power

The key component for transforming wind energy into more useful forms, such as mechanical power or electricity, is the aerodynamic rotor. Similar to an aircraft propeller or helicopter rotor, an efficient and durable rotor is a product of aerodynamic and structural analysis, a specialized domain of aerospace technology. Wind power systems under development by aerospace companies incorporate rotors from 25 to 300 meters in diameter, and are capable of producing from a few kilowatts to thousands of kilowatts. The smaller units are designed to provide sufficient power for individual residences and the larger ones for farm and small communities. They vary in configuration from simple propeller-like systems to unique and complex airfoil designs.

Solar Power Satellite

One of the most daring and challenging concepts being proposed as a means of capturing vast amounts of solar energy is the Solar Power Satellite (SPS) system. These satellites, possibly 50 square kilometers in size, would be put into geosynchronous orbit, 35,800 kilometers high, where they would convert solar energy to electricity and beam it to earth via microwaves for distribution to electrical utility grids. Recognizing the potential of this system, NASA and DOE are spending \$15.6 million jointly to evaluate the feasibility of the concept, assess its economic practicality and its environmental acceptability. The reference system satellite now being studied would provide 5,000 megawatts of power. Final recommendations of the program are due in June 1980. The engineering challenges surpass those of the Apollo mission, but do not appear to be insurmountable.

Biomass

Extracting energy from biomass would at first seem to be unrelated to aerospace expertise. Biomass includes any organic materials, such as animal waste and agricultural, forest or sea crops, which can be burned directly or converted into liquid, gaseous or solid fuels, or petrochemical feedstock. Two examples are burning wood and conversion of sugar cane to ethanol by fermentation. Here, though, the industry provides again an example of developing alternative energy sources through combining particular skills linked to space programs—in this case, waste processing as part of life support systems for manned spacecraft—with general systems development experience. This DOE funded project aims at achieving an energy selfsufficient feed lot/meat packing plant system. The key to the system is a cattle manure fermentation process which produces not only a fuel gas but a protein feed product which is "recycled" through the cattle.

Ocean Thermal Energy Conversion (OTEC)

Aerospace companies working with the National Science Foundation were the first to evaluate the feasibility of large scale OTEC systems and continue to be the leading designers and prime candidates for fabrication of OTEC pilot plants for DOE. The most critical components of OTEC systems from both cost and performance standpoints are the heat exchangers. Huge exchangers are required to extract heat from the sun warmed uppermost levels of the ocean for boiling a highly volatile liquid whose vapor will drive an electricity generating turbine. Heat exchangers are also required to use the cooler water from several thousand feet below to condense the vapor for recycling through the system. A unique combination of skills is required to design and integrate the exchangers into a practical system: systems management and large hardware know-how capability, special materials technology, thermodynamics and structural analysis capabilities, experience in solving marine bio-fouling problems and designing deep submersible vehicles. DOE, therefore, is relying on the aerospace industry to develop the first working OTEC systems.

Ocean Kinetic Energy

The kinetic energy of ocean waves and tides is another potential source of nearly limitless energy. Systems which produce electricity from tidal motion have been operating in France and the USSR since the early 1960's. Improved energy storage techniques are needed to make tidal systems economical. Several aerospace companies are pursuing research in these areas.

FUSION

Harnessing the nuclear fusion process—the basic energy producing reaction of the sun and also the hydrogen bomb—would give mankind a virtually unlimited, clean source of energy. The fuels deuterium and tritium are available from sea water. Unlike the fission process, fusion produces little radioactive waste. The feasibility of sustaining fusion for production of commercial power is only now being tested in the laboratory. If an experimental fusion reactor can be developed in the 1980's which produces more energy than is put in, DOE says, a demonstration power plant could be running before the end of the 1990's. A commercial network of fusion electricity plants could be in place by 2025.

Aerospace firms are very closely associated with the major federal laboratories and universities pursuing fusion research and development. As contractors for design and development of reactors and their subsystems, they are applying their advanced technology experience in plasma physics, extremely high temperature-high strength materials, cryogenics, superconducting magnets and overall systems analysis and engineering, to help harness fusion power for practical use.

FOSSIL FUEL TECHNOLOGIES

COAL

Several innovative coal technologies are being investigated by aerospace firms.

Magnetohydrodynamics

One of the promising technologies for extracting electrical energy from coal is magnetohydrodynamics (MHD). MHD devices generate electricity directly from a very high temperature ionized gas produced by burning coal combined with a "seed" material such as potassium. Waste heat from this process can be used to drive a turbine generator, thereby producing additional electricity from the same coal. MHD systems have the potential of producing 50 percent more electricity from the same amount of coal than conventional coal fired utility plants, with greatly reduced sulfur emissions. The Electric Power Research Institute estimates that MHD could furnish about 3 percent of projected U.S. demand by the year 2000.

Several aerospace companies are engaged in pioneering developments in this technology. Their experience with extremely high temperature, heat resistant materials, superconducting magnets and overall systems integration makes them well qualified.

Coal Gasification and Liquifaction

Although coal gasification and liquifaction are principally the province of traditional energy companies, several aerospace companies are working either independently or with DOE to demonstrate the feasibility of deriving both low and high BTU gas and synthetic liquid fuel from coal. One project, based on liquid rocket technology developed for the space program, involves the construction of an experimental facility which will convert 100 tons of coal a day into high BTU pipeline quality gas.

FUEL CELLS

Chemical fuel cells were put to use by aerospace engineers during the 1960's to supply spacecraft power and became the primary power sources for astronauts aboard Gemini and Apollo. Since the 1960's the range of fuel cell sizes, power outputs and

applications has expanded. Today, cells small enough to supply a small apartment house and large enough to supplement a metropolitan utility grid are within the state-of-the-art. The basic fuel cells for space missions combined hydrogen and oxygen in a pollution free process for producing electricity. Today's fuel cells can also be made to operate on a variety of conventional fuels, such as natural gas, propane, diesel oil or processed coal, extracting energy from these sources more cleanly and efficiently than conventional powerplants. One aerospace company, with extensive experience in developing fuel cells, has provided a 4.8 megawatt unit to a New York utility to supplement Manhattan's electrical supply. Other utilities are also ordering multi-megawatt fuel cells to meet part of their electrical demands.

CONSERVATION

Conservation is broadly defined by the DOE to include reducing national energy demand through practice of an energy frugal ethic, increasing the efficiency of current energy conversion technologies and developing new methodologies and technologies for using energy. Aerospace companies are actively involved in many conservation efforts which fit within this definition. Also many technological by-products of aeronautical and space research such as automobile aerodynamic drag analysis are now being broadly applied toward energy conservation goals.

Some areas where aerospace companies are active-

Energy management

Aerospace companies are designing and marketing computer controlled energy management systems. These systems automatically control heating and air conditioning systems and other high energy consumption equipment in industrial plants and commercial buildings so as to maximize total energy conservation.

Energy conversion

Several companies are involved in the effort to increase the efficiency of fossil fuel power plants. Waste heat recycling systems and more efficient industrial gas turbines based on aerospace technology are being developed. Advanced research on the combustion process may lead to a broader range of useable fossil fuels, such as powdered coal or residual fuels, for power generation.

Energy storage

Compact, high power electrical batteries are required for space missions. Automobiles and small industrial vehicles are now being built, combining such batteries with fly wheel energy storage devices. An entire panoply of potential storage systems like these is emerging from aerospace research.

DISINCENTIVES INHERENT TO THE CURRENT INDUSTRY/GOVERNMENT RELATIONSHIP

The foregoing is evidence of the energy options that technology can offer and it testifies to the applicable technological and managerial capability of the aerospace industry. Aerospace companies, however, face some strong deterrents to a full commitment to develop alternative energy technologies. Because of the size of investment required and the uncertainty of what will be competitive in future energy markets, industry generally has accepted the inevitability of government support. It is by no means clear, however, that the rules governing the industry/DOE relationship give sufficient weight to the fact that industry itself will ultimately have to accept the full responsibility for ensuring the future success of new energy technologies in a competitive market.

For the most part, market incentives are not yet adequate to undertake large scale private energy technology development. The potential returns on such investments could be great, but they are uncertain and the long development and commercialization lead times assure that what profit there is will be deferred far into the future. Furthermore, with the decline in energy consumption growth rates, the growth of the market may be decreasing.

The aovernment, therefore, has justifiably seen fit to get the energy technology development and commercialization cycle started. Unlike DoD or NASA (space) funded research programs, the government will not be the principal customer for the products of DOE energy research. New energy technologies will have to be purchased by commercial. industrial and private consumers, if these technologies are to become the keystones for continued economic growth which traditional sources have been. For example, magnetohydrodynamics plants will have to become competitive alternatives for utilities and likewise solar home heating systems for residential customers. If the DOE is successful in stimulating the development and growth of competitive alternative energy technology, normal market forces will take over, and the Department will no longer be necessary. If industry finds itself in competition with government programs backed by high levels of funding, industry R&D in related areas will be curtailed and the developing technology will be slowed¹. These important considerations are central to defining appropriate roles for government and industry collaboration in the development and commercialization of energy technology.

It is the intent of relevant legislation to foster early and maximum involvement by the private sector. Public Law 95-91, which established DOE, purports "to assure to the maximum extent possible, that the productive capacity of private enterprise shall be utilized in the development and achievement of the policies and purposes" of federal energy programs. Public Law 93-577, inherited from ERDA, under which much DOE R&D is procured, emphasizes full private sector participation in carrying out energy research, development and demonstration and sets specific limits on the federal role. In effect, it stipulates that a federal R&D program shall be initiated only when private enterprise is unlikely to satisfy an urgent need in a timely manner; or when there are limited opportunities to induce private support through regulatory actions, end use controls, tax and price incentives, public education or other alternatives to direct federal support; or when investment risk or magnitude is so high that private capital is unable or inadequate to support effective efforts.

Yet, there are many within the private sector who believe that even though DOE is obligated to seek maximum reliance on private enterprise, too many of its policies and practices work as disincentives to industry involvement. Without federal incentives, industry can no more participate in DOE energy technology development than it can in an open market without adequate incentives.

Improved program planning with a long-term federal commitment for continued support could act as a strong incentive for industry. Clearly, DOE is still in a transitional phase with many growing pains to overcome. A systems approach to energy technology planning, similar to that developed for aero-

¹ Introduction to the Analysis of Commercialization Conditions, Booz, Allen and Hamilton, Inc. for ERDA, July 1976.

space and defense programs and proven by successful completion of many long range projects, is lacking in the Department. Without this sort of comprehensive planning, key decisions affecting the future of programs are made on an ad-hoc basis, adding an intolerable degree of uncertainty to federal support. The Booz Allen study, referred to earlier, reported that a reasonably long-term commitment to support particular energy technologies is perhaps "the single most influential action government might take to encourage commercialization of that new technology". Furthermore, it would seem logical for industry to have a greater role in planning the development of a technology for which it must ultimately assume the responsibility for marketing.

Aerospace firms, doing business with DOE, must also face the prospect of having their own inventions. including those developed with company funds, commercialized by their competitors. As a result, firms seeking to gain a foothold in the energy market are necessarily cautious about pursuing government funding for their innovative ideas. This situation, a consequence of DOE rules on patents, data and copyrights is clearly inconsistent with DOE's responsibility to provide incentives for development of new energy technology. Under these rules, companies under contract to DOE are not granted irrevocable rights to inventions, but lose title to the government. Further, title to inventions conceived and even patented prior to the contract but which are "first actually reduced to practice in the performance of the contract" are lost to the government (currently the government holds title to a total of about 28,000 inventions of which only 5 percent have been utilized). Although there is a waiver procedure whereby industry can be given irrevocable rights, numerous unrealistic criteria must be met.

Other procurement practices, such as cost sharing and fixed price contracts for R&D often inhibit greater industry participation. Cost sharing on risky long term energy research may be inappropriate, especially where there is a history of a lack of program continuity and the potential for government withdrawal. In cases where the government is funding competing energy technologies, cost sharing puts industry in competition with the government, a situation from which industry must readily retreat. For, if the government decides to push a given technology, competing technologies and their backers could be snuffed out. Firm fixed price contracts for the acquisition of hardware which is either in development at the time the RFP is released or for which final drawings and specifications do not exist will also deter companies from responding. DoD experience has proven that in a rapidly developing technology, incentive contracts based on cost performance and schedule will have better results.

Organizational conflict of interest rules are another disincentive for industry. These controversial rules could well work counter to DOE's mission by preventing highly qualified and experienced aerospace companies from participating in DOE R&D. They arise from the dual responsibility of government to maximize competition for federal contracts and at the same time to select firms which are most qualified to fulfill the public need. The stringency of DOE rules as originally proposed may have grown out of the public mood of distrust for large institutions and the call for absolute accountability for and disclosure of all their activities.

Reasonable conflict of interest rules would insure that the government avoid assignment of work which would place a contractor in an inherent conflict of interest situation, in other words, where his necessarily biased performance of one contract would give him an unfair competitive advantage on another. The proposed rules greatly expanded such conflict of interest situations and required contractors to warrant against any possible conflicts under penalty of loss of the contract and black listing. Although DOE's final rules have been liberalized somewhat, industry is cautiously awaiting their future interpretation by DOE. Some aerospace companies contend that almost by definition many companies best qualified and deeply involved in a particular area would still have "conflicts" and thus be excluded.

In summary then, aerospace firms often find themselves in the position of being most ably qualified to contribute to the development of new energy technologies but frustrated from doing so by government policies which purport to promote greater reliance on industry.

