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SPACE TECHNOLOGY'S POTENTIAL FOR INDUSTRY

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The transfer of space technology to industry is a very large working interface—involving much of our new technology, many of our basic industries—and we can only assume that all *first* reports will be incomplete. So, at the beginning of these remarks, it might be useful to break down the kinds of things that flow from accelerated technical programs—such as the civilian space program. For this purpose, the results of these programs can be sorted into three principal classifications.

First is *specific products and components* which include weather satellites, communications satellites, fuel cells, rocket engines, boosters, and guidance equipment. The benefits that will come from improved communications or more accurate weather predictions, for example, are too numerous to mention, but a few remarks as to the relative costs of such systems compared to costs of other means of doing the same thing are pertinent. One expert in the communication industry has said that a single satellite costing about $40 million and placed in a 22,300-mile-high orbit could accommodate as much traffic as a system of ground and submarine cables costing over 10 times as much.

Similarly, the cost of providing weather observations from a satellite is not expensive when we consider the area covered. A weather ship in the North Pacific, the birthplace of much of our weather, costs about $1 million to maintain and operate annually, but it can observe an area of only about 200 square miles. A weather satellite costs about four times as much—$4½ million—but it can observe an area of approximately 640,000 square miles in each picture it takes!

Thus, the cost advantage of observatory or communications satellites makes them immediate candidates for transfer to commercial application.

Second, are the *technologies* developed by such projects; from these flow back advances in materials, new reliability and quality-control measures, and process development such as thin-film circuitry and micro-miniaturization.

For a typical booster such as Atlas/Agena, the cost of launching satellites into a 6,000-mile orbit is approximately $10,000 per pound, and the payload is limited. Weight savings through miniaturization of electronic components, then, receive high order priority. Miniaturization, one of the most significant developments in industry in recent years, has received continuing stimulus from the needs of the space program to reach the ultimate in weight savings and reliability. But this technology will have impressive impact in greater value and service to the customer in consumer and industrial products as these advances are reflected there in the future.

The two-way flow of technological developments in materials is also worth noting. For example, in the electrical lighting industry years ago, research in high-temperature resistance led to some special but unneeded materials, such as pyrolytic graphite, which were never useful in lamps—but which now find important applications in the space program.

The third element, flowing from our space efforts, is *the advancement of the general technical-managerial climate*—creating continually higher standards for technical and program management.

The sheer size and complexity of space projects (as of many recent military undertakings) is sharpening the role of management. The techniques developed to cope with the monstrous complexities of such projects will be useful in many other fields. These will be useful as applied in greatly expanding services and controls such as urban transit systems or air traffic control. The requirements for high-order reliability and performance to schedule and budget, where many absolute and unpredictable unknowns exist, cannot help but tune program management techniques to greater effectiveness wherever they are used.

Space and defense work embraces the toughest kind of technical problems (every job is one which has never been done before) with impossible schedules under tight budget limitations, and against some of the roughest competition in the world. These kinds of challenges amount to feeding raw meat to our management, our engineers, and our scientists.

In keeping with our national goals, and the extent of the challenge involved, there has been a tremendous flow of technical capability and business information into the civilian space program. This is a field characterized by rapid technological progress, keyed more to unique requirements than to competitive economic factors. Time scales for development tend to be short and obsolescence rapid. Requirements are continually becoming more severe. That is, environmental conditions are increasingly unfamiliar and hostile, the amount of power needed is growing, accuracy of regulation and control must be better and better, and the sources of energy are becoming more diverse. Once limited to the airplane engine itself or a wind-driven propeller generator, the aerospace designer must now take into consideration the use of combustible gases in fuel cells, adaptability of atomic reactors, radioactive isotopes, sunlight, radio or light waves beamed from the ground, and, perhaps, even the photochemical energy of the atmosphere through which the aerospacecraft will fly. Once limited to radio transmitters and receivers, lights, and a few instruments, the electrical load to be supplied now may include comfort heating and cooling, ventilating, oxygen and water regeneration, food processing, entertainment, vehicle stabilization, and, perhaps, even propulsion. Once restricted to 20,000 or 30,000 feet altitude and a few hundred miles an hour, the environmental conditions now include devastating vibration, high-acceleration takeoff conditions, the searing heat of hypersonic reentry through the upper atmosphere, the nearly perfect vacuum, and the deadly radiation disturbances of outer space, with no dependable gravitational field to keep convection processes going and men and equipment safely in place.

What are we bringing back from this great venture to the extremes of our techniques? In asking, we should be aware that the results may not be what we expect. In fact, the use of a scientific or technological development is often quite different from what was originally intended.

In the past, the creation of a new technology in one field has had an impact on many others. The automobile industry was largely responsible for such developments as efficient internal combustion engines, alloy steels, synthetic rubber, and new fuels. The aircraft industry created a wide market for aluminum alloys, which now have countless industrial uses. Similarly, the great technological advances of our space industry will have, in time, tremendous implications for all of us though many will never leave the Earth.

Although the space age is only 6 years old, a number of people have been concerned about the relatively slow rate of transfer of space technology developments and their commercial application. Thus, the Denver Research Institution Study concludes that "relatively little importance can be attached to the direct transfer of products from missile/space programs to the civilian sector of the economy at this time."

The National Aeronautics and Space Administration and its administrator, James Webb, placed a great deal of importance on this problem in 1962 and established within the NASA Office of Applications an industrial applications group, to act as a catalyst for provoking a technological fallout from space to the civilian economy. This group contracted with the Midwest Research Institute in Kansas City to uncover potential applications of space technology to industrial and consumer products, to document them and to circulate them to industry. Also working for this industrial applications group, the Denver Research Institute found 145 carefully screened examples where industry was making products and using processes originating in the national space effort.

This was only a start, but an important one. Requirements which we do not now foresee will generate uses for present space-oriented technologies as the increasing complexity of our civilization brings these needs to the fore.

In this context, however, we must remember that a *time-lag* really does exist by the very nature of the problem. It will also vary as we look again at the three types of transfers that we might expect to flow from our space program.

Out of No. 1, *specific products and components,* if our assumptions are correct, there will be a few isolated items for which there are already a foreseeable requirement and an economic basis. Examples are the already-mentioned communications satellites, which in spite of their very big price tag can fill a need for more communications services more economically than other ways. To some extent the same thing would also apply to weather satellites and to the whole field of communications in space activities which promises to make startling advances.

It is noteworthy in the above examples that one of the basic parameters enabling transfer is the cost parameter. Also, a need, or "market", already exists. One of the functions of business is the entrepreneurial function of exploiting a need or want for an innovation that did not previously exist to satisfy a requirement, and a part of the usually considerable timelag from scientific development to product in use may be spent simply in persuading the public—through product promotion—that the innovation really matters and will provide the service needed more effectively than any other method.

There are also highly important peripheral conditions which make possible the use or need for a product—where advances in the product generate the requirement for advances in related equipment and vice versa.

Witness the classic example of the Model T, and the development of individual transport in this country. In 1900, a few more than 4,000 passenger automobiles were sold in the factory. They were an enthusiast's or a rich man's hobby. It took 20 years before factory sales topped 1 million. It took only 5 years for sales to rise nearly 1 million more. What was going on in this time? Technical progress, of course, but progress was not paced only by technology. All those other relevant forces that attend the growth of a product, an enterprise, and an industry were in the picture over the years. The development of greatly improved roadways and highway systems were needed to provide the "need" for auto volume. Sales organizations, advertising, repair shops, service stations, highways, motor vehicle codes, driver's tests and licenses—all the developments like these came on the scene to influence one another and the total expansion of the industry.

In a recent TV program, Bob Newhart summed it up this way: "The man who invented the wheel didn't accomplish much, but the fellow who put four of them together really had something."

Although space science was underway in this country only 5 years after the first plane flight, with Robert Hutchin Goodard's experiments in the basement of the Worcester Polytechnic Institute in Massachusetts, large expenditures on missile/space programs have been made only in recent years, and there has not been sufficient time for many product transfers as such to take place. Most of this transfer is still well ahead of us.

No. 2, *the tranfer of technology,* rather than of products, will be by far the most important for some time to come.

The least promising transfers are the systems and devices in the first category—because the systems and their components are the optimum for very specialized, very complex functions which seem unlikely to be economically adaptable to widespread needs in the home or industry.

In the process of system optimization, the field of aerospace is especially characterized by the fact that low weight, small size, and high reliability have become far more important than direct cost. It would probably not be correct to say that systems optimization is more important in the aerospace field than in other fields—it is extremely important in all fields. However, it may well be more difficult because the number of parameters to be taken into consideration is generally larger. Furthermore, the overall system optimization must generally be carried out with respect to overall mission performance rather than with respect to a single system alone, which complicates the task of the aerospace designer.

Some very promising transfers do appear, on the other hand, in the areas of new materials, new design approaches, and new production techniques. Many of them are true innovations; they offer new ways of performing old or new functions—new shortcuts, better performance, lower cost. But they are seedlings brought out in a special climate of cost and time urgency. Adapting them for commercial growth in the climate of economic competition will require further time and effort but will bear fruit.

Dramatic, but limited, examples are the cardiac pacer and the patient-monitoring devices made possible by the aerospace industry's success in miniaturizing electronic components.

Here a promising further development is taking place at our Valley Forge Space Technology Center, where bioscientists in the Space Sciences Laboratory, working under a contract from NASA, have successfully demonstrated that useable electrical power can be drawn from living animals. This means that in the future such lifesaving devices as the heart pacer, or heart pump as it is sometimes called, may be powered without cumbersome and failure-prone batteries. And some day . . . in the future . . . transmitters implanted in the human body and powered by the body's own electricity may telemeter back to a doctor's office a continuous report on the state of a patient's health.

It is probably more meaningful and accurate, for some time to come, to consider space contributions to the commercial area in terms of the transfer of technology rather than in terms of the transfer of products. Materials, processes, manufacturing techniques, operating procedures, and new standards born of space requirements will replace many such commercial practices currently in use to provide products which will better fill the needs to which they are oriented.

The third category, that of *the increased ability of industry to manage large, complicated systems* with the related engineering, manufacturing, and financing requirements, and their controls, is a factor which will transpose to industry on a more nearly current basis. This is an educational process, and this education in the forms of achievement of new standards of excellence, the nature of problems which have to be solved, the pitfalls against which we must guard in the future, the importance of timely integration in technical and operational areas, and the myriad of related problems, is part of the heritage of anyone and everyone associated with the space program. As these people and their associates work on new problems, as their efforts are used in new fields, as they change job assignments, and as they receive promotions to more influential positions, a great many of the advanced operational techniques, together with the seasoning brought about by the underlying experiences, will be sprinkled throughout industry and will accrue to the general benefit and well-being of industry in this country and all those affected by it.

It is patently evident that as the level of education increases in any community the benefits accrue to the overall welfare of that community and its neighbors—whether this be a civic community, a nation, or an industrial community. Thus, it is indeed the case that the entire economy of our country and the welfare of our people cannot help but realize benefits from the intensive, rigorous educational process taking place as our space work progresses. This involves broad technological advances, reliability performance requirements at a level never before encountered, extensive integration of relatively unrelated disciplines and of the contributing activities to each main event, detailed surveillance and control of schedules, costs, and performance of all the elements as well as the whole involved in each project. The benefits of this experience can never be taken away, and those who have had the advantage of it will provide an important impact in many other areas of work and on many future projects.

Now, what, if anything, do these characteristics tell about how our space efforts are, or might better be, geared into the processes of technological advance and economic growth?

The transition from a science-originated opportunity to an economic development is frequently extremely demanding of all industrial functions and resources. An example is atomic power—the Atomic Energy Act opened the door to the commercial development of atomic power in 1954. It took 10 years and a billion dollar investment by electrical manufacturers and electric utilities to make it commercial. In other words, market development and process refinement go hand in hand in importance as related to the development, invention, or technology itself.

The key technological innovation in a development may take several forms: a material with novel properties, such as semiconductor materials; a new component, such as the cryogenic gyroscope; or a novel combination of known technologies.

In research and development, technological innovation is, as has been said ". . . like golf, a game of misses." We are fortunate if a small fraction of the product of commercial research results in useful products. The game becomes one of bringing the fractions that succeed to market on a timely basis to achieve the business which makes the effort worth while.

A key person in this process is the engineer- or manager-entrepreneur, who can see commercial possibilities in the application of scientific principles and who labors to perfect usable products and techniques. This kind of entrepreneurship has become increasingly valuable as the advance of science has made available new knowledge, new products, new production methods, and new resources.

The emphasis is on the change which occurs as a result of market forces after the product or technique has reached the commercial stage. The technical developments immediately preceding commercialization, and the contributions of the engineer-entrepreneur are of particular significance. Such contributions are the difference between invention and innovation, and the technical change is clearly affected by market forces sensed and met. It is not enough to be able to create the product; the market development to create the *need* for the product is at least as important.

This market development has to take place on a scale which *pulls* a product into widespread use, instead of attempting to *push* a product simply because you know how to manufacture it. It is almost impossible to overemphasize the importance of marketing in the process. Marketing was described in a recent issue of Forbes as "telling the customer what you can do for him, as opposed to old-fashioned selling which consisted of asking him to do something for you."

In summary, the new things that are learned and the increased abilities that are generated as a result of the space program may not constitute anything that would not have happened in the fullness of time in any case, but the concentration of effort, in order to meet extremely demanding requirements, has accelerated the development of higher technical sophistication and greater systems ability, and is of great value in itself—even though it may have arrived at this point far earlier than our consumer and industrial economy can assimilate it. We must not be too impatient for the industrial requirements to catch up, for this new technology is spawned by an unnatural (as compared to traditional) emphasis of great magnitude outside of the industrial business economy.

The eventual capabilities and applications that will come of this—slow though they may seem to us—are going to be of great importance to all of us in the years ahead.

As Alfred North Whitehead said more than half a century ago, in words that might have been written to describe our national space program:

> Modern science has imposed on humanity the necessity for wandering. Its progressive thought and its progressive technology make the transition through time, from generation to generation, a true migration into uncharted seas of adventure. The very benefit of wandering is that it is dangerous and needs skill to avert evils. We must expect, therefore, that the future will disclose dangers. It is the business of the future to be dangerous; and it is among the merits of science that it equips the future for its duties.

Let us substitute the word "opportunity" where he has used "danger."