Union Calendar No. 928
86th Congress, 2d Session - - - - - House Report No. 2091

THE PRACTICAL VALUES OF SPACE EXPLORATION

REPORT

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS
U.S. HOUSE OF REPRESENTATIVES
EIGHTY-SIXTH CONGRESS
SECOND SESSION

PURSUANT TO

H. Res. 133

[Serial I]

JULY 5, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

UNITED STATES
GOVERNMENT PRINTING OFFICE
58231° WASHINGTON : 1960

COMMITTEE ON SCIENCE AND ASTRONAUTICS

OVERTON BROOKS, Louisiana, *Chairman*

JOHN W. McCORMACK, Massachusetts
GEORGE P. MILLER, California
OLIN E. TEAGUE, Texas
VICTOR L. ANFUSO, New York
B. F. SISK, California
ERWIN MITCHELL, Georgia
JAMES M. QUIGLEY, Pennsylvania
LEONARD G. WOLF, Iowa
JOSEPH E. KARTH, Minnesota
KEN HECHLER, West Virginia
EMILIO Q. DADDARIO, Connecticut
WALTER H. MOELLER, Ohio
DAVID S. KING, Utah
J. EDWARD ROUSH, Indiana
THOMAS G. MORRIS, New Mexico

JOSEPH W. MARTIN, JR. Massachusetts
JAMES G. FULTON, Pennsylvania
GORDON L. McDONOUGH, California
J. EDGAR CHENOWETH, Colorado
FRANK C. OSMERS, JR. New Jersey
WILLIAM K. VAN PELT, Wisconsin
A. D. BAUMHART, JR. Ohio
PERKINS BASS, New Hampshire
R. WALTER RIEHLMAN, New York

CHARLES F. DUCANDER, *Executive Director and Chief Counsel*
Dr. CHARLES S. SHELDON II, *Technical Director*
SPENCER M. BERESFORD, *Special Counsel*
PHILIP B. YEAGER, *Special Consultant*
JOHN A. CARSTARPHEN, Jr., *Chief Clerk*
FRANK R. HAMMILL, Jr., *Counsel*
RAYMOND WILCOVE, *Staff Consultant*
RICHARD P. HINES, *Staff Consultant*
Lt. Col. FRANCIS J. DILLON, Jr., *Staff Consultant*
Comdr. HOWARD J. SILBERSTEIN, *Staff Consultant*

LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C., July 1, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics.

DEAR MR. CHAIRMAN: I am forwarding herewith for your consideration a staff study, "The Practical Values of Space Exploration."

This study was undertaken pursuant to your request for information covering the various utilities of the national space effort. The study has been prepared by Philip B. Yeager and reviewed by other members of the professional staff.

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

LETTER OF SUBMITTAL

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C., July 5, 1960.

Hon. Sam Rayburn,
Speaker of the House of Representatives,
Washington, D.C.

Dear Mr. Speaker: By direction of the Committee on Science and Astronautics, I submit the following report on "The Practical Values of Space Exploration" for the consideration of the 86th Congress.

Overton Brooks, *Chairman.*

CONTENTS

86th Congress, 2d Session | HOUSE OF REPRESENTATIVES | Report No. 2091

THE PRACTICAL VALUES OF SPACE EXPLORATION

July 5, 1960.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

Mr. Brooks of Louisiana, from the Committee on Science and Astronautics, submitted the following

REPORT

[Pursuant to H. Res. 133]

58231°—60——2

THE PRACTICAL VALUES OF SPACE EXPLORATION

INTRODUCTION

This report has been undertaken for a special reason. It is to explain to the taxpayer just why so many of his dollars are going into the American effort to explore space, and to indicate what he can expect in return which is of value to him.

Such an explanation, even after 2 years of relatively high-geared activity in the space exploration field, appears to be warranted. There is still a segment of the U.S. population which has little, if any, notion of the values that the space program has for the average citizen. To these people the expenditure of billions of dollars on missiles, rockets, satellites, Moon probes, and other space activities remains something of a mystery—particularly when so many other worthy projects throughout the land may be slowed or stalled for lack of funds.

If, therefore, the practical value of the American space program is being questioned, it is a question which needs to be answered.

It is interesting to note that the problem is not unique to the United States. In the Soviet Union, which counts itself as the world's prime investigator of space, there is likewise an element of citizenry which finds itself puzzled over the U.S.S.R.'s penchant for the interplanetary reaches.

"What do sputniks give to a person like me?" a Russian workman complained in a letter which *Pravda* published on its front page. "So much money is spent on sputniks it makes people gasp. If there were no sputniks the Government could cut the cost of cloth for an overcoat in half and put a few electric flatirons in the stores. Rockets, rockets, rockets. Who needs them now?" [1]

It goes without saying that the workman was severely chastised by the Soviet newspaper, but his point was made.

No matter where taxpayers live they want to know—and are entitled to know—what good a program of space exploration is to them.

During the 1960's it is expected that the U.S. Government will spend anywhere from $30 to $50 billion on space exploration for all purposes, civilian and military. It is the intent of this report to delineate in lay language, and in terms which will be meaningful to those who have not followed the American space program closely, the reasons for this great investment and the probable returns.

[1] Associated Press dispatch, dateline Moscow, June 12, 1960.

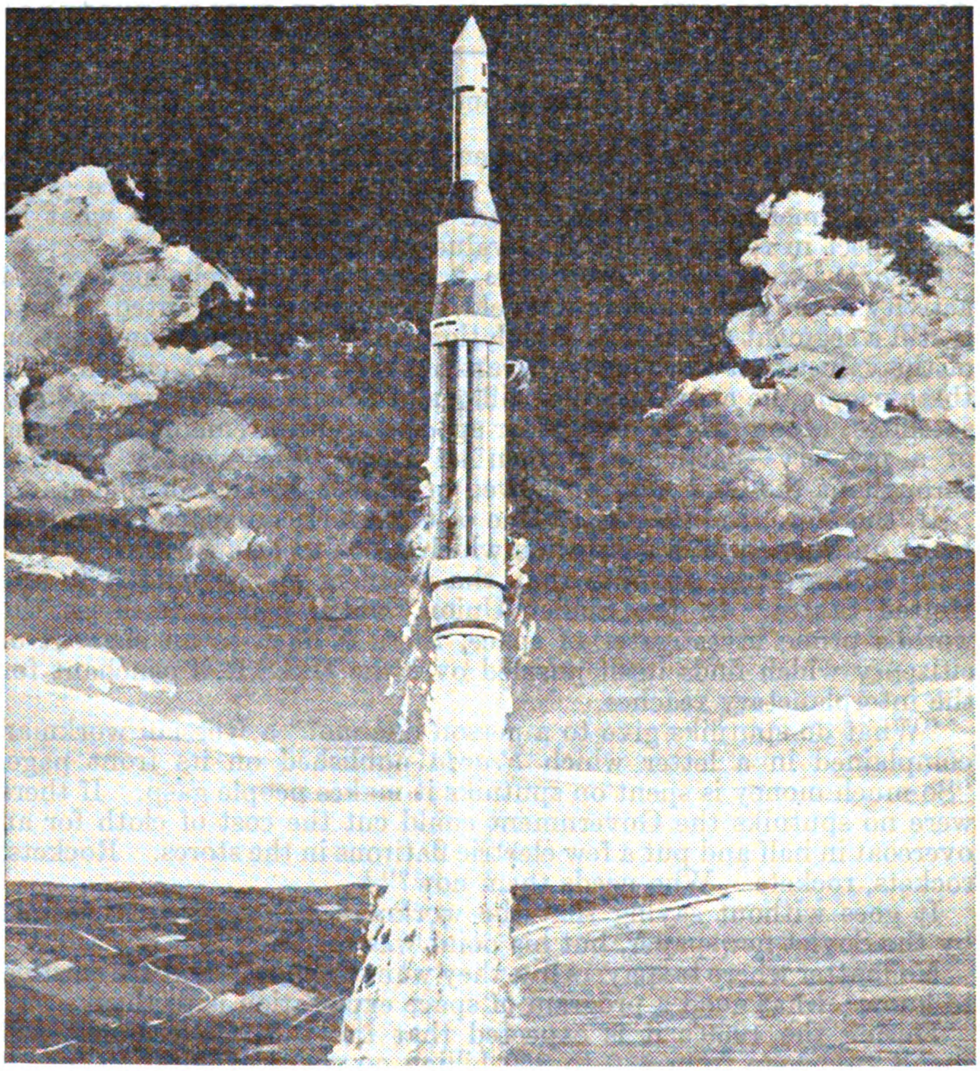

FIGURE 1.—A single shot of the 8-barreled Saturn of the future will cost millions of dollars, maybe tens of millions. What makes it worthwhile for the taxpayer?

I. THE UNSEEN VALUES

The United States has not embarked upon its formidable program of space exploration in order to make or perpetuate a gigantic astronautic boondoggle. There are good reasons, hard reasons for this program. But, in essence, they all boil down to the fact that the program is expected to produce a number of highly valuable payoffs. It not only is expected to do so, it is doing so right now.

Many of the beneficial results can be identified.

Those already showing up are detailed in the sections of this report which follow. They include the most urgent and precious of all commodities—national security. Beyond that, they also include a strengthened national economy, new jobs and job categories, better living, fresh consumer goods, improved education, increased health, stimulated business enterprise and a host of long-range values which may ultimately make the immediate benefits pale into relative insignificance.

Practical uses such as those just listed mean the taxpayer is more than getting his money's worth from American space exploration—and getting a sizable chunk of it today.

Nevertheless, if we can depend on the history of scientific adventure and progress, on its consistent tendencies of the past, then we can be reasonably sure that the greatest, finest benefits to come from our ventures into space are yet unseen.

These are the unpredictable values, the ones which none of us has yet thought of.

Inevitably they lag behind the basic research discoveries needed to make them possible, and often the discoveries are slow to be put to work after they are made. Investors, even governments, are human, and before they invest in something they normally want to know: What good is it?

We can be sure that many American taxpayers of the future will be asking "what good is it?" in regard to various phases of the space program.

There was an occasion when the great Scottish physicist, James Clerk Maxwell, was asked this question concerning one of his classic discoveries in electromagnetism. Maxwell replied: "What good is a baby?"

Now, as then, it takes time for new knowledge to develop and become useful after its conception and birth.

SOME EXAMPLES OF THE UNEXPECTED

A graphic illustration of "unseen" benefits in regard to atomic energy has been expressed by an experienced researcher in this way:

> I remember a conversation I had with one of our nuclear scientists when I was a member of the Weapons Systems Evaluations Group almost 10 years ago. We were talking about the possible peaceful applications of fission. We

> really could think of little that could be done with it other than making fissionable material into a form of destructive power. There had been some discussion about harnessing the power of fission, but this seemed to us to be quite remote. It seemed difficult to conceive of the atomic bomb as anything but sheer power used for destructive purposes. Yet today the products of fission applied to peaceful uses are many. The use of isotopes in industry, medicine, agriculture are well known. Food irradiation, nuclear power reactors, now reactors for shipboard use, are with us, and it is hardly the beginning. I frequently ask myself, of late, what 10 years from now will be the commercial, shall we call it, applications of our missile and rocket programs.[2]

There are innumerable examples of the way in which invention or discovery, or sometimes just simple human curiosity, result in useful payoff. And frequently no one suspects the direction the payoff finally takes. The point, of course, is that *any* knowledge eventually pays dividends. The things we learn from our national space program will produce benefits in ways entirely unrelated to missiles or interplanetary travel. (See secs. III and IV.) The reverse is also true; knowledge gained in areas quite remote from outer space can have genuine value for the advance of space exploration.

Investigation into the skin of a fish provides a good case in point.

A German inventor who migrated to California after World War II had long been interested in ways to reduce the drag of friction produced by air or water on the surface of objects passing through them. One day, while watching a group of porpoises cavort past a speeding ship with the greatest of ease, it occurred to him that the skin of these animals, if closely studied, might shed light on ways of cutting surface friction. It was many years before the inventor was able to enlist the aid of aquarium managers in securing porpoise skins for study. In 1955, however, he obtained the necessary skins and found that dolphins, in fact, owe much of their great speed to a unique skin which markedly reduces the effect of turbulence against it. From this knowledge has come the recent development of a diaphragm-damping fluid surface which has real potential not only for underwater high-speed bodies, such as submarines, torpedoes and underwater missiles, but for any vehicle where fast-moving gases or fluids may cause drag.[3]

The implications of this knowledge for satellites near Earth or for reentering spacecraft are obvious.

Sometimes a reverse twist in reasoning by a speculative mind will result in enormous practical utility.

In Cambridge, Mass., a sanitary engineer teaching at the Massachusetts Institute of Technology began to wonder about the principles of adhesion—why things stick to each other. Do they only stick together because some sticky substance is holding them, or are there other reasons? "If a person is sick," he asked himself, "is it because a cause of sickness is present or because a cause of health is absent? We now know that in infectious diseases the first alternative is true;

[2] Gavin, Lt. Gen. James M., U.S. Army (retired), speech to the American Rocket Society, New York City, Nov. 19, 1958.

[3] Kramer, Max O., "The Dolphins' Secret," New Scientist, May 5, 1960, pp. 1118–1120.

the patient is ill because he harbors pathogenic germs. The opposite case prevails in deficiency diseases, where necessary vitamins are absent from food and illness is brought about by this absence. To which of the classes does adhesion belong? When we cannot produce a dependable bond, are we dealing with the lack of some adhesive force or with existence of an obstacle to sticking?"

Operating on the theory that adhesion might result not only from the presence of a sticky agent but from the removal of all impediments to sticking, this scientist has now managed to produce strong adhesion between the least sticky of substances—polyethylene plastics. He has done it by studying the molecular structure of polyethylenes and removing all impurities which normally find their way into the manufacture of such material. The next step: "We hope to prepare adhesive joints in which a noble gas acts as an adhesive. Noble gases are the least active substances known to chemistry; if they can adhere, it is clear that no specific forces are needed for adhesiveness." [4]

No great imagination is required to perceive the meaning which this new knowledge, if proved out, will have for our everyday lives—to say nothing of its usefulness in the making of astronautic equipment.

THE ULTIMATE VALUES

In any event, it is apparent that where research is concerned—and especially space research with its broad scale of inquiry—we cannot always see the value of scientific endeavor on the basis of its beginning. We cannot always account for what we have purchased with each research dollar.

The Government stated this proposition when it first undertook to put the space program on a priority basis:

> Scientific research has never been amenable to rigorous cost accounting in advance. Nor, for that matter, has exploration of any sort. But if we have learned one lesson, it is that research and exploration have a remarkable way of paying off—quite apart from the fact that they demonstrate that man is alive and insatiably curious. And we all feel richer for knowing what explorers and scientists have learned about the universe in which we live.[5]

In this statement there is political support for what the historian, the anthropologist, the psychologist consider to be established fact—that some innate force in the human being makes him *know*, whatever his formal beliefs or whatever his unconscious philosophy, that he *must* progress. Progress is the core of his destiny.

This is a concept which, in connection with space exploration, has been recognized for many years. One of the earliest and most perceptive of the space "buffs" stated it before the British Interplanetary Society in 1946 in these words: "* * * our civilization is no more than the sum of all the dreams that earlier ages have brought to fulfillment. And so it must always be, for if men cease to dream, if they turn their backs upon the wonder of the universe, the story of our race will be coming to an end".[6]

[4] Bikerman, Dr. Jacob J., reported in New Scientist, Mar. 3, 1960, p. 535.
[5] "Introduction to Outer Space," a statement by the President, the White House, Mar. 26, 1958.
[6] Clarke, Arthur C., "The Challenge of the Spaceships," Harper & Bros., New York, 1955, p. 15.

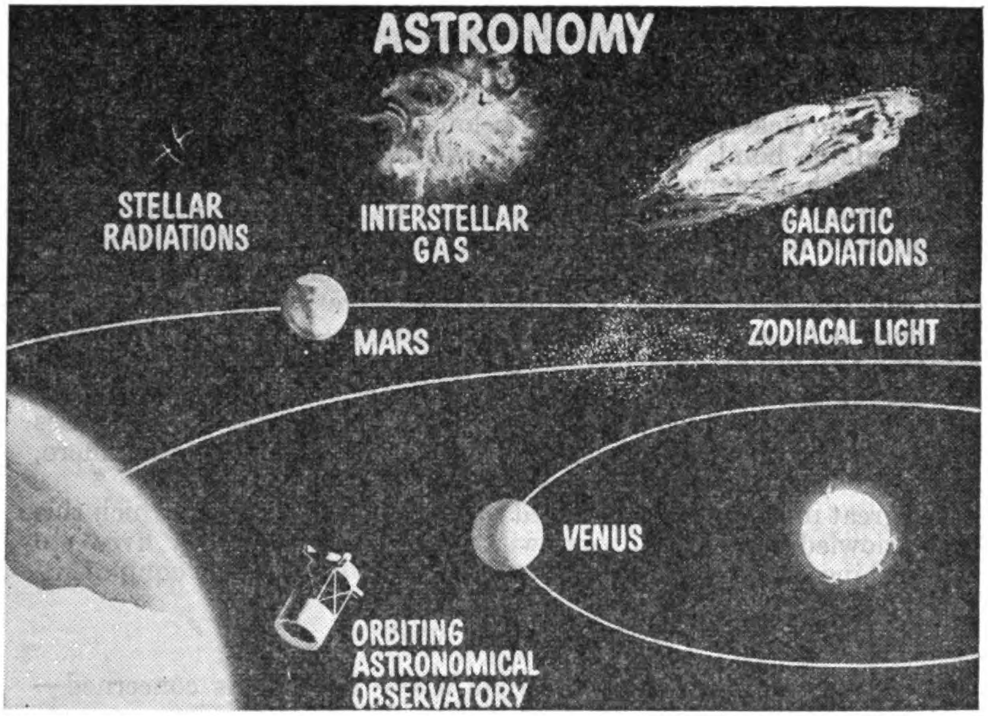

FIGURE 2.—In the years immediately ahead, the orbiting observatory or the manned satellite will uncover crucial information about the nature of the universe.

STEERING A MIDDLE ROAD

In any endeavor which is as futuristic as space exploration it is not difficult to become lost in the land of the starry-eyed prognosticators. Conversely, it is also easy to find oneself lining up with the debunkers and the champions of the status quo, for their arguments and views give the impression of being hardheaded, sensible.

If one must err in either direction, however, it is probably safer, where space is concerned, to err in the direction of the enthusiasts. This is because (and subsequent parts of this report will show it) the Nation cannot afford not to be in the vanguard of the space explorers.

Events today move with facility and lightning rapidity. Today, more than ever, time is on the side of the expeditious. We can no longer take the risk of giving much support to the scoffers—to that breed of unimaginative souls who thought Robert Fulton was a fool for harnessing a paddlewheel to a boiler, who thought Henry Ford was a fool for putting an internal combustion engine on wheels, who thought Samuel Langley was a fool for designing a contraption to fly through the air.

There are always those who will say it cannot be done. Even in this era of sophisticated flight there have been those who said the sound barrier would never be broken. It was. Others said later that space vehicles would never get through the heat barrier. They have. Now, some say men will never overcome the radiation barrier in space. But we can be sure they will.

It is undoubtedly wise for the layman, in terms of the benefits he can expect from the space program in the foreseeable future, to steer a reasonable course between the two extremes. Yet one cannot help remembering that the secret of taking practical energy from the atom, a secret which the human race had been trying to learn for thousands of years, was accomplished in less than a decade from the moment when men first determined that it was possible to split an atom. It is difficult to forget that even after World War II some of our most respected scientists sold short the idea of developing long-range missiles. Impractical, they said; visionary. But 6 years after the United States went to work seriously on missiles, an operational ICBM with a 9,000-mile range was an accomplished fact.

THE TIME FOR SPACE

All of the glowing predictions being made on behalf of space exploration will not be here tomorrow or the next day. Yet this seems less important than that we recognize the significance of our moment of history.

We may think of that moment as a new age—the age of space and the atom—to follow the historic ages of stone, bronze, and iron. We may think of it in terms of theories, of succeeding from those of Copernicus to those of Newton and thence to Freud and now Einstein. We may think of our time as the time of exploiting the new fourth state of matter: plasma, or the ion. Or we may think of it in terms of revolutions, as passing from the industrial cycle of steam through the railroad-steel cycle, through the electricity-automobile cycle, into the burgeoning technological revolution of today.

However we think of it, it is a dawning period and one which—in its scope and potential—promises to dwarf much of what has gone before. Those who have given careful thought to the matter are convinced that while some caution is in order, the new era is not one to be approached with timidity, inhibited imagination or too much convention. Neither is there any point in trying to hold off the tempo of this oncoming age or, in any other way, to evade it.

Mark Twain once listened to the complaints of an old riverboat pilot who was having trouble making the switch from sail to steam. The old pilot wanted no part of the newfangled steam contraptions. "Maybe so," replied Twain, "but when it's steamboat time, you steam." [7]

Today is space time and man is going to explore it.

[7] Related by T. Keith Glennan, Administrator, National Aeronautics and Space Administration, in an address before the Worcester (Mass.) Economic Club, Feb. 15, 1960.

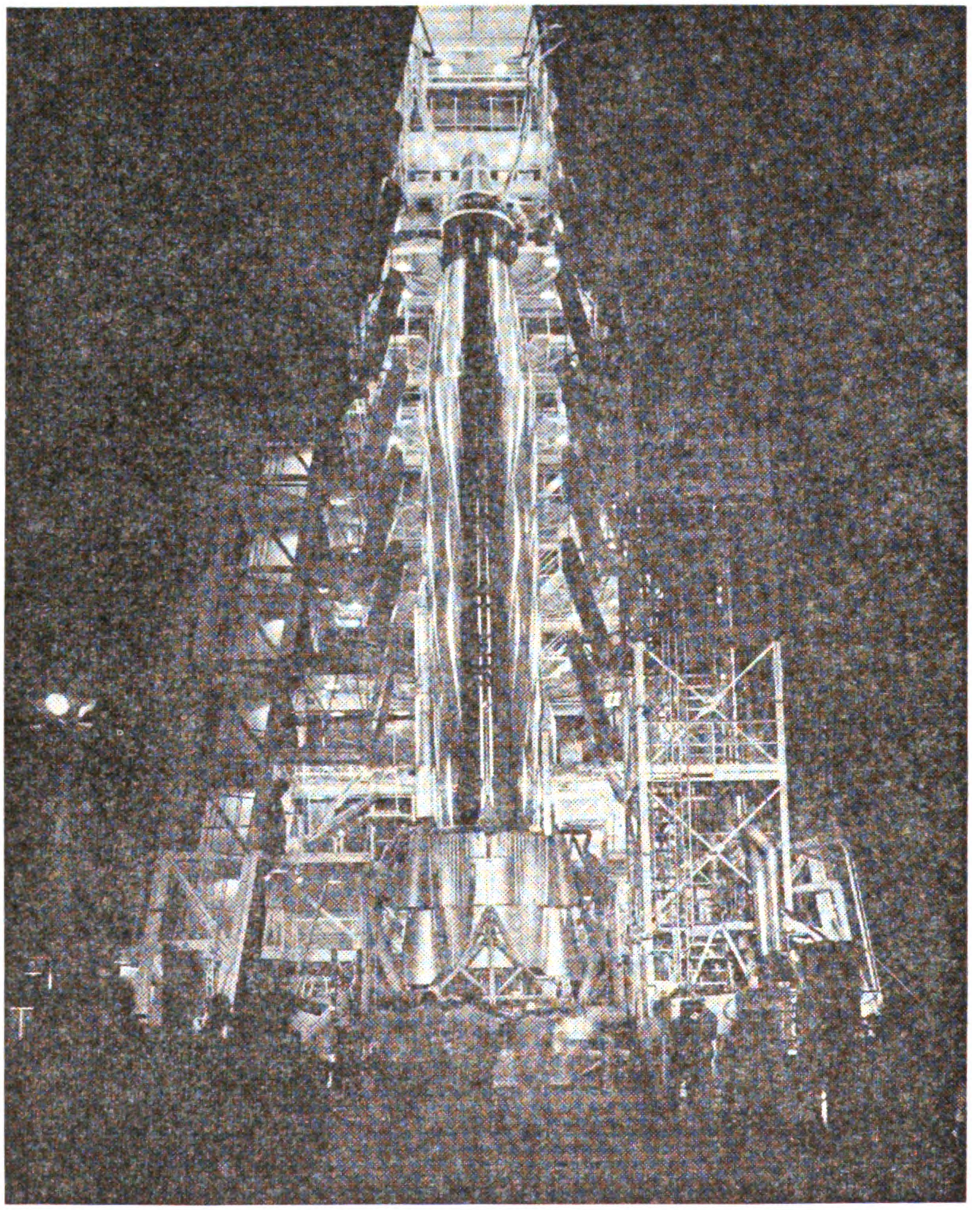

FIGURE 3.—The versatile Atlas can be used either for launching man into space or to carry a nuclear warhead as far as 9,000 miles.

II. National Security Values

There is no longer doubt that space exploration holds genuine significance for the security and well-being of the United States as a nation.

It does so in at least three ways. One results from the uses which our Armed Forces can make of the knowledge gained from space exploration. A second results from the influence and prestige which America can exert within the world community because of her prowess in space exploration. A third results from the possibility that space exploration, eventually, may prove so immense and important a challenge that it will channel the prime energies of powerful nations toward its own end and thus reduce the current emphasis on developing means of destruction.

The first two values definitely exist. The third seems to be a reasonable hope.

THE MILITARY USES

From the beginning it has been recognized that space exploration, the research connected therewith, and the ability to operate therein is of more than passing interest to the military.

Congress recognized the fact when it passed the National Aeronautics and Space Act of 1958 and directed that "activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States * * * shall be the responsibility of, and shall be directed by, the Department of Defense." [8] In the amendments to the Space Act proposed in 1960, this directive was strengthened: "The Department of Defense shall undertake such activities in space, and such research and development connected therewith, as may be necessary for the defense of the United States." [9]

It is possible to argue, and indeed it has been argued, that ballistic missiles such as IRBM's and ICBM's are not really "space" weapons, that they are simply an extension of the traditional art of artillery. For the purposes of this report, however, the argument appears to be largely a semantic one. Such missiles do traverse space, they are guided through space, and they employ the same engines and principles which are presently used for purposes of scientific space exploration. While more advanced "space" weapons may evolve in the future, the missile as we know it today cannot very well be divorced from our thinking about space and its practical uses.

Going on this assumption, and casting an eye in the direction of the Iron Curtain, it is obvious that the Soviet Union is going all-out to exploit space for military purposes.

Military men have known for years that the tremendously powerful booster which the Soviets have been using to launch their massive sputniks was originally designed to carry the primitive heavy version of the A-bomb across continents.

---

[8] Public Law 85-568, 85th Cong.

[9] H. Rept. 1633, 86th Cong., 2d sess., p. 6.

If there was ever doubt of the extent to which the Soviets intend to make space a selected medium for military purposes it was erased when Premier Khrushchev made his address to the Supreme Soviet early in 1960. He commented in part:

> Our state has at its disposal powerful rocket equipment. The military air force and navy have lost their previous importance in view of the modern development of military equipment. This type of armament is not being reduced but replaced. Almost the entire military air force is being replaced by rocket equipment. We have by now sharply cut, and it seems will continue sharply to cut and even discontinue the manufacture of bombers and other obsolete equipment. In the navy, the submarine fleet assumes great importance, while surface ships can no longer play the part they once did. In our country the armed forces have been to a considerable extent transferred to rocket and nuclear arms. These arms are being perfected and will continue to be perfected until they are banned.[10]

While it is difficult to assess the actual extent of the Soviet preoccupation with missiles, it has been reported that the Russians are building upward of 100 IRBM and ICBM bases to be manned by about 200,000 men. Most of these, at least the intermediate range bases, are said to be along Russia's Baltic coast, in East Germany, in the southern Ukraine and in the Carpathian Mountains.[11]

In any event, the space age is clearly "here" so far as the military are concerned, and U.S. forces—particularly since the development of the much lighter atomic warheads—have been likewise diligent in their space efforts. This is because many military minds are now agreed that:

> We are moving inevitably into a time of astropower. We face a threat beyond imagination, should events ever lead to open conflict in a world of hypersonic velocities and a raging atom chained as our slave. We must be strong, we must be able to change to meet change. What may come against our beloved America will not be signaled by one light from the North Church steeple, if they come by land, or two, if they come by sea. Never again. They will come through space, and their light of warning will be the blinding terror of a thermonuclear fireball.[12]

It is important to note, in connection with military matters, that pure rocket power is not the only avenue to success in space use. The American Atlas missile, for example, which can carry a nuclear warhead and which operates on considerably less thrust than the powerful Soviet boosters thus far demonstrated, has nevertheless shown the capability of negotiating a 9,000-mile trek and landing in the target area. This is about 1,500 miles farther than any Soviet shots revealed to the public in the 2½-year period following the first sputnik. It is also a sufficient range to permit reaching almost any likely target on the globe.

[10] Speech to the Supreme Soviet, Jan. 14, 1960.
[11] Associated Press dispatch, dateline London, Dec. 2, 1959.
[12] Scott, Brig. Gen. Robert L., USAF (retired), Space Age, February 1959, p. 63.

From the military point of view, the meaning thus brought out is that sophistication of missiles together with reliability and ease of handling is more important than pure power.

When we begin to consider both the civil and military aspects of space use in the decades ahead, however, rocket power acquires fresh importance. It is, as one expert says, "the key to space supremacy." [13] Not only is much heavier thrust required for ventures farther out into space, but probably thrust developed by different means as well, such as atom, ion, or even photon power.

This suggests the possibilities of weapons which today are considered to be "way out" or "blue sky"—in short, farfetched. Yet they include the ideas of men with solid scientific training as well as vision. For example, Germany's great rocket pioneer, Prof. Hermann Oberth, "has proposed that a giant mirror in space (some 60 miles in diameter) could be used militarily to burn an enemy country on Earth. For peaceful purposes, however, such a space mirror could be used to melt icebergs and alter temperatures." [14] Another reputable German scientist who has been working for a number of years on photon (electromagnetic ray) power as a source of propulsion, declares that if such power is possible so is "the idea of a 'death ray,' a weapon beam which burns or melts targets, such as enemy missiles, on which it is trained. The idea has been familiar in science fiction for a long time and has been scorned often enough. Yet, if the photon rocket is possible so is the ray gun." [15]

Still another proposal, one made to the Congress, involves use of the Moon as a military base. "It could, at some future date, be used as a secure base to deter aggression. Lunar launching sites, perhaps located on the far side of the Moon, which could never be viewed directly from the Earth, could launch missiles earthward. They could be guided accurately during flight and to impact, and thus might serve peaceful ends by deterring any would-be aggressor." [16]

In spite of the fact that ideas such as these are being sponsored by competent and responsible scientists, other scientists equally competent and responsible sometimes cry them down as impractical, impossible or even childish. One engineer, for instance, describes maneuverable manned space vehicles as having "no military value," bases on the Moon as having no military or communications use, and the idea of high velocity photon-power for space travel as "a fantasy strictly for immature science fiction." He also characterizes the reconnaissance satellite, which U.S. military authorities have long since programed and even launched, as being "definitely submarginal * * *. A fraction of the cost of a reconnaissance satellite could accomplish wonders in conventional information gathering." [17]

Controversies such as these are difficult for the person who is neither a scientist nor a military expert to judge. One is inclined to recall, though, the treatment received by General Billy Mitchell for his devotion to nonconventional bombing concepts; the fact that the utility of the rocket as developed by America's pioneer, Dr. Robert H. Goddard, was generally ignored during World War II; the fact that it

---

[13] Ostrander, Maj. Gen. Don R., USAF, before the American Rocket Society, Los Angeles, May 10, 1960.
[14] Cox, Donald and Stoiko, Michael, Spacepower, John C. Winston Co., Philadelphia, 1958, p. 16.
[15] Saenger, Dr. Eugen, New Scientist, Sept. 10, 1959, p. 383.
[16] Boushey, Brig. Gen. H. A., USAF, Hearings before the House Select Committee on Astronautics and Space Exploration, Apr. 23, 1958.
[17] Pierce, Dr. J. R., "The Dream World of Space," Industrial Research, December 1959, p. 58.

took a personal letter from Albert Einstein to President Roosevelt to get the Manhattan Project underway.

Yet today the bomber, the missile, and the nuclear weapon form the backbone of our military posture.

In other words, history seems to support the proposition that no matter how remote or unlikely new discoveries and approaches may first appear, the military eventually finds a way to use them.

Will it be any different with space exploration?

OUR POSITION IN THE INTERNATIONAL COMMUNITY

Like the military values of space research, the practical value of space exploration in terms of world prestige has also been acknowledged almost from the beginning of the satellite era.

The White House, in its initial statement on the national space program, declared:

> It is useful to distinguish among (the) factors which give importance, urgency, and inevitability to the advancement of space technology (one of which) is the factor of national prestige. To be strong and bold in space technology will enhance the prestige of the United States among the peoples of the world and create added confidence in our scientific, technological, industrial, and military strength.[18]

Only recently, however, has the full impact and meaning of this phase of our national space program come to be widely recognized. It has been stated, perhaps in its most forceful and succinct form, by an American official in a unique position to know. The Director of the U.S. Information Agency, part of whose job is to keep track of the esteem in which America is held abroad, has told Congress:

> Our space program may be considered as a measure of our vitality and our ability to compete with a formidable rival and as a criterion of our ability to maintain technological eminence worthy of emulation by other peoples.[19]

This element of space exploration takes on particular significance in light of the current international struggle to influence the minds of men, in light of the rising tide of nationalism throughout the world, and in light of the intensification of the cold war as demonstrated by the now-famous U–2 incident and the hardening attitude of oriental communism.

In the words of an influential newspaper:

> Wholly apart from the intellectual compulsions that now drive man to move higher and higher into the high heavens, it seems clear that our country can be niggardly in this field only at the risk of being completely and forever outclassed by Russia—a gamble that could have the most fearful political, economic, and military consequences.[20]

Incidentally, there is another prestige factor to be considered. This is what might be called the chain-reaction factor: the likelihood that technological preeminence in the space field will attract top talent

[18] 5 supra.
[19] Allen, George V, testimony before the House Committee on Science and Astronautics, Jan. 22, 1960.
[20] Editorial in the Washington Evening Star, Apr. 4, 1960.

from other parts of the world to the banner of the country which develops it, and thus constantly nourish and replenish the efforts of that country. It is a consideration which has not received general attention, although it has been discussed before some of the world's leading space scientists.[21]

Here again, as with the military situation, the Soviets are making every effort to exploit their dexterity in space. They are pursuing the prestige gambit directly and indirectly. In the first category, for example, they give top priority to space exhibits in important public forums—as their duplicate sputniks strategically placed at the world's fair and the United Nations attest. Premier Khrushchev's delight in making gifts to foreigners of miniature Soviet pennants similar to that carried in Lunik II—which hit the Moon—is another instance.[22]

The indirect drive for prestige via space technology is far more important. It has been described by a congressional committee as follows:

> It is difficult to escape the conclusion that the Soviet Union in the last several years has demonstrated a great skill in coordinating its progress in missilery, its success in space missions, and its foreign policy and world image. Shots seem to have been timed to maximize the effects of visits of Soviet leaders and to punctuate Soviet statements and positions in international negotiations. This is not to equate their space activities with hollow propaganda. Empty claims do not have a positive effect for long. Nor is there any firm evidence that it has been possible for political policymakers to call their shots at times inconsistent with good scientific and technical needs. The conclusion is rather that the many elements of scientific, technical, military, political, and psychological policy are all weighed, and tests which make a full contribution to such a combined strategy are carried out and supported with appropiate publicity.[23]

There is also evidence that scientific endeavor by the Russians for prestige purposes is having repercussions on internal policy. Great emphasis is currently being placed on the demonstrable usefulness of scientific effort—to the extent that Soviet colleges, research institutions, examining boards, and academies of science have been directed to be more exacting in conferring scientific degrees and titles. Newness and usefulness are requisite, but, at the same time, degrees may now be awarded for other than dissertations; inventions and textbooks of major importance may also earn a degree for their authors.[24]

Within the prestige context, it is true that the United States must labor under certain handicaps because of the nature of its democratic system.

No effort is made in the American space program to hide the failures which result from its highly complex character. Our burnups, misfires, explosions, fizzles, and lost or wayward vehicles are well publicized. Those of the Soviet Union rarely are. Even though most nations are well aware that the Russians must be having their troubles,

[21] Remarks of Hon. Aubrey Jones, Minister of Supply, to the International Astronautical Federation, London, Sept. 1, 1959.
[22] Associated Press dispatch, dateline Rangoon, Feb. 18, 1960.
[23] "Space, Missiles, and the Nation," report of the House Committee on Science and Astronautics, May 18, 1960, p. 53.
[24] The New Scientist, Mar. 3, 1960, p. 547.

too, the appearance of uniform success fostered by the U.S.S.R. inevitably contributes to an image of scientific superiority. In addition, the Soviets have developed a habit of striving for spectacular "firsts," most of which undoubtedly are undertaken almost as much for prestige reasons as for scientific ones.

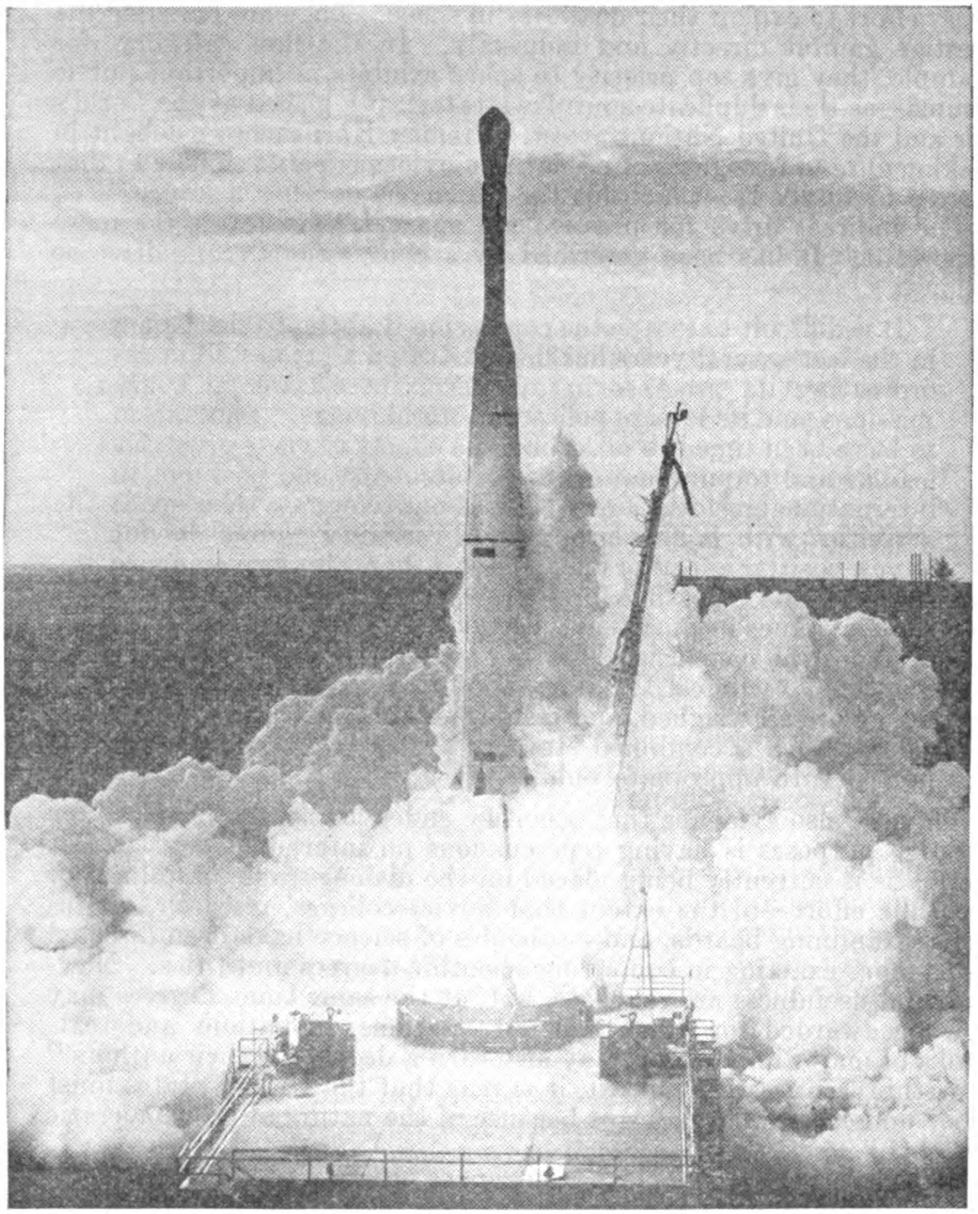

FIGURE 4.—Symbolic of the American effort in space is this Thor-Able rocket, shown here launching the Tiros weather satellite into a near-perfect orbit. This same vehicle, which launched the record-breaking 23 million-mile communication probe—Pioneer V—has contributed enormously to U.S. prestige abroad.

Still, the United States has not done badly from the prestige angle. So far as the world's scientific fraternity is concerned, it may even be well in the lead.

In the first 30 or so months following the opening of the space age, as signaled by the launching of Sputnik I in October 1957, the United States put 21 satellites into orbit out of 42 attempts. Two out of five deep-space probes were successful. The degree of success for all major launchings ran better than 50 percent. The American effort has been based on a broad scope of inquiry and includes long-range communications, weather reporting, navigation and surveillance vehicles, as well as information-gathering satellites.

During the same period the Soviets launched four Earth satellites, one deep-space probe, one lunar-impact probe and one satellite into a much elongated Earth orbit which circled and photographed the Moon. Most of their vehicles have been substantially heavier than those launched by the United States, although complete information on their scientific purposes and the result obtained has never been disclosed.

The world political value of such programs cannot be discounted. To the extent that the welfare of the United States depends upon its stature in the eyes of the rest of the world (which is believed considerable) and to the extent that the scientific capability of the United States influences such stature (which is also believed considerable) our space venture has very marked practical utility. It may even mean the difference between freedom and dictatorship, between survival and oblivion.

SPACE AS A SUBSTITUTE FOR WAR

A natural outgrowth of the military and prestige facets of space exploration is the question of whether this activity, in time, will replace the forces which have historically driven nations into armed conflict.

Any number of social scientists and historians have speculated that this might occur. The theory is that the conquest of space may prove to be the moral equivalent of war by substituting for certain material and psychological needs usually supplied through war; that the absorption of energies, resources, imagination, and aggressiveness in pursuit of the space adventure may become an effective way of maintaining peace.

Put another way, nations might become "extroverted" to the point where their urge to overcome the unknown would dwarf their historic desires for power, wealth, and recognition—attributes which have so often led to war in the past.

The fact that the United Nations, late in 1959, agreed to set up a permanent Committee on the Peaceful Uses of Outer Space attests to the hopes and potential of such a development.

Of course, whether this condition will actually develop is anybody's guess. But in a world where brute force is becoming increasingly dangerous and catastrophic, the bare possibility of such a result should not be ignored by those who may be contemplating the values of space exploration. It could be the highest value of them all.

58231°—60——4

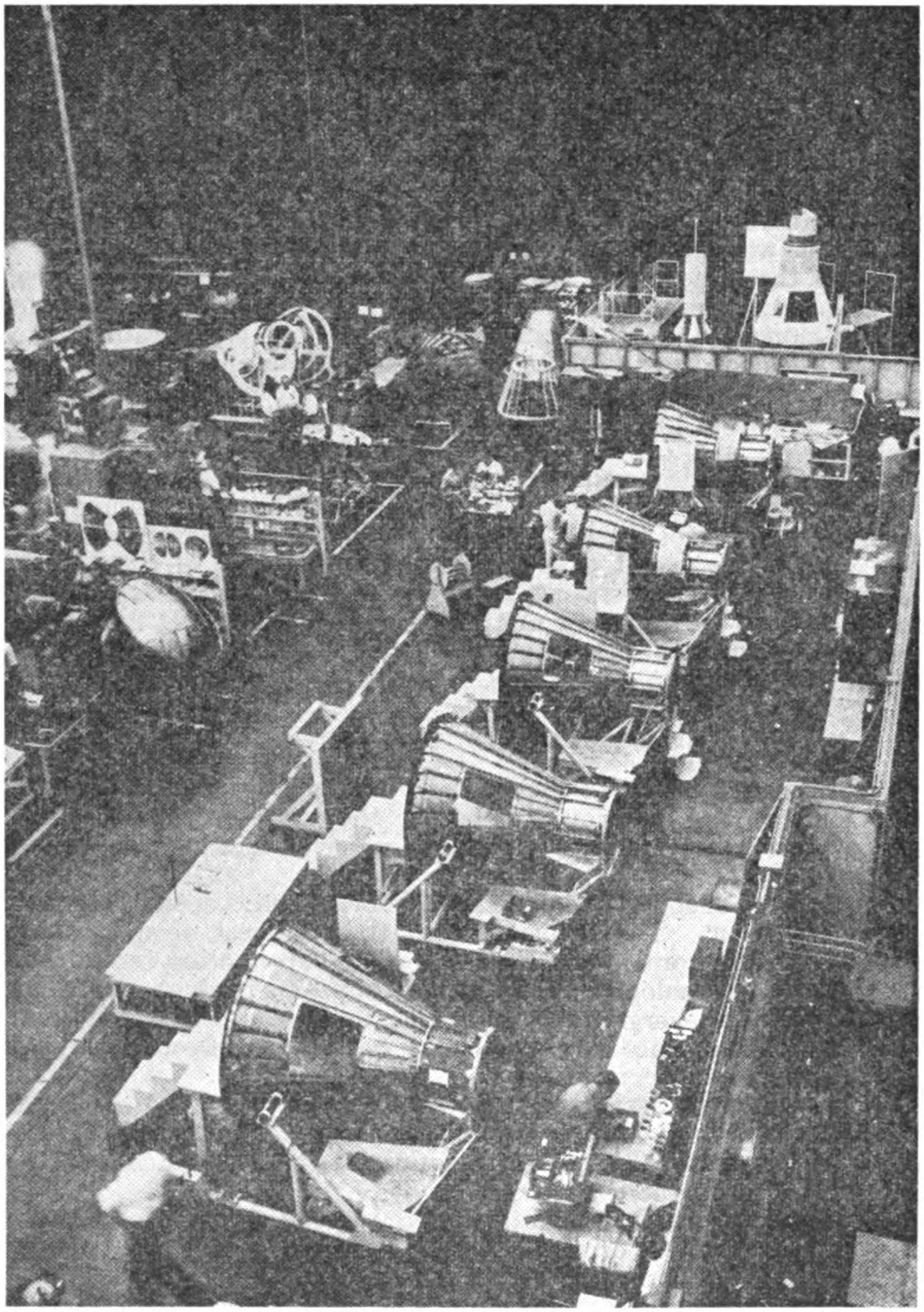

FIGURE 5.—Today's assembly lines for automobiles and aircraft are being supplemented by the growing astronautics industry, here shown turning out capsules for manned space flight.

III. The Economic Values

We in the United States believe that we have the world's highest standard of living. Our current wealth, prosperity, consumer goods and gross national product are at a peak hitherto unreached by any country.

Nevertheless, economists who see the steady preponderant outflow of goods and capital from the United States and who study the rising rate of economic capability in other countries can find little room for complacence in the present status of things. They are also well aware of the Soviet Union's announced intent of beating the United States at its own game: economic expansion.

Military historians are likewise aware that even strong economies, when they become static, do not guarantee safety. On the contrary, they seem likely to induce a dangerous national apathy.

> This syndrome is familiar in history. Carthage suffered from it. Carthage enjoyed enormous prosperity and was flourishing when she was destroyed by her Roman competitor. Much later, Rome had a gross national product without precedence. Her wealth and splendor were unsurpassed when the Vandals and Visigoths began their onslaughts. Neither Rome's great engineering skills, its architectural grandeur, its great laws, nor, in the last analysis, its gross national product, could prevail against the barbarians. Their GNP was negligible; nevertheless they ransacked the mighty Roman Empire.
>
> The gross national product is no insurance of survival. It is not a sign of military strength, and indeed, it may not even be sufficient for the economic battle.[25]

Thus from the point of view of economic stimulus and continued commercial dynamism, space exploration should be—and is proving to be—a godsend.

U.S. EXPENDITURES ON SPACE

It is impossible to arrive at accurate figures which might help indicate the extent of this effort in dollars and cents. But we do know that the U.S. Government is presently putting about $3.5 billion annually into the research and development phases. How much more may be going into the purchase of completed space hardware is difficult to say; certainly it is a higher figure still. The National Aeronautics and Space Administraton, in presenting its 10-year plan to Congress recently, indicated that this agency alone expects to average between $1.5 and $2 billion a year during the next decade.

The amount of effort going into space-related programs on the part of private industry, measured in dollars, again can only be roughly estimated. But it is a sizable figure and is known to be growing. It may amount to half the governmental research and development outlay.

[25] Gavin, James M., address to the International Bankers Association, Bal Harbour, Fla., Dec. 2, 1958.

These figures add up to a very important segment of the national economy, and the fact that they represent a highly active and progressive segment is particularly heartening to the economic experts of the Nation.

THE SPREAD OF ECONOMIC BENEFITS

One of the most useful characteristics of the space program is that its needs "spread across the entire industrial spectrum—electronics, metals, fuels, ceramics, machinery, plastics, instruments, textiles, thermals, cryogenics, and a thousand other areas." [26] The benefits from space exploration thus have a way of filtering into almost every area of the American economy, either directly or indirectly. "Perhaps the greatest economic treasure is the advanced technology required for more and more difficult space missions. This new technology is advancing at a meteoric rate. Its benefits are spreading throughout our whole industrial and economic system." [27]

A graphic example of the manner in which the technological and economic benefits from the space program can grow may be seen from the development of the X-15. This rocket craft, designed to "fly" beyond the Earth's atmosphere at altitudes up to 100 miles, is the product of 400 different firms and contractors.

Inasmuch as other nations, those which generally have lagged behind the United States in technical know-how, are now rapidly bringing their technology up to date—this windfall from our space program is especially opportune. It is providing the incentive to American industry to remain in the world's technological van. And it is emphasizing that economic leadership is a dynamic thing, that U.S. mass-production techniques which have enabled the Nation to compete so well in foreign markets are no longer, of themselves, sufficient guarantee of superior economic position.

While America's space exploration program, on a formal basis, came into being as recently as October 1958, its impact on the national economy has probably been sharper than that of any single new program ever conceived. For there are now at least 5,000 companies or research organizations engaged in the missile-space industry. And more than 3,200 different space-related products have been required and are being produced to date.[28]

One can only speculate on the economic effect which the space program is having on investments or on investors who have no other connection with it. It seems significant, however, that the stock market pages in recent months have come to devote a good deal of attention to "space issues." Financially speaking, space has thus become a major category. That it has done so in such a short period would seem to have marked implications for the future.

In brief, space exploration is becoming almost an industry in itself, and there are those who believe it destined to become the largest industrial spur in the Nation before too many years have gone by.

One expert, an experienced hand not only in astronautics but in the business world as well, describes the outlook in this fashion: "A great industrial change is taking place in the United States. The aircraft industry, which long considered missiles as a small department, now finds itself becoming a part of the large missile and space

---

[26] Mitchell, Hon. Erwin, in the House of Representatives, June 2, 1960.

[27] Dryden, Dr. Hugh L., Deputy Administrator, NASA, Penrose lecture before the American Philosophical Society, Philadelphia, Apr. 21, 1960.

[28] Missile-Space Directory, Missiles and Rockets, May 30, 1960, pp. 85–359.

flight industry. It is an elemental evolution. An industrial change is upon us comparable to the advent of mercantilism." [29] He has predicted that within a decade or so the astronautics industry will be larger than the automotive industry of the entire world.

While such predictions may be overly optimistic, they can scarcely be dismissed as irresponsible in the light of what has already happened.

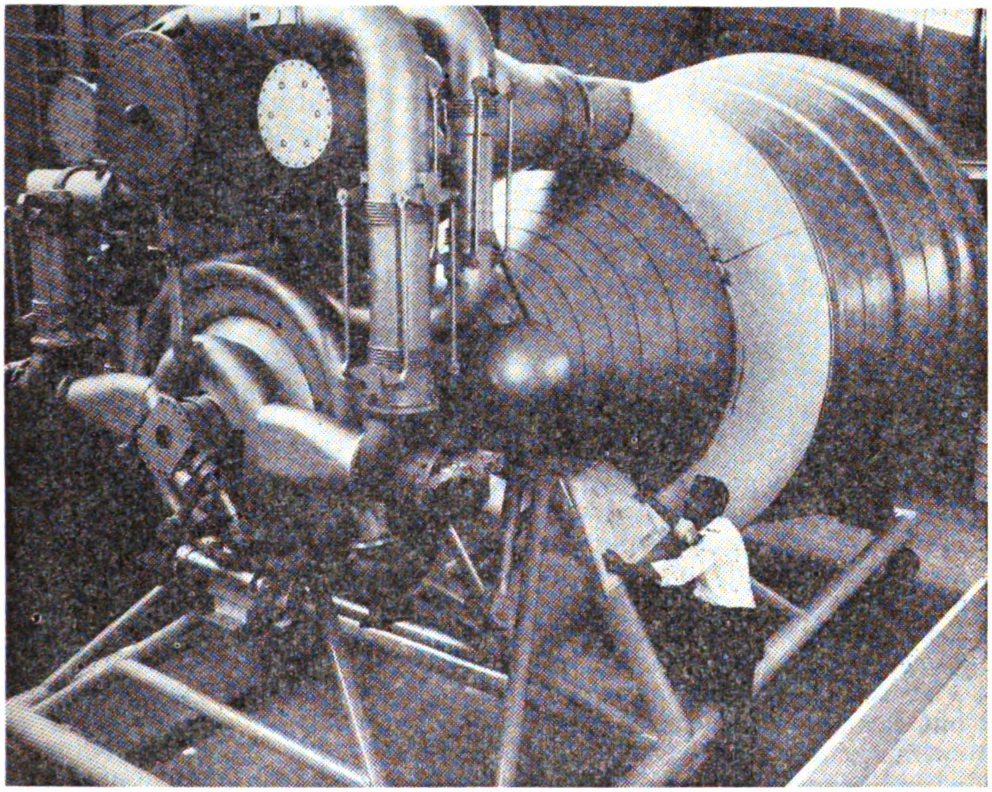

FIGURE 6.—Booster engines of tomorrow, such as this mockup of the 1,500,000 pound thrust single engine, will place broad requirements on men and materials.

CREATION OF NEW INDUSTRIES

Whether or not we think of the missile-space business as being a self-contained industry, the requirements and exigencies of space exploration can be expected to result in the creation of new or greatly strengthened industrial branches, for example:

Research

This phase of the American economy is having a phenomenal growth. Not only have many established industries now placed research high on their organizational charts, but hundreds, perhaps thousands, of new businesses are springing up which are entirely devoted to research and development. R. & D., as it is called, is their stock in trade, their only product. And space exploration appears to have given them their greatest boost.

One recent study on the subject regards research as the fourth major industrial revolution to take place in American history, following

[29] Haley, Andrew G., general counsel and past president of the International Astronautical Federation, "Rocketry and Space Exploration," Van Nostrand Co., Princeton, N.J., 1958, p. 156.

the advents of steam mechanization, steel, electricity-and-internal combustion engines.

> The fourth industrial revolution, ours, is unique in the number of people working on it, its complexity, and its power to push the economy at a rate previously impossible.
>
> Today between 5,000 and 50,000 *technical entrepreneurs* (top R. & D. engineers, leading scientists, and highly effective technical managers) are directly analogous to an estimated 50 to 500 men in all of the first three periods. Thus about 100 times the effort in terms of qualitative (effective, creative, patent-producing) manpower is being spent on the fourth revolution as on the other three combined.
>
> Total manpower, of course, is much more than that: there are probably 700,000 engineers and industrially oriented scientists in the United States today, as against 2,000 even as late as Edison's first high voltage light bulb. Whereas Edison worked with 20 to 100 scientists in his laboratory, and Fulton labored alone, there are 5,000 industrial laboratories today employing from 20 to 7,300 technical men each.[30]

New power sources

One of the greatest demands of spacecraft of the future will be for new sources of power. While rocket propulsion power is part of this picture, the power needed to operate space vehicles after launching may prove to be the larger and more important need. Progress has already been made in this direction by use of special kinds of batteries and solar cells which convert the sun's rays into electric current. But these will need supplementing or replacing eventually as greater power becomes necessary.

It would be rash to predict the outcome of this complicated field, but certain very promising methods can be listed.

One is the fuel cell, which converts fuel directly into electric power without the necessity for machinery or working parts. Much progress has been made on the fuel cell in recent months. In England a 40-cell unit has been used to drive a forklift truck and to do electric welding. It develops up to 5 kilowatts.[31] In the United States a 30-cell portable powerplant developing 200 watts has been delivered to the Army and Marine Corps,[32] while a 1,000-unit cell has been developed in the Midwest which provides 15 kilowatts and drives a tractor.[33]

Another method is plasma power, or power generated through the use of hot ionized gas. Such gas acts as a conductor of electricity and when employed as a "magnetohydrodynamics" generator it can be used for a variety of purposes. It has the advantage of being simple, rugged, and efficient. Some day it may also prove very economical. Already 10 municipal areas along the Mason-Dixon line are preparing to experiment with electric power derived from this source.[34] It has been estimated that "as much as 1 million watts could be generated by shooting a stream of plasma at speeds three times that of sound through a magnetic field only 3 feet long and with the magnetic poles 6 inches apart."[35]

---

[30] Ruzic, Neil P., "The Technical Entrepreneur," Industrial Research, May 1960, p. 10.
[31] Bacon, F. T., "The Fuel Cell, Power Source of the Future, New Scientist, Aug. 17, 1959, p. 272.
[32] Science Service dispatch, dateline Lynn, Mass., Apr. 25, 1960.
[33] Sharp, James M., "The Application of Fuel Cells in the Natural Gas Industry," Southwest Research Institute, San Antonio, Tex., Mar. 4, 1960, pp. 2–3.
[34] Lear, John, "Towns To Be Lit by Plasma," New Scientist, Nov. 19, 1959, p. 1006.
[35] Pursglove, S. David, Industrial Research, March 1960, p. 19.

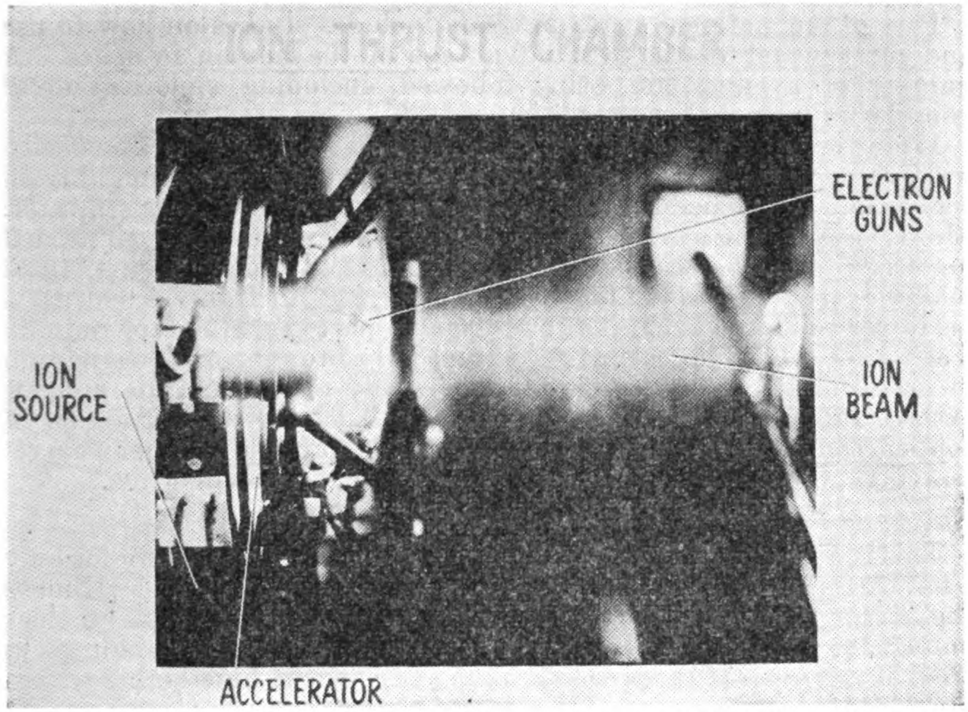

FIGURE 7.—The possible power source for space ships of the future, the ion jet, has significant counterpart uses for the commercial world.

Another possible source is photoelectric power. While a number of very difficult problems block the practical generation of this kind of power, the astronautics research division of one American company has now succeeded in increasing the efficiency of photoelectric cells by a factor of more than 300.[36] So the possibilities in this area are looking up. As discussed in section II, photon power derived from the ejection of electromagnetic rays may someday prove a source for accelerating vehicles once they have escaped from Earth's gravity.

Another possibility, of course, is atomic energy about which much has been said and written. If, as some scientists believe, extensive space exploration by manned crews will depend on harnessing this great source of energy—both for booster purposes and for operating spacecraft in the distant parts of our interplanetary system—this fact alone may assure that the obstacles to practical nuclear energy are overcome faster and more completely than would otherwise be the case. It is interesting to note that the science of controlling nuclear fusion (as opposed to fission) has come so far in the past several years that 11 private power companies are pooling their resources to advance this state of the art.[37]

New water sources and uses

A look into the future indicates very strongly that water will become a major world problem, possibly by the beginning of the 1970's, which is likely to be another "dry" decade. Present water supplies, coupled with the increasing population and the many new uses for water, are barely adequate now. In another 10 years the situation could be critical.

[36] Ibid.
[37] Ibid., p. 18.

Part of our national space program includes studies on how to use and reuse water to the best advantage of the human in space. A number of avenues are being followed, including vaporization of volatiles in biological wastes.[38]

From research of this kind it is more than possible that knowledge will evolve which will prove useful in the practical production of fresh water from other chemical compounds or mixtures, including seawater. More than that, it could lead to new ways for extracting much needed materials from the sea. Seawater contains 40 basic elements, 19 in relatively copious amounts. These elements run from 18,980 parts parts per million of chlorine to 0.0000002 part per billion of radium. Yet, so far, we have learned to extract only bromine and magnesium in useful amounts.[39] Conversely, the study of how marine animals extract rare elements from the seawater, such as the extraction of copper compounds by the octopus, could provide astronautic researchers with important clues for keeping man alive in space.

Noise and human engineering

This is a field in which research has been going on seriously for only a few years. Most of it has developed since World War II. Human engineering is involved primarily with the reaction of people to their immediate surroundings and how to arrange those surroundings in order to permit the most comfortable and efficient functioning within them.

The noise aspect of human engineering, as it may develop from the problems of astronauts operating in a silent world, could lead to a variety of innovations for improving the performance of workers or even the general attitude of people living in urban areas. In today's world, where humans are subjected to so many different kinds, degrees, and sources of noise, psychologists consider the matter to be of no small importance.

High speed-light weight computers

> Space vehicles now need electronic computers for determining the moment of launch, for fixing orbits, for navigation, and for processing collected data. Computers will precede man into space. They will take over guidance and decision functions beyond limits of human physiology, psychology, versatility, and reaction time.[40]

The trend in this direction is marked and space exploration is accelerating it. Because of weight and size limitations, and due to the genius of research, the giant electronic brain of today will soon disappear and be replaced with an apparatus only a small fraction of its present size. The implications for the business and professional world are great. And a not inconsiderable side effect, according to many modern technicians, will be the flood of brainpower released from time-consuming chores and thus made available for more basic, creative thought.

---

38 Space Business Daily, June 13, 1960.
39 Cox, Dr. R. A., "The Chemistry of Seawater," New Scientist, Sept. 24, 1959, p. 518.
40 Hines, L. J., Space Age News, Apr. 25, 1960, p. 4.

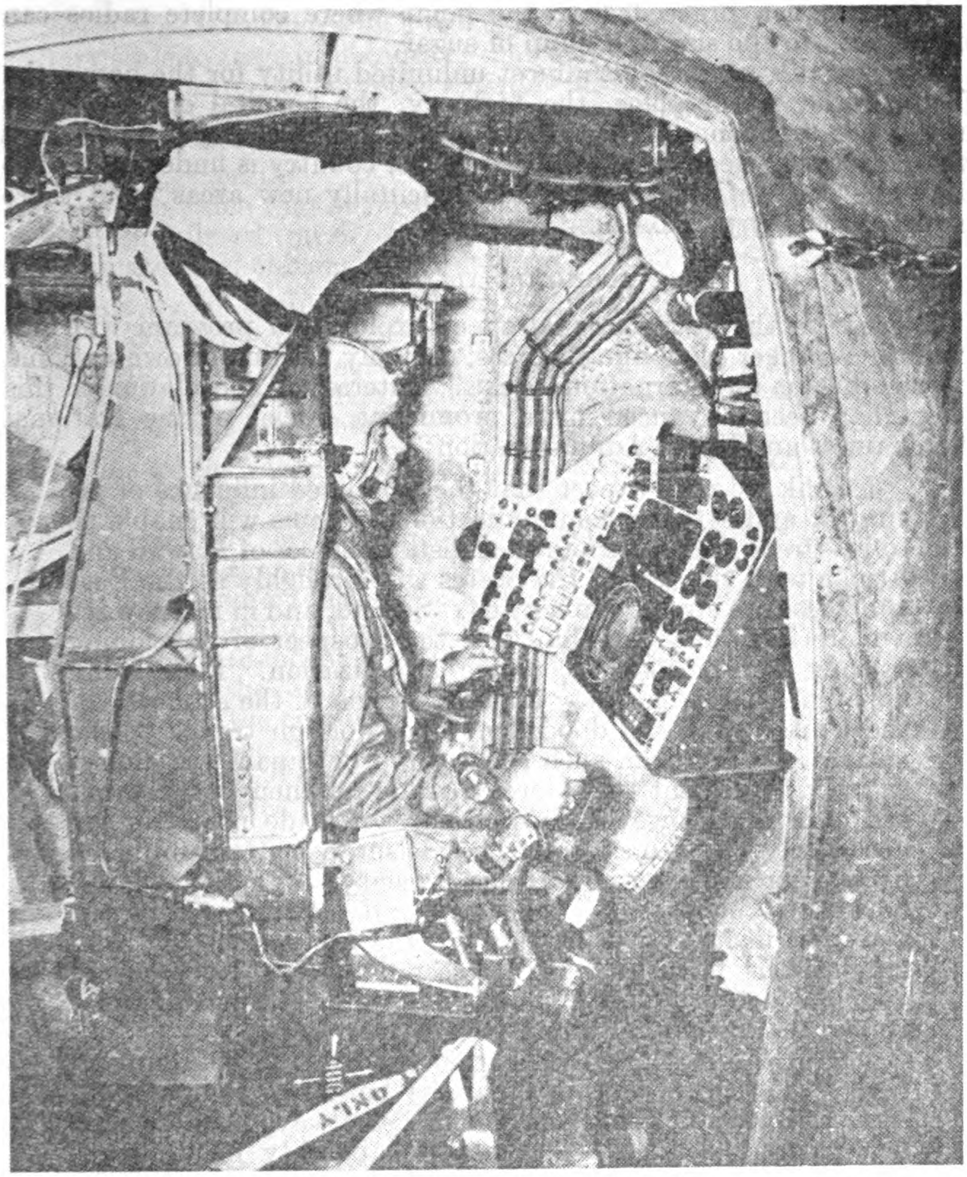

FIGURE 8.—The needs of tomorrow's spacemen will lead to marked advances in human engineering and psychology.

Solid state physics

Few areas of effort are advancing this extremely promising art faster than space exploration, which places a premium on light weight and small size. The miniaturization of equipment being placed in U.S. satellites, for example, has been one of the contemporary wonders of the world of science.

A big part of this march toward tiny equipment is in the field of electronics, where the process is called microminiaturization, molecular electronics, micromodular engineering or a number of other terms. In essence it refers to the greatly reduced size of equipment through "integrated circuits," coupled functions, the building of complicated components into a single molecular design and so on.

The art has proceeded to the point where complete radios can be reduced to the size of a lump of sugar.

Clearly, this trend holds almost unlimited utility for the home, the factory, the marketplace, the highway, the hospital or just about any other arena one cares to name. So great is the promise that virtually every electronics company in the country is undertaking "to take the state of the art into fundamentally new areas" and there exploit its many possibilities.[41]

ECONOMIC ALLIANCES

It may be that our national space exploration program will also result in stronger economic alliances, not only within our own national borders but on an international basis. Interesting speculation to this effect has been advanced by a prominent official of the National Aeronautics and Space Administration:

> I think we may expect that the combined influence of jet aircraft and satellite communications systems will enable us to integrate the now somewhat distant States of Hawaii and Alaska with the rest of the States as thoroughly as the East and West are already integrated. Second, and in many ways a more intriguing possibility, is the prospect of developing a truly international economic organization. It is quite apparent that even today a large fraction of the economy of the United States is dependent upon foreign trade. Some nations of the world, such as England or Japan, are almost entirely dependent upon foreign trade for their basic standard of living; however, current foreign trade practices are necessarily based on a somewhat leisurely pattern enforced by our current communications capacity. Whether we will be able to increase the efficiency and effectiveness of our activities in foreign trade through the use of the new communications facilities now foreseen will of course depend upon our political ability to work out viable arrangements for our mutual benefit with our oversea friends.
>
> One of the lessons of history in the fields of communications is that an increase in capability has never gone unused. The capability of doing new things has always resulted in it being found profitable to use this capability in all fields, both commercial and governmental.[42]

PRIVATE ENTERPRISE IN SPACE

Up to now space exploration has been more or less the exclusive domain of the Federal Government. It seems likely that this situation will not change much in the near future. But the question finally arises: Is the nature of space such that the traditional American concept of private enterprise can have no place in it?

On this score there is debate. Recently, however, there have been indications that businessmen feel they will be able to conduct certain business operations and services in space.

> The space frontier will inevitably increase the scale of thinking and risk taking by business. When we are dealing with

[41] Gaertner, W. W., "Functional Microelectronics," Missile Design and Development, March 1960, p. 34.
[42] Stewart, Dr. Homer J., address to the American Bar Association, Miami Beach, Aug. 25, 1959.

> space, we are dealing with a technology that requires a planetary scale to stage it; decades of time to develop it; and much bigger investments to get across the threshold of economic return than is customary in business today. Business must now think in international terms, and in terms of the next business generation. It must step up to the big risks with the same vision that enabled an earlier generation of builders to push railroad tracks out across the wilderness and lay the foundations of our modern economy.[43]

Incidentally, it should be pointed out that space exploration is already encouraging the formation of business of all sizes. Myriads of small businesses have sprung up, many of them "suppliers of specialty equipment for the larger concerns that have responsibility for major components and systems." [44]

To what extent will private enterprise become involved? Here is one view:

> As the years pass by, and space apparatus becomes more reliable, and the work of obtaining scientific data from space acquires a more routine character—certainly many of the necessary operating facilities could be put on a self-liquidating, private-industry basis.
>
> Probably the first opportunities for private investment will come in the commercial use of satellites. Looking even further into the future of space exploration, perhaps there would be economic justification for a privately owned launching service that would put objects into space for the peaceful purposes of friendly governments, international agencies, industry, and the universities.
>
> The base itself, from which the commerical launching service would operate, might be modeled after a port authority. Such a nonmilitary, international space port could develop as a center for many private enterprises related to space operations. These might include service and maintenance facilities; data-processing services; space communication centers; laboratory facilities; standardized equipment for satellites and other space vehicles; fuel supplies; medical services; biological services; and general supplies.
>
> Moving away from the idea of a commercial space port, must all future tracking stations, observatories, and data-processing stations be Government owned? How about experimental stations for the simulation of space environments? How about laboratories and stations actually constructed in space? Or will privately owned facilities one day offer these services on an international basis to governments, industries, universities, and international agencies?
>
> Most likely the first businesses suitable for commercial operation, using space technologies, will be worldwide communication by satellite, private weather forecasting, and high-speed Earth transport by rocket.[45]

[43] Cordiner, Ralph J., "Competitive Private Enterprise in Space," lecture at U.C.L.A., May 4, 1960
[44] Ibid.
[45] Ibid.

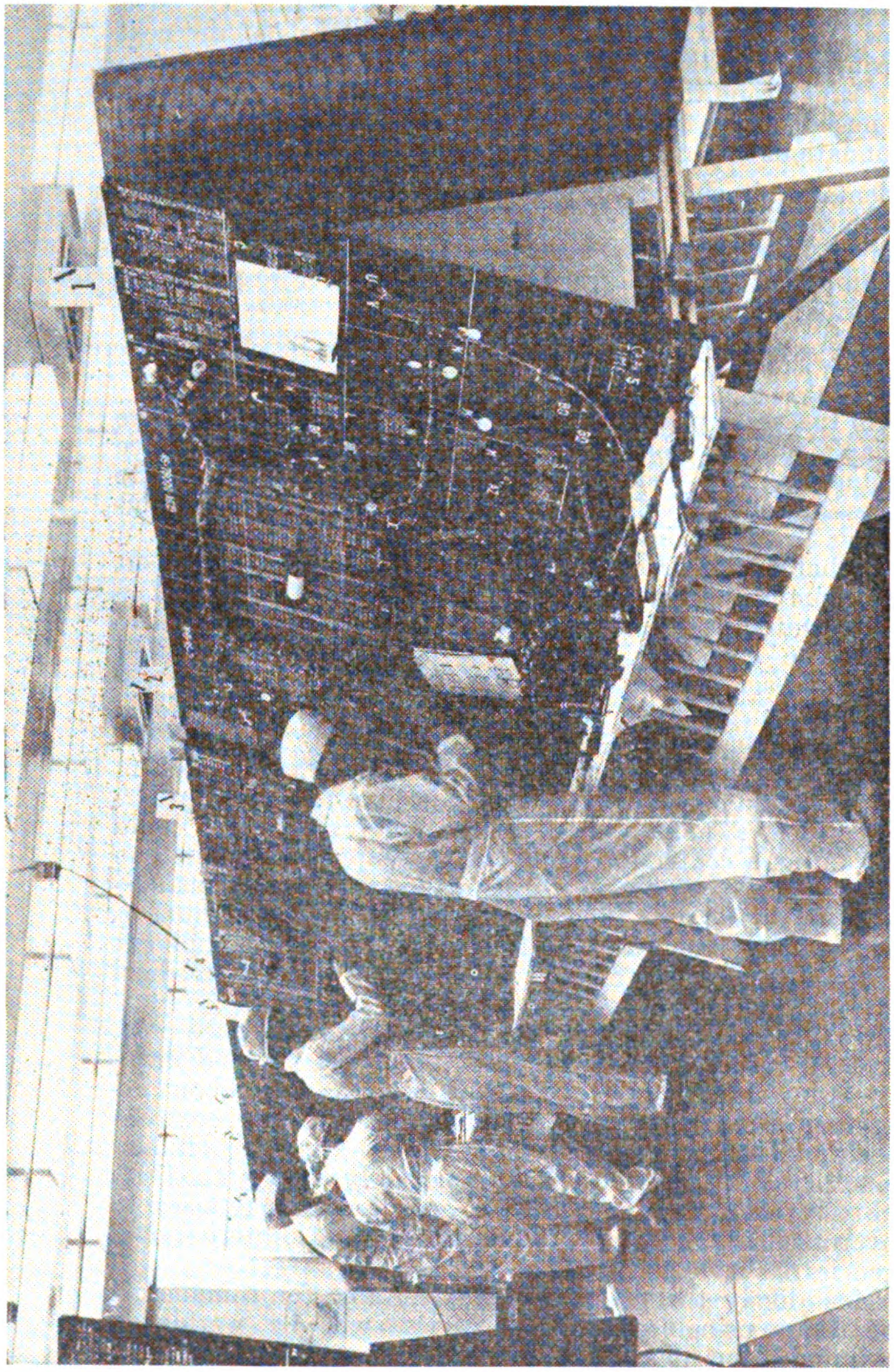

FIGURE 9.—The electric and electronic needs of the space program are requiring more and more skilled labor.

JOBS

There probably is no reliable way to gage the number of Americans who are employed today because of the national space effort, nor to estimate accurately the number who are likely to be employed in the years ahead.

This much can be said, though. They already number in the tens of thousands, probably in the hundreds of thousands.

The Administrator of the National Aeronautics and Space Administration has reported that his agency presently employs 18,000 persons. And he adds "in spite of the size of this organization, we estimate that approximately 75 percent of our budget will be expended through contracts with industry, educational institutions, and other nongovernmental groups."

Thus the number of persons privately employed who are working on NASA projects is, of itself, a high figure. The number employed in, by, or for the Department of Defense on missiles or space-related projects is undoubtedly higher.

In addition to these must be added the men and women employed by private industry in a capacity not directly related to the space program but whose jobs have been created nonetheless by its stimulus.

> The fact is that the military and peaceful needs of the space program are already employing a significant percentage of the industrial work force, and will make up an even larger proportion of total employment and production of the country as the years go by. The aircraft industry, for example, is broadening its scope to include missile and space technologies. Much of the electronics industry is devoted to missile and space needs. The communications, chemical, and metallurgical industries are increasingly involved. These industries are already among the largest employers in the United States, and they are the major employers of the Nation's technical manpower. Hence we are not speaking of a minor element in the national economy, but of its leading growth industries.[46]

This phase of the space program's value should not be eyed merely from the standpoint of scientists and the labor market. It has major significance for the professions—for doctors, lawyers, architects, teachers, and engineers. All of these will be vitally concerned with space exploration in the future. The doctor with space medicine and its results; the lawyer with business relations and a vastly increased need for knowledge in international law; the architect with the construction of spaceports and data and tracking facilities; the teacher with the booming demand for new types of space-engendered curricula.

As for the engineer—

> In this pyramid of scientific and engineering effort there will be found requirements for the services of almost every type of scientist and engineer to a greater or less degree. In the forefront, of course, are the aerospace and astronautical engineers but the development of the Saturn

[46] Ibid.

launching vehicle has also enlisted the cooperation of civil, mechanical, electrical, metallurgical, chemical, automotive, structural, radio, and electronics engineers. Much of their work relates to ground handling equipment, special automotive and barge equipment, checkout equipment, and all the other devices needed to support the design, construction, testing, launching, and data gathering.[47]

AUTOMATION AND DISARMAMENT

Finally, an economic value of extreme importance could be the ultimate role of the space program in modifying the threat to labor which is inherent in automation and disarmament. Space exploration, opening up new and profitable vistas, could take up much of the slack thus imposed and do it at a higher and more intellectual job level.

Automation, as we know, is already in the process. In agriculture alone it has bitten deeply into the laboring force and yet produces greater crops than ever.[48] It is gathering strength in many other fields.

Disarmament is a long way from being a reality. But all nations of the world are striving for it, or at least giving lipservice to its principles, so it may one day emerge as a reality. If this happens, space exploration again may be a most important element in taking up the slack which a prominent reduction in defense activity could not help but bring about.

Indeed, there are some who already foresee a complete substitution of space for defense, and who prognosticate that in the 1990's "the economy of nations is now based on the astronautics industry, instead of war." [49] Certainly, some new economic force would be crucial to nations deprived of the need for devising and manufacturing weapons.

---

[47] 27 supra.
[48] See "The Problem of Plenty," U.S. News & World Report, Apr. 13, 1959, p. 97.
[49] Markuwitz, Meyer M., and Gentieu, Norman P., "The Rocket, A Past and Future History," Industrial Research, December 1959, p. 78.

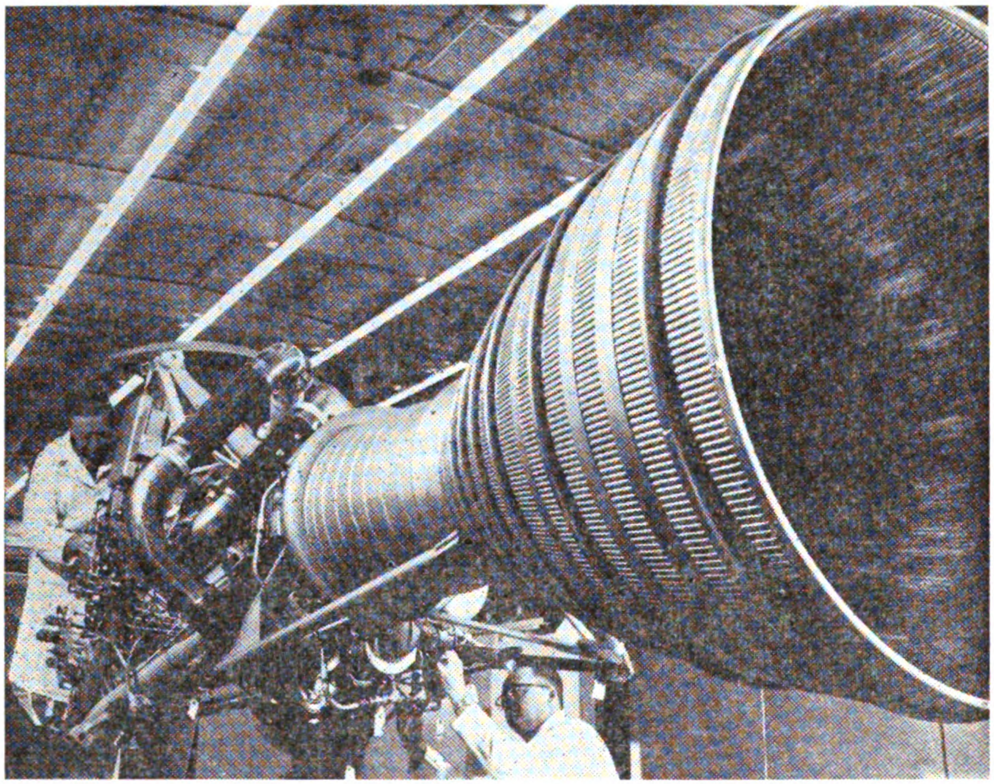

FIGURE 10.—A host of new materials, skills, and engineering techniques are bound up in the construction of rocket engines such as this first stage booster.

IV. VALUES FOR EVERYDAY LIVING

The so-called side effects of the space exploration program are showing a remarkable ability to produce innovations which, in turn, improve the quality of everyday work and everyday living throughout the United States.

In setting forth specific ways and means in which the space program is producing practical uses, it must be kept in mind that no attempt is made here to separate uses resulting from the civil phases of the program from those developed by the military phases. Inasmuch as the two are closely intertwined, it would seem impractical to do so. And, in instances where the same or similar research is being conducted by a single contractor on behalf of both phases, it is usually impossible to do so.

TECHNOLOGICAL BENEFITS

This category of the practical uses of the space program is impressive indeed.

Most of us are familiar with the plans which the United States has for using artificial satellites in ways which will be beneficial to all mankind. These include the satellite used for worldwide communications, for global television, for quick and accurate navigation, and for much improved weather prediction and weather understanding.

Here, however, is a summary of space-related developments about which the American public has heard considerably less:

> First, there is the high-speed computer. Developed initially to meet military demands for faster calculation, the computer is an integral part of American industry, making it possible to do many operations with a high degree of efficiency and accuracy. Thermoelectric devices for heating and cooling, now adapted for commercial applications, were originally designed to provide energy sources for space vehicles. The glass industry, as a result of work done during and after the Second World War on lenses and plastics, promises substantial gains in the consumer fields of optics and foods. Pyroceram, developed for missile radomes, is now being used in the manufacture of pots and pans. Materials suitable for use in the nuclear preservation of food may make us even better fed than we already are.
>
> Medical research, and our health problems, can use such things as film resistance thermometers. Electronic equipment capable of measuring low-level electrical signals is being adapted to measure body temperature and blood flow. In a dramatic breakthrough, illustrating the unexpected benefits of research, it has been found that a derivative of hydrazine, developed as a liquid missile propellant, is useful in treating certain mental illnesses and tuberculosis.

Of course, the aeronautics industry has benefited tremendously. Engines, automatic pilots, radar systems, flight equipment, capable of meeting the high standards required by space vehicles represent a great improvement over our already excellent aircraft.

A plasma arc torch (has been) developed for fabricating ultrahard materials and coatings by mass production methods. The torch, an outgrowth of plasma technology, develops heats of 30,000 degrees and can work within tolerances of two-thousandths of an inch. Another application from the missile field, which shows real possibilities, is a reliable flow meter that has no packings or bearings. This was first developed for measuring liquefied gases and should have a very wide industrial usefulness. It may even lead to improvements in marine devices for measuring distance and velocity.

Ground-to-air missiles that ride a beam to their targets must measure the distance to the target plane with an accuracy of a few feet in several miles. This principle, now being applied to surveying techniques, has revolutionized the surveying industry.

The solenoid valve, which seats itself softly enough to eliminate vibration, has been applied very satisfactorily to home-heating systems.

The use of the jet drilling for mining is another, and worthy of amplification. Missiles are already working the economically unminable taconite ore of the Mesabi Range, have helped build the St. Lawrence Seaway, and are bringing down costs in quarrying.

It is estimated that taconite will be supplying about a third of our ores in less than 20 years. Until 1947 we were unable to mine this very hard rock, and then suitable rotary and churn drills were produced. Jet drilling, now available, cracks and crumbles stone layers by thermally induced expansion and is somewhere between 3 and 5 times faster than rotaries.

Jet piercing can take us far deeper into the earth than we have been able to go so far, to new sources of ore and hydrocarbons.

In stone quarrying, jet spalling and channeling are proven techniques. Stone quarrying has been expensive and wasteful heretofore. Rocket flame equipment allows cutting along the natural cleavage planes, or crystal boundaries—hence cuts stone thin without danger of cracking and, in addition, produces a fine finish that cannot be obtained when cutting by steel or abrasive tools.

Scientific literature is beginning to contain speculations on using the principle of the missile engine to save unstable intermediate products of the chemical processes. The high heats achieved in the rocket engine can, perhaps, be utilized to produce desired products that would be lost by slow cooling. But the high rate of cooling accomplished by expanding gases through the engine nozzle, it is thought, would save these unstable compounds.

> Infrared has come into its own through missile electronics. Infrared—since it cannot be jammed—appears to be challenging radar for use in guidance devices, tracking systems, and reconnaissance vehicles. Infrared is being used industrially to measure the compositions of fluids in complex processes of chemical petroleum refining and distilling. Infrared cameras are used in analyzing metallurgical material processing operations, to aid in accuracy and quality control. The entire infrared field should be significantly assisted in its growth and application through our missile-space programs.
>
> Another very promising outcome from missile development is a computer converter that can quickly transform analogue signals—such as pressure measurements—into digital form.
>
> In the near future, when guidance devices permit soft landing, rocket cargo and passenger transport will become feasible. Mail may become almost as swift as telephone.
>
> We are making rapid progress in the economics of space travel: payload costs for Vanguard were about $1 billion a pound; for the near future launchings, payload cost should be about $1,000 per pound. When payload costs are about a hundred dollars a pound we may expect commercial space flight.[50]

Hundreds of other examples of the space program's value for everyday living could be cited.

One with wide possibilities is a new welding process by using a high-powered electron beam gun, developed for the fabrication of spaceships and other space vehicles. This method permits welding joints capable of withstanding temperatures up to 3,000° F.; it can be used on metals such as molybdenum and pure tungsten. And, its developers say, it results in welded joints that have deep penetration and narrow weld beads that are virtually free of contamination.[51]

Another ingenius application, resulting from the Navy's space research program, has significant utility for medicine and surgery. This is a glass fiber device which, when placed in the mouth during dental work or in the area of surgical incision, permits a much magnified televising of the operation. It holds considerable promise for teaching techniques in many fields.[52]

Another example is a finely woven stainless steel cloth designed for parachuting space vehicles back to Earth. The cloth is made of fine wire of great strength which can withstand tremendous temperatures and chemical contamination. The wire from which the cloth is woven is about one-fifth the thickness of a human hair and is believed to have marked potential for industry and consumers alike.

Here is an additional list of examples: [53]

---

[50] 25 supra. See also address to the American Bankers Association, Oct. 28, 1958.

[51] Space Business Daily, June 17, 1960.

[52] Feldman, George J., cited in a letter to the House Committee on Science and Astronautics, Apr. 29, 1960.

[53] From Michelson, Edward J., "How Missile-Space Spending Enriches the Peacetime Economy," Missiles and Rockets, Sept. 14, 1959, pp. 13-17.

Microminiature transmitters and receivers—used by police and doctors.

Target drone autopilot—used as an inexpensive pilot assist and safety device for private aircraft.

Inert thread sealing compound—used by pump manufacturers serving process industries.

Satellite scan devices—used in infrared appliances, e.g., lamps, roasters, switches, ovens.

Automatic control components—used as proximity switches, plugs, valves, cylinders; other components already are an integral part of industrial conveyor systems.

Missile accelerometers, torquemeters, strain gage equipment—used in auto crash tests, motor testing, shipbuilding and bridge construction.

Space recording equipment automatically stopped and started by sound of voice—used widely as conference recorder.

Armalite radar—used as proximity warning device for aircraft.

Miniature electronics and bearings—used for portable radio and television; excessively small roller, needle and ball bearings used for such equipment as air-turbine dental drills.

Epoxy missile resin—used for plastic tooling, metal bonding, adhesive, and casting and laminating applications.

Silicones for motor insulation and subzero lubricants—used in new glassmaking techniques for myriad products.

Ribbon glass for capacitors—used widely in electronics field.

Radar bulbs—used in air traffic control equipment.

Ribbon cable for missiles—used in the communications industry.

Automatic gun cameras—used in banks, toll booths, etc.

Fluxless aluminum soldering—used for kitchen utensil repair, gutters, flashings, antennas, electrical joints, auto repairing, farm machinery, etc.

Lightweight hydraulic pumps—used in automated machinery and pneumatic control systems.

Voice interruption priority system—used for assembly line production control.

Examples such as the foregoing, it might be pointed out, do not generally emphasize an area in which space exploration is making one of its greatest contributions. This is the creation of new materials, metals, fabrics, alloys, and compounds that are finding their way rapidly into the commercial market.

Less demonstrable but equally (and perhaps more) significant areas which may expect to benefit from space exploration are set out beginning on page 35.

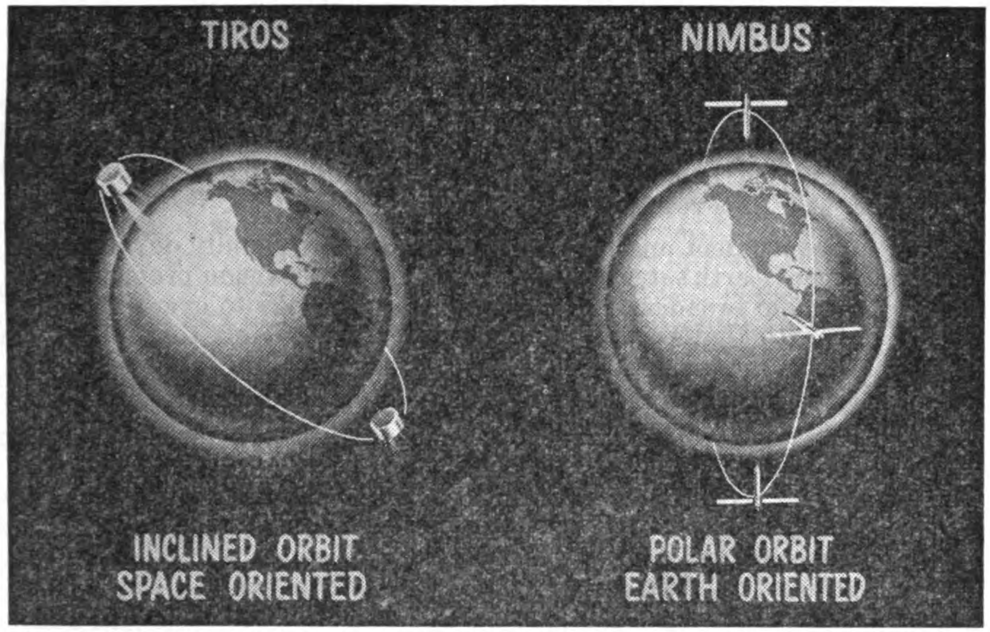

FIGURE 11.—Vital information about the forces which cause weather can be learned from meteorological satellites such as these. Even a slight increase in the accuracy of weather prediction will be worth millions of dollars annually.

FOOD AND AGRICULTURE

An extremely difficult problem bound up with space travel of any duration is that of food. Astronauts will not be able to take large supplies of food on their voyages and probably will have to reuse what they do take. Learning how to do this is no easy matter. Some doubt if it can be done. Others are optimistic.

> The body of scientists now working directly on space feeding and nutrition is working effectively at a rate only attained by high motivation. But this motivation suffices, and their efforts will ultimately provide at least a partially closed space feeding system by the time it is critically needed and, eventually, an ideal one for long voyages of man into the remoter reaches of outer space.[54]

If the optimists are right, it is conceivable that the information gained from this research will have profound influence on food and agricultural processes in the future. The use and growth of synthetics or new foods, and their effects on the soil, could prove invaluable as the world's population climbs and the demand for food multiplies.

Better understanding of weather processes, as provided through space exploration, will also be valuable in terms of agriculture. Long-range accurate weather prediction would be worth millions of dollars in proper crops planted and crop damage avoided.

Meanwhile, as in other technological areas, space research is providing specific new tools for the food and agriculture industry. Infrared food blanching, for instance, is highly effective in preparing foods for canning or freezing. The development of a new forage harvester based on principles of aerodynamics uncovered by missile engineers is another example.

[54] Tischer, R. G., "A Search for the Spaceman's Food," Space Journal, December 1959, p. 46.

COMMUNICATIONS

This is a field of enormous promise, and its practicality has already been demonstrated to the extent of placing satellites into precise orbits, such as Tiros (weather) and Transit (navigation), and of communicating at long distances—23 million miles in the case of Pioneer V. As a result:

> Government and industry technicians are rapidly developing new Earth satellites to beam not only television programs but radio broadcasts and phone conversations to every spot on Earth that's equipped to receive them. Thus this space project, far more than most, will touch the ordinary citizen. The goal: a workable, worldwide communications system in space before this decade is over. It will be, declares one researcher, "the ultimate in communications." [55]

Incidentally, the first worldwide communications system of this type, and whether it is conducted in English or Russian, may have crucial prestige and propaganda ramifications.

Such facilities should be possible through a system of carefully placed satellites so that radio signals can be relayed to any part of the globe at any time.

Moreover they appear to be essential when one considers that within the next 20 years existing techniques are apt to be stretched beyond reasonable economic limits by demands for long distance communications. It is difficult to see how transoceanic television will otherwise be possible when it is realized that there is presently a capacity of less than 100 telephone channels across the Atlantic and a single television channel is equivalent in band width to 1,000 telephone channels. It appears that a system utilizing satellites is the most promising solution to this problem.[56]

More esoteric communications systems may also arise from space research.

> In some future year when a cruising space vehicle communicates with another space vehicle or its orbiting station, it may use a beam of light instead of conventional radio. Not that radio will be inoperative under the airless conditions of space—rather the reverse—but there is reason to believe that communication by sunlight not only will be cheaper but will entail carrying much simpler and lighter equipment for certain specialized space applications. (The Air Force) is developing an experimental system that will collect sun rays, run them through a modulator, direct the resultant light wave in a controlled beam to a receiver. There the wave will be put through a detector, transposed into an electrical impulse and be amplified to a speaker. Depending on the type of modulator used, either the digital (dot-dash) message or a voice message can be sent.[57]

Might not such a system find practical usage on Earth, particularly in sunny, arid lands?

[55] Kraar, Louis, Wall Street Journal, May 4, 1960.
[56] 7 supra.
[57] Release No. 38-60, Air Research and Development Command, May 2, 1960.

WEATHER PREDICTION AND MODIFICATION

Meteorological satellites should make possible weather observations over the entire globe. Today, only 20 percent of the globe is covered by any regular observational and reporting systems. If we can solve the problems of handling the vast amounts of data that will be received, develop methods for timely analysis of the data and the notification of weather bureaus throughout the world, we should be able to improve by a significant degree the accuracy of weather predictions. An improvement of only 10 percent in accuracy could result in savings totaling hundreds of millions of dollars annually to farmers, builders, airlines, shipping, the tourist trade, and many other enterprises.

Perhaps even greater savings will come from warning systems devised for hurricanes and tornadoes.

The slight knowledge which humans actually have of weather forces can be seen from the fact that at present we do not even know exactly how rain begins.[58] Learning to predict it and to modify it, through space application, might help slow down the soil erosion of arable land—that "geological inevitability * * * which man can only hasten or postpone." [59] It is noteworthy that the two leading nations in space research, the United States and the U.S.S.R., are among the most affected by soil erosion.

The "leg up" which the United States has in this particular phase of space research is illustrated by the acute photographic talents of the Tiros satellite and their meaning to weather experts. The following description of some of the earliest pictures by the Director of the Office of Meteorological Research, U.S. Weather Bureau, is illuminating.

> This picture, labeled "No. 1," was the storm that was picked up in the early orbits of Tiros on the first day of launch, April 1. This shows the storm 120 miles east of Cape Cod, with dry continental air streaming off the United States, not shown by clouds, and off the coast the moist air streaming up to the north, counterclockwise around the center, producing widespread clouds and precipitation as far north as the Gulf of St. Lawrence.
>
> On that same day mention was made of a storm in the Midwest. That is illustrated by photograph No. 2. This was centered over southeast Nebraska, a rather extensive storm. Again, we have a clear air portion shown by a dark area, the ground underneath, which has less brightness than the clouds, the cold air from Canada streaming into that area, not characterized by clouds, and to the east the moist air from the Gulf of Mexico, in this general neighborhood, streaming around into that center and producing rather widespread rains. In this case near the Gulf of Mexico, where the cloud is extremely bright, indicating that the clouds are very high, thunderstorms were found in that area.
>
> It is a sort of situation in which tornadoes are to be found in this very bright cloudy area, especially this time of year in the Midwest.

[58] Lear, John, "Where Does Rain Begin?" New Scientist, Mar. 24, 1960, p. 724.
[59] "Wind and Soil," New Scientist, May 26, 1960, p. 1327.

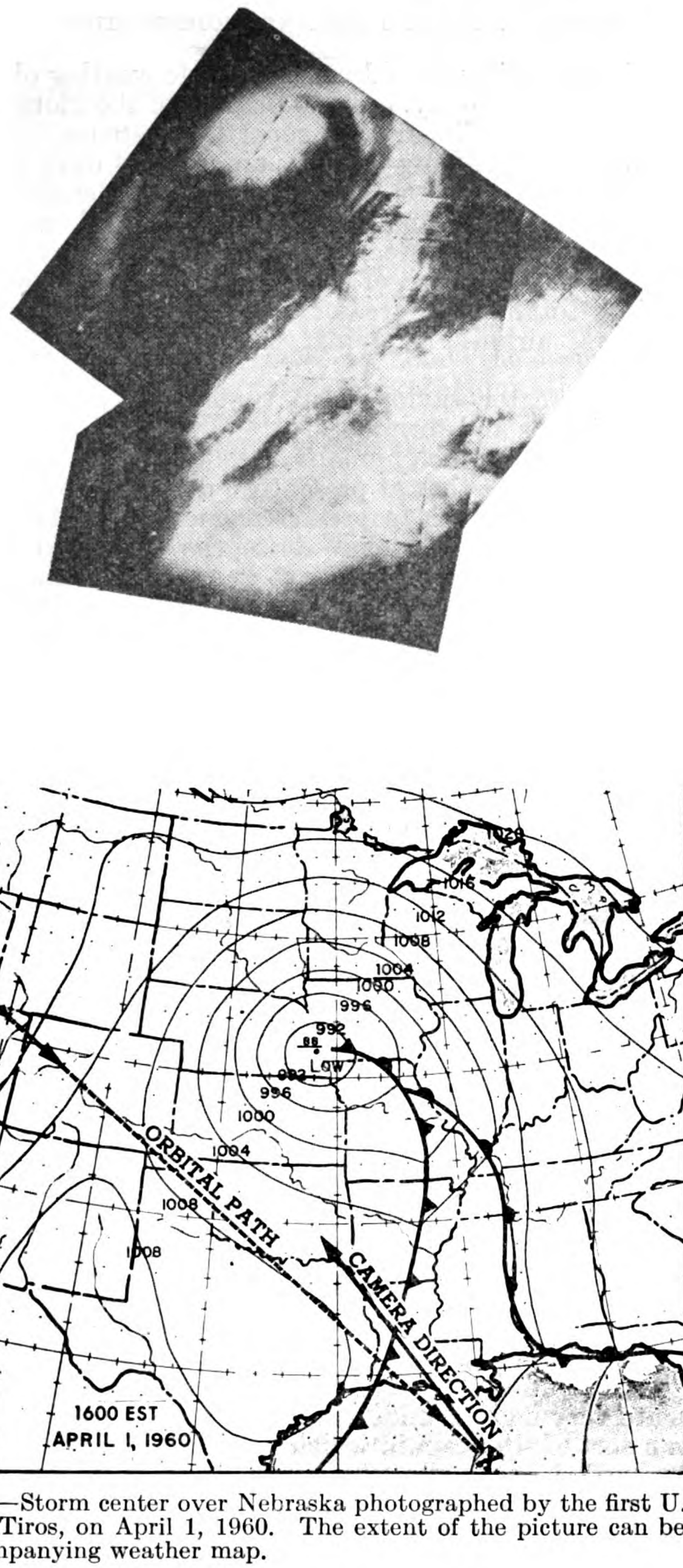

FIGURE 12.—Storm center over Nebraska photographed by the first U.S. weather satellite, Tiros, on April 1, 1960. The extent of the picture can be seen from the accompanying weather map.

> A third vortex was observed, also April 1, in the Gulf of Alaska, 500 miles southeast of Kodiak Island. The vortex circulation is clearly evidenced by the clouds which form in a circular array, and the large clear area in the center of the storm.
>
> No. 4 picture refers to a very big storm 1,500 miles in diameter located 300 miles west of Ireland on April 2. This is a very old storm which was whirling around, had no fronts associated with it. It has long since wound up around the center. There is a rather well-marked structure to the clouds that you can see. It is quite different from the pictures in the first two. These are storms mostly over the continental area or just off the coast. The storms over the oceans seem to show more of a banded structure. By that I mean circular bands of clouds, of width perhaps ranging from 20 miles to a few hundred miles, spiraling around the center in a counterclockwise manner.[60]

HEALTH BENEFITS

Of all the problems contingent upon space flight it is doubtful if any are more perplexing than the biological ones. In fact, it now appears quite likely that the limiting factor on manned space exploration will be less the nature of physical laws or the shortcoming of space vehicle systems than the vulnerability of the human body.

In order to place humans in space for any extended period, we must solve a host of highly complicated biological equations which demand intensive basic research. The other side of the coin, however, is that when scientific breakthroughs do occur in this area, they will probably be among the most beneficial to come from the space program.

An idea of what is going on in the space medicine field can be obtained from this summary:

> Engineers already have equipped man with the vehicle for space travel. Medical researchers now are investigating many factors incident to the maintenance of space life—to make possible man's flight into the depths of space. Placing man in a wholly new environment requires knowledge far beyond our current grasp of human biology.
>
> Here are some of the problems under investigation: The determination of man's reactions; the necessity of operating in a completely closed system compatible with man's physiological requirements (oxygen and carbon dioxide content, food, barometric pressure, humidity and temperature control); explosive decompression; psychophysiological difficulties of spatial disorientation as a result of weightlessness; toxicology of metabolites and propellants; effects of cosmic, solar, and nuclear ionizing radiation and protective shielding and treatment; effects on man's circulatory system from accelerative and decelerative g. forces; the establishment of a thermoneutral range for man to exist through preflight, flight, and reentry; regeneration of water and food.[61]

In addition, intensive efforts are being brought to bear on such problems as the effect on humans who are deprived of their sensory

---

[60] Wexler, Dr. Harry. Press conference conducted by the National Aeronautics and Space Administration, Apr. 22, 1960.

[61] Lockheed, Missiles and Space Division, medical research, Sunnyvale, Calif.

perceptions, or whose sensory systems are overloaded, or who are exposed to excessive boredom or anxiety or sense of unreality, or who must do their job under hypnosis or hypothermia (cooling of warm-blooded animals).

A recent space medicine symposium heard this theory advanced by a prominent medical scholar:

> Attractive, indeed, for the space traveler would be the choice of hibernating during long periods when there was nothing he had to do. With the increase of speeds and the lowering of metabolism, consideration of flights running several hundred or even thousands of years cannot be offhandedly dismissed as mere fantasy. During prolonged flights of many months or years there will be very little to see and that of negligible interest. The most practical way of dealing with the problem might well be to have the pilot sleep 23 of the 24 hours.[62]

Lowering the body temperature would be one way of inducing the necessary deep sleep.

Another possibility of handling some of the biological problems of space flight, suggested by another physician, would be for astronauts to discard the 24-hour Earth day and establish a longer rhythm for their lives.[63]

At any rate, and while we may not now see just how it will come about, knowledge gained from experiments such as these may result in important medical and psychological advances.

In the drug and technological area of medicine, concrete benefits have already resulted from the national space program. These include, as already mentioned, a drug developed from a missile propellant to treat mental ills, a means of rapidly lowering blood temperature in operations, and a small efficient valve which could replace the valve in a human heart.

Particularly gratifying, from the standpoint of medical value is the Army's work toward an anti-radiation drug which could be taken before exposure to reduce the biological effects of radiation.[64] Such a drug, which is of special interest to astronauts who might be required to subject themselves to varying belts of radiation, might be of even greater use in the cause of civil defense.

A final and far-reaching phase of the health side of space exploration deals with the basic nature of biology itself—how and under what conditions life grows. Up to now biological science has been largely "the rationalization of particular facts and we have had all too limited a basis for the construction and testing of meaningful axioms to support a theory of life." [65] Through research made possible by the space program it may be possible to alter this condition. "The dynamics of celestial bodies, as can be observed from the Earth, is the richest inspiration for the generalization of our concepts of mass and energy throughout the universe. The spectra of the stars likewise testify to the universality of our concepts in chemistry. But biology

[62] Lewis, Dr. F. J., before the Space Flight Symposium, San Antonio, Tex., May 28, 1960.
[63] Kleitman, Prof. Nathaniel, before the Space Flight Symposium, San Antonio, Tex., May 26, 1960.
[64] Taylor, Lt. Col. Richard R., USA (MC), testimony before the House Committee on Science and Astronautics, June 15, 1960.
[65] Lederberg, Joshua, "Exobiology-Experimental Approaches to Life Beyond Earth," Science in Space, ch. IX, National Academy of Sciences, Washington, D.C., February 1960.

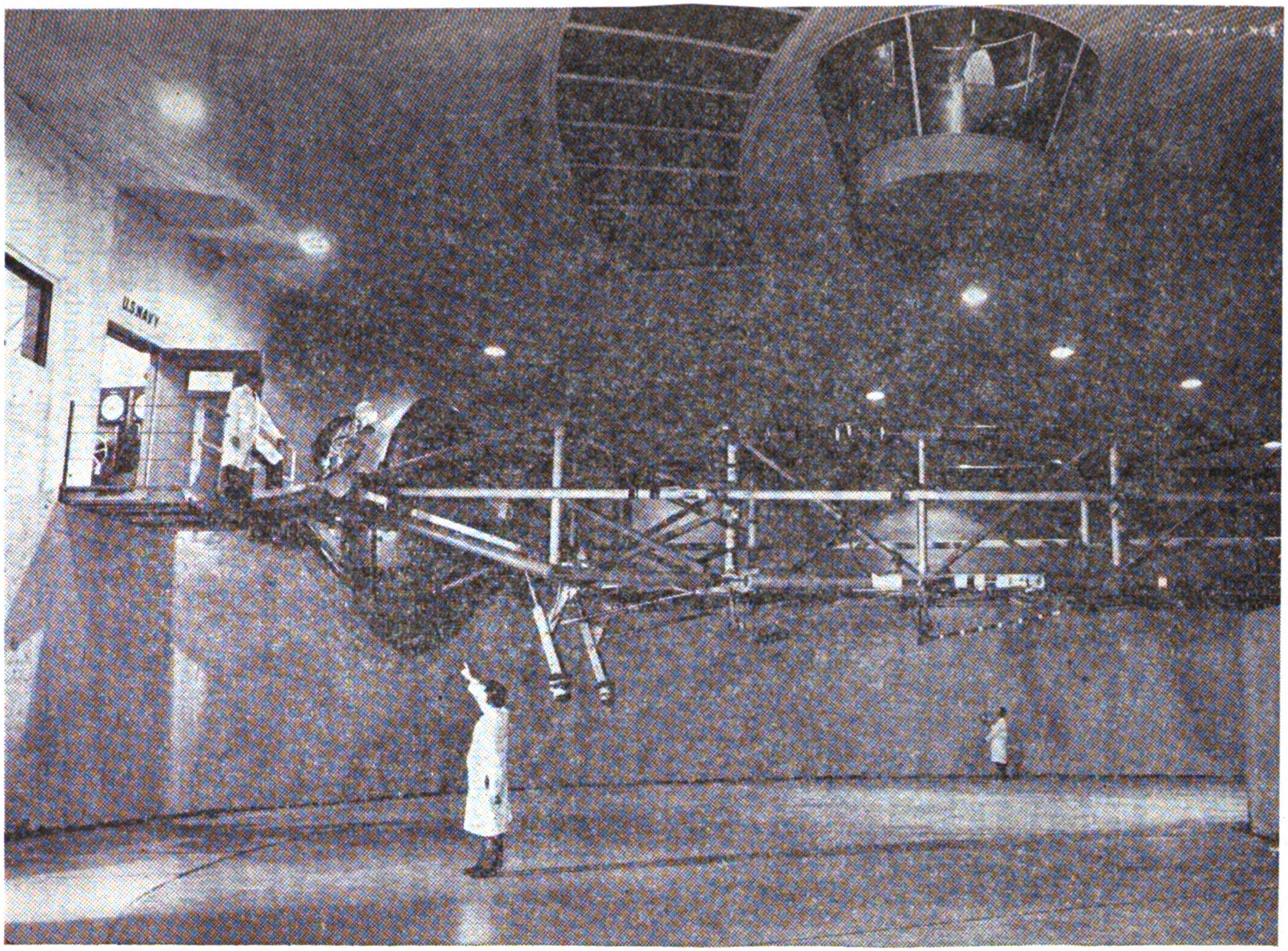

FIGURE 13.—Biological reactions uncovered in space medicine studies, such as this centrifuge experiment, may lead to important health discoveries.

has lacked tools of such extension, and life until now has meant only terrestrial life." [66]

The secrets which this research may divulge and their meaning for human health can only be imagined. But they certainly would not be minor.

EDUCATION BENEFITS

No enterprise has so stirred human imagination as the reach of man toward the exploration of space. New worlds to explore. New distances to travel—3,680 million miles to Pluto, the outermost planet of our solar system, 8 years journey at 50,000 miles per hour when we attain such a capability. Innumerable problems ahead. New knowledge needed in almost every branch of science and technology from magneto fluid dynamics to cosmology, from materials to biology and psychology.[67]

"New knowledge needed" means better and stronger education is essential. And not only in the physical sciences. In the social sciences and the arts as well.

> Certainly man's space adventure can help profoundly to make a finer creature of him, but only if his adventures on Earth can do so as well. Essentially what this means to a social psychologist is that we must somehow raise our level of education to the point where most men most of the time can appreciate and actively absorb the implications of knowledge and developments in all areas sufficiently to let them enrich their personal philosophies. Obviously this kind of education is only in part a scientific one.[68]

Moreover, the technical and management aspects of the space program involve collaboration with nonscientific persons such as businessmen, bankers, and public officials in assessing worthwhile objectives and in judging the technical and economic feasibility of projects designed to accomplish these objectives.[69] Consequently each type must educate the other in his own specialty if an effective, stepped-up space program is to be achieved.

The demand

Apparently the demand for specific formal education in the science of astronautics is increasing faster than it is being supplied. Although many colleges and universities have been setting up courses dealing with astronautics, the state of the art does not seem to have crystallized to the extent that it permits fashioning a career in the field at the educational level. Of course, discontent is created. One publication has editorialized:

> We have received a surprising number of letters from young people who actually want to know how and where they can get started in a career in astronautics. These, for the most part, are high school students—and, evidently, they couldn't get the information they wanted from their own school. * * * Isn't the age of space yet important enough for all the high schools to sponsor interest in our space programs and to point out the need for a constant flow of young brains? [70]

[66] Ibid.
[67] Dryden, Dr. Hugh L., speech before the Engineering Society of Cincinnati, Feb. 18, 1960.
[68] Michael, Donald N., "Space Exploration and the Values of Man," Space Journal, September 1959, p. 15.
[69] 67 supra.
[70] Space Age, August 1959, p. 3.

The answer undoubtedly is that such grassroots demand will bring about increased academic curricula in astronautics in direct proportion to its magnitude.

Meanwhile, the availability of work for persons with a background in space-related subjects can be gaged to some extent by observing the variety of personnel requirements on major space exploration projects.

A single American firm, for example, uses 49 different professional specialists in its work for the National Aeronautics and Space Administration and in its space work for the Department of Defense.[71] Multiplied by the thousands of companies which are doing similar work, the list gives an idea of the astronautic demand confronting the Nation's educational institutions:

Acoustician
Aerodynamicist
Aeronautical engineer
Agricultural engineer
Astrodynamicist
Astronomer
Astrophysicist
Biochemist
Biophysicist
Ceramics specialist
Chemist
Computer specialist
Crystallographer
Development engineer
Doctor of medicine
Electrical engineer
Electronic engineer
Experimental physicist
Flight engineer
Gyroscopics specialist
Hydraulic engineer
Information theory analyst
Inorganic chemist
Logical designer
Magnetic device engineer
Mathematician
Mechanical applications engineer
Mechanical engineer
Mechanisms specialist
Medical electronic engineer
Metallurgical engineer
Methods engineer
Nuclear physicist
Oceanographer
Organic chemist
Physical chemist
Pneumatic engineer
Process engineer
Production engineer
Project engineer
Psychologist
Reliability engineer
Sociologist
Solid state physicist
Structural engineer
System analyst
Theoretical physicist
Thermodynamicist
Transducer engineer

[71] Minneapolis-Honeywell, Military Products Group.

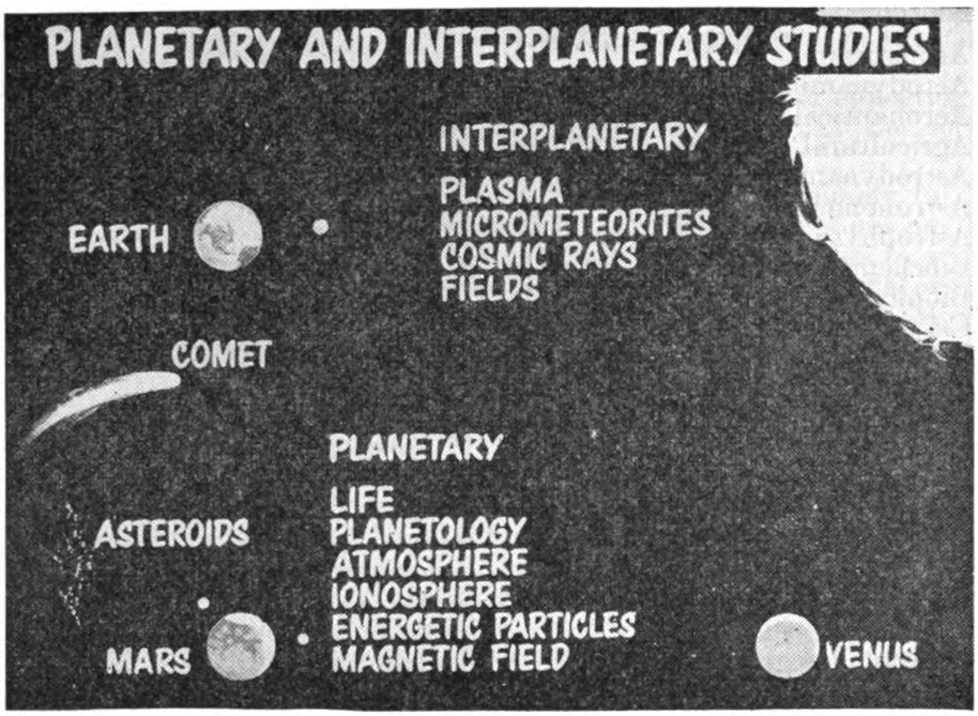

FIGURE 14.—Exploration within the solar system means a wealth of new knowledge which could lead to learning the secrets of life.

V. Long-Range Values

In assessing the *practical* values of space exploration it does not seem logical to limit considerations to those values which are immediate or near-future ones. The worth of a present activity may be doubled or trebled because of its long-range potential.

Such values may not be practical within the context of today's usage, but they may be extremely practical if we are willing to concede that those of us living today have an interest in and a responsibility for what happens on Earth in the decades and centuries to come.

TROUBLE SPOTS

Thinking along these lines it is not difficult to conjure up a picture of some of the difficult physical and social problems which will be facing the Earth in the years which stretch ahead. The foregoing sections of this report, for example, have already indicated extensive difficulties inherent in at least five major categories.

(1) Bursting population.
(2) Acute water shortage.
(3) Soil erosion and disappearance.
(4) Too much leisure.
(5) Intensified nationalism.

In each area it is probable that space exploration will ultimately play an important role.

Population

Social scientists have been warning for years of the drastic social upheavals which must inevitably accompany an "exploding" population. It is a problem the complexity of which grows in geometric progression as time goes on. In the United States nearly 300 years were required to produce 90 million people. In the past 60 years this number has doubled. The implications are obvious. They are only too plain to urban and suburban planners who endeavor to cope with the antlike construction and activity of the human race as it burgeons with each succeeding year.

Of course, this is not a domestic matter but a global one. Its seriousness has been described as follows: "Projection of the post-World War II rate of increase gives a population of 50 billions (the highest estimate of the population-carrying capacity of the globe ever calculated by a responsible scholar) in less than 200 years." [72] A European professor of medicine adds that any surge in human longevity at this time is quite undesirable from the standpoint of making elderly persons useful or cared for. "The problems posed by the explosive growth of populations * * * are so great that it is quite reassuring to know that biologists and medical men have so far been

[72] Hauser, Philip M., "Demographic Dimensions of World Politics," Science, June 3, 1960, p. 1642.

unsuccessful in increasing the *maximum* lifespan of the human species * * * and * * * it would be a calamity for the social and economic structure of a country if the mean lifespan were suddenly to increase from 65 to 85 years."[73]

Some anthropologists pessimistically wonder if man is going to prove like the locust by populating himself into near extinction from time to time.

Without subscribing to this view, one must nevertheless take notice of the difficulties posed by population increase, not merely those of food, shelter, education, and the like but also those resulting from cellular, cramped, close living.

Whichever phase of the problem is studied, it seems not unreasonable to conclude that space research will help find a solution. New ways to produce food, new materials for better shelter, new stimuli for education—all of these are coming from our space program. As for the matter of adequate living room, space research may result in ways to permit an easy and efficient scattering of the population without hurting its mobility. This might result from the development of small subsidiary types of craft, or "gocarts," originally designed for local exploration on other planets. Such craft, whether they operated by air cushion, nuclear energy, gravitational force, power cell, or whatever, conceivably would permit Earth's population to spread out without the need for expensive new roads—which, by the way, take millions of acres of land out of productive use.

A development of this sort, together with new power sources to replace the fossil fuels on which factory, home, and vehicle now depend, might also all but eliminate the growing smog and air-pollution blight.

Water shortage

A direct result of the population increase, multiplied by the many new uses for which water is being used in home appliances, etc., and plus the greatly increased demand for standard uses such as indoor plumbing, irrigation, and factory processing, is the likelihood that water shortage will be high on the list of future problems. Ways to conserve and reuse water, together with economical desalting of sea water, will be essential in the decades ahead. Space research may provide part of the answer here, too. (See New Water Sources and Uses, sec. III.)

Soil erosion

The Russian steppes of Kazakhstan are providing the world with a great contemporary dust bowl, reminiscent of the middle 1930's when dust from the Great Plains stretched from Texas to Saskatchewan. Questionable agriculture policies, drought, and strong easterly winds are among the forces blamed for the trials of southern Russia.[74] So great is the extent of this disturbance that the dust cloud has been identified in photographs taken by American weather satellites.

[73] Bacq, Prof. Z. M., "Medicine in the 1960's," New Scientist, Jan. 21, 1960, p. 130.
[74] 59 supra.

Of course, "wind erosion is only one of the processes whereby the Earth's arable land is diminishing and the deserts increasing; erosion by water can also sweep away the soil." [75] But insofar as the current dust bowl of the Soviet steppes has "diminished food resources at a time when the number of mouths to feed is increasing so rapidly, the world is the poorer." [76]

What can space research do about this vital trend, which again seems destined to accelerate in the future?

While we cannot be sure, we can conjecture that improved soil conservation might turn out to be the greatest benefit of weather understanding and modification. Agriculture policies might be adapted to the long-range patterns uncovered by weather satellites and, eventually, through better understanding of the making of weather, it may be possible to modify weather forces in a manner which will preserve the soil.

In a more remote vein, it may be that knowledge gained from a first-hand study of the Moon or other planets in the solar system will eventually contribute to the conservation of soil on Earth in ways as yet unimagined.

Added leisure

Acquiring more time for leisure sounds good. Very much more leisure than most people now have, however, is apt to present trouble in itself. Since it appears that the time is not far away when those living in the highly developed countries will no longer have to concentrate their prime energies on the traditional quest for food, clothing, and shelter, a potentially dangerous vacuum may be the result. At least the psychologists seem agreed that people must feel a useful purpose in their lives and have ways to pursue it.

> Above all, leisure makes a challenge to the human spirit. Athens, in her Golden Age, displayed a genius for the creative use of leisure which can be seen as complementary, and indeed superior, to her genius for military and commercial ventures. There have also been such periods of all-pervasive inspiration in the history of other peoples * * *. The doubling of our standard of living will present a growing challenge to the human spirit and produce graver consequences, should we fail to meet it. We neglect the proper use of leisure at our peril.[77]

In other words, the answer to the problem does not lie solely with the golf course, the yacht club, the theater, or the lengthened vacation. Much more will be required.

The intellectual stimulus of space exploration and research, which undoubtedly will divide into numerous branches like capillary streaks from a bolt of lightning, should be markedly useful in helping to fill this vacuum. Space research would seem particularly applicable in this role since it deals with fundamental knowledge and concepts which are satisfying in terms of psychological needs and sense of purpose.

[75] Ibid.
[76] Ibid.
[77] "The Challenge of Leisure," M. G. Scott, Ltd., London, August 1959, p. 20.

Intensified nationalism

Ever since World War II the era of colonialism has been on the wane. Many nations have proclaimed, won, or wrested their independence during that period. Others appear to be on the verge of doing so. At any rate, it is clear that in the decades ahead the world is going to see the rise of even more independent nations with strong nationalistic feelings.

History implies that developments of this sort are often accompanied by international unrest—because of the normal ebullience of national adolescence and the desire to be accepted by the world community, as well as a variety of concomitant political and economical upheavals.

For whatever trials may lie ahead on this score, space exploration may prove to be much needed oil on rough water.

Ambitious, advanced, sophisticated space exploration in the future is almost certain to require a high degree of international cooperation and perhaps even a pooling of resources and funds to some degree. Already America has found it expedient, in some cases mandatory, to depend on facilities in other countries for her ventures into space. A good example is the close cooperation between the United States and tracking bases located in Canada, Australia, South Africa, and elsewhere. An even better one is the important part played in U.S. efforts by England's giant radio telescope at Jodrell Bank. Most of our launches are followed by this equipment and much of the best scientific information gained from it. In the case of Pioneer V, Jodrell Bank was essential to keep in touch with the satellite at the longer distances and, moreover, was actually required to separate the fourth stage of the launch vehicle and direct the payload toward its Venus orbit.

Mutual need and cooperation thus fostered by space exploration can be expected to siphon off some of the political tensions of the future, especially as more and more nations become interested in space and inaugurate complex programs of their own.

LIMITATIONS ON SPACE RESEARCH

There are some who are convinced that the exploration of space is rigidly limited and that the landing of men on extraterrestrial bodies other than the Moon is quite improbable. They are sure that extensive travel outside the solar system is impossible.

Admittedly, the problems of such travel are enormous. But are they incapable of solution?

> Twenty-six million miles to Venus, 49 million miles to Mars, 3,680 million miles from the Sun to Pluto at the outer edge of the solar system. The nearest of the stars is 25 million, million miles away, and travel to it at 10 miles per second would require 80,000 years. Is the travel of man to the stars a futile dream? Each generation of man builds on the shoulders of the past. The exploration of space has begun; who now can set limits to its future accomplishments? [78]

[78] 27 supra.

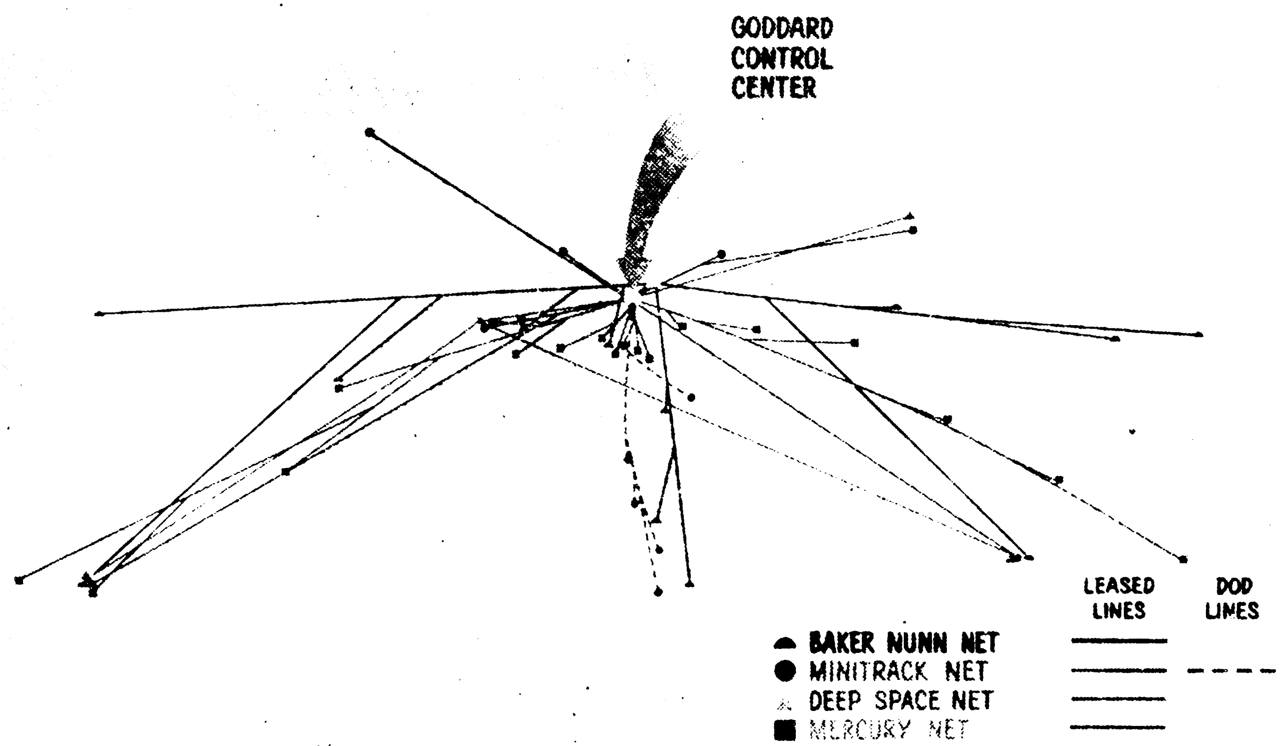

FIGURE 15.—Need for international cooperation in the U.S. space program is illustrated by this map showing the areas from which help must be procured for projects already planned or underway.

That is the thought of one of the Nation's most expert space scientists.

*"Who now can set limits * * *?"*

It seems to mesh curiously well with one of the most interesting phenomena of our day—the emergence of a breed of engineers, technicians, teachers, and scientists who do not recognize limits and who refuse to concede that something cannot be so because it fails to fit conventional patterns or conform to the physical laws of the universe as we now know them. Of this there is growing evidence.

For many years it has been an accepted "fact," for instance, that the Moon is a dead world with no life upon it. The suggestion made by the great 16th century mathematician, Johannes Kepler, that some life might exist on the Moon was debunked into silence long since. Yet today a fellow of the British Royal Astronomical Society writes that the first men to arrive on the Moon may find not only plant life but possibly animal life. "The fact that terrestrial organisms may be unable to survive in the surroundings of another planet is by itself no more significant than that fishes and other marine animals die when exposed to the air. From their point of view air is uninhabitable because they have failed to equip themselves with lungs." [79] And he adds that his surmise "leaves out of account the possibilities of the Moon's underground world, which are incalculable, for there water, the vital gases, congenial temperatures, and increased pressures will all be present. Only sunlight is absent."

Then there is Project Ozma, the search for life on other planets or in other star systems, which began in April 1960 at Green Bank, W. Va. It is being undertaken by the National Radio-Astronomy Observatory and consists of carefully directed listening by radio-telescope for signs of intelligent broadcasts originating outside Earth.

At Stanford University another astronomer is concentrating the efforts of part of his laboratory on behalf of a similar idea. The chances are, he believes, "that the superior races of other planets in other galaxies have already developed a communications network among themselves, and have entered a joint program to scan all the other solar systems looking for signs of awakening civilization among the backward planets. Each of the advanced communities might pick as its probe assignment a single other solar system—and one such probe may well be circling our Sun right now on a routine check for life." [80] Unexplained delayed echoes of earthly radio transmissions received in the past, it is thought, could be evidence of such a scheme.

Are goings-on such as these nonsense?

Here is the answer given by one hard-headed science writer:

> Centuries may pass before there is any sign of intelligence outside the Earth. But the advantages of communication with another civilization that has survived our present dilemmas are far too great to permit the experiment to be abandoned.[81]

[79] Firsoff, Dr. V. A., "The Strange World of the Moon," Basic Books, London, 1959.
[80] Reported by David Perlman, San Francisco Chronicle, June 7, 1960.
[81] Lear, John, "Is Anybody There?," New Scientist, Apr. 14, 1960, p. 933.

The results of recent and more orthodox experiments have already done much to shake the complacency of scientists in regard to their concepts of space. Investigations have disclosed that, far from being a complete vacuum, space is relatively full of matter and energy. Hydrogen gas, radiation belts, cosmic particles, solar disturbances of unknown nature, micrometeorites—and, from Pioneer V, proof of a 5-million ampere electromagnetic ring centered about 40,000 miles away.[82] The director of the Smithsonian Astrophysical Laboratory in Cambridge, Mass.,[83] has said that more and more startling astrophysical information was gathered during the first few weeks of the space age than had been accumulated in the preceding century.

In brief, it is becoming the vogue in science to refuse to say "impossible" to anything. On the contrary, the watchword for tomorrow is shaping up as "take *nothing* for granted."

FUNDAMENTAL KNOWLEDGE ABOUT LIFE

Everything learned from space exploration thus far indicates that the knowledge lying in wait for those who manage to observe the universe from outside Earth's atmosphere will be far grander than anything uncovered to date.

We may finally learn the origin of our universe and the method of its functioning. A good part of this knowledge may be no farther away than the next 3 to 5 years. Satellite telescopes now under construction are expected to elicit far more information than even the 200-inch giant at Mount Palomar. One such observatory satellite, to be launched in 1963 or before, "will permit a telescope of about 10 feet in length to point at heavenly bodies within a tenth of a second of arc for periods up to an hour. Present plans call for an orbit between 400 and 500 miles, as a lifetime of at least 6 months is required to observe the entire celestial field." [84]

Perhaps, and sooner than we think, we shall find a clue to the destiny of all intelligent life.

Perhaps the theory advanced by a noted eastern astronomer will turn out to be true—that biological evolution on the habitable planets of the universe may be the result of contamination left by space travelers arriving from (and leaving for) other worlds. In other words, the fruition of life on the various planets of the millions of solar systems might be the product of a wandering group of astronautic Johnny Appleseeds who leave the grains of life behind them. "Space travel between galaxies has to be possible for this, but of course this needs to be only quite a rare event. In a time of about 3.3 billion years, the most advanced form of life occurring in a galaxy must be able to reach a neighboring one." [85]

The notion seems fantastic.

[82] Aviation Week, May 9, 1960, p. 32.
[83] Whipple, Dr. Fred L.
[84] Western Aviation, June 1960, p. 16.
[85] Gold, Dr. Thomas, "Cosmic Garbage," address to the Space Scientists Symposium, Los Angeles, December 1959.

But when we look clear to the end of Earth's road (and assuming the astrophysicists are right in their theories about the evolution and ultimate death of our solar system) we know that Earth will one day become uninhabitable. Life on Earth must then perish or move elsewhere. If we further assume that mankind will not want to die with his planet and if we acknowledge that other worlds may have been through this entire cycle in eons past—perhaps the notion is not so unreasonable after all.

Whatever the truth is on this score, space exploration will certainly be of "practical" value to our descendants when that dim, far-off day arrives.

PSYCHOLOGICAL AND SPIRITUAL VALUES

Long before the arrival of that millenium, however, the knowledge and understanding awaiting us through the medium of space exploration is certain to have profound effects on the human race psychologically and spiritually.

It already has had effects on humans of all ages.

Adults, who are paying the taxes to support the space exploration program and reaping its practical values, are also thinking of themselves, their country, and their world in broader, more knowledgeable terms.

In a sense, children may be even more deeply involved.

> There is a special group which may play a useful role in spreading the new values growing from the exploration of space, and this is the children who play at spaceman today. Whether or not they take this interest with them beyond childhood remains to be seen. However, the unique fact in the present situation is that never before have children rehearsed a role that really will not exist until they are adults. To be sure all of them will not fulfill this childhood role, but the fact that the reality lies ahead rather than in the past (as with cowboys and Indians) may stimulate them to retain a sensitivity for the various meanings man in space can have for our future.[86]

Put it another way—if it is true, as a modern Chinese philosopher has said, that the search for knowledge is a form of play, "then the spaceship, when it comes, will be the ultimate toy that may lead mankind from its cloistered nursery out into the playground of the stars." [87]

---

[86] 68 supra, pp. 12, 13.
[87] 6 supra, pp. 3, 4.

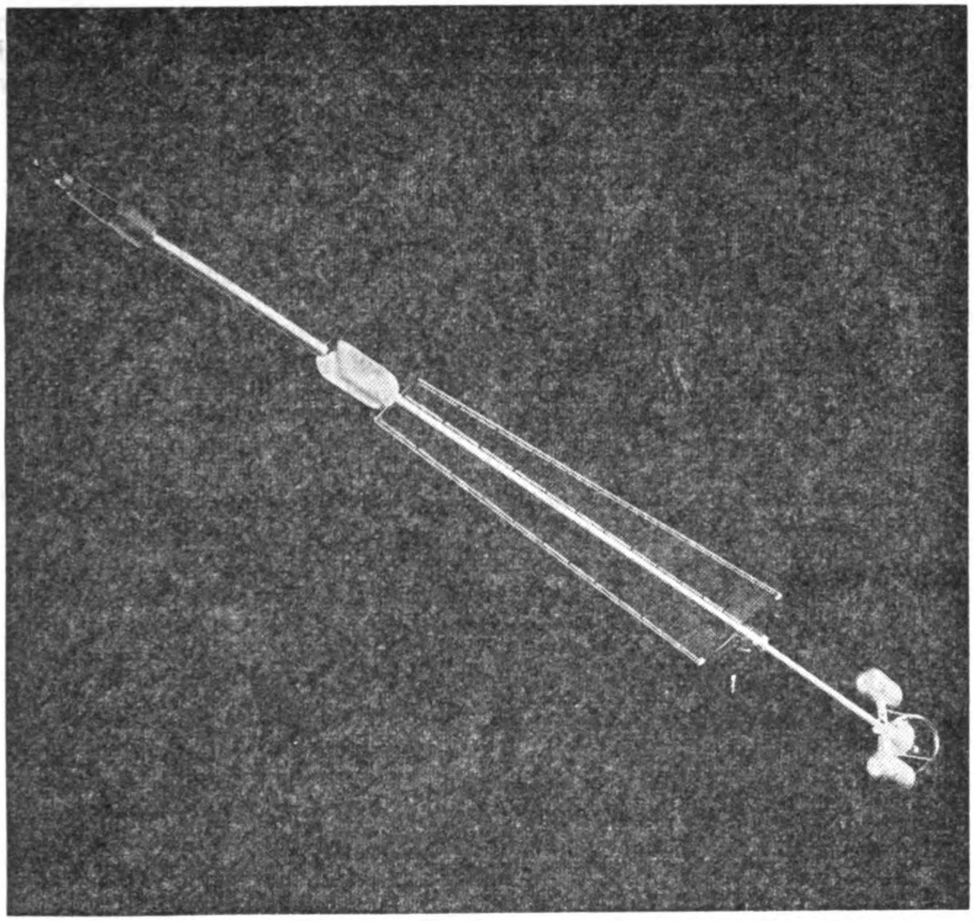

FIGURE 16.—Space vehicles of the future may look like this artist's drawing of an electrical propulsion craft. The nuclear reactor is located at the extreme left, followed by a neutron shield, heat exchanger, gamma-ray shield and propellant. The center tank houses turbogenerating equipment. Excessive heat is dissipated in the large radiator. At the extreme right are two crew cabins, landing vehicle and a ring-shaped accelerator.

MATURING OF THE RACE

The psychological and spiritual changes necessitated by this evolution may be at a cost far beyond dollars—because many of us will be hard put to negotiate them, especially if they come too rapidly.

Nevertheless, negotiating them must also be placed in the category of "practical" values—for in the long run it seems to be an essential part of the maturing of mankind.

> The years ahead will face us with many sputniks and thereby will require of our citizens stern, costly, and imaginative participation in programs to meet and surmount the many complex challenges with which our growing technology confronts us. To succeed in space and to succeed on Earth, we must somehow learn to make the larger world of ideas, so brilliantly exemplified by the satellites, the immediate environment of the individual. There is a race we must run—the race for an enlightened and involved public.[88]

[88] Michael, D. N., "Sputniks & Public Opinion," Air Force, June 1960, p. 75.

So if we can accept the wrenches which space exploration is apt to apply to our time, pocketbook, energy, and thinking, the values and rewards as outlined in this report should gather headway and grow continuously greater.

> Space technology is probably the fastest moving, typically free-enterprise and democratic industry yet created. It puts a premium not on salesmanship, but on what it needs most—intellectual production, the research payoff. Unlike any other existing industry, space funccions on hope and future possibilities, conquest of real estate unseen, of near vacuum unexplored. At once it obliterates the economic reason for war, the threat of overpopulation, or cultural stagnation; it offers to replace guesswork with the scientific method for archeological, philosophical, and religious themes.[89]

Such conclusions seem a bit rosy. But sober study indicates that they may not be too "far out" after all.

[89] Industrial Research, December 1959, pp. 8, 9.

O