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MILITARY TECHNOLOGY AND NATIONAL SECURITY

Part I: Focus on Technology

THE TECHNOLOGICAL CONFLICT 6
Col. Raymond S. Sleeper, USAF

THE ROLE OF MANAGEMENT IN TECHNOLOGICAL CONFLICT 19
Gen. Bernard A. Schriever, USAF

Part II: From Concept to Inventory

RESEARCH AND DEVELOPMENT PLANNING 32
Col. Florian A. Holm, USAF

BASIC RESEARCH IN THE AIR FORCE 47
Brig. Gen. Benjamin G. Holzman, USAF

FROM CONCEPT TO APPLICATION 67
Col. Lee R. Standifer, USAF

REQUIREMENT TO PROTOTYPE 85
Col. Edward A. Hawkens, USAF

RESEARCH AND TECHNOLOGY MANAGEMENT 102
Maj. Gen. Marvin C. Demler, USAF

WEAPON TESTING 106
Col. Charles G. Allen, USAF

Part III: Forging Military Space Power

BALLISTIC SYSTEMS 126
Maj. Gen. W. A. Davis, USAF

AERONAUTICAL SYSTEMS 145
Maj. Gen. Robert G. Ruegg, USAF

Electronic Systems 160
Maj. Gen. Charles H. Terhune, Jr., USAF

Space Systems 177
Maj. Gen. Osmond J. Ritland, USAF

The NASA Program 189
Col. Francis X. Kane, USAF

Aerospace Medicine and Bioastronautics 205
Lt. Col. George Zinnemann, USAF, MSC

Part IV: Resources

Facilities 222
Lt. Col. Clyde L. Wade, USAF

People 241
Col. Marcel Lind, USAF
Maj. Clifford W. Muchow, USAF

Part V: The Future

Tomorrow's Role in Aerospace 258
Maj. Gen. William B. Keese, USAF

The Contributors 266

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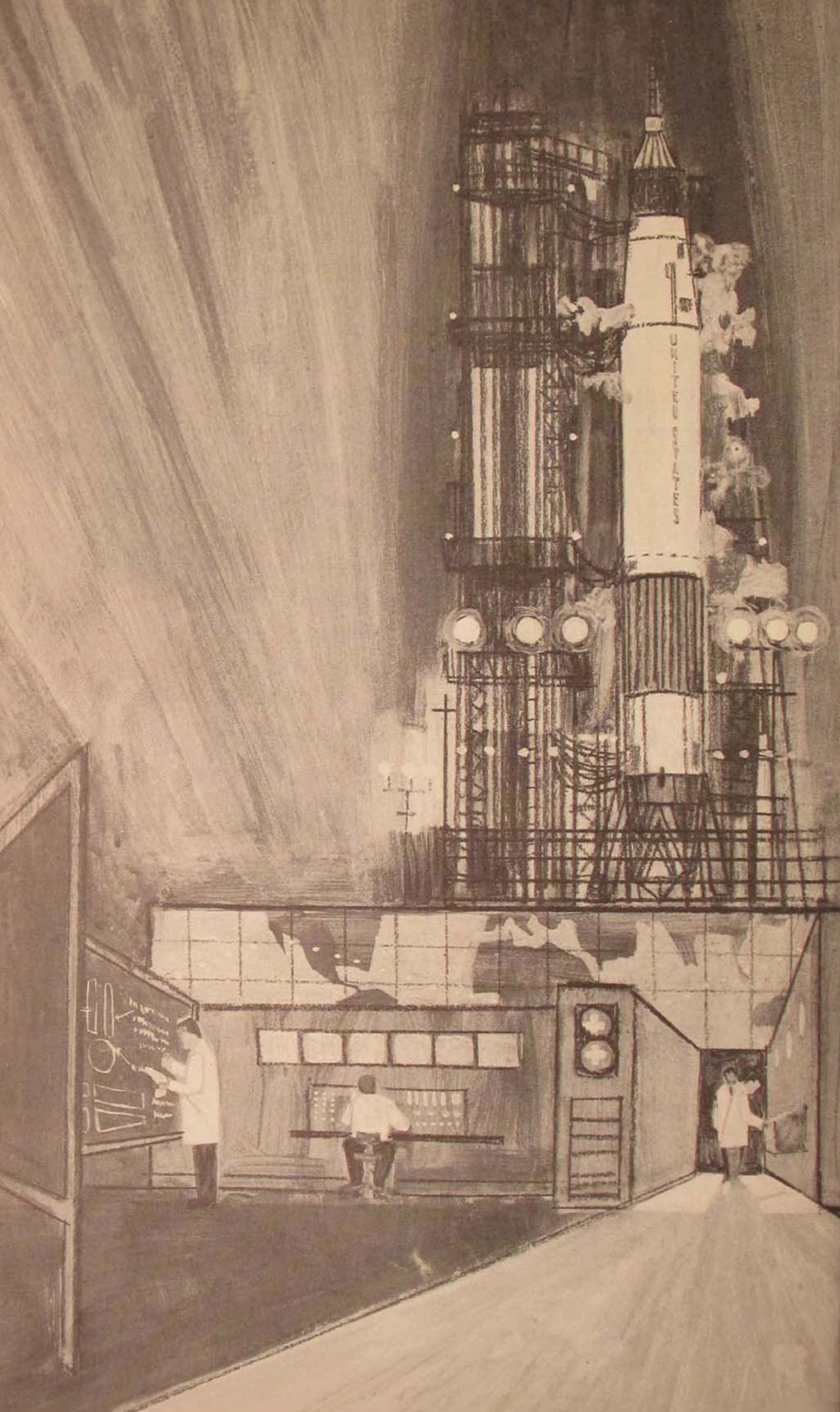

UNITED STATES

part I

FOCUS ON TECHNOLOGY

Traditionally the instruments of strategy have been either political, economic, psychological, or military—and often a combination of two or more of these—but since the advent of the atomic era, technology has also played an increasingly significant role as a strategic tool. For a time we felt secure in the inviolability of our superior technology, but by the mid-Fifties the emergence of the Soviet technological challenge had become manifest. The Sixties have seen our re-emergence at the pinnacle of technological achievement, our military technology testifying to the security of the Nation and to the ingenuity, skill, and devotion of those on whom the accomplishment depends. Such an achievement can result only from an alchemical blending of strong ingredients. As the formula grows more complex, the function of management becomes ever greater in compounding the elixir for technological supremacy.

THE TECHNOLOGICAL CONFLICT

Colonel Raymond S. Sleeper

HISTORICALLY accepted theory of conflict awards prime importance to four instruments of national strategy which may be used by the United States to achieve its national objectives in relation to the Soviet Union. These four instruments of national power have been considered to be the political, the economic, the psychological, and the military.

During the cold war it has been accepted that the military tends to be the "enabling" instrument of power. This means that so long as the United States retained preponderant military power this power deterred Soviet commitment of direct military aggression in spite of the fact that the Communist hierarchy was fully dedicated to world domination by all possible means. It also means that while the U.S. military preponderance deterred Soviet military aggression this power *enabled* the United States to employ economic, political, and psychological instruments of strategy to achieve the expressed U.S. objective of containing Communist expansion. We shall see that, in spite of our enjoying deterrent military power over the past ten years, the Communists have made significant progress in undermining the power of the Free World by means of political and psychological internal offensives against free men and their governments in free nations.

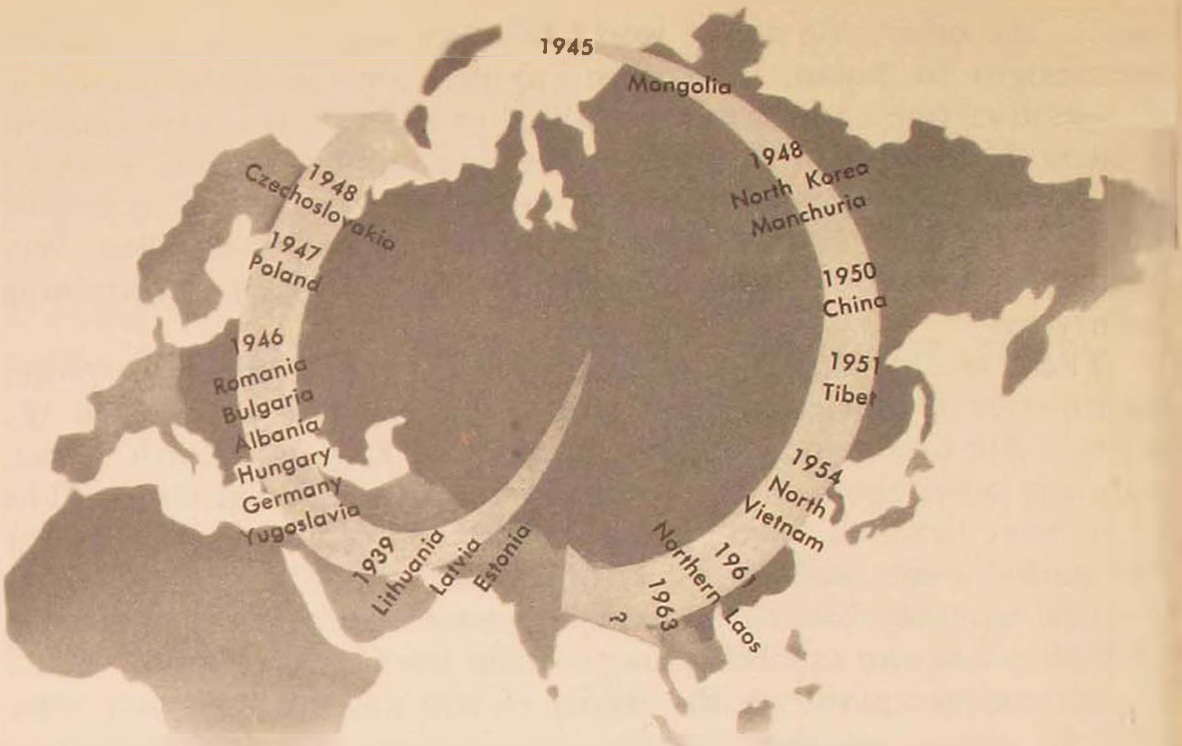
Tibet and Cuba were the most recent victims of Communist aggression, in 1958 and in 1960. During the Forties it was believed by many that the Soviets possessed the potential military power following World War II to invade Western Europe, but our atomic forces apparently did succeed in deterring this Soviet aggression that many feared. At the same time our economic and military aid to Europe, the formation and increasing effectiveness of the North Atlantic Treaty Organization, and the blooming economy of Western Europe have succeeded in restoring West European strength and preventing Communist take-over. This is important. The great strategic value of Western Europe has been reserved to the free nations. Our strong military deterrent posture has *enabled* our economic, political, and psychological instruments of power to keep West Europe free and to re-establish her power.

On the other side of the world we have also succeeded in build-ig strength in Japan, in the Philippines, and to some degree in ertain other free nations that are allied to the U.S. It is very difficult assess the combined strength of the Communist nations. Without r one moment degrading the great value of positive U.S. economic nd military aid throughout free nations, it is nevertheless very bering to view the progress the Soviets are making in undermining ee nations.

There was very little question in 1955 that U.S. deterrent power as superior to Soviet military power. In the days of 1955–56 the rategic Air Command deployed to bases in England, North Africa, nd many other spots on the circumference of the Soviet Union. The oviets were deterred from aggression by U.S. military power. In the 955 period some military analysts believed the U.S., together with s allies, not only had the military power to deter Soviet aggression ut clearly had the capability to persuade the Communists to behave a manner acceptable to the family of free nations. This was essen-ally the root conviction that led to John Foster Dulles' policies of rinkmanship," when he was saying that we would respond in a anner and with weapons of our choice in order to discourage Com-unist aggression into Indo-China.

In the Lebanon crisis and again in the Taiwan Strait crisis of 958 the deployment of significant U.S. military power persuaded the ommunists not to embark upon aggression in those areas. In 1960 nd 1961, however, the Communist internal offensives in the Congo nd in Cuba were not dissuaded by the presence of U.S. and United ations military power. Similarly, the presence of the Seventh Fleet f the coast of Vietnam has not dissuaded the Communist internal fensive against the free governments of Laos and South Vietnam. uba, Laos, and South Vietnam are the obvious examples of Com-unist internal offensives which are now being waged against free ations. It is important to recognize that these separate conflicts in sia and in the Americas are the fruition of careful Communist ans for internal aggression which are taking place in all free coun-ies and which simply happen to be most evident in these countries present. Moreover these internal Communist offensives are not eing deterred by U.S. military power.

The Communist strategy for internal offensive action is not in-llible. It can be defeated in the present and future as it has been efeated in the past. What is essential, however, is a full recognition the strategy and the necessity for positive, continuing preventive tion. Such offensives have been turned back in Greece, in the hilippines, and progress has been made toward turning back an ensive in South Vietnam. In addition the United Kingdom has en very successful in combating the Communist internal offensive Malaya. The counter methods are similar in each case. They are own. It is only important here to recognize that the Communist



Communist Progress in Eurasia

internal offensives against free nations can be defeated. But it is necessary for the U.S. to enjoy freedom of action in these areas if we intend to prevent Communist take-overs. We will enjoy less and less freedom of action in these areas if Communist forces grow stronger than ours and deny us freedom of action.

Laos is a good example. In violation of the Geneva Conference, in December 1960 Soviet aircraft lifted supplies directly into Laos in support of the Pathet Lao. The Communists committed open air aggression against the free government of Laos. We can expect the Communists to employ their forces with greater daring if their overall military capability gains parity with ours.

Communist Political-Psychological Offensive

Subversion—The Internal Offensive

Phase

I — establish base of power in target country
II — expand base and infiltrate
III — take over key power positions
IV — seize power (the critical stage)
V — consolidate (eliminate all opposition)

Now if the Soviets should make a major breakthrough in developing new weapons, they could conceivably gain military superiority, at least in some military sphere. If we have now succeeded in closing the "missile gap," the most serious threat in the near future would appear to be the early development by the Soviets of the military capability to dominate near space. This capability could consist of antisatellite missiles, maneuverable satellites with offensive capabilities, satellite interceptors, or other similar developments. If the Soviets should achieve control of near space, the results could be most grave. They would be able to pre-empt our atomic striking capability to a large degree. They could exercise control over much that transpires on the surface of the earth and in the atmosphere. They would probably attempt to keep us within the atmosphere. In short, they would attempt to realize all the benefits that the surrounder has over those who are surrounded. The Soviets have given us repeated warnings that they intend to dominate space for important military and political reasons. It is wishful thinking to hope that they will not use their significant lead in space to facilitate their political and military goal of dominating the world. It is obvious that this situation must be prevented. It can be prevented by technology.

The Technological Instrument of Strategy

We have discussed the traditionally accepted four instruments of national strategy that have been used in realizing national objectives, but brief reflection upon the ongoing technological explosion and its impact upon the conflict between the United States and the Soviet Union leads to the conclusion that a fifth instrument of national strategy has joined the team. Not only has it joined the team but it has taken on a priority and stature that overshadow some of the other instruments. The reasons for this include the tremendous potential and the complexity of the technological explosion together with the particular military conditions that currently exist between the U.S. and the U.S.S.R.

Military power has traditionally been the "enabling" instrument of national power. The nation which had preponderance of military power could more effectively employ its political, economic, and psychological instruments. As one studies the relative military power of the United States and the Soviet Union over the last ten years, it is clear that the Soviets, by rapidly developing atomic power, jet bombers, jet fighters, intercontinental missiles, and earth satellites, have reduced the advantages originally held by the United States. Some go so far as stating that the Soviets have achieved what is variously called a "nuclear stalemate," a "balance of terror," or "military parity." We can state without much risk of contradiction that history shows that "stalemates" or periods of "balanced" international power relations are transitory. Therefore it could be that we are in a transitory period during which the relative military power of the United States and the Soviet Union will change. The greatest opportunities for significant changes in military power derive from the technological instrument of power. It appears that the technological instrument of power will be the instrument which may enable one of these nations to gain a major power advantage over the other. There are several very interesting facets of this situation which should be noted.

First, we should note that in the last twenty years the process of transition of a weapon system from research and development to initial operational capability has been greatly altered. The first B-17's delivered to the 19th and 7th Bombardment Groups in 1940 had already been undergoing testing and had been under R&D for several years. Nevertheless it was another 12 to 18 months before the aircraft were shaken down by the operational units and were ready for combat. Today, if a nation should test a military satellite and prove it successful, that nation would have the task immediately thrust upon it of incorporating the satellite into the operational forces. In short, the moment a military space vehicle is successful, it is, to a degree, operational. The long "shakedown" period experienced in 1940 is probably not quite as applicable today.

Second, Soviet propaganda blasts against "balloon flights" and U-2 flights and their attacks against our aircraft paralleling their borders have demonstrated their extreme sensitivity to reconnaissance. Dr. Zhukov, a Soviet military analyst, stated in the October 1960 issue of *International Life* that the Soviets had then the capability to destroy U.S. satellites. Soviet destruction of any U.S. satellite in the next 12 to 24 months would confront the United States with grave political and military operational problems and decisions. Thus, should Soviet interceptors be able to destroy U.S. satellites as early as 1963, they could possibly further develop their military capability to dominate near space. They have not, to our knowledge, attempted to intercept any of our weather satellites yet. This does not mean that they are not most sensitive to these satellites. It may mean that they are not yet able to intercept them or that they will not commit an interception force until they have the capability of launching a clearly decisive force with the potential of restricting our use of near space.

During such a period our R&D vehicles launched might find it necessary to fight for access to space. The expression often heard throughout the Air Force Systems Command, that AFSC troops are combat forces in the front lines of the cold war, thus begins to make a lot of sense. If one recalls that during the period when we were rushing to achieve an ICBM capability there was a span of several months when the only operational ICBM facilities available to the U.S. were those in AFSC, then it should not surprise us in the future if there is a period of time when the only operational U.S. space combat capabilities are those in AFSC.

We should note also the major jumps in aerospace capabilities that take place in moving from the atmosphere to space. In the 1955 period, when the philosophy of air control, having been quite fully developed at Air University, was being considered by the Air Staff as a contribution to national strategy designed to deter enemy aggression, the most difficult aspects to accept were the requirements for large numbers of aircraft in order for the U.S. to patrol and gain control of the air over potential enemy areas and thereby significantly control the behavior of such an enemy. The major jumps in altitude, speed, and range produced by leaving the atmosphere give spacecraft the capabilities required to effectively control space (at least in given areas) in such a manner that present nuclear strike forces may be pre-empted. This might be done in a number of ways.

(1) Conceivably the U.S.S.R. might develop such an effective aerospace defensive capability as to deny the U.S. the ability of confidently launching an effective nuclear attack. Such a development is not very probable, but it must be considered. The relative missile strengths of the United States and the Soviet Union are, of course, important in this context. Missiles do not, however, have the capability to patrol, to be recalled, or to establish the presence of military power in aerospace over a hostile nation, which manned spacecraft do have. Moreover, while there appear to be new missile developments in the offing, these developments do not seem to promise major breakthroughs in the over-all growth of strategic capabilities.

(2) Another and probably more likely method of controlling space would be to combine elements of both defensive and offensive systems into the most effective military space force possible. This might then permit the Soviet Union to restrict our use of space in such a manner as to make a nuclear strike launched by missiles and aircraft impractical and possibly very difficult. The implications of such a development are quite interesting. Assume, for example, that one nation over a period of time builds in great secrecy and then suddenly launches an overwhelming force of spacecraft that have significant offensive bombing and interception capability. Assume that elements of this space-alert force are overflying the second nation at all times —in fact, they are patrolling its skies. Under these postulated conditions the second country's strategic retaliatory power is to a significant degree pre-empted. The initiation of nuclear war in response to such a patrol force would seem unlikely. Yet the political-psychological impact of such a spaceborne force on the leadership and populace of the second nation would probably cause fundamental accommodation of its national objectives to those of the first nation.

Is this what Gromyko had in mind by his remark on 23 December 1960? "The time has come when it is possible to cut short the attempts by the aggressors to start world war. More, conditions are being created in which war can be eliminated for good from the life of human society." Whatever the answer to this question may be, no elaboration of the gravity of the potential threat of the Soviets' developing a capability to restrict our freedom in space is needed. It is clear that the Soviets must not be permitted to win a military technological superiority in space. The conflict must be won by the United States, not for cold-war advantages, not for national prestige purposes, but for vital national survival. In winning this race our goal is not to dominate any nation or to dominate space. Our goal should probably be to attain the capability to prevent any hostile force from dominating space. To put it in positive terms, our goal should be to ensure the peaceful use of space.

A Technological Strategy Needed

If the U.S. and the U.S.S.R. are waging technological conflict—and the evidence is clear that they are—then the U.S. needs a national technological strategy to win this conflict. This strategic plan must be responsive to the growing Soviet technological threat. Such a strategy does not seem to exist in any coherent form. Moreover the technological strategy needed must fit into or pattern, as the case may be, our military, economic, political, and psychological strategy.

The establishment of such a national objective in space and explanation of the importance of this objective constitute a most urgent undertaking.

A very important input to designing a winning technological strategy involves a clear understanding of U.S. aerospace research and development capabilities and marshaling these capabilities to achieve the objectives of the strategy. To do this adequately, the U.S. needs a technological plan for winning the technological war. This is probably largely the task of AFSC because the resources to perform this task are, for the most part, in AFSC. Of course the AFSC plan for winning the aerospace technological conflict would require endorsement and support from higher-level echelons in the Government.

Another very critical input to designing this strategy is detailed analysis of the Soviet technological strategy. By discovering the Soviet technological strategy, we are enabled better to marshal our own and Allied technological capabilities to permit us to outmaneuver Soviet technological actions.

In recognition of the need for increased emphasis in this area, the Commander, AFSC, in January 1961 directed the establishment of a command-wide foreign technology program. At the same time he requested the organization of a Foreign Technology Division and its assignment to AFSC. In February he directed the establishment of a Deputy for Foreign Technology in each division and center to be organized at the operating level of each command. The AFSC foreign technology program is now under way, but it needs and is receiving vigorous support in the Systems Command, in the Air Staff, and in

DOD. As the AFSC foreign technology program builds up, action is especially needed to initiate and implement AFSC foreign technology evaluation and operational planning cycles to produce and keep updated a USAF Technological War Plan to ensure success in the aerospace race against the U.S.S.R.

The winning of the technological conflict may require rapid operational commitment of essentially R&D vehicles. AFSC must therefore stay constantly alert for new Soviet technological developments in space the purpose of which might be to restrict our access to space. AFSC must be constantly prepared to recommend new weapon systems that can be rapidly developed to successfully contest such an eventuality. It would therefore appear that an important feature of the USAF plan should be to gain and maintain aerospace supremacy. In this connection it should be noted that the U.S. has fought and won three major conflicts in which we have achieved control of the air over enemy territory, and we know quite well the principles and requirements for winning such conflicts. The application of these principles to winning the conflict for control of aerospace is not a simple task, but the U.S. has resources of knowledgeable people to tackle this task. Many of these resources reside in the USAF, so in tackling this task the Air Force should assume a major role. USAF space research, development, and weapons acquisition programs, together with foreign technology programs to ensure their effectiveness, will be central resources in winning the conflict.

The Technological Battle Areas

As in any broad conflict, it is helpful and instructive to analyze the specific areas of conflict. In the technological war we can distinguish several specific areas. The areas are, of course, closely interrelated and interdependent. In addition each supports, in its own right, the over-all technological strategy that is being pursued to win the technological war.

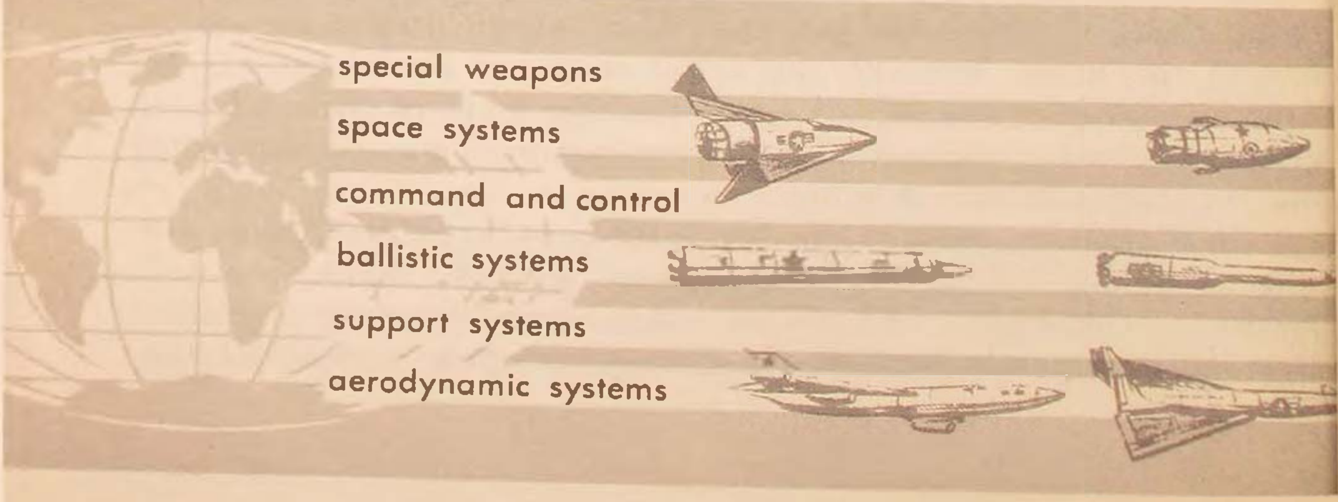
(a) Fundamental to all areas of the conflict is the national base of education and spirit of the people. We Americans have prided ourselves for years on our broad technological know-how. It is one of the cornerstones of our way of life. Teen-age hot-rod mechanics, flying clubs, rocket clubs, and the "do-it-yourself" trend are just a few of the many facets of the broad technical proficiency of the American people. But we all know that the bulk of this technical genius is geared to the profitable chores of maintaining and improving our very high standard of living.

In Russia, the technical genius of the people is channeled by the state into the military engineering and scientific fields that will produce technological and military superiority. Communist leadership has consistently pursued the educational goals to produce this superiority. Lenin stated that education must be a weapon for moving society forward on the road to Communism, and Stalin said that "to build socialism . . . we must master science . . . to master science we must learn from our friends and particularly from our enemies . . ." Khrushchev has embraced and extended these goals to meet the modern demands of Soviet society. Technological and military superiority are twin goals of Soviet leadership. Khrushchev repeated them in his famous speech of 6 January 1961 when he stated that no stone must be left unturned which will lead to military superiority over the West. These goals are more important to the Communist leadership than a higher standard of living for the population. We have known this a long time, of course, but the point here is that Soviet leadership has created a national educational base and population spirit aimed at achieving world domination.

The Soviets are devoting over 5 per cent of the gross national product to education while we are spending about 3.6 per cent in the United States. Over all, the Soviets are producing two to three times as many scientific and technical professional graduates yearly as the United States. Moreover predictions are that Soviet production of science and engineering professionals will significantly increase by 1970, reflecting the Soviet commitment to military-technological superiority.

It is therefore gratifying to see President Kennedy pushing his legislative program to improve U.S. education. The President's program should help, but the American people at large must become aware of the tremendous technological challenge and realize that our response to this challenge is rooted in our national educational base and in our very society. We must invent democratic responses to the Communist threat of educational technological superiority that will stimulate, motivate, produce, and mobilize the professional manpower of the United States. It may be prudent to consider extending

The battle areas in the technological war are those technologies resulting in superior systems, firmly grounded in and dependent on the education and capabilities of the people as well as on basic and applied research programs and facilities.



our various political and military alliances into the fields of education and technology in order to ensure the security of the West.

(b) The next important area of technological conflict lies in basic and applied research. Both these phases of research are rooted deep in the national education and the spirit of the people, but they are, of course, the foundation of all military technology. This area of conflict between the Soviets and the United States needs a tremendous amount of research and evaluation. We Americans do not hold a good record for applying new principles derived from basic research, expanding them through applied research, and adapting them for military weapon systems. One only needs to note that, in spite of the Wright brothers, no American-designed combat aircraft did battle in World War I. Similarly Goddard's excellent work in liquid rocket technology was first picked up by the Germans and exploited by them during World War II. It was only after we saw the utility of the V-1 and V-2 bombs that we really became interested in rockets.

We do enjoy excellent basic and applied research facilities throughout the country, some of them superb. They exist in universities, in nonprofit corporations, in institutes, in industry, and in the military services themselves. There is a lot of evidence, however, that basic and applied research need far more national and popular support in the U.S. than they are now receiving.

We have always recognized that basic and applied research in Russia have been fundamentally good. As a result of Soviet programs initiated as early as 1920, a tremendous amount of new basic and applied research data began to appear in the early and mid 1950's. These data appeared in the form of new Ph.D.-type theses, new technical journals, and other new publications. What was happening, it appears, was that the Soviet educational plans and their programs to expand basic and applied research initiated as early as 1920 were now beginning to produce. The war years had depressed the expansion and production of basic and applied research in the Soviet Union. After the war years, new institutes began to appear, new research facilities were built, and the result was that much new technical data began to appear.

Not only have the Soviets expanded their own basic and applied research facilities but they have greatly expanded their capabilities to adopt and adapt basic and applied research from Western nations. As many as 25,000 translators are reportedly available to work on Western technological information, and we see evidence of this in the periodic publication of large compendiums on the state of the art in particular technologies. A good example is "Silicides and Their Uses" by G. V. Samsonov, a document that rather well summarizes knowledge of silicides in Russia, Great Britain, France, and the U.S. through 1959.

The Soviets are therefore not only rapidly expanding their own basic and applied research capability but also systematically capturing basic and applied research information from the entire world. In contrast, there is concern in several circles in the United States that we are not investing sufficient national resources in basic and applied research.

(c) One of the most critical battle areas in the technological war is aeronautical systems technology. On 9 July 1961 the Soviets paraded tremendous numbers of aeronautical systems at the Tushino Air Show. Here Western eyes saw many new Soviet aerodynamic systems fly publicly for the first time. Some of the new systems seen were expected. Others were not. The Bounder airplane was seen to fly in this air show for the first time. There is not general agreement on what the Bounder is. It could be a supersonic transport prototype. It could be a supersonic bomber prototype. It is probably a test bed.

The present U.S. inventory of aerodynamic vehicles is superior to that of the Soviets. The B-52, the B-58, some of the 100-series aircraft, and some of the newer aircraft, together with the air-to-air and air-to-surface missiles affiliated with these aircraft, leave little doubt that the U.S. is significantly ahead of the Soviets in aerodynamic system technology. But where are the Soviets going in aerodynamic systems in the future? Are they developing new aerodynamic systems that would be significantly superior to those that we now have in our inventory or on the drawing boards?

(d) The Soviets stole an early lead on the U.S. in the development of missiles by vigorously exploiting German technology. There has been a lot of heat generated over whether or not the Soviets are ahead of the U.S. in ICBM's. All in all, with the tremendous success of the Minuteman missile and the success of the Polaris system we probably are justified in believing our missile technology is superior to that of the Soviets. In the fall of 1961, however, when the Soviets started nuclear testing, they also initiated a new series of ICBM tests, firing them into the southwest Pacific Ocean. At that time Marshal Malinovsky announced that the Soviets were testing "invulnerable missiles." On 17 March 1962 Khrushchev boasted that the Soviets then had huge new invulnerable missiles that could travel over 20,000 miles to the target. Such missiles could probably carry new large warheads.

(e) The Soviets electrified the world when they launched Sputnik I in 1957. A little over 4½ years later the Soviets were orbiting manned spacecraft and satellites over the U.S. at altitudes barely above 100 miles. Khrushchev has boasted that these spacecraft could carry 50- and 100-megaton warheads. He has boasted that these warheads could be deorbited to any spot on the earth.

We have made significant progress in our own space programs, but we must be frank and recognize that the Soviets have clearly demonstrated a superior booster capability, they have acquired a superior knowledge of bioastronautics, and they enjoy a superior spacecraft payload capability. It is pure wishful thinking to believe for a moment that the Soviets will not militantly exploit this lead in space technology to achieve their objectives in dominating the world.

(f) We believe that the U.S. is probably ahead in command and control systems. Our electronic industry and our radio, TV, and telephone facilities in the West are truly sources of tremendous strength and flexibility. Nevertheless close study of the Soviet communication system, such as that done by Dr. Alex Inkeles at the Harvard Russian Research Center, leads us to suspect that the Soviets have achieved command and control systems fully adequate for their purposes. Studies made of the Soviet capabilities to jam the Voice of America radio transmissions also show the tremendous resilience, flexibility, and broad capability of the Soviet communications structure.

(g) Soviet progress in the development of nuclear weapons has been phenomenal. In the first 10 years, from 1949 to 1959, the Soviets demonstrated complete competency in the development of nuclear weapons. We did see some unsophisticated aspects in their weaponry, but we recognized they could probably be corrected.

During the sham moratorium period many people felt that the Soviets were conducting tests underground or in space. (See some of Dr. Edward Teller's articles on this matter.) At any rate it is clear today that the Soviets were vigorously preparing for new tests during the period when we obligingly stood down our nuclear technological development forces.

The tests that the Soviets initiated in the fall of 1961 constituted a tremendous technological surprise to the West. Some people have said that as a result the Soviets are two to four years ahead of us in the development of nuclear weapons. Others are not quite so pessimistic. It is clear, however, that the Soviets made great strides forward in this critical technological battle area and that we must continue to press ahead if we intend to maintain nuclear weapons deterrent capability against the Soviet Union.

THE BATTLE AREAS in the technological war are all critical to our national security. Significant defeat in any one area will provide the Soviets with a breakthrough which they will exploit in their quest for world power. Since the end result of a successful technological strategy is to achieve significant military superiority, it may be helpful to at least suggest what appears to be the Soviet strategy.

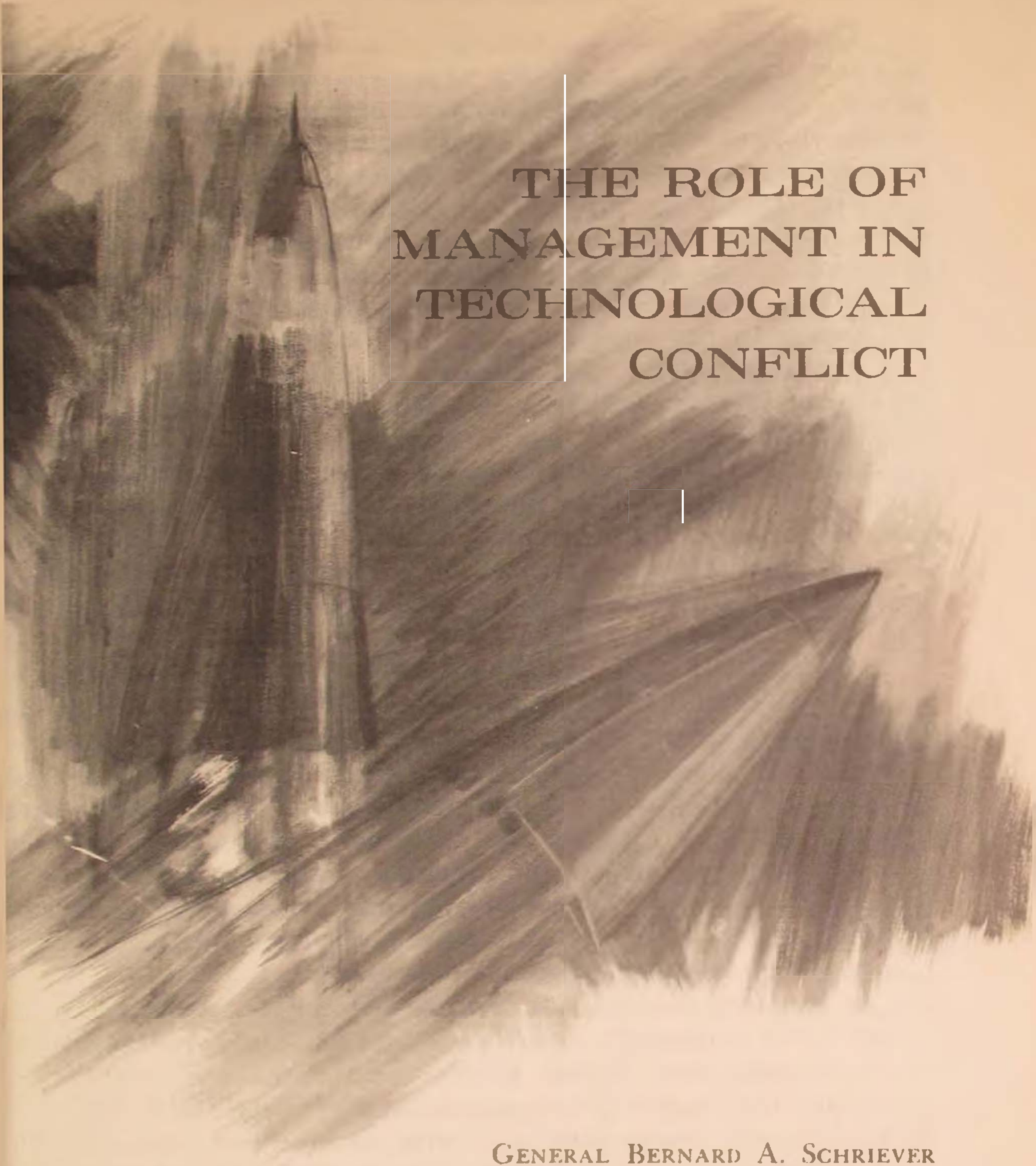
Clearly the Soviets are embarked upon world domination. They recognize that in order to succeed in this goal they must achieve significant military superiority over the U.S. They have invested large national resources in education and in basic and applied research facilities. In the aeronautical systems area, it appears that the Soviets feel confident they can defend themselves. In the missile area, the Soviets boast that they are well ahead of us. And they now boast that they have the capability to destroy our missiles on re-entry. The Soviets as a nation have stressed the development of space capability.

Here it appears that in the areas mentioned previously they enjoy a two- to four-year lead over the U.S. It appears that the Soviet leaders are embarked upon a technological strategy of outflanking us in aerospace. It appears that they are embarking upon a major campaign to develop a military space capability which would in fact constitute a strategic aerospace envelopment. Thus, in old infantry language, the Soviets are conducting a vigorous holding attack in the aerodynamic and missile technological battle areas while executing a strategic aerospace envelopment in the space systems technological battle area.

The U.S. has operated for years on the assumption that we enjoy military technological superiority. New Soviet developments in basic and applied research, in aerodynamic systems and ballistic systems, in space systems, in nuclear weapons, and in the so-called exotic weapon areas (maser/laser, plasma research, and the like) give us serious cause to ask if this assumption is valid today.

The challenge is that we must mobilize our technological resources and plan our technological strategy for countering and controlling the new technological developments that we see appearing in the Soviet Union. And we must do this with great urgency and personal dedication.

Headquarters Air Force Systems Command



THE ROLE OF MANAGEMENT IN TECHNOLOGICAL CONFLICT

General Bernard A. Schriever

TWENTY years ago a comparative handful of men set to work under wartime conditions of haste and secrecy on the development of an entirely new type of weapon—the atom bomb. Eight years ago a similar but larger effort was initiated to develop the intercontinental ballistic missile. Today, with the same sense of urgency, the Air Force is creating scores of new weapon and support systems, most of them more complex than the atom bomb and many of them more demanding in time and resources.

This rapid advance in military technology since World War II is a measure of the enormously increased requirements of national security. Military strength has long been heavily dependent on science and engineering; today, in the space age, technological superiority is the cornerstone of national survival.

The rapid progress of modern science and the continuing Soviet threat have combined to create this situation. The "technological explosion" of the last two decades has had far-reaching consequences. In less than a generation the store of mankind's scientific knowledge has been more than doubled.

As a result of this accelerated technological advancement, weapon systems become obsolete at an increasingly rapid rate. Ten years ago the manned bomber was the sole strategic aerospace delivery system; but the development of intercontinental ballistic missiles multiplied delivery speed many times and ushered in the space age. Progress has been incredibly rapid—from Thor, Atlas, and Titan to Minuteman, and from soft to hardened sites. In the 1950's the heat barrier was conquered by modern technology, just as the sound barrier had been conquered in 1947.

Meanwhile the Soviets have shown that they fully intend to use science and technology as major instruments in their drive toward world domination. In this environment of accelerating technology—and in face of the gravest threat our nation has ever known—the Air Force is confronted with the challenging task of maintaining technological superiority. Meeting this challenge is as much a matter of time as a matter of performance. Not only must new systems embody the latest technical developments; they must also become operational in time to meet anticipated future needs. Consequently technological planning must be projected years into the future.

In the task of acquiring modern aerospace systems today, the pacing factor is management—not science or technology. Management is the element that directs, guides, coordinates, and controls the many aspects of system development, such as analysis and evaluation of foreign technology, planning, anticipating future breakthroughs, basic and applied research, advanced technology, training and utilization of personnel, testing, production, procurement, and contract management. The need to utilize all our research and development resources effectively, efficiently, and on a timely basis and the need to translate new discoveries into new weapons with the shortest possible lead time—these are our two basic management problems in maintaining technological supremacy today.

The responsibility for systems acquisition is assigned to the Air Force Systems Command. Briefly stated, the mission of AFSC is to acquire, on a timely basis, the tools with which the Air Force operational force structure is to be equipped. The magnitude of the task is indicated not only by the number of systems involved—currently more than 80 in various stages of the acquisition cycle—but also by the resources assigned to AFSC: 64,000 military and civilian personnel; facilities worth on the order of 2 billion dollars; and an annual budget in the neighborhood of 8.5 billion dollars, which is nearly 10 per cent of the entire Federal budget.

The task of systems acquisition must be accomplished within the framework of the over-all Air Force program established by Headquarters USAF. Within the authority delegated by the Department of Defense, Headquarters USAF is responsible for determining how to proceed with program execution within current or planned resource capability. It issues directive documents authorizing the conduct of individual programs by the field commands, and it takes action to ensure adherence to schedule, continuing resource balance, and proper utilization of program products. It must ensure proper coordination between commands and must continuously evaluate and readjust programs and resources in the light of changing requirements and objectives.

In carrying out the responsibilities assigned to it by Headquarters USAF, the Air Force Systems Command in turn assigns operating responsibility for systems acquisition directly to its four product divisions—Aeronautical Systems Division, Ballistic Systems Division, Electronic Systems Division, and Space Systems Division. These divisions plan and submit for approval individual system programs designed to satisfy the requirements of Headquarters USAF. Within the scope of the directives received, the divisions utilize the resources allocated and execute individual programs. Their management authority is limited only by the approved scope, schedule, and performance characteristics of the system being acquired. They establish objectives and performance criteria; they monitor results and issue necessary instructions. In essence, then, the divisions perform day-to-day management of all participating activities within the approved program.

The AFSC headquarters has several unique management responsibilities. It must direct the total resources of the command, providing policy and procedural control over all AFSC elements—the four system divisions and the Foreign Technology Division, Aerospace Medical Division, and the Research and Technology Division; the seven development and test centers; and the three Contract Management Regions—and administration of the Armed Services Technical Information Agency. It must establish and manage the total command functional and technical programs which the Air Staff integrates into the total Air Force program.

In addition Headquarters AFSC provides strong support to the planning, requirements, intelligence, and decision-making processes of Headquarters USAF. It exercises directive authority over the applied research program, foreign technology program, planning studies analyses, and forecasts for the future. It allocates work and distributes resources based on mission assignment, resource availability, and over-all competence. It establishes policy and publishes procedural instructions to ensure that both research and systems acquisition activities are incorporated in an orderly fashion into the over-all technical and functional programs of the command.

Thus the achievement and maintenance of technological supremacy calls for management responsibility at three distinct levels within the Air Force. Each echelon is uniquely qualified to provide a specific type of review. The division level provides primarily a technical review. It can provide only a limited functional review, that is, a determination of the proper balance among the programs assigned to the division. The command level provides a complete functional review across all AFSC program lines. The third level of review—at Headquarters USAF—takes into account the reviews conducted at division and command level and considers the additional factors of priority and availability of new resources, within the context of the total Air Force program.

ALTHOUGH this is the logical relationship among the different echelons of management, the relationship has not always been preserved, for reasons that can be shown by Air Force experience in developing the intercontinental ballistic missile. Beginning about 1955, both the Office of the Secretary of Defense and the Air Force recognized that the urgency of ICBM development demanded "streamlined" administration. Accordingly a working group was established by the Assistant Secretary of Defense for Research and Development to evaluate administrative and control procedures with the objective of reducing any delays that might impede achievement of the earliest operational capability.

A report entitled "Streamlined Administrative Procedures" was submitted to the Office of the Secretary of Defense and was approved. In essence, the intent of the report was to centralize authority to the maximum extent with the Commander, ARDC, at the operating level and with the Secretary of the Air Force at the final review and policy level. Although "complete authority and control over all aspects" was delegated to the project office, several significant adjustments were made in each higher echelon for the purpose of expediting approvals and eliminating delays which had previously occurred in the decision-making process. These adjustments included actions (1) enabling the project office to deal directly with Headquarters USAF by making it part of the command headquarters; (2) establishing a single control office at Headquarters USAF to ensure coordinated and timely staff work on a concurrent—rather than consecutive—review basis; (3) providing for an integrated/consolidated review and approval by all functionally responsible staffs at the Secretarial level; and (4) combining the justifications and concurrences required by various Assistant Secretaries in a single approval group at the OSD level. In addition the streamlined procedures provided for a delegation of responsibilities for management to the Secretary of the Air Force *subject only to final review and guidance by Office of the Secretary of Defense/Ballistic Missiles Committee.*

These actions proved to be highly successful in expediting decisions and minimizing delays on the three ballistic missile programs, Atlas, Titan, and Thor. This success may be due primarily to the relatively few programs involved and the centralization of emphasis in terms of technical and managerial competency at each echelon of command. But in spite of the success achieved, there were certain drawbacks from the standpoint of the several staffs or agencies concerned with the allocation and administration of resources and activities necessary for execution of the programs. These drawbacks became especially marked as the programs progressed from the early research and development phases to the operational phase, during which time the number of organizations and agencies involved increased tremendously and functional expertise was required to an increasing extent in order to accomplish all aspects of the programs.

The "streamlined" procedures, then, although successful from the standpoint of timely decisions and minimum delays in execution, could be criticized from the standpoint of qualitative and quantitative functional participation and efficiency. As a result of these criticisms and the expanding nature of the program management requirements, the procedures were formally modified in 1960.

The net result of this modification was to place the functional staffs back in a recognized strong position relative to the Ballistic Missiles Committee. Pending Secretarial decisions were then carried out by means of normal functional areas directing resource allocation and implementing actions. This same time period marked a turning point in the evolution of the decision-making process at higher levels. Not only did the modified procedures provide for more detailed scrutiny, resulting in an increased level of detail and time required for program approval within the Air Force, but simultaneously the approach to decision-making in the Office of the Secretary of Defense was evolving in a like manner. In many respects conditions were ripe for the growing centralization of authority at the higher levels of the Department of Defense.

As a result of these trends, a policy of "selected systems management" was established in early 1961. This forerunner of the designated systems management procedures involved a redesignation of the Ballistic Missiles Committee as the Air Force Ballistic Missiles and Space Committee (AFBM&SC), with its responsibility broadened to include space systems. In addition it was provided that, on an exception basis, specific instructions or decisions might emanate directly from the Office of the Secretary of the Air Force to the field, and in such instances response would be authorized directly to the

Secretary. Furthermore the AFR-375-series concept of management was recognized as applicable to the seven missile and space systems selected to be under the active management cognizance of the Secretary of the Air Force, provided that adjustments in program documentation resulting from AFR 375-4 did not produce significant departures from previous missile and space program coverage or levels of detail.

In addition to those systems selected for "active management cognizance," others were assigned to the Secretary of the Air Force for direct management control, with no management participation by intervening command echelons: direct contact and control were to be maintained between the Secretary's office and the operating field project office.

At the same time the AFBM&SC assumed a larger role than that described in the original AFBMC charter, which provided primarily for review and approval of the annual development plans, with "maximum latitude and authority" given to the Air Force. By contrast, the AFBM&SC was to advise and assist the Secretary of the Air Force in establishing program objectives, review all changes affecting the operational program, review the impact of technological developments, review all major management problems, and review schedules, development and test results, missile support, and program milestones. With the advice of the AFBM&SC, the Secretary retained full authority for approval of actions pertaining to these items. Thus the net result of the early 1961 changes in management of highest priority systems was to establish the means for even tighter control based on a more detailed knowledge of an increasing number of programs.

THIS TREND—the management of more and more programs in greater and greater detail at higher and higher echelons within the Department of Defense—culminated in the redesignation of the AFBM&SC as the Designated Systems Management Group (DSMG) and the addition of several more programs to the list of systems to receive "special management emphasis." These actions took place during the summer of 1961. The stated reason for establishing "redline procedures" was to assist higher departmental levels in discharging their responsibilities for accomplishing urgent research, development, and production programs. The establishment of these procedures appears to have been based on the premise that streamlined channels, as originally provided for in the ballistic missile program, are sound in principle and can be applied to many important programs in today's environment.

It has become increasingly clear in practice, however, that designated system redline procedures have not proved as effective as it was hoped they would be. They have frequently resulted in the bypassing of functions that must be performed at the various echelons of management, functions that are essential to the proper management of the total Air Force program.

A cardinal principle in the AFSC interpretation and application of the redline concept was the utilization of the joint staff review process established in conjunction with the Systems Review Board (SRB) activity at Air Staff level. Under this concept, there were to be no intermediate-level reviews or disapproval authorities (and attendant program delays) between the responsible system program office (SPO) and the Designated Systems Management Group. Although program documentation was to be authorized and provided in advance of and as a basis for recommendations leading to decision by the DSMG, and although presentations were authorized for joint AFSC/USAF "informational" reviews at the Systems Review Board level, complete functional staff action was not possible at the Headquarters AFSC level in the majority of program submissions. As a consequence, AFSC staff input and recommendations to either the SRB or the DSMG were lacking. The staff recommendations that have been possible have resulted primarily from system-oriented SPO/SYSTO (Systems Staff Officer) activities, which lacked the broader total program functional area inputs required for over-all integrity and balance when viewed collectively from a total Air Force standpoint.

This approach to the implementation of the redline concept did not have the desired effect. It did not result in a streamlining of systems management. On the contrary, it had virtually the opposite effect. While AFSC was effectively eliminating its headquarters staff as a significant point of input and control with respect to its assigned functional authorities, the numbers and types of reviews being accomplished on various aspects of its programs at every level above AFSC headquarters were increasing rapidly. These reviews have involved an increasing number of people. More questions have been asked, and additional justifications have been required.

Thus the attempt to eliminate levels of review has actually resulted in an increase in detailed data required at the top and a decrease—in the name of urgency—in the quality of review. The requirement for increased detail at the top levels of management is indicative of an effort to consolidate the entire review process at a level which may not be best qualified to perform all aspects of review.

The inadequacy of such attempts to streamline the decision-making process suggested that the answer lay in another direction. First, we did not assume that the various levels of review are duplicative. Properly utilized, each has a unique and appropriate function. The project level—laboratory or system project office—should be recognized as the last word technically within the command. It follows that program review at AFSC division level should logically be primarily of a technical nature. The capability for functional review at this level is limited to a consideration of the balance among programs assigned to the division.

The basic capability which is missing from the division-level review process is the capability for complete functional evaluation across all AFSC program lines. This critical ingredient has been frequently eliminated in attempts at streamlining, even though it is essential to sound top-level decision. Logically it cannot be eliminated from the cycle, and with equal logic it can best be performed at the command level, where there is the required degree of knowledge of all programs assigned to the command.

Review at Headquarters AFSC, then, must be primarily functional in nature. To implement the functional emphasis, a basic adjustment of existing funding and programing practices was considered. For example, in annual program submissions total dollar levels are assigned by division and center; a balanced program is required of each. Under the procedures for reprograming requests, divisions were required to identify the programs from which dollars may be taken from within their assets. These requirements presupposed a capability at division level that did not and should not exist. They forced the divisions to perform a degree of functional review that must be acknowledged and performed in the command headquarters.

Designation of programs which should yield funds can most realistically be done in the headquarters after a review of all programs. It is not realistic to assume that a program assigned to the division originating a reprograming request is the one which should yield funds. This assumption would be valid only if each division had the program assigned the lowest priority, which can obviously never be the case when there is more than one division. Moreover, priority is not the exclusive consideration.

For these reasons, Headquarters AFSC has revised its approach so as to place increased emphasis on functional review while at the same time reducing the requirements imposed on the divisions. In addition staff offices in the headquarters have augmented their capability to allocate resources to divisions and technical programs assigned to divisions; to evaluate the impact of program changes on a total program basis; and to indicate clearly to Headquarters USAF the portions of resource requirement involved in program changes that can be met within the resources of the command, the portions that represent new requirements, and the alternatives that are appropriate within the purview of higher authority.

This increased capability at the command level promises to reduce the scope of the review effort at Headquarters USAF and to permit readjustment of emphasis there to matters pertaining to relative priority and new resource requirements related to program changes. At the Department of Defense level it should be possible to treat change proposals with a higher degree of credibility because of the completion of staff work at all levels by the echelon best qualified to perform a particular aspect of review.

From this brief history of weapon systems management in the Air Force, several useful lessons may be drawn. First of all, it can be seen that the unique short-circuit management techniques and administrative procedures employed on some programs in the past cannot be universally applied with the same effectiveness. They must be recognized as fruitful in the past and as potentially appropriate in the future for programs involving extreme national urgency or risk where it is obvious that normal program management techniques are inadequate to accomplish the approved objectives within the time period prescribed.

But such specialized procedures may not be extended beyond a relatively few programs without some deleterious effect on the normal management structure and on the portion of the system program that does not fall within the highest priority category. The recent trend has been to add more and more systems to the specialized management list, thereby diluting the amount of special management emphasis that might be applied in the priority areas and degrading the normal management emphasis available for lesser priority systems. Accordingly, the list of "designated systems" is being re-evaluated with a view toward reducing that list to a number more consistent with the time and talent available for "special" management emphasis at the higher levels of the Department of Defense.

Second, the increased number of personnel assigned to perform the staff function of the Department of Defense has tended to hamper the effectiveness of the basically sound "package" approach to program management. In practice, decision-making has become a piecemeal, functionally separated, subitem-by-subitem process, which is in fundamental contradiction to the objectives of both the original "streamlined" administrative concept and today's "package" concept. Studies should be initiated to find better ways of implementing these concepts of program management. One approach might involve the establishment of a single office or integrated joint activity, such as the OSD/BMC, that would be responsible for reviewing all aspects of individual programs in a total integrated context, considering the relationships among dollars, people, technical facilities, schedules, and other aspects of programs.

Third, because of the past approach to redline procedures, insufficient staff coordination and review had been provided on system programs, and an improper balance in staffing responsibilities existed in Headquarters AFSC as compared with the Air Staff and higher levels. AFSC review procedures were adjusted to provide a more intensive functional review than in the past, covering all aspects of the nondesignated system programs and, on an expedited basis, the designated system programs.

In order to achieve this objective and to meet the Department of Defense requirements for more definitive proposals, for more detailed and accurate estimating, and for continuous programing on a five-year basis, several procedural adjustments were required. One of these put programing emphasis on proposals or change proposals which require approval by the Office of the Secretary of Defense. Specifically, all changes that exceed the resource, schedule, or funding thresholds established by OSD are thoroughly reviewed by the functional staff in Headquarters AFSC before they go to Headquarters USAF. In addition, those changes made within AFSC's approval authority are reviewed and approved on a continuous basis prior to their being submitted as an accumulated exception to the OSD thresholds.

In the same manner the concept of continuous programing has been implemented within AFSC to avoid piecemeal, inconsistent recommendations to higher authority. This is accomplished by using the Headquarters AFSC staff as a central command review group on a continuing basis, since this is the only agency having broad enough knowledge of the entire command program to pass on new proposals or change proposals in context with the entire technical and functional programs assigned to AFSC.

Other actions within AFSC have strengthened the functional review at this level. One of these was the establishment of an AFSC Council comparable to that existing in Headquarters USAF. In addition to advising the commander on other important matters, the Council reviews all significant proposals and changes to ensure qualitative and quantitative completeness as well as total program integrity before they are recommended to Headquarters USAF.

We are also strengthening the technical validity and position of program proposals submitted to Headquarters USAF. To achieve this, all technical presentations and responses to queries about technical aspects of programs will be made as far as possible by the program manager or by those project-level personnel best qualified to discuss the technical aspects of the program. AFSC will continue to strengthen its present system of using highly qualified technical consultants and advisory groups to ensure technical credibility at all levels in the decision-making process. A further increase in management credibility will be achieved by continuing improvement in the cost estimates which are continuously required by higher echelons both as part of the initial proposals and annual budgetary updating cycles and also quite frequently as part of the extensive analysis process within the Department of Defense.

These actions promise to bring a significant improvement in the management capability that is the pacing element in achieving technological superiority. But their continuing effectiveness, in the final analysis, is governed by the quality of the people involved. This is the constant factor in any management equation, and any program for management improvement must take it fully into account. Changes in organization or procedure alone do not reach the heart of the problem. In addition to the necessary procedural changes, AFSC must make intensive and continuing efforts to attract, utilize, and retain the very best people, both military and civilian. People, it appears more and more, are the key element in our strategy for waging and winning the crucial technological contest of our time.

Headquarters Air Force Systems Command

part II

FROM CONCEPT TO INVENTORY

Military technology is ultimately bound up in the research and development process. The various systems on which our national security rests are the products not of circumstance but of the most astute research and development planning that man and machine can provide. The planning anticipates the hardware of as far as a score of years into the future. Beyond the plans lie the processes that carry the new idea from the drawing board to the active inventory—the basic research, applied research, advanced technology, development, testing, and evaluation required to render a product operational. Inevitably Air Force research and development have become increasingly complex and diverse, compounding the problems of control; but by July 1963 the management of applied research and advanced technology programs will be centered in seven laboratories covering technical areas of Air Force concern.

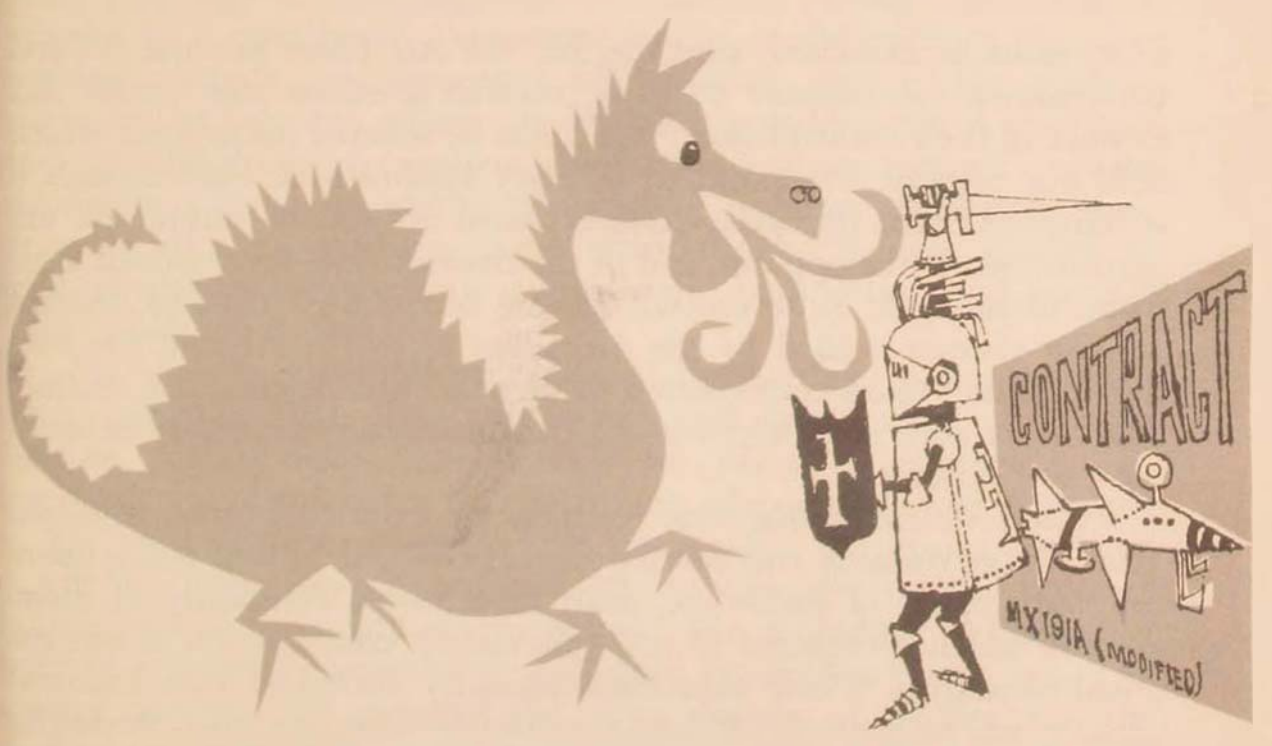
RESEARCH AND DEVELOPMENT PLANNING

Colonel Florian A. Holm

FROM time to time some of the Nation's leading scientists and military authorities have taken the position that research and development cannot be planned. They have argued further that it should not be planned even if planning were feasible because planning dampens creativity, smothers new ideas. It is said that planning, to be effective, must be of such a long-term nature that it is fraught with the uncertainty which increases rapidly as one attempts to look farther and farther into the future. And, even if planning could be precise as of some point in time, the unpredictable political tenor of the moment or an unexpected turn of events always seems to upset the finest of research and development plans. These advocates of laissez faire in research and development overlook the simple fact that planning is being done and will continue to be done in spite of their admonitions. In fact, the very act of overt abstention from planning is a plan in itself—and a very dangerous one.

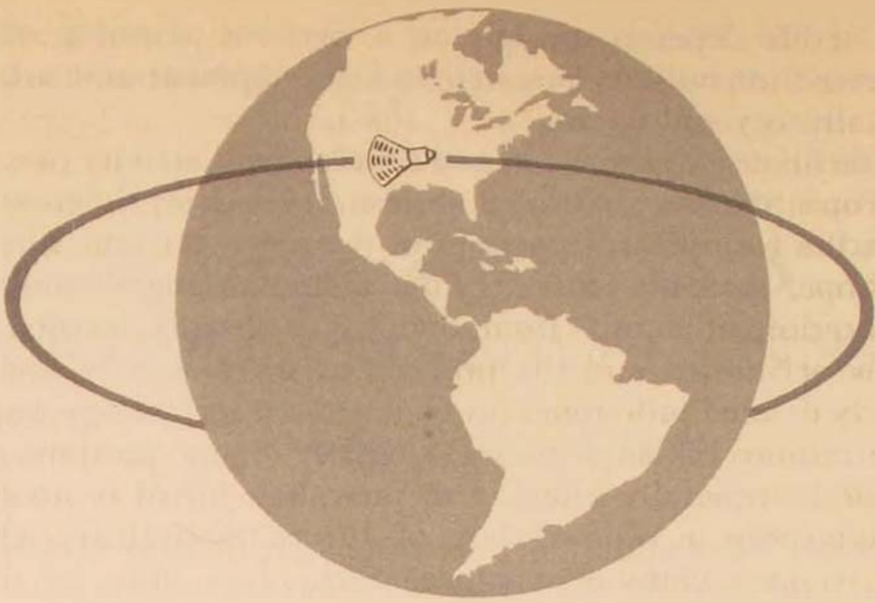
The obvious consequence of a "no planning" plan is that the legitimate objectives of military research and development may be neglected and emphasis placed on secondary and collateral objectives, such as personal and organizational aspirations. In such an environment the research scientist or the military project officer must be expected to continue to push forward in those areas where he is most competent, without stopping to consider whether they are the areas of greatest payoff to the Nation. The fiscal fortunes of any particular effort would be dependent primarily on the salesmanship of its champions and their positions of strength relative to the champions of other efforts. It would be fortuitous indeed if the technical areas selected by this random method were also those most vital to our national security. This remote circumstance would yield an obvious bonus in that the researcher would make greater progress in the areas for which he was best qualified. But even if such a happy situation should exist, the military tactician and strategist would be reduced to a hat-in-hand attitude of hopeful waiting. With no basis for technological forecasting, he could only respond to each new technical innovation as it occurred. It seems, therefore, that the very survival of our way of life depends strongly on a vigorous planning effort to provide purpose for military research and development and substance for military strategy and tactics.

The wide diversity of research and development activity conducted by the Air Force Systems Command necessitates entirely different planning approaches for different portions of the R&D spectrum. The planning for a broad span of technology (as in human engineering) must be handled quite differently from that for a sharply focused effort which can be scheduled and the progress of which can be measured against clearly defined milestones (as by advanced technology engineering demonstrations of solid rocket engines). Some portions of research should be generally oriented to provide a broad technological base for supporting a wide variety of future capabilities. On the other hand, certain items of advanced technology must be demonstrated, one at a time, on such an elaborate and expensive scale that only a few demonstrations can be afforded prior to the initiation of systems development programs. Some activities are not readily amenable to planning of any kind. For example, basic research probably cannot be planned in detail, and we scorn the notion that fundamental inventions can ever be scheduled. Even here, however, some selec-



Crusade of Champions

As a planning technique the "crusade of champions" is not unknown in R&D management circles. It can be attractive to the manager whose pet project is beyond the point of diminishing returns. A project may be sustained for years by hard-sell tactics stressing its favorable potentials. Formal planning techniques cull out fading projects by exposing all their attributes, the bad as well as the good.



National Scientific Prestige

Growing awareness of technological conflict has stimulated a re-examination of our national objectives. In consideration of the impact of military research and development on the posture of modern nations, national scientific prestige has been added to the set of security objectives supported by the Defense establishment.

tivity must be exercised, since neither the Air Force nor the Federal Government can support all basic research scientists who would like to work in their chosen fields. Areas must be selected for support which hold out promise for advanced military applications, even though it is recognized that the areas to be explored are usually virgin and unpredictable. At the opposite end of the research and development spectrum, planning is quite crucial because of the high costs of modern weapon systems needed by the Air Force in the future and the relatively limited resources expected to be available for their acquisition. The importance and effectiveness of planning vary gradually between these two extremes.

The problems facing AFSC planners are extremely broad in scope. The types of research and development performed, as well as the quantity and quality of each type, must be adjusted constantly to maintain the balance required to make maximum contribution to our national objectives. Those objectives normally associated with national security can be generalized into operational categories, such as central war offense, central war defense, limited war, logistics, reconnaissance, and intelligence. However, the development of major weapon systems often influences objectives normally considered to be outside the military sphere. The fact that we are engaged in a scientific race—that we are waging a technological war—is becoming increasingly evident. The current evolution of strategy for waging and winning a technological war or race of science involves technical planning at the highest levels. Technology has assumed such a significant role in determining the posture of modern nations that national scientific prestige usually is treated along with the traditional military objectives. Since technology knows no sovereign bounds, its planners must take into account the fact that the needed technology may emerge anywhere about the globe. The investigators in the Soviet Union, Japan, Western Europe, or South America, for example, are all potentially capable of increasing our total technical and scientific knowledge. The contributions of international technology assume major significance in basic research, where the risk of pursuing an unprofitable project is greatest, the military potential is most nebulous, and the probability of technological surprise is least. At the weapon systems development end of the R&D spectrum, vigorous competition almost completely displaces international technological cooperation.

The Techniques of Planning

In all military R&D planning, an important objective is to minimize elapsed time between the initiation of a concept and attainment of its operational capabilities. This over-all objective necessitates an integrated view of these activities in order to prevent technological surprise by a competitor. Important aspects of the military planning problem include the ensurance of optimum timing, the realistic assessment of risks and military potentials, the assignment of priorities, and the allocation of resources among the various research and development efforts. Integrated plans which achieve satisfactory solutions to all these problem areas must also be flexible enough to respond rapidly in a dynamic environment, both within and external to the planning community.

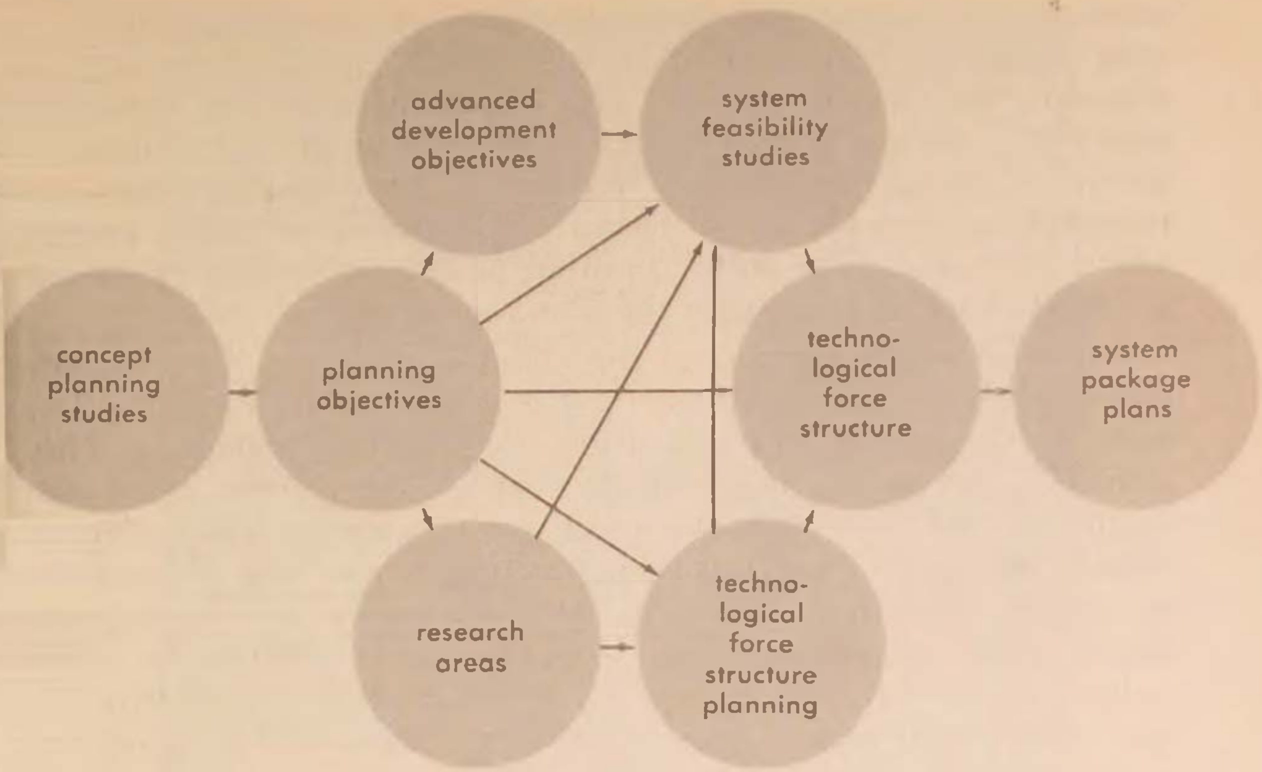
To achieve full implementation of the national policy of deterrence, comprehensive plans for research and development within the Defense establishment must provide for effective deterrents at all levels. Recent history has illustrated the adeptness of the adversary in his continuous probing for soft spots along the entire spectrum of conflict, from general nuclear war through the various types of limited war to the many aspects of cold war, including technological warfare, economic competition, and other paramilitary activities. The science race must be included also as an element of conflict, and the strategy of winning it must be considered as separate objectives to be evaluated with respect to all possible reactions of the Communist bloc. Then step by step we can also attain and maintain the initiative in this new area of conflict.

All possible means must be considered for attaining our national objectives within this environment of "total conflict." Superior in-being military forces must be maintained throughout the planning period by (1) optimum employment of currently available weapon systems in a high state of readiness, (2) modernization of in-being forces through the exploitation of available technology, and (3) advancement of technology to provide a base for future generations of weapon systems. These three different kinds of activities occur simultaneously, but they are generally oriented toward three different time periods.

Historically it has required five to ten years to modernize in-being forces to any considerable extent and ten to fifteen years to produce in-being forces based on significant advances in technology. Thus production and procurement activities are oriented primarily to objectives within the first five years in the future; operational development of weapon systems and major hardware projects are intended to provide modernized in-being forces during the second five-year period in the future; and the in-being forces to be available during the third future five-year period will result from today's applied research and advanced technology efforts. The fact that basic research is expected to have its greatest impact during a period fifteen to twenty years in the future is sufficient reason for leaving this area largely unplanned, because of the inherent difficulty of forecasting events or situations so far ahead.

The most useful common denominator for planning throughout all these time intervals and within the very complicated conflict environment has been found to be the weapon system. Technology in its own right plays a prominent role as a means of influencing men's minds in the technological warfare in which we are engaged. In fact the major world powers probably are tempted from time to time to perform technological "stunts" purely for this purpose. However, the genuine technical advancement that offers potential for the development of new and greater weapon system capabilities is a far more effective instrument of technological warfare—and hence holds the greater interest of military planners in both camps. Qualitative future trends in the performance characteristics of U.S. weapon systems are plotted for comparison with similar trends in weapon systems of foreign powers in order to assess the ability of this nation to carry out its national objectives. These trends are normally plotted by systems category, such as aeronautical systems, ballistic missile systems, space systems, and command and control systems. Comparison of the weapon systems performance trends of the opposing military powers is a useful technique for predicting potential voids or weaknesses in future military forces of the United States. When a potential weakness is forecast, a sequence of events is triggered to provide capabilities in time to prevent the actual diminution of our relative strength.

At the earliest indication of any potential problem, conceptual planning studies are initiated by the Air Force Systems Command either in-house or through contractor efforts. The need for a specific conceptual study can arise for a number of reasons: to react to poten-



AFSC Planning

The Air Force Systems Command planning process begins with a conceptual planning study. This study is designed to exploit new technologies and to examine new concepts of operational use for advanced weapon systems. Technically feasible concepts of sufficient military worth are established as planning objectives to guide the technical areas of research, the advanced development objectives, the system feasibility studies, and the analyses of technological force structure planning. The many interactions of these activities result in a required technological force structure, from which elements may be selected at appropriate times for more thorough designing and offered as system package plans for approval and funding.

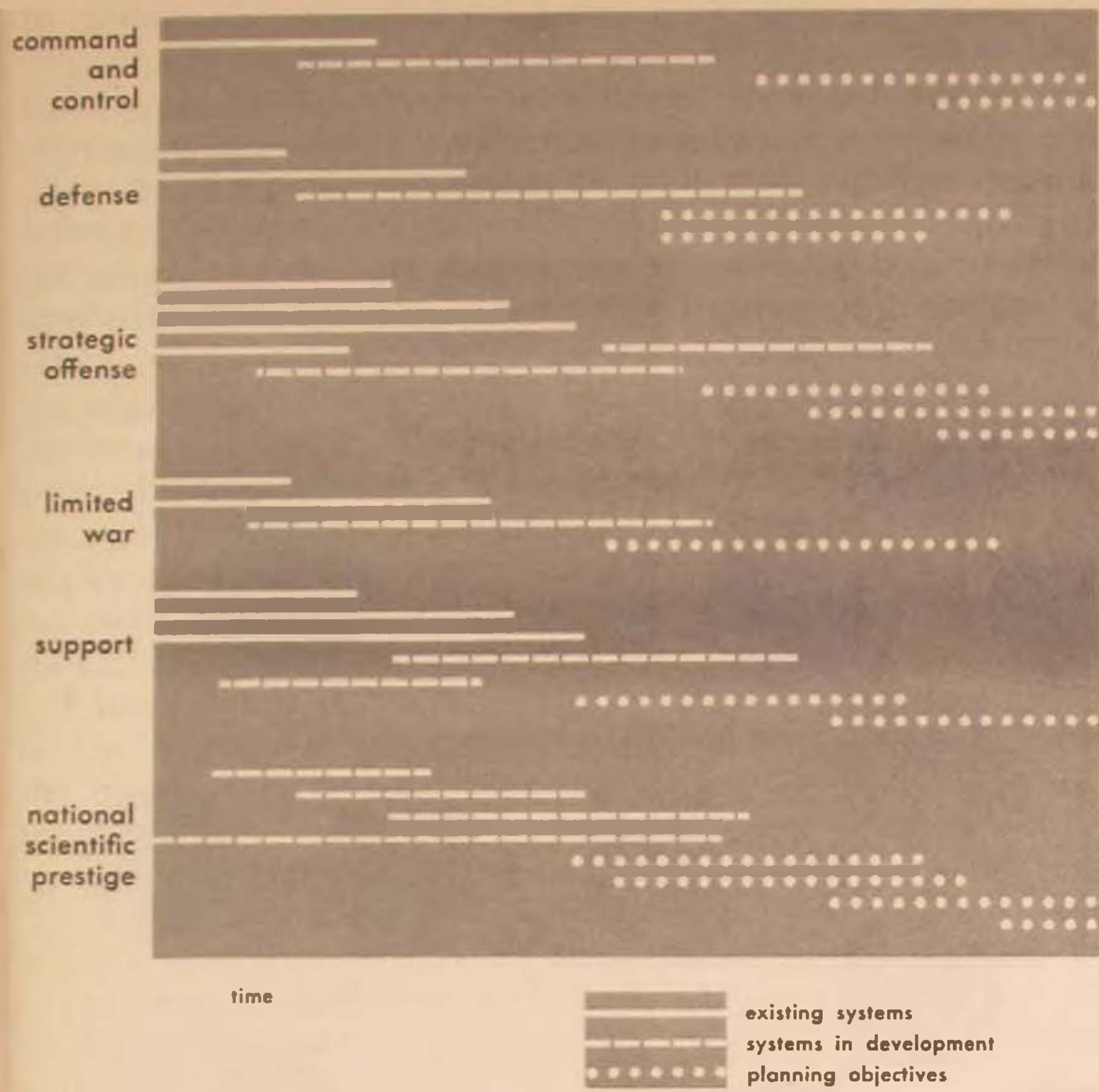
tial enemy advances, to exploit significant scientific advances, or to explore in a scientific manner excursions into the unknown—the area of speculation and imagination. The conceptual study is the primary mechanism through which new technologies are examined for their military potential and new operational concepts are introduced to exploit technological innovations. The planning study activity truly comprises the rudder which steers the ship of technology and the gimbal which guides the spacecraft of strategy.

An important result of these studies is the crystallization of thinking concerning future capabilities required by the Air Force. These results are usually expressed as system concepts although they may take other forms that express clear-cut technical objectives, the attainment of which will give the Air Force a desired capability. A great many competitive and alternative concepts are compared in a series of analysis tasks and finalized by means of command-wide planning conferences to establish specific future requirements. These requirements are published and kept current in AFSC planning objectives (PO's) and are expected to be of military worth and technically attainable during the 1965–1975 time period. They constitute the long-range planning goals of the command and serve as nuclei around which decisions can be made to initiate and invest in weapon systems at future dates as specified in the planning objectives.

Another major purpose of the planning objectives is to identify and emphasize those critical technical problems to which specific effort must be directed in order to attain the desired capabilities. They provide guidance to programs devoted to the generation of new technology and ensure alignment of these programs with future operational needs. A further important function of planning objectives is to provide an early opportunity for identification of long-range resource requirements and thus direct planning attention to major unique or unusual requirements for resources. Both quantitative and qualitative requirements for personnel can be planned by using PO's as the basis for workload forecasting.

Indicators of future changes in required systems capabilities are to be found in the trends of our own and foreign technology. This brings us to one of the most difficult aspects of planning military research and development: the identification, plotting, and forecasting of pacing technical parameters upon which future systems capabilities are predicated. Several methods of technological forecasting have been developed by the planning activity at Aeronautical Systems Division, and they are currently in use within various elements of AFCS. The most common technique is the extrapolation of existing rates of progress as long as a technological area is in its growth phase. Other forecasting techniques include derivation from primary trends or from precursive events and the dynamic simulation of the process of technological improvement.

It becomes apparent that a complete systems framework can be projected across the entire planning period by combining the planning objectives with those systems already in inventory and those known to be under development currently. This total framework, called the technological force structure (TFS), serves as a valuable integrating tool in research and development planning for the Air Force Systems Command. The TFS is kept current by maintaining information on a wall plotting board concerning forecast estimates of the number of each kind of weapon system, the expected dates for initial operating capabilities and phase-outs of systems, changes in planning objectives, and forecast feasibility dates for major items of advanced technology. Technical programs of the Army, the Navy, the National Aeronautics and Space Administration, and other scientific

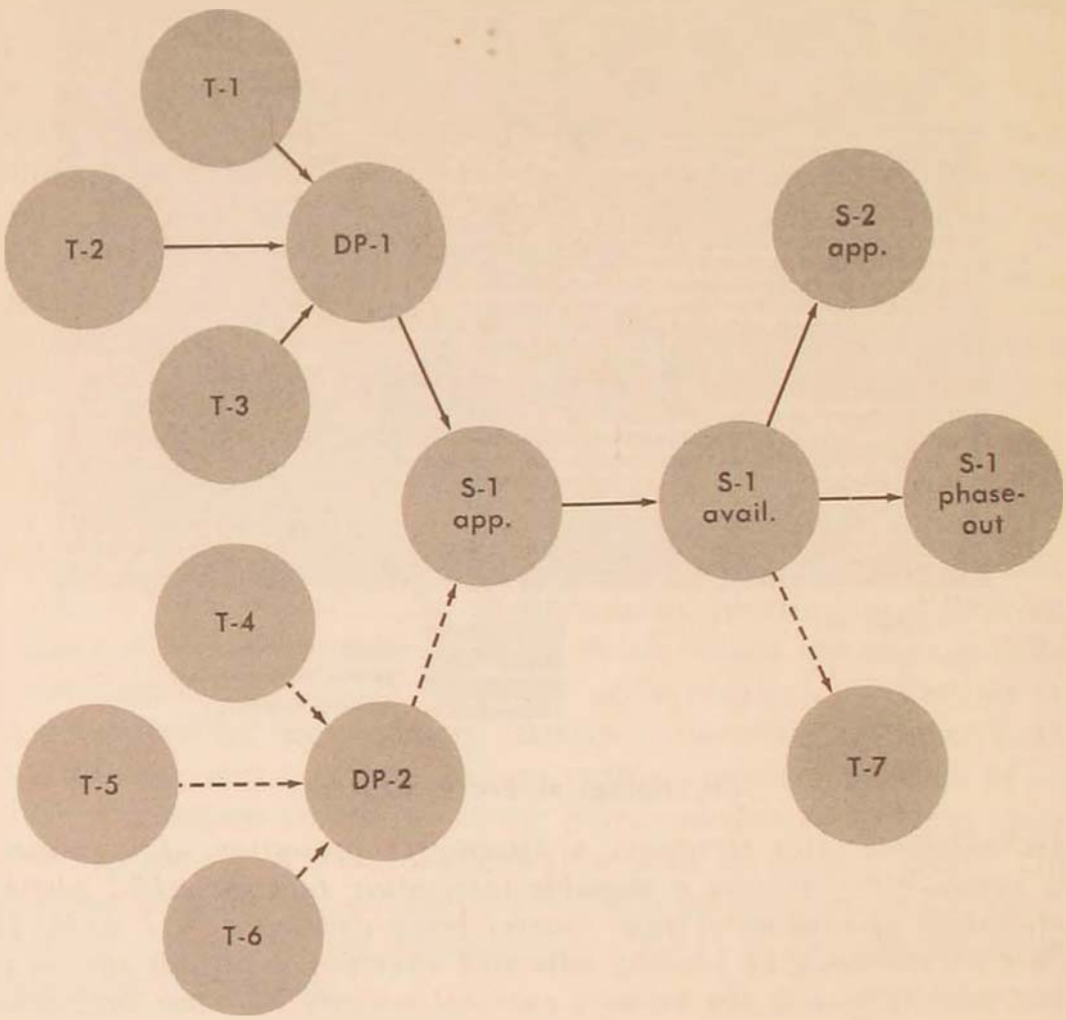


Technological Force Structure

The technological force structure, a fifteen-year projection of a framework of systems capabilities, provides a valuable integrating tool for AFSC planners. Interrelationships of existing systems, systems being developed, and AFSC planning objectives are indicated by plotting estimated operational periods against calendar time and with respect to the primary national military objective supported. Decisions concerning individual systems, planning objectives, or advanced technology efforts can be facilitated and improved by the over-all perspective afforded.

agencies are also plotted and kept current, insofar as possible, to ensure adequate support of the programs of other agencies that have objectives in common with those of the Air Force. A recent phenomenon which necessitates meticulous plotting of the projected systems framework is the variation in systems development cycles and expected operational lifetimes of systems as we actually enter the era of operational aerospace weapon systems. Expendable systems, such as some of the unmanned satellites currently envisioned, wreak havoc with our historic planning factors based on aeronautical systems.

Portions of the TFS are studied intensively through a series of technological force structure plans (TFSP). Each TFSP results in cost-effectiveness comparisons of two or more weapon systems in specified operational environments to serve as a basis for making recommendations concerning acquisition of one or more of the systems being evaluated. In a like manner those technical capabilities which are needed to fight the technological war or science race are "war-gamed" against the strategy which governs this portion of our national objectives.



The PERT Network

The program evaluation and review technique (PERT), an automated scheduling device formalized during development of the Polaris Fleet Ballistic Missile, is being adapted to chart interrelationships of Air Force programs. Its use is illustrated by portions of a typical network. Several technical approaches, T-1 through T-6, are initiated to solve two problem areas of system S-1. At decision points DP-1 and DP-2 selections are made from among the available solutions, and the system approval is shown as "S-1 app." The broken arrows indicate activities that are desirable but not as critical as those marked by solid arrows. When system S-1 becomes available, it can support activities leading to the approval of other systems (shown as S-2) or initiation of other efforts in advanced technology (shown as T-7). Scheduling is completed by estimating a date for each identified event.

In order to keep the command effort in proper focus and on schedule, a simplified program evaluation and review technique (PERT) network has been prepared for most of the major elements, and a Super-PERT has already been set up to interrelate a major portion of the technical plan, as represented by the TFS.

After the time dimension of the over-all technical plan of AFSC has been tentatively integrated, complete costs must be estimated for each of the elements included. The estimate covers research and development costs, initial installation and inventory investment, and the cost of operations over the expected lifetime of each system. Both the total cost and the time-related cost trends are significant. At this point reality is injected into the planning activities of the command. Economic projections of the gross national product are taken as points of departure, and estimates are made of the resources which will be available for systems acquisition by the Air Force during selected future time intervals.

Immediately it becomes apparent that the Nation cannot afford all the systems concepts projected. This is as it should be because of the many uncertainties in the development of systems, particularly those that are still in the planning objective stage. Often two or more systems concepts are postulated to achieve the same results in the force structure, with full knowledge that there is little likelihood of more than one system being developed to do the same job. Parallel approaches are introduced deliberately at the very early stages in order to increase the over-all likelihood of attainment of an effective force structure.

The Evaluation of Planning

Once the technological force structure with its associated costs and schedules has been established, we are ready to undertake the problem of evaluating it in its entirety. A rather detailed procedure formulated for this purpose will be described, although it has not been fully implemented because it must await completion of the PERT networks. Again we begin the problem with consideration of national military objectives. The first sets of judgments involve an assessment of the relative value that each of the national military objectives would have if they were to be completely attained. A major impediment encountered at this point is that no single individual is expected to possess the competence to make the required judgment at this level. The reluctance of authorities to document their personal judgments is quite understandable in view of the fact that these judgments should be made ultimately by the American people as a whole.

However, the absence of an expressed judgment is, in itself, a tacit judgment that all national objectives are of equal importance.

Such a judgment is intuitively unsatisfactory to most participants in the evaluation process. Therefore it is usually desirable to make a set of tentative judgments even at this very high level. In the face of such doubts, individual judgment can often be strengthened by group participation or collective judgments of carefully selected groups. Sometimes a collective judgment is preferred anyway because experts from different fields can make unique contributions to a common problem. Also key executives from several echelons can sit together to compare their judgments based on information available to them only at their own levels. This participation has been found quite useful in the entire evaluation process.

Next the over-all effectiveness of the entire technological force structure should be evaluated with respect to each national military objective for a given time period or evaluation interval in the future. The intervals are normally the same three or four five-year increments previously mentioned. The relative effectiveness of a particular system can then be evaluated in its proper context by judging the per cent of degradation in over-all effectiveness of the technological force structure as the particular system under consideration is removed completely from the force structure. The total effectiveness of a system is found by summing its relative effectiveness values with respect to each objective for a given time period. This is the only feasible approach found to date to permit the comparative evaluation of the effectiveness of different kinds of systems, e.g., comparison of an offensive system against a defensive system or a logistic system. The technological feasibility of each system is then estimated as a function of time in terms of the probability that the system could be in an operational status any time during the interval under consideration.

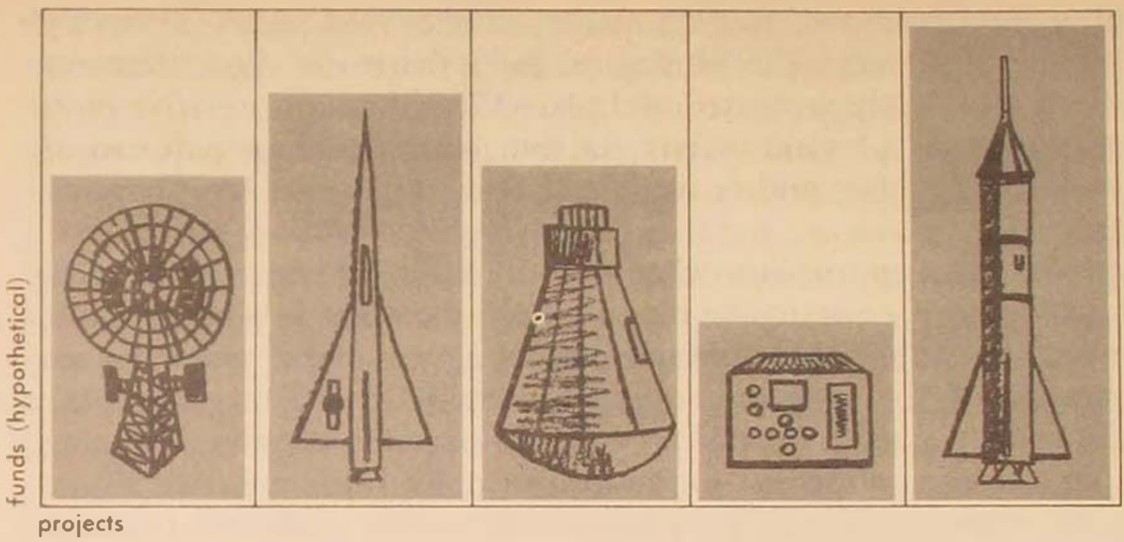
The desirability of each system can now be estimated as a direct function of its effectiveness and feasibility and as an inverse function of its cost. This estimate is somewhat different from the normal cost-effectiveness analysis because of the introduction of feasibility, which makes the present analysis more comprehensive and more universally applicable than cost effectiveness alone. All the systems in the TFS can now be ranked in accordance with their desirability. But the problem is not yet complete. Beginning with the first time interval, the desirability of each system should be considered in conjunction with the system cost during this interval and the total budgetary limitations in order to estimate the likelihood of funding that particular system during that period. Proceeding in a similar manner to each subsequent interval permits the estimation of the over-all likelihood that a particular system will become available to the Nation at any time during the foreseeable future.

This type of estimate can be quite valuable to the command as guidance for the application of effort. Everyone likes to bet on winners. Greater efforts can be justified for those systems having high desirability and likelihood, and the quality of effort expended inevitably will be higher. A current technological force structure whose elements have been completely evaluated and placed in the proper relative positions can provide a logical matrix for budgetary decisions required as budget levels fluctuate and as new fiscal years appear on the planning horizon.

As the time approaches when solutions for all the critical technical problems of a particular planning objective are in sight, it must be determined whether a militarily useful system based generally on the concept of the planning objective could actually be acquired. At this point a system feasibility study is initiated, usually involving three or more contractors in addition to an in-house Air Force team. In these studies gross configurations are designed to meet designated systems objectives, equipments are specified, and operational employment schemes are proposed. If a single contractor approach offers outstanding merit, it may receive special consideration, but normally the in-house team synthesizes a system from the best features of several approaches. The technical feasibility and military worth of the resulting system are then evaluated and recorded. If the resulting system appears sufficiently promising or if it could fill a void for which there are no other contenders, a system package plan will be prepared immediately and proposed to higher echelons for approval and funding. Otherwise the system will be the subject of a special technological force structure plan analysis to establish its relative cost effectiveness with respect to other systems that could be available in the same time period to perform similar functions.

The acquisition of weapon systems can be treated just like any other purchasing problem by maximizing value received per dollar expended. This criterion is permissible because in most cases the customer can choose either System A or System B. However, some areas of research cannot be treated in this manner because of the intimate interactions between research projects or between technical areas. That is to say, Project A may be of no value by itself, but some portion of Project A may have value in conjunction with some portion of Project B. This is particularly true in the case of large technical areas such as propulsion, guidance, or flight control. Any specific weapon system normally requires advances in all or several technical areas simultaneously. Furthermore each technical area has such a wide breadth of effect on Air Force systems that it could be catastrophic to terminate or substantially reduce the rate of progress or effort in any of the major areas of technology.

Since, as has been shown, the projects of research and advanced technology normally cannot be selected by solution of the classical purchasing problem, a method of resources allocation has been developed to permit distribution of available resources in accordance with a proportional allocation decision model. The proportion of resources



Proportional Allocation

The acquisition of weapon systems is usually approached by ranking the various alternatives in the order of their cost effectiveness. Priorities may then be assigned and systems procured by beginning acquisitions at the top of the priority list and proceeding down until budgetary limitations are reached. However, broad areas of research cannot be managed in this manner. Propulsion advances, for example, are not alternative to those in electronics or human engineering. All technological areas are essential, and each must receive its share of resources. Sound development demands proportional allocation of manpower, money, and materials.

going to any technical area depends on the operational value of advancements in that area, the probability of achieving planned advancements in the area, the cost of making these advancements, and the share of the total national program in this particular technical area which must be borne by the Air Force.

The value of a specific advancement in a technical area can be assessed only by an evaluation of its contributions to the technological force structure, particularly to the planning objectives. Adjective scales have been formulated to assist in the evaluation of each technical area of interest to AFSC with respect to each of the mentioned evaluation factors. In each case this evaluation is based on forecast trends of the technical parameters that are pacing progress in the area under consideration. A numerical index is calculated for each area by multiplying individual ratings for the technical area with respect to the several adjective scales provided. The total resources available are then allocated to the various areas in accordance with this numerical index. This planning tool has been used by one AFSC division to plan its resources utilization for the past three years on a full-scale test basis. The decision model currently in use, or a modification of that model, may be ready for use throughout the command in the near future. This model does not indicate the total quantity of resources required to accomplish the mission of a given organizational element, but it does indicate the most expeditious use of the resources that are available to any element.

PLANNING of research and development within the Defense establishment is quite important and also inevitable. Accordingly, an explicit, rational approach to this planning task has been described. Specific planning tools and decision models already in use within the Air Force Systems Command have been described, and the course of their future development has been indicated. The decision models described have been offered as an aid to the judgment of the executives within the Defense establishment who must come to grips with some extremely complex decisions. These techniques are suggested not as replacements for executive judgment but rather as a formal method for handling large numbers of judgments in a uniform manner. Their primary contributions would be comprehensiveness and consistency. The technological force structure and the Super-PERT provide a comprehensive overview of AFSC planning activities and permit integration of the

Decision Aids for Planners

Good military R&D planning accepts no substitute for the seasoned judgments of men with long, significant experience in research and development, in management, and in military operations. Securing the greatest possible benefit from such experience is an overriding task. Expert, efficient judgment can be focused and decisions can be strengthened by computer assistance in precise definition of problems, in providing check lists for uniform consideration of all relevant variables, and in storing judgments so as to avoid the drudgery of remaking the same decisions. The competent executive or military commander need not fear the automation of decision processes any more than engineers fear the slide rule. Rather, he should welcome any labor-saving technique that frees him from some of his enslavement to minutiae and enables him to devote a greater part of his time to decision.

strategic and technological dimensions of the research and development planning problem.

Such management tools facilitate decentralization of operative management to lower echelons within the divisions and centers of the Air Force Systems Command. The explicit nature of the planning tools permits flexibility and dynamic planning as unexpected contingencies arise. Theoretical contingencies can be postulated and examined with these tools to establish research and development policies. Possible future applications of such planning tools might include the establishment of criteria for measuring the effectiveness of technical area managers. They may also provide a basis for orderly organizational planning to attain the environment required to foster creativity and maximum research and development productivity.

Renewed emphasis is being placed on research and development planning throughout all echelons of the Department of Defense. For example, the national defense budget is presented to Congress with funding estimates extending almost a decade into the future. Weapon systems are now planned and initiated as complete system package programs, including cradle-to-grave cost estimates, plans for logistic support, personnel and facility requirements, and even a preliminary operational employment concept. The planning within AFCS reflects this new longer-range point of view. The resulting planning products are designed to produce new harmony and unity of purpose among the subordinate elements of the command. The primary impact on higher echelons takes the form of increased credibility and acceptance of proposals, which result from the demonstration that all salient aspects of each proposal have been adequately considered. The beneficial effects for both the implementers and the higher management surely will increase as further experience is gained and as planning methods are improved. More thorough planning in the context of technological warfare will develop a new and more adequate perspective of the true impact of military research and development in today's highly complex community of nations. Equally important is an appreciation of the significant extent to which military strategy is influenced by planning technology.

We dare not expend less than a maximum effort in military research and development planning. This effort must be sharply focused. Now is not the time to play games with other agencies or with other management echelons merely for the sport of getting approval of more projects than the competition or for the sheer pleasure of seeing decisions reversed. The Air Force Systems Command is the operational command in the current technological warfare, since it is the technological leader of the Air Force. The Air Force leads the Nation, and the Nation leads the Free World. Therefore the burden of technological strategy for the defense of the entire Free World rests squarely on this command.

Headquarters Air Force Systems Command

BASIC RESEARCH IN THE AIR FORCE

BRIGADIER GENERAL BENJAMIN G. HOLZMAN

IN 1960, in an essay defending the biological research program of the Air Force, I wrote that the ballistic missile is a stupid beast. It only goes where you tell it to go. If you do not know where to send it, it is virtually a worthless piece of hardware. Once launched on its trajectory, it is irrevocably committed. It cannot exercise judgment or make critical decisions, and in the event of instrumental errors or simple malfunctions it cannot make essential adjustments. Judgment, decision-making, and wisdom are capabilities that can be found only in a human operator.*

Since the publication of that essay, our data-processing machinery has grown increasingly intelligent. Components have become microscopically small, memories larger and more efficient, and switching speeds greater. This progress is recorded in hundreds of research papers that mark the advance of computer technology. In spite of the progress, the manned-bomber offensive delivery system is still the more economical, reliable, flexible, and efficient, and it will remain in our inventory of weapons well into the future.

We were sharply reminded of the unique role of the human operator when the automatic orientation system of Colonel Glenn's Mercury capsule operated erratically. The mission itself would have failed had not the human operator been there to control the capsule attitude. Until we are able to build into our missiles the machinery that can replicate with reasonable fidelity the great reliability and efficiency of the human brain, we must continue to depend heavily on the versatile mechanism of man's neural system.

Defending the role of manned weapon systems, which many among us (mentally at least) have already consigned to the Smithsonian, may seem remote from a discussion of fundamental knowledge. Actually it has a great deal to do with fundamental knowledge and with the Air Force research program. Those working close to the frontier of knowledge not only appreciate the promise of research but also realize its limitations.

*From *Science*, 132 (23 September 1960), 793-94. The same line of reasoning, I might note, was amplified in penetrating detail by Major General James Ferguson in *Air University Quarterly Review*, XII, 3 & 4 (Winter-Spring 1960-61), 251.

It is impossible to build a successful weapon system without a rigorous understanding of the basic physical principles upon which it operates. The scientist understands the broad barrier that often separates our present state of the art from our ultimate goal. Our research goal with respect to the manned bomber is, of course, to make it truly obsolete. We think we know the pathway to this goal—or at least we think we possess the knowledge that will help us select the pathway. This knowledge leads to an appreciation of the constraints that are real, the constraints that are imaginary, and the constraints that we hope are temporary. A knowledge of constraints is a prerequisite to effective research. Probably there will never be a computer to approach the sophistication of man's brain with its 100 billion or more components. Even simple animals with their primitive nervous systems can perform tasks far beyond the capabilities of the most advanced electronic gadgetry.

If we wish to eliminate man from our weapon systems and future space vehicles, we do not re-examine existing machinery to see what improvements we can make. The system that will be able to make rational judgments in flight, self-correct programing errors, and make decisions based on sensory inputs will not be a system evolving in a direct line of descent from present hardware. The system that fully replaces the manned bomber will incorporate techniques as yet undeveloped. The space vehicle that will routinely take us to the planets with a high order of probability of a successful return will in all likelihood result from research that has yet to be performed.

If asked the nature of this research, we cannot give an easy answer. I would guess that the research will have little relationship to the Air Force need for a completely effective ballistic missile. Let me describe a hypothetical scientist and a hypothetical research project. We will locate this man at one of our large universities. He is conducting the research project under a small Air Force contract of $12,000. This, I should add, is not an unusually small contract because basic research contracts are characteristically small, often involving a single investigator. Half the contract money will be spent on computer analysis.

This scientist is looking for a signal, a very weak signal buried deep in electronic background noise. Many hours of expensive computer time must be used because the weakness of the signal requires a lengthy correlation process. Ultimately the computer tells him that there is in fact a signal buried in the noise. He writes a technical paper on his work, and it is accepted for presentation at a scientific conference attended by leading scientists in his field.

What has been the important subject of this year-long study? What has the hypothetical scientist discovered? The subject under study was a sea worm, and he has discovered a brain wave in this sea worm.

For this bit of knowledge the Air Force has spent $12,000. Now

Research does not necessarily mean massive projects involving multitudes of men and intricate, costly devices. Often important discoveries result from the efforts of the individual scientist—the solitary researcher alone with his thought, his books, and the blackboards scrawled with the runic tracings of his trade.

if the signal in which our scientist was so engrossed had been one that originated in outer space and represented a message from some distant point in the universe, everyone would agree that the effort and the expense devoted to the project were worthwhile. But would it really be more worthwhile in terms of ultimate benefit to the Air Force? I don't think so. Neural systems—even those of sea worms—are the most efficient data-processing systems we know of. Any knowledge that helps us to understand neural networks places us nearer the time when we may be able to replicate them. An understanding of the simple system of the sea worm is a logical first step to the understanding of more complex systems. The computing systems of our future manned space vehicles or our ballistic missiles might well trace their origin to this one small project.

Ten years ago the staff officer at the Pentagon level reading of the brain wave discovery would have reached for the phone, called the laboratory director, and demanded to know why an irresponsible contract so foreign to Air Force needs was let. Today we at the laboratory level find that those at higher headquarters who review and pass on our program are increasingly well informed and enlightened as to the nature and purpose of fundamental research. In a sense this enlightenment represents a general reflection of the profound changes that have come about in our national attitude. Although we do not always profess to understand where our research efforts will lead us, we do recognize that research is the wellspring of future Air Force technology.

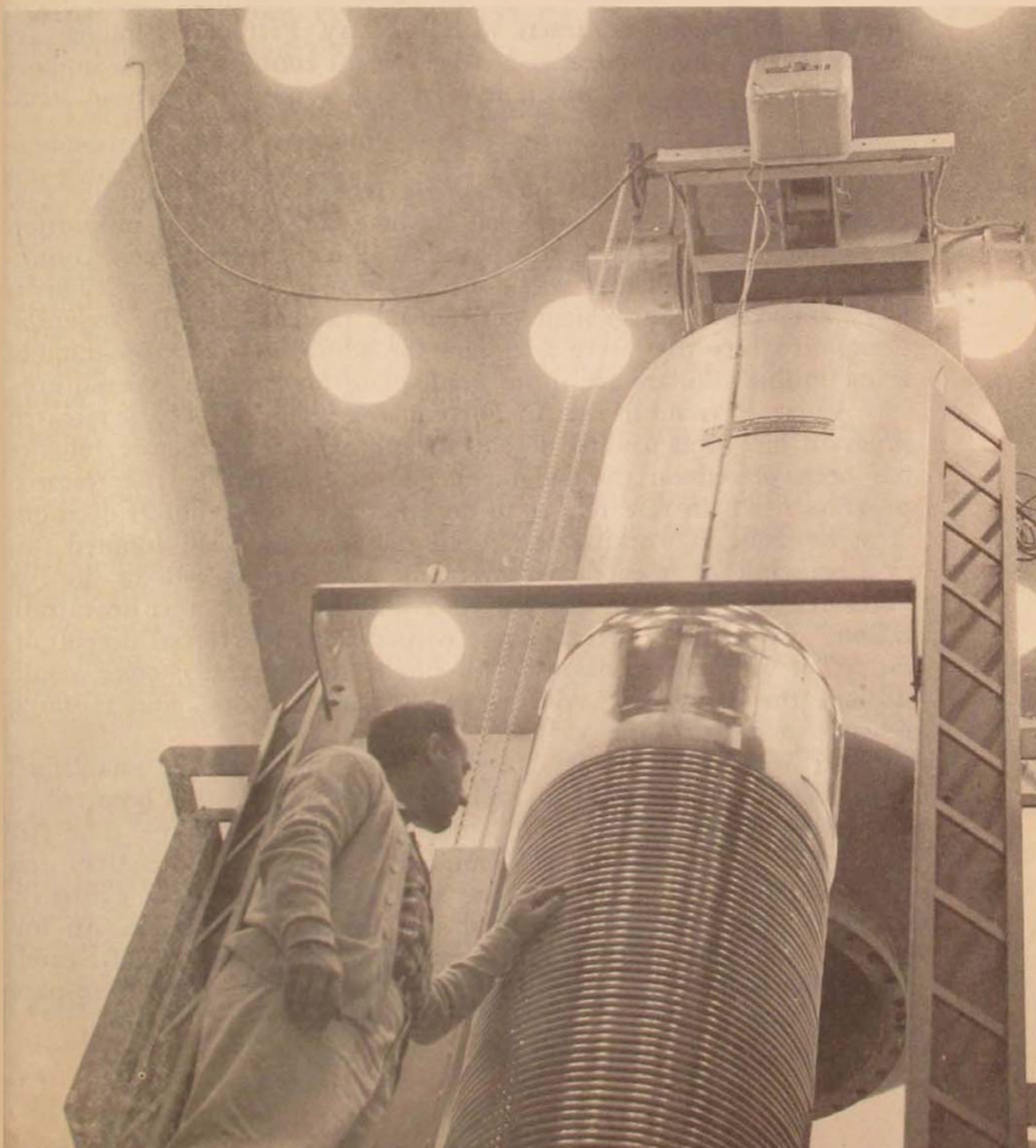
research—basic and applied

There have been many definitions of basic research—almost as many as there are people who have discussed the subject. In the main most scientists are agreed that basic research is concerned with the discovery of previously unobserved phenomena, with finding new insights into the subtle relationships of apparently unrelated events, with revising established beliefs, with constructing logical and consistent models of natural phenomena—in a word, with the ordering of the universe. Fundamentally, basic research tries to find answers to questions. In seeking these answers it often creates more questions than it answers. But at least we know that there is a question to be answered. The scientist engaged in basic research is not necessarily concerned with putting the new knowledge he seeks to practical application. He contributes to man's reservoir of knowledge. It is to this reservoir that those engaged in applied research and development must go for their raw material.

If we define fundamental research rigidly, we find that very few of our industrial concerns support research of this kind. They may claim to, under one or another of the many definitions for basic research, but in reality they do not. They are largely concerned with applied research. Most informed people are aware that industry tends to lump together all its applied-research, development, and product-improvement efforts and call these efforts basic research. But I suspect that these same people would be astonished to know that, under a strict Air Force definition, most of the research conducted within our universities can be labeled as applied rather than basic. The Air Force annually spends several hundred million dollars for research in universities, and the primary source of the funds is—surprisingly enough—the Air Force applied and systems research programs, not the basic research allotment.

In discussing fundamental and applied research in this fashion, I have deliberately distorted the difference. First, I may have implied that fundamental research is more important than applied research. This would be equivalent to saying that eggs are more important than chickens. Next I have implied that there is a sharp demarcation between fundamental and applied research. What we are really talking about is a spectrum. Just where fundamental research ends and

The 3-mev Van de Graaf electrostatic generator at a special Air Force facility for research on radiation damage to electronic materials and devices. In addition to the Van de Graaf for generating high voltages, the laboratory facility has a cobalt-60 radiation source of 10,000 curies. Research is also directed to improving the electronic characteristics of materials through radiation bombardment.



applied research begins on this spectrum cannot be rationally determined. But intrinsically it makes no difference to the Air Force, except for bookkeeping purposes, as long as the research is of some practical Air Force interest, however tenuous.

So it is impossible to say exactly how much money the Nation or the Air Force is spending on basic research. We do know that the expenditure is rising. The budget figure given for the Air Force basic research contract program has risen over the past seven or eight years from a few million dollars to about $50 million at the present time. Many arbitrary classifications of individual research efforts were made in order to arrive at a discrete group of projects which the Air Force calls its basic research program. Even if we accept the classifications as completely valid, the Air Force expenditure for basic research is actually much higher because it does not include Air Force support of in-house laboratories and not-for-profit groups. One buried research expenditure is an outgrowth of Air Force multimillion-dollar development and systems contracts with industry. Part of the money received by the company under a development contract goes to support its own basic research, which it carries as a normal overhead item.

research management

As the Air Force has increasingly recognized the requisite role of fundamental research and has devoted an increasing proportion of its budget to research, the patterns of management have continuously changed, and they will doubtless change in the future. This is to be expected. Management policies and practices and the organizational structure that were adequate for administering a program of a few million dollars are quite inadequate for present expenditures.

A marked trend in the Air Force management of its basic research program has been toward decentralization. More and more reliance has been placed on the judgments of those closest to the research program itself. In research, as in no other activity, technical decisions must be made at working level, and the Air Force has adopted this as a principle of research management. The very growth of the Air Force research program has played a part in forcing this decentralization, just as the growth of large corporations has forced decentralization of product divisions. No single headquarters office could manage the day-to-day activities of the large, diverse, and far-flung research activities of the Air Force.

Let us consider the Air Force structure that has been established to manage these activities. In 1961 a major reorganization occurred in the research and development activities of the Air Force. The Air Research and Development Command, which for more than ten years had managed the Air Force R&D effort, passed from existence. The Air Force Systems Command was created in its stead. An important but small segment was carved out of the old Air Research and Development Command and became the Office of Aerospace

Research. This office assumed Air Force responsibility for that research toward the basic end of the research spectrum.

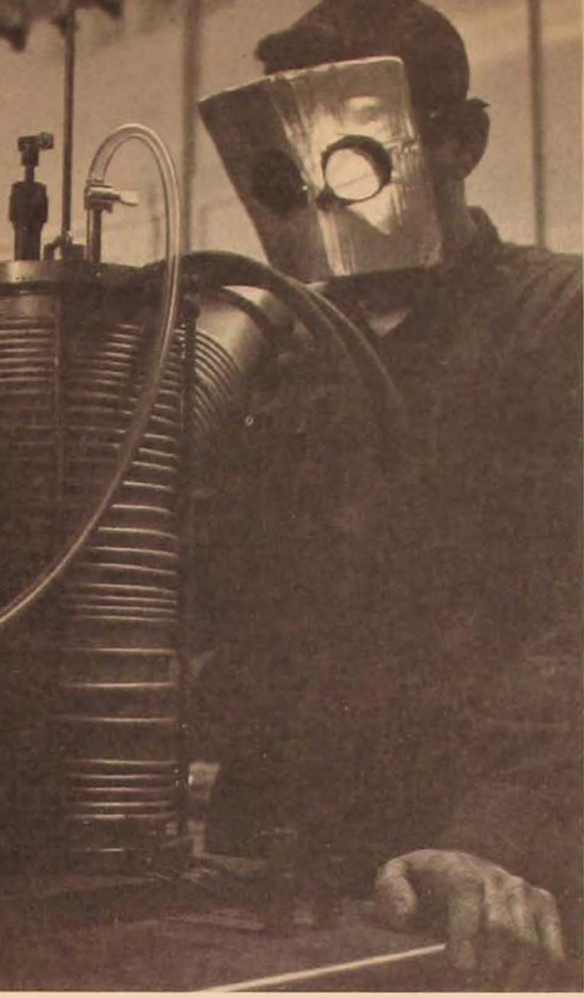
The Office of Aerospace Research, located in Washington, D.C., inherited the largest in-house laboratory group of the Air Force, the Air Force Cambridge Research Laboratories (AFCRL); also a smaller in-house group at Wright-Patterson AFB, the Aeronautical Research Laboratories; the Air Force Office of Scientific Research, primarily a contract group engaged in supporting basic research; and another small group in Brussels, the European Office, responsible for managing the sizable Air Force contract effort with European industry and universities.

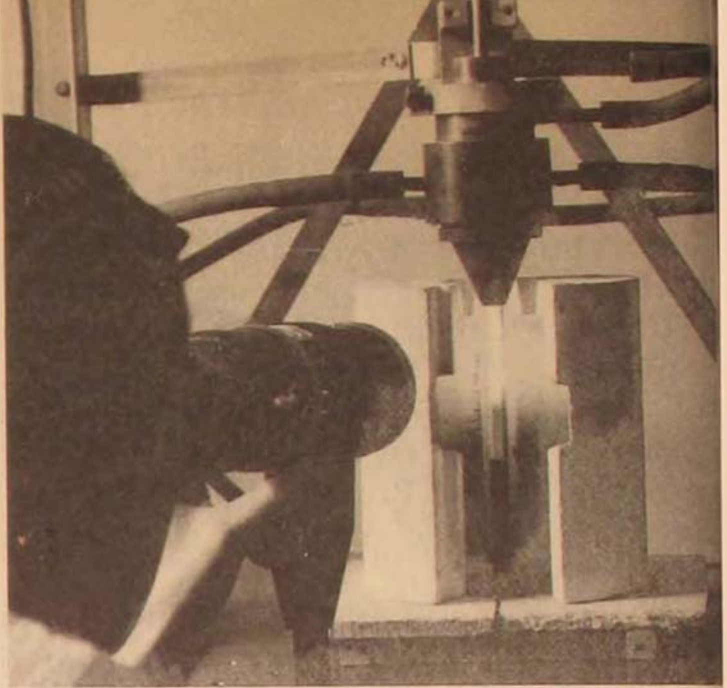
There is still another channel through which the Air Force supports basic research. This is through the not-for-profit institution. The Lincoln Laboratory, the MITRE Corporation, the RAND Corporation, and the Aerospace Corporation all conduct Air Force-funded research. The Lincoln Laboratory and the RAND Corporation have been with us for some time, but MITRE and Aerospace are relatively new.

The Air Force technique of establishing nonprofit contractors to conduct research has recently aroused a good deal of discussion. Since the Air Force already maintains a large contract research program and conducts research within its own laboratories, why was it necessary to set up these nonprofit organizations? Why not expand the Air Force in-house laboratories? The Air Force would like to expand its laboratories. For my part, I should like to see the Air Force Cambridge Research Laboratories doubled or tripled in size. Practical and realistic considerations—manpower, budget, and resources in general—preclude it. These are the rocks upon which so many hopefully launched recommendations by scores of Air Force study committees have foundered.

It would be well, I think, to note certain things implicit in the Air Force research mission because this mission has made the Air Force not-for-profit contractor a practical necessity. The Air Force research mission is to conduct research in *all* fields of science of potential interest to the Air Force, not just in those fields where capability exists. The domain within which the search for new knowledge takes place is not one restricted to U.S. scientists. For this reason the Air Force research mission has both a positive and a negative side. We must be the first to uncover and to exploit new knowledge in order to maintain Air Force superiority. The negative corollary is that we cannot permit any adversary to accrue some new knowledge that we may not have—and worse, that we may not be aware of. We must therefore be thorough, we must investigate all fields, we must continuously probe or guard each subsector of the frontier of knowledge. We cannot leave vulnerable gaps where no work is done.

The frontier is explosively expanding. It is also a frontier with a diversity of features. The fragmentation of scientific disciplines and



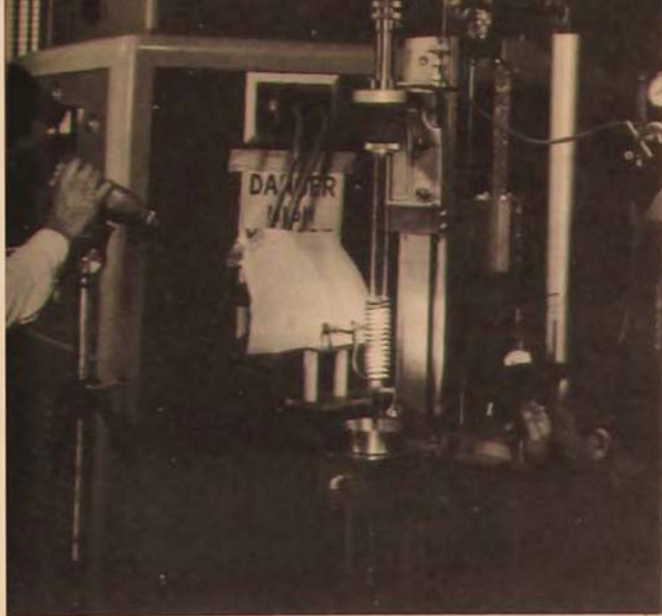


The artificial production of single crystals for use in electronic devices comprises one of the largest Air Force efforts in electronics. Induction furnaces form the single silicon or germanium crystals.

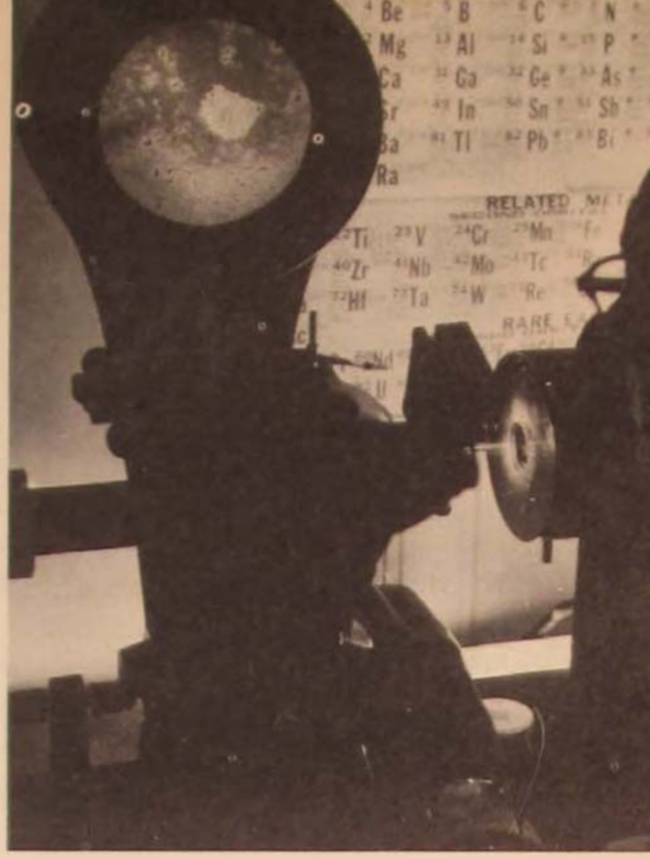
the violent acceleration of the volume of scientific literature are almost frightening phenomena. They have combined to force us each year to enter new fields. Once we have entered the field, we must then have within the Air Force the capability to sift through the research product and to relate this product to Air Force needs. All this has a direct bearing on the establishment of the not-for-profit institutions. Each of them has a different mission. Some perform pure research; some attempt to correlate the scientific data and to interpret and exploit these data for the Air Force.

It is true that much of this role could be filled by the Air Force laboratory, and it is being filled to a limited extent wherever these laboratories have the capability. But in the fierce competition for qualified scientific manpower, the Air Force laboratory is at a grave disadvantage. There are many factors that influence the expansion of an in-house laboratory. Manpower spaces are one of the more influential of these factors. Recruitment is another. Even if the recruitment of qualified scientific talent were not a problem, we in research recognize that the operational commands can ill afford to transfer several thousand manpower spaces to the research commands.

We find that we cannot get around the not-for-profit institutions by simply expanding our contract program. There is a limit to expansion in this direction. There must be someone within the Air Force—or responsible to the Air Force—who is qualified technically to evaluate the contractor proposal and who can tell the contractor,



A Verneuil furnace grows aluminum oxide crystals—ruby, sapphire, and rutile.



The man-made crystals are carefully evaluated under a microscope.

in effect, "Your research proposal could be of great interest to the Air Force were it not for the fact that your approach violates certain fundamental laws of physics." If on the other hand the proposal is good, then there must be someone within the Air Force who has the insight to recognize its merit and know whether or not the work relates to Air Force problems.

The supply of people within the Air Force qualified to make such judgments is limited. In relying on contracts too heavily, we also lose cohesion. The parts of the program are scattered and unrelated. The not-for-profit organization, then, represents the only means at the disposal of the Air Force for filling its expanding technical mission. Through these organizations we are able to augment Air Force scientific manpower without raiding the operational commands. These not-for-profit organizations are sensitively responsible to the Air Force; they apply themselves to the evaluation of the product of research and assemble relevant parts into a meaningful pattern in terms of Air Force needs.

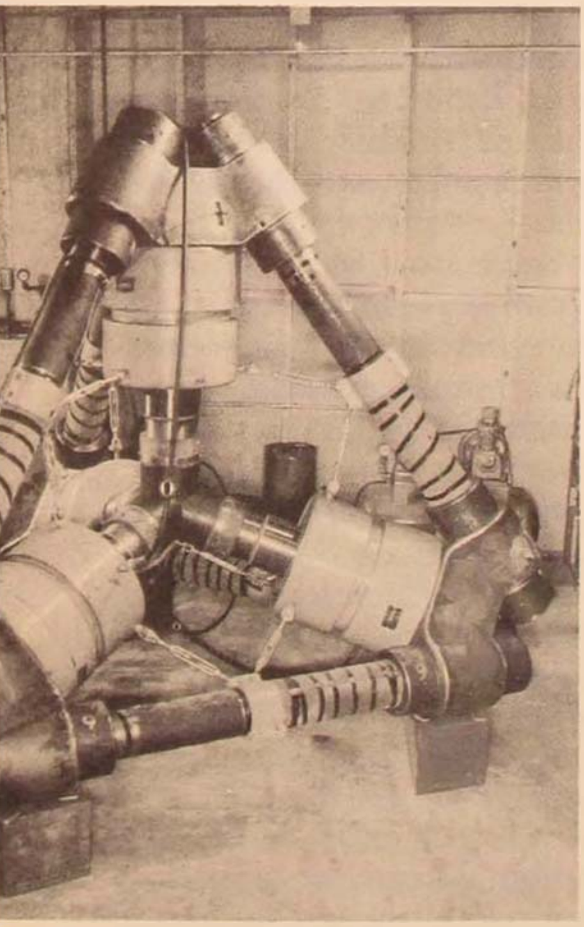
research and Air Force needs

What are the needs of the Air Force? They can be described simply. We would like more efficient propulsion systems, we want to communicate over all distances with improved reliability and security, we want to be able to build more intelligence into our computers, we want to detect and destroy all hostile vehicles, and we want to know and understand all aspects of the environment within which the Air Force now operates and will operate in the future.

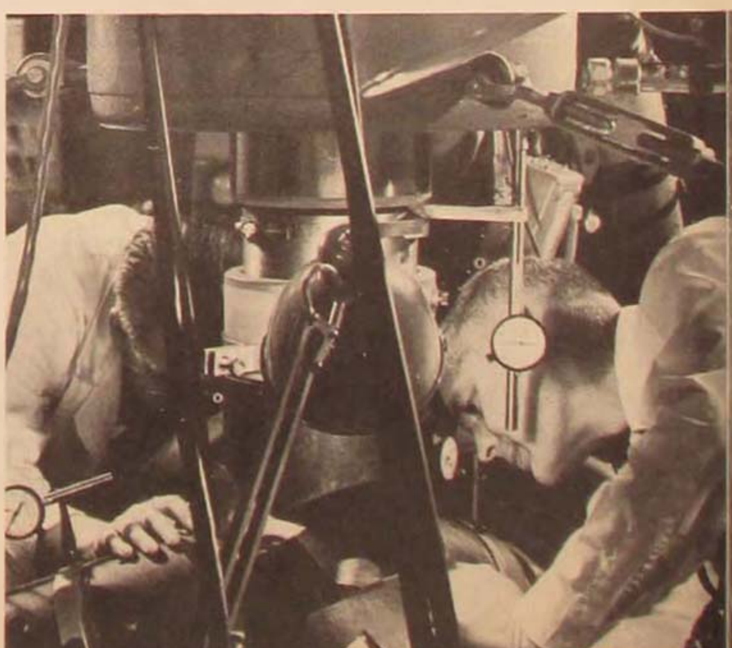
Keen insight—insight growing out of scientific knowledge—is required to gauge the potential of a research effort from the standpoint of these needs. As we move toward the basic research end of the research spectrum, the potential in relation to Air Force needs becomes increasingly blurred. Also the probability of payoff decreases. In backing basic research we are backing the long shot. If there is a payoff, however, it may be one of magnitude.

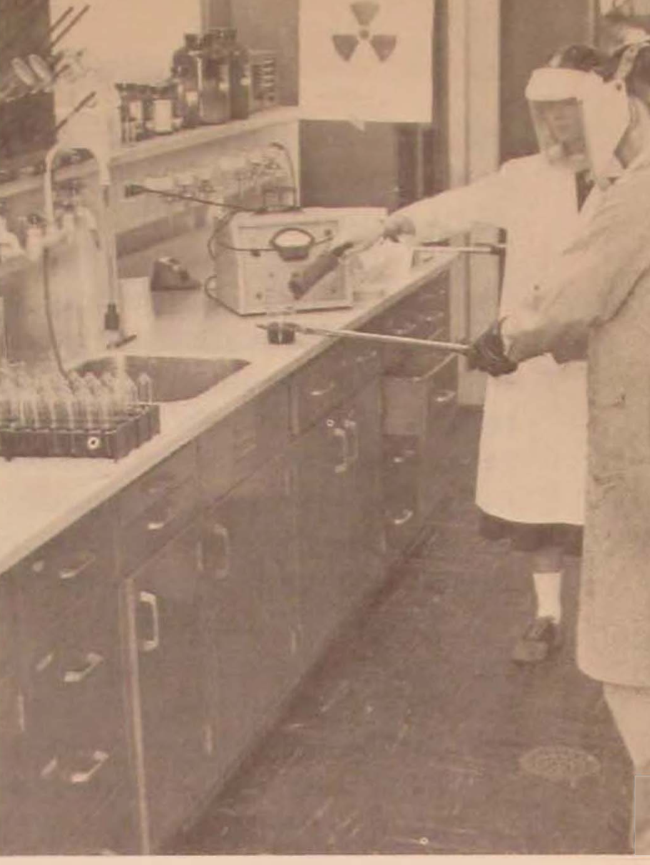
By way of example of research in its purest form, I would like to describe one research effort which the Air Force supports at AFCRL. This effort is carried out by one man, Dr. Johannes Plendl, who may be found among the many top civilian scientists serving in Air Force laboratories. Dr. Plendl is a theoretician. He needs no equipment except a note pad, a desk, some reference books, and a blackboard. For three years he has investigated atomic lattice vibrations. Naturally he would like to make a discovery that would lead to an improvement in Air Force capability, but this is not his primary motivation. His basic objective is to uncover some new aspect of the cohesive forces that hold matter together in the solid state.

Over the past year or so Dr. Plendl has published the results of



A tetrahedral anvil press used in growing diamonds. The diamond, potentially an excellent semiconductor, functions at temperatures far exceeding the operational temperatures of silicon and germanium. The Air Force, among the first research organizations to grow diamonds in this way, subjects many materials to ultra high pressure and temperature, hoping to discover materials that have favorable electronic characteristics.





Air Force scientists examine radioactive material that has passed through an ultrapurification process. Before a crystal of semiconductor material can be grown, the basic solution must be highly purified. A neutron activation process measures the level of impurity of the source material.

his research in a series of three papers appearing in the *Physical Review.* Already references to his work are given in papers published by others. Dr. Plendl has discovered a previously unknown relationship among the lattice vibrations of certain crystalline materials and has formulated a set of laws governing these lattice vibrations. A more comprehensive understanding of hardness of materials has evolved from this research, and doubtless future textbooks on crystallography will devote considerable space to Dr. Plendl's work.

Important as Dr. Plendl's work may be from a scientific standpoint, it is not a breakthrough in the accepted sense. It does not directly promise the Air Force a new and unique capability. The results were not even reported to higher headquarters as a research accomplishment. This research may represent only a curious observation without immediate prospect for practical application. On the other hand Dr. Plendl's discovery could lead in many bright directions. With an expansive imagination we can see implications to all major areas of Air Force electronics—to communications, to detection, and to data processing. For space applications, we can see the work leading to smaller and smaller electronics packages, to greater reliability, and to new materials that resist high temperatures and ionizing radiation. When we describe the work realistically, however, all we can say is that the research results will help the crystal physicist to better understand crystal structures. The journey from there to a piece of operational hardware is a far, far distance. Dr. Plendl's theorems are simply available to other scientists, one of whom may find in them a key to some magnificent prize for the Air Force. The point is that such work must be performed and the results placed at the disposal of the applied research scientist, or certainly there can be no prize.

Let us build on this example. The research relates to one of the largest research areas of the Air Force, electronic materials research. Our electronics equipments of the future will evolve not from increased sophistication in present components but from radically new items made possible by the discovery of basically new electronic materials. What is imposed on us is a painstaking atom-by-atom investigation directed toward the combination of atoms in new forms and the equally painstaking testing of these new substances to determine whether or not they possess useful or promising characteristics. Much current effort is focused on crystals.

Crystals of present interest to the Air Force are rubies, sapphires, garnets, rutiles, fluorides, tungstites, and other solid crystals. We now have in one of our laboratories a high-pressure, high-temperature press that will produce diamonds, potentially an excellent semiconductor. The Air Force is using this press primarily, however, not for producing diamonds but for subjecting a variety of materials to extreme high pressure, hoping to develop some new material not found in nature that may have unique electrical properties.

We do not know what this research will uncover. But in 1953, when we began an intensive research program in silicon purification and silicon single-crystals growth, no one would have predicted that this work would give birth to a major sector of the electronics industry, that sector concerned with silicon semiconductors. Is there a crystal now under investigation that may, through impetus given by the Air Force, follow a development pattern similar to that of silicon?

I would suggest silicon carbide as a candidate. Silicon carbide semiconductors can operate at white-heat temperatures and can withstand high radiation dosages. In 1962 an ingenious furnace designed by AFCRL went into operation for growing silicon carbide crystals of large size and high purity level. If silicon carbide lives up to its promise, we anticipate that in 10 to 20 years silicon carbide transistors will have become an essential part of our space technology.

The Air Force materials research program is not unique. All the crystals I have discussed are being investigated under a diversity of research approaches in industrial, university, and military laboratories all over the country. A great deal of this materials research—in some cases as much as half—is being supported by the Air Force. This support arises out of the desire to channel the research along lines of Air Force interest.

The question might be raised as to what distinguishes Air Force interests from the interests of others. The answer is found in the kinds of technology desired. The demand of the military for new technologies has far outstripped the relatively modest demands of the civilian market. Germanium transistors are adequate for civilian products. There was no need from the standpoint of the consumer market to investigate silicon simply because silicon promised better heat-resistant properties. Certainly from the standpoint of a consumer product there is no need to investigate silicon carbide, which can operate at 750°C and also resists radiation damage.

research and space

As we review the many Air Force research efforts in the many scientific disciplines, a curious pattern becomes apparent. We see that the product of this research, as in the case of silicon carbide, leads rather directly to some space application.

How did this pattern come about? Did some higher headquarters direct that the Air Force research laboratories support heavily those projects relating to future space operations? The pattern evolved from a combination of factors, one of which is a natural outgrowth of scientific progress. But it evolved also from a partly reasoned, partly intuitive judgment that space must be the future environment of the Air Force. The Air Force is not interested in space per se. It is interested in carrying out its surveillance, warning, and defensive mission more effectively.

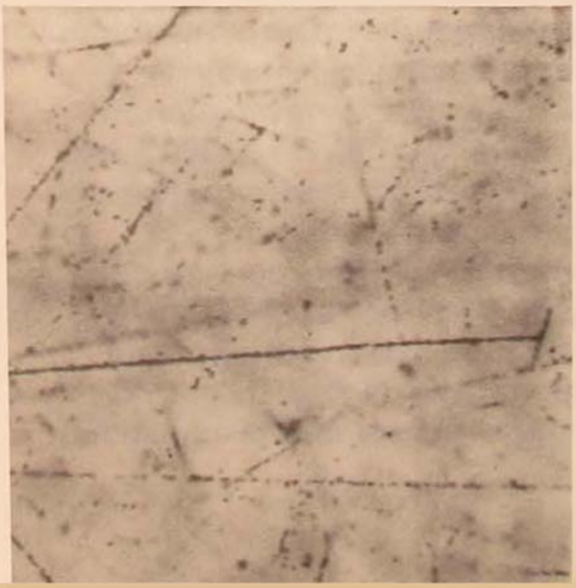
To an increasing extent the Air Force relies on the scientist to tell it what is feasible, what is not feasible, and what appears to be just over the horizon. This advice provides the basis for future strategic and defensive concepts. Difficult decisions based on this advice, which invariably is couched in restraining qualifications, must be made by the Air Force. Should we wait, for example, until a new, highly acute sensitivity detector is fully developed, until a highly efficient solar energy conversion technique is practical, and until precise measurements of atmospheric and communications parameters are made before we begin to consider assembly of a new satellite surveillance system? Obviously not.

If we sit back and wait until the success of the surveillance system is absolutely certain, unnecessary years of delay will ensue before the operational vehicle is launched. We must emphasize today certain research efforts related to the system, and we must gain a base of experience for those space operations that might involve the vehicle. While space holds high promise of enhanced capability, this enhanced capability is still only a promise. Scores of technologies must emerge into feasibility before the promise is realized. One of these might well be the radiation-resistant silicon carbide semiconductor, which in extending the useful life of the electronics equipment in a space vehicle could spell the difference in economic feasibility.

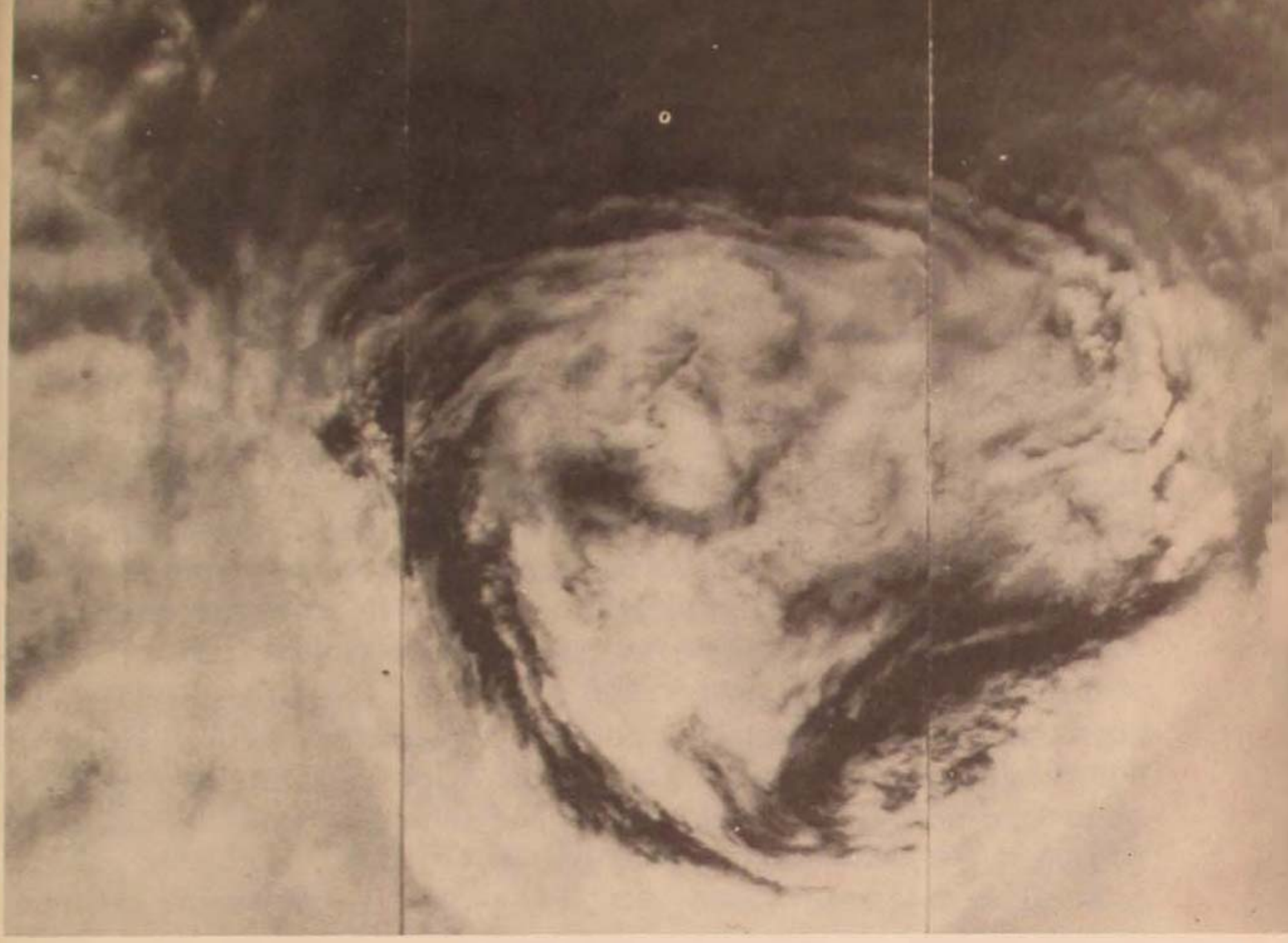
The accelerated pace of scientific research and the new and unknown directions in which this research is taking us have forced the Air Force, the DOD, and the Administration into a re-examination of the Nation's over-all research and development effort—and the proper roles of its many agencies responsible for major phases of the research effort. The National Aeronautics and Space Administration has the primary responsibility for the exploration of space for peaceful purposes. But this broad mission responsibility is intimately associated with an identical Air Force mission to maintain the peace. If the Air Force is to evolve effective military systems, it must seek an understanding through research of all the unknown parameters of space. To allot research in space for either peaceful or military purposes would be much like assigning the responsibility to exploit Newton's laws of physcis to one group and not to another.

During the Thirties and Forties a somewhat similar division of responsibilities in research areas existed in meteorology. The U.S. Weather Bureau was generally considered as the Government agency having the primary responsibility for the furtherance of atmospheric research. Yet the atmosphere is the medium in which the Air Force lives. Today 14 different Government agencies are involved with the conduct of meteorological research because of the intimacy of this science with their mission. A most harmonious relationship has always existed between the military and the U.S. Weather Bureau in pursuing research in meteorology, mainly because its Chief, Dr. F. W. Reichelderfer, who himself had a military background, understood that it would be impossible to separate the atmosphere for civilian purposes and military purposes. There is no scientific knowledge of the atmosphere that would not have equal importance to both civilian meteorology and military meteorology. Nor is there any scientific knowledge pertaining to space that may not have pertinence to the military. We cannot categorize space operations and space research as pertaining primarily to the mission of one agency or another.

Space operations, from the standpoint of surveillance and warning, appear to be on the not-too-distant horizon. Already several large systems are at an advanced planning stage. Destruction is another matter. Today the prospect of achieving the ability to kill a hostile ballistic missile in space appears dismal. But I suspect that the solu-



Cosmic rays are detected by means of photographic emulsion blocks sent into space by satellite or balloon. When a cosmic ray (high-energy proton) strikes an atom in the emulsion block, the atom is split, generating subatomic particles. Their tracks expose the film. The objective of the research is to determine the frequency of occurrence of cosmic rays and thus the danger they may hold for man and for his vehicles in space.



Hurricane Carla photographed in September 1961 by AFCRL's U-2 airplane from an altitude well above the 50,000-foot height of the hurricane. Three film strips, each representing a 25-mile segment, compose this view of the storm. A Tiros satellite simultaneously filmed the storm from a higher altitude, and scientists' interpretation of its pictures was assisted by comparison with those of the U-2.

tion of this problem will be found only by researches leading to operations in space. Too often our thinking on this matter has been earth-bound, as if seeking a means of destroying a high-flying bomber from the bottom of the ocean.

Because of the Air Force's long-standing anticipation of future space operations, we often find within Air Force laboratories the Nation's top scientific investigators in fields of research directly related to Air Force space operations. A number of examples will indicate the wide scope of these investigations.

Geophysics. The history of Air Force space probes spans the years from the V-2 rocket flights back in the Forties to today's piggyback rides on ICBM's and satellites. Through instrumented rockets and satellites Air Force research laboratories are producing a constant stream of valuable geophysical data influencing almost every phase of our atmospheric and extra-atmospheric operations. In 1961 scientists in one Air Force laboratory alone (AFCRL) conducted experiments in more than 100 satellites and rockets. Instrumentation for these experiments, often ingeniously designed, covered a range of research areas. Of particular importance are the variations in pressure, temperature, and composition of the atmosphere at all levels. In many cases the only such information recorded consists of data taken by Air Force scientists. Atmospheric density at extreme altitudes is of critical importance to the X-20 Dyna-Soar program. If estimated density at the critical re-entry altitude is in error by as much as 10 or 15 per cent, the Dyna-Soar vehicle could miss its scheduled landing area. Other rocket and satellite instrumentation packages were designed to collect data on such diverse matters as micrometeorites, extreme ultraviolet solar radiation, auroral characteristics, and geomagnetism. Data from non-Air Force research vehicles are often made available to Air Force scientists for analysis. Films taken from the Tiros satellites are a prime example. The value of this weather satellite to the military meteorology program cannot be overstated.

Radio Astronomy. The Air Force has long considered radio astronomy to be intimately a part of its research function. Using its own large radio telescopes and through contracts with leading radio observatories, the Air Force has mapped the radio stars, has examined hydrogen gas densities in space, and has plotted sources of galactic noise. This information has become a part of the literature on space and represents the general background of information upon which future space planning will be based.

Radio telescopes are an intrinsic part of space hardware. Since electromagnetic theory dictates that increased resolution or sensitivity of an antenna can be achieved only by corresponding increase in the size of the antenna, antennas designed for focusing the weak signals from space have grown increasingly large. The largest of these antennas is the 1000-foot radio telescope completed at Arecibo, Puerto Rico, in the latter part of 1962. The Advanced Research Projects Agency (ARPA), AFCRL, and Cornell University have joined together to bring this incomparable research instrument into being. With this huge, sensitive instrument we will be able to look farther into space than man has ever been able to look before. We have created a new world center for radio astronomy.

We should keep in mind the essential contributions made by the respective agencies involved in this effort, for the joint effort it represents is more and more characteristic of the diversity of skills needed in our large research endeavors. Certainly to Cornell University must go the credit for conceiving the large dish at Arecibo and for the basic design of the telescope itself. The installation is on Air Force property, in a natural bowl formed by several mountain peaks.

The particular configuration of the Arecibo radio telescope was made possible as the result of research conducted within the Air Force in 1952. This research consisted of a theoretical study on the correction of aberrations in spherical reflectors. The Air Force technical report on this matter gathered dust in the archives of our technical libraries until the special need, represented by the Arecibo dish, was created. Future space operations will rely heavily on the Arecibo telescope.

But the Air Force research scientist is already considering larger antennas. AFCRL has proposed an unconventional antenna configuration which will have an effective aperture of over 2000 feet yet can be built with relative economy. This antenna, as proposed, would be six or seven times as sensitive as the Arecibo telescope. With this antenna the range of communications with space vehicles will be more than twice the range possible with the highly sensitive Arecibo telescope. A model of this unique antenna is now being constructed by the Air Force.

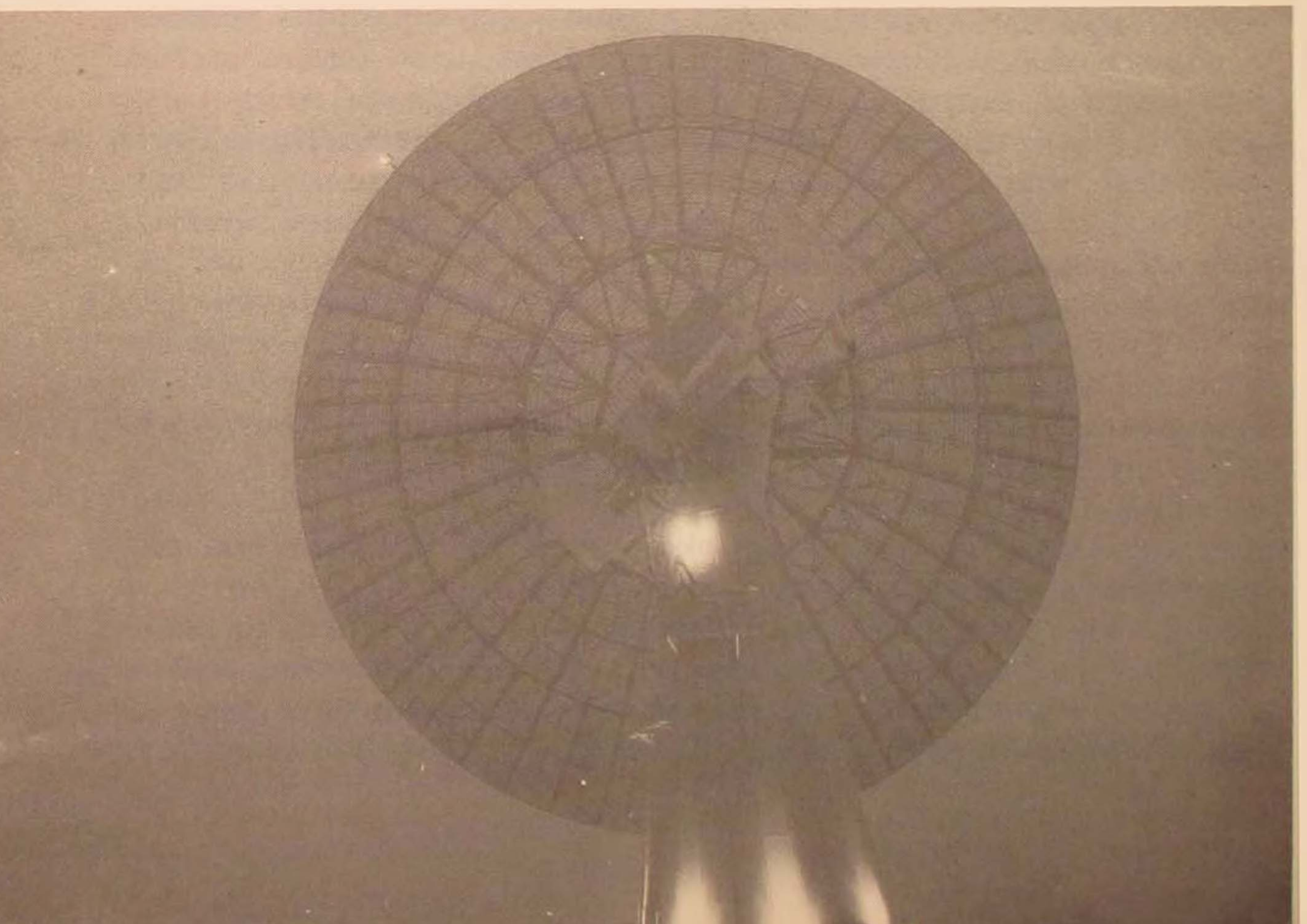
Solar Observations. At Sacramento Peak Observatory in New Mexico the Air Force operates one of the most complete solar observatories in the world. Many studies are being carried out at this observatory that have a bearing on future space operations. One such study of immediate and critical importance involves protons emitted from the sun. Fast solar protons may be the biggest hazard the space traveler will have to face. Unlike the Van Allen radiation, the position of which is known and presumably can be avoided, solar proton radiation is intermittent and cannot be easily predicted over long periods. To the unprotected man solar protons can be exceedingly dangerous, and they can damage some types of sensitive instruments. The least expensive defense against damage is simply to avoid solar proton showers by limiting operations to safe time intervals when they do not occur. AFCRL scientists at Sacramento Peak Observatory are studying methods for predicting the safe periods. The observatory has been making 5-day predictions with great accuracy and is now focusing attention on extending the forecast period. NASA relied on its predictions in scheduling the first manned Mercury orbital vehicle.

Plasma Sheath Research. For a number of years a team of Air Force scientists, supported by a number of well-chosen contractors, has been investigating the properties of the plasma sheath, the ionized gas envelope that surrounds a missile or a rocket on re-entry. During the critical re-entry phase the plasma sheath can completely nullify telemetry, communications, and radar equipment for a period of several minutes to a half hour, depending on the nature of the re-entry vehicle. The Air Force is attempting to overcome communications blackout during re-entry by a combination of proper frequency selection and antenna design. Through research tests with missiles the Air Force hopes to minimize plasma sheath effects. Lack of a solution to the plasma sheath problem would prove particularly severe for Dyna-Soar, since the pilot could be isolated from all communications for a period up to 30 minutes.

To these examples of research programs directly related to space operations can be added scores of others—research in nuclear, chemical, and electric propulsion; in life sciences, aeromechanics, geodesy, infrared radiation, optics, energy conversion, propagation character-

To focus all signals to a common point, reflecting radar antennas, whether used for communications or astronomy, are usually given a parabolic configuration. In many respects the spherical antenna is more efficient, but a means must be found to correct its aberrations. One means is the Cassegrain technique of adjusting focus, as in the experimental antenna here. The signal is first reflected by the primary reflector to the surface of a secondary reflector in front, which then reflects the signal to the pickup point.

Air Force radio telescope in Massachusetts is used for investigating atmospheric densities, measuring refraction indexes, and communicating by means of moon relay.



Artist's sketch of the 1000-foot radio telescope at Arecibo, Puerto Rico, the largest in the world. Completed in the fall of 1962, it was funded by the Advanced Research Projects Agency and constructed under Air Force management, the prime contractor being Cornell University. With the Arecibo radio telescope man is able to "see" farther into the universe than ever before.

istics of satellite signals passing through the atmosphere, satellite tracking, and topography and atmospheres of the planets; and in studies of meteorological factors involved in launch and recovery operations.

I HAVE TOUCHED on research falling at many different points along the research spectrum—some at the basic end and some at the limits of applied research bordering on development. In doing so I hope I have also left the impression that research must be considered as something more than the kind of activity typified in two of the examples I have used—the search for a brain wave in the sea worm and Dr. Plendl's lattice vibration studies.

While these examples perhaps represent the classic notion of research, research embodies much more. It exists at many levels in an intricate and complex web of activities. The physical process of research consists of observing, measuring, recording, and analyzing natural phenomena—atomic and subatomic particles, gravity, the elements, electromagnetic behavior, the earth, atmosphere, the sun and stars. Man-made components, equipments, and large systems are subjected to like processes.

Our Air Force has witnessed a geometrically increased dependency on technology, and this technology is hemmed in by the limits of our scientific knowledge. The bounds of scientific knowledge set the restraints to the technical ambitions of the Air Force. While an increased budget for research is a partial solution to easing these restraints, the rate of expansion of our scientific knowledge is set ultimately by the availability of our national scientific brainpower. The Air Force has the obligation to see that this resource is used wisely and to purpose. For this the Air Force must necessarily rely on the scientist for guidance.

The scientist, in a sense, serves the Air Force as odds maker. He tells the Air Force the probabilities of payoff for a given expenditure on a given research effort. He cannot speak with certainty because the results of research are never certain and the factors involved are enormously complex. In an Air Force that has come to assume that all things are ultimately possible through science, the scientist has become the practical realist. He at once encourages the Air Force to investigate a diversity of research fields and carefully delineates the constraints, founded in physical limitations, to Air Force aspirations.

Air Force Cambridge Research Laboratories

FROM CONCEPT TO APPLICATION

Colonel Lee R. Standifer

REGARDLESS of field of endeavor only the ignorant fail to recognize the very real area that exists between the birth of an idea or concept and its eventual realization in some form of practical application. In science and technology this area, usually wide and topographically crisscrossed with many dead-ending paths of investigation, is the realm of applied research. Further description of applied research is difficult because of the frequently vague interpretations given to the terms "concept" and "application." These differences in interpretation may be as varied as the backgrounds of the individuals concerned with any given development problem. In this regard then, "concepts" in applied research may be theoretical postulates formulated from the results of basic scientific research, or they may be required technological capabilities derived from analysis of desired future weapon systems. The product of applied research is that new practical knowledge which makes advances in technology possible.

If any difference can be said to exist between basic and applied research, it is in the philosophy or motivation which underlies the research. Any other distinction is arbitrary. The Air Force recognizes the philosophies that can apply and differentiates its research accordingly. It performs basic research, which is neither time-oriented nor weapon-system-oriented, solely to provide the most comprehensive store of scientific knowledge possible. Modern society is identified in both comfort and living standard with its technology, and it is also protected by its military technology based on science. If we are to survive in this era of threatening sociopolitical ideologies, with their own rapidly emerging technologies, we simply cannot afford to relax our efforts in basic research.

Applied research is said to derive from and have an interface with basic research, but actually it overlaps basic research. The Air Force recognizes two distinguishing characteristics of applied research:

(1) Applied research has some desired objective.

(2) Applied research has a time schedule, albeit not a rigid one, within which this objective is to be reached, if possible.

The objective may be as general as the laboratory synthesis of a new, theoretically predictable compound or as explicit as the measurement of the thermal diffusivity of a proposed nose cone material. Thus applied research may exploit further any interesting phenomenon uncovered by basic research, or it may attempt to solve a specific requirement dictated by an advanced system concept. In either case the objective is acknowledged as having foreseeable application by the Air Force. Of particular significance is the fact that the result of applied research will frequently create new concepts as well as feed back into current concepts for advanced systems.

technical areas

The knowledge continually evolving from basic research and the ever changing desire for advancements in weapon systems dictate a dynamic applied research effort which, in the Air Force, is administered by the Air Force Systems Command. To prevent undue abrupt dislocations in the program, AFSC distinguishes a number of "technical areas" as having continuing pertinence to all systems. The current list consists of 27 technical areas. They are defined in broad terms so as to accommodate the minor perturbations in specific objectives which occur as a result of annual review. The evolution of the detailed specifics encompassed by each area is a complex process requiring many data feedback channels and much coordination.

Air Force Applied Research Technical Areas

Program Structure	*Technical Area*
710A	Nuclear Weapons Effects
720A	Nuclear Applications
720B	Aerospace Ground Equipment Techniques
720F	Deployable Aerodynamic Decelerators
720H	Materials
730D	Navigation and Guidance
730E	Flight Control
730F	Aerospace Vehicle Detection and Defense Techniques
730J	Computer and Data Processing Techniques
740A	Advanced Weapons
750A	Mechanics of Flight
750E	Non-Rocket Propulsion
750F	Flight Vehicle Power
750G	Rocket Propulsion
760B	Surveillance Techniques
760C	Communications
760D	Electromagnetic Warfare
760E	Electronic Techniques
760F	Reconnaissance
760G	Electromagnetic Vulnerability Reduction
760H	Intelligence Techniques

760K	Electromagnetic Wave Techniques
770A	Aerospace Environment
780A	Life Support
780B	Aerospace Medicine
780C	Radiobiology
780E	Human Performance

Each technical area is assigned a technical area manager (TAM). In general, that particular AFSC division exerting the greatest effort in a given area is made responsible for that area and for providing a competent individual to function as TAM. It may be that all the projects and tasks which comprise a technical area are not performed wholly by one division but may be performed in fact by other divisions or command elements. Each AFSC activity that has actual work or urgent requirements in a particular area appoints as its representative a technical area coordinator (TAC), who works with and supports the technical area manager in preparing an integrated program.

Although it is true that applied research is formulated from promising basic research and the dictates of advanced system requirements, these are not the only sources of guidance for the TAM/TAC team. The Scientific Advisory Board and its recommendations are an influence; the gaps revealed by accomplished work are another; and there are always deficiencies in the operation of current systems which, because of broad impact and urgency, require rectification by continued applied research.

Of all these sources, the most influential are the requirements resulting from studies of hypothetical advanced weapon systems. These are systems both feasible and desirable for future Air Force operations but impossible to achieve by current technology. Such hypothetical systems result from deliberations on and dictates of geopolitics, grand strategy, and the indicated trends of applied research and technology. Advanced planning groups at the various divisions of AFSC formulate these systems and their characteristics into planning objectives. Each planning objective describes an over-all performance capability and indicates the date by which it is required. The interrelationships between these planning objectives, which may range from such considerations as commonly required research to competitive means for mission accomplishment, are coordinated by planning objective coordinators (POC's) from these advanced planning groups.

Each year the technical area managers prepare new or modified applied research objectives (ARO's) to meet the requirements generated by the planning objectives. The various sets of ARO's for each technical area are submitted by the TAM's to AFSC headquarters for approval. The approved ARO's then constitute official guidance for the particular fiscal year. Subsequently the TAM brings the individual projects and tasks of each area in line with this official guidance, to the limits of his available resources. The ARO's are also circulated to non-Government technical research organizations as an indication of

Air Force interest and to stimulate the submission of new ideas and approaches to the solution of research problems.

The planning objective coordinator is also a member of the applied research management team. Whereas the technical area manager and the technical area coordinator view the applied research from a technical standpoint within an area and stress state-of-the-art progress, the POC is concerned with progress of particular efforts in several technical areas which support his assigned planning objective. The POC deals across the board with many TAM's and TAC's to make known his need for proper integration and to promote timely progress of the many efforts needed to meet his planning objective. Thus the TAM/TAC/POC management affords a "check and balance" approach within the applied research program to ensure that a maximum level of effort is directed toward potential future systems.

The existence of 27 different technical areas and the fact that applied research objectives may be defined so as to support several planning objectives, plus the formal documenting of numerous projects and tasks against the ARO's, pose a truly tremendous problem for efficient management.

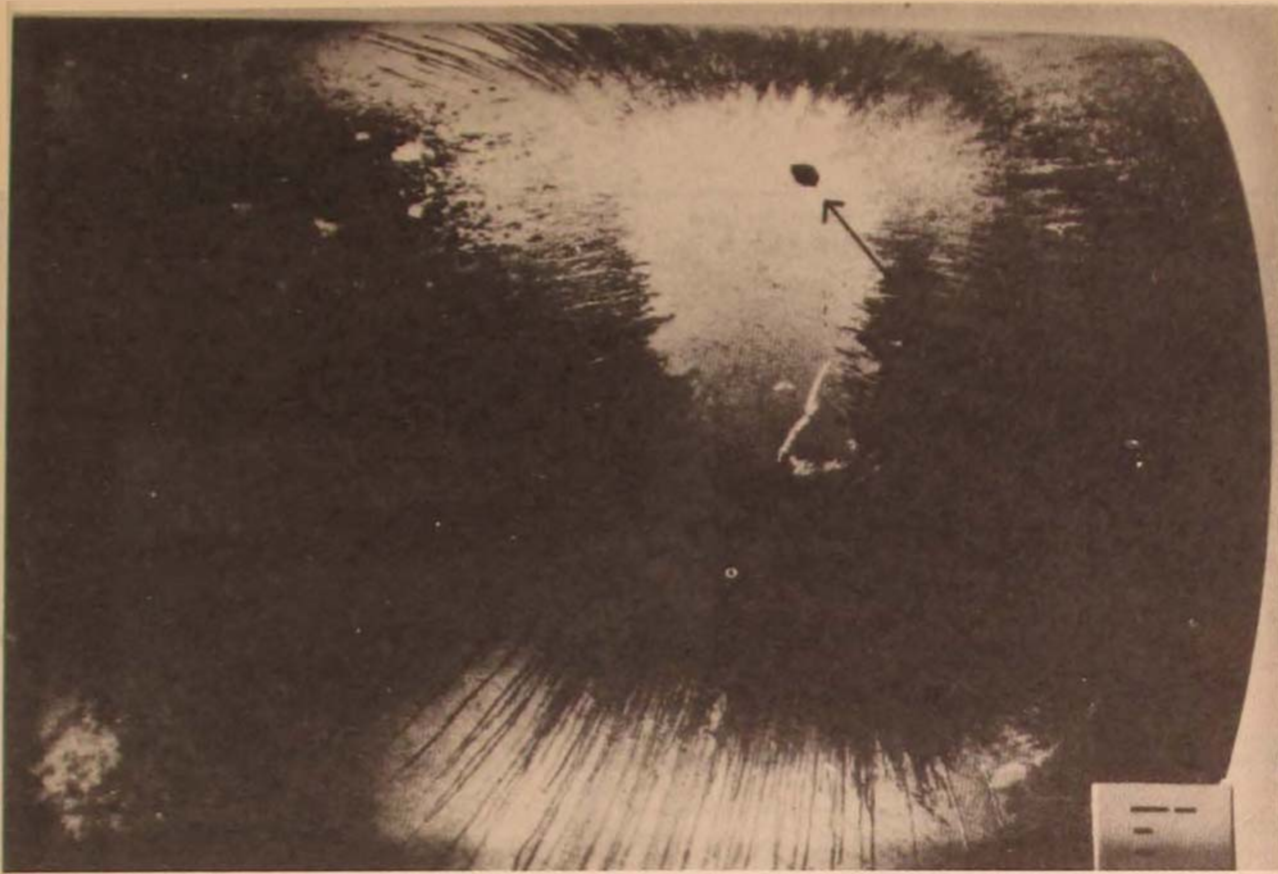
interface with technology

Successful applied research in itself is no guarantee of similar success in achieving a real new system or vehicle. It does indicate the probability (or improbability) of developing the technology to produce a real system. A weapon system is the successful integration of proved technologies in materials, structures, communications, navigation, guidance, control, etc.—technologies developed from applied research in these very same disciplines.

The interface between applied research and technology is, again, an indistinct and poorly defined transition, one of the many similar "gray" areas in research and development. In the area of materials, this interface is called "application" and is considered to be an extension of applied research. Generally speaking, "application" explores the potential of applied research for reduction to practice and eventual technology. The transition from research to technology is best illustrated by actual examples.

Winged re-entry vehicles dictate the need for leading-edge materials that are both strong and resistant to high temperatures. Applied research in metallic materials has produced new refractory alloys of molybdenum, niobium, and tantalum which show promise of meeting the strength and temperature requirements but which unfortunately must be protected against the highly oxidative environment of the hot re-entry boundary layer. Additional research indicates that oxidation resistance may be obtained by protecting the refractory alloys with chrome-titanium or aluminum-based coatings.

These are promises held out by research. Before they can be realized, application study must determine the reproducible engineer-

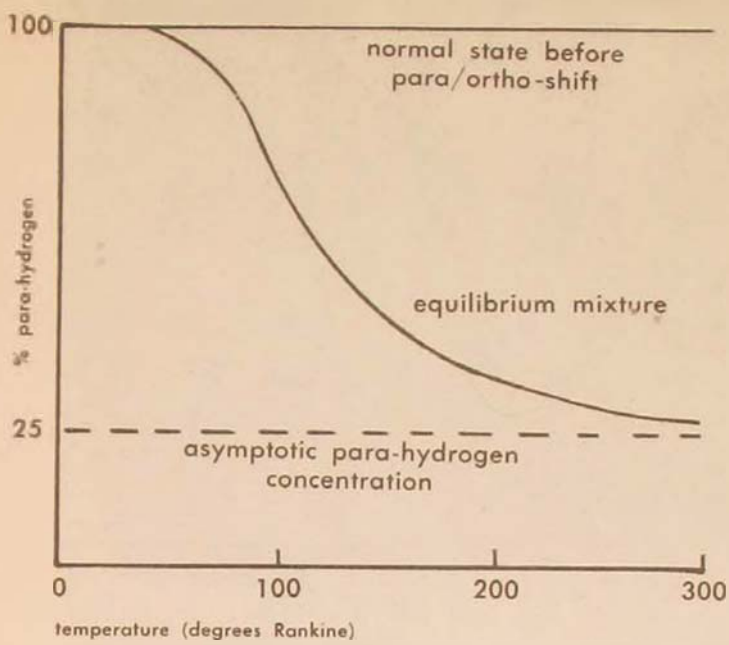


In the effort to prevent metallic oxidation, a specimen of the leading edge of a molybdenum-alloy wing was coated with silica (SiO_2) and then subjected to an aerodynamic and thermal environment that simulated atmospheric re-entry conditions. The hole burned through the specimen (arrow) and the surrounding light area where the protective coating has been stripped off are both the results of oxidation.

ing properties of both the substrate alloys and the coatings, the variables to be considered in production of the alloys, and the most suitable means of applying the coatings to the substrates. Eventually the best combination of alloy and coating is selected for use on the vehicle. As the application studies progress and reliable engineering data begin to emerge on the various alloy-coating combinations, the specific size, shape, and weight requirements imposed by the system vehicle are examined for any peculiar demands on forming processes. If manufacturing techniques for such processes as joining, forming, and coating are not available, they will be developed.

Only when the required leading-edge materials can be made fully available by a demonstrably proved technology can this one aspect of a boost-glide re-entry vehicle be considered solved. Similar evolutions from research to technology must occur in all the other pertinent technical areas before the vehicle problem as a whole can be considered solvable.

As another illustration of transition from research to technology we can postulate the requirement that a self-contained liquid-hydrogen propulsion system also be used as a heat sink. Basic research has shown that the hydrogen molecule can exist in either of two forms: *ortho,* in which the nuclei of the two hydrogen atoms spin in the same direction; or *para,* in which they spin in opposite directions. The conversion of the *para*-form to the *ortho*-form is endothermic,



Per cent para-*hydrogen vs. temperature.—Liquid hydrogen at its one-atmosphere equilibrium temperature of 36.7° Rankine is 99.79 per cent* para-*hydrogen. At higher temperatures the* para-*form gradually shifts to the* ortho-*form until the equilibrium concentration is reached. Time required to complete the shift varies from a few hours at 500°R to many days at 40°R. Uncatalyzed liquid hydrogen acting as a heat sink remains virtually all* para-*hydrogen (top line). The vertical distance between the curves indicates the additional heat sink available from the* para-/ortho- *shift.*

and it is this process which is to be exploited to make the liquid hydrogen serve as the heat sink. Normal liquid hydrogen at its boiling point of 36.7°R is virtually all *para*-hydrogen. The thermodynamic equilibrium ratio of *para*- to *ortho*- shows a sharp decrease with increasing temperature. Unfortunately, however, as the temperature of liquid hydrogen is raised above its boiling point, the thermodynamic equilibrium ratio curve is not followed, and the concentration of the *para*-form remains vertically displaced above the curve.

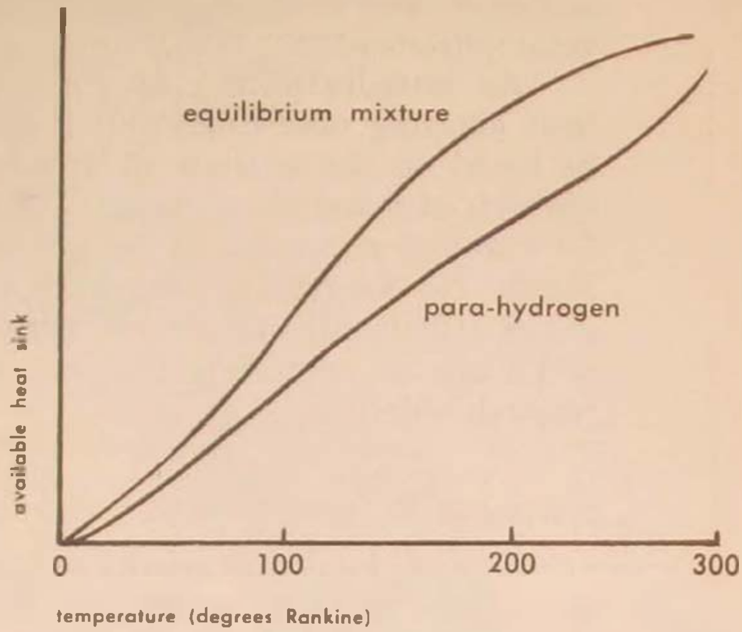
It is the problem of applied research to find some means of achieving the thermodynamic equilibrium ratio of *para*-hydrogen to *ortho*-hydrogen at the desired temperature. The interfering kinetics and the reasons therefor must be ascertained. The possibilities of catalyzing the *para*- to *ortho*- shift must be investigated analytically and the analytic study simultaneously paralleled by a laboratory screening of available promising catalysts.

If a catalyst is found or synthesized, then again practical applicability must be determined from the standpoint of reproducible engineering and environmental properties of strength, shock and vibration resistance, etc. Finally, the technology for production and fabrication into the desired vehicle-borne heat exchanger component must be developed and proved.

The Complexion of Applied Research

The numerous problems revealed by analysis of proposed weapon systems can rarely be solved by research in any one given engineering

Available heat sink vs. temperature. —With no catalyst to speed the shift from para- *to* ortho-*hydrogen, the available heat sink is that of* para-*hydrogen. With a catalyst the shift is completed in shorter, more useful time. Thus the available heat sink of the equilibrium mixture of* para- *and* ortho-*hydrogen, including the endothermic nature of the shift, is markedly greater than when* para-*hydrogen alone is used.*



or scientific discipline. Now and henceforth lift and drag must account for boundary layer temperatures and chemical kinetics; aerodynamics is expanded to aerothermodynamics; stress analysis must allow for time–temperature variations; and time–temperature analysis must look to thermodynamics and physical optics. Propulsion may involve ionization potentials and mass–energy conversion. Communications, navigation, and guidance are no longer designed around vacuum tubes, capacitor plates and wire, but around the behavior of matter in the solid state.

Hypersonic flight and space operations and the bizarre influences introduced by this new era of flight are causing a deeply significant change in the conduct of Air Force applied research. Much of the research demanding attention today can only be attacked by an interdisciplinary scientific or engineering team that can simultaneously apply the knowledge and skills of several areas to a given problem.

This fact is nowhere better exemplified than in the area of data handling. Because of hypervelocity flight and resulting time compression, data analysis by the human mind will frequently be impossible in the time interval permitted for decision-making. Data handling and analysis consequently will be accomplished by computers; but even with computers the mass of data and the physical restrictions of weight and size, plus the demands of reliability, make conventional electronics useless.

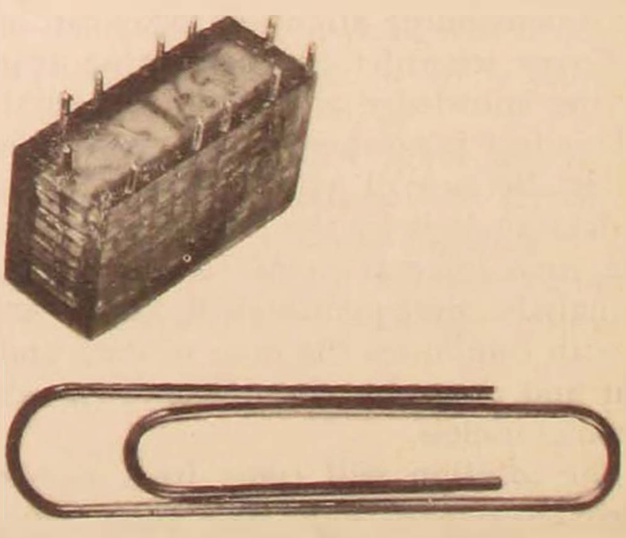
The solution will come from new classes of devices based on applied research in solid state physics in which electronic and magnetic behavior will be tailored by chemical changes to certain crystal lattice structures. Entire assemblies of circuitry will be grown by exploiting the peculiar behavior of thin film interfaces between various crystal blocks. The approach to such research is now being made by combining the talents of physicists, chemists, electronics engineers, and all other specialists who can contribute to its successful accomplishment.

An interdisciplinary approach is also needed for re-entry problems affecting nose cones and leading edges. Such an approach will be based on the analyses of aerothermodynamicists and the applied research of materials scientists. A similar approach now is mandatory for many if not most of the problems facing Air Force applied research. No longer can the classical scientific and engineering disciplines remain aloof from one another. They must research together and learn to appreciate the contribution each can make toward a research objective.

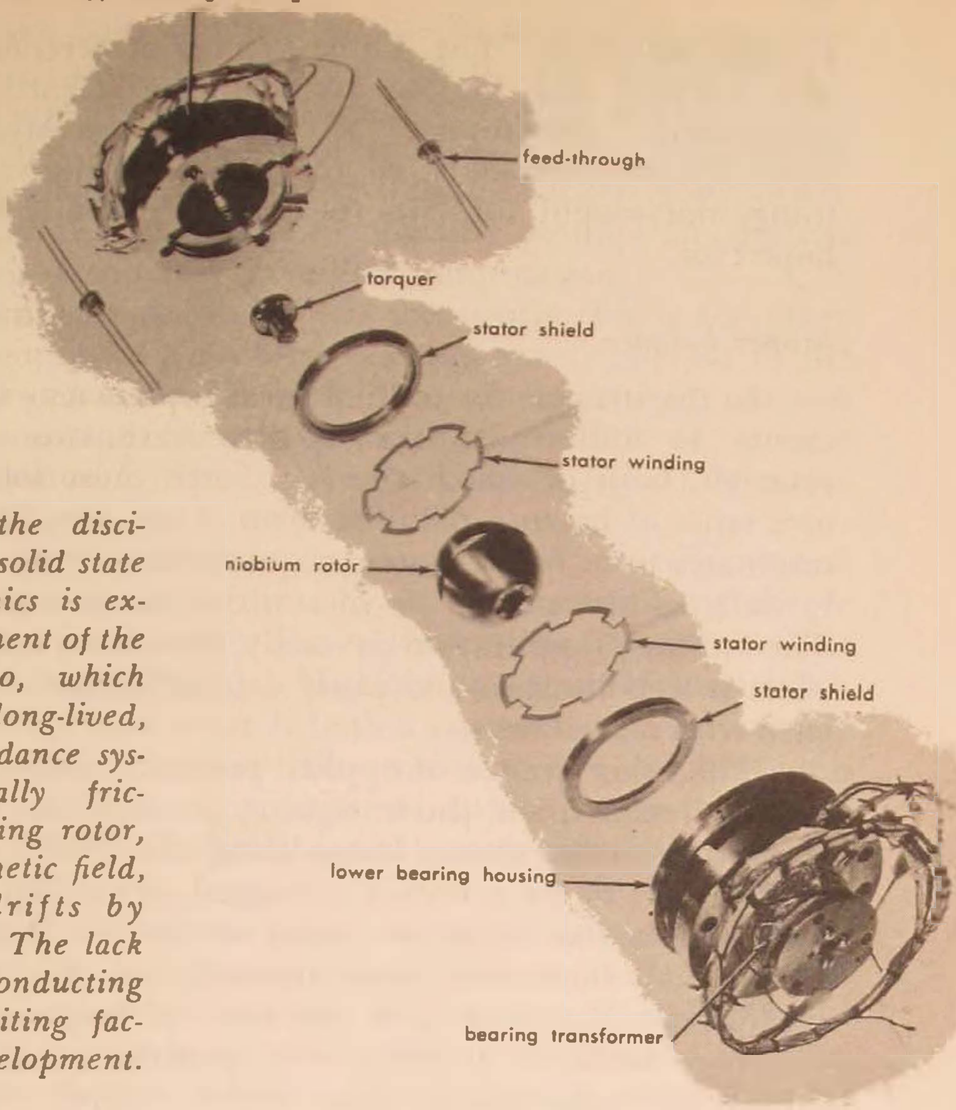
increments vs. breakthroughs

One of the characteristics of applied research mentioned earlier—in contrast to basic research—is that it usually has a time-oriented objective. Unfortunately the mere statement of an objective is too frequently taken to mean that it can be achieved; yet in research, applied as well as basic, nothing could be further from the truth. An applied research objective is a desirably possible goal best achieved, from prior analysis of the problem, by the approach assumed in the program. But inherent in research is the uncertainty of success. If successful achievement of the objective were predictable with absolute certainty, then the program would not be research but simple development—and very simple at that.

Any assumption of research must accept occasional failure as a normal possibility. In research, however, it is not trite to say that negative results have value, for they do. A negative result does supply an answer to a point at issue, and it forewarns other researchers



The solid state functional electronic block (FEB) is a result of cooperative interdisciplinary research in solid state physics, electronics, and materials science. This molecular electronic device contains sixteen complete amplifier circuits. Comparison of the operating elements of two computers built to do the same job, one using the advanced FEB's and the other using present-day transistorized elements, shows that the FEB operating element will be lighter by 98%, smaller by 99.7%.



Interplay between the disciplines of metallurgy, solid state physics, and electronics is exemplified in development of the superconducting gyro, which is a key to reliable, long-lived, precision inertial guidance systems. The essentially frictionless superconducting rotor, suspended by a magnetic field, reduces random drifts by orders of magnitude. The lack of improved superconducting materials is the limiting factor in hardware development.

in the same area that the desired objective cannot be reached by the approach taken. Is applied research, then, always faced with only an even chance for success? No. A major portion of Air Force applied research has objectives the success of which is better than a 0.50 probability. Such goals are defined where indications of prior work are promising or where only modifications to basically proper molecular structure or item configuration must be investigated to yield the desired answer.

By and large when the successful end result of applied research can be predicted with some degree of certainty, then the achievement is usually a minor incremental increase in capability. Frequently this is necessary and important. On the other hand breakthroughs, like discoveries, are rarely predictable, only occasionally yield even to brilliant research attack, and can never be ordered. They just happen. All things being equal, the chance for success varies inversely with the magnitude of the advancement or improvement represented by the applied research objective. This is the reason for the often-heard description, a "high payoff, high risk" program.

In the eighteenth century Horace Walpole, in alluding to the

Persian fairy tale, "The Three Princes of Serendip," coined a word now accepted and finding favor in the scientific and engineering community. "Serendipity," according to the Merriam-Webster *New International Dictionary*, is "the gift of finding valuable or agreeable things not sought for." In research, serendipity is a boon fervently hoped for.

proper balance

In the struggle for technological supremacy—which today is tantamount to military superiority—there are two avenues of applied research, both of which the Air Force must follow. Maintaining a nice sense of balance between them is not easy. One of these avenues originates from future system requirements. Objectives here are usually well defined and to be met within some stipulated time period. The military application is easily discerned, and consequently the effort is well justified and easily defensible when resources are threatened with curtailment.

The other avenue of applied research has its origin in the results of basic research and the intriguing promises they hold out. Although an end use is not always immediately discernible, there are attractive implications of an eventual enhanced technology—and there are few technologies that have no value to the Air Force. Experience has shown that, inevitably, good research will find or develop its own application. Moreover it is this kind of inquisitive applied research which, as much as anything else, produces those unexpected breakthroughs, breakthroughs from which entirely new possibilities for advanced systems are frequently conceived.

In its constant search for talent, the Air Force can ill afford to overlook ingenious and fresh approaches by imaginative scientists and engineers. Not all researchers who refuse to be bound by scientific conservatism, dogma, and convention are crackpots. Max Planck's correct expression for blackbody radiation was the result of a brilliant guess that energy was absorbed or radiated in discrete quantities. His radical assumption of a quantum of action and a new universal constant was completely revolutionary and impossible to derive from classical electrodynamics. The same was true of Einstein's intuitive assumption of the constancy of the speed of light, which led to his relativity theory and the equivalence of mass and energy. And what better example of ingenuity is there than the Wright brothers' airplane? Yet neither of the Wright brothers even went to college, let alone had a degree!

system vs. cut-and-try

In solving a given problem in applied research, one can follow either an Edisonian approach or a systematic analytical approach. Both have value, and the choice of either—or, as may happen, the decision to undertake both simultaneously—depends solely upon the problem and the circumstances surrounding it. The Edisonian approach is a "cut-and-try" empiricism employed when the particular problem is urgent and several possible solutions appear available. It involves little more than selecting and testing the various possibilities. While it is not illogical, it must make optimistic assumptions derived from relatively sparse, frequently unverified, information.

When time permits, a researcher will frequently choose the other approach to the solution of a problem, i.e., systematic analysis of the relative significance and variability of all the parameters involved and correct determination and interpretation of the effects of all the interrelated phenomena. Unfortunately this highly logical scientific approach is usually slow.

The Edisonian approach, implying, as it does, concurrent and parallel efforts, seeks to compress time by the accelerated expenditure of funds and manpower. The more scientific approach seeks the best solution for a lower ultimate cost, but it is more time consuming. When a problem arises from what is both a current and a foreseeably long-lasting requirement, it may be profitable to employ both methods of attack: the Edisonian empirical approach for the immediate present and the theoretically logical analytical approach for the future.

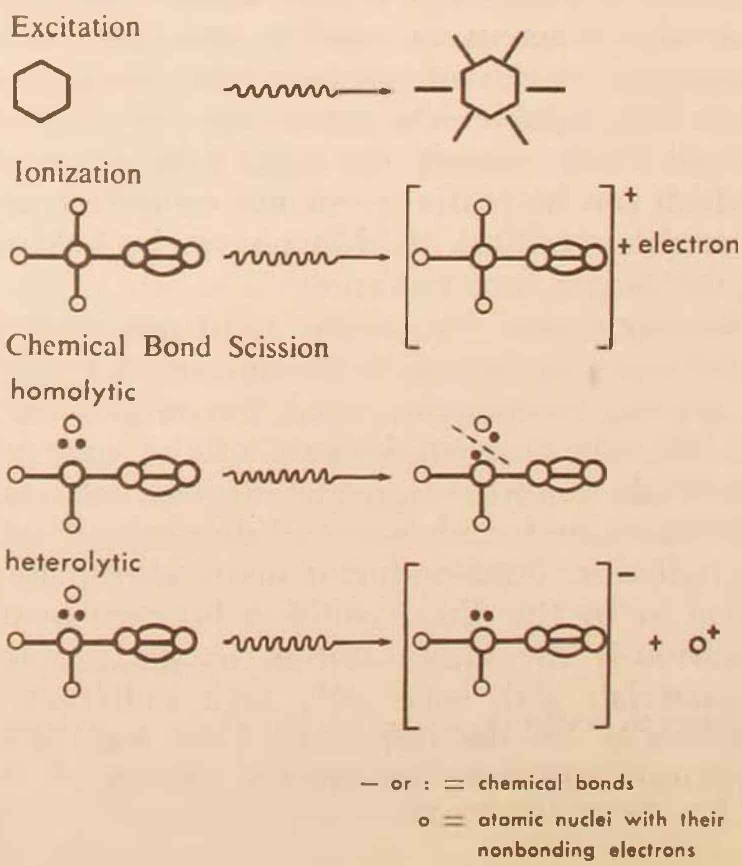
One of the best examples of a simultaneous empirical and analytical attack on an urgent problem is the research on radiation resistance and radiation-resistant materials. Despite the cancellation of the nuclear-powered aircraft program, it must be recognized that the prime energy source in most future vehicles will be some form of nuclear power. Solar cells and fuel cells will do for some applications, but the power density inherent in nuclear reaction makes it too attractive to be ignored. As a consequence, today and certainly for the future, reactors for flight-vehicle power will continue to be increasingly supported. Unfortunately the reactor generates radiation, the intensity of which can be partially but not completely attenuated by shielding. If weight is critical, shielding must be held to a minimum, increasing the danger from radiation.

The major damage caused by nuclear radiation arises from the ionization produced in substances by the gamma and fast-neutron flux, particularly the gamma component. Even for unmanned vehicles, radiation poses a difficult problem because of the susceptibility of practically all materials to some degree of degradation. Lubricants, fluids, plastics, adhesives, and rubber are all deleteriously affected by long exposure to radiation. Semiconductor materials can be damaged either by ionization or by the direct collision between neutrons and atomic nuclei. Obviously the ideal solution to the problem is the development of materials with sufficiently high radiation resistance to function satisfactorily for the duration of the required mission. The longer the duration, the more difficult the problem.

To date, the Edisonian addition of antioxidants, inhibitors, and similar stabilizers has increased the radiation resistance of certain materials substantially. In particular, rubbers have been developed with several times the resistance first observed a number of years ago. The addition of these "antirads" was not purely a haphazard guess. Actually it had been demonstrated that several particular molecular configurations were radiation resistant, whereas others were oxidized in the presence of oxygen under ionizing conditions. At best, however, the choice of base stocks and additives has been semiempirical.

Several years ago in the technical area of materials it was decided that the empirical or semiempirical approach, although it might solve some of the more urgent immediate requirements, would not provide the necessary background and theoretical basis for the solution of future more stringent radiation-resistance requirements. Since that time a steady effort has been maintained to unravel all the complex chemical reactions triggered by the absorption of ionizing energy in matter. Included are the kinetics of energy distribution in molecules, the effects of secondary and tertiary electrons, the reason for

Basic effects of ionizing radiations on materials.—When materials are subjected to ionizing radiations, the ultimate products result from the basic interactions illustrated. The excited, ionized, and radical species lose their excess energy through collision and reaction, either with unaffected neighboring molecules or with one another, to form new stable chemical entities. Knowledge of these basic reactions and of the nature of the initially formed species enables researchers to predict macroscopic effects of ionizing radiations on the behavior of materials.



the stability of various resonant molecular configurations, and the reasons for various other phenomena peculiar to an ionizing environment. This is basic research in nature, but applied research in philosophy. Above all, it is necessary research if we are to acquire a logical basis for the development of required radiation-resistant materials for the future.

in-house vs. contract

Any discussion of the complexion of Air Force applied research must include one extremely important feature: research by contract. By far the greater portion of Air Force research is performed by industry, universities, and various research institutes under contract to the Air Force. In other words, it is purchased. Not that the Air Force is without research talent or capability of its own. It has many competent, outstanding, and dedicated researchers, military and civilian. It also owns splendidly equipped laboratories and unique specialized facilities. Despite all this, the magnitude of the total research effort that must be exerted in today's race for technological supremacy is simply too massive to be accomplished in-house. The in-house research conducted by both the Air Force Systems Command and the Office of Aerospace Research is exciting and invaluable, but for the task confronting the Nation it is not enough. All the brilliance, all the tremendous engineering and scientific brainpower and resources of the country as a whole must be brought into the program.

This vastly complex program embraces many interrelated and contributing disciplines. It is a highly organized and structured program involving the coordinated individual efforts of the Government, the Air Force, industry, the universities, and the research institutes. Finally, it is expensive and demands the utmost in management and executive skill for proper administration.

The Management of Applied Research

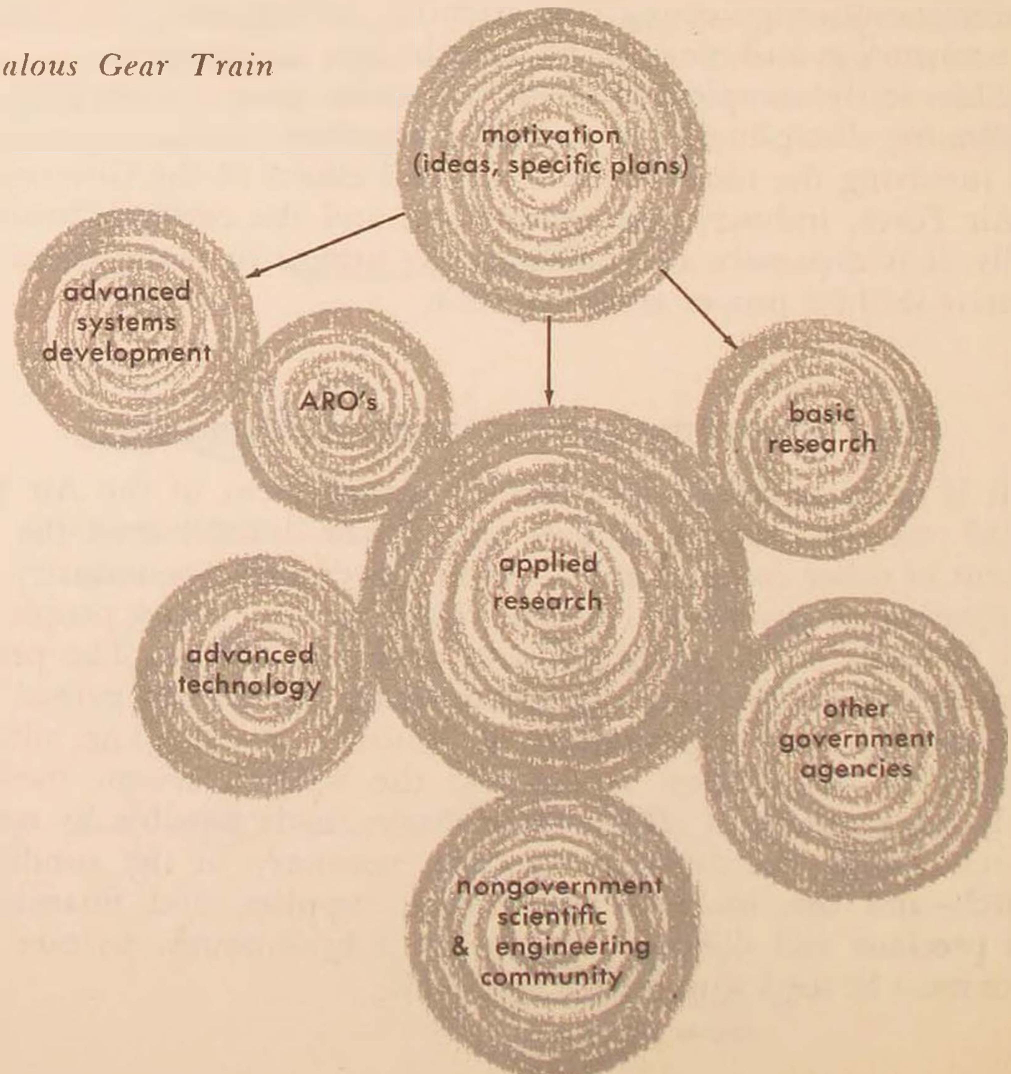
It is futile to debate whether the management of the Air Force applied research program is more peculiar or difficult than the management of other complex functions in Government or industry. The management of any effort involving large monies, many people, and costly facilities is difficult and has its own peculiarities. The product commodity of applied research is knowledge, knowledge gained from the revelation and exploitation of Nature's secrets. The ultimate hardware of the weapon system and the weapon system itself are merely the synthesis of all the technologies made possible by applied research. Of all the different resources necessary to the conduct of research—and this includes laboratories, supplies, and finances—the most precious and difficult to come by is brainpower. So rare a resource must be used with utmost efficiency.

This discussion has noted the numerous aspects, the many interfaces with other technologies and disciplines, the guidance received and influences exerted, and the varied uncertainties and intangibles characterizing applied research. In the Air Force Systems Command the challenge already presented by the scientific objectives of the program is further complicated by the huge and intricate administrative framework within which the program must be accomplished.

research relationships

To clarify what is implied by the intimate relationships between applied research and other significant Air Force and non-Air Force activities, we can picture applied research as a particular gear in an anomalous or abnormal gear train—though the analogy is only an approximate one. In an actual gear train, of course, motive power is applied very directly to the drive gear only. In our gear train motive power is applied to several of the gears simultaneously. It takes no deep engineering knowledge to appreciate that this is impossible without a very delicate and sensitive control. The position of applied research objectives and advanced technology is obvious; they can either govern or be governed by advanced systems development or

The Anomalous Gear Train



applied research, depending on which of the latter is supplying motive power at any given time. The interaction between basic research and applied research is similar. This situation, while it may appear mechanically and physically impossible or anomalous, is intrinsic in all research and development and makes patently clear the importance and urgency for coordination.

Management's role in the gear train should be evident from the accompanying illustration. For applied research, management controls the motive power, directs all the resources and materiel which comprise the "gear wheel," and, above all, ensures that all points of contact with the other "gears" are smooth, well mated, and lubricated.

contract funds and supporting resources

The complexity with which AFSC research management must contend is typified by its applied research contract program. Funds for this program are allocated directly to each technical area and come from the familiar "610–680" series of funds, which provide for all contractual military research and development. Applied research in the military sciences is covered specifically, for example, by "680" funds. Program *support* funds, on the other hand, are allocated by organization, and among these are the "P-690" funds, which provide for such operational necessities as travel, supplies and equipment, phone calls, and miscellaneous overhead. Manpower is also allocated by organization.

Essentially, although the various technical areas are approved by programs for a given level of contract funds, AFSC can only allocate among its divisions the resources in manpower and support monies which it has received from USAF. In other words, the support resources are distributed organizationally. If the situation appears paradoxical, it must be remembered that the ultimate approval for much of all supporting resources, manpower and funds included, rests with Congress. Thus all functions defined by the missions of the Air Force and its Systems Command must be performed with the fixed resoures so approved. It is from these resources that manpower and money must be allocated to support the contract effort in the 27 technical areas. It is not unusual then that in the competition for manpower and support funds there are frequent instances where these funds are disproportionately small for the contract effort involved and approved in a given area.

the in-house program

The argument for in-house applied research concurrent with a contract program can be substantiated by a number of reasons, of which only the more significant need be discussed.

If the Air Force Systems Command is to have the best possible contract research program, it must also have expert engineers and scientists for the inception of new ideas and the initiation of specific work, the evaluation of contractor-submitted proposals, the competent direction of contractor efforts, and the interpretation of contract results. It is impossible to achieve and maintain this capability without a vigorously active in-house research program which can keep pace with modern advances in science and engineering and whereby technical personnel can submit their own theories to test.

Another reason for an in-house program is to attract those top-notch researchers, particularly civilians, who would otherwise be reluctant to enter Federal service without the opportunity to continue working in a laboratory. These "rare birds" are invaluable to the manager. In addition to providing the engineering and scientific skill he must have, they provide motivation and inspiration to the young engineers just entering the service.

Of course the in-house program competes with the contract program for scientific manpower. Project engineers engaged in in-house research are no longer available for conducting the contract program, and the contract work may become an inordinately heavy load for the rest of the technical staff. There are instances, however, where the project engineer assumes supervision of a contract program while maintaining a limited in-house effort. This may be a program complementary to his contracts, an attempt to upgrade his own capability, or an original approach to his technical problem. Whatever the reason, such work is commendable and extremely gratifying to the manager.

Not only does the in-house program compete for manpower, it must also be supplied with supporting funds for equipment, facilities, travel to scientific meetings and symposia, and all the overhead incidental to the experimental work and the publishing of reports and papers. Rarely are these monies adequate for the complete demands of both the in-house and the contract programs.

the project engineer and his environment

We have discussed at length the origin of concepts, objectives, and guidance and the mutual influences exerted by and on these inputs by applied research. Only briefly, however, have we referred to the one individual upon whom the entire applied research program, in substance, depends: the project engineer. Who is he? In applied research, he is the line organization engineer or scientist, military or civilian, who, after receiving all the guidance and hopeful objectives of the research program planners, must come up with the answers to their requirements. Upon him devolves the double task of defining the technical specifics of the problem and pinpointing the likely solutions thereto. The total program in any one technical area is the summation of all the necessary pieces of research advanced by all the various project engineers.

Responsible management acknowledges that the applied research program structure, in essence, evolves from the lower, if not the bottom, echelons of the organizational structure. The project engineer is the key man in the program; he, even more than funds, is the one indispensable asset to the manager. Without the project engineer the funds can be spent, but not well spent. It is his knowledge and creativity which give form and substance to the program; it is only through the particular segment of manpower he represents at the individual or section level in the laboratory that the program is accomplished. Neither the procurement buyer, nor the contracting officer, nor any of the other participants in the mechanics of administration can originate or conduct the program. Their function is to support the project engineer, not dictate to him.

We stress the role of the project engineer because the unique environment in which he is required to operate occasionally threatens to minimize his importance. Because of the dual in-house–contract nature of AFSC applied research, the environment is unique; with rare exception, the serene calm of the university laboratory is lacking. Because many command activities conduct both types of programs, there is a definite business element in the atmosphere of the laboratory. Moreover, on the scale demanded by national security, Air Force applied research is big business.

One more element must not be forgotten and it, too, very definitely colors the environment. This research is for and by a military organization with an overriding military mission. All legal restrictions on Government procurement apply, as well as most of the rules, regulations, and policies governing normal Air Force practices and procedures.

the manager

It is extremely difficult to treat the role of the applied research manager other than by implication and the problems which confront him. As with the project engineer and his significance for a single research program, so it is with the manager at the directorate level of an AFSC division and the over-all research effort. He is the one man who must formulate all the projects and tasks under his purview into an expression which yields the corrected, integrated area effort.

Through his laboratory chiefs and subordinates he furnishes guidance and motivation for the various projects under his jurisdiction. Similarly he must arbitrate conflicting demands made on his resources by particular programs stemming from these same projects and tasks. Some form of priority system becomes almost inevitable—a priority system based on an objective discrimination between urgency, technical merit, and academic interest as well as on a deep appreciation of the limited resources available to him and an ability to operate with them.

As mentioned earlier, the disposition of manpower and supporting-funds resources against documented projects and tasks becomes particularly acute at the technical area level. Organizationally, at the level of a directorate within one of the command's divisions, the problem is even worse. The director, as a manager, usually must provide for more than one technical area. Again, his contract funds will be approved against the technical areas, with all his other resources allocated to him organizationally. He must be prepared to submit and defend all requests for support of his in-house program: the equipment, the laboratories, special facilities, supply funds, and the numerous incidentals prerequisite to his program. Above all, he must develop an organization with the structure, capability, and outlook to adapt and contribute to the ever changing aspects of aerospace technology.

THERE IS little argument against the need for an applied research program in the Air Force or doubt of its dominant role as precursor in the development of required advanced technologies. Its inherent nature, however, must never be overlooked, forgotten, or discounted. Because it is research, it will always involve risk. This characteristic of research, applied as well as basic, cannot be overemphasized and must be recognized and accepted by all in positions of authority. The public, too, must acknowledge the situation because it is the public who pays for the program.

Acknowledgment of the risk involved in research does not by any means imply that timidity be displayed in deliberations on programs. On the contrary, boldness and vision are eminently desirable for forward-looking research. No significant achievement or contribution has ever come from the unimaginative plodder who plows himself into a technical rut. When the payoff potential is high, a decision to gamble to a given degree is fully warranted. Occasionally there are overexuberant proposals to embark on full-scale development before the research has yielded a positive result. Also occasionally there are some sponsors of pet research programs who refuse to admit failure when it does occur and continue to expend money, time, and manpower fruitlessly. The safeguard against such wasteful research is decisive action by top management.

For those who in the name of national economy argue against research, it should be pointed out that laboratory experiments are infinitely less expensive than an outmoded technology which can cost us our national freedom.

Aeronautical Systems Division, AFSC

REQUIREMENT TO PROTOTYPE

COLONEL EDWARD A. HAWKENS

IN THE decades following 1970, the Air Force can reasonably expect to perform a wide variety of advanced missions, both within and outside the earth's atmosphere. Reconnaissance, weapon delivery, communications, and logistics will undoubtedly still have eminent roles, as will other Air Force missions not yet realized. In order to defeat or discourage hostile acts by any unfriendly nation, these missions will require not only a much-refined capability to conduct atmospheric missions but also the capability to boost very large payloads into orbit economically.

Such advanced missions will be accomplished effectively only after great advancements have been made in many technical specialties. Obviously, systematic progress toward a particular requirement does not just happen, nor are any two technologies advanced in exactly the same way. Each mission-oriented acquisition is in all likelihood the product of an intensive and unique development effort, which presents the scientists and engineers involved in it with many perplexing problems and challenges.

Although each technological area is beset with its own problems, the three-phase approach exercised by the Air Force is sufficiently flexible to produce results in any development program. Applied research is the first phase of this process. It is usually soon followed by, and thereafter is accompanied and complemented by, the advanced technology phase. The advanced technology stage of the process is also soon accompanied and complemented by the third and final phase, development, so that often the three phases are progressing concurrently. All three phases of this state-of-the-art growth process are required to reach the capability of producing highly advanced equipment; nothing less will suffice. This over-all process generates continually advanced concepts, evaluates these concepts through analysis and experimentation, and brings the best of them to maturity for effective integration into advanced weapon systems.

The intricacies and complexities of the development process can be demonstrated by showing the process at work in a vital technological area, propulsion. For example, one of the challenging problems confronting propulsion engineers has been the need to increase fuel-

applied research. The analytical and experimental exploration of performance.

advanced technology. The confirmation of performance and structural integrity; an outgrowth and/or combination of one or more research projects.

development. The design, fabrication, test, and qualification for production of propulsion systems which have been shown to be technically feasible.

These propulsion-oriented definitions are fairly liberal interpretations of corresponding topics presented in Air Force Regulation 80-9 on the general subject of program structure.

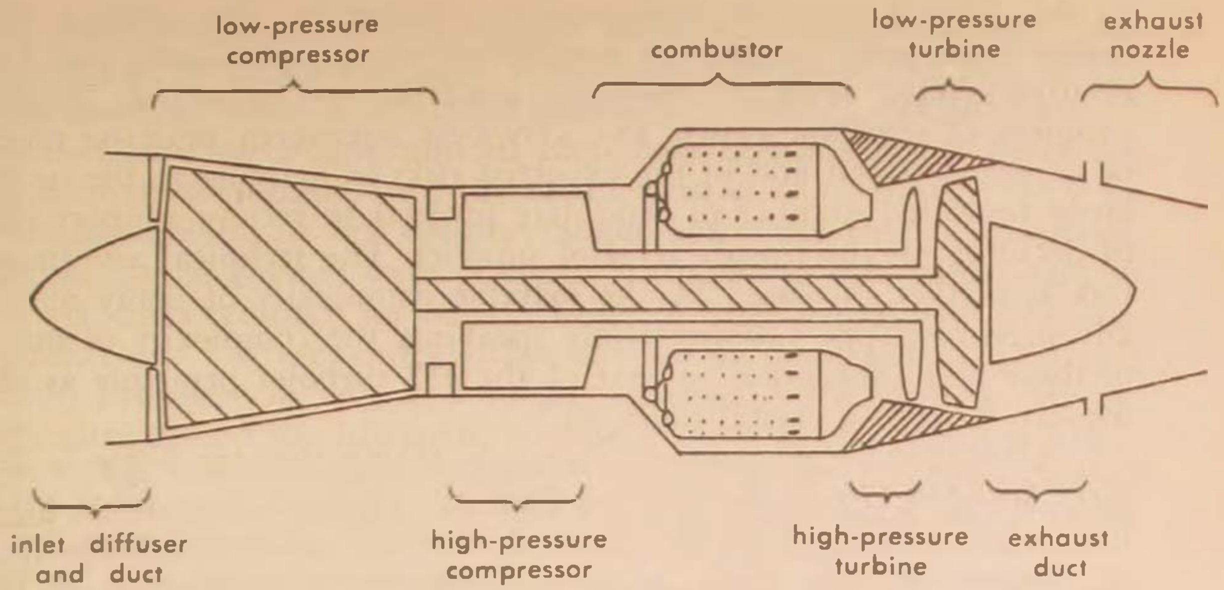
utilization effectiveness to more than double that of present-day engines. Such a development problem is first attacked at the applied research level.

Applied Research

The applied research phase begins with a propulsion concept. If it proves valid, its implementation may eliminate one or more of the technical obstacles blocking the path to greater mission capability. The concept generally is an adaptation of existing knowledge and is conceived to produce a practical solution to a particular technical problem. A typical example may clarify this point.

More than a decade ago a series of engineering analyses was completed which showed that turbojet engine fuel consumption could be reduced by more than 20 per cent if an engine could be built having a 12 to 1 compression ratio, rather than the 6 to 1 ratio typical of engines of the day. A related series of analyses showed that an improvement of this order in fuel consumption could extend the range of a typical airplane by about the same percentage. The propulsion engineers were then challenged to provide this substantially increased pressure ratio in a lightweight engine that could be operated safely at any thrust setting over a broad range of flight altitudes and velocities.

Further analyses resulted in an engine concept which promised an effective solution. The concept amounted simply to employing two compressors, one behind the other but neither mechanically connected to the other. The first compressor would supply pressurized air to the second in much the same manner that reciprocating engines are supercharged. With this arrangement each compressor could employ a modest pressure ratio, since the over-all pressure ratio would be the product of the pressure ratios of the two compressors. For an over-all pressure ratio of 12, a pressure ratio of only about 3½ need be em-



Employment of two mechanically unconnected compressors in tandem permits the attainment of the desired high pressure ratio in the J57 dual-compressor turbojet.

ployed in each compressor. This promised to be a considerably less difficult task than trying to provide a 12 to 1 pressure ratio in a single compressor. Indeed, one segment of opinion at that time considered the attainment of so great a pressure ratio as 12 to 1 to be well-nigh impossible, regardless of the method employed.

Thus was the J57 turbojet engine conceived. The accompanying sketch shows its two compressors in tandem, driven through concentric shafts by individual turbines. Variations of this highly successful engine now propel the Air Force B-52, C-135, KC-135, VC-137, F-100, F-101, early U-2, and F-102 aircraft, the Navy F8U, A3D, and F4D aircraft, and most American commercial jet aircraft.

This example illustrates another point about applied research, one that is typical. There was no formal requirement for a 12 to 1 engine when this applied research program started; no aircraft had been designated to employ it. In fact it was not until several years and many millions of dollars had been invested in its applied research program that aircraft applications began to firm up. The point here is that the performance of the engine promised to be good enough that applications could be anticipated with reasonable confidence. This made it possible to justify carrying the program forward.

In recent years a metamorphosis has taken place in air-breathing propulsion. Conceptually, many new propulsion cycles, components, and arrangements have evolved which have tremendous potential for furnishing the Air Force with remarkable future capabilities. This progress has stemmed from Air Force programs designed to catalyze national efforts to develop superior advanced propulsion. As a result of this progress a major management problem has also evolved. Because of the large number of worthwhile areas under study and the relatively fixed level of resources available, an extremely critical problem of selection exists. The very best assessment must be made of potential payoff and of the expected risks in arriving at the necessarily restricted number of candidate projects to receive support and in deciding on the proper level of support. The technical assessment task is further increased by the extreme complexity of many of the advanced concepts. Comparatively speaking, the complexity of many of these new concepts is to that of the J57 turbojet principle as the modern TV is to a crystal radio set.

A representative problem currently facing the Air Force is the certainty that the dollar cost of boosting payloads into orbit must be sharply reduced if the Air Force is to afford space operations on a meaningful military scale. In each of the several approaches to the solution of this problem (booster recoverability, booster staging, and others), propulsion technology plays a vital role in that the effectiveness with which the propulsion system utilizes fuel has a direct effect on the weight of the payload that can be carried. This, then, is a propulsion technical problem to be surmounted: how to increase, by much more than 100 per cent, fuel-utilization effectiveness; in other words, how to increase the amount of thrust that a given quantity of fuel can provide for a given length of time.

Conceivably an air-breathing flight engine may be the answer to this problem, as it has relatively high efficiency. Furthermore, because the air-breathing engine uses oxygen directly from the atmosphere rather than from a storage tank, it can provide much greater fuel-utilization effectiveness than rocket engines, which must use stored oxygen.

Today's air-breathing engines are velocity-limited to about 1750 knots for turbojets and about 2600 knots for ramjets. Orbit velocity is about 14,750 knots. The problem clarifies itself further, then, to the need for achievement of much higher velocity capability for air-breathing engines and the integration of air-breathing propulsion advantages into a highly effective propulsion system capable of acceleration all the way to orbit. This is another example of applied research being based upon an anticipated requirement and ahead of the establishment of a specific requirement.

A new propulsion concept may originate from several technical specialties. For example, a new concept in propulsion can be born as a result of new materials, new fuels, new engine cycles, better component performance, optimum component arrangement, or dual use of a propulsive system. The fuels specialty is one of particular interest to air-breathing propulsion technologists at present because of the increasing availability and favorable properties of liquid hydrogen. Although liquid hydrogen is by no means a new fuel, having been produced in laboratory experiments by Dewar in 1898, its present availability in production quantities permits consideration for a variety of uses, including extremely high-velocity air-breathing propulsion. The extreme coldness of liquid hydrogen (–423°F), which makes it an excellent refrigerant, and its high heat of combustion (over 2½ times that of gasoline) are the characteristics that make it very interesting, despite its low density (about one tenth that of gasoline). If ramjet-type engines were operated uncooled in the atmosphere at the velocities required for booster missions, they would heat to incandescence and fail very quickly. But the use of the cooling capacity of liquid hydrogen in any of a variety of possible techniques can significantly extend the life span of these engines at the required velocities. Thus we have an example of an improved mission capability made potentially possible by the favorable properties of a newly available fuel.

The discussion may now turn to the evaluation of ideas or concepts in an applied research program from the time of their inception to the delivery of the best ones to an advanced technology program for a much broader and more intensive investigation.

Applied research seeks to answer two basic questions about a particular concept and to do so as nearly concurrently as possible. (1) Is it technically feasible? (2) Does its worth justify its cost? There is no profit in proving that a technical idea is sound unless it provides the Air Force with enough additional mission capability to justify the expenditure of time, labor, and money involved.

How are these questions answered? The history of the J57 turbojet engine provides an example of how the first question was answered. It was by no means certain that the engine's compressor could be made to deliver either the efficiency needed to achieve the lower fuel consumption or the broad range of stable operation necessary to make it practical and safe to use. Individual test programs had to be carried out for each set of blades in the compressor, and the minimum acceptable performance for each had to be clearly specified. As the programs reached their individual goals, the blade sets were then tested collectively as a further step. In this manner it was ultimately demonstrated that the knowledge and skills needed to build a satisfactory 12 to 1 compressor had been acquired. Question (2) had been answered affirmatively by the engineering analyses, which indicated a 20 per cent improvement in aircraft range capability. Enough investigation of other engine components (combustor, turbines, etc.) and of a complete engine incorporating all the components, including breadboard engine tests, had been carried out concurrently to show that an engine of advanced capabilities could be constructed. Thus performance had been analytically and experimentally explored, paving the way for subsequent confirmation of performance and structural integrity.

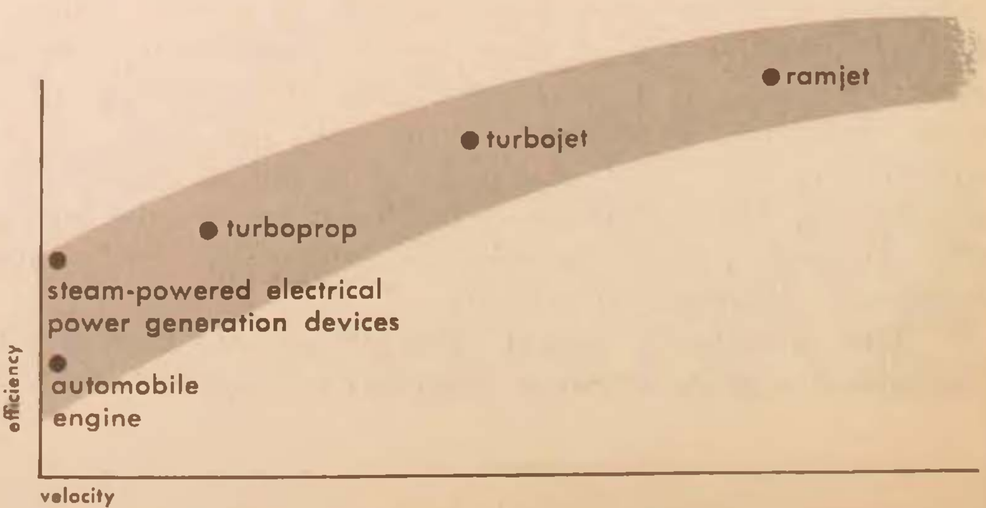
This is a fairly typical example of the method employed in propulsion applied research programs to approach and demonstrate feasibility. We identify the critical technical factors in proposed components; we specify minimum acceptable performance goals for each; and we then work to reach these goals or to prove that it is not possible or practical to do so. At the same time we investigate the integration of all the components into a propulsion system of advanced capabilities. We culminate the process with breadboard tests for a first and minimum-confidence-level demonstration of propulsion system feasibility.

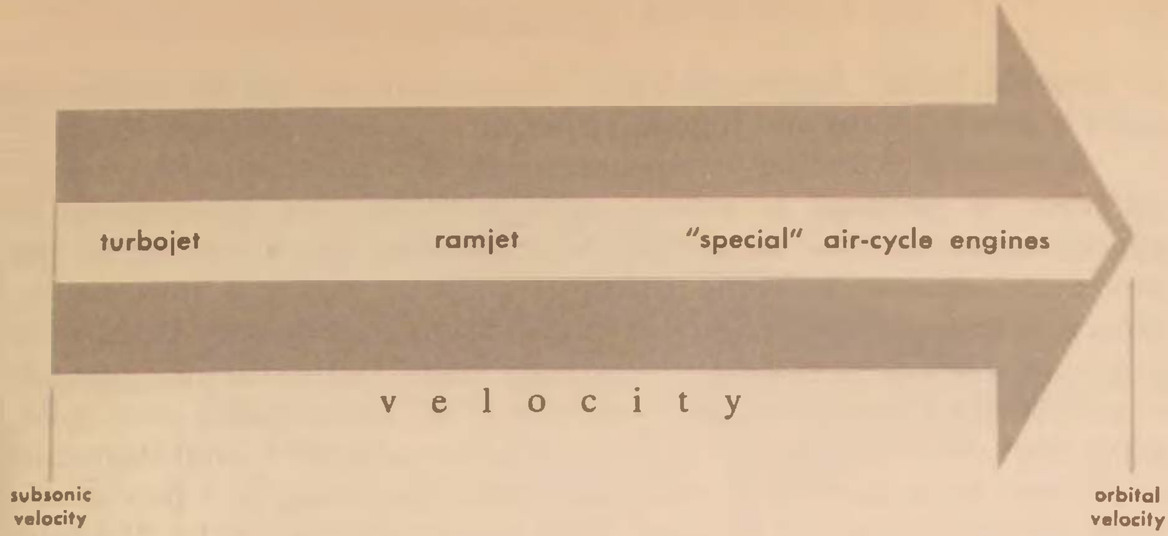
To answer the question about the technical worth of a concept generally requires a somewhat different approach, involving aerospacecraft orientation. The mission performance (payload for example) achievable by a typical hypothetical aerospacecraft having a "conventional" propulsion system is estimated first, purely by analysis. The new-concept or proposed propulsion system is then substituted for the conventional propulsion system, and the analysis is repeated to estimate its mission performance. A comparison of the two propulsion systems, made in this way, establishes the relative advantage attributable to the proposed propulsion.

Advanced Technology

If the answers to the questions of technical feasibility and desirability are favorable, then the new propulsion concept is ready to enter the broader and more intensive advanced technology investigation. Because the advanced technology phase is provided, the applied research program is expected to deliver no more than a minimal level of confidence in its establishment of technical feasibility and worth. These two phases of the over-all Air Force procedure, applied research and advanced technology, are very closely related—in fact

The fuel-utilization efficiency of air-breathing flight engines increases with velocity, becoming considerably higher than that of conventional industrial-commercial energy-conversion prime movers, such as automobile engines and steam-power equipment for generating electricity.





No one propulsion system is capable of high fuel-utilization effectiveness over the entire range of needed velocities. At low velocities the turbojet has highest performance, at higher velocities the ramjet is most effective, and at very high velocities the "special" air cycles offer the highest performance potential.*

they generally operate concurrently. The same is true of the relationship between the advanced technology and development phases.

As the applied research phase of integration testing continues, it quickly gets into fabrication and test costs beyond the fixed limit of the applied research budget. Advanced technology funding is geared to larger expenditures and provides an assist to research at this time. The advanced technology phase carries the program into the structural integrity and performance confirmation phase. It may include extensive flight weight construction, extensive laboratory testing, and in some cases even flight testing where required to establish a reasonable confidence level as to feasibility.

Advanced technology in a propulsion-oriented sense is essentially a process for advancing the confidence level on a technical basis to provide the justification for asserting that a particular propulsion concept *can* provide the required performance. An adequate confidence level must be established to enable management to make sound decisions to develop and employ a propulsion unit in support of our national objectives. We must demonstrate high-confidence feasibility for a particular propulsion concept to reduce, to an acceptable level, the risk associated with authorizing the very great investment required for its development. This cost plus that of an aerospacecraft procurement program may well total many *billions* of dollars. In this day of the "cost squeeze," of ever increasing development costs, operational costs, and fixed costs within a fixed budget, it is absolutely essential

*Examples of "special" air cycles are LACE (liquid-air-cycle engine)—a cycle which employs liquid air as its working fluid; ACES (air collection and enrichment systems)—a cycle which produces liquid oxygen in flight; SCRAMJET (supersonic combustion ramjet)—an advanced ramjet cycle employing combustion in supersonic flow; and LATA (liquid-air-turbo-accelerator)—an advanced turbine cycle employing liquid air as part of the working fluid.

to provide solid, high-confidence demonstrations of feasibility as quickly as our means and ingenuity permit.

Advanced technology is an outgrowth of a prior applied research program, or perhaps of several such programs. Its relationship to applied research may, in an approximate sense, be compared to the procedure employed in the chemical industry when a formulation process is first investigated and established on a laboratory basis, with concurrent initial consideration of pilot plant factors. If its potential is sufficiently promising, the process is then investigated in a pilot plant operation. In this way it is possible to acquire a high degree of confidence in its feasibility and worth before investing in a production plant for marketing the product. The resources required for the pilot plant operation are, of course, much greater than those required for the laboratory investigation.

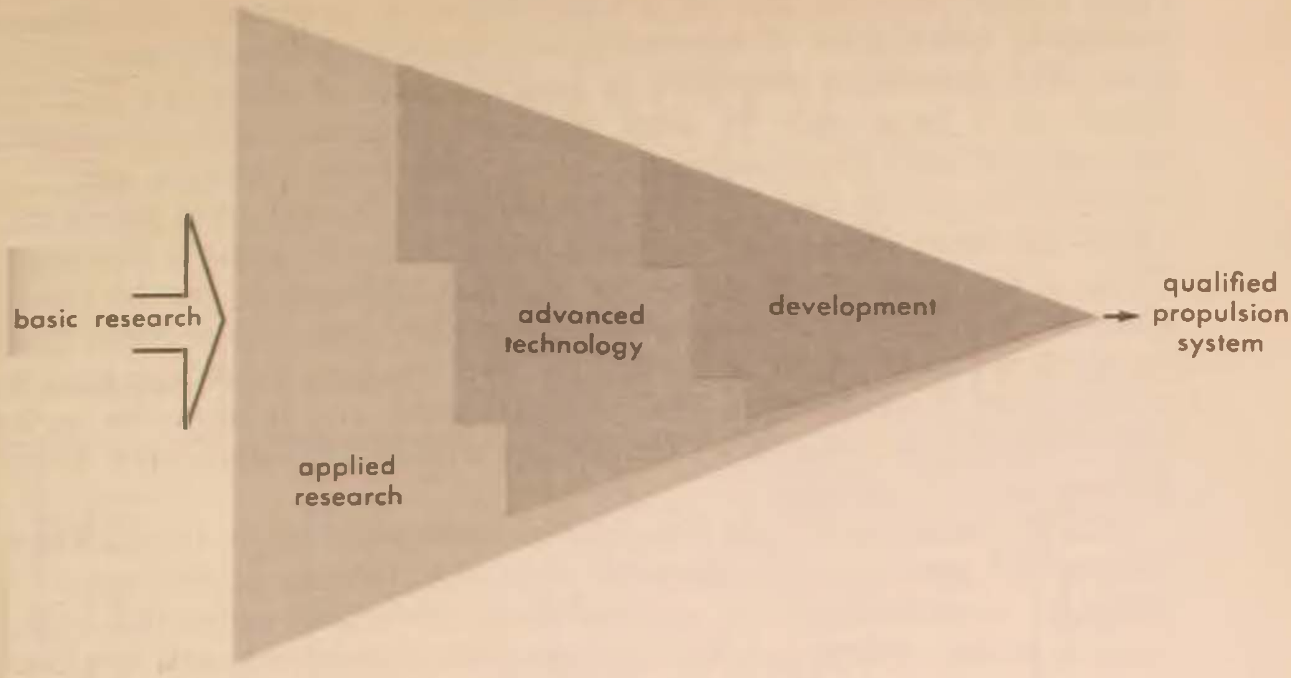
Ordinarily there is a considerable time overlap in these programs. Such concurrency is necessary and can significantly reduce the elapsed time required for the over-all program. The whole process—applied research, advanced technology, and development—is analogous to a pyramid, viewed from the standpoint of the total propulsion program. The applied research area covers a large number of efforts, each requiring comparatively modest resources. The advanced technology area covers a modest number of efforts carefully selected from the candidates evolving out of applied research, each requiring intensive advanced effort and sizable resources. Finally the development area concentrates on the very few candidates selected out of the preceding areas for specific vehicle application, each requiring very large resources.

In the implementation of an advanced technology program, how do we go about getting the job done? What factors are important? How do we set technical goals? How do we measure progress toward these goals? How do we measure confidence level? What is our over-all objective?

As an example, suppose we want to acquire the means for extending the flight velocity capability of air-breathing propulsion to as high as orbital velocities in support of the Air Force responsibility for military aerospace boosters. Achievement of these velocities is tremendously important, for it offers the possibility of boosting payloads into orbit economically. This then is the over-all objective.

How do we accomplish an advanced technology job? What is the job? Very simply, it is to advance the confidence level in the technical feasibility of any particular propulsion system that may have been selected as having the potential of meeting a requirement, anticipated or otherwise.

Again the J57 turbojet will illustrate the procedure. At the end of the applied research program, the compressor had been investigated minimally, enough to show that the efficiency and operational



Applied research receives many of its inputs from basic research and advances the more promising concepts until they are determined feasible and worthy of greater effort in the advanced technology phase. Occasionally certain aspects of an applied research program may be carried directly into a production system without going through normal procedures of the advanced technology and development phases.

flexibility goals were attainable and that the desired engine could be constructed.

It was the task of the advanced technology program to support the investigation at this point and carry it forward. Concurrent test programs for each of the engine's major components (compressors, combustor, turbines, bearings/shafts/lubrication system, and control system) were planned and carried out to acquire the knowledge and skills required to build successful components. When these programs had progressed sufficiently, the components were assembled into a complete engine with which to perform a functional demonstration. Successful completion of this activity confirmed high-confidence feasibility.

The J57 engine certainly had not at this point in its history achieved qualified status (necessary for employment in Air Force operational aircraft). Nor would it be qualified until many thousands of test hours had vouched for its reliability and performance. What *had* been accomplished at this point was high-confidence confirmation of the engine's feasibility, thus minimizing the risk associated with authorizing its development.

We have mentioned the term "confidence level" several times and implied that confidence is measurable. It can be measured in an approximate way but not to a high degree of precision, since it is essentially qualitative. A reasonable approximation is sufficient, however. The procedure employed is basically one of milestone specification on a large scale in every technical program undertaken. At the outset of each program, specific technical accomplishments (goals) expected at specific times during the period of the program are identified—the more the better, one per month per component if possible. Then as the program progresses, actual accomplishment can be compared to anticipated accomplishment for that time. This, then, can be employed as an index of confidence level. As long as we stay nearly on schedule, the confidence level remains good, and it improves with each milestone we pass. If we stumble technically, the confidence level will sag correspondingly.

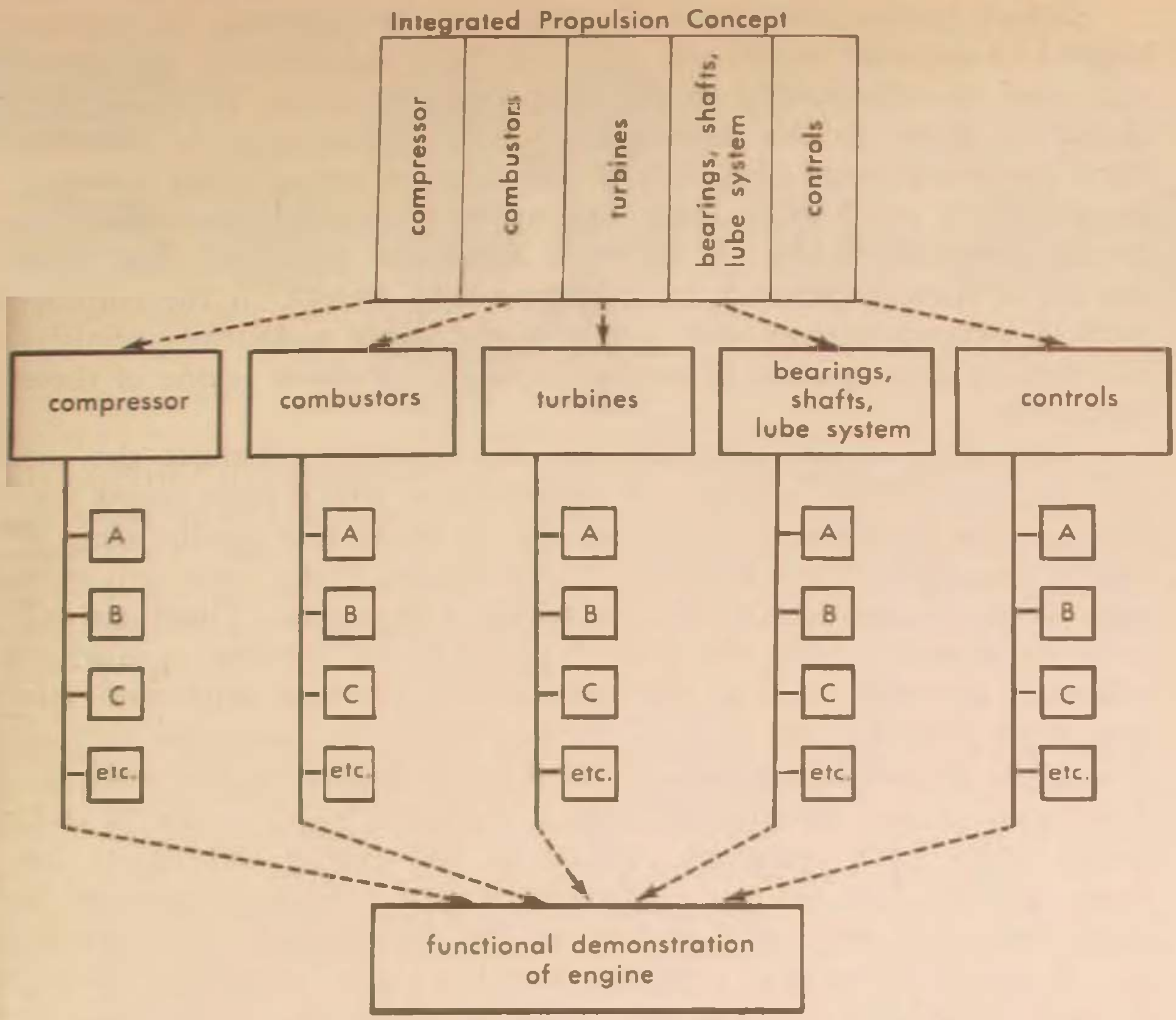
Other technical factors deserve and receive attention during both the applied research and advanced technology phases as well as considerable attention later in development. These are reliability, producibility, and maintainability. An adequate measure of each of these factors in all new propulsion systems not only ensures the safety demanded of man-carrying weapon systems but also results in dollar savings through reduction in the total number of systems that must be purchased and supported in order to secure a given level of operational capability.

Adequate reliability can be ensured only through exhaustive testing of a component of fixed design in its proper environment. Since propulsion components change frequently, and sometimes radically, during applied research and advanced technology, these program phases do not establish that adequate reliability has been achieved. They do, however, lay the groundwork for such a demonstration during the development phase of the over-all program.

Development

The development phase employs the knowledge and skills acquired in the advanced technology phase to tailor a propulsion system concept to the requirements of a specific aerospacecraft. Experimental models are built and tested to prove a flight-worthy (qualified) propulsion system. The propulsion development program ultimately results in a list of parts that are suitable for production. The development phase will show that these parts can be assembled by an established procedure and thereafter safely operated to produce specified performance, all of which will be specifically proved by tests.

For a better understanding of the development program, it is worthwhile to review briefly what was accomplished in the advanced technology phase. First, and most important, the performance desired of the propulsion system had actually been achieved in testing a complete though rudimentary propulsion system. Second, although the



In the advanced technology phase each component of the system under study must meet certain specific requirements or "elements of feasibility" (represented by A, B, C, etc.). *When all have been demonstrated to be achievable, individually and together, feasibility of the complete program package will have been established.*

testing had not been extensive, it demonstrated that the propulsion system possessed or could acquire acceptable structural integrity. Finally, concurrent analysis of the propulsion system in various "analytical model" aerospacecraft had guided the advanced technology program enough so that the propulsion system was shown to be suitable for similar future aerospacecraft. Thus it is apparent that the development phase inherits a solid foundation on which to build.

The task from this point forward resolves itself into planning and carrying out a very thorough test program to acquire a high order of propulsion system reliability. No sacrifice is permitted in the performance of the propulsion system or of the aerospacecraft, nor may the program schedule lag. The battle to prevent loss of performance or slippage of program schedule must be fought keenly and with great perseverance.

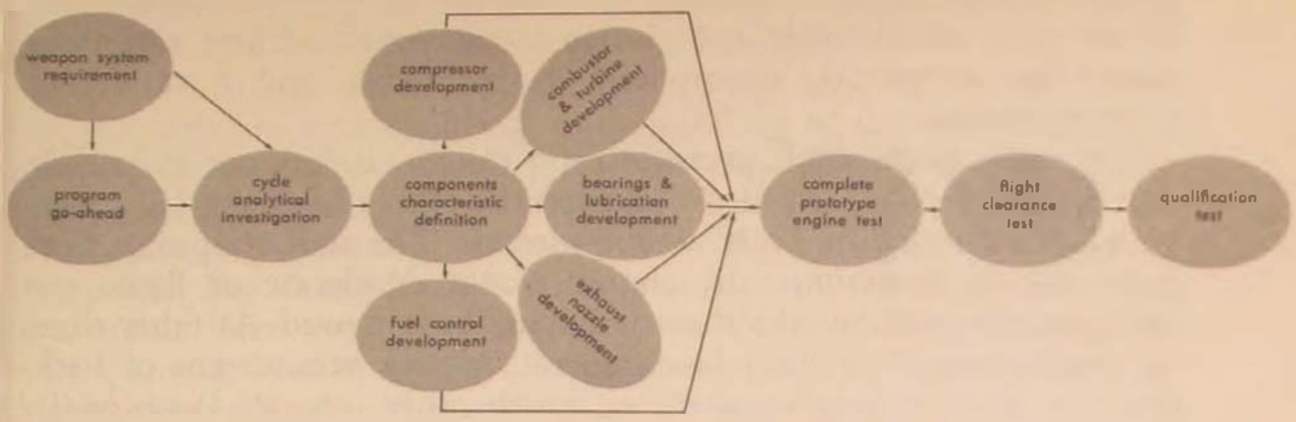
Before further discussion of propulsion development, it may be helpful to consider briefly the program for a hypothetical aerospacecraft and its relationship to the propulsion program. When a "go-ahead" is given to the development of an aerospacecraft, the Air Force customarily sets up a special management group called a system project office (SPO) to manage all aspects of its development. The membership list of the SPO includes Air Force personnel skilled in the art of management of the entire weapon system, in the employment of weapon systems, and in each of the major technical specialties involved in development of aerospacecraft. Propulsion is one of these specialties.

Very early in the aerospacecraft development program, the SPO will lay out a master schedule or timetable in which every important event in the program will be scheduled to occur at a specific time. A similar but subordinate schedule is laid out for every important component of the aerospacecraft, including propulsion. These are all properly phased so that the over-all program can proceed in synchronization. Keeping track of the relationship between scheduled and actual performance on each of these subordinate programs and assessing the impact of any variations on the over-all program constitute a tremendous and complicated task. It is one to which a specific technique called PERT (program evaluation and review technique) has been applied. The PERT network imposes an orderly progression of concurrent and sequential phases on the development of a system.

A typical propulsion program plan has many "milestone" events, or goals, scheduled to occur at appropriate intervals. Under the concept of concurrency many of these events are scheduled to occur in parallel or during roughly the same period. Although this may be a more costly way to do the job, under urgent circumstances the time compression achieved is well worth the cost. It is also possible that the extra investment may ultimately be recovered through the greater length of time an aerospacecraft remains in service. A final comment on the concept of concurrency is in order. Program funds and priorities must be adequate at all times if the concept is to succeed. It has been assumed in this discussion that both have been ensured.

The propulsion specialists of the SPO team prepare a set of specifications which the propulsion system must meet. These specifications include a detailed description of the performance expected of the propulsion system, specific altitude-velocity points at which performance must be demonstrated, minimum requirements for initial flight clearance (experimental flight only), requirements for qualification, and requirements for acceptance of production units. Such explicit specifications help ensure that propulsion will contribute its share to the accomplishment of the Air Force mission for which the aerospacecraft is being developed.

The detailed requirements for the specific propulsion system having been established, the most costly phase of the entire process



A simplified master program evaluation and review technique (PERT) network for development of a turbojet engine. Many additional events would appear in an actual PERT network. Computer analysis of the net automatically calculates the critical path to realization of the requirement. The time needed to complete the entire program is estimated by analysis of the time needed for each event in the net.

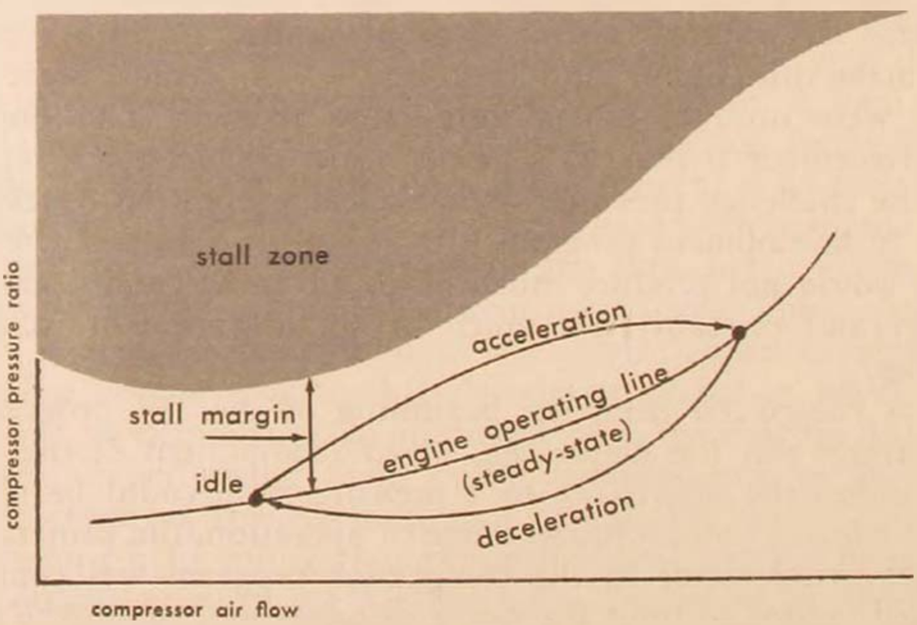
remains. This consists of the many thousands of hours of development testing, of components and of the assembled propulsion system, as well as the preliminary flight testing required to eliminate the bugs and provide a reliable, operable propulsion system that gives the required advancement in Air Force capability. Experience has shown that the equivalent of forty to fifty experimental propulsion systems will be required in this process. Normally extensive modifications will be required in this effort as the experimental program proceeds to apply the necessarily severe performance and endurance standards. The end product is the fully qualified propulsion system.

The J57 turbojet underwent a typical development process in which some very difficult technical problems had to be overcome in order to make this engine the success that it has become. Some of the problems were unique; others were more routine. The important thing to remember is that, as a group, these problems are representative of the challenge presented by a typical propulsion development program. A development program with few or no significant technical problems would not produce much of an advancement in propulsion technology and probably not much of an advancement in mission capabilities.

It was recognized from the beginning of the J57 program that the compressor was the major "go, no-go" component of the engine. That is, unless the desired 12 to 1 pressure ratio could be obtained with high efficiency and a broad range of operation, the project would fail. A very vital factor in the compressor program was compressor stall, which tended to limit the range of operation. As can be seen in the accompanying compressor "map," the "stall zone" is a region of unstable, unsafe operation that must be avoided. Sufficient "stall margin" must be provided between the stall zone and all steady-operation points of the engine to permit the engine to be accelerated (and decelerated) satisfactorily and also to accommodate airflow variations caused by maneuvers, atmospheric contaminants, and a variety of other conditions.

Because of the high pressure ratio sought, it was not surprising that compressor stall problems plagued the early life of the J57 turbojet when operating in experimental aircraft. The stall symptoms were quite varied. Sometimes the engine would decelerate or flame out unexpectedly, without the throttle having been moved. At other times the engine would produce loud, staccato noises, reminiscent of backfiring in reciprocating engines but much more intense. Occasionally flame would stream out the tailpipe. Stall at various times also produced mild vibrations, slight "choo-choo" noises, and unusually long acceleration times.

In retrospect, compressor stall in this engine was a very interesting phenomenon, though at the time it was regarded as an extremely critical, dangerous, and destructive problem, one which had to be solved in the shortest possible time. The best engineering talent available worked many 60- to 80-hour weeks until the problem was whipped. And it was whipped—decisively! The efforts of these people improved the design of several of the engine's components; and the improvements, in concert, broadened the stall margin of the engine and thereby solved the problem. The improvements included (1) fitting the compressor with large air-overboard bleed valves, (2) improving the compressor's aerodynamic/thermodynamic effectiveness by altering the setting and contour of many of the compressor blades,



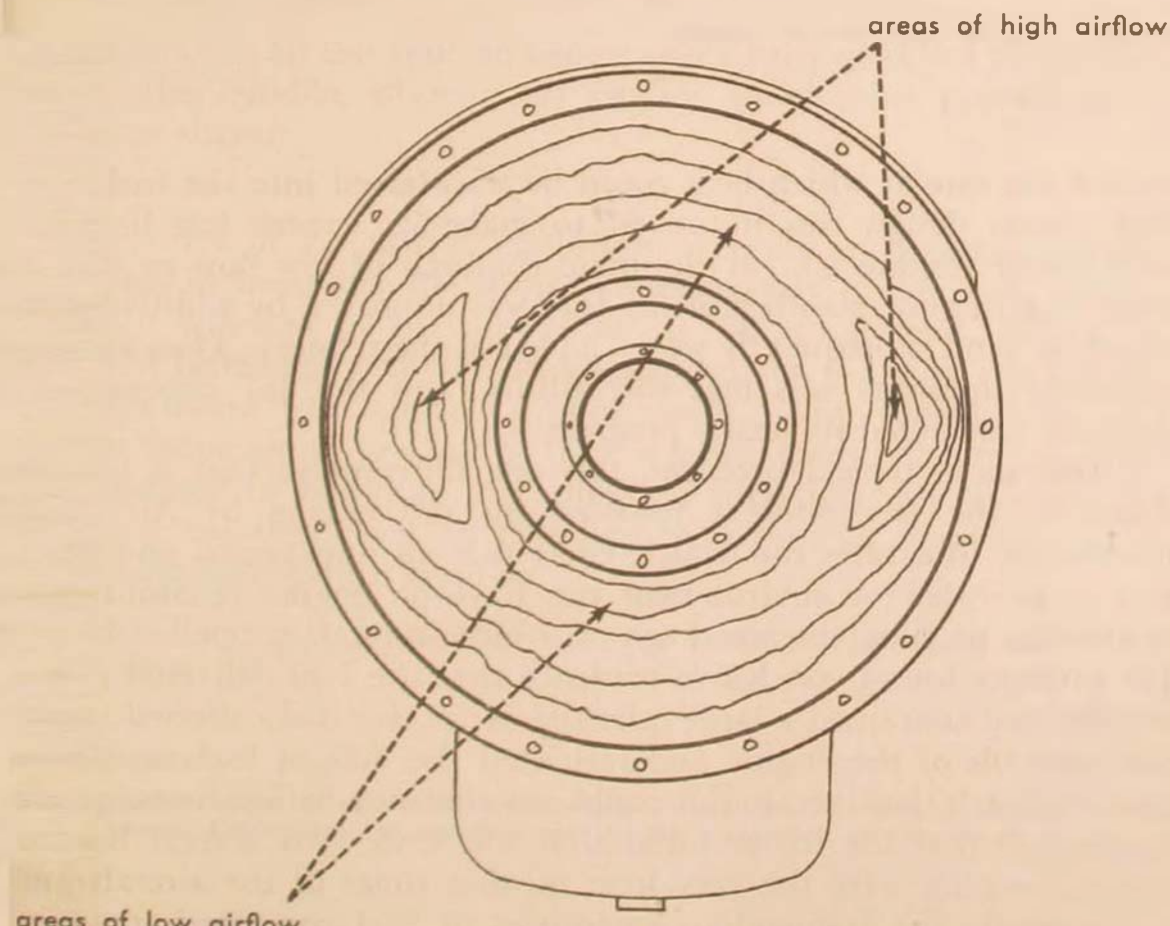
To prevent turbojet engine compressor stall, adequate stall margin must be provided in the engine to ensure acceptably short acceleration times and allow for airflow variations due to maneuvers, atmospheric contaminants, or other conditions.

(3) similarly altering the blades in the turbine section, and (4) fitting the engine with a new, more accurate fuel control.

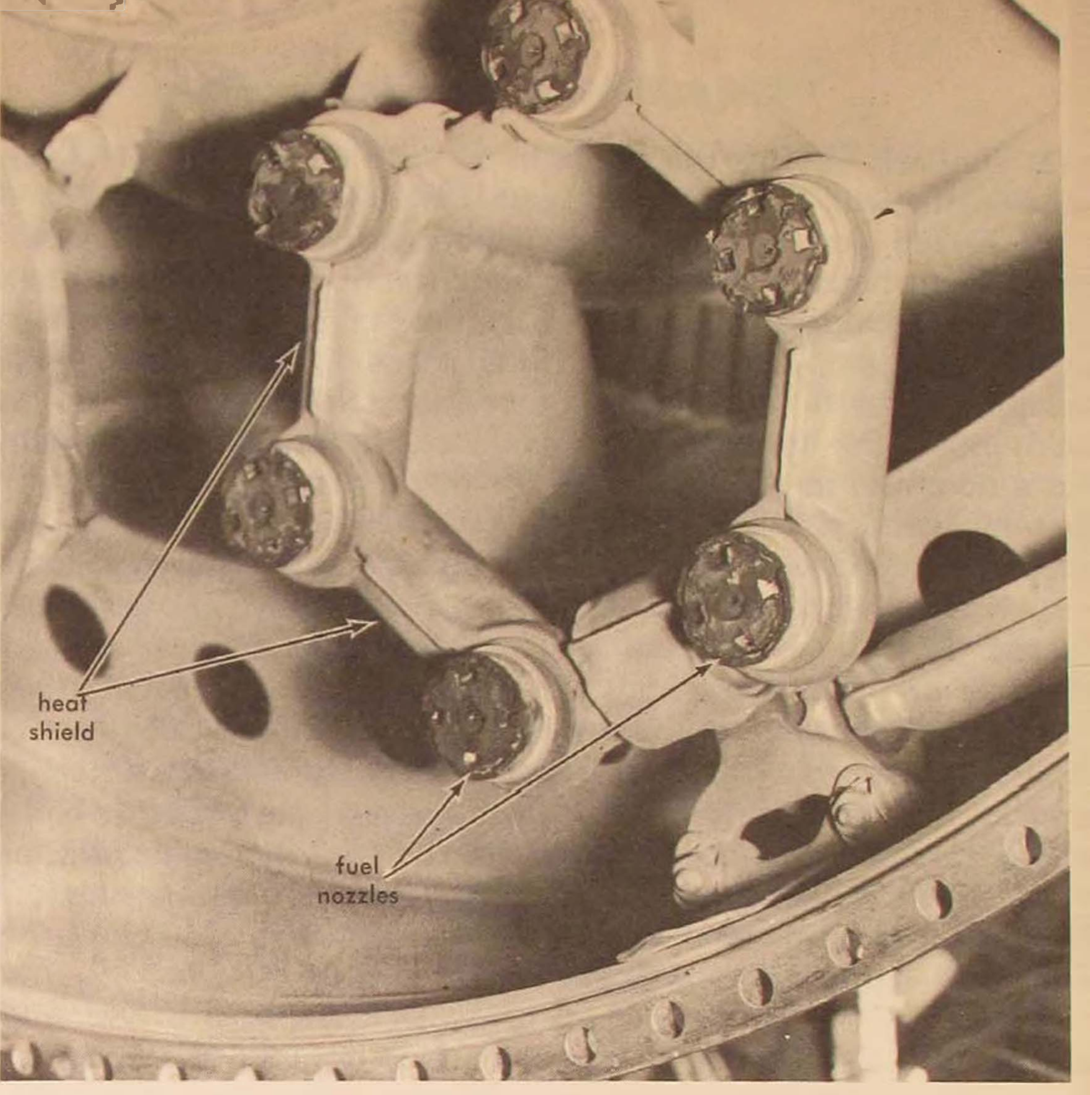
In the process of effectively eliminating compressor stall from the J57 turbojet, a much better understanding of the stall phenomenon was obtained. As a result it became possible to show that pilot techniques and influences of installations in the aircraft could be major factors in causing an otherwise stall-free engine to become stall-prone. For example, stall could result from air being delivered in a nonuniform way to the engine by an airplane's ductwork (as in accompanying sketch). Thus the program provided criteria for the improvement of both airplane ducts and flying procedures.

Another very troublesome and unique problem encountered early in the J57 turbojet program was "coking" of the engine's fuel nozzles. Because of the engine's high pressure ratio, the air leaving the compressor and flowing around the fuel nozzles was quite hot (more than 650°F). Heat was transferred very rapidly through the metal of the nozzles into the fuel flowing in them, causing part of it to boil. This caused a residue to be deposited by the fuel in the nozzles, and it plugged some of them in a very short time. While the nozzles were being plugged, the combustor section of the engine deteriorated rapidly, and engine failure occurred soon thereafter.

The solution to this problem involved changes to both the fuel system of the engine and the fuel itself. A heat shield was added to



Typical air distortion at inlet to engine



J57 turbojet engine fuel nozzle cluster

reduce the rate at which heat could be transferred into the fuel. The fuel system design was improved to make its screens less likely to accumulate residue and to eliminate channels of low flow or stagnation. The thermal stability of the fuel was improved by additives that could be (and subsequently were) added at the refinery. Thus another technical challenge was met successfully, and the J57 development program continued its steady progress.

One more typical problem, this one different in that it was induced by the environment imposed on the engine by Air Force operations, illustrates the drastic effect that an unexpected and therefore unprovided-for environment can have on engine reliability. Investigators probing the wreckage of a large aircraft propelled by the J57 turbojet found conclusive evidence that the fuel delivered to the engines had contained a large quantity of ice. Ice had collected in the fuel controls of the engine and restricted the flow of fuel to the engines so much that the aircraft could not continue flying. Investigation established that the ice accumulation was caused by several factors: the major ones were the very long mission times of the aircraft and consequently the tremendous quantities of fuel consumed, the tendency of the fuel itself to give up water as it cooled in the tanks and fuel system of the airplane, and the flight-operations and maintenance procedures which did not adequately circumvent this hazard.

The latter factors were improved very quickly in accordance with the recommendations of the investigators and other information, but procedural changes were only a partial solution to the problem. Means had to be found to retard or eliminate the formation of ice in the fuel. Fuel heaters were successfully developed for this purpose, and each engine was fitted with one. These heaters use a small amount of hot air from the compressor to warm the fuel whenever its temperature nears the freezing point of water. Fuel-borne ice has thereby been effectively eliminated as a deterrent to engine reliability.

These problems were a few of the technical challenges met successfully in the J57 turbojet development program. They are normal for any such program in which a large improvement in the state of the art is sought. It is interesting to note that the J57 development program consumed more than:

- 12,000 full-scale engine test hours in test cells (and the equivalent of 45 test engines)
- 80,000 component test hours
- 600 development flight test hours (plus thousands of suitability flight test hours in experimental models of operational aircraft).

The product of all this time and effort was a fully qualified propulsion system: the reliable, efficient J57 engine, which now propels many Air Force aircraft.

The severity of the task of evolution of superior advanced systems from idea to inventory has grown tremendously in the past decade. Judicious selection of the approaches to be emphasized, out of an extremely broad and complex field of candidates, is a most challenging and significant management requirement. The expeditious and efficient reduction to practice of these selected areas requires the highest standards in planning and program direction. Fortunately, the Air Force has developed an excellent management capability which ensures dramatic future progress.

Aeronautical Systems Division, AFSC

Acknowledgment:

The author wishes to express his indebtedness to the Pratt & Whitney Division of the United Aircraft Corporation for materials used in the preparation of this article.

RESEARCH AND TECHNOLOGY MANAGEMENT

Major General Marvin C. Demler

THE Research and Technology Division of the Air Force Systems Command was activated in 1962 to centralize the management of Air Force applied research and advanced technology programs. Its primary area of responsibility is that portion of the weapons acquisition cycle which lies between basic research and the development and production of individual weapon and support systems. The work carried on in this area is essential to the task of translating basic scientific knowledge into operational aerospace systems. The bulk of it is conducted or sponsored by Air Force in-house laboratories. More than $400,000,000 of AF funds is involved annually.

The need for strengthening the management of in-house laboratories has been recognized for some time. In October 1960 the Commander of the Air Research and Development Command designated a task force to study ways of improving the working environment in ARDC in-house laboratories. When the Air Force Systems Command was established in April 1961, a Deputy Chief of Staff for Research and Engineering was made a part of the headquarters staff to ensure continuing attention to research in the new organization. Studies went ahead to determine ways of improving the organization and management of applied research and advanced technology.

In the following months, the strengthening of in-house laboratory capabilities throughout the Government, particularly in the Department of Defense, became a matter of national policy. On 14 October 1961 the Secretary of Defense sent a memorandum on the subject to the Secretary of each military department. This was followed by a memorandum from the Director of Defense Research and Engineering to the Assistant Secretary of the Air Force (R&D), quoting a portion of the Defense Secretary's directive stating that "in-house laboratories shall be used as a primary means of carrying out Defense Department programs." The Chief of Staff asked the Scientific Advisory Board "to examine research and development activities within the Air Force with major emphasis on a drastic improvement of our in-house laboratories."

The SAB committee report of April 1962 contained two major recommendations:

> All of the Air Force research and advanced technology . . . should be under a single command—the Air Force Systems Command. There should be a highly qualified individual reporting directly to the Commander, AFSC, and solely responsible for the management of the entire Air Force research and advanced technology programs.
>
> The laboratories should be regrouped in orderly fashion to reflect the pertinent scientific disciplines and to afford a manageable span of control. Individual Research and Technology Laboratories should be formed, such as Propulsion, Materials . . . Each laboratory director should be directly and exclusively responsible to the Manager of Research and Technology. . . .

As a result of these several actions, in April 1962 a Research and Technology Division, Provisional, was organized around the small staff of the Deputy Chief of Staff/Research and Engineering, which moved from Andrews Air Force Base to Bolling AFB in Washington, D.C. During the next three months detailed operating plans were drawn, and in July the Chief of Staff approved the activation of a permanent division. The chief objective of the new R&T Division is to strengthen the laboratories that are the primary organizations conducting and sponsoring research and technology. Laboratory directors and staff must be technically competent, experienced, and highly motivated. They must have clearly defined missions and lines of responsibility, and they must be assigned important and challenging work. Modern facilities and full support for in-house research must be provided. A second objective is the reduction of intermediate echelons of review so that laboratory directors may formulate their programs and present them directly to the Commander and Scientific Director of the division. Such reductions in staff echelons will provide additional manpower for the laboratories.

The R&T Division is taking specific action to create new opportunities in Air Force laboratories for scientists and engineers of high professional caliber, by offering challenging work, ample support, a favorable scientific environment, competitive pay scales, and recognition of outstanding performance. It is initiating a planned program of professional career development to attract and retain competent people in the laboratories, and it is improving management through the introduction of control procedures that are flexible enough to allow scientists and engineers to work freely and with initiative and imagination.

The goal of all these efforts is to make maximum use of the total resources of U.S. and foreign technology. Ideas, techniques, and assistance from all available sources will be funneled to AFSC laboratories in each technical area and directed toward potential Air Force applications.

The planned operating elements of the Research and Technology Division under consideration consist of seven major laboratories: the Air Force Rocket Propulsion Laboratory, Edwards AFB, California; the Air Force Weapons Laboratory, Kirtland AFB, New Mexico; the Air Force Aero-Propulsion Laboratory, the Air Force Materials Laboratory, the Air Force Flight Dynamics Laboratory, and the Air Force Avionics Laboratory at Wright-Patterson AFB, Ohio; and the Air Force Electromagnetics Laboratory, Griffiss AFB, New York. The plan is to form these seven laboratories by consolidating the more than thirty laboratories assigned to AFSC, and each is to be responsible for planning, initiating, and executing the total program in a single broad area of technology.

The establishment of a limited number of major laboratories eliminates the need for the Technical Area Manager/Technical Area Coordinator (TAM/TAC) method of applied research management. Although this system has worked well in the materials area, where all work is concentrated in a single location, it has proved to be a cumbersome means of coordinating work in the other technical areas. The division is now in the process of consolidating the 27 applied research technical areas in line with the new laboratory organization. This will provide for a cleaner interface with the six areas of basic research and will align Air Force programs very closely with the new DOD program packages for budgeting purposes. Within each area of technology, laboratory directors will be given maximum operating authority. They will receive their resources as a laboratory program package, much like a system program package. They will be responsible for planning, initiating, and carrying out programs in their own areas, and will report directly to the Commander, R&T Division.

Each laboratory will have both techniques groups and an applications group. The techniques people have as their objective the generation of new technology. The applications group will work closely with the AFSC systems divisions to apply this technology to the solution of problems in present and future systems. The ability to accomplish this vital transition function—from techniques to application—within a single organization is a major step in speeding the flow of technology into systems.

Each of the laboratories will serve as a focal point for all available information in its own area of technology, including that being generated by system developments. They will furnish technical assistance to the system divisions on a direct request channel from the system project office. In this way it is planned to provide improved technical input for new system development plans, at the beginning of the development cycle.

The R&T Division will be responsible for management of the advanced technology portion of the advanced development program. Advanced technology programs are experimental demonstrations which bridge the gap between applied research and systems applications. Each laboratory will have the capability to manage advanced technology programs and will manage programs unique to its assigned technical area. When an experimental program becomes sufficiently complex to be managed as a system, the appropriate systems division will be asked to manage the entire package, with the laboratory responsible for the technical aspects.

It needs to be recognized that the R&T Division has been established to do a job that has never been attempted before—the centralized management of applied research and advanced technology programs through major laboratories concerned with broad technical areas. The division is still in the process of organization, and not all the laboratories will be assigned until July 1963 when the division becomes fully operational.

Under this new organizational setup, the research programs aimed at furnishing the technology for the next generation of systems will not have to compete with present system programs for management's time, interest, and resources. At the same time the Research and Technology Division will foster the same sense of urgency for these research programs that is present in system programs. Its efforts will be devoted not only to enlarging the Air Force technological base but also to establishing procedures which encourage rapid translation of technology into systems applications. In this way the R&T Division will play an increasingly important role in the mission of AFSC to attain and maintain technological superiority.

Research and Technology Division, AFSC

WEAPON TESTING

COLONEL CHARLES G. ALLEN

IN THE LATE Forties industry officials, military leaders, technicians, and test pilots gathered at Edwards Air Force Base to evaluate several X-model prototype fighter aircraft. The winner of the competition was to receive a production contract, the first models of which would appear one to two years later and be employed in a drawn-out static and flight test program prior to production acceleration. This process of weapon acquisition for the tactical inventory was time-costly; the finished product was obsolescent when it was produced.

The urgency associated with acquiring a strategic missile force results in time compression—or concurrency—so that the design, fabrication, production, testing, and preparation of technical data are accomplished, to a large degree, concurrently. Employment of the time compression concept spotlights the emphasis on design and test. A perfect design would make testing superfluous, but today's weapons push the state of the art into unknown regions of zerogravity, re-entry, and other environmental extremes. Testing, then, is essential to prove the validity of the design and must be accomplished as rapidly as possible for feedback into production.

Missile weapon system complexity, induced by automaticity, close tolerances, and precision operation, is often not fully appreciated. Aside from the personnel subsystem, the ground environment for fueling, checkout, and launch represents 70 to 80 per cent of the weapon system; the missile represents the other 20 to 30 per cent. The Atlas F, for example, contains some 1500 missile components, and its ground support systems have an additional 4500 components.

To integrate thousands of airborne and ground support components into an operational system requires a tremendous amount of testing under conditions far different from those for testing aircraft. A major missile cannot be test-flown and recovered for modification and improvement. No pilot is aboard to observe, report, analyze, or adjust in-flight failures. Only a limited number of test vehicles is available, and flights are necessarily restricted to the Atlantic and Pacific missile ranges. Every aircraft delivered to the using agency is capable of practicing all the techniques and maneuvers of an actual combat mission, whereas deployed missiles (other than those at Vandenberg and Patrick) can only be ground-checked for proper component and subsystem function.

Missile component failure, both on the ground and in the air, often results in headline publicity. Fortunately even failures provide invaluable data to the development test program. The purpose of testing is to determine not only how good an article is but also its weaknesses. As an example, during a routine test exercise on 3 December 1960 the Titan missile silo at Vandenberg AFB was destroyed when a launch-platform hydraulic floor control valve failed. It was a costly, unscheduled test, but as a result a weakness was uncovered that led to the redesigning of the entire hydraulic system of the launch-platform operation. Similarly, other spectacular test failures have caused raised eyebrows and skeptical retorts after the announcement that a certain degree of success had been achieved by them.

No weapon system test has a single objective. Generally each test has a number of primary and secondary objectives, and for the most part the objectives are achieved prior to the terminal phase of the test. Thus, seldom does a test fail to achieve some measure of success from the standpoint of the tester. An interesting illustration is offered by the May 1961 test of a Titan launch from an underground silo. All test objectives were achieved by the time the missile was 100 feet in the air. It exploded before it had completed two minutes of flight, and to the casual observer it appeared to be "another failure." Actually the explosion itself was a scheduled test. After all primary test objectives had been achieved, the Navy was permitted to check out the command destruct system. It worked, but only those in the know realized that a complete success had been achieved.

Fundamentally, testing has a twofold objective: determination of performance in accordance with specifications; and repeatability of performance, or reliability. How long does this take? In a sense, the C-47 is still being tested by each pilot and maintenance technician. When sufficient Unsatisfactory Reports (UR's) are accumulated on an item, it is redesigned. Testing is completed when the article is no longer in use. The formal testing program, of course, is much shorter.

The testing of Air Force weapon systems is performed in accordance with Air Force Regulation 80-14. The regulation specifies a logical sequence of three functional categories of testing:

Category I - Subsystem Development Test and Evaluation
Category II - System Development Test and Evaluation
Category III - System Operational Test and Evaluation.

Clear understanding of the current concept of weapon testing within the Air Force Systems Command requires consideration, in sequence, of the three test categories. Generally there is no clear line of demarcation in the transition from one category of testing to another. For the sake of simplicity, this discussion treats each category separately.

Category I

Missile test operations in Category I range from those on individual components through static firings and flights tests, including checkout, of operational equipment. Component qualification is essential before the testing of major assemblies of the complete weapon. Once this is accomplished, flight-testing, base activation, and performance improvement proceed simultaneously.

An initial stumbling block is that engineers must often design airborne equipment in the dark, so to speak. Because of a lack of knowledge about the environment in which these components must function, they often have to be designed, assembled, and flown to gather data on which the original design should have been based. Although we are becoming more knowledgeable, missile weapon systems are still, relatively speaking, in their infancy. Usually there are no tried and true rules and no backlog of experience to follow in conducting tests.

An associated problem has been the need for industry to develop new production methods and testing techniques so as to ensure the precision and durability required for failure-free operation of missile components. These stringent requirements led contractors to establish at their home plants an integrated test facility for the Titan and a similar facility for the Atlas, making possible the testing of components, subsystems, and the weapon system at one location. This procedure saves both time and use of industrial talent by permitting concurrent development with a minimum of communications difficulty.

The Atlas provides a good illustration of a typical Category I test program. Missile qualification testing is accomplished at six locations: San Diego, Point Loma near San Diego, Sycamore Canyon, Edwards Rocket Base, and Vandenberg AFB, all in California, and Patrick AFB, Florida. Initial qualification of component subassemblies is carried out at the laboratories of the home plant or at qualified commercial testing laboratories. Approximately 2500 people at San Diego are engaged in testing, test support, or analysis and evaluation of test data from all the facilities. Components and major subassemblies are further qualified at Point Loma for tests involving cryogenics or dangerous chemicals as well as for the destructive testing of entire missile tank sections. Static firings to evaluate the performance of the missile under captive conditions are carried out at Sycamore Canyon and at Edwards Rocket Base. Tests at these sites serve to further qualify the performance of components and provide data enabling corrective action before flight-testing.

Patrick AFB is the base of operations for the Atlantic Missile Range, where the continuing program of missile performance optimization is carried through flight-testing. Component performance is still important, but here the emphasis is on the gross performance of the missile in flights down range. Launch control equipment at this facility is expressly designed to provide as much countdown and flight data as can be acquired and only approximates the equipment at the operational sites.

A good example of component development test is in the history of the Atlas missile motor-driven helium changeover valve. Development of this valve typifies the process by which the gap between design specification and manufacturing tolerances is bridged. It also illustrates the difficulties involved in obtaining reliable operation under extreme operating conditions.

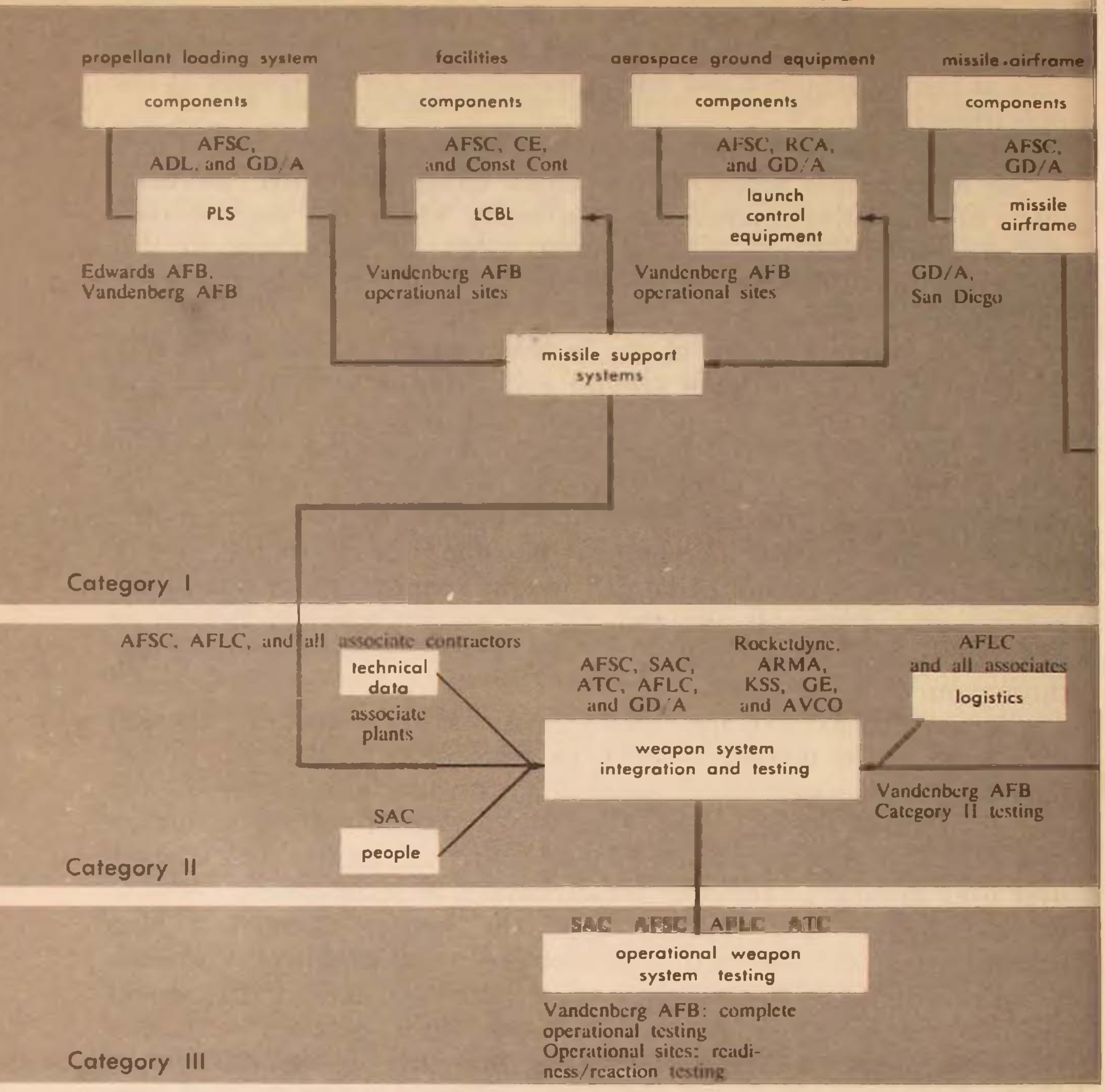
In the original design of the missile tank-pressurization systems, the interconnection between ground and airborne pressurization was defined. Helium was to be supplied and pressure programed by ground units until shortly before launch. At that time the airborne helium storage bottles would take over to maintain tank pressures throughout flight. The major objectives were (1) to keep the airborne storage bottles as small and light as possible, bowing to the rule of thumb that every pound of launch weight requires about one and a half pounds of propellants; and (2) to ensure sufficient helium to maintain proper tank pressures (and missile structural integrity) throughout powered flight.

Spherical bottles in the missile thrust section were to be charged with supercooled helium (–280°) to some 3000 pounds per square inch. Liquid nitrogen, circulated through shrouds around the bottles, was to continue chilling the helium (with helium volume shrinkage made up by inflow of additional gas) until the moment of changeover from ground to airborne pressurization. At changeover, extremely cold helium was released from the bottles through a heat exchanger to the fuel and liquid-oxygen tank pressure regulators.

To accomplish this changeover, a valve was needed that would open to release a high-pressure cold gas while exposed to engine vibrations, permit a high flow rate, and not close again. Procurement specifications were prepared defining package size, weight, and performance requirements. Responses to the resulting invitations to bid were evaluated by engineering and purchasing, and a vendor was selected. A limited purchase order authorized the production and testing of some half-dozen valves. The valves were then subjected to flight certification testing, utilizing laboratory facilities of the prime contractor for functional tests and a commercial laboratory for environmental and other specialized tests.

The functional testing discovered severe oscillation during the opening actuation of the valve. Engineering analysis of test data disclosed that the ½-inch intake created a resonant condition. The trouble was corrected by redesign to a ¾-inch intake. Retest after the change confirmed its adequacy, but further functional testing revealed sealing problems. These were traced to the valve seating design, which was modified to provide knife-edge seat contact.

Typical Missile

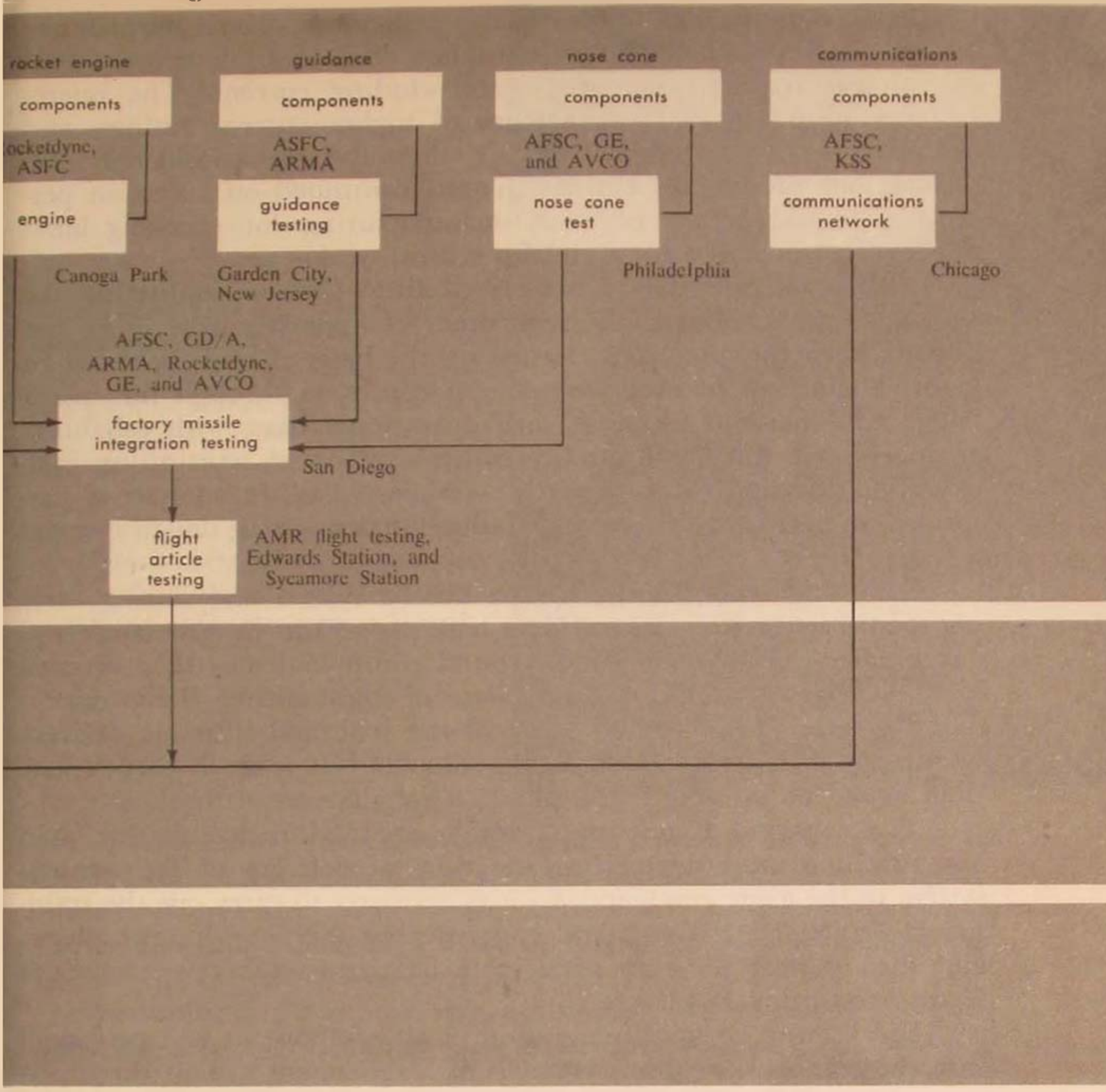


General scope, meshing of subsystems, participants, and locations of activities

GLOSSARY

ADL — Arthur D. Little Company
AFLC — Air Force Logistics Command
AFSC — Air Force Systems Command
AMR — Atlantic Missile Range
ARMA — American Bosch Arma Corporation
ATC — Air Training Command
AVCO — AVCO Corporation
BSD — Ballistic Systems Division
CE — Civil Engineering
Const Cont — construction contractor
GD/A — General Dynamics/Astronautics
GE — General Electric Company
IG — Inspector General
KSS — Kellogg Switchboard System
LCBL — Launch Control Board Launcher
PLS — propellant loading system
RCA — Radio Corporation of America
SAC — Strategic Air Command
STL — Space Technology Laboratories

Test Program



of the three testing categories for the Atlas intercontinental ballistic missile.

With this change, the valves met all requirements and were flight-certified. They were then distributed to the Point Loma, Sycamore, and Edwards test facilities for further evaluation. At Point Loma the valve performed satisfactorily through repeated actuation cycles over a wide range of input conditions. Early tests at Sycamore and Edwards, with the valve installed in missiles for static firings, also confirmed soundness of the design. The valve was ordered into production.

Further testing of missiles at Sycamore and Edwards began to show that the valve was prone to hang up in either the open or closed position. Failure analysis indicated that the motor operation overrode the position-limiting microswitches. Teflon bumpers were added to eliminate the problem. A later rash of failures resulted from a combination of problems: motors and microswitch leaves burned out because Teflon washers created too much drag, and low temperatures or voltages required excessive motor-winding current. The microswitches were replaced by switches of higher current ratings, and the washers were redesigned. Finally the valve was considered satisfactory, but production evaluation tests continued on a certain percentage of valves out of every manufacturing lot—checking burst pressure, motor stall torque, etc., for critical weaknesses.

Although flight data have played little part in confirming the adequacy of this particular item, other components have quite frequently been completely redesigned on the basis of their behavior in flight. Evaluation of every component continues through the installation and checkout phase at each operational base, with reliability engineers and Air Force quality control personnel scrutinizing each operation for signs of component weakness. Failure analysis is performed on every critical or major failure, and resulting design changes are retrofitted.

Following static testing of the missile system and during early phases of flight-testing, operational base design can be generated, and development of the operational ground equipment may then proceed concurrently with the advanced phase of flight-testing. This concept of concurrency leads to activation of the base and ultimate delivery of the weapon system to the using command at a much earlier date than would be possible if the phases took place sequentially.

The concept of concurrent development also dictates that man and machine must dovetail at the time of delivery of the weapon system to the using command. So it is necessary to carry out the training of Strategic Air Command crews during the development phases and then permit them to participate heavily in the test operations leading to turnover of the facility.

Focal point for final integration of all components and personnel into the complete weapon system is at Vandenberg AFB in the Operational Suitability Testing Facility (OSTF), referred to as TF-1 during the testing of Titan. While the operating prototype weapon systems are being tested at Vandenberg, operational bases are only slightly behind in construction and installation of equipment. All information collected during testing at the OSTF is immediately made available to downstream sites.

Many compatibility and improvement changes must of necessity be generated because of testing experiences at Vandenberg. Compatibility changes are those that must be adopted to ensure proper functioning of the weapon system. Improvement changes are adopted only after weighing their importance, cost, and impact on the schedule.

Control of changes generated at Vandenberg is of utmost importance. The configuration of all operational bases must be clearly defined at all times and the incorporation of changes rigidly controlled. Whenever a change is approved, a complex scheduling prob-

First Atlas E ever launched from an operational facility bursts into a cloud of flame after rising a few feet from its launch pad at Vandenberg AFB on 7 June 1961. It was determined that the malfunction was in the missile itself. The aerospace ground facility and allied equipment were thus proved to have functioned normally, and most of the test objectives were achieved.

lem of sequencing, parts availability, and installation time must be resolved for each downstream site. Achieving identical final configuration of all operating bases is a complicated task. AFSC personnel at Vandenberg must constantly bear in mind the impact of their test activities on the entire activation program.

Verification of technical data for use by SAC personnel on operational bases is one of the most important functions performed during the Vandenberg testing program. Many reviews of this material are conducted, including verification of the data by actual operation of the facility. This process by no means concludes the perfecting of technical data, but it does provide the basic manuals to SAC in time to support turnover of new bases.

During the TF-1 phase of Category I testing of Titan, a solid emphasis was placed on the early development and verification of technical data. The Titan Category II program will concentrate on further updating and verification of these data in relationship to changes that have been made to overcome certain problems that cropped up during the Category I test program.

Category II

Although the Category II program has several clearly defined and specific objectives, it is basically aimed at ensuring that men and machines function together properly. The emphasis is placed upon establishing the Air Force crew's ability to maintain and operate the system, utilizing the proper technical data. The over-all objective of the Category II program, however, is to evaluate the weapon system to determine the degree of compliance with operational requirements. Specifically, the Category II test program seeks to establish:

hardware capabilities and limitations
the adequacy and accuracy of technical data
personnel subsystem performance
adequacy of operations, maintenance, and logistic plans
stability in readiness condition for extended periods
reliability
vulnerability
safety procedures
configuration control.

All these objectives must be accomplished within a realistic operational environment, yet with adequate instrumentation to record all required parameters. At an OSTF an instrumentation building or room is provided, but even with its elaborate associated instrumentation and wiring installations within the facility it has no significant effect on the operational configuration of the OSTF. The instrumentation building for Atlas F OSTF contains over 45 multichannel recorders, with a total of 442 channels available for recording purposes. Two kinescope recorders are available for the seven closed-loop TV cameras. A network of 13 remote-control motion-picture cameras provides photographic coverage.

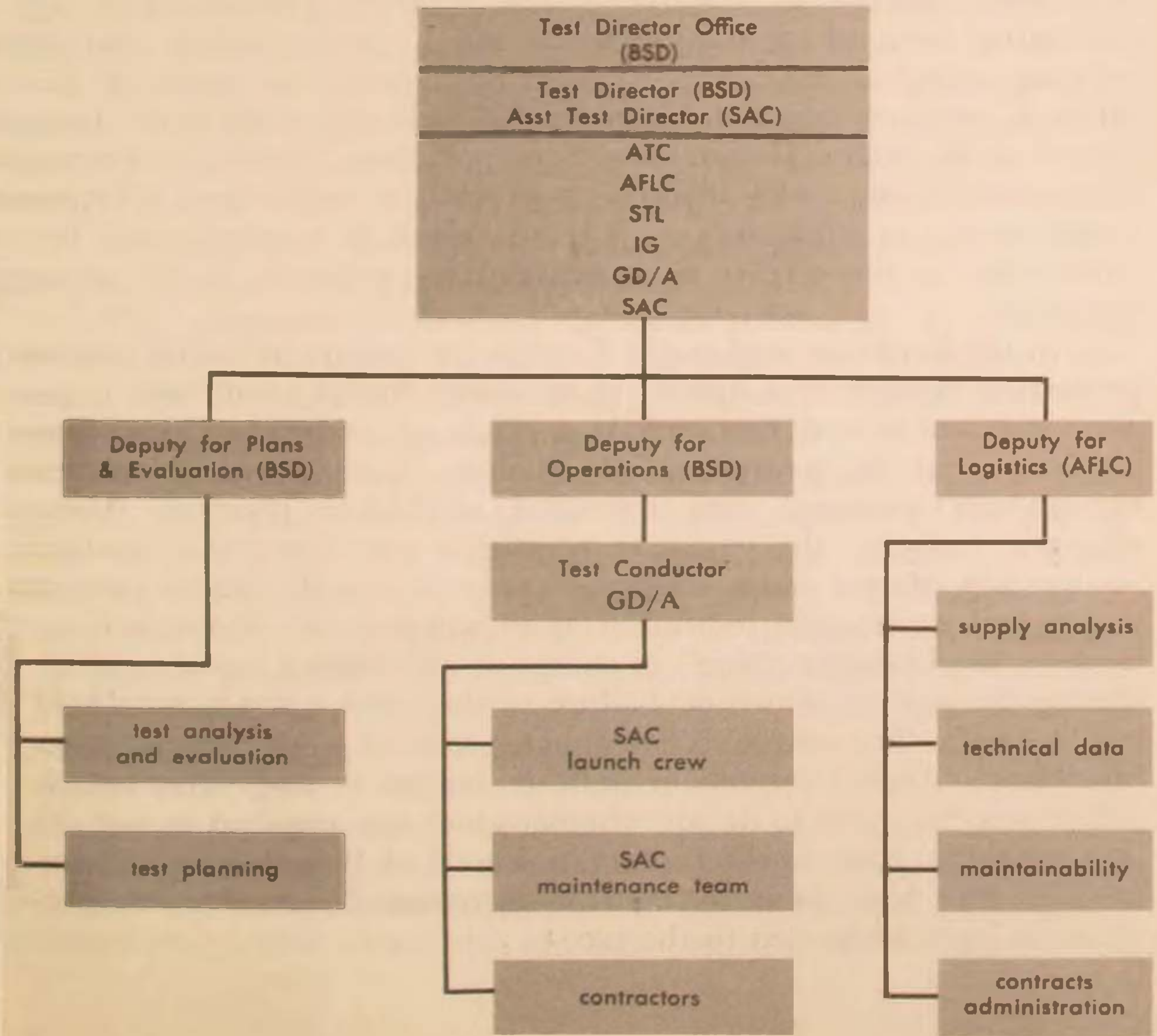
Restrictions inherent in testing within the missile program become important at this point. Time and economy limit the number of actual launches that may be made, necessitating careful and thorough planning to obtain all possible data from each test. Data on as many as 500 parameters are recorded during a single test operation. Operations with cryogenic fluids and rocket propellants are inherently hazardous. Inasmuch as personnel cannot work safely on a fueled missile, test personnel are largely dependent on data analysis for determining the cause of malfunction during a fueling exercise. Often an entire test must be aborted and rerun to accomplish a simple adjustment that cannot be made while the missile is fueled. Proper scheduling and coordination of all activities to minimize down time for modifying, setting up, or refurbishing are vital to the accomplishment of the task within time limits. The importance of planning is reflected in the organizational structure established to support Category II testing, shown in the accompanying chart. This general organization has been implemented for test programs at Vandenberg.

Basic to the program is the integrated test plan prepared by the Ballistic Systems Division well in advance of the starting date. This plan outlines the general sequence of testing, with specific objectives identified for each test series. Primary and secondary instrumentation parameters for each test series are identified. Each series normally terminates with a launch. Using this plan, the test force must design tests to meet the objectives and must produce test directives to identify in detail the sequence, procedure, configuration, instrumentation, personnel, and reporting to be used for each operation. These test directives are published as a joint Air Force–contractor effort and often run over 200 pages, including reference documents.

Normally all tests are monitored by several test teams, each of which has a particular area of primary interest, such as hardware design, technical data, instrumentation, or personnel subsystems. Composition of the teams varies, but they normally include an engineer, operator (SAC or contractor personnel), personnel subsystem observer, inspector, writing group representative, and an Air Force Systems Command project officer. Pretest briefings are conducted by each team to ensure that all members are familiar with test procedure, have possession of latest updated technical data and required data-collection sheets, and are thoroughly familiar with their duties and responsibilities. It is particularly important for exact configuration to be reviewed, to ensure valid testing and results.

For initial launches at Vandenberg the weapon system contractor,

Category II Air Force Test Organization



as test conductor, is responsible for actual hardware operation. In the early stages of Category II, contractor personnel perform all functions, with SAC personnel receiving "over the shoulder" training. As testing progresses, more and more functions are assumed by SAC until in the final phases contractor personnel merely monitor the operation. All tests are conducted in strict accordance with operational procedures and applicable technical orders.

Immediately following test completion a review is conducted by each team captain. Team recommendations are immediately reviewed by the test conductor. Upon approval they are sent to the test force review boards at Vandenberg. These boards take action on all design discrepancies classified as questions of compatibility, make recommendations to the system project office (SPO) on suggested product improvement changes, ensure that changes are incorporated in the configuration control document, and report on action taken. Other boards perform these reviews for technical data and the personnel subsystems.

Adequate evaluation and interpretation of test results are essential to the success of a test program. Data from many types of recorders must be reduced to usable form and interpreted by appropriate analysis groups.

Test results in the Vandenberg Category II test programs to date have been effective in identifying and resolving problem areas, in indicating areas where improvements can be accomplished, and in refining technical data. For example, with only two thirds of the Atlas E program completed, nearly 3000 change pages have been issued to 54 technical manuals. Some of these changes corrected errors, others improved sequencing or clarity, and others reflected modifications to configuration. The net result is a considerable improvement in the quality of technical data available to the using command.

In the hardware area, early E series test results indicated several important changes that needed to be made. Initial countdown times were not within specifications. As a result of analysis a change was initiated that accelerated missile fueling, increased liquid-oxygen storage-tank pressure, and decreased chilldown pressure. These changes brought the countdown within specifications. Another change was effected when it became apparent that the launch control officer had no positive indication as to whether the missile had received a liquid-oxygen "slug" (a charge of supercooled liquid oxygen) during the commit sequence. Failure to slug after a five-minute hold could destroy the missile. The change provided a warning light on the launch control console to indicate failure to slug. The launch officer was then able to decide whether abort was required or not. At the two-thirds point in the E program a total of 19 such compatibility changes had been processed and 35 recommendations for improvement changes forwarded to the SPO.

The personnel subsystem testing is primarily concerned with the areas of human design considerations relative to maintainability, operability, safety, etc.; technical publications used by personnel in operating and maintaining the system; work conditions affecting personnel performance; adequacy of the number and skill identification of personnel used on the job; and the adequacy of training received and the means by which it was imparted to personnel.

Maintenance and operating personnel are observed as they perform assigned tasks using operational technical-data check lists. Observer personnel are assigned on a one-for-one basis for each operator. This observer-to-operator ratio is reduced only where space is quite limited. Each observer has a copy of the technical data so that he can detect any deviation from required conditions. Deviation from operational data, difficulties encountered because of insufficient or inadequate tools, poor lighting, equipment design, safety factors, etc., are recorded on the observer's personnel performance check list. During task performance observer personnel do not converse with the individuals being observed.

After completion of the operating tests, each observer interviews the individual he observed. The post-test interview form used consists of 27 operational questions and 23 troubleshooting questions. Following the interview the observer reviews the data recorded on the post-test interview forms and the personnel performance check lists and initiates personnel subsystem deviation/difficulty reports (D/D's) on this information. In one ICBM Category II program that was completed in August 1961, 1097 D/D's were generated and 1231 corrective actions were recommended in the following areas: equipment design, 141; technical data, 555; job environment, 27; personnel selection, 19; organizational control and training, 278; and miscellaneous (logistics, safety, communications, etc.), 211.

The personnel performing the tasks monitored by personnel subsystem observers were assigned to SAC. Before the start of the program, aptitude tests and background interviews were administered to 32 Air Force and 44 contractor personnel.

Of the military personnel tested, 4 were officers, with a grade spread from chief warrant officer through captain. Their average time in service was 14.9 years, and their average missile experience was 3.2 years. They had been assigned to related mechanical or electronic career fields before assignment to missiles. The remaining 28 military personnel tested were airmen, with a grade spread from airman second class through master sergeant. Their average time in service was 11.4 years; average education, 12.2 years; and average missile experience, 3 years. They also had been assigned to related mechanical or electronic carreer fields before assignment to missiles.

The contractor personnel tested were those performing the operational and maintenance requirements on the missile. Military personnel tested were those who are now, or soon will be, performing the tasks previously performed by contractor personnel. The test used was the Employee Aptitude Survey designed by Psychological Services, Inc., Los Angeles. It was administered by two contracted psychologists, both licensed by the State of California. The scores were grouped by contractor and military personnel to enable easy comparison.

	maximum possible score	*contractor personnel score*	*Air Force personnel score*
Test 1, verbal comprehension	30	15.8	21.3
Test 2, numerical ability	75	28.0	32.8
Test 3, visual pursuit test	30	16.3	19.5
Test 4, visual speed and accuracy	150	81.6	96.9
Test 5, space visualization	50	25.6	31.9
Test 6, numerical reasoning	20	8.4	10.1
Test 7, verbal reasoning	30	12.1	15.7
Test 8, word fluency	none	41.8	43.6
Test 9, manual speed and accuracy	750	360.1	423.6
Test 10, symbolic reasoning	none	52	81

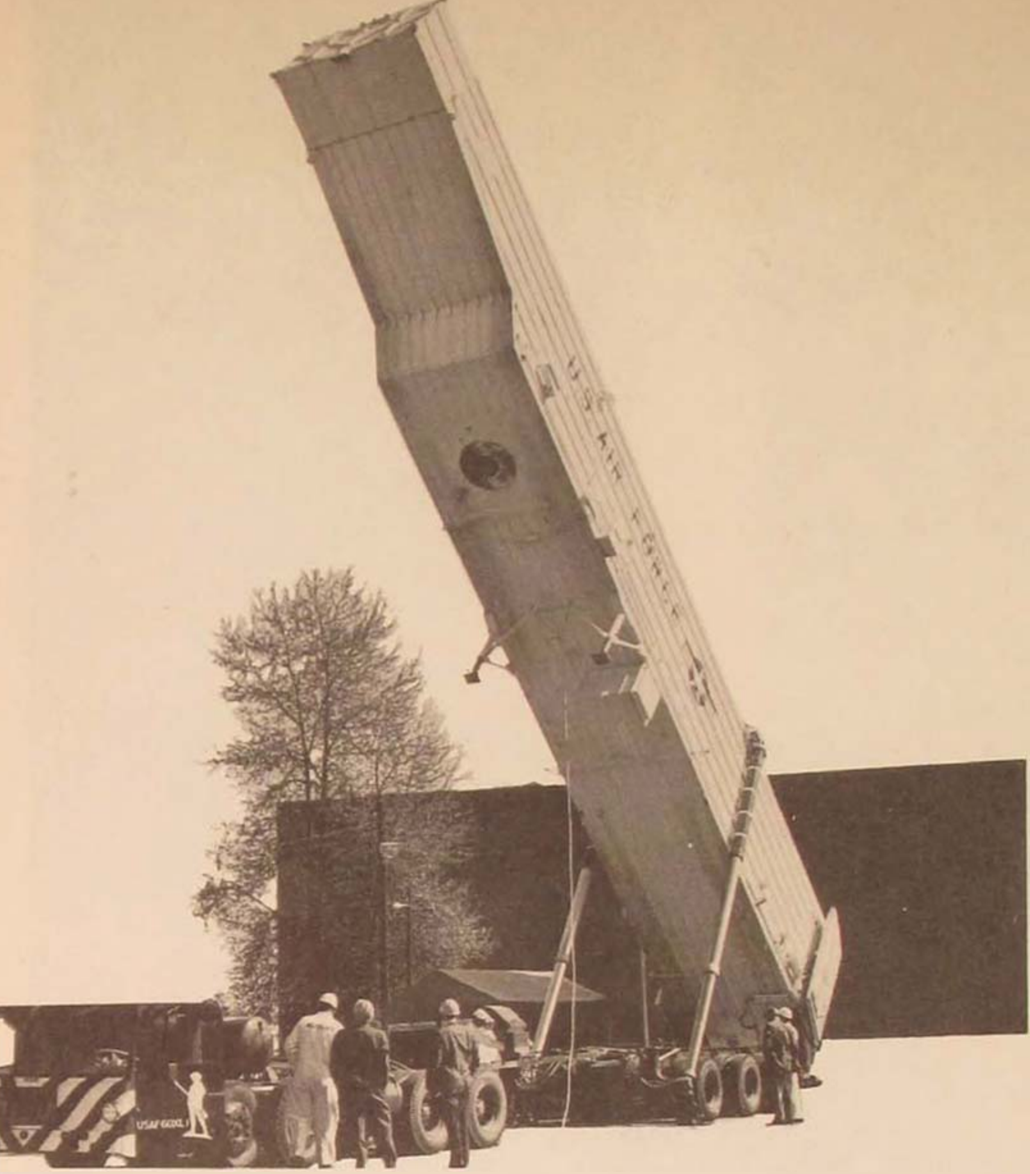
The pros and cons of whether this was a representative sample of each group will not be discussed here, but probably it was. It should be noted, however, that the men on the Air Force crews were selected personnel.

The personnel observed in this particular Category II program displayed all the normally expected reactions and capabilities. Many technicians were extremely competent and demonstrated an eagerness to do their best. Others, though probably equally competent, seemed to care less about their job performance. In the final analysis, it is people who will make a weapon system perform in the desired manner. Most hardware deficiencies can be overcome by adequate competence (training and experience) combined with a desire to excel. Though little information was gathered that pertained directly to this combination of factors, it is felt that they will be a major element in making the weapon system work. It will take a great amount of effort, however, to maintain the eagerness of those assigned to the weapon system. It is probably true that the personnel portion of any weapon system will be the least predictable component.

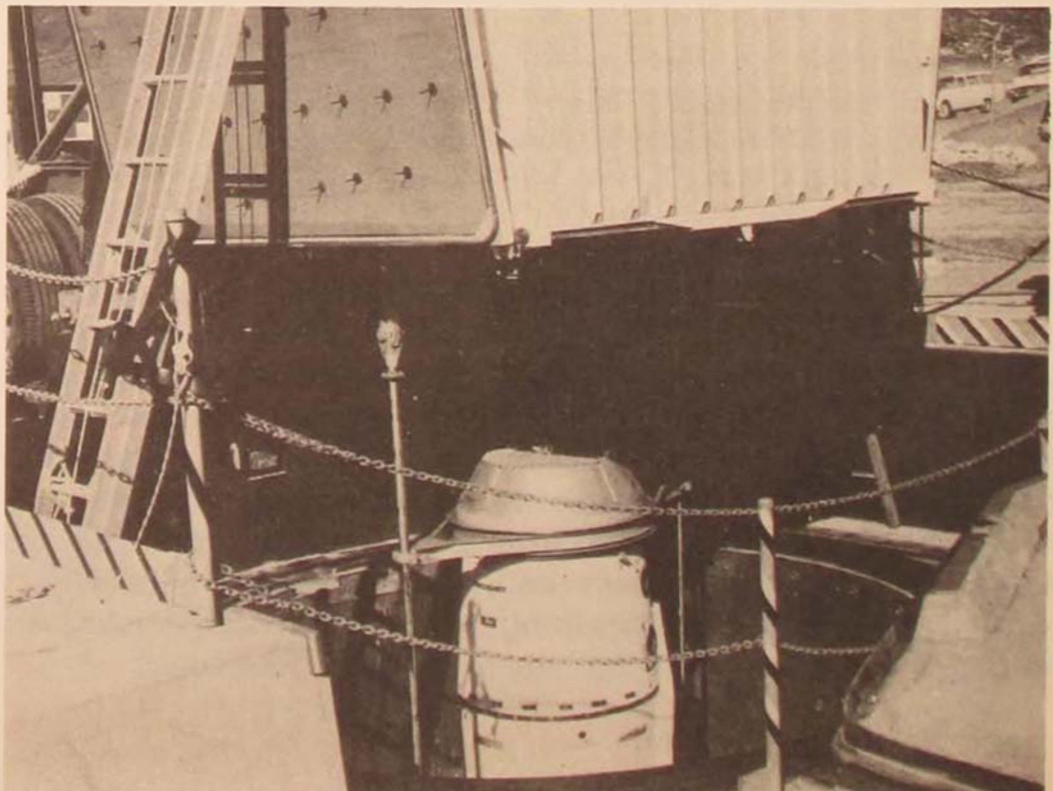
As in Category I testing, the importance of configuration control in Category II cannot be overemphasized. Changes generated as a result of testing must be expeditiously processed for downstream application, inasmuch as a large percentage of the operational bases throughout the country will be turned over to SAC while Category II testing is still in process at the OSTF. Early testing and rapid downstream application of results become even more important in weapon systems such as Minuteman, where the numerically large production runs and the rapid rate of deployment of the operational facilities

The "Water Bird" test tool, used in activation-certification exercises at Vandenberg AFB, helps test the Atlas F launch platform lifting system. Weight of the tankage, which is built to scale, is varied by the amount of water pumped into it.

make it mandatory that the majority of the changes be incorporated early in the cycle. Failure to do so could result in astronomical costs and down time for a critical portion of the missile force due to a large retrofit requirement. In some instances operational problems and equipment failures are fed back by the operational bases to Vandenberg for resolution during the test program. The E series operational Atlas, for example, will have had some 650 design changes incorporated by the end of the entire testing program. Facilities and aerospace ground equipment will have had approximately 1500. This volume of changes makes configuration control absolutely essential to the success of the program.



A Minuteman transporter-erector, environmentally controlled for transporting the solid-propellent missile, ties onto two pylons and is hydraulically lifted to vertical position over the silo. A hoist in the front end of the 65-foot TE attaches to support rods on either side of the missile and lowers it into the 80-foot hole, where it is locked on its ring and is poised and ready to go on command.



Category III

At the completion of the Category II tests, the Atlas OSTF is turned over to the using command for Category III testing. For Titan testing, the third launcher of TF-1 will be turned over. At this point, these sites will be configured identically to the operational sites after the updating program resulting from the Category II test program. Category III testing is conducted by a test force consisting mostly of SAC personnel, supplemented by AFSC, ATC, AFLC, and contractor personnel. The purpose of this category is to enable SAC to confirm its ability to use the equipment following its own management techniques. Some of the Category III testing is done at operational bases. Specific examples of test objectives are:

- To determine the operational usefulness of the system and develop the most effective operational tactics, techniques, doctrine, and standards.
- To determine any operational deficiencies and provide quantitative and qualitative data for product improvement programs.
- To obtain data on the rate of parts consumption, maintenance, and support facility requirements, supplemental to data obtained during previous tests.
- To obtain data on organizational and personnel skills and training requirements, supplemental to data from previous tests.
- To evaluate the adequacy of the authorized distribution of manpower and training.
- To obtain supplemental data relative to minimum maintenance requirements in terms of personnel, skills and training, special tools, test and support equipment, special facilities, and general performance standards for doing maintenance tasks.

During these tests AFSC has the specific responsibility of acting as assistant test director to the test force and providing technical assistance during the testing and evaluation of results.

The management organization for this test program is similar to the Category II organization with two major differences:

(1) Contractor participation is held to the absolute minimum, all tasks being accomplished in a tactical environment with squadron personnel.

(2) The using command manages and conducts all operational and evaluation tests with the assistance of AFLC, ATC, and AFSC.

THE FACTOR of utmost importance in tests is the continuing refinement and improvement of weapon system reliability. It is recognized that the ICBM systems are still being developed toward their ultimate capability. Ever increasing automation and the inception of remote-controlled, mass-produced systems like Minuteman make the demand for ultimate reliability more severe than ever.

On the basis of experience in the Category I and Category II

The missile used for initial chilling tests on the Atlas F silo test facility never leaves the launch, but it does simulate all prelaunch missile functions. Liquid

programs, changes in design, manufacturing techniques, and quality control have been made to improve the products toward their ultimate reliability goals. Because terms such as "fairly reliable," "pretty reliable," and "quite reliable" do not provide a numerical basis for operational planning and policy decisions, they have been supplemented by a mathematical model concept in which failure data and operational life data are collected on the weapon system and worked into a representative model to yield numerical measurements of reliability. A numerical score can be determined by dividing successful missions by total missions attempted; but because few missiles are actually flown, such a figure is not highly significant. Or countdown reliability can be combined with flight reliability to broaden the data base. This result has a higher confidence level but serious weaknesses.

The mathematical approach is to write an equation that describes probability of success (reliability) and then "plug in" experimental or estimated values for the variables. Such an equation is called a reliability mathematical model, and for the operational mission it is the product of hardware reliability and human reliability. Human reliability can be found by observation and testing of many simulated operational missions; hardware reliability can be determined separately by the use of a hardware reliability mathematical model. Operating time and failure data can be collected for each component or functional block every time it is operated under conditions like those prevailing in the operational mission. These data yield failure rate (or mean time between failures), from which reliability is calculated. Individual component and functional block

nitrogen is used in the early phase of testing. When the platform and the missile are down and the 65-ton doors are closed, the site assumes a "hard" condition.

reliabilities from such volumes of data combine to give a result that could be rivaled by the ratio-of-succesful-missions-to-total-tries method only after many hundreds of simulated missions. Use of this reliability equation is now well established in the over-all testing programs, and early results confirm faith in this concept of reliability assessment.

In essence, ICBM weapon system testing, as it operates today, starts with a three-pronged mission that never varies, regardless of which system is involved. This mission is to

—maintain a certain in-commission rate

—maintain an ability to place the nose cone on target

—maintain this capability on an ever-ready basis.

To accomplish this mission, there must be clearly defined, progressive steps. First is determination of the weapon system's configuration and abilities; next is identification of the operating and maintenance personnel and their skills, and training them to meet the skill objectives; then the development of technical data for use by the operational crews; and finally, logistic support.

Each of these phases must be developed fully and play its part perfectly, or all the accomplished testing will have been in vain.

Headquarters 6595th Aerospace Test Wing

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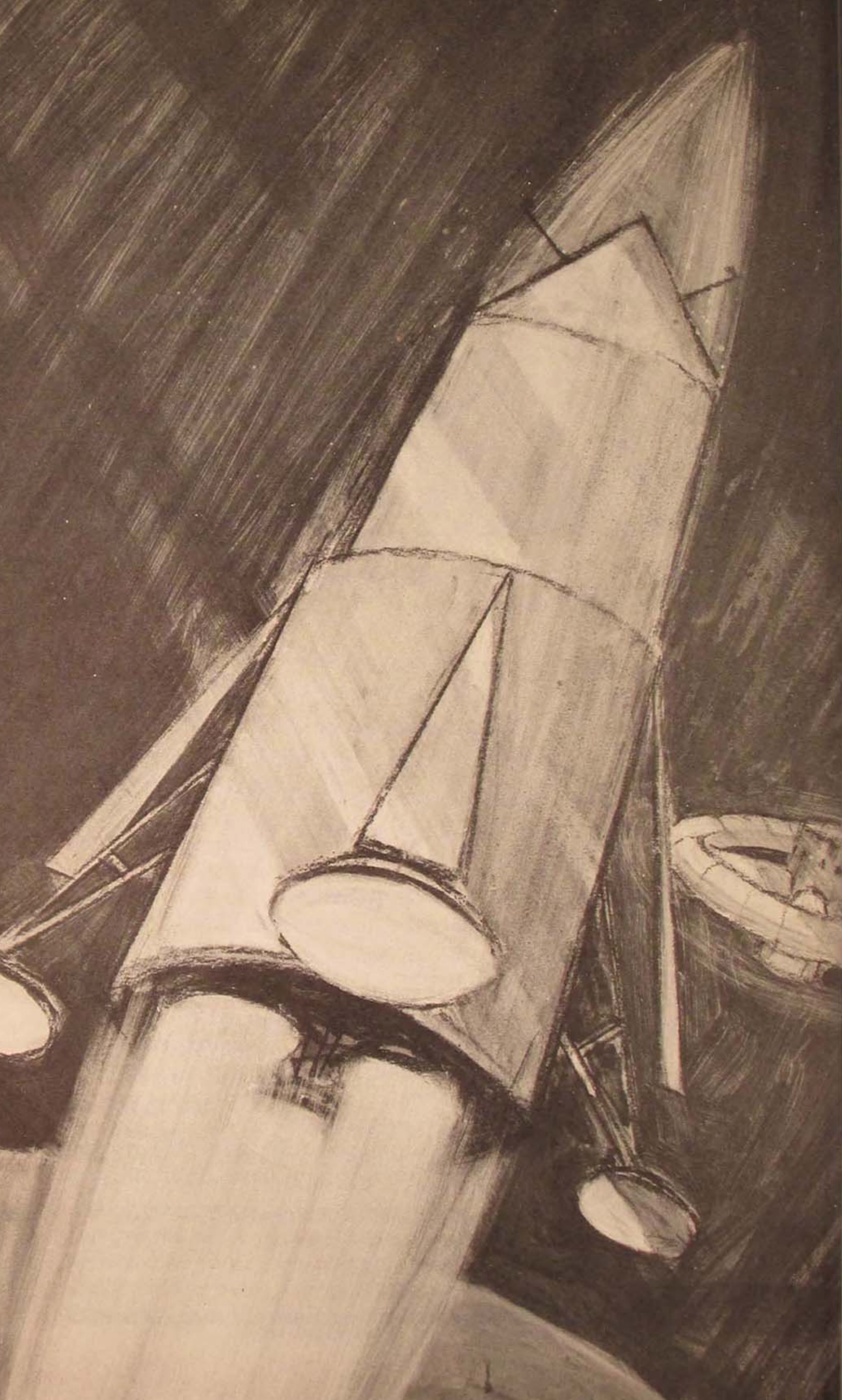


part III

FORGING MILITARY SPACE POWER

The lone scientist seemingly lost in his theoretical realm—the team of scientists and engineers concentrating on a single recondite problem in propulsion—and thousands like them—all contribute to the advancement of technology. The ultimate payoff is in the physical achievements of the systems that evolve from the synthesis of all the efforts—the tensely attended manned orbital flights of the Mercury program, the vast BMEWS radar network policing northern skies, the X-15's record altitudes and speeds, and many another impressive accomplishment of the aerospace age. These achievements are the products of the Air Force Systems Command developmental divisions—the Ballistic Systems, Aeronautical Systems, Electronic Systems, Space Systems, and Aerospace Medical divisions—and of their counterpart in the nonmilitary phases of space technology, the National Aeronautics and Space Administration (NASA). Through their efforts, separate and combined, the true strategic impact of technology materializes as aerospace power in-being on the side of the Free World.

BALLISTIC SYSTEMS

A New Order of Weaponry for a New Dimension of Defense

Major General W. A. Davis

TODAY at launching sites on the windswept plains of our Midwest and at underground missile-loaded silos in the western half of the Nation, Strategic Air Command crews stand ready to launch in the defense of this country a military striking force of proportions not before equaled in history. These forces are the first in a new order of weaponry—the intercontinental ballistic missiles. Their potential for lightning-fast, massive reaction constitutes one of our strongest bids for world peace.

The technological development and the construction necessary to form the total mosaic of this new dimension of defense are still not complete. Yet the emergence of this unprecedented deterrent force can be assessed today from a plateau of solid achievement. It is the story of a tough job accomplished by a tough team. In seven years ballistic weapon systems that actually exceed the formidable performance specifications originally established for them have been brought into our active defense inventories. This feat has been accomplished through the force-feeding of a technological revolution and the high-pressure forging of new management concepts and techniques for channeling and exploiting it.

Ballistic missile development has already been widely publicized. The purpose of this discussion is to summarize the present status of our ballistic missile power as a functional element of the command superiority vital to our national defense and to indicate the role of management in expanding and upgrading our missile capability. For our purposes the ICBM program began with the specifications outlined in late 1955 for the first United States ballistic missile weapon system, to be called the Atlas and given from that point forward top development priority among the Nation's defense projects. Some idea of the tremendous task that lay ahead can be gleaned from a comparison of those specifications with the performance characteristics of the German V-2 rocket, the only practical precedent for this type of weapon. The Atlas was to have 10 times the gross weight of the V-2 and 33 times its range; accuracy was to be increased by a factor of 20. The re-entry problem appeared almost insoluble, and guidance, total ground environment, training, and operational deployment were still only question marks on the planning papers.

One of the vital factors in the equation for success in this undertaking was the rapid advancement of our technology. Another was the management of time and resources so as to compete with the all-out effort we knew the Soviets were making toward development of this type of weapon that would nullify distance as a defensive barrier, slash attack warning time to minutes, and give the nation possessing it tremendous power for war or peace.

Since the mid-Fifties the United States had developed, brought to operational status, and wholly or partially deployed five major ballistic weapon systems. Two more are rapidly approaching operational status, and development has begun on still another.

The Thor intermediate-range ballistic missile, developed in a record-breaking three years, is by now something of an operational veteran. It has been deployed overseas for more than three years and in addition has become our "Old Reliable" as a booster for satellites and space probes. The Army-developed Jupiter is also on duty overseas as an element of our NATO missile force. The Navy's Polaris has already firmly established the capability for undersea missile launch.

Of the long-range intercontinental ballistic missiles, all three versions of the Atlas are now fully operational and being maintained in combat readiness by the Strategic Air Command. This gives us three Atlas D squadrons, three semihard Atlas E squadrons, and six fully hardened, underground squadrons of the Atlas F. Titan I, our second ICBM, is also fully operational in six squadrons in Colorado, South Dakota, California, Washington, and Idaho. Six additional squadrons of Titan II, an advanced version of Titan I, will be operational by the end of 1963 in Arizona, Kansas, and Arkansas. The first flights of Minuteman, our second-generation, solid-fuel, three-stage ICBM, became operational at Malmstrom Air Force Base, Montana, in late 1962. Other Minuteman bases are now under construction in South Dakota, North Dakota, Missouri, and Wyoming, bringing presently authorized strength to sixteen squadrons. Pending Congressional authorization, additional squadrons will be procured after fiscal year 1963.

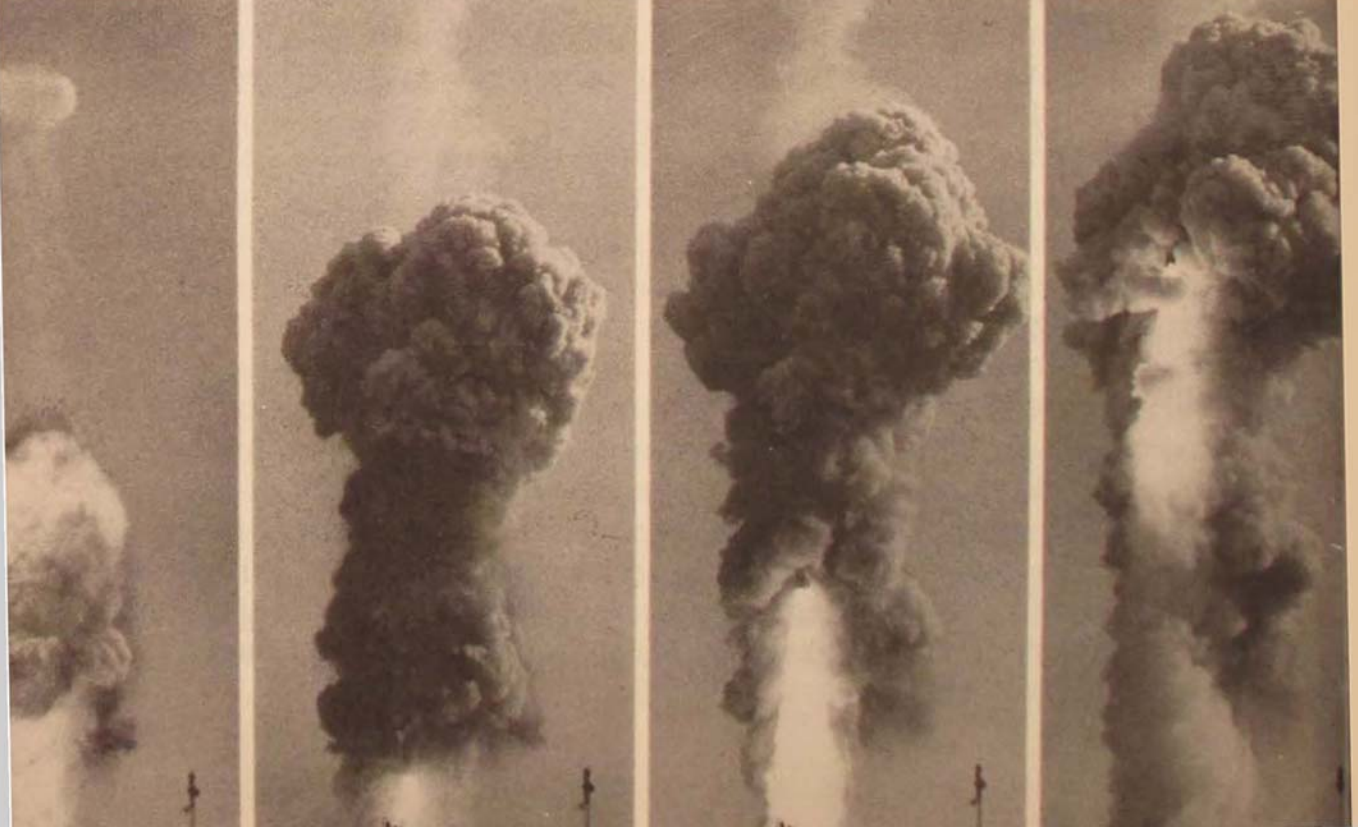
Development of a mobile medium-range ballistic missile (MMRBM) was assigned to the Air Force early in 1962, and selection of contractors for the various subsystems was announced recently. Thus the ballistic systems are beginning to come of age as the hard core of strategic striking power of our aerospace defense.

We still face a tremendous job in developing and fielding even the ballistic missile force presently programed. We can now, however, in true perspective take stock of the strides in both missile technology and management that have brought these formidable weapon systems to front and center of our deterrent strength. Concurrent developments in almost every area of missile technology, combined with the strengthening of skills in systems engineering and missile management generally, have contributed to a rapid increase in the mission capabilities of the ballistic systems.

Advances in Missile Technology

Advances in rocket propulsion have enabled the boosting of increasingly heavy payloads and the drastic reduction of minimum defensive reaction time. The first power plant designed for the Thor developed a thrust of 135,000 pounds. Today on special stands at Edwards AFB testing is going forward on the F-1, a 1.5-million-pound-thrust engine.

The cryogenic liquid oxidizers used in the Thor, Atlas, and Titan I present many problems and complexities in handling. They cannot be stored in the alert missile but must be loaded immediately prior to launch. Even with the most rapid loading techniques, reaction time of the cryogenic missiles cannot be cut below the inescapable minimum of time required for fueling. In addition, complex propellant-loading systems are required at the sites. These systems must be maintained and operated in accordance with standards of surgical cleanliness, for the most minute contamination can trigger an explosion. These disadvantages have been eliminated from Titan II by the use of noncryogenic propellants. Titan II is powered by a hypergolic fuel incorporating hydrazine, a colorless liquid that looks and smells like household ammonia, and an oxidizer, nitrogen tetroxide. This propellant can be stored at normal temperatures in the missile. The use of storable propellant and the capability for firing the missile direct from the silo without elevating it to ground level greatly simplify the ground support environment and radically reduce reaction time.



It is with Minuteman, however, a second-generation missile and the first of our solid-propellant systems, that we have been able to achieve our greatest leap forward in terms of capability, economy, and mission effectiveness. This achievement is primarily due to the inherent advantages of a solid propellant. The solid fuel becomes an integral part of the three missile rocket engines at the point of manufacture. It requires no site loading equipment and can be safely and economically handled and stored at normal temperatures. Minuteman also costs much less to manufacture than the first-generation missiles. Its mechanical simplicity makes it more reliable and much easier to maintain than its predecessors. Operating from the most streamlined launching environment of all the intercontinental missiles, Minuteman can be stored, ready-fueled in its silos, for comparatively long periods of time and with minimum maintenance. It can be fired in salvo direct from the silos within seconds after the command is given. Since its first flight test Minuteman has consistently demonstrated potential for becoming the workhorse of our missile arsenal.

The contractor base for continued gains in propulsion has broadened and deepened as our missile technology developed. In fiscal year 1961 some 60 firms throughout the country were engaged in almost 150 contracts for research, development, and production work on propulsion for ballistic and space systems. The prognosis is excellent for rapid advances in the future.

In the area of missile guidance, a strengthening industrial capability in electronics has been the key to major improvements in the weapon systems. In 1954, when the electronics industry was just beginning to get into stride, radio guidance was our best bet for re-

Minuteman, fastest reacting of our intercontinental ballistic missiles, roars from its underground silo in a successful R&D test launch at Cape Canaveral. A perfect smoke ring rises above the pillar of fire a split second after ignition. Exhaust gases and 5000-degree flame surround the missile until it is well above ground. The silo is 12 feet in diameter and some 85 feet deep. Solid-propellant Minuteman missiles can be stored on alert in silos for comparatively long periods of time with minimum human maintenance. They are remotely monitored and fired from a launch control center that commands a number of missiles and can launch them either singly or in salvo.

liability and accuracy. Since then the expanding electronics industry has supported the trend to inertial guidance for the advanced models of all our present ballistic systems. These modern, self-contained guidance systems have provided us with a higher measure of security and a simpler ground environment. Present equipments are capable of almost instantaneous reaction and have a reliability factor that appeared at the inception of the program to be many years beyond our reach. We have managed to build a high degree of flexibility into these equipments as well, and the present state of the art is a healthy lead-in to the increasingly automated systems of tomorrow.

One of the most remarkable areas of technological advancement has been that concerned with the problems of missile re-entry vehicles. This was one of the most important—if not *the* most crucial—of the question marks facing us in 1954. The Mark 2 re-entry vehicle developed for the Thor was a first solution to give us a reliable operational intermediate-range missile in the shortest possible time. A copper heat-sink shield for the Mark 2 has proved adequate for IRBM requirements. It was apparent early in the program, however, that the weight of copper shielding required for safe re-entry of an intercontinental warhead could well prove a crippling limitation. The answer was found in the ablative re-entry vehicle designed to allow the burnoff of some but not all of the exterior surface of the vehicle as it hurtles earthward. As the special surface coating burns and vaporizes, heat is carried away or dissipated by its turning from a solid to a gas. The primary requirement for this type of re-entry vehicle was the development of special lightweight ablative materials that would be exceptionally resistant to high temperature and friction. The progress made by the driving research effort to develop such coating materials and to optimize design is indicated by the steadily rising number designations of the missile re-entry vehicles: Mark 3 on the Atlas, Mark 4 on Atlas E and F and Titan I, Mark 6 on Titan II, Mark 5 and 11 on Minuteman.

In July of 1958, while still working to prevent atmospheric destruction of the re-entry vehicle, we became concerned with another re-entry problem and began development effort on penetration aids to provide maximum built-in countermeasures against enemy interception and destruction of the warhead. We have made considerable headway to date on a number of approaches to the problem of penetration. Today we think and work in terms of a re-entry *system* incorporating warhead, penetration devices, and re-entry vehicle. This system is a far less vulnerable and more sophisticated element of the total missile than it was a few years ago. Much of our updating and evolutionary modification of ICBM's within the next decade will undoubtedly be concentrated upon the re-entry system. Progressive improvement of this "business end" of the weapon system can yield high dividends in steadily increasing mission capability, not only of new generations of missiles but also of those already on duty in our active inventories.

The rapid advance of missile technology is nowhere more graphically apparent than in the area of ICBM launch facilities and ground environments. A tour of missile sites now operational or under construction affords a panoramic view of the evolution of our ballistic weapon systems during the past eight years. The sites are the final molds of each missile series, and they reflect the increasing mission capabilities being achieved by integrated advances in the many specialized fields of missile technology—the quickening reaction time, the rising index of reliability, the growing invulnerability to enemy attack.

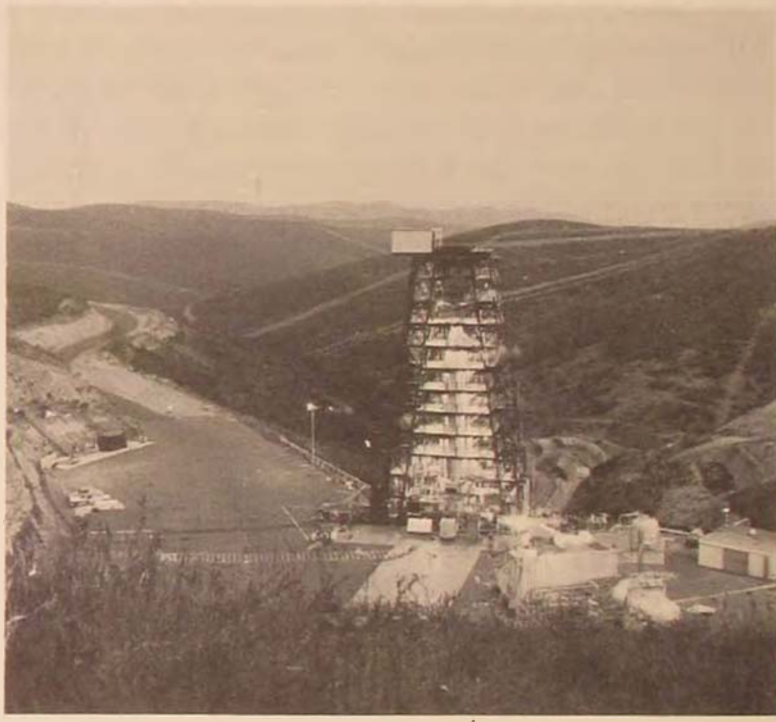
The predominant trends are toward greater speed and automated simplicity of launch and toward increased protection of the alert missile by site hardening and dispersal.

Six distinct launcher configurations are represented on the sites, falling roughly into three phases of launcher development. The early models of the Atlas were designed for launch from above-ground soft or semihard emplacements. These range from the completely exposed surface gantry, in which the missile is stored vertically, to the concrete "coffin" type, either above the ground or partially or wholly buried, in which the missile is stored in horizontal position and erected to the vertical before fueling and firing. In general these early models involve extremely complex ground environments, including facilities for storage and loading of liquid propellants. They require comparatively large operational crews. The necessity for propellant loading immediately prior to launch makes their reaction time the longest of any of our ICBM's—close to the maximum 15 minutes. This delay, combined with the softness of the launch emplacements, makes them also the most vulnerable to enemy attack. The great virtue of these early missiles is that they are there, holding the line of our deterrent strength while we are creating improved reinforcements.

With the Atlas F and the Titan I we moved into what might be called a second phase of site development. These missiles are stored in completely hardened, underground vertical silos grouped in complexes which also provide underground housing for all support equipment. The missiles are loaded with propellants, then raised from the silo by elevator for launch. These, too, are extremely complex mechanisms. The elevator system alone incorporates about 300,000 parts. The hardened site represents a great step forward in protection of the stored missile, however. Vulnerability to anything but a massive, direct hit is limited to the time required for topping off and elevating the missile after the silo doors are opened.

The third and most significant major advance in silo design has been made possible largely by the development of noncryogenic,

Atlas intercontinental ballistic missiles on the production line or "dock" at the General Dynamics/Astronautics plant, San Diego. These thin-skinned cylinders must be kept under pressure constantly until they have been fueled.

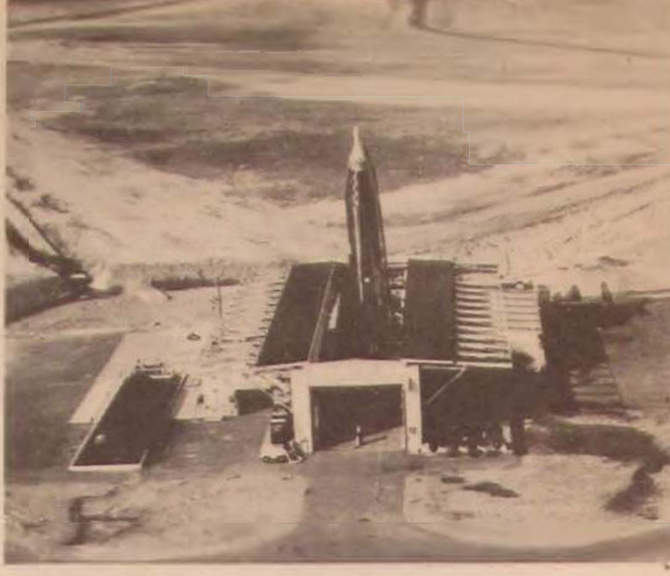


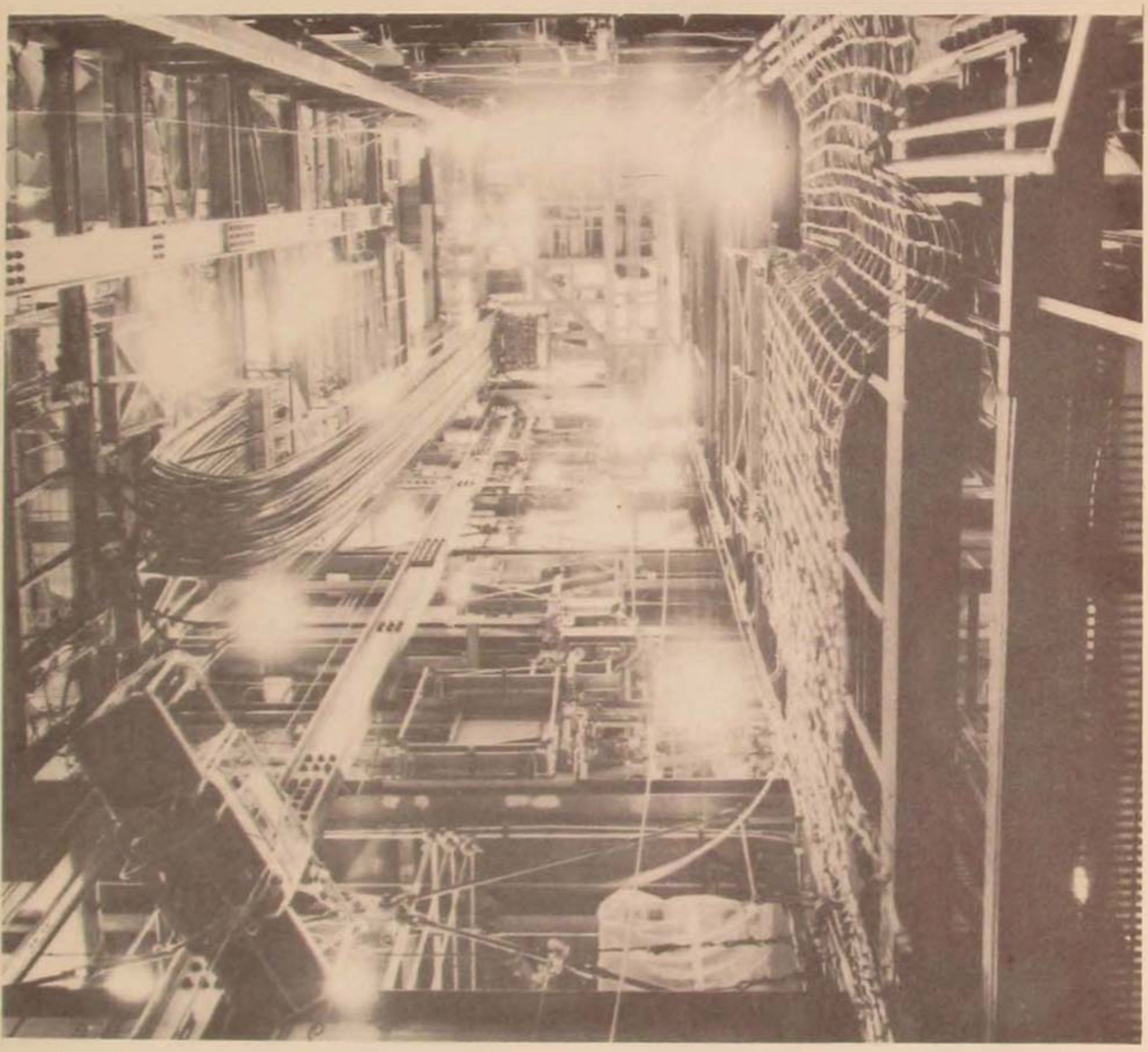
Early "soft" or gantry-type Atlas site

storable liquid and solid propellants. Titan II and Minuteman are stored ready-fueled in their vertical underground silos and fired from within the silo when the command is given. Their reaction time is a fraction of that required for the earlier missiles, and they represent the ultimate to date in survivability.

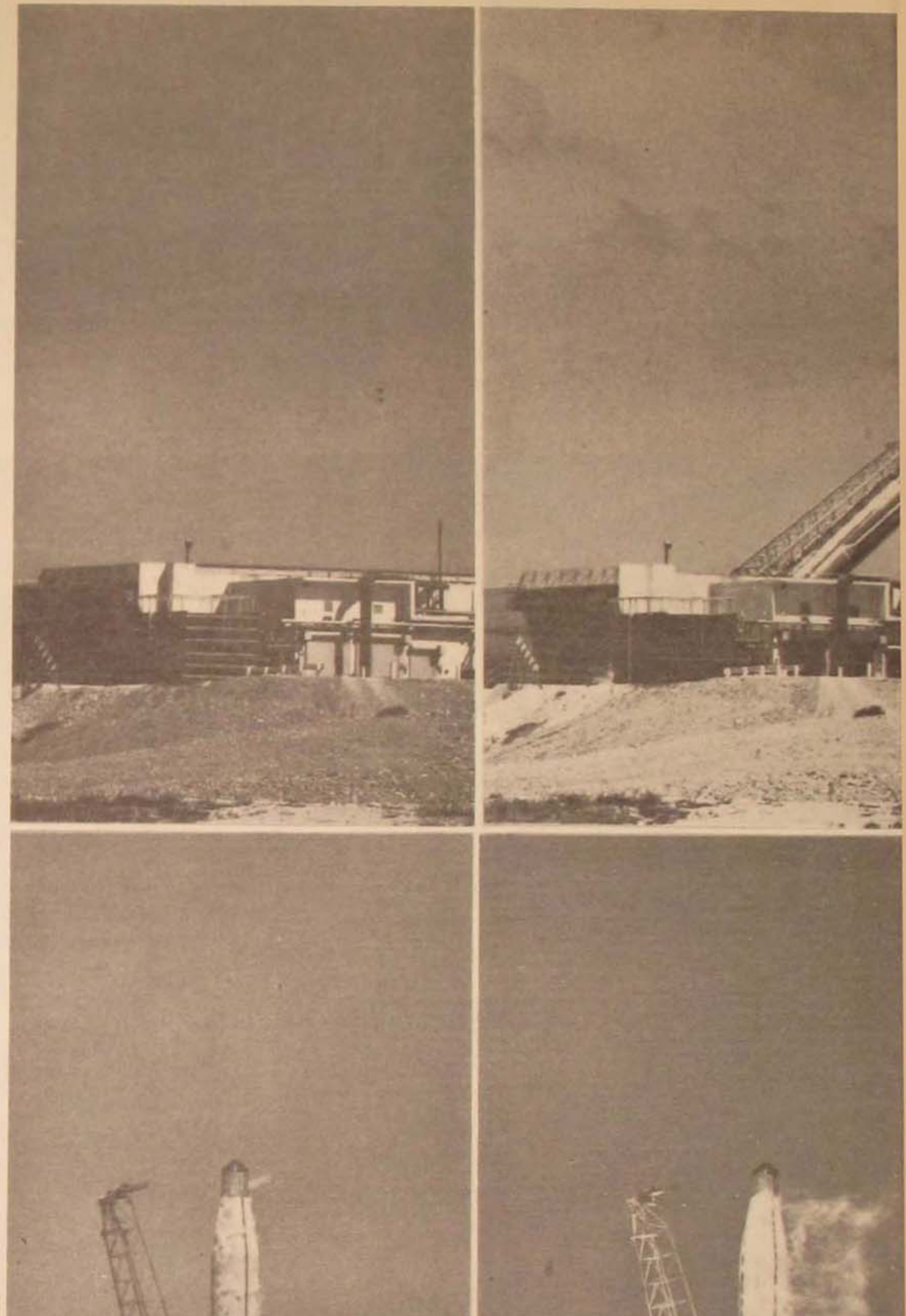
One telling index to the increasing integration and simplicity of the launch environments which have accompanied these improved capabilities—and, incidentally, contributed to the reliability of the weapon systems—is the number of equivalent chassis or "drawers" of electronic equipments involved in the launching of the various missiles. An average of 40 drawers is required for launch of most of the

Atlas D launchers at Francis E. Warren AFB, Wyoming, exemplify the semi-hard "coffin" type of emplacement.

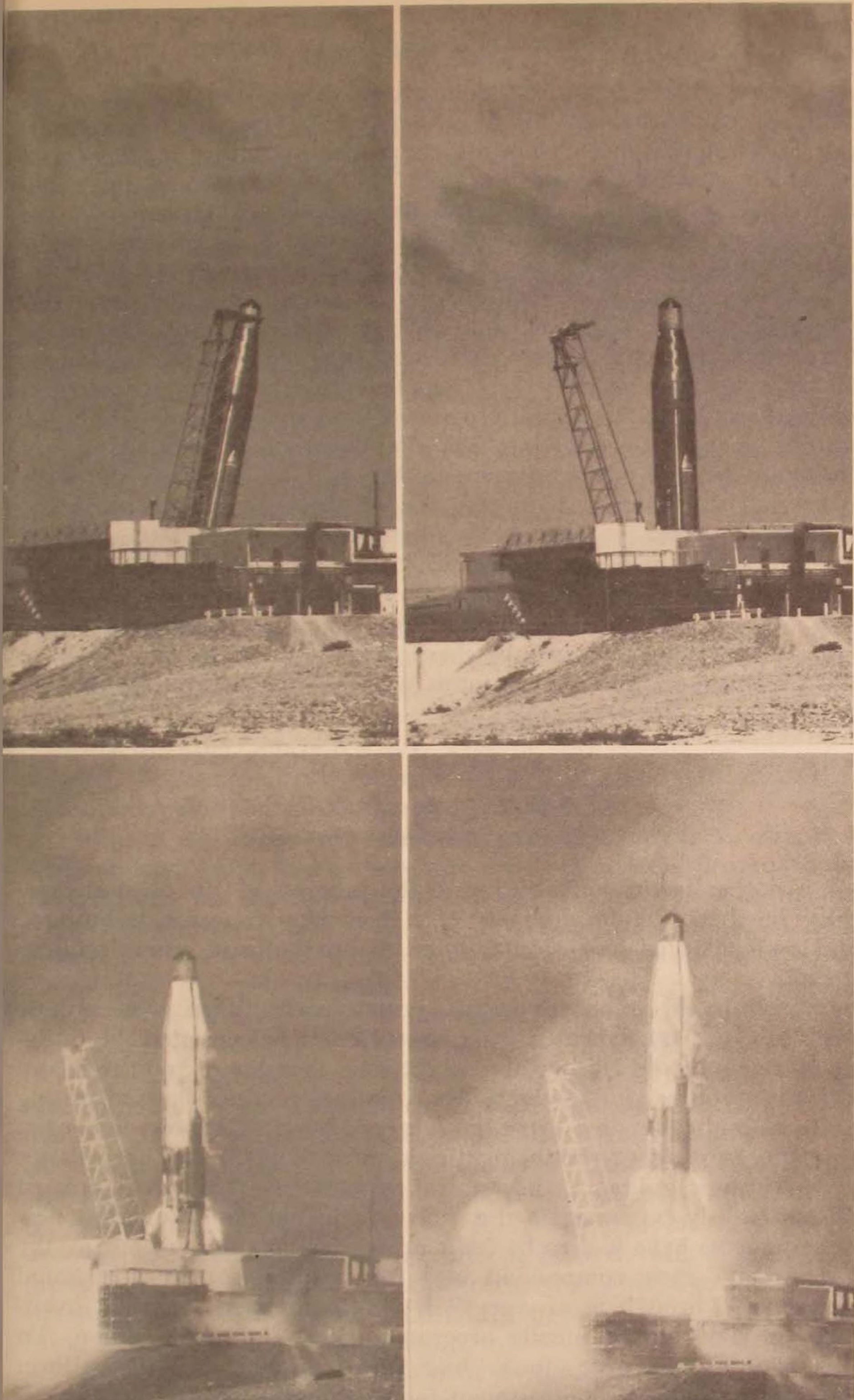




Looking upward from level 8 of a typical Atlas F launch silo under construction at Schilling AFB, Kansas. The missile can be fueled and launched from the top of the silo in 15 minutes or less. The silo is 174 feet deep, 52 feet in diameter. Its leaf-opening doors of reinforced concrete weigh 140 tons apiece; counterweights for the elevators weigh 208 tons each. The interior of this silo, shown in the early installation and checkout phase, gives some idea of the number and complexity of the equipments and the installations that must be made within the concrete and steel shell as well as of the problems of precise interface that are encountered. The six Atlas F sites being activated will generate enough electricity for a city of 1,680,000 persons, the approximate population of metropolitan St. Louis.



Reaction capability of the Atlas in launch from the semihard or "coffin" emplacement is shown in sequential photographs taken during the 15-minute period of a training launch conducted at Vandenberg AFB, California. The flight was



successful, the missile impacting 5000 miles down the Pacific Missile Range. This Atlas, equipped with the Mark 2 heat-sink type of re-entry vehicle, represents the first operational configuration of the 82-foot, 260,000-pound strategic missile.

Atlas series. Titan I requires about 21 drawers. Titan II manages on 10. Minuteman, the most highly automated of all the ballistic systems, can be launched by equipments contained in only 4½ drawers, 2 of which constitute power supply. The size of human operating crews has undergone a roughly similar reduction. A fraction of the crew required for launch of one of the early ICBM's can operate a flight of 10 Minuteman missiles.

Advancements in the state of the art are not the sole reason for the evolutionary improvements so strikingly demonstrated in the launch environment. Growing skill and experience in the fundamentals of systems engineering have enabled us to exploit technological trade-offs essential to rapid progress. One typical payoff for better systems engineering has been the simplification of monitoring and checkout functions and equipment. We had to approach the early Atlas and the Titan I with the idea of checking everything in the system to prevent the one small failure that could abort the mission. For the later-generation missiles we have been able to engineer systems which perform competent and representative readiness checkouts without physically monitoring every element of a given system. Our approach to performance checkout is now somewhat similar to the statistical sampling techniques used in quality control of production.

Management for Growing Missile Power

Another factor contributing to the progress of our mission capability has been the development of management concepts, techniques, and tools adapted or custom-tailored to our ballistic system requirements.

From its inception the ballistic systems program has posed unique problems of management. In the first place, it has entailed the build-up throughout the Nation of a whole new complex of industrial and military resources for research, development, production, and testing of these radically new types of weapon systems. Whole industrial segments capable of producing liquid propellants, solid propellants, and electronic guidance and control systems have had to be created or enormously expanded in the shortest possible time. Complete new environments have had to be built up for researching and testing the systems and their components and for training future operational personnel. Through fiscal year 1961 the Government facilities investment in the ballistic missile program totaled almost $2 billion. To this figure American industry had added more than $198 million of its own funds. This investment for production and test facilities is exclusive of the great bulk of costs for the actual operational facilities, the missile sites. The total program costs of the Thor, Atlas, Titan, Minuteman, and the new MMRBM through FY 63 will approximate $17 billion. A significant portion of this amount represents investment in the basic capacity to design, develop, produce, and test effective hardware.

In addition to problems of resources, money, and time, the challenge to management was complicated by the fact that the missile effort required a major reshuffling of relationships within the framework of existing defense industry. Companies accustomed to the role of major prime contractor became in some instances subcontractors. Companies not associated with aerospace a decade earlier and still struggling with the problems of expansion and technological development of their product were called upon to assume heavy responsibilities as associate contractors or first-tier subcontractors. The formation of a new working team of defense industry along the new lines was not easy. Its accomplishment in record time is a testimonial to the creativeness and flexibility of the United States' industrial base for defense.

As eventually shaped up, the industrial team consists of some sixty associate missile contractors and other civilian elements that contract directly with the Air Force. These account for about 125,000 persons in industry engaged directly in the ballistic missile effort. The work of the associates is supported by more than 2000 principal first-tier subcontractors, who in turn secure missile components, supplies, and services from many more thousands of second-, third-, and fourth-tier subcontractors.

Within the Air Force itself major readjustments to the new weapons have been necessary as the ballistic systems proved to be powerful catalytic agents in terms of management. The size, the urgency, and the specialized needs of the missile program began early to split the seams of existing organizational structures. Initially, responsibility for procurement and for engineering and research functions was divided between the Special Aircraft Project Office of Air Materiel Command, established in 1954, and the Western Development Division of the Air Research and Development Command. In 1961, after a number of organizational mutations through the years, responsibility for the total ballistic missile program was consolidated in the Ballistic Systems Division of the Air Force Systems Command. BSD now has available, under one organizational "roof," the management resources required for the development, test, evaluation, procurement, production, site activation, and planning for the support and operation of ballistic systems. This organization has streamlined channels of command and done much to unify the drive toward an operational missile force.

The organization of the Ballistic Systems Division is that of a tightly integrated team. Management of each missile is centered in a system program director responsible for the weapon system as a whole. The Deputy for Engineering and Technology, Hq BSD, is concerned with developments across-the-board in such broad areas as propulsion, guidance and control, and re-entry vehicles. The Deputy Commander for Site Activation has in his organization the U.S. Army Corps of Engineers Ballistic Missile Construction Office (CEBMCO), which, under operational control of BSD, is charged with basic construction of the sites. The Deputy Commander for Site Activation is at present an Army Corps of Engineers general officer, assigned to BSD for the site activation job. The construction experience of the Corps of Engineers makes it an extremely valuable member of the team in this unprecedented task. A Site Activation Task Force (SATAF) Commander located at each of the sites is responsible for over-all management of the site's activation from initial groundbreaking until turnover to SAC. He is supported by an Army Corps of Engineers Deputy for Construction on the site.

Many management concepts and tools developed in the late Forties and early Fifties to cope with the quickening evolution of our aerospace power have proved to be eminently adaptable to the missile effort. Among these are the orientation of management by weapon system; direct logistic support, with minimum intermediate warehousing and maximum use of airlift; and the extensive utilization of electronic data-processing equipments for programing, inventory control, and an ever growing list of functions.

Other approaches to more effective management have been specially developed and tailored to the imperatives of the missile program. Concurrency was a necessity if the deadline established for an operational force of these new weapons was to be met. Compression of research, development, production, and testing into tightly integrated, overlapping phases gave us delivery of the first Thor for testing nine and one-half months after the contract was signed. It cut more than three years off the development time of the Atlas, and it is producing comparable results with Titan and Minuteman.

Less sweeping in application but also typical of the new approaches necessitated by the ballistic weapons are some management systems that have been developed to keep the raw material of management decisions and actions at our fingertips in the fast-moving, tightly geared missile program. CRAM is an automated information system for the recording, reporting, analysis, and management of procurement activities. It minimizes manual recording and reporting and helps to reduce the procurement time cycle. Another system, CHAMPION, is a systematic approach to integrated hardware management. Inputs from the Schedules and Allocation Board, contractors, buyers, AF logistics managers, and the sites flow into the information processing center to provide a wealth of completely current information on master hardware requirements; schedules and contract actions, dollar and man-hour costs; hardware deliveries, a potential problem area; the progress and costs of our configuration control management, etc. The program evaluation and review technique (PERT) has been adapted for use by our system program directors and for construction of Atlas F and Titan I and II sites. PERT is a quantitative management control tool to define and integrate what must be done to accomplish a project on time. It is a technique for focusing management's attention on danger areas and on areas of effort that require trade-offs in time, resources, or technical performance to improve the capacity to meet major deadlines.

Missile Site Activation

Some background here will prove helpful to an understanding of the unique challenge to management posed by the enormous and unprecedented task of missile site construction and activation.

In a sense, missile site activation has become the practical proving ground of advances in both missile technology and management. At this point missiles and environment are mated to form the total functioning weapon system, and they must prove their integrated capabilities before turnover to the operational units of the Strategic Air Command. This is truly the final assembly line for our ballistic missile weapon systems. On the sites we can see at last, in sharper relief than elsewhere throughout the program, the end product of missile power toward which we have been driving.

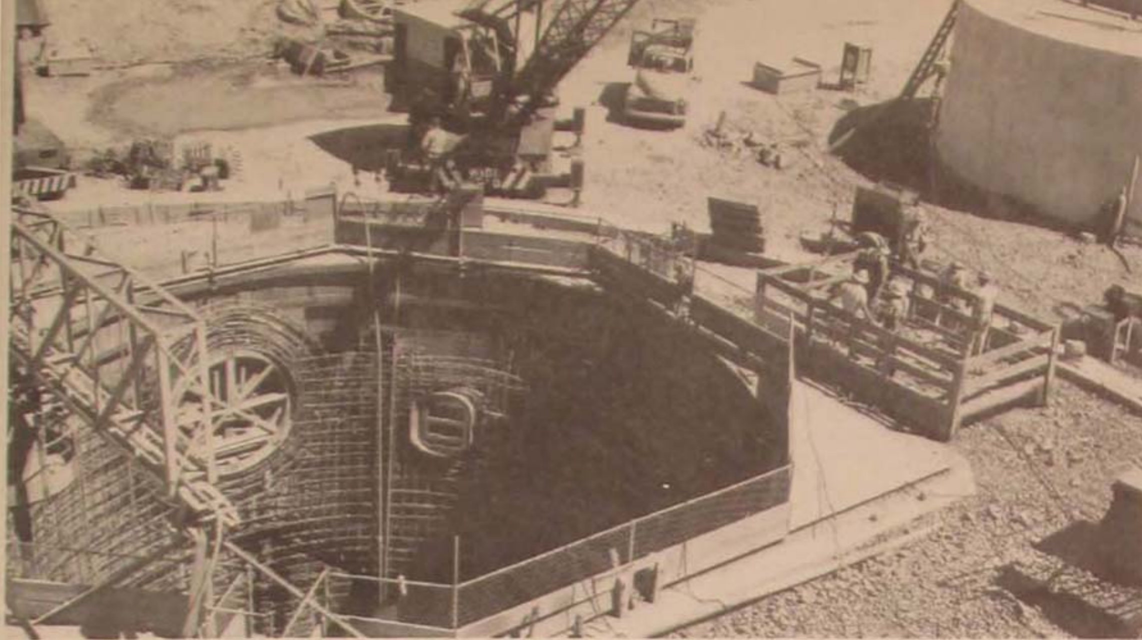
The construction of the ballistic missile sites is the largest building job ever undertaken by the United States Government. Twenty-two bases in 18 states are programed to house a total of 41 squadrons of the Atlas, Titan, and Minuteman, which will constitute the backbone of our deterrent aerospace power. The sites stretch from Plattsburgh, New York, to Marysville, California; from Abilene, Texas, to Spokane, Washington. They encompass a total area of more than 100,000 square miles. The largest is twice the size of Maryland, and one site has missile launchers in three states.

The missile bases are for the most part in isolated, undeveloped areas that have the most varied extremes of topography and climate. We must import the greatest part of our working forces and create the whole functional environment—access roads, communications, the entire spectrum of facilities for a work force that ranges between three and four thousand persons on a site at peak activity. The total working team engaged in the site activation job includes the Air Force, the U.S. Army Corps of Engineers, some 30 prime and associate missile contractors, 55 building trades contractors, and workmen from some 30 labor unions. The nature of the work is new to all of us, and we have had to learn to function effectively together as a team under extreme pressure. Fortunately it has proved a tough, hard-driving team of exceptionally well-qualified specialists drawn from many career fields in every part of the Nation.

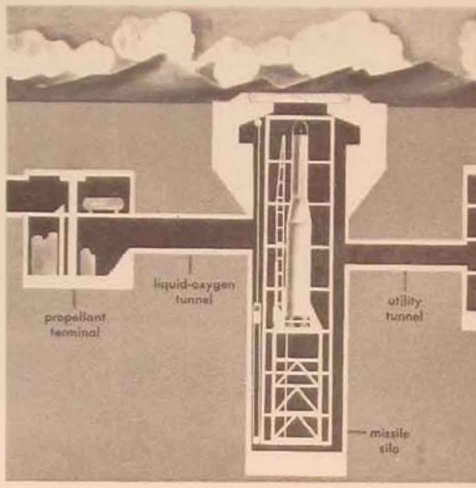
We are building at most of the sites what is essentially a number

Aerial view of a Titan I 3x3 silo-lift complex under construction at Lowry AFB, Colorado. The three silos are flanked by the smaller structures of the equipment and propellant loading terminals. The two domed structures at upper left are the launch control center and the power house; the larger structure is about 62 feet high. (The antenna silos are out of the picture to the left, above the line of the control center.) To permit maximum open-air construction, the entire area of each cluster of structures is first excavated to a depth varying from 40 to 70 feet. When construction is completed, the area is refilled to the orginal ground level and further hardened. Some sites have as many as 12 complexes dispersed over a wide area for additional protection, sometimes as much as 60 miles apart.

of compact, underground cities with built-in atmosphere, water, power, fuel, and communications. The launchers themselves are precision mechanisms, sixteen stories deep for the Atlas and Titan, served by an intricate mass of electronic sensing, control, testing, and guidance equipments. They must fit the missiles like a second skin. And the missiles are continually evolving as we work, necessitating changes in launcher and ground environment to take advantage of the increased capabilities made possible by technological advances. It is difficult to establish valid learning curves or across-the-board standards of performance and work measurement. Communications and reporting procedures become a major management problem on this 10,000-mile production line, on sites where launch complexes are as much as sixty miles apart and a jeep trip around the site perimeter would take two and a half days.

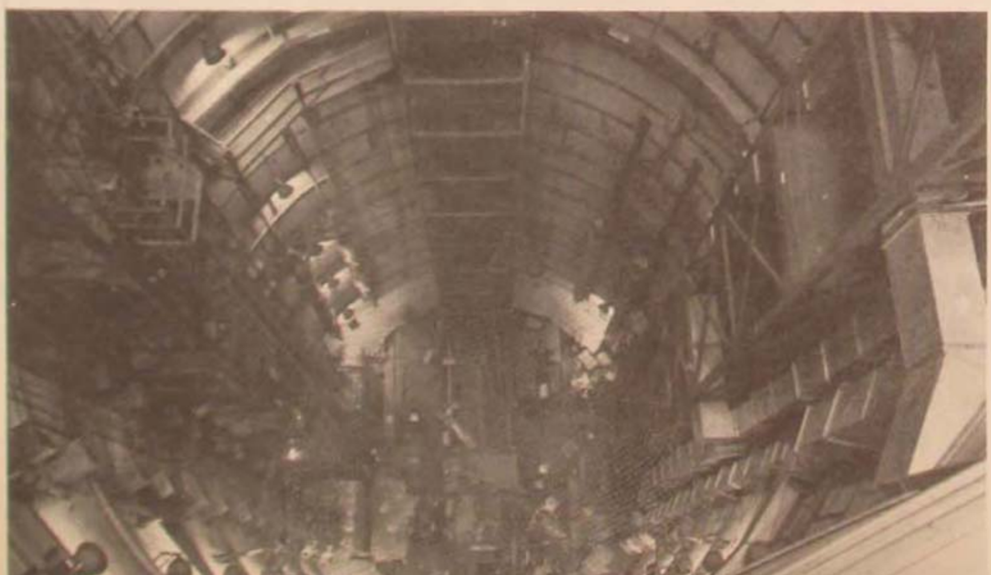


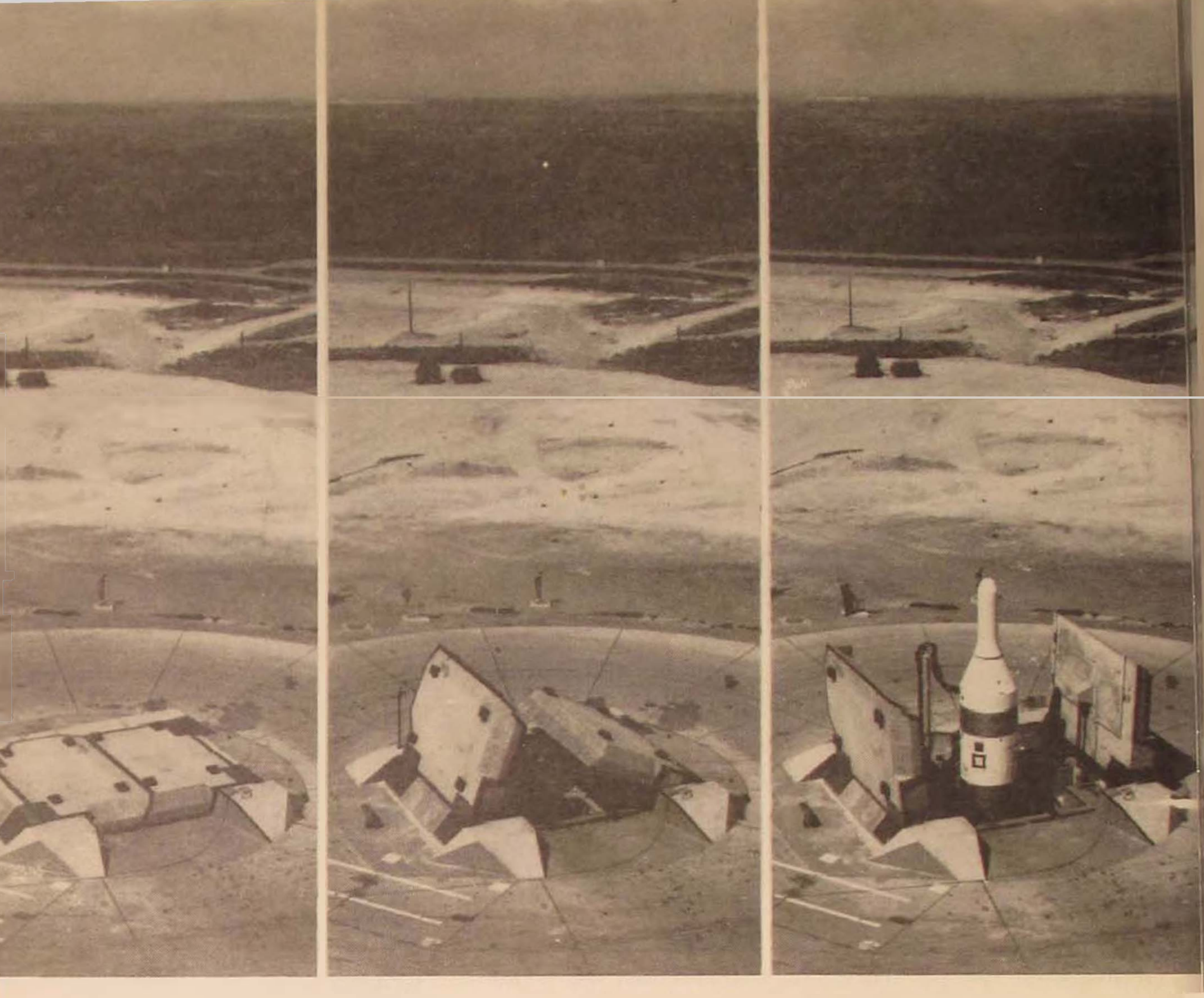
Silo construction at Larson AFB, Washington, to house a Titan I underground. Work is progressing 30 to 60 feet below the original ground level, as indicated by excavated earth banked in background. When the structures are finished, refilled earth and concrete will afford them a 25–35-foot protective cover. Though Titan II fires from within a silo, Titan I is fired from the surface after being elevated through the opened concrete doors of its silo.



Typical Titan hard site

View looking down into the concrete and steel "innards" of a 16-story underground Titan I launch silo in construction at Beale AFB, California. The programed complement of six Titan I squadrons calls for construction of 18 site complexes, totaling 54 launch silos, propellant and equipment terminals, 36 antenna silos, 18 power houses, and 18 launch control centers—all hardened by a cover of earth and reinforced concrete. The missile will be suspended within the silo in a large steel crib and lifted by elevator to the surface for firing. Total liquid storage for operational Titan I sites includes 720,000 gallons of RP-1 rocket fuel, 1,404,000 gallons of liquid oxygen for use as fuel oxidizer, 1,206,000 gallons of diesel oil for power generating station, and 1,120,000 gallons of water.

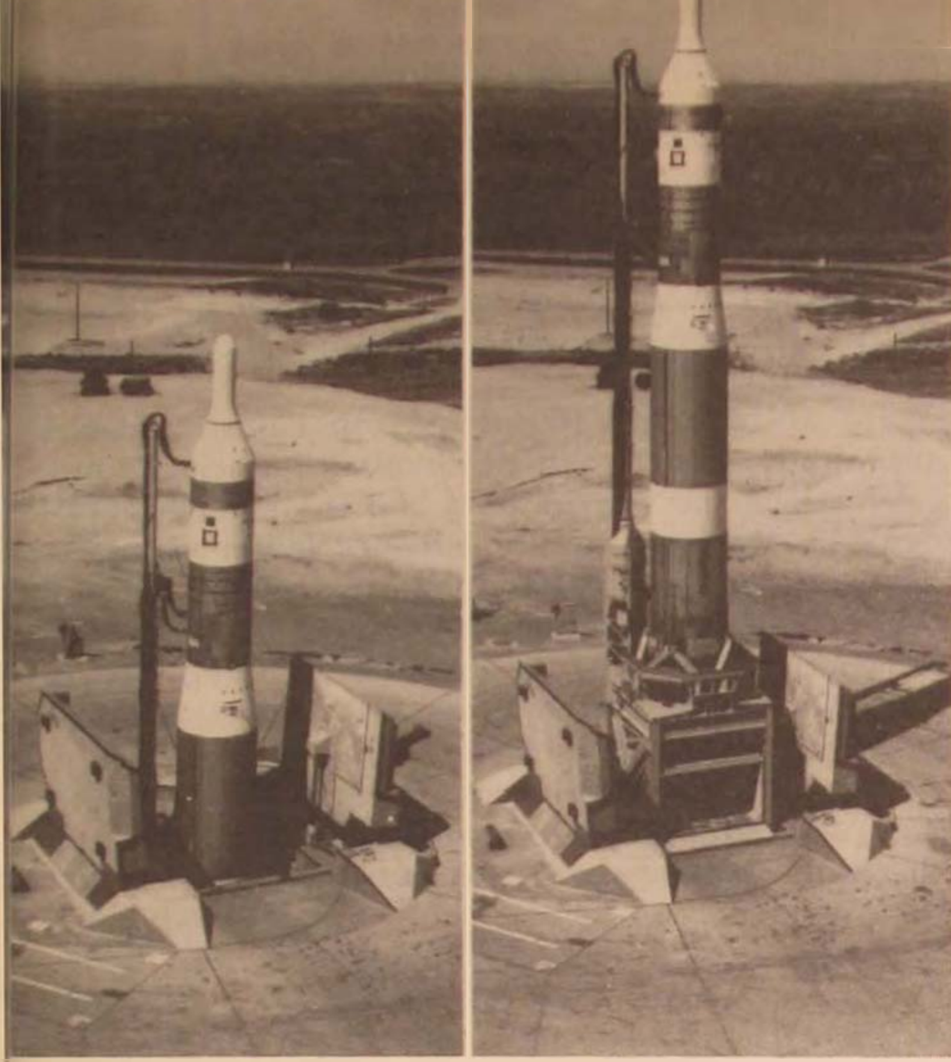




Titan I rises smoothly to firing position at the operational suitability testing

All these management challenges must be met within the framework of two dominant considerations—available resources and time. We must effectively balance dollars and deadlines.

One of the most valuable management disciplines helping us to accomplish this task is DYNAMO (dynamic action management operation). Based on the principle of management by exception, the DYNAMO "Alert" system channels reports in to Headquarters BSD Control Center daily from each of the sites, to give us a constantly updated profile of progress on a multitude of key aspects of site activation. When trouble develops or threatens to develop at a site, a report comes in to us that labels the difficulty according to its degree of seriousness. A "Suspect" is a situation that is substandard and may get worse but one that at the moment the SATAF Commander at the site thinks he can clear up without special help. A "Bogey" is a tougher problem, already beginning to hurt, that requires treatment beyond the resources of the site commander. A "Bandit" is present, serious trouble that calls for the full fire-fighting treatment at Headquarters level.



facility at Vandenberg Air Force Base, California.

Each of these "Alerts" is posted and monitored in the Control Center. A specific "crew chief" is assigned to it, and he remains responsible for it until it is solved, by whatever means and with whatever help he finds necessary. In addition to ensuring fast, concentrated action on bottlenecks, DYNAMO has been extremely useful to us for early identification of soft spots in the program, problems common to more than one site which indicate the need for basic preventive action at Headquarters level.

We supplement DYNAMO, of course, by other systems and techniques and by as much periodic pooling of experience as the geographic scope and urgency of the job will permit. Regular meetings of all SATAF's at Headquarters BSD or at one or another of the unfinished sites and constant firsthand inspections help us to broaden and pool our growing experience and to focus our management resources for most effective results.

SITE ACTIVATION is progressing well. We are now over the hump of most of the initial unknowns in both the technology and the management of missiles. We have broken trail for a steadily accelerating drive toward the fielding of our total programed long-range missile capability—on schedule.

The evolution of these formidable weapon systems will continue—and with it problems and questions which will demand the utmost that we can bring to them of expanding knowledge, creative ingenuity, and hard, unremitting work.

Already, though, we have a powerful force of ballistic missiles many orders of magnitude greater than we envisioned when the program began in 1954. Along the way we have laid the foundations of a tremendous dividend: we have established our Nation's base for the exploration of space. The industrial capability, the technological advances, the great complex of research, test, launch, and tracking facilities, the management tools, the very team identity and habit of urgency wrung out of the development of the ballistic systems—these constitute the "first-stage booster" of our space effort.

The ballistic systems truly give a new dimension of deterrence for the national defense—and a powerful momentum toward the capabilities in space that will safeguard our future security.

Ballistic Systems Division, AFSC

AERONAUTICAL SYSTEMS

Major General Robert G. Ruegg

In assessing the complexities of the technological task ahead, many often are inclined to cling somewhat too tenaciously to comparisons with the past. They keep comparing their lot with the "good old days" when it was a relatively simple process to move an air vehicle from concept to operational use. They count the electronic components in the advanced systems now under development and contrast the total number with that contained at one time in the B-17 and other early aircraft. They perform all manner of computations to depict the increased complexity of current and projected systems as compared with those of past years.

I believe these comparisons no longer are entirely valid. Assuredly our technological foundation comes from the past, and we continue to learn from our past efforts. But we cannot realistically continue to compare our current and projected requirements in terms of the performances of the past. Today we are developing entirely new performance capabilities for operational environments scarcely conceived or even imagined during the early years. In reaching for these new standards of performance, we must recognize that the factors of complexity, cost, and time have necessarily become a way of life, albeit a most exacting one. It is a way of life in which the past is what we do today, and the planning for tomorrow—in an unrelenting battle with cost, complexity, and time—becomes a most critical consideration. It is a way of life in which the effectiveness of our management, in the final analysis, will be the measure of our success or failure in providing superior, timely, and economical systems.

Effective management in any enterprise is essentially the process of making the right decisions at the right times. What complicates this process in the management of complex, advanced systems and technology is that many alternatives are available to the decision-maker. He must identify, relate, and measure the effect of actions in one area with those planned in many others. There is also the physical problem of providing, speedily and accurately, all the information needed for timely, valid decisions. Additionally, report and control information must be provided during all stages of system acquisition to enable the decision-maker to keep programs within prescribed dollars and schedules and to keep them properly balanced, technically and financially, with all other elements of the total force structure.

These and other factors, as well as the detailed management processes employed by the Aeronautical Systems Division (ASD) and other organizations of the Air Force Systems Command in dealing with them, are covered in depth elsewhere in these chapters. Also described are the programs under way to improve the very science of management—the fundamental techniques, processes, tools, philosophies, and concepts being evolved to keep management in pace with the rapidly increasing rate of advancement in systems development and technology as well as with the urgent need to reduce ever increasing systems cost and development time.

Within our own area of advanced aeronautical systems, selectivity has become the key action in all phases of acquiring new systems and of charting the course for research and development activities. And what is selectivity but the judgment of a decision-maker armed with the latest and most valid information upon which to exercise that judgment! At the Aeronautical Systems Division, for example, we manage the acquisition of an exceptionally wide range of systems and related equipment and conduct a comprehensive program of applied research and advanced development in the technical areas of materials, navigation and guidance, flight control, vehicle defense, advanced weapons, mechanics of flight, propulsion, electromagnetic warfare, reconnaissance, and many others. Obviously, because of limiting effects of cost and time, we cannot pursue all promising avenues but must be painstakingly selective—a selectivity which must give us no less than "order of magnitude" increases in technological capability and systems performance within budgeted costs and time.

How best to achieve this essential selectivity? We achieve it at ASD by maintaining—for both our research and development and systems areas—an especially strong in-house planning and analysis capability. This capability is a unique, built-in strength factor of selectivity that brings together and integrates for effective decision-making the judgment inputs from managers and technologists at all organizational levels. It is further bolstered by management techniques that provide all concerned with the most reliable facts and figures for effective surveillance and control of program performance, cost, and time.

In the research and development area, ASD's Deputy Commander/Technology directs considerable laboratory attention to technological planning and analysis, which can best be characterized as exploratory pioneering. The scientists and engineers engaged in this work do not duplicate or compete with the more specifically defined studies conducted under contract or grant with universities, research institutes, and industrial research departments. Instead they conduct the very early scientific explorations essential to gain for management a full understanding of all aspects of tomorrow's technical problems and requirements. They define the problems to be solved. They investigate technical feasibility and determine the avenues of greatest potential payoff. They use specialized test facilities to demonstrate and evaluate their investigations and determinations. In sum, they gain the knowledge to most effectively determine program requirements and to competently direct and guide the effort of outside research and development organizations in their fulfillment.

From this exploratory, pioneering know-how emerges selectivity based on especially sound judgment and decision-making—a selectivity that guides our program into those areas of research most conducive to breakthroughs and to knowledge that can inspire entirely new system concepts. The growing national effort and advancements in bionics and molecular electronics are but two examples of the many based on the very early exploration, recognition, and guidance in these fields by our own applied research planners and analysts. At the same time this kind of selectivity enables us to provide the technology needed to fulfill our visualized systems requirements and the techniques to translate that technology most rapidly into operational systems.

An extremely wide variety of weapon system alternatives is made available to us by our ever expanding body of advanced scientific and technical knowledge. Here again, because of the factors of cost, performance, and time, we must achieve the highest possible degree of selectivity, not only in determining which system concepts should be pursued but also in planning their related technological effort.

The in-house capability organized to achieve these vital program objectives is vested in our Directorate of Advanced Systems Planning. Its planners and analysts are specialists in materials, propulsion, guidance, power generation, production cost and analysis, and many other fields. They critically examine and evaluate all competing advanced system concepts from such standpoints as technical and operational feasibility, performance, cost, time, military worth, and national defense need. In these analyses they draw upon the technical judgments and exploratory findings of our ASD applied research and advanced development laboratories as well as the latest state-of-the-art information from the Nation's research and industrial complex.

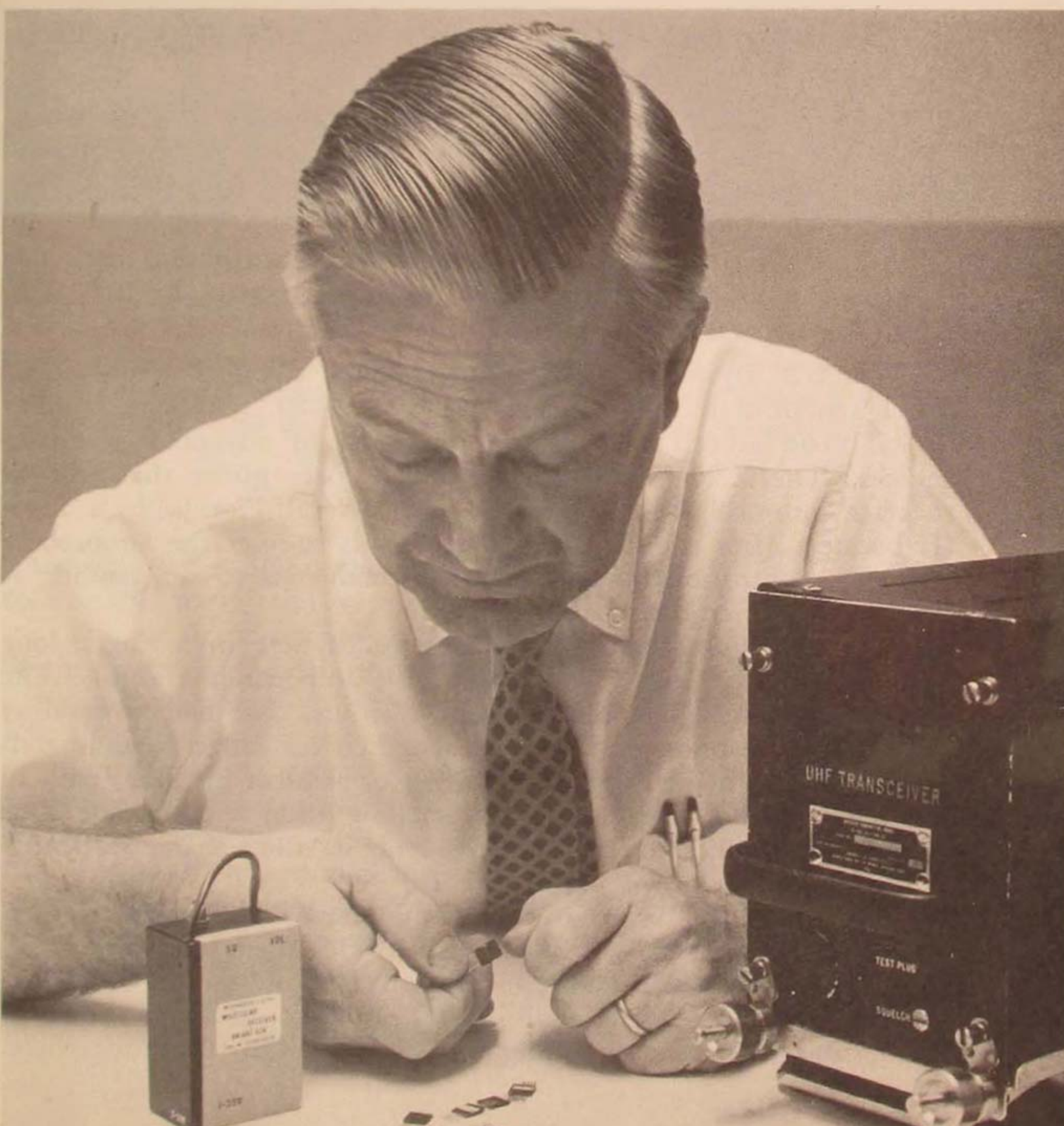
Pointed up by these system analyses are the relative worth of concepts for future weapon systems and the technological problems that must be solved in order to bring selected systems into being. The problem areas so defined also help to guide the applied research and advanced development programs of our laboratories into the most needed and productive channels. In turn, the resulting laboratory findings flow back to our system analysts to add realism to their studies.

When systems are approved and programed, in-house capability shifts to our Deputy Commander/Systems Management, which operates through an organization of system program offices, and to our Deputy Commander/Engineering. The engineers of the latter organization provide us with competence and judgment in the field of

Bionics and Molecular Electronics

The Aeronautical Systems Division has sponsored significant pioneering research in bionics and molecular electronics, both recent projections beyond conventional electronic theory. Bionics is a technology which, through the study of living systems, seeks to create electronic circuits that perform in a manner analogous to the more sophisticated functions of living systems. In one of many bionics study projects at ASD a maze runner, an "artificial mouse," was developed as an experimental instrument to investigate the elementary "learning" and "decision-making" processes of a network of neuron-like devices. Electronically stimulated by "reward and punishment" signals, the artificial nerve network motivates the "mouse" (shown going through its paces) to "learn" to find the way to its goal outside the maze.

The molecular electronics program at ASD is markedly increasing the operational reliability of electronic devices, at the same time substantially reducing their size, weight, and power consumption. In this field of solid state research, matter possessing predetermined electronic properties is synthesized to create tiny blocks of materials that exhibit electronic functions previously performed by many conventional electronic components soldered together. When functional electronic blocks like those being examined below are interconnected, they can form complete functional electronic systems. The experimental radio receiver based on molecular electronic techniques (left) has the same general performance capability as the receiver portion of the AN/ARC-63 transceiver (right). Yet the molecular receiver weighs less than ½ pound and occupies 9 cubic inches against the ARC-63 receiver's weight of more than 5 pounds and bulk of 148 cubic inches.



systems engineering. They make the complex engineering decisions and compromises, locate and correct any possible technical deficiencies, incorporate wherever possible the latest technical advancements, and direct and guide the test and evaluation program. Working closely with system managers on each system in ASD's program, they ensure that system performance and reliability objectives are fulfilled.

All the in-house capabilities mentioned here provide us with the technical competence, the judgment, and the selectivity required to guide and manage our assigned programs most effectively within the Air Force–industry–science team concept under which we operate. Thus at ASD our in-house capability fosters a continuous and vigorous interplay and data flow between exploratory researchers, planners and analysts, managers, and scientists and technologists at all levels of the organizational structure. Concepts, ideas, and judgments flow from the top down and from the bottom up! Further invigorated and nourished by inputs from our many contractors, this wealth of data gives us the selectivity needed not only to manage system programs competently but also to chart and guide the research and development effort which can best meet future system requirements and inspire new system concepts.

WITHIN this perspective of our organization and how it works, let us consider the major systems managed by the Aeronautical Systems Division.

• X-20 Dyna-Soar. The most advanced manned aerospace research system under our management is the X-20 Dyna-Soar, familiar in its broad aspects to everyone interested in advanced aerospace vehicles. The X-20 is a manned, winged space glider that will be rocketed into orbital flight from Cape Canaveral, Florida, by a Titan III booster. After orbiting the earth, it will re-enter the atmosphere under the control of the pilot, who will maneuver it to a landing at Edwards Air Force Base, California.

The glider will enter the earth's atmosphere in a single, long glide, its wings giving it aerodynamic lift and maneuverability. The combination of high speed, extreme altitude, and maneuverability will permit the pilot to shorten or lengthen his range by thousands of miles and to maneuver far to the left or right of his flight path to reach his landing site. During his shallow glide re-entry, the X-20 pilot will be subjected to a g-load no higher than that experienced by a jet airliner pilot.

Portions of the surface of the X-20 glider will be heated in varying degrees from 2000 to 4000 degrees Fahrenheit, and such heat-resistant materials as high-nickel-alloy steel, molybdenum or columbium and ceramics will be used in the glider's construction. The heat will be radiated from the glider surfaces back into the atmosphere.

The initial objective of the X-20 Dyna-Soar program is to develop the necessary technology to exploit the potential of the atmosphere for future military hypersonic and orbital vehicles. In the final phases of its flight-test program, the manned Dyna-Soar (depicted in an artist's drawing) will be rocket-boosted into orbital flight from Cape Canaveral, Florida. It will re-enter the atmosphere under control of the pilot, who will maneuver it to a landing at Edwards AFB, California.

Throughout the flight, the pilot's compartment will be kept at a comfortable room temperature.

The air at the stagnation point, approximately one foot in front of the glider, will heat up to 20,000 degrees, and the problem of communicating through the resulting plasma sheath is receiving considerable laboratory attention.

The Dyna-Soar program is being carried out through a series of progressively advanced steps. The first-step objective is to develop the technology required to exploit the potential of the atmosphere for future military hypersonic and orbital vehicles. In many technical areas of this phase of the program the National Aeronautics and Space Administration is working closely with the ASD X-20 System Program Office. The system contractor is the Boeing Company.

Four principal technological objectives are embraced by this initial step of the Dyna-Soar program:

(1) Exploration of the flight regime. The maximum heating regions of the re-entry speed/altitude flight regime will be explored to obtain critically needed data concerning hypersonic aerodynamics, stability and control, boundary layer heat transfer, structures, and materials.

(2) Maneuverability during re-entry. Investigation will be made into the degree of glider maneuverability during re-entry conditions, the effect of maneuvers on the glider, and the lateral and range variations resulting from various maneuver patterns.

(3) Conventional landing. The ability of the hypersonic glider to make a controlled landing in a conventional manner will be demonstrated during this first step.

(4) Man's role in space. The pilot's capability to maneuver and guide the glider during re-entry to the preselected landing area will be demonstrated.

The X-20 research and development program is vast and complex. We look to it to provide the technological foundation for the operation and recovery of manned military aerospace systems of the future. Although Dyna-Soar is programed in its first step solely as an experimental aerospace research craft, succeeding steps will explore the important operational capabilities inherent in hypersonic, winged aerospace vehicles of this type.

In this step-by-step approach to a military aerospace system capability, the research accomplishments of the rocket-powered X-15 airplane have increased confidence in the Dyna-Soar concept. Flown to an altitude of 314,750 feet and at a speed of 4151 statute miles per hour or mach 6, the X-15 has contributed needed technical data on many problems related to hypersonic flight and high-altitude operations. By comparison, though, the X-20 research and development effort is of even greater magnitude and complexity. The X-20 will fly more than 17,000 miles per hour, or mach 25, at an altitude of approximately 100 miles. Significant state-of-the-art advancements in a much wider range of technical areas must and will be made during the development and flight testing of the space glider.

The step-by-step flight-test program presently scheduled for the X-20 will progress from manned air launches to unmanned ground launches and finally to manned ground launches. First, the full-scale manned space glider will be tested, like the X-15, in a series of drops from a B-52 carrier. In these early tests at Edwards AFB a small rocket engine will propel the X-20 to low supersonic speeds. In this speed regime its stability and control characteristics and maneuvering capabilities will be investigated. In general, these flights are expected to yield substantial data on subsystem operation and on the glider's handling qualities and landing characteristics, with particular emphasis on the man–machine relationship. The initial airdrop is scheduled for sometime in 1965.

The second phase of the test program will be started at the

Atlantic Missile Range beginning in 1965. A Titan III will boost the unmanned X-20 to orbital velocities to test the booster-glider combination, to evaluate the launching and stage-separation operations, and to gain the needed operational and environmental data for the manned flights to come. Finally, the first of a series of manned flights is scheduled for 1966, when the space glider will be boosted to orbital velocities from Cape Canaveral and brought back in a gliding landing to Edwards AFB. This phase of the test program will provide significant data on the contributions made by a pilot's judgment and flexibility to vehicle performance and reliability as well as information on all aspects of glider and subsystem operation.

The X-20 program will furnish a wealth of knowledge and know-how from which we can, with selectivity, build the future generations of military aerospacecraft—knowledge and know-how not only in the areas of advanced system research and development, design, and testing but also in the interrelated areas of producibility, maintainability, reliability, supportability, and many others. At the same time, from this program will emerge practical competence and experience in techniques vital to the advanced management of performance, cost, and time in aerospace systems.

• Aerospaceplane. A follow-on to the X-20 program could well be the development of a manned aerospaceplane that will be designed to take off from existing runways, go into orbit, maneuver into a parking orbit, deorbit, maneuver while entering the earth's atmosphere, and land at an air base in the conventional manner. A manned vehicle of this type could have many important military applications in space. At the present time the Aeronautical Systems Division is conducting exploratory and advanced investigations in those areas applicable to an aerospaceplane.

• XB-70. Our present XB-70 program calls for developing three prototype airplanes and a prototype bomb-navigation system. These models will be used to develop the technology for mach-3 aircraft flight, to determine the performance characteristics of a mach-3 airplane, and to demonstrate its capabilities. The first of the three is being assembled at North American Aviation's plant at Palmdale, California. The prototype or "technological version" of the aircraft is referred to as the XB-70.

Powered by six YJ93 turbojet engines, the XB-70 will cruise at mach 3 or three times the speed of sound—approximately 2000 miles per hour. It will be able to carry a sizable load of both nuclear and nonnuclear weapons.

In developing the technology to get the desired speed and range, ASD gave special attention to specific aerodynamic, propulsion, and structural aspects of the airplane.

The first job in aerodynamics was to increase the aerodynamic efficiency of the airplane, the ratio of lift to drag. This advance was made possible in the XB-70 development program by application of the aerodynamic principle known as compression lift, developed by scientists of the National Advisory Committee for Aeronautics in 1956. In its working application the compression lift principle will enable the XB-70 airplane to achieve the "planing effect" generally associated with a speeding motorboat. Simply and briefly, behind or downstream of shock waves at supersonic speed is a region of higher-pressure air. Designing the airplane to superimpose the wing on the pressure field causes it to be buoyed or lifted up much in the manner that a speedboat planes on its "step" or bow wave at high speed. In this way the lift given the XB-70 is increased in relation to the drag or air resistance it encounters, and subtained supersonic flight becomes possible over very long range.

The second job, to increase the efficiency of the propulsion system of the XB-70, involved its engines, fuel, and air-intake ducts. Design features were incorporated into the six turbojet engines to give maximum efficiency at three times the speed of sound and at high altitudes and to give the best possible engine performance at lower speeds and altitudes.

Also incorporated into the XB-70 engines are features which greatly improve the efficiency of this basic jet-engine process. For one, the angle of attack of the fixed blades in certain stages of the engine compressor units automatically changes in order to most efficiently compress the air and deliver it to the combustion chamber. The afterburners of the XB-70 are designed to operate continuously throughout the entire mission instead of intermittently. When less than maximum thrust is desired, the afterburner power can be regulated by modulating the afterburner nozzle area and the rate of fuel flow. The development of special high-temperature alloys for the engines' turbines, nozzles, and blades and of a more effective method of cooling the turbines makes it possible for the XB-70 engines to operate at a much higher temperature. This improvement in the combustion process markedly improves the efficiency of the XB-70 propulsion system.

One of the most difficult problems was to find some method by which the air-inlet duct could accept supersonic air at its intake and efficiently deliver subsonic air to the face of the engine. This must be done to get the necessary over-all propulsion system efficiency for long-range flight at supersonic speeds. Without getting into the many technical details involved, it can be said that an air-duct efficiency was obtained which far exceeded the predictions of even our most optimistic engineers. These improvements in the propulsion system made possible obtaining desired airplane performance with the use of conventional hydrocarbon fuel instead of the exotic, expensive fuels normally required for superior performance.

Such design features and many more have resulted in the highest thrust-to-weight ratio ever achieved by a large turbojet engine.

The third job was to ensure the structural efficiency or integrity of the XB-70, an objective complicated by the aerodynamic heating problems posed by an airplane moving at 2000 miles per hour. During high-altitude flight an airplane normally encounters an outside temperature of about –65° Fahrenheit. Despite this subzero surrounding temperature, the skin of an airplane flying at twice the speed of sound rises to 250°. At three times the speed of sound the skin flush surfaces reach a temperature of approximately 450°, and the leading edges reach 630°. Because aluminum loses strength at a prohibitive rate at temperatures above 250°, it could not be used for the XB-70 structure. Airplanes designed to fly significantly faster than twice the speed of sound must be constructed of high-temperature materials such as steel, titanium, beryllium, and nickel alloys.

The XB-70 structure not only must carry the load but also must retain its strength at high temperatures and insulate the fuel load from the heat surrounding the airplane. In addition the structure must be extremely light in weight. The answer was found in honeycomb sandwich panels made of stainless steel, which are used for the major portion of the XB-70 structure. The honeycomb panels are made by laying up an inner skin of stainless steel, a sheet of braze alloy foil, a honeycomb core blanket, another sheet of foil, and an outer skin of stainless steel. Each panel is then sealed in a retort to eliminate gaseous contamination, and brazed and heat-treated in a fire-clay tool that conforms to the contours of the airplane. The complete operation produces correctly contoured panels as large as 10 by 20 feet. These panels are then welded together without the use of bolts or rivets to form the structure of the XB-70.

This type of honeycomb sandwich paneling is both strong and a good heat insulator. It can keep the structure intact at high-speed conditions and also prevent the fuel from overheating. Unfortunately it cannot keep the XB-70 cabin cool enough for the crew and for the sensitive electronic equipment. Hence the electronic equipment bay and crew cabin will be cooled by a mechanical refrigeration system, the latter maintaining a comfortable 80° despite the 450° temperature of the outside skin of the airplane.

• Supersonic Commercial Transport. The aeronautical advancements being embodied in the XB-70 already are contributing greatly to the technology needed for developing the supersonic commercial transport and for furthering mach-3 flight technology generally. Being developed under the direction of the Federal Aviation Agency, the supersonic commercial transport program is receiving close support from the Aeronautical Systems Division in the technical research areas of aerodynamics (structures and materials, aeroelastics and loads, subsystems), propulsion (engine, fuels, controls), and problems associated with the sonic boom.

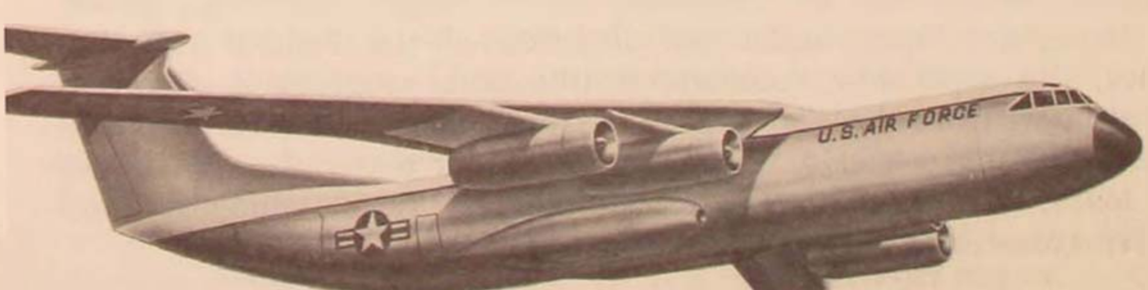
• F-111A Tactical Fighter. Vital for limited-war operations are high-performance tactical fighters and transports capable of short-roll take-off and landing, a capability needed in many parts of the world where prepared runways are short or nonexistent. To that end, the Aeronautical Systems Division is managing the development program of a new tactical fighter, the F-111A, which will combine great mobility and high speed with the ability to use short runways for tactical air superiority and close support to the U.S. Army ground forces. At the same time, the new aircraft will meet the requirements of the Navy carrier-based fighter mission.

To be powered by two Pratt and Whitney JTF10A-20 turbofan engines, the two-man F-111A will have a variable sweep wing which will extend and retract during different phases of flight. Its top speed will be approximately 2.5 times the speed of sound, with a supersonic speed capability at sea level. The F-111A will be able to carry all types of conventional and nuclear weapons. This aircraft development and others are part of the extensive program being managed by ASD to evolve concepts, equipment, and techniques for defeating aggression in limited-war situations.

• C-141A Transport. Contributing to the limited-war programs is the development of the Lockheed C-141A jet transport, designed to ensure the rapid deployment of Army troops and equipment to overseas areas as well as to meet USAF strategic airlift and normal transport requirements.

Of conventional modern design and construction, the C-141A will emphasize simplicity, austerity, and reliability. To be powered by four turbofan engines, it will cruise at 440 knots and will be capable of carrying a 60,000-pound payload over a range of 4000 nautical miles. Its other payload/range combinations will be directly responsive to specific emergency war missions in support of the Strategic Air Command and the U.S. Strike Command, as well as to normal logistics

The C-141A StarLifter jet transport is scheduled for operational use by mid-1965 to meet USAF strategic airlift and normal transport requirements. It will also be employed as part of the completely modernized cargo-handling and shipping technique being developed as the 463L Materials Handling System.



support of ZI and overseas bases. The C-141A will be able to fly nonstop and unrefueled from the ZI to either Europe or the Far East with substantial cargo loads. For domestic commercial airline operation it will have the capacity to carry over 80,000 pounds of cargo from coast to coast.

The C-141A is programed for first flight in late 1963. Its operational use is expected in mid-1965.

• 463L Materials Handling System. To further increase the speed and efficiency of global transport operations, the C-141A jet aircraft will be employed as part of a completely modernized and advanced cargo-handling and shipping system now being developed under ASD program management as the 463L Materials Handling System.

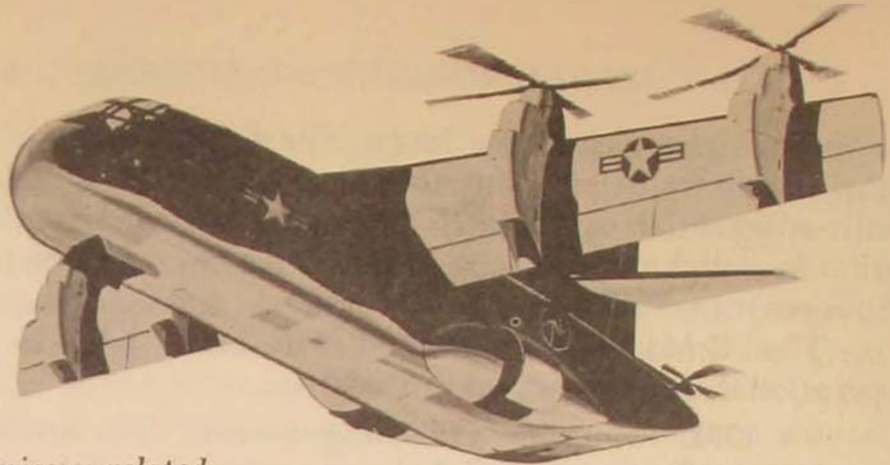
The 463L development represents a total materials handling system. In addition to the C-141A, other cargo aircraft such as the C-54, C-118, C-121, C-124, C-130, C-133, C-135, and civil transports will utilize applicable portions of the 463L system, including pallets, conveyer rollers and rails, loading equipment, and automated terminals. At the same time the 463L system will be compatible with all modes of surface transportation and their cargo-handling techniques.

Represented in the ASD C-141/463L System Program Office are members of the U.S. Army, Military Air Transport Service, Air Training Command, Air Force Logistics Command, and, because of its intended use for civil transport, the Federal Aviation Agency.

The 463L system will go far beyond the usual considerations of handling and transporting cargo. It will start at the earliest point in the transportation cycle—the air materiel area or the manufacturer's plant. There cargo will be consolidated and palletized—adaptable and equipped for side or end loading in all the aforementioned cargo aircraft and also adaptable for airdrop from the aircraft if necessary.

All operations related to the handling and loading process at the cargo air terminals will be automated and mechanized, the degree depending on the volume handled at each terminal. The paper work involved with in-transit control will be greatly simplified. Only one air transportation document, a machine-readable card, will be used from source to destination for transportation instructions, label preparation, manifesting, accounting, and reporting. The priority system assigned to military air cargo will be similarly simplified, with a two-priority system currently being tested to replace one in which 4 to 30 different priorities are now used.

The entire system will be conducive to complete flexibility in the type and number of aircraft that can be loaded, unloaded, and serviced simultaneously, ensuring expandability during emergencies. In all, the 463L will result in a considerable savings in cargo handling and shipping time, manpower, and dollars. It is expected to be operational as a worldwide logistics system by 1965.



The problems and techniques related to vertical take-off and landing (VTOL) transport operations for the 1965–1970 period are being explored through development of five full-scale prototypes of the XC-142 VTOL for triservice use. The XC-142 (shown in an artist's drawing) will have a maximum speed of 355 knots and a cruise speed of 250–300 knots.

• XC-142 VTOL. The problems, procedures, and techniques associated with vertical take-off and landing transport operations for the 1965–1970 period are being explored through the development of five full-scale prototypes of the XC-142 VTOL. Program-managed by ASD for triservice use, the XC-142 will combine the vertical take-off advantages of helicopters with the speed of a fixed-wing transport for close forward-area logistics support. To be powered by four turboprop engines, this tilt-wing transport will fly at a maximum speed of 355 knots and an average cruise speed of 250–300 knots. The combat radius of the XC-142, with 32 fully equipped troops or other payloads up to 8000 pounds, will be 200 nautical miles. Its ferrying range (empty) with auxiliary tankage will be 2600 nautical miles. Prime contractor is the Chance Vought Corporation, subsidiary of Ling-Temco-Vought, Inc.

EVEN AS new, superior systems must be kept moving continuously from concept to flight line, so must the aeronautical systems of the force-in-being be kept constantly improved and updated to reflect technological advances. The systems managed by ASD in this important "product improvement" area relate directly to virtually all the Air Force operational missions and include the B-58 and B-52 bombers; the F-101, F-104, F-105, and F-106 fighters and fighter-bombers; the KC-135 tanker; the Falcon, Hound Dog, Bullpup, Quail, Bomarc, and Mace missiles; and a wide variety of cargo, helicopter, and trainer aircraft. The "product improvement" effort involves many projects and takes many directions. ASD studies and tests of the B-58 tire, for example, resulted in new specifications and increased the life of the tire from five landings at 140,000 pounds to ten landings at the full aircraft gross weight of 163,000 pounds. In another of many examples, the take-off power, climbing ability, and range of the B-52H were augmented by the use of new turbofan engines, and its firepower was increased by the addition of an ASG-21 Gatling gun armament system. A newly redesigned wing for the B-52G/H will significantly add to its structural life and use. At the same time the study and development program from which the redesigned wing emanated has contributed much to advancing the state of the art in predicting the structural fatigue life of full-scale weapon systems.

In closely examining all the systems within ASD's program, we see the full systems picture against an environmental background of rapidly soaring costs and complexity and increasing development and acquisition time. We see, too, a management process which promises to become as complex as the very systems whose costs and time the management must keep under constant check and control. And we see a supporting research effort of an interdisciplinary nature which already cuts across virtually every known field of science and technology.

It is within this environment that the Aeronautical Systems Division's "pool" of in-house capability has its special significance and contribution. Into this churning "pool" flow ASD's techniques and experience in managing the acquisition of its wide diversity of systems, the judgments of its systems analyses, the guidance of its exploratory pioneering research effort, the advanced knowledge, know-how, and new concepts of its broad-based applied research and advanced development program, and much more.

It is in this "pool" that all these managerial and technological skills, talents, and experiences come together and are integrated to give us the judgment needed to plan and guide our program competently—and the selectivity needed to pursue those paths which can yield the most systems performance and technological capability with the least expenditure of funds and time.

And it is in this "pool" that the real strength of the Aeronautical Systems Division is mirrored.

Aeronautical Systems Division, AFSC

ELECTRONIC SYSTEMS

Major General Charles H. Terhune, Jr.

War is more than weapons and tactics, and changes are taking place in other military fields which affect its character perhaps as much as tactical innovation. Until the *Enola Gay* dropped the first atomic weapon in August 1945, a primary concern of the military commander was the amassing or concentrating of a clear superiority of firepower. As Napoleon put it, "The principles of war, not merely one principle, can be condensed into a single word—'concentration.' " Today every nation possessing nuclear weapons and the means for their delivery can concentrate more than enough power to destroy its enemies.

According to Von Clausewitz, another important objective in warfare is speed. But with ICBM's able to leap hemispheres in a half hour and with IRBM's launched from land, sea, or air able to reach from continental perimeter to heartland in approximately ten minutes, the tactical advantage which historically belonged to the weapon with fractionally higher speed simply does not exist today. Indeed some ICBM's have to be slowed down to prevent them from reaching escape velocity.

In short, we have arrived at that unique point in military history at which the newest generation of weapons possesses, practically speaking, all the firepower and speed they can usefully employ. For the weapons designers, priorities are shifting. The question is no longer the simple one, "Who can get there 'fustest with the mostest'?" The character of war has changed.

Two new problems are of ascending importance today in military and political considerations: Can the wisest political decisions and the proper military decisions be made in sufficient time for the employment of today's super aerospace weapons? Can those weapons be precisely controlled in the execution of those decisions? These are the questions which go to the heart of what is called "command and control." It is becoming increasingly clear that the major power having the more rapid, accurate, and reliable command and control capability will possess a vital military advantage over an enemy that is equally powerful, if not more so. It is the function of the Electronic Systems Division (ESD) to carry out the Air Force responsibility for ensuring that the United States achieves and maintains a recognizable superiority in command and control capability over all other powers.

The matter of command and control is particularly critical to this Nation in light of its peaceful intentions and avowed policy of nonaggression. If our defense against a surprise nuclear attack is to continue to be based upon our ability to retaliate with superior aerospace forces, then the importance of our command and control systems can hardly be overestimated.

To conduct warfare today, to be able to make the vital decisions for the employment of weapons and forces, aerospace commanders must, first of all, have four services rendered for them by their command and control systems: the gathering of data on the activity of both friendly and enemy weapons, the transmission of the data from the four corners of the earth to a central location, the processing or analyzing of the data, and the display of the processed data. Once decisions have been made and the action orders issued, four additional services must be performed by the same or related command and control systems: the transmission of orders to the forces and weapons in the field, the conversion of those orders into weapons activation signals, the transmission of ground-to-air signals for the control of the weapons in action, and the return transmission and processing of reports on the activities and accomplishments of the weapons.

Command and control systems are centralized in the combat operations centers of the major Air Force operational commands, in the control centers of the regional and overseas theaters, and in the backup or emergency facilities of both ZI and overseas commands. The significance of these centers becomes steadily more important as the need for centralized decision-making and weapons control increases. Several of these centers are now being redesigned to raise their level of effectiveness and increase their survivability. The NORAD Combat Operations Center, for example, is being placed underground to enhance its ability to withstand an attack and maintain sustained wartime operations.

At the higher level of national political leadership, virtually the same services need to be rendered by command and control systems in order that decisions of national politico-military strategy may be made and follow-on orders issued and executed. More than two years ago, in addressing both the United States Congress and later the military committee of the North Atlantic Treaty Organization, President Kennedy expressed very clearly the importance he places on command and control systems and stated his intention of having the services of such systems continuously available to his office. The command and control systems that serve our Air Force commanders are part of the larger complex of military systems that feed vital data into the Chief Executive's office. From the standpoint of aerospace power, such special command and control services and facilities as may be required for the President and his advisers are being intensely studied at ESD.

systems managed by ESD

To provide the USAF with appropriate command and control capability, the Electronic Systems Division is presently managing sixteen system programs.

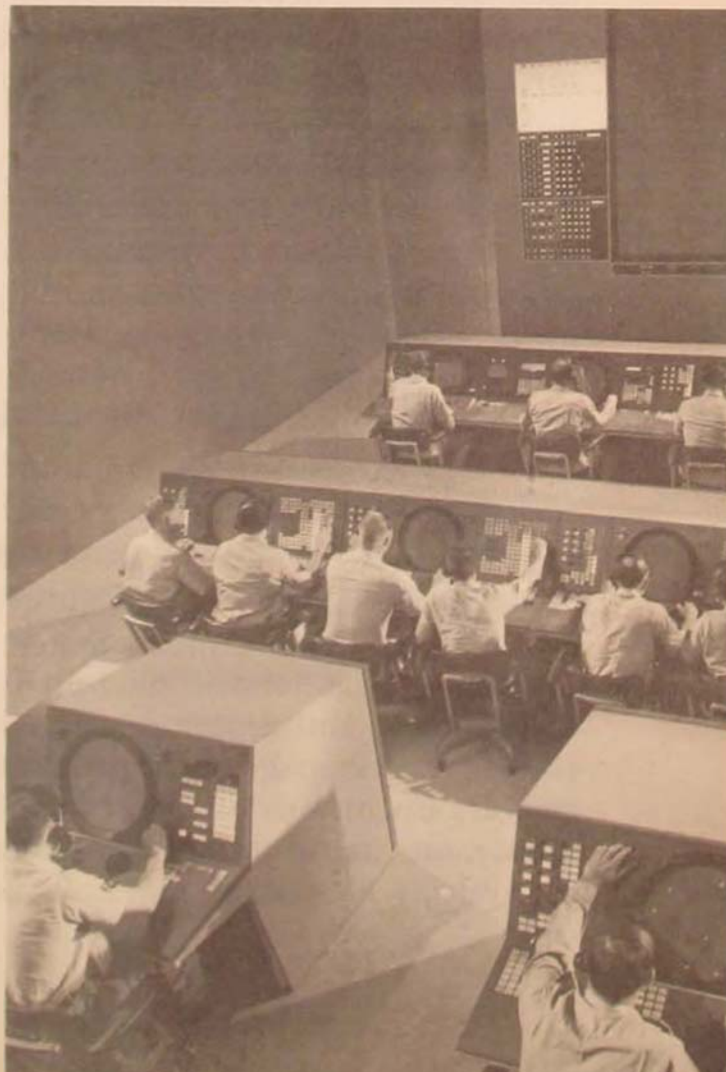
• Air Weapons Control System (412L). This system is primarily for use outside the United States for the control of manned and unmanned air-breathing weapons and for providing initial target bearings for ground point defense weapons. The system will perform the tasks of weapons control for air defense, traffic control for all types of military aircraft, and supporting command and control services for strategic weapons. It will provide the overseas theater or battle-zone air commander with the services of air surveillance, aircraft identification, threat evaluation, and assignment and control of weapons. The equipment is being designed for permanent ground emplacement or for air-transportable, temporary lash-ups. The system most closely resembles the permanent U.S.-Canadian-based SAGE system in function and equipment characteristics.

• DEWEast (413L). The eastern extension of the DEW Line across Greenland, commonly called DEWEast, was completed 30 July 1961 and turned over to the Air Defense Command for operation. The system consists of four new radar installations, one on the east and one on the west coast of Greenland and two on the central icecap. Communications lines tie the new system to the eastern terminus of the main DEW Line at Cape Dyer on Canada's Baffin Island and to the USAF installation at Reykjavík, Iceland. The system is supported logistically from Sondrestrom Air Base on the east coast of Greenland, to which there is also a communications tie. The DEWEast extension adds a 1200-mile flank to the main DEW Line, enhancing substantially the U.S. ability to detect a hostile air-breathing threat from the north. At present refinements are being carried out under ESD supervision to bring the line up to peak efficiency.

• Semiautomatic Ground Environment (416L). SAGE is the ground environment of the North American continental air defense system. Featuring the automatic processing of aircraft control and warning data by electronic digital computers, the system divides the U.S. and southern Canada into 22 sectors in which air defense operations against an air-breathing attack would be conducted on an area basis from direction centers. The sectors are combined into nine larger regions, in which operations are supervised from a control center. The control centers, in turn, come under the strategic guidance of the NORAD Combat Operations Center. The giant computer in each direction center has sufficient storage capacity to permit the transfer of operational control between adjacent sectors in the event of damage. SAGE direction centers and control centers accept automatic inputs from long-range radars, gap-filler radars, airborne early-warning aircraft, picket ships along the coastlines, Texas Towers, and the U.S. Weather Bureau. Direct intercept control may be exercised by the direction centers and control centers over air defense aircraft, Bomarcs, and Nike-Ajax and Nike-Hercules missiles. The last of the 21 U.S. sectors was completed in December of 1961. The final sector in Canada, with a unique, hardened direction center near Ottawa, is still under implementation.

• NORAD Combat Operations Center (425L). This program will provide the North American Air Defense Command with a hardened combat operations center capable of sustained operations in the face of a nuclear attack. The new COC is to be placed under a mountain near Colorado Springs and will replace the present soft one at Ent Air Force Base. Other than hardening, the major improvements in the new COC will be in data processing and displays.

• Traffic Control and Landing System (431L). TRACALS, as it is abbreviated, has as its objective the updating of the traffic control and landing systems at USAF bases throughout the world. The increase in recent years in the volume of air traffic and the rise in aircraft speeds—both of which promise to continue to increase—have necessitated a revamping of present landing facilities and techniques. The USAF and the Federal Aviation Agency are teaming up to achieve as much standardization as possible in military and civilian air traffic



Heart of the 412L Air Weapons Control System is the operations center, where the incoming data picked up by electronic sensors are processed by a digital computer. Operators at push-button query panels request the computer to supply selected information about the air battle on their personalized displays. The Air Weapons Control System provides overseas theater commanders with the latest in electronic devices for conducting a combat air operation or for the control of routine peacetime missions.

control. Field tests are presently under way on a new high-volume traffic control radar. Specifications for the system will allow for the handling of mach-4 aircraft by 1970, a service ceiling of 100,000 feet, and landing and take-off rates of one per 30 seconds for each runway in use at the time.

• Weather Observation and Forecasting System (433L). This system features electronic computer processing of the vast quantity of weather data that must be considered for accurate weather forecasting. Two computer centrals, which will be linked to the many subscribers by new high-speed communications circuits, are planned for the United States. Improved data-processing and communications techniques will provide more accurate and more up-to-date forecasts than those presently available. The R&D effort associated with the program includes development of new radars and meteorological sensors for more accurate weather observation. New display techniques are also being devised, including computer-activated television screens. The system, which is being developed with the full coordination of the U.S. Weather Bureau and the Federal Aviation Agency, will ultimately include inputs from the new generation of weather satellites.

• Intelligence Data Handling System (438L). This system will bring to the field of intelligence the advantages of the electronic digital computer in high-speed, high-volume data processing. The system program calls for extensive studies to be made of intelligence information to determine ways for programing the data for electronic processing and analysis. The present methods of manual or "human" intelligence data handling are simply not fast enough for operations in the aerospace age.

• Strategic Air Command Control System (465L). This system will supply the Commander in Chief, SAC, and the commanders of the three numbered Air Forces under SAC more accurate and more detailed information on the status of SAC weapons and personnel by means of improved electronic sensors, data processors, and data display devices. The goal of the system is more effective command and control of SAC's globally dispersed, ever alert weapons and forces.

• Electromagnetic Intelligence System (466L). This system will acquire intelligence by electromagnetic means. The subsequent processing and transmission of the data to the several users will be by modern, high-speed, electronic equipments and techniques.

• Air Force Control System (473L). This system will provide the latest in electronic data-processing and display devices to assist in the rapid and accurate command-level actions that Hq USAF must take in the management of Air Force resources used in support of military operations of the JCS or the unified and specified commands. The most important feature of the system will be its flexibility in control. By use of master control panels, the computer may be asked to supply a very great variety of detailed information to battle-staff members who may need specific facts in addition to those shown on the large situation displays. Depending on the degree to which the computer may be queried, certain decisions can be reached in a precise, step-by-step fashion. The program plans call for the equipment to be placed in the present Air Force Combat Operations Center in the Pentagon but later moved to a hardened site.

• Ballistic Missile Early Warning System (474L). BMEWS is designed to provide approximately 15-minute warning of a mass attack of ICBM's against North America from the north. To accomplish this, BMEWS now has two gigantic radar detection stations, at Thule, Greenland, and Clear, Alaska, and will have one later at Fylingdales Moor, Yorkshire, England. Data from these forward sites are returned over a vast communications network to a central computer and display facility at NORAD headquarters, Colorado Springs, where the data are coordinated and synthesized. Warning and threat evaluation displays in the NORAD Combat Operations Center would indicate to the Commander in Chief and his battle staff the status of any ICBM attack on this continent. Simultaneously Headquarters USAF and Headquarters SAC receive BMEWS data for their information and action. Civil Defense representatives at NORAD would be able to translate the BMEWS warnings into population alerts throughout the U.S. and southern Canada. In England the Royal Air Force will receive readouts from the BMEWS system which will provide an alert of any ICBM or IRBM attack, though warning time there will of necessity be less than that provided in this country. BMEWS radars, with ranges of approximately 3000 miles, can detect satellites in orbit and serve as a major data source for the Space Detection and Tracking System (496L). Pending the development of an effective antimissile defense system, the warning time provided by the BMEWS system is of critical importance to the credibility of the U.S. deterrent.

• Nuclear Detection and Reporting System (477L). It is the function of this system to supply NORAD and other appropriate military and civilian agencies information on nuclear detonations within the NORAD area of responsibility. The system will be capable of determining the location, the approximate magnitude, and certain other characteristics of a nuclear explosion.

• Air Communications System (480L). AIRCOM is an evolutionary approach to improving communications throughout the Air Force. Though from a management point of view all systems are considered as a collective and the goal is effective intersystem as well as intrasystem communications, Air Force communications as a whole will be improved by degrees and by segments. In practice, 480L breaks out into a group of projects requiring individual management, each project having a priority appropriate to the specific service to be rendered.

• PACCS (481L). This system, just entering the development stage, is to be a survivable command and control system for control of the strategic force in the trans- and post-attack periods.

• Emergency Mission Support System (482L). Distinct from 431L, this system is designed as an air-transportable traffic control and communications system for emergency use in areas where fixed facilities are not available, such as the zone of engagement in a limited-war situation. In the design of the system prime consideration has been given to reducing to the minimum the time between equipment offloading and the providing of actual traffic control service.

• Space Detection and Tracking System (496L). The mission of SPADATS, also known as Space Track, is to detect, track, identify, and catalog all orbiting objects. Information from a wide variety of military and civilian sensors feeds into Headquarters NORAD, where computers assimilate the data. By means of these data, orbiting objects may be identified and predictions made as to lifespan and orbital characteristics. Plans for improving the system call for additional sensors of greater range and discrimination capability to provide more accurate and more nearly continuous coverage of all orbiting objects.

management of ESD

As one can readily assume from the review of the ESD programs, command and control systems are tremendously varied in their mission, function, equipment, funding, and priorities. Consequently the attainment of standardized management is extremely difficult. Lessons learned in one program rarely apply directly to the next system. The basic principles of good management are, of course, applicable to all programs, but they are not always applicable in the same way and to the same degree.

BMEWS and SAGE, for example, are "mass" systems. They involve great quantities of equipment and encompass the full range of communications and electronics technologies. Extensive R&D has also gone into the two programs. They have cut across the lines of interest of many military commands and Government agencies. Deadlines have hung heavy over the heads of the program directors. The management of the two programs, therefore, has been primarily a matter of master coordinating. By contrast, the Emergency Mission Support System (482L) is a much smaller program, involving very little specialized R&D and far fewer agencies. A systems integration contractor will design a few special buffer kits to ensure that the individual pieces of equipment can work together even though purchased off the shelf from present suppliers. From a management point of view then, this program is a small, neat package; but a few dollars saved or lost will appear quite important in the program financial records.

Command and control system programs do not as a rule include a phase leading to a system prototype and its checkout. Many individual pieces of electronic equipment do go through a prototype cycle and on occasion even rather large subsystems do—for example, the SAGE Cape Cod test sector or the present test installation of weather equipment at Westover AFB. Command and control systems, however, are "one each" items. They are characterized by a continuing evolution of system configuration rather than a system design or configuration that becomes fairly permanently frozen in consequence of development, as is the case with most weapon systems. Furthermore, the story of command and control systems is itself basically one of continuous evolution. Each system is clearly the successor of a forerunner—sometimes a system, sometimes something less than a system. In other words, command and control system programs rarely end in a clear-cut fashion as a weapon system program does. They are subject to follow-on improvement phases, which may very well turn out to be the initial phases of successor programs.

The management of each system at ESD is carried out individually under the direction of a system program office, as with aircraft and ballistic missile systems. The SPO is the point of contact for all interested Air Force commands and Government agencies and is also the supervisor of the industrial contractor or contractors associated with the program. The programs are monitored collectively by a Deputy

Status boards in SPADATS Control Center at Colorado Springs display timely tracking information on all man-made objects in earth orbit. Through closed-circuit television, information is piped to the Combat Operations Center, where it is available at all times to the Commander in Chief, NORAD, and his battle staff.

for Systems Management on the ESD staff. He serves as a single point of reference for the commander on all systems and oversees the SPO operations, particularly management practices. Of especial importance, the Deputy for Systems Management is in a position to look across the system programs and study the possibilities for technical integration between systems. This is an area in which tremendous savings can be realized and in which the value of certain systems may be significantly enhanced.

Efforts toward technical integration can lead to such actions as the reprograming of the computers of the Ballistic Missile Early Warning System, an action which now enables these computers to report to the Space Detection and Tracking System the data acquired from the BMEWS radars concerning orbital objects. Originally programed to discriminate against orbital objects and to report only ICBM detections, the BMEWS computers, after a slight and relatively inexpensive modification, are now providing a major share of the data being received at the SPADATS center at Headquarters NORAD.

A modern management tool recently applied to command and control systems is PERT (program evaluation and review technique). As currently employed at ESD, PERT is time-oriented and is used as a means of keeping a close tab on the many facets of these complicated and costly systems. By breaking out an entire system program into a series of actions or steps and subjecting each of these to computer analysis, PERT enables a program director to determine in a very brief time the exact status of all the varied operations going on in his program. The rather heavy reporting burden implied for the contractor and other responsible agencies is more than offset by the success of the system in spotting and isolating potential problem areas before troubles develop that are correctable only by special effort and at considerable additional cost. A sophisticated analysis of PERT data also enables a system program director to ascertain precise costs and man-hours represented by the many activities in his program and hence to make over-all evaluations of the efficiency of his management.

Another management tool used by the Electronic Systems Division to improve its in-house effectiveness is the periodic manpower survey, which ensures that all personnel are used in positions of maximum importance. The last survey resulted in the reallocation of 117 position spaces, most of which went to programs with ascending responsibilities.

Over the past two years ESD has conducted a steady program of management improvement, a basic feature of which is the assembling at Laurence G. Hanscom Field of representatives from all commands that will use, operate, or support our systems. Essentially, four interests must be coordinated to produce effective command and control systems: the program developer-manager (i.e., AFSC), the operator-user, the logistician, and the personnel trainer. At Hanscom now are representatives from all major Air Force operational commands and from the Air Force Logistics Command, Air Training Command, and a number of other interested agencies, including Air Force Communications Service, Office of Aerospace Research, Royal Air Force, and Royal Canadian Air Force. The constant coordination of this team is essential in the implementation of ESD's systems and in its studies leading to the designing and planning of new systems and new environments. The interlocked efforts of this team are a concrete example of the concept of concurrency in action.

applied research and development

Associated with very nearly all system programs are extensive applied research and development activities. At ESD these activities are directed by a Deputy for Technology.

In command and control, as in aircraft, missiles, and space programs, a constant effort is made to convert the discoveries of science into finished equipment. One generalized distinction between the R&D effort associated with command and control systems and that of other weapon and support systems is that our R&D leads to new "software" as well as new hardware. Techniques in data processing, for example, are as important to command and control systems as improvements in computer design. Information on how the human mind actually makes decisions—or on what causes inaccurate decisions to be made by intelligent, well-balanced people—may be as important to an aerospace commander as the development of a new acquisition radar. An analysis of a foreign language that would make it possible for that language to be translated by an electronic computer with acceptable accuracy is as essential to our intelligence programs as the development of a new high-altitude electronic sensor. In short, the objective of all command and control systems is to help make more rapid, more accurate decisions. This involves "software" as well as hardware.

Air Force research is divided into 27 technical areas, each controlled by a technical area manager (TAM). Some areas are based on scientific disciplines; others are system-oriented or mission-oriented. Those which relate to electronics as a discipline or to the future of electronic systems have been assigned to ESD to manage. Regardless of the location or primary mission of the Air Force laboratory involved or the extent of its activities, those projects which pertain to electronics are programed, funded, and directed by ESD TAM's. Electronic developments which contribute to aircraft and missile systems are managed by ESD TAM's even though the system program package remains under the supervision of a different AFSC division.

The R&D phases that follow research, namely operational support and advanced development, remain under ESD for management. These phases embrace such varied things as the IBM-developed Machine

Language Translator, electronic security alarms for missile sites, special electronic sensors and photographic devices for intelligence purposes, and a tremendous complex of instrumentation equipment for the several missile ranges and their worldwide tracking networks.

A provision for testing is inherent in any management structure which visualizes concept-to-checkout responsibility, as in the presently assigned responsibility of AFSC. At Hanscom Field is the central facility of the huge Evaluation SAGE Sector, a vast network of radars, computers, control consoles, and associated communications circuits. At the test site of Rome Air Development Center at Verona, New York, is a weird assembly of one-of-a-kind electronic devices whose every electronic impulse is recorded, analyzed, and evaluated. Other ESD test facilities are at Paramus, New Jersey, and at Eglin AFB, Florida. Since these facilities are not sufficient to satisfy all ESD requirements, others are being contemplated.

Despite the huge proportion of the budget for research, development, test, and evaluation (RDT&E) which electronics already consumes, there is far more electronics research proposed than can be funded. It is the function of ESD to select those items which are most critically needed by the Air Force to meet its requirements in both present and future time periods. The technical area managers turn to every available source for guidance in the selection of the appropriate programs. Each program is carefully matched against stated requirements in the USAF Long Range Research and Development Objectives, checked against stated needs of operational commands, and finally reviewed by the Air Force Scientific Advisory Board.

Although many desirable research programs have to be eliminated for financial reasons, the TAM's encourage the submission of ideas for research programs from all possible sources. Recognizing that competent researchers are themselves often sound judges of what should be researched, the ESD TAM's particularly urge scientists in military and civilian laboratories to propose projects from the bottom up. Of course our own system program offices and advanced planners offer many suggestions and very noteworthy guidance on applied research efforts.

A check-and-balance technique has been provided to make sure that future or proposed electronic systems do not arrive at a critical state of development only to discover that a key research item is missing. The technique is to establish a planning objective coordinator (POC) for each hypothetical or proposed system. Since each approved applied research planning objective (ARPO) with the proposed system has the possibility of evolving into something larger than originally planned—even of evolving into a system itself—the POC guides each ARPO with much the same care that the system program directors use on full systems. The POC constantly analyzes and evaluates his hypothetical or proposed system to determine what research remains to be done. He establishes research milestones—even employs modified PERT procedures—and stays constantly aware of the progress of each research task that leads to his objectives. In the past the pressures of the research programs have, on occasion, caused the TAM's to lose sight of the full effects of changes in their programs on related systems. Now each change is coordinated with the POC, who can allow or stop the change according to its effect on his system. The POC does not control funds, but he has a loud voice and a big stick.

The management capability represented in the TAM's and POC's would be meaningless if a well-rounded technical competence did not also exist within or near ESD. The organizations that form what is called the "Hanscom Complex" provide this concentration of competence, which is richly augmented by other organizations in the immediate area of this "heartland of electronics." Integral to the Hanscom Complex are the Electronic Systems Division itself with its assigned system program offices; the Air Force Cambridge Research Laboratories (AFCRL) of the Office of Aerospace Research; the tri-service-funded, Air Force-managed Lincoln Laboratory of the Massachusetts Institute of Technology; and the MITRE Corporation. Backing up these organizations are the electronics laboratories of the Rome Air Development Center (RADC) and the Aeronautical Systems Division (ASD). These organizations collectively provide a range of technical abilities that span the entire research and development field. The basic research in electronics and geophysics of AFCRL ultimately has as its principal beneficiary the systems of ESD. The labs also perform a sizable portion of applied research in support of these systems. RADC and Lincoln Laboratory are the prime performers of applied research and advanced development in support of command and control systems, with the electronics laboratories of ASD doing research under ESD management in their areas of specialized competence. RADC has an increasing role in systems engineering for the ESD SPO's, providing technical direction for several of them.

The Department of Defense, through its Advanced Research Projects Agency (ARPA), sponsors and funds multimillion-dollar programs each year in scientific areas. These programs are assigned throughout the three services for control and contractual management. The establishment of the Electronic Systems Division provided ARPA with a single focal point for its electronics programs related to the Air Force. Each ARPA project under the cognizance of ESD falls under the purview of the Directorate of Applied Research, where it comes under the watchful eyes of the same TAM's who are responsible for related Air Force programs. Thus for the first time research and development in electronics come under a single management agency, with the management of electronic operational support and advanced development residing side by side with the TAM's of ESD.

The conquest of space is as much the concern of the electronics engineer as of the missile engineer. If man is to penetrate to the moon and beyond, it is essential that he be in constant communication with this planet. The research projects of ESD must therefore include such subjects as the effects of transmission in normal and disturbed space environments. Since the plasma sheath which surrounds an inbound space vehicle adversely affects electromagnetic signals, it must be thoroughly researched if we are to meet the needs of telemetry and communications. Propagation effects through and beyond the layers surrounding the earth are yet another challenge.

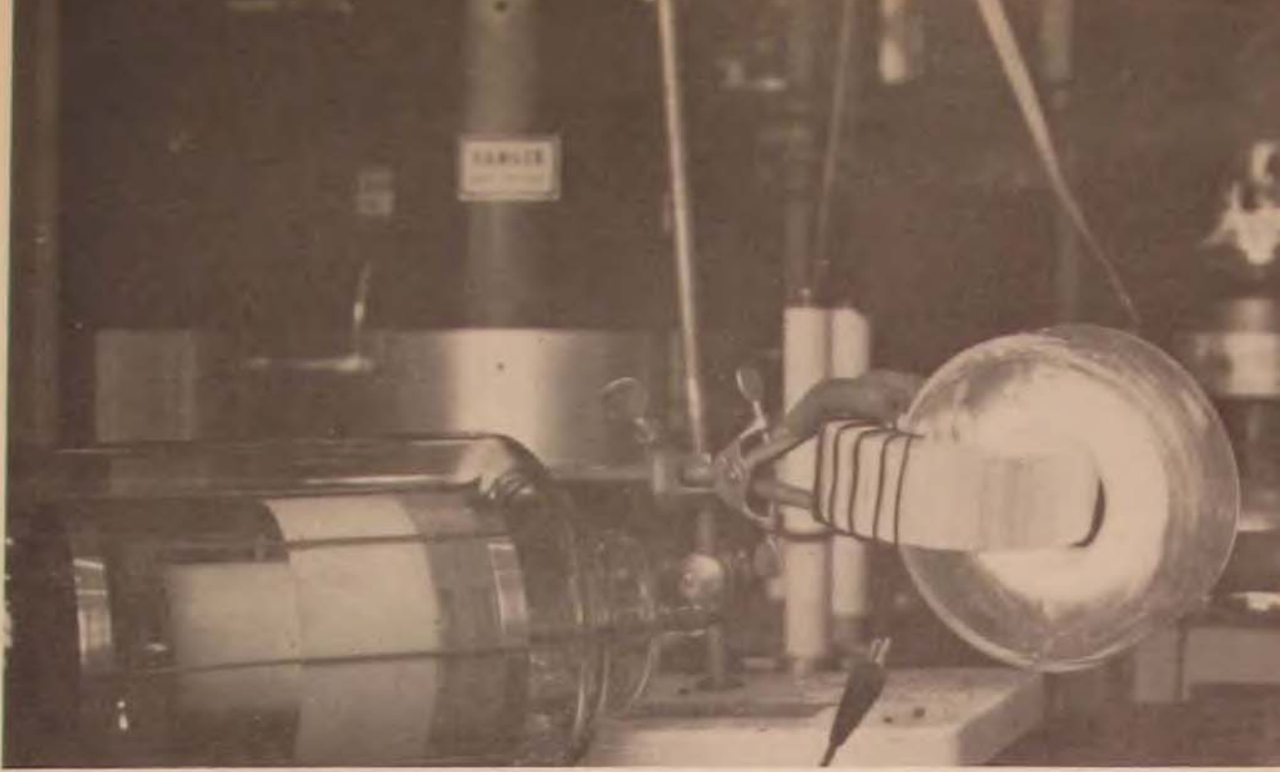
Many problems regarding effective and reliable earthbound communications have yet to be solved. In the military sphere, for example, communications that can operate during an atomic attack and survive it have not yet been perfected. New means of transmitting information through and above the earth must be found. All these problems are being studied under ESD-managed research programs. ESD-sponsored programs are also looking into communications satellites and other extremely high-altitude reflectors such as balloons and halos of hair-thin metallic dipoles.

Radars for the surveillance of orbital and space objects are another challenge requiring new development. New techniques that show promise for longer-range surveillance involve the use of frequencies in the optical range. Distance alone is not the only problem for the designer of radars for the aerospace age. These radars must be able to deal with a much greater volume of objects and must have much greater powers of discrimination. For example, radars for tracking satellites will have to be able to maintain constant surveillance of what will eventually be thousands of objects traveling at fantastic speeds.

One of the prime advantages of ESD as a single agency for the management of all Air Force electronic systems was earlier indicated as being the ability to look across the line of all the systems and from that vantage point see omissions and possible multiple applications. The same advantage devolves to ESD in the management of its research and development activities. Omitted research could result in the failure of a vital program, and repeated research would be an inexcusable waste of critical funds. Continued centralized management of all Air Force electronic research thus will result in more and more achievement for each RDT&E dollar.

advanced planning

The advantage which a single management agency possesses for the integration of efforts has a future-tense as well as a present-tense aspect. In the command and control field, the ability of ESD to plan future systems from a central position is the advantage of being able to do more than "quick fixes" and "post-mortem" modifications. By proper advanced planning, ESD will be able to prevent mistakes rather than siphon off its talent in correcting them. The thought frequently recurs in the minds of ESD personnel, "How many of our present



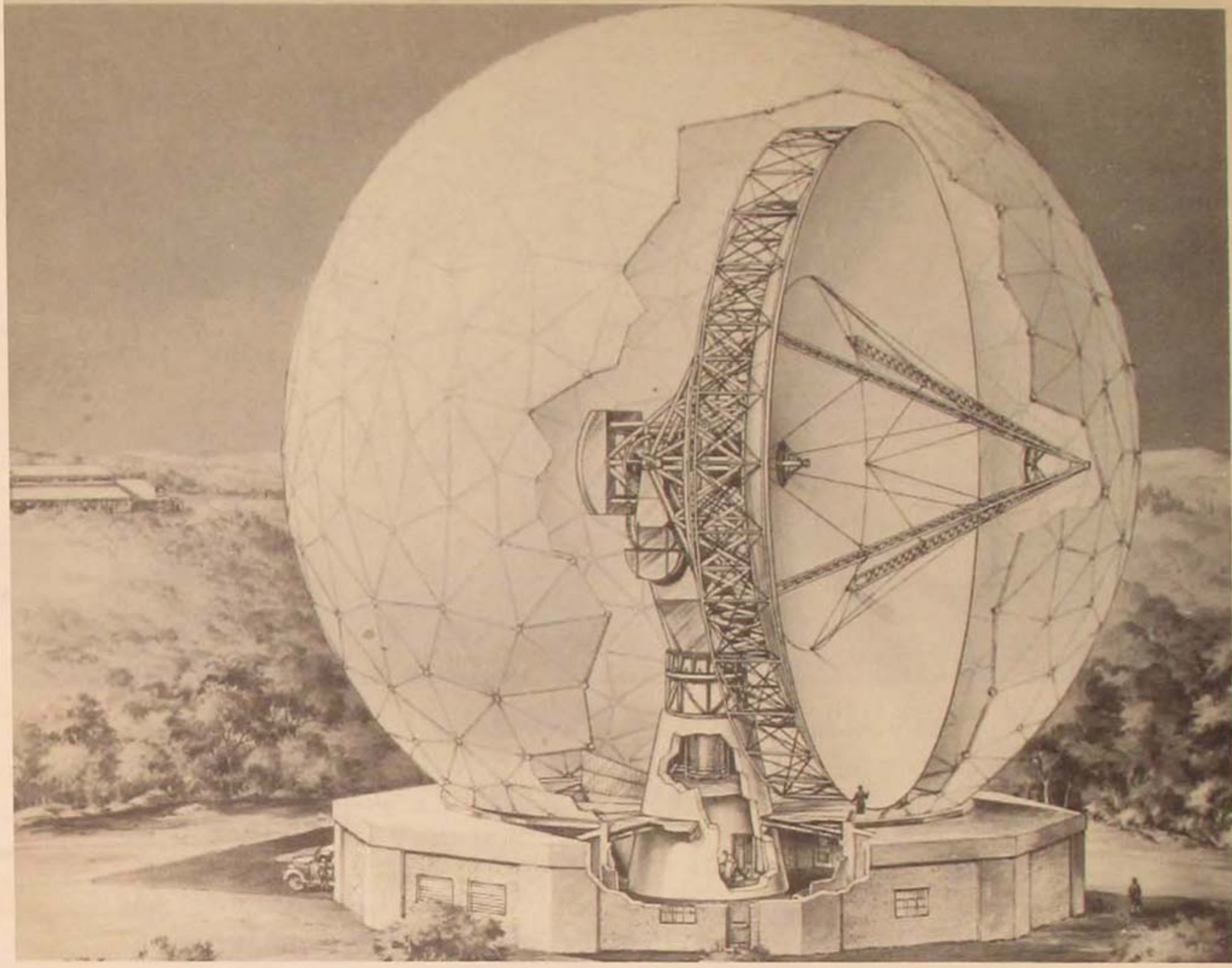
Man's conquest of space requires a thorough knowledge of plasma, the electrically conductive gas made up of neutral and ionized particles and free electrons but which, taken as a whole, is electrically neutral. Here a plasma switch is tested.

problems could we have avoided if only we had been in business three or four years ago!"

ESD's Deputy for Advanced Planning can approach the requirements of distant time periods not by simply extending the technical integration of existing systems but by being able to design and integrate whole families of systems along functional lines.

The concept of the functional integration of command and control systems is a somewhat difficult one to grasp, but it can be illustrated clearly by a combat operations center such as the new NORAD COC. Here the planners of data processors and data displays must first analyze the North American Air Defense Command along functional lines and then relate the proposed command and control services to the basic command functions. The decisions the CINCNORAD must make will not be based solely upon the input of a single electronic sensor nor upon the capability of a single weapon system; they will be made in light of essential functions to be performed by his command.

In planning command and control systems for space operations, ESD advanced planners work along functional lines. Here command structures and existing command and control systems pose no limitations upon the planners. Instead they can study space operations as an entity, knowing that this or that function must be performed by some form of space vehicle under the direction of some future command. Command and control services can thus be studied in relationship to basic functions, with the result that the total electronic environment can be designed to contain the minimum number of

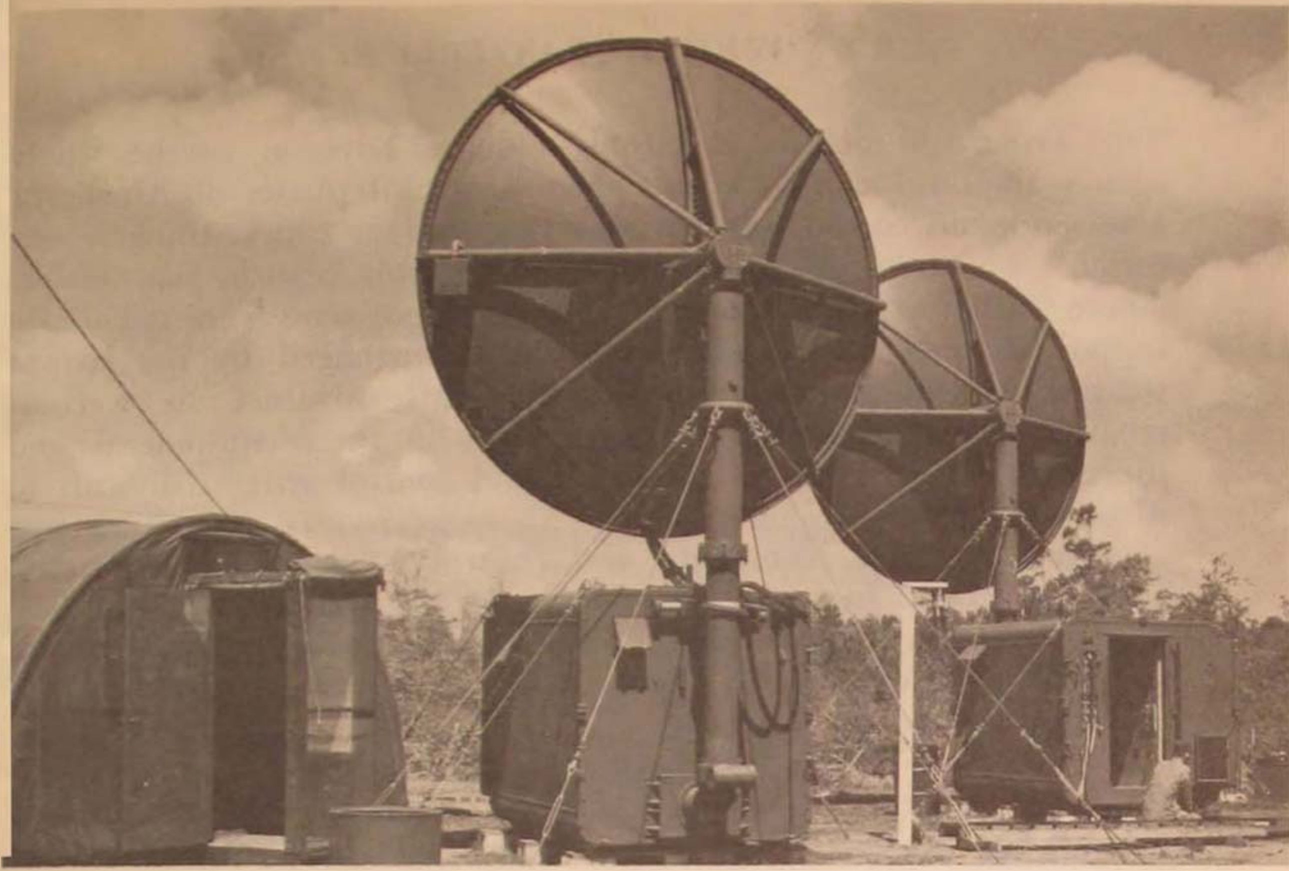


The Haystack Radar will be the world's most precise tracking radar when completed in 1963. With its 120-foot-diameter X-band antenna, it will provide an advanced research tool for communications studies with passive and active satellites, for measuring inhomogeneities in the atmosphere, and for radar study of the lunar surface. The Haystack is being built by the Electronic Systems Division for operation by the Lincoln Laboratory of Massachusetts Institute of Technology.

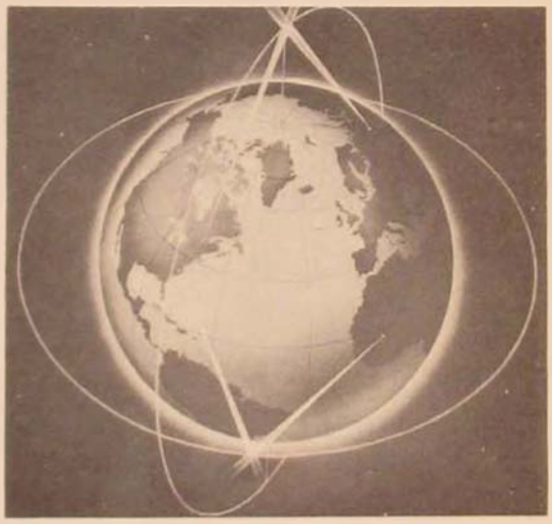
systems and yet provide the requirements of all space operations. Defining a space command and control environment will be one of the most important tasks of our Deputy for Advanced Planning in the coming months.

This future space command and control environment, though susceptible of clearer definition than the present ground electronic environment for air-breathing operations, must be related to the present environment. The Deputy for Advanced Planning must also determine the schedule of events that will have to take place in future development of the present environment until it merges with the space environment. The two environments will form what Major General Kenneth P. Bergquist, when Commander of ESD, frequently referred to as an "aerospace control environment."

ESD's advanced planners have many plans under consideration



The AN/TRC-66 troposcatter radio provides voice, teletype, and digital communications between tactical sites to a range of about a hundred miles. Designed for rapid airlift, the AN/TRC-66 radio features a 14-foot inflatable paraballoon antenna and transportable shelter.



Project West Ford, a controversial communications project, is designed to use as passive reflectors millions of tiny dipoles in a band orbit about the earth. MIT's Lincoln Laboratory conducts the research sponsored by ESD.

that are less comprehensive than "environment" plans. Individual systems must sometimes be considered on their own merits as plans for new and revolutionary weapon systems appear on the horizon. Such systems must be evaluated against the picture of the total aerospace control environment so that their proper place and priority may be established.

To blueprint the future of ESD operations is the function of advanced planning. It is at once both the most valuable and the most challenging function to be performed on the staff.

THE EVOLUTION of the Electronic Systems Division as the single agency responsible for the management of all phases of Air Force command and control systems was slow and at times strangely uncertain. The concept of command and control, as such, was elusive. There was strong debate as to whether these systems were essentially support systems that logically should be managed by the parent weapon system organization or sufficiently distinct to warrant separate management. The great variety in their equipments and functions tended to make command and control systems difficult to picture as part of a common family.

Now, however, command and control is generally understood and appreciated in responsible circles in the military and political branches of government. The President has clearly indicated understanding of the subject. The period of large-scale education for acceptance is coming to an end.

Today the single management agency exists. It is properly located. It is properly supported. Organizationally it is equipped to manage the design, development, procurement, and implementation of command and control systems. For the first time, the trained and experienced personnel of ESD, while continually improving management techniques and procedures, can now concentrate on the essential job of delivering command and control systems within the time period allotted and within the dollar ceilings established. The result should be a significant improvement in the Nation's command and control capability and a consequent enhancing of the Nation's aerospace deterrent.

Electronic Systems Division, AFSC

SPACE SYSTEMS

Major General Osmond J. Ritland

THE FAR-REACHING significance of space was well stated by Vice President Lyndon B. Johnson in an address to the American Rocket Society on 13 October 1961: "The future of this country and the welfare of the free world depend upon our success in space. There is no room in this country for any but a fully cooperative, urgently motivated all-out effort toward space leadership. No one person, no one company, no one Government agency has a monopoly on the competence, the missions, or the requirements for the space program. It is and it must continue to be a national job of all Americans. . . ."

In this spirit the Space Systems Division of the Air Force Systems Command accepts its share of responsibility for establishing and maintaining United States aerospace competence. This division is the central management agency within the Air Force equipped and chartered to utilize the full potential of the Nation's space technology and apply that technology to military requirements for satellites, other space vehicles, and the boosters needed to launch them. Its job is first to investigate the military character of space and then translate concepts into research and research into hardware.

The first serious military study of satellites was contained in a paper entitled "Preliminary Design of an Experimental World-Circling Space Ship" completed 12 May 1946 through a contract between the Air Force and the RAND Corporation. For several years before Sputnik, Air Force planners were thinking ahead to satellite systems for observation and communications purposes. And the possibilities of a manned lunar expedition were considered in a study program begun by the Air Force in 1957.

Our initial space capabilities, however, are a product of the legacy of technologies from ballistic missile research and development. Well over 90 per cent of the successful U.S. satellites and space probes have been boosted by vehicles designed as ballistic missiles. Our space exploits depend on many other ballistic missile technologies—on structures, propulsion, re-entry, command and control, guidance. The vast team of scientists, technicians, and managers who were assembled to fulfill ballistic missile requirements constitutes the strong base for creation of systems capable of conquering space.

Early in 1961 the former Ballistic Missile Division of the Air

Research and Development Command evolved into the present two divisions—the Ballistic Systems Division and Space Systems Division—under the Air Force Systems Command. Since that reorganization the Space Systems Division has continued the space programs begun under BMD and has added new ones. The SSD responsibilities may be grouped under four major categories.

First, the division conducts applied research and directs advanced technologies to constantly extend the state of the art.

Second, it supervises the development and procurement of certain military space systems.

Third, it provides some launching facilities and services and, if required, conducts the launch, performs tracking and control, and recovers payloads from orbit for the National Aeronautics and Space Administration (NASA) as well as the Air Force.

And, fourth, SSD supports other agencies in the attainment of national space objectives.

The Space Systems Division headquarters is in Los Angeles. The principal field organizations are the 6595th Aerospace Test Wing at Vandenberg Air Force Base, California, which is primarily responsible for launching space vehicles, and the 6594th Aerospace Test Wing at Sunnyvale, California, which is primarily responsible for control of space vehicles in orbit and for their recovery, if required.

A vital adjunct to in-house Air Force scientific and management responsibilities is the Aerospace Corporation, which occupies the same building as the SSD headquarters. The Aerospace Corporation was established in June 1960 as a nonprofit, private corporation to "engage in, assist, and contribute to the support of scientific activities and projects for the United States Government." Its widely diversified competence objectively complements the Air Force in meeting its responsibilities in the immense area of aerospace technology, for discriminating selection and planning of advanced systems, for technical steering of a broad industrial base in the execution of approved development programs, and for supporting laboratory operations to ensure prompt, valid application of the latest scientific advances.

The Space Systems Division, the Aerospace Corporation, and a host of industrial contractors constitute a team that holds pre-eminent responsibility for the national military space posture and is capable in all space activities from planning through development and use.

satellite systems

Our nation's predominant space interests, now and for the near future, fall into three general areas. First, we want to make space a laboratory for the scientific advancement of mankind and the progress of civilization; knowledge of the universe is a fundamental requirement if we are going to be functional in the regions beyond the atmosphere. Second, we want to establish space communication centers to link the peoples of the world closer together and to ensure our global communication capabilities under any circumstances. And, third, we must investigate space as a possible arena for future deterrence. Militarily, these objectives represent imperatives in the fulfillment of our national security responsibilities.

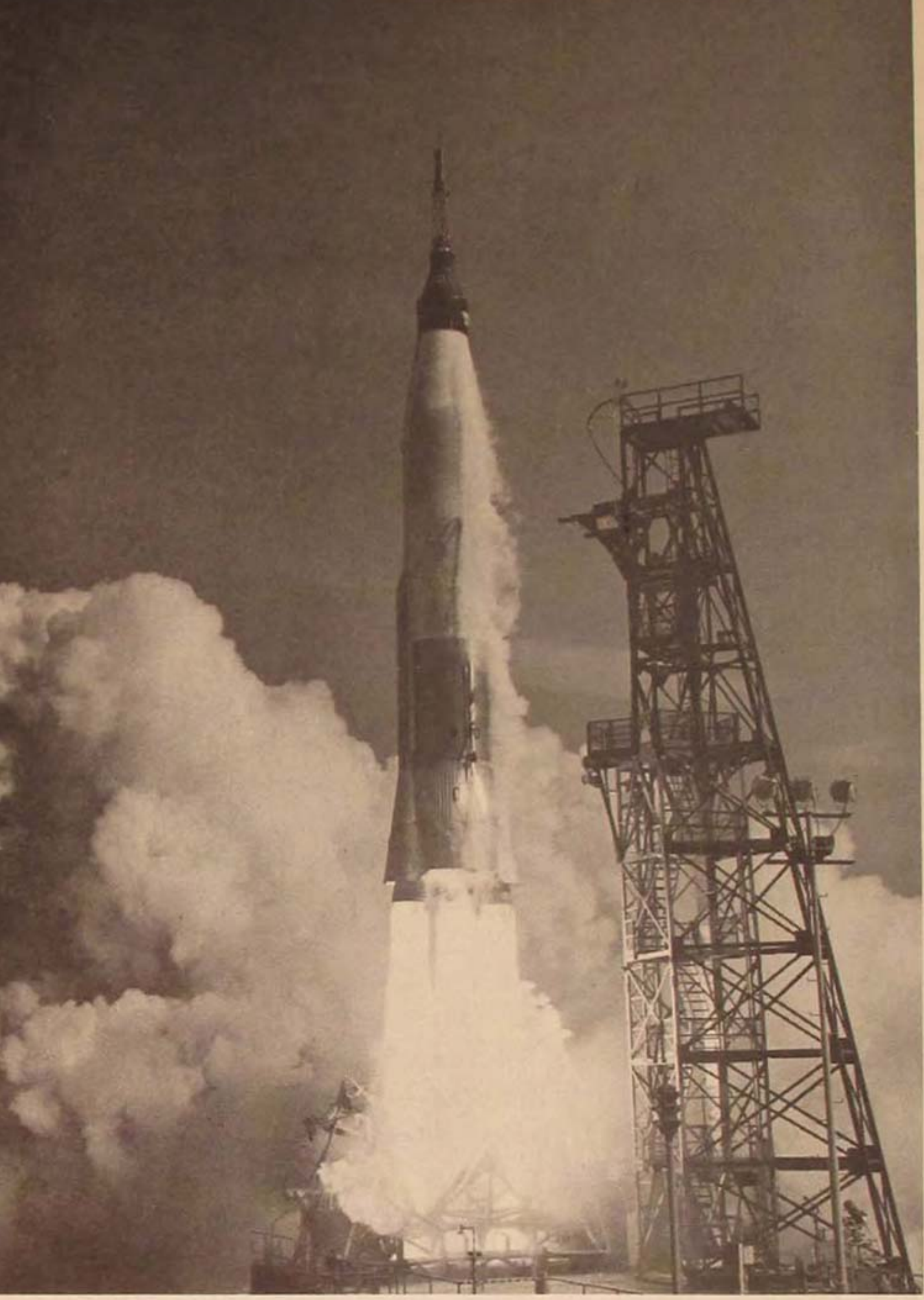
Our progress in these directions during the last few years has been predicated on the most practical use of available capabilities. The Air Force, along with the other services, has been conducting a variety of developmental programs which take maximum advantage of present-day space capabilities.

Out of these programs the Defense establishment and the National Aeronautics and Space Administration have not only learned a great deal about the space environment and our potentials there but have also laid the groundwork for a number of satellite systems which will significantly improve long-range communication and navigation, extend the warning time preceding any ballistic missile attack, enhance our knowledge of and ability to forecast weather conditions, augment our information-gathering abilities, and make it possible to inspect satellites. Still more systems which will further increase our security and strengthen our national space capability are now in stages of hardware experimentation or advanced study.

Backing up these DOD and NASA programs are extensive efforts in applied research and advanced technology for space purposes. Order-of-magnitude improvements in propulsion, increased performance, a higher index of reliability and long life, lower costs, better sources of auxiliary power, better guidance, and more effective control systems are among the objectives receiving priority attention during this period in which boosters derived from the ballistic missile serve as our major means of placing objects into orbit.

From the national defense point of view and from our Air Force position as partners in the United States space program, the space systems that we seek are systems which will augment our defense, strengthen our national security, and help ensure that space is preserved for peaceful purposes. Our job is threefold. We must learn to live in space and return from it, and we must also learn to work effectively while there. This latter problem is compounded by the fact that not only do we not have all the answers today but we do not yet know all the problems. Our exhaustive and unrelenting technological search is aimed directly at isolating the problems, defining the requirements, developing the technologies, and then—in an intelligent and sequential manner—arriving at those space systems required for the fulfillment of our military obligations.

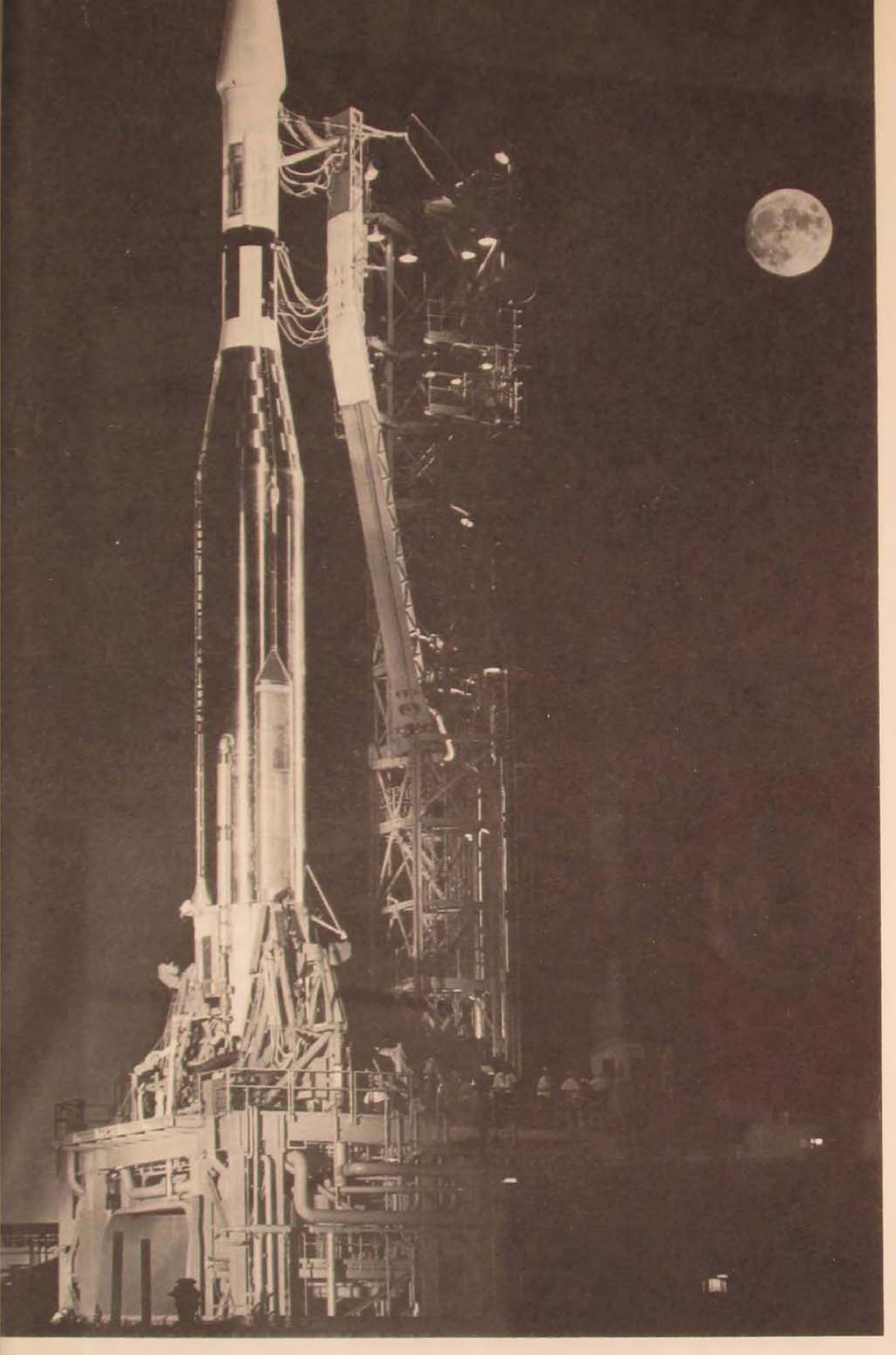
The Air Force mission has not changed, but the regions in which that mission must be carried out have expanded greatly and the challenges have become correspondingly intensified. The Space Systems Division is a part of the vast resources the Air Force has marshaled in its comprehensive assault against the unknowns of space.



The Air Force gives broad support to NASA's Mercury program—the Atlas booster, payload integration, special safety features, and checkout, launch, and tracking services. USAF ballistic missiles serve as boosters in many space probes.

launch services and launch systems

Whatever a space vehicle's destination—earth orbit, deep probe, synchronous orbit, or solar orbit—it must have a take-off point and launch and service facilities. The Space Systems Division procures the booster, mates it with the payload provided, puts the package on the pad, conducts the launch, and injects the payload into orbit or places it on the proper trajectory. SSD will also track rockets and satellites, if required, and attempt to recover the payload where desired. The division provides all these services for NASA, for the Army, for the Navy, and actually for any qualified agency having a requirement. In other words, SSD has customers for the launch services it provides.



The Atlas-Agena Ranger II launch vehicle on the pad at Cape Canaveral. In their responsibility for bridging the distance between earth and moon, NASA and the military services have made partnership plans to accelerate the total space dexterity of the United States. The Ranger program typifies this working partnership.

Mercury. Probably the most widely known example of this SSD function is the Mercury program of NASA. While it is a national program in the fullest sense of the word (the Army and the Navy also play major roles), Mercury and its NASA project directors depend heavily upon the services and facilities of the Air Force. The booster is an Air Force Atlas, Air Force technicians participate in the check-out and launch of the vehicle, and Air Force tracking facilities feed into the global communications net essential to the success of every Mercury flight. Air Force responsibilities for Mercury also include some of the safety features provided the astronaut during the boost phase. The Air Force will also be engaged in Gemini, the NASA follow-on to the Mercury program. Here the Air Force will supply Titan II boosters, with special pilot safety features, together with launch support services for the two-man space mission.

Ranger. The NASA Ranger program uses two Air Force-developed boosters, the first-stage Atlas and the second-stage Agena. The current NASA lunar test and impact packages are launched for that agency under this program, which also performs a number of other space experiments. The Mariner II spacecraft, launched 27 August 1962 for NASA, also was boosted by an Atlas-Agena.

Blue Scout. In response to certain lesser booster requirements, SSD has developed and put into use a versatile solid rocket system known as Blue Scout. Blue Scout is the Air Force counterpart of NASA's Scout vehicle. The two cooperative programs began in 1958 with an Air Force/NASA memo of understanding which established the basic Scout development program under NASA and provided for an Air Force program of modification and application of the basic vehicle to fulfill USAF requirements.

Blue Scout, now in its application phase, is designed to accommodate AFSC and DOD space environment experiments while serving also as a test bed for ballistic missile and satellite components. Blue Scout is currently being used for applied research projects needing space flight time but which are not heavy or significant enough to justify the expenditure of a Thor or Atlas booster. The system consists of a family of vehicles, available in combinations to meet a variety of requirements. Since Blue Scout serves functions similar to those of both a sounding rocket and a ballistic-missile-derived booster, it is ideally suited to perform large numbers of important space jobs that do not require the performance levels of the more costly boosters. Furthermore Air Force crews assemble, check out, and launch the Blue Scout.

Blue Scout's versatility stems from the building-block principle on which it is structured. Payload packages can be orbited by using the four-stage USAF Scout configuration, or Blue Scout Junior can send a 26-pound probe to an altitude of 125,000 miles. In carrying out the Blue Scout launch service, SSD generates no mission or payload requirements but is strictly a service agency, providing the hardware and the launch facilities for those organizations having requirements.

SSD now has three families of basic launch vehicles suitable for space purposes: Blue Scout, for light packages and for use in developing instrumentation and techniques for larger systems; the Thor-Agena system, for military research and development programs; and the Atlas-Agena system, for Ranger, Mariner, and similar projects.

Future Launch Vehicles. Beyond these current vehicles we have requirements for a launch vehicle with the versatility and economical workhorse qualities of the C-47 aircraft—a launch vehicle which, through standardization, can reflect favorable reliability and cost-effectiveness characteristics. We are engaged in a DOD-approved program which is directed toward the attainment of a practical booster system applicable to a broad range of space missions. This program is based on Titan II technology and makes use of the building-block principle to arrive at the various configurations available from an imaginative utilization of solid and liquid engine stages.

The program which we call Titan III, but which is more properly the military standardized space launch vehicle system, is built around a modified two-stage Titan II ICBM, using liquid-fueled booster engines with parallel-staged "strapped-on" 120-inch solid-propellant boosters. The resulting three-stage rocket will generate more than two million pounds of thrust at lift-off. With a first stage consisting of the two 120-inch-diameter solid rockets built in segments, the vehicle will have a fast reaction time plus the efficiency at altitude provided by the high-energy nature of the second- and third-stage storable liquid propellants.

Two standard launch vehicle (SLV) configurations have been identified in the Titan III program to date, but this initial pattern is subject to variations through the development, use, and arrangement of additional liquid or solid engine combinations. The first Titan III mission to be assigned by the Department of Defense is the boosting of the Air Force X-20 Dyna-Soar boost-glide manned orbital vehicle. In fact Titan III is expected to accelerate the Dyna-Soar program by eliminating the suborbital flights in favor of an initial unmanned orbital flight demonstration.

The progressive nature of the Air Force's launch vehicle family is worth noting. In the four systems—Blue Scout, Thor-Agena, Atlas-Agena, and Titan III—each succeeding vehicle has more than tripled the capability of its predecessor, and the vehicle inventory has the capacity to launch both light and heavy payloads into low, high, or synchronous orbit as well as into escape trajectory.

Advancement of technology in the large solid motor field has contributed to the Titan III program in that it has shown the feasibility of using the large solid motors as a first stage for the Titan III configuration.

What's next in space?

The outlined programs indicate our capabilities now and for the near-term future. But from this toe hold that we have acquired on the space frontier, we must now look much farther and much deeper if we are to realize the broad potentials the space environment offers for security and progress.

In the Air Force we are largely concerned with the military implications of space, for our national obligation is the defense of freedom. Our mandate in this area is clear. Our course of action is becoming equally clear. To be truly effective in space we must develop, produce, and implement those capabilities and facilities necessary to the accomplishment of our space responsibilities. While many of these blend with, contribute to, and benefit from programs directed by the National Aeronautics and Space Administration, others are peculiarly military in nature and demand the sense of urgency traditional to military considerations.

If, for example, we are to acquire satellite systems for early warning, for surveillance, for inspection, and for military communications, we must be assured of systems capable of long life and continuous operation. We must have sufficient numbers of these satellites to provide global coverage. And if we are to meet these operational objectives, we must achieve a high order of reliability for our systems along with greatly reduced launching costs. A further military requirement not shared by related civilian ventures is a fast-reaction launch alertness—the same caliber of ready responsiveness attained in the ballistic missile program.

At present there are a number of obstacles standing between us and the realization of these objectives. In the first place, our launching costs are too high. Today it costs something over $1000 for each pound of useful payload put into orbit. To arrive at a reasonable military cost-effectiveness index, we must reduce launching costs, at least to one-tenth of present rates and preferably to about one-twentieth.

Second, the useful life of payloads in orbit is too brief. It is clear that since we are going to require networks of sophisticated satellites, we must increase substantially their life expectancy and our ability to control them in orbit. Otherwise it may be prudent to develop some sort of satellite maintenance and repair technique.

Third, the means of returning objects from orbit must be improved. If we are to continue operating effectively in space, we cannot rely indefinitely on the imperfect methods of aerial or surface recovery used in the Mercury program. While this system is satisfactory for today's investigative activities, it is not practical for the long-range space exercises of tomorrow. It is not good economy to build expensive devices, use them once, and abandon them. The same is true of the eventual requirements for manned space flight.

Fourth, maneuvering capability in space is essential for inspection, docking, and transfer operations. If we are to carry out any sort of intensive space operations, military or civilian, we shall have to be relatively as flexible in space as we are today in the air.

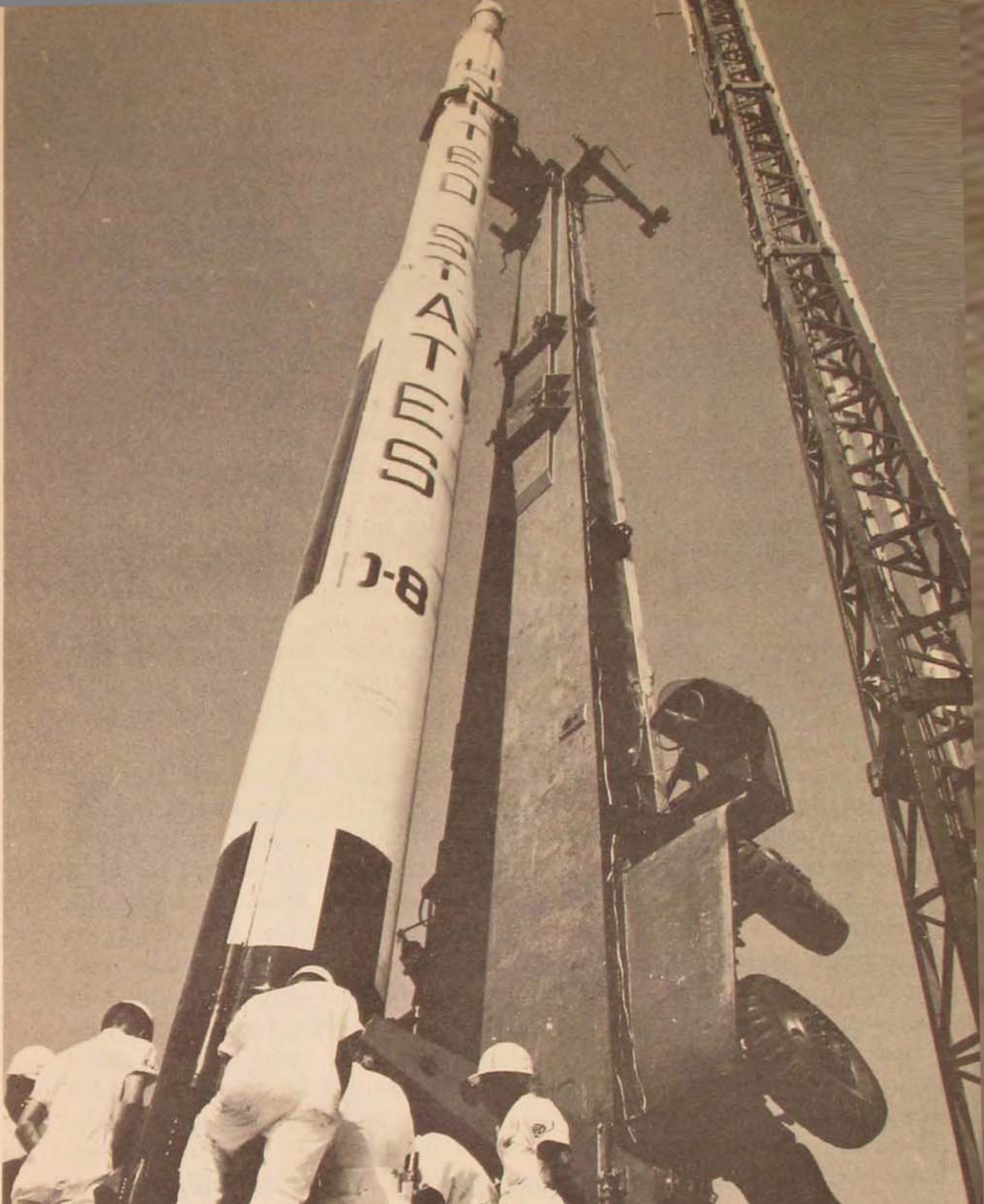
And, fifth, we must develop and use better and broader power-supply systems. Nuclear energy appears to be a promising solution to this problem, but much work remains to be done.

The next order of business in our pursuit of an effective space dexterity is the expansion of technology—the development of fundamental capabilities that will enable us to progress from our present plateau to the heights of achievement we seek to attain. To acquire these fundamental capabilities, we must work diligently during the next several years in order to evoke from space those stores of knowledge and experience essential to our fuller understanding and use of this new environment. The Air Force must continue to work closely with NASA and with the scientific and technical fraternities and be conscientious in the cross-fertilization and exchange of ideas and technologies. We must continue to conduct hardware tests. But above all we must think productively, constantly blending the ideal and the practical into an imaginative approach to the problems that challenge us.

The successful orbital flights, the schedule of further Mercury program flights now being carried out, and the imminence of the Gemini, Apollo, and X-20 Dyna-Soar flights all serve to focus national attention on the importance of manned spacecraft. If we are to learn to use space on a routine, day-to-day basis, we must intensify the development of manned spacecraft. We must develop the ability to place large payloads in space, the ability to navigate and maneuver spacecraft, to go into space and return at times and places of our choosing, to rendezvous in space and accomplish refueling or cargo transfer—in short, the ability to transport, use, and support man in space. To deny man a place in space would be to overlook his unsurpassed capacity to observe, reason, and control judiciously. These are the functions we shall need in space just as surely as we have needed them in every other medium of human achievement, and it is to develop them that the programs I have mentioned are receiving heavy support.

Finally, the key to the timely utilization of space by man—for military or civilian purposes—is flexibility. Space vehicles and programs should not be blueprinted just to comply with objectives that can be defined now. Vehicles designed now should be adaptable to any reasonable modifications dictated by the new knowledge flowing from our space programs. For example, a manned space observatory should be designed so that it can meet new or additional mission requirements. Even the prototype space station should be inherently adaptable for use as a space laboratory or as a command post.

But a more immediate target on the space frontier is the accom-



A "blue suit" launch capability has been developed in support of the Air Force Blue Scout booster program. Versatility of the Blue Scout family, derived from the NASA Scout program, permits use of solid-propellant rockets in a variety of projects for which higher performance and more expensive rockets are not needed.

plishment of a manned lunar expedition, called for by President Kennedy. We in the Air Force in general and in the Space Systems Division in particular have been engaged in lunar flight study exercises since 1957. As a consequence we recognize that the achievement of an expedition to the moon's surface is a severe and demanding task. In the process of gaining this objective, we shall acquire many of the fundamental capabilities essential to our future space operations. The lunar mission therefore represents a natural focus for a variety of space activities vital to the national interest. For example, in attaining this national objective we must develop

- —reliable, standardized, very-high-thrust boosters and associated launch techniques
- —a capability for sustained manned space flight and for landings and take-offs in a hostile environment
- —the ability to rendezvous and maneuver in space
- —the guidance, navigation, and communication systems necessary for large-scale space operations
- —the capability to return from space to an earth landing.

These achievements are of great importance to our national security. Through a national program, conducted in the all-out manner appropriate to a nationwide undertaking, we can realize the practical benefits which will serve our common interests.

Today no one has a mastery of space. If the United States is to be proficient there, we as a nation must earn that proficiency. If we are to be space leaders, we must demonstrate a space superiority. Having done so, we shall be able not only to explore but also to use the space umbrella for our protection, if necessary. The development of space capabilities in our reach for the moon can help us do both.

In our own century we have seen the effect of strategic advantage employed in the name of peace. While only the United States possessed the atomic bomb and the means to deliver it, the strategic initiative which these capabilities provided was sufficient to deter war on a global scale. Once this advantage was canceled, science and technology again became the breeding ground for new orders of weaponry. Ballistic missiles and space systems have resulted, and a new dimension of defense has been created.

Today aerospace is the beckoning area on which we must continue to focus our technical and scientific attentions, for in these days of rapid and far-reaching advances, strategic surprise is the eventuality we must guard against. And it is in space that strategic surprise may occur. The technological contest in which we are now engaged may be expected to continue for many years to come.

The fact remains that a clear-cut strategic advantage, elusive though it may seem, might be found in space. If the United States acquires this advantage, it will remain benign in the hands of the Free World. We cannot be assured that such an advantage would not become malignant in the hands of an enemy. Because this possibility exists and because space is the new grab-bag environment where anything may be possible, we would be derelict in our military responsibilities if we ignored the opportunities or evaded the challenges suggested by space. This, basically, constitutes the mission of the Air Force Systems Command. It is the "why" of the military role in space.

General Schriever has observed that, historically, we have tended to overestimate what we could do on a short-term basis and to grossly underestimate what we could do on a long-term basis. In the past we have been notably slow to recognize the military applications of certain new inventions. Two of the most significant technical achievements of this century—the first practical airplane and experiments with liquid-fueled rockets—are American. Yet other nations made the first important military applications of these technical developments. An extension of this national habit into the far reaches of space could be disastrous.

We learned in the ballistic missile program that once objectives were set their attainment followed in rapid succession, regardless of how imposing the challenges and obstacles appeared to be. In space we are learning the same lesson. Our national response to the challenges of space has been, over all, positive and productive. The NASA–DOD team approach has been fruitful in the identification of space as a scientific frontier of unparalleled magnitude. The same team attitude has been instrumental in reaching a foundation of agreement on the not inconsequential problem of determining just what we want to do in space.

In the course of the technological contest it will become increasingly evident that space, in addition to its other potentials, constitutes an important arena for future deterrence. Our response to that circumstance must represent our pre-eminent military obligation in the years ahead.

Our defense is based on the realization that only by a strong military posture can we preserve our security. Were we shortsighted in our outlook on the totality of space, we would risk making ourselves the victims of technological surprise, outflanked in our long-run objectives—the advancement of human knowledge and understanding and the defense of our democratic institutions.

Space Systems Division, AFSC

THE NASA PROGRAM

Colonel Francis X. Kane

On 25 MAY 1961 the President announced a new national goal—a manned landing on the moon within the decade. He expressed the purpose of this ambitious program in these words: "Now it is time for this nation to take a clearly leading role in space achievements which in many ways may hold the key to our future on earth." With this decision, the lunar program of the National Aeronautics and Space Administration took on characteristics familiar in national defense projects. These are delimitation of objective, a specific goal to be attained, and a time frame in which the project is to be completed. A sense of urgency was imparted to the entire scientific program for exploration of space, and a specific project was identified as a national objective. Moreover, with the assignment of this mission to NASA came the decision to allocate sufficient resources to permit attainment of the goal.

The discussion and analysis which preceded the President's decision indicated clearly that attainment of the objective of a manned landing on the moon would severely tax our scientific and technical resources in two areas: skilled personnel and technical facilities. This fact was easily identified since the scientific endeavors of NASA do not occur in isolation from other scientific and technical efforts of this nation, and specifically, from the requirements of national defense. The interweaving of the NASA program with other facets of our national endeavors was pointed out by Dr. Hugh L. Dryden, Deputy Administrator of NASA, in a speech on 29 December 1961, in which he stated that the personnel of the NASA space program must come from every walk of national life. He also stated that the ultimate and practical purpose of the manned lunar exploration is twofold: "(1) Insurance of the nation against scientific and technological obsolescence in a time of explosive advances in science and technology; and (2) Insurance against the hazards of military surprise in space."

Over the years the relations between the United States Air Force and NASA (and its predecessor, the National Advisory Committee for Aeronautics) have been marked by a spirit of collaboration and cooperation. The two agencies have worked together on many projects that have been of direct benefit to the Nation in developing scientific and technical data and experience and, more importantly, in contributing to our national security. When NACA was abolished and

NASA established, the Air Force stressed continuation of the previous policy of full cooperation. Later General Thomas D. White, as Air Force Chief of Staff, stated, "To the very limit of our ability, and even beyond this to the extent of some risk to our own program the Air Force will cooperate and will supply all reasonable key personnel requests made by NASA."

When the President pronounced manned lunar exploration a national goal, the Air Force took the initiative in trying to establish working relationships between the Air Force Systems Command and NASA on manned space projects. The need for a close relationship at the operating/management level was apparent, primarily because the limitation of scientific personnel and technical facilities precludes unnecessary duplication of facilities and competition for technical resources. Furthermore, under a Department of Defense directive of 6 March 1961 the Air Force has the prime responsibility for research and development of military space projects. The bulk of the resources necessary for these R&D projects, currently some 90 per cent, are within the Air Force—more specifically, within the Air Force Systems Command. Consequently it was apparent that support of NASA by AFSC would extend across the whole range of the Systems Command's activities, involving to varying degrees all the centers and divisions of the command. Since the primary purpose of the centers and divisions is to contribute to our national security by conducting top-priority research and development programs, detailed relationships had to be worked out which would preclude interference with these high-priority defense projects. On the other hand, the need for such relationships was not merely to prevent duplication and competition but to provide mutual support, so that the national goals of both the scientific exploration and the high-priority defense projects will be served adequately and in a timely manner.

manned space projects

NASA's three principal manned space-flight projects are Mercury, Gemini, and Apollo.

Mercury. The Mercury project is so well known that it suffices here merely to touch on the main aspects. The Mercury capsule is launched from the Atlantic Missile Range by an Atlas booster, accelerated to 17,500 mph, and placed in near-earth orbit at an altitude of about 100 miles. The maximum time in orbit depends upon the life-support capabilities on board the capsule. It is planned to extend the flight of one of the astronauts during 1963 to a full-day mission—up to 22 orbits. The capsule is designed for ballistic re-entry and for recovery by water landing.

The Mercury project comes under the over-all direction of the Office of Manned Space Flight in NASA. Project direction is under NASA's Manned Space Flight Center at Houston, Texas. Support by the Department of Defense is provided under the direct control of the Commander, Atlantic Missile Range, within the guidance provided by the Joint Chiefs of Staff. The Air Force Systems Command provides support through the Air Force Missile Test Center and its facilities at Cape Canaveral and down range and through the Space Systems Division, which is responsible for support of the Mercury capsule and Atlas booster. The Aerospace Medical Division provides life support for the project.

Gemini. Whereas the goal of the Mercury project is to demonstrate the feasibility of manned space flight, the goals of the Gemini project are to attain prolonged duration in orbit (up to 14 days), to conduct multimanned experiments in orbit, and to develop the capability for rendezvous and docking with another orbiting body.

The Gemini program follows the technical path pioneered by Mercury. The manned capsule will be much like the Mercury capsule in appearance, the major difference being that it has been enlarged to provide room for two pilots and increased life-support capability. It also incorporates many refinements of design to simplify launch preparations and promote reliability. The booster for the Gemini will be the Titan II, a liquid-fueled rocket designed for instantaneous launch. The Gemini will be launched from Cape Canaveral and probably will use the same tracking network as Mercury. The two-man vehicle will be placed in a near-earth orbit similar to that of Mercury.

In addition to longer duration in orbit, the Gemini project will lead to the all-important capability to rendezvous with another satellite and dock with it. As presently planned, the docking in orbit will consist principally of bringing the two satellites into physical contact. Thus, there will be no transfer of fuel, equipment, or personnel. Nevertheless perfection of the techniques for rendezvous and docking is essential to the impending Apollo and to military space missions in the offing. The schedule for the Gemini project calls for several unmanned ballistic flights in 1963. Manned spacecraft missions of varying duration will follow, one week in orbit being scheduled for 1964. The highly important full rendezvous mission is also to occur in 1964.

The responsibilities for Gemini are essentially the same as those for the Mercury project. The Systems Command is providing support through the Atlantic Missile Range for launch, through the Aerospace Medical Division for life support, and through the Space Systems Division for necessary engineering of the Titan booster and its interface with the manned capsule. The Gemini project may prove especially significant for future manned military missions because the Air Force will participate in it with NASA to some degree, and the information, techniques, and demonstrations of rendezvous and docking—all products of the Gemini project—will be available for future manned military missions.

Apollo. The Mercury and Gemini projects are steppingstones to the vital goal of a manned lunar landing before 1970. A valuable source of technical details and analysis which has contributed to this goal is the planning study conducted by AFSC entitled "Lunar Expedition." Under the former study requirement program, various contractors working with the Space Systems Division investigated the problems, technical approaches, and operational considerations involved in a lunar exploration. Their findings were made available to NASA. Recently NASA announced certain decisions concerning the lunar project, although others are still pending so as to maintain maximum flexibility within the limits of the time schedule for the program.

Several operational approaches to lunar exploration have been investigated.

(1) The direct ascent. The Apollo would be launched from Canaveral for flight direct to the moon and landing on its surface.

(2) The lunar orbit and landing. Under this approach the Apollo spacecraft would be put in orbit around the moon and then all or part of it would deorbit and land on the moon surface.

(3) The earth orbit. The Apollo spacecraft would first orbit the earth and then depart for the moon from this "parking orbit" and land on the lunar surface prior to the return to earth.

(4) The earth-moon orbit. In this operational mode the Apollo spacecraft would first orbit the earth, then orbit the moon, and subsequently land.

NASA has chosen the lunar-orbit rendezvous technique, using a two-man lunar excursion module for the actual landing.

The responsibilities for the Apollo project are essentially the same as for Mercury and Gemini. Over-all direction rests with the Office of Manned Space Flight at NASA headquarters. Detailed project control will be with the Manned Space Flight Center at Houston. The launch will be accomplished at the Atlantic Missile Range from the pads being constructed at the new site expansion at the Cape.

One of the main differences between the Apollo and the Mercury/Gemini projects lies in the boosters. Instead of using ICBM boosters, the Apollo project will employ the boosters developed under the direction of the Marshall Space Flight Center, Huntsville, Alabama, including the Saturn in its several modes. The first and highly successful launch of a Saturn was accomplished in October 1961. Saturn launches are directed by NASA's Launch Operation Center at Cape Canaveral, but under the present plan some support will be provided by the Systems Command in the launch phase from the Atlantic Missile Range and assistance in tracking and data processing. As with Mercury and Gemini, the Aerospace Medical Division will be responsible for life-support activity in connection with the Apollo project.

environmental exploration and investigation

In addition to the manned space-flight projects of NASA, a number of other projects are under way in the agency's space science program which will result in exploration of the space environment, investigation of space phenomena, and specifically a detailed analysis of the composition and character of the surface of the moon. These projects fall in the general categories of space probes, scientific satellites, moon exploration, and deep space exploration.

Space Probes. Investigations of the characteristics of the upper atmosphere and of space have been conducted with a wide variety of vehicles, from balloons to aircraft, to research aircraft, to equipment carried into space by rockets. The X-15 is an example of a research aircraft being used to explore the upper atmosphere and the fringes of space. Similarly the Air Force "Man High" balloon program carried man to the outer edges of the atmosphere. Rockets have carried scientific payloads into space in a wide variety of investigations under Air Force and NASA projects, such as Argo, Nike-Asp, Juno, the Cree sounding rocket, the Javelin-Journeyman space probes, Explorer, and Pioneer.

Air Force Systems Command support of these scientific space probes has been principally through activities at launch sites, through design of payload packages, through the testing of components and rockets, and finally through a great deal of financial support across the command in various activities of its centers and divisions.

When investigations are directed to upper atmosphere research, NASA space probes are conducted principally at Wallops Island, Virginia. Probes requiring larger boosters are launched from the AMR. Others have been launched from Eglin AFB and from Fort Churchill, Canada, which is managed by USAF. Payload packages have been developed by Air Force Special Weapons Center and Air Force Cambridge Research Laboratories.

Scientific Satellites. Another phase of the investigation of the space environment is the program of scientific satellites. The principal projects identified at this time are the Orbiting Geophysical Observatory, the Orbiting Astronomical Observatory, the Orbiting Solar Observatory, the Ionosphere Satellite, the Gamma-Ray Telescope, and the Fixed Frequency Topside Sounder. These are all unmanned projects.

The plan is to start launching the orbiting astronomical observatories in 1964 and continuously after that. The objective is to have one OAO operating in a satisfactory orbit above the earth's atmosphere at all times, in order to make precise telescopic observations of the sun, stars, planets, and nebulae. This may require one or two launches per year. Weight in orbit will be 3500 pounds.

The orbiting geophysical observatory will be the workhorse for the geophysicists. The first launch of the 1000-pound satellite is scheduled in 1963. It will be sent on either a polar orbit or a highly elliptical orbit. Each of the OGO's will carry from 30 to 50 different experiments on board.

The orbiting solar observatory is a stabilized satellite, and about six are expected to be placed in orbit during the next two to three years. In subsequent years improved versions of the OSO will be sent up in a continuing program. First launch was made successfully from the Cape in March of 1962.

Responsibility for this phase of the scientific exploration of the space environment is assigned to the Goddard Space Flight Center in Greenbelt, Maryland. This center is responsible for other programs which will be described later, but it will play a key role in the highly important determination of the characteristics of the space environment so vital to continued and sustained manned space operations.

Moon Exploration. NASA has under way two unmanned space projects, Ranger and Surveyor, which will directly support the manned landing on the moon, and a study called Prospector. The Ranger project received national attention early in 1962 when the scientific payload of the third shot came within 20,000 miles of the moon in an attempt to photograph and televise pictures of the lunar surface. NASA will undertake some 12 to 15 more Ranger launches.

The Ranger is launched by an Atlas-Agena B to achieve a parking orbit around the earth and then is accelerated to the escape velocity of 24,500 mph. Then under command from the earth it is oriented and a mid-course motor is fired to put it on a collision course with the moon. At 5000 miles from the moon the scientific payload is programed to take television photographs of the lunar surface and record radar reflection characteristics. At 70,000 feet from the lunar surface a retrorocket capsule separates from the spacecraft. This capsule is slowed down to zero velocity a thousand feet from the surface. The instrumented capsule then makes a free fall to the surface and sends back information on lunar shock waves and meteorite impact over a 30-day period.

The Surveyor project has as its objective the exploration of the lunar surface. There are two phases of the project. The first phase, soft landing, will be attempted in 1963. The second phase, to obtain precise lunar orbit with the Surveyor, will first be launched in 1965.

The Ranger and Surveyor projects are the responsibility of the Jet Propulsion Laboratory (JPL), a nonprofit organization operated by the California Institute of Technology under NASA contract. The Air Force Systems Command assists with the launching and tracking and gives other support through SSD and the Aerospace Corporation. The Aeronautical Chart and Information Center, working with the Air Force Cambridge Research Laboratories, has prepared a photographic atlas of the moon and will continue to map the moon for NASA. Launches will be from the Atlantic Missile Range.

Deep Space Exploration. The projects identified at this time for deep space exploration are Pioneer, Mariner, and Voyager. The Pioneer project is well known because of the highly successful Pioneer V, which is orbiting the sun and which has transmitted information from as deep as 20,000,000 miles in space. It was launched in 1960, using a Thor-Able booster, and has investigated radiation and other types of electromagnetic fields. The Mariner space probes will investigate Mars and Venus. Mariner R (so called because it is a modified Ranger and called Mariner II after its successful launching) was launched in August 1962 to probe the atmosphere of Venus. It passed within 22,000 miles of Venus on 14 December 1962. Mariner B, to be launched in 1964, will investigate the planet Mars. Project Voyager has as its mission to place spacecraft in orbit around Mars and Venus in 1967. Like the Ranger, the Mariner and Voyager projects are the responsibility of the Jet Propulsion Laboratory.

earth satellite projects

In addition to the projects which are in direct support of or will make direct contributions to manned lunar exploration, NASA has other projects which only indirectly support manned lunar space operations. Their primary objective is to collect data that are of day-to-day use for earth operations. The two most important general fields are weather satellites and communications satellites. The international satellite program also gathers significant space data.

Meteorological Satellites. This program consists of three projects: Tiros, Nimbus, and a follow-on called Aeros. Six Tiros satellites have already been successfully launched, and a total of 15 is now planned through 1964. The Tiros satellites have sent back televised photography of large storm centers. They are launched by the Thor-Delta vehicle from Cape Canaveral. They use solar-powered batteries for on-board power, and their orbit is chosen by the type of weather to be studied. For example, Tiros IV was launched to study ice formations in the northern hemisphere during the winter months. First launch of the second-generation weather satellite, called Nimbus, is expected toward the end of 1963. Later Nimbus is anticipated to be operating in orbit almost continuously. The Aeros will be a meteorological satellite in synchronous or 24-hour orbit so that it will stay in a fixed position relative to the earth. Research and development on it is not expected to start for several years, but studies made to date indicate that the operational system will use three or four satellites simultaneously.

Responsibility for weather satellite projects is assigned to the Goddard Space Flight Center. The Air Force Systems Command has given support in launch operations and in tracking on orbit. The Weather Bureau of the Department of Commerce also participates in this program by stating technical requirements and providing funding.

Communications Satellites. The NASA communications satellite program embraces both passive and active types. The Echo I was a familiar sight as it orbited the earth in its role of a passive reflector. Under a project called "Rebound" an attempt will be made to launch three or more Echo-type satellites from a single Atlas-Agena vehicle and to disperse them in orbit.

The active communications satellites are Telstar, Relay, and Syncom. Telstar is the experimental industry communications satellite; the first of four was launched in 1962 and was extremely successful as a communications link between the United States and Europe. The Relay satellite is an active transponder and was launched on 13 December 1962. The Syncom is designed as a repeater satellite in synchronous orbit, with launch scheduled early in 1963.

As with the weather satellites, the communications satellites are the responsibility of the Goddard Space Flight Center. The responsibilities of the Systems Command for support of these projects are similar to those for the weather satellites.

International Satellites. NASA is engaged in several international scientific satellite programs. S-51 or Ariel, the first of the international scientific satellites, was launched for the United Kingdom in 1962. The second U.K. satellite, S-52, is in early development at this time. Additionally NASA supported the Canadian scientific sounding satellite S-27 or Alouette, which was launched into polar orbit in 1962.

This wide variety of satellite projects with their many complex payloads is essential to the scientific exploration and determination of the space environment. Through them we will learn more about the ionosphere and its effect on our ability to communicate with men in spacecraft. These satellites additionally will collect data on electrons in the atmosphere, the temperatures in space, the concentration of ions. Also, the entire matter of the relations of the earth and sun will be explored by some 96 satellites over a ten-year period.

supporting research and development

Satellites, both manned and unmanned, are the principal tools of the NASA program. Their effective use depends on a host of supporting research and development operations which are the responsibility of the NASA centers. These operations include booster research and production, launch operations, vehicle design and systems engineering, and life support. Also space operations depend on on-orbit tracking and communications, the collection and reduction of data, and the recovery of spacecraft, especially manned spacecraft.

Boosters. The pacing aspect of our space program has been the availability of boosters with adequate payload capability. Our space projects have depended almost exclusively on boosters employing adaptations of missiles—the Thor, Jupiter, Atlas, and Titan—as the first stage. Our payloads in orbit have been "booster limited," tailored to the boost available. Until the recent decision to design and build the Titan III booster, space booster developments beyond ICBM's were sponsored by NASA. Also based on missile hardware are the NASA Centaur, which mates a new upper stage using the high-energy fuel liquid hydrogen with a modified Atlas first stage, and the Delta, an improved Thor-Able. The Saturn series of large NASA launch vehicles is the first break from the use of modified missiles as one or more stages in space booster development. The initial Saturn, known as the C-1, employs eight improved Thor engines in its first stage, and its successor, the C-5, uses eight F-1 engines, with nearly ten times the take-off thrust of the C-1. Both use liquid oxygen and kerosene in their first stages and the Centaur high-energy propellant combination in their upper stages. Additional, still more potent launch vehicle combinations are envisioned by NASA for the period beyond 1970. One candidate, the Nova, constitutes a next larger step in chemical propellant boosters. Others would gain payload for long-range missions through use of highly efficient rocket systems with a nuclear heat source and hydrogen working fluid.

Responsibility for booster development for the manned lunar program is assigned to the Marshall Space Flight Center, which works with the Atomic Energy Commission for the nuclear rocket development program. Other NASA boosters are the responsibility of other NASA field centers. Centaur has been transferred to Lewis Research Center, as has the NASA Agena. Goddard Space Flight Center has the Delta program, and the Scout solid rocket program is managed by Langley Research Center.

Launch Operations. NASA will use the Atlantic Missile Range facilities for most of its space launch operations. Extension of the existing Cape facilities by acquisition of over 70,000 acres of ground has been under way for some time. Master planning of the site to accommodate boosters of the sizes necessary for manned space operations began with the Presidential decision of May 1961. New designs for launch facilities have been developed, and new concepts for logistic support have been necessary because of the tremendous size of the boosters.

Production, test, and launch operations of NASA are centered in the southeastern United States. Production will be at the NASA Michoud plant near New Orleans, with testing at a nearby site in Mississippi. Boosters will then be barge-transported by the inland waterway to the new launch complex at Canaveral. A buildup of the industrial facilities at the new site is planned so as to minimize the complexities of the launch pads themselves. The major problems to be resolved in master planning center around the hazards inherent in vehicles of great size, particularly when experience with masses of explosives such as they carry is very limited.

The responsibility for launch operation is assigned to the Launch Operation Center located at Cape Canaveral, which reports directly to the Office of Manned Space Flight. Systems Command support is given by the Space Systems Division for booster development and by the Missile Test Center for launch operations. Additionally Air Force personnel are assigned to the Marshall Space Flight Center.

Global Tracking and Communications. NASA has developed a worldwide network of tracking stations called the Mercury Net. Some of the stations are used exclusively for Mercury operations; some are Department of Defense facilities which are used in other programs as well. NASA has tracking stations located in 17 countries, and 13 of these countries operate the facilities located on their soil.

The nerve center of the existing NASA global network is at the Goddard Space Flight Center. While the Launch Operation Center at the Cape uses the considerable capability of the AFMTC for data collection and reduction, the central location for tracking manned operations is at Greenbelt. It receives data from other stations of the worldwide net and transmits them to the flight controller at the Cape for display and decision-making. Obviously Goddard will continue to play an important role in future manned space flight, notably in the rendezvous, docking, and transfer of the Apollo vehicle on its flight to the moon and return.

Research Facilities. The considerable capability which NASA has in its facilities at the Langley, Ames, and Lewis centers will be used in the research necessary to support manned space flight in the future. These laboratories are now engaged in investigations of vehicle design, materials, and propulsion for flight secondary power, such as ion propulsion. It now appears, however, that the augmented workload required to support the new national goal will lead to greater use by NASA of industrial and contractor facilities for research projects. Thus NASA is approaching a management technique similar to that already used by the Air Force Systems Command in its mixture of in-house and contracted research.

In the past, the AFSC provided support for the NASA research program in its own in-house facilities at the Arnold Engineering Development Center, the Materials Central, the Aerospace Medical Division, the Aeromedical Laboratory, and the Holloman Sled facilities. The wind tunnel test facilities at AEDC, for example, provided invaluable support to the Mercury program through test of the escape system. As far as the future is concerned, NASA has programed over $600 million in FY 63 and 64 for research, test, and laboratory facilities, so that NASA is becoming independent in this phase of its operations.

funding the NASA space program

It is estimated that manned exploration of the surface of the moon will cost the U.S. between $35 and $50 billion. The impact of the national decision to conduct the exploration within the decade can be seen by the growth of NASA expenditures:

FY 1960	$523,500,000
1961	966,700,000
1962	1,825,000,000
1963 (est.)	3,760,000,000

It now appears that NASA will seek about $5.712 billion for fiscal year 1964. This is more than the annual outlay for the Strategic Air Command and is considered the "plateau figure" for the rest of the decade. Experience with the defense budget and the uncertainties of R&D projects, particularly those of great magnitude and importance, would indicate that the figure may rise above the expected plateau.

Of particular interest is the division of the budget according to mission. In FY 62 expenditures were divided as follows: $1.1 billion for the manned lunar program and $550 million for other programs. In FY 63 the figures are quite significant. The manned lunar program will require $2.8 billion, $900 million going to all other programs. In future years it is anticipated that between 65 and 70 per cent of the total NASA budget will go to the Apollo project. On the basis of these estimates, Apollo will require from $23 billion to $25 billion of the total NASA budget in the 1960's. Of this amount it has been estimated that about 40 per cent, that is, some $8 to $10 billion, will be spent on the Apollo spacecraft alone.

Some additional figures are supplied in contrast to the NASA budget so as to lend perspective to the magnitude and importance of this program. The present total Air Force investment in the Atlantic Missile Range, including the Cape and the downrange facilities, is estimated at about $600 million. This is from the initial decision to build the long-range proving ground. By comparison, the initial expenditure by NASA to augment the existing facilities is estimated at $1 billion. Furthermore, in fiscal year 1963 a national total of $5.4 billion will be allocated to space projects. Of this total the Department of Defense has $1.5 billion for all its programs, including projects of the Army, Navy, and Advanced Research Projects Agency in addition to those assigned to the Air Force and given to the Systems Command for prime responsibility of operation. For FY 63 NASA requested $2.2 billion for manned space flight projects in addition to Mercury. The NASA expenditure will be nearly 15 times that of the Department of Defense for its single manned space flight project, Dyna-Soar.

personnel

To attain its goal of national prestige, NASA plans an expansion of personnel both in the scientific and technical fields and in the supporting roles as well. At the start of 1962, 22,156 people were employed. The current goal is an expansion to 40,000 for the total program. The most recently approved augmentation was for an additional 5000 people, half of whom are to have skills in scientific and technical fields.

The largest NASA center from a personnel point of view is the Marshall Space Flight Center, which employs nearly 7100 people. The largest expansion will be the activation and manning of the Manned Space Flight Center at Houston. Construction of facilities began in February 1962, and when completed some 2900 personnel will be employed there. The size of the NASA headquarters was doubled during 1962, and the personnel of the Office of Manned Space Flight more than tripled during its expansion phase.

cooperation between NASA and AFSC

The relations between NASA and the Air Force, particularly AFSC, have been marked by a spirit of cooperation since establishment of the National Aeronautics and Space Administration. The spirit of cooperation has been evident in the series of some ten agreements between the two agencies, covering a range of activities. Additionally the Air Force has assigned highly qualified personnel to NASA, there being at present over one hundred such officers. They serve in a variety of capacities from chiefs of project offices to research engineers. The types of specialty represented cover the entire spectrum of technical skills of the Systems Command. The Air Force is providing support to the NASA programs listed in the accompanying table.

NASA Programs

Ranger	NASA Scout probe system
Surveyor	Vanguard
Apollo	Javelin-Journeyman
Gemini	Cree sounding rocket
Mercury	Iris solid-propellant rocket
Centaur	Juno
Saturn	Nike-Asp
NASA F-I rocket engine	NERV
Agena B	Space Track
Able projects	Wallops Island tracking system
Tiros	Vega
Delta	Kiwi
Echo	X-15 research aircraft

These cooperative relationships were on an informal basis until the expansion of the NASA programs necessitated more detailed arrangements at the operating/management level. With the announcement of the Presidential decision in May of 1961, the Air Force took the initiative to establish such working relationships. After a great deal of detailed study and analysis, specific proposals were made to the Department of Defense and to NASA on the nature of such arrangements and the timing of their establishment. Because 90 per cent of the resources of the Department of Defense which have a direct bearing on space activities are within the USAF and because the bulk of these resources are in the Systems Command, an operating/management structure was evolved to provide a direct interface between Systems Command and NASA.

Within the Air Force Systems Command, Major General O. J. Ritland has been named Deputy to the Commander for Manned Space Flight. He is the counterpart of the Director of the Office of Manned Space Flight within NASA. General Ritland's office is divided into two functioning groups. One group is physically colocated with NASA and works with the directors of the NASA Office of Manned Space Flight. The other is physically located in the headquarters of the Systems Command and is directly concerned with the specific projects making up the NASA and Air Force space programs. Both groups have been deliberately restricted in number, in keeping with their functions as expediters for specific problems which arise during the course of either Air Force or NASA projects. The Deputy to the Commander for Manned Space Flight is the focal point within AFSC for all USAF actions pertaining to the national space effort.

At the project level there will be detailed interrelationships. For example, at the Atlantic Missile Range an office has been established and specifically designated as the principal point of contact with the NASA activities at the launch site. Similar offices will be established and designated at other pertinent divisions and centers of AFSC. NASA has also established such points of contact within its own structure, especially at the center level.

Underlying all this joint action is the clear principle that each agency will be responsible for managing its own resources and the attainment of its own goals. Thus there will be clear fixing of responsibility, but there will be simultaneously a mechanism for providing support when needed. Furthermore this support will be reciprocal in nature.

impact of the NASA space program

The establishment of a national goal in the lunar program, the focusing of effort on manned lunar operation, the allocation of significant national resources to the program, and the sense of urgency throughout will have great impact on all future space operations. Equally significant are the attitudes of the individuals controlling the national space program and the general lines of policy which they have established. The significant aspects can be discussed under three general categories:

a national point of view
the utilization of the technical and scientific base
the contribution to national defense.

• The members of the Space Council and the leaders of NASA are acutely conscious of the high priority of the national goal established by the President. Nevertheless they have adopted the point of view that the NASA program must be integrated with other national actions of high priority. In practice, this means that they take a national point of view in approaching individual problems which have arisen in connection with the NASA space program.

• The leaders of NASA have taken as their point of departure in the expansion of their program the scientific and technical base created by the missile programs of the Air Force. Furthermore they have followed the general strategy of the Air Force in utilizing this base. Notable features of this strategy are the utilization of skills and facilities wherever they exist in our national life, in industry, in the university, or in the not-for-profit organization. This does not mean neglect of the existing facilities for research which are under the control of NASA, but it does mean that expansion in the future will be largely outside the structure of NASA. Specifically, James E. Webb, NASA Administrator, has stated that about 85 per cent of the NASA funds are spent with industry, universities, and nongovernmental institutions. By far the largest part of this goes to industry. Thus once again from the national point of view the manned lunar landing program will have the direct and indirect benefits of the type which have resulted from the Air Force missile program.

From a practical point of view, implementation of this policy will mean expansion of the existing Air Force–industry team into an Air Force–NASA–industry team. In planning and implementing its manned lunar landing program, NASA has already utilized the resources, skills, and talents of the industries which support the Air Force—the list of NASA contractors reads like the list of Air Force contractors. This policy line will have several direct benefits of a different type. NASA will make maximum use of the existing scientific and technical base under this approach, rather than construct an entirely new base. This approach will also ensure maximum cross-fertilization in the research, planning, and engineering aspects of the space program.

• The third general line of policy reflected by NASA's leadership is that even while conducting a high-priority program it must give maximum support to national defense space projects. In discussion of the space effort it has recognized the direct benefits which can result to our national security from the manned lunar landing program. The intense nature of the technological conflict, the need for gaining and maintaining technical superiority, and the vital place which space projects will play in this struggle have been publicly recognized by NASA, notably in a statement by Dr. Dryden:

> The manned lunar exploration program constitutes essential insurance against finding ourselves with the position in the new technology inferior to that of a possible enemy. The freedom of space combined with great power of nuclear energy for destruction forecast the future development of weapons systems now only dimly understood. There are many defense applications already evident and underway as the responsibility of the Department of Defense. The components, vehicles, techniques, and knowledge developed in the civil programs are constantly available for defense applications.

TO RECAPITULATE, the NASA space program has

- —a clearly defined goal of manned lunar exploration
- —a time schedule when this goal is to be attained: within the decade
- —allocation of adequate resources for attainment of this goal
- —a comprehensive program for investigation of the space environment, for development of operational techniques, and for research and development to produce the equipment and facilities necessary for this great exploration project.

The general policy lines already established for the conduct of the program have clearly identified it as a national project with direct benefit to national defense. This mutual benefit is reflected in the reciprocal support of the principal aspects of the national lunar exploration. It follows that these joint operations will in large measure establish the characteristics of military manned space operations for the future. Also they will lead the way in pioneering techniques and in developing standardized equipment.

One vital facet of these future military space operations is already becoming apparent. The successful flights of our astronauts have once again returned man to his rightful place at the center of operations. Our own success is making apparent what should have been understood with the successful orbiting operations conducted by the Soviet Union: namely, that the skepticism about the feasibility of manned space flight was completely unfounded. Instead of using an incremental approach based on black-box technology, we find now much sentiment for the use of man in early research and technology in space. Thus the doubts of the skeptic have been replaced by the intuitive understanding of the military technologist.

Finally, we must examine the NASA program from the perspective of protracted conflict and the resulting struggle to capitalize on exploding technology to defend the peace and ensure the continuation of freedom. The initial planning of the manned lunar exploration has made it apparent that the United States will expend about the same amount of its treasure as it has contributed to economic aid and mutual security programs. Thus once again the U.S. citizen is supporting his Government in making a costly commitment to the national role of world leadership. This is at once an affirmation of our desire to remain free and a note of optimism as to the outcome of the technical struggle.

One striking fact emerges—this is the most concentrated effort in man's history for the sole and express purpose of advancing the cause of science. The amount of knowledge acquired is certain to produce an intellectual revolution of great proportions as we learn about our own environment, about space, and about the universe and as we experience the resulting expansion of the human spirit.

Since its inception NASA has considered all the data and knowledge which it has accumulated as available for the rest of the world. It has made a reality of the ideal that basic science cannot have a security classification and that the advancement of science must result in the betterment of mankind. By contrast, the Soviet Union has maintained its paranoiac security restrictions on its space operations. While propagandizing the so-called "peaceful intent" of their space program, the Soviets have largely treated their data as military secrets. As a result our scientific data have been available for Soviet use, but most Soviet data have not been given to us.

At first glance it would appear more prudent to adopt a secretive policy like that of the Soviets, but careful consideration convinces us that security restrictions in all areas of science are not practical for us. Such a policy would be incompatible with our more basic objectives as the leader of freedom in the struggle against the dictatorship. There is another route we can and must follow.

First, we must ensure that our scientific effort benefits our defense directly. Looking at the competitive approach to space from a practical point of view, we can see that the operational experience and the new skills we acquire and the new facilities we build will all be ours exclusively. The Soviets will realize no benefit from these manifestations and results of our effort. This means that our defense can be modernized and that we shall maintain our technical lead. We shall continue to provide the strength necessary to defend the peace.

In addition we should continue to make our scientific knowledge available to the world. From this offering, the reward will come back in the evidence that our science is the advanced science and that its benefits are intended for the good of all men. In this fashion the coming scientific revolution will be a Western revolution, and especially an American revolution. The great consequence over all will be affirmation of faith in our free system and the incontrovertible evidence of its vitality and supremacy.

Headquarters Air Force Systems Command

AEROSPACE MEDICINE AND BIOASTRONAUTICS

LIEUTENANT COLONEL GEORGE ZINNEMANN

HOMO SAPIENS modestly admits to representing Mother Nature's ultimate achievement in the evolution of living things. On this planet, at least, the human species has far outstripped its nearest competitors in intellectual, cultural, constructive, and, indeed, destructive capabilities.

An unfortunate by-product of man's advanced evolutionary stage is the physiological and psychological specialization which severely limits excursions from his normal environment. Although man has shown considerable variation in his ability to tolerate certain geographic extremes—the Eskimo's resistance to cold, the African tribesman's resistance to heat, the Andean highlander's capacity to live and work at great altitudes—the aerospace environment offers man none of the physiologic necessities and comforts that he requires to survive and function effectively. Yet it has been well established that only a highly trained human participant can ensure the success of certain aerospace missions, whether they be devoted to scientific exploration or to military objectives. No lower species can be counted upon to make adequate decisions and take appropriate action to deal with the unforeseeable situations inherent in aerospace travel and missions.

Aviation medicine is the specialty that deals with the devices and techniques needed to protect man within the region which is now regarded as being relatively close to the earth's surface. Aerospace medicine and bioastronautics are logical extensions of aeromedical objectives. Reaching far beyond the clinical and preventive medical requirements of man in atmospheric flight, aerospace medicine encompasses the research, development, and test programs necessary to explore his capabilities and limitations in space environments. Its ultimate aim is to promote the safety and effectiveness of man in space flight operations.

Despite the comparative newness of this field of medical science, its body of technical literature is extensive. It would be impossible to summarize that literature here and superfluous to reiterate the hazards and problems confronting the astronaut or enumerate the protective devices and techniques available or required to overcome them. Among other sources, the Summer 1958 issue of the *Air University Quarterly Review* was devoted to "The Human Factor in Space Travel," for which the foremost authorities in the field wrote about their specialties. And though great achievements in aerospace flight have since taken place, the basic problems remain essentially the same.

It may be appropriate, however, to redefine the technical areas which encompass the problems and obstacles confronting man in space. The order in which they appear does not necessarily reflect their relative importance.

• Radiation Biology: Research to determine radiation hazards in space and their effects on the human body, to establish shielding requirements and problems, and to develop radiation-detection instruments and warning devices. Such work is needed to provide improved design criteria and personnel protection as well as more reliable techniques for diagnosis and prophylaxis of radiation sickness and injury.

• Stress Tolerance: Research to determine how much the human body can stand in terms of those stresses which will be encountered in advanced weapon systems, such as prolonged acceleration and weightlessness, heat, noise, vibration, confinement, and so on, as well as combinations of these.

• Capsule Habitability: Research and development on the problems of supporting man in closed or partially closed life-support cells and suits, including provision for respiration, nutrition, waste collection and processing, sanitation and hygiene, suit protection, abrupt deceleration protection, and closed ecological systems.

• Human Engineering: Research to determine which capabilities and limitations of man are related to the design of the equipment he will use and to ensure the best man–machine combinations in Air Force systems.

• Crew Performance: Research to determine the job requirements for the various specialties used in Air Force systems and to develop techniques for use in selecting and training people for these jobs.

• Bioelectronics: Research and development on advanced sensing techniques and electromechanical and electronic instruments for the measurement, recording, and reduction of data on the body's responses to various environmental influences and operational stimuli.

• Bionics: Research to clarify the physical, chemical, and electrical principles operative in the components, circuits, and behavior of the nervous systems of man and the lower animals and then simulate various elements of such performance in electronic devices that may substitute in part for human functions.

• Animals in Space Environments: Research on the base-line characteristics of animals with respect to their level of function, tolerance of stress, and type of behavior, as well as on applicable instrumentation, protection, and training techniques. Such work provides a capability of substituting animals for man in exceptionally hazardous ground or flight tests and furnishes data on probable human responses earlier than they could otherwise be obtained.

• Field Operational Testing: Research, development, and proof testing of observation techniques, monitoring devices, countdown and checkout procedures, subject holding and examining facilities, data recovery subsystems, test control and abort criteria, and similar complex field operations required for successful conduct of bioastronautics testing in flight vehicles.

If each of these areas of investigation is to be pursued with an intensity of effort proportional to its importance, the necessary resources in manpower, money, facilities, and equipment will be vast. Their procurement would have a profound effect upon the national economy.

Basically, there are two main reasons for putting a man into space: one is directed toward purely military objectives; the other is associated primarily with peaceful scientific exploration. The two are not unrelated, however. It can easily be demonstrated historically that military research and development have resulted in major increases of basic knowledge. As a matter of fact large-scale exploration of far-away, unknown, and forbidding regions has frequently been conducted by military establishments because they had the extensive resources and disciplined organizational teamwork required for success. On the other hand "peaceful" exploration has often borne results of tremendous military significance.

Military space programs naturally place most emphasis upon the potential operational applications of space flight, i.e., upon vehicle maneuverability and flexibility, upon various strategic or tactical mission capabilities, and upon inspection, repair, rendezvous, and logistic or other supporting functions. Peaceful scientific space exploration is of course more basic since its purpose is to increase man's knowledge of his surroundings, though such knowledge can rapidly become a valuable military tool.

In any ultimate sense man is indispensable to both types of space programs, particularly as they become more sophisticated. Before manned space programs, exploratory or military, can be safely and successfully carried out, however, a certain amount of information and experience must be obtained. This is especially true as time and distance away from the earth increase, for increases in these parameters subject man, or any living organism, to influences which are relatively unexplored. Since these influences act in combinations difficult or impossible to simulate on the earth's surface, preliminary studies relating to them made in more readily accessible situations are of little or no value.

Fortunately, the Air Force possesses unrivaled resources and facilities for the pursuit of a national effort in bioastronautic research and development.

Bioastronautic Research Activities

The USAF bioastronautics complex comprises a number of individual organizations contributing to the various phases of the program. The facilities in existence and under construction, including extensive mobile support units, constitute a total physical plant that cost approximately $36,350,000 to develop and build, the replacement value of which is now in excess of $47,000,000. Occupying and using this extensive physical plant are more than 2000 people. Of this total, 842 are highly trained professionals, who constitute one of the Nation's most valuable assets in the race for space. Among them are 282 military and civilian scientists who have doctoral degrees in one or another of numerous scientific specialties and who devote full time to research. In addition there are 214 people with master's and 346 with bachelor's degrees in the sciences.

The organizations that carry on the research work are scattered from Massachusetts to Florida to Alaska. Their missions and facilities may only be suggested in outline.

▲ Heading the structure at Headquarters Air Force Systems Command is the Commander's Assistant for Bioastronautics. He plans, directs, and provides technical guidance to the organizations listed below for efforts in biosciences, environmental protection, human engineering, and personnel and training research and development. He effects liaison with industry, universities, and other governmental agencies on bioastronautic programs.

▲ The Aerospace Medical Division of AFSC, with headquarters at Brooks AFB, Texas, manages bioastronautic research and development programs in support of Air Force systems development, assigned research programs in support of Air Force personnel clinical and system aerospace medicine requirements, and specialized educational programs in aerospace medical subjects as directed.

Functioning as part of the Aerospace Medical Division are five research organizations:

(1) 6571st Aeromedical Research Laboratory, Holloman AFB, New Mexico

Mission: Performs research and tests on human tolerance to abrupt acceleration and deceleration; develops methods and procedures for testing life-support and ejection capsules and crash protection devices in actual and simulated extreme environments; trains, conditions, instruments, and maintains all chimpanzees and many other test animals for all track, chamber, and other extreme performance tests.

Major research facilities: Closed respiratory chamber system capable of performing complete metabolic studies in large primates under various altitude and gas environmental conditions; an underwater deceleration tank; a rapid-cycling pressure chamber; sonic wind-blast sleds; physiological data acquisition system; short deceleration track.

(2) 6570th Personnel Research Laboratory, Lackland AFB, Texas

Mission: Conducts research and development in support of the operation and qualitative improvement of the Air Force personnel system, including the development and evaluation of concepts and techniques concerned with the functional areas of personnel requirements, procurement, classification, training, assignment, utilization, proficiency measurement, promotion, retention, separation, and accounting.

Major research facilities: Personnel, classification, and evaluation records dating from 1943 on approximately 1,970,000 people. IBM-650 computer with 5 tapes and 1 RAMAC (random access method of accounting control) unit plus normal EAM (electronic accounting machine) support equipment.

(3) 6570th Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio

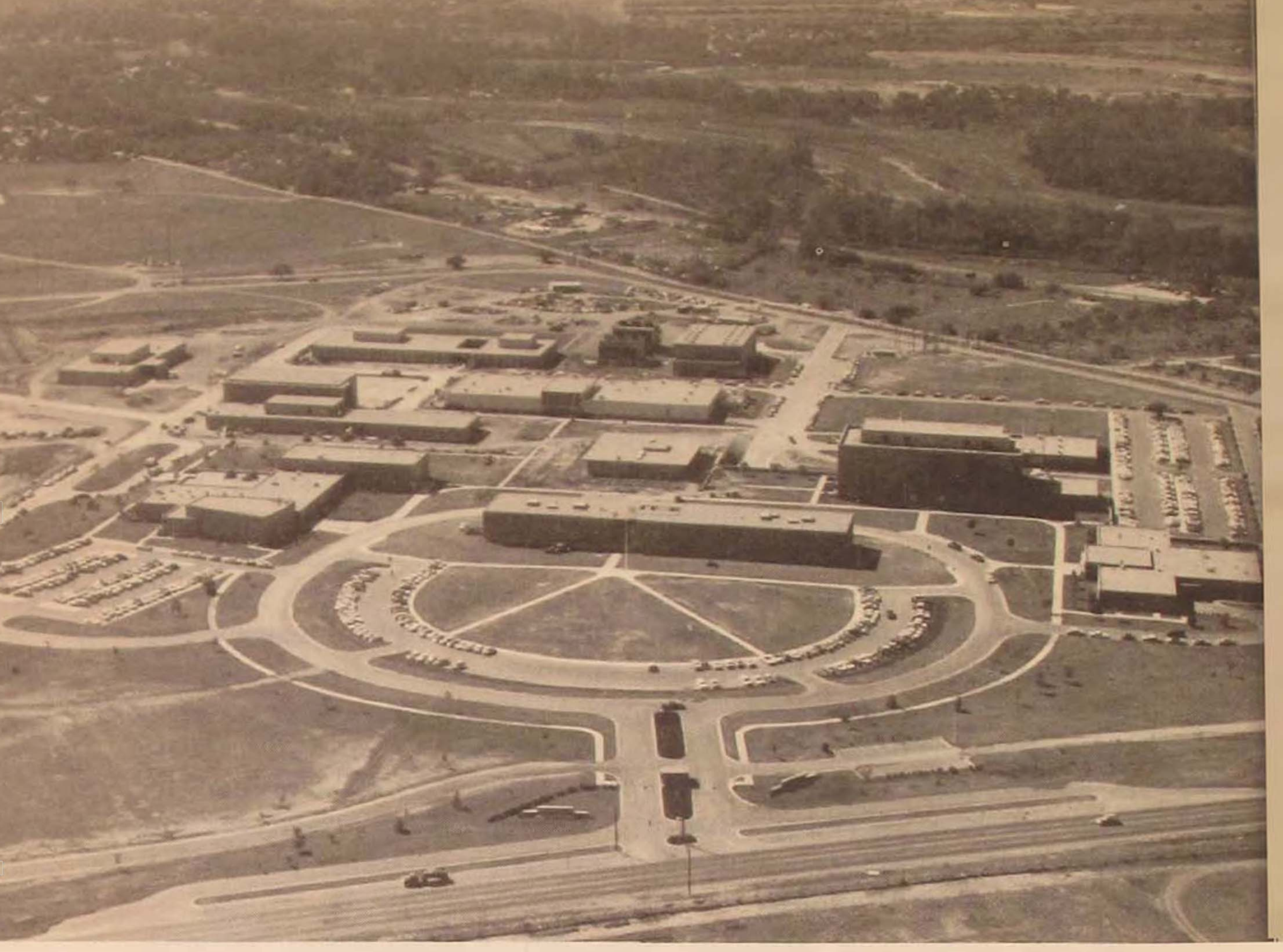
Mission:

a. The Biomedical Laboratory performs research on human tolerance for mechanical, thermal, sonic, chemical, and other environmental stresses, as well as on human requirements for water, food, oxygen, light, air pressure, sleep, exercise, and other factors of physiological importance in preserving health and prolonging the ability to work, whether in stressful Air Force ground environments or in advanced aerospace systems.

b. The Behavioral Sciences Laboratory performs research on sensory functions and perception, on response time and psychomotor activity, and on learning and various kinds of intellectual performance. Such work is essential in promoting optimal matching of human characteristics to machine design and in developing training and simulation techniques for crew training.

c. The Life Support Systems Laboratory performs research and development on atmospheric control and respiratory equipment, foods, waste disposal and regenerating equipment, functional protective clothing, and similar technology needed to sustain man in inhospitable or hazardous environments.

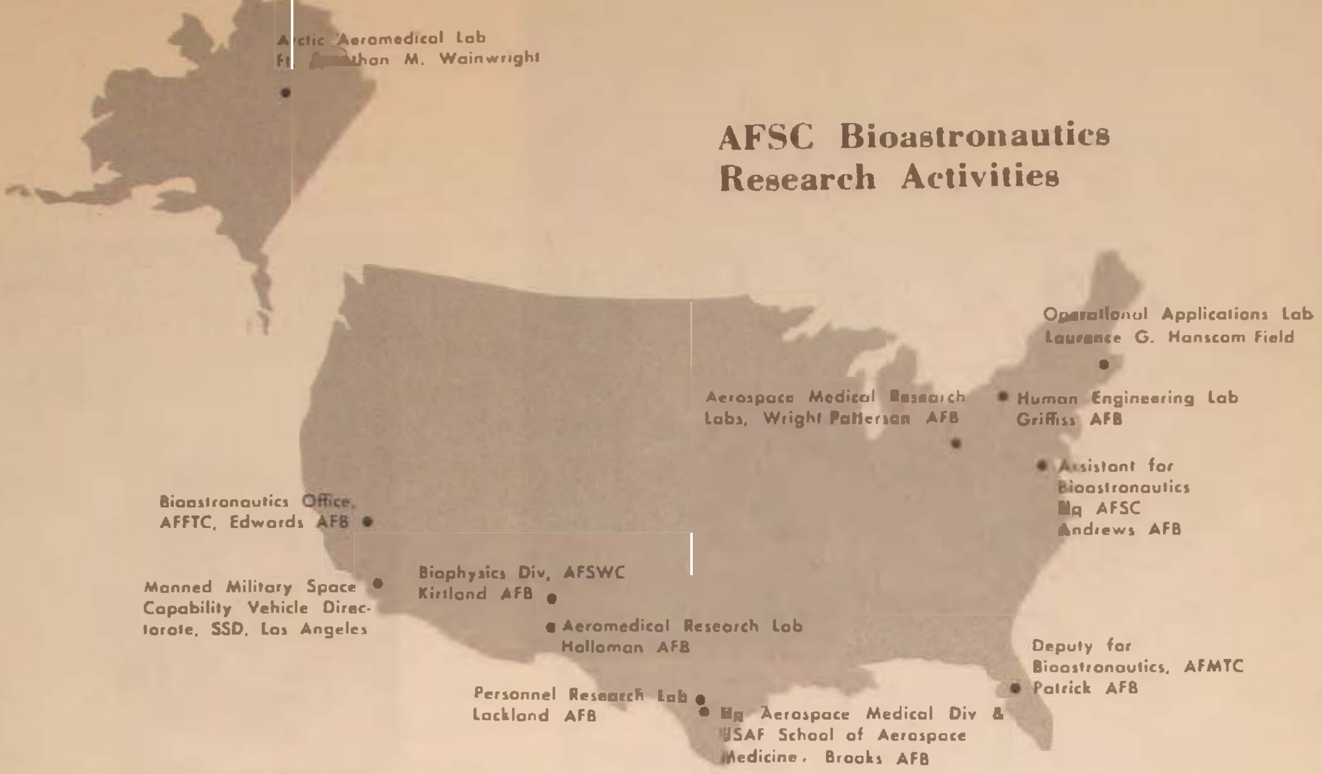
Major research facilities: Complex bioacoustic research laboratory with a unique 30′ x 30′ anechoic chamber; histopathology laboratory; environmental chambers; high-altitude chambers; 22-g centrifuge (40′ boom, 20′ radius); 30′ x 40′ flotation test pool; 20′ amplitude vertical accelerator; 40′, 30-g vertical decelerator; C-131B aircraft especially instrumented for zerogravity studies.



Research in Aerospace Medicine and Bioastronautics

THE HUB of aerospace medical and bioastronautical research for the Air Force is the Aerospace Medical Division and School of Aerospace Medicine complex at Brooks Air Force Base, Texas. The physical establishment consists of the professional building, academic building, bioastronautics-biodynamics building, vivarium, bionucleonics building, power plant, altitude laboratory, library, research institute, research shops, and flight medicine building. A bio-systems research building has recently been approved. Many experimental investigations are conducted within this educational-research complex, but the Aerospace Medical Division's research program is both more extensive and more far-flung than one cluster of laboratories—its activities stretch from Florida to Alaska, from California to Massachusetts. Though the program reaches to the far corners of the Nation, all elements of the division work together in close coordination to extend man's knowledge of the bio-related subjects essential to his mastery of aerospace.

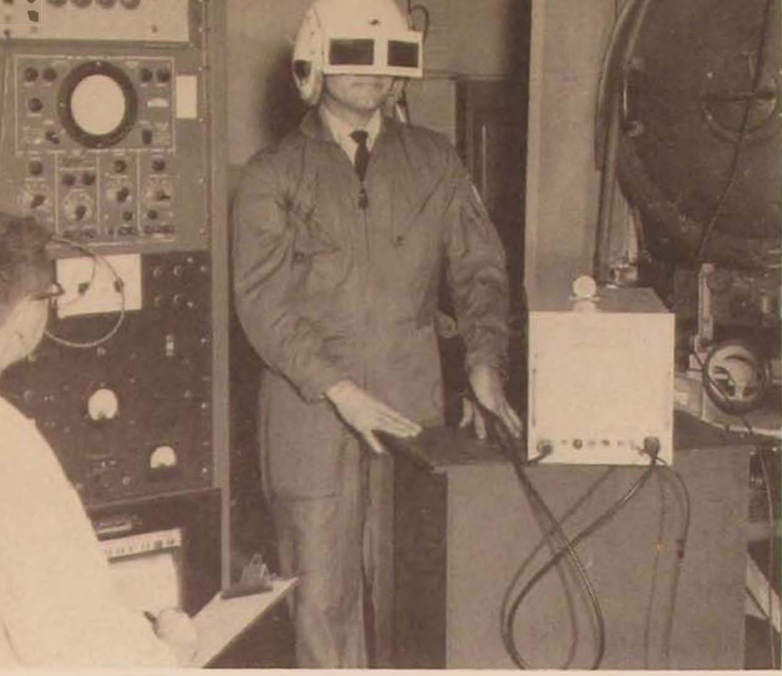
AFSC Bioastronautics Research Activities



Temperature Response

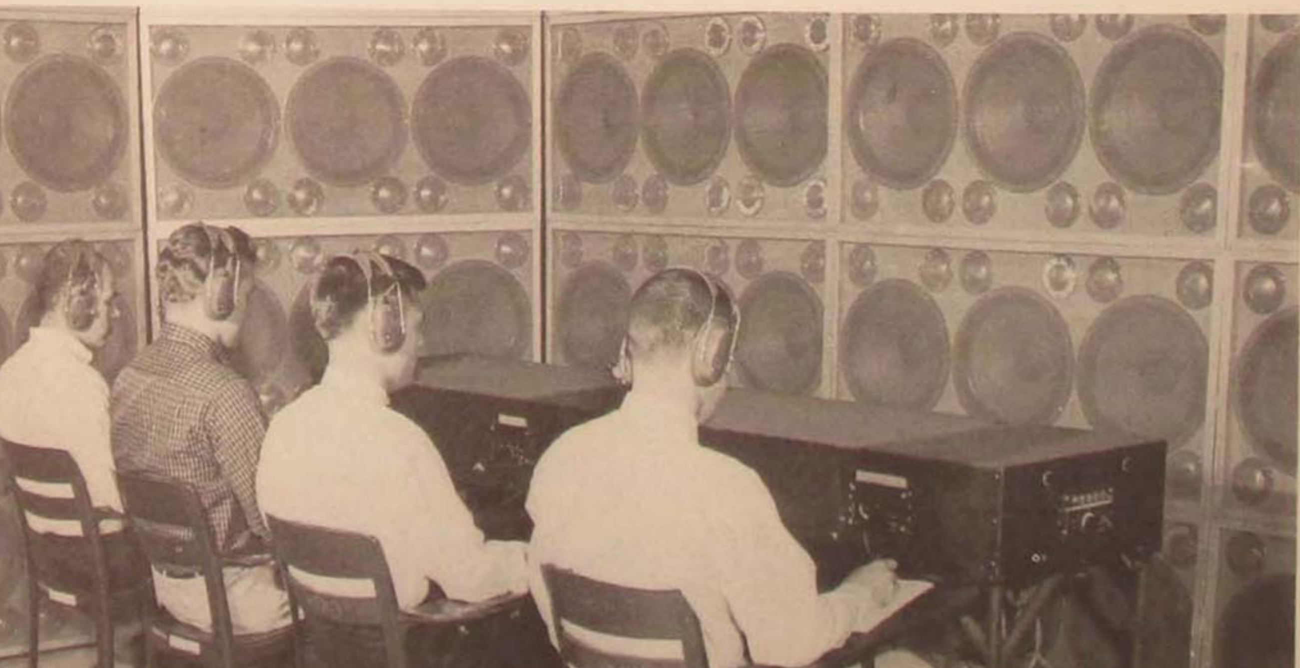
Body heat loss in subzero conditions is studied at the Arctic Aeromedical Laboratory in Alaska. The subject is heavily covered except for hands, feet, and face. To find how body insulation affects cooling of the extremities, thermocouples attached to hands and toes lead to instruments that record temperature changes.

The heat pulse oven simulates temperature stresses that may be met during atmosphere re-entry. The 4-foot sheet-aluminum cube is heated by incandescent lamps. The programmer at left controls wall temperatures from 75 to 450°; rates of heating reach 200°/minute. Instruments at right record the subject's responses.



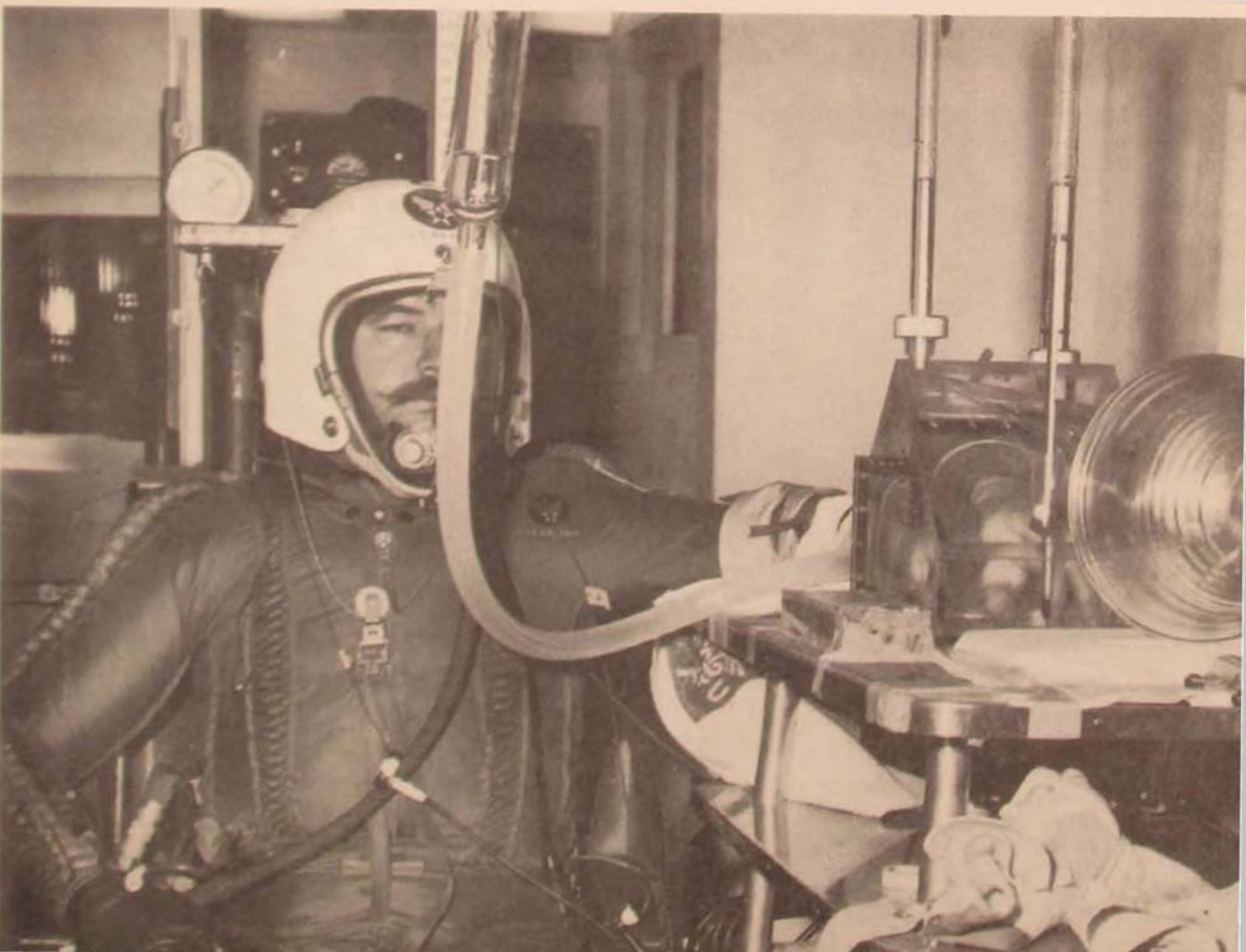
Light and Noise Disturbance

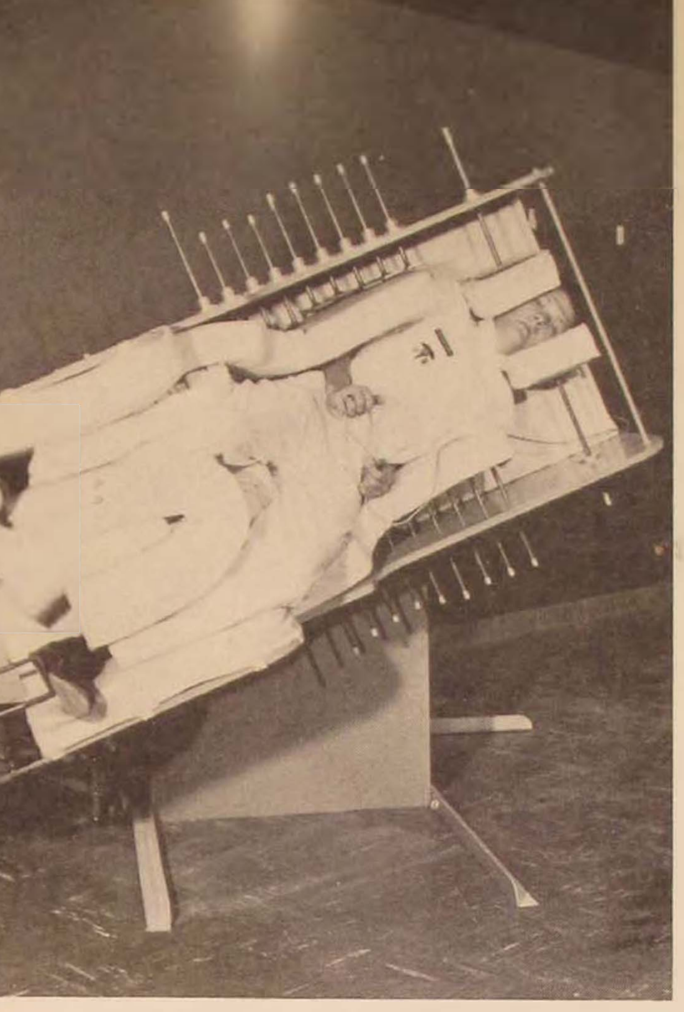
Adverse effects of brilliant light and intense noise on flight personnel pose serious problems for investigators at the Aerospace Medical Research Laboratories, Wright-Patterson AFB. To protect aircrews from blinding nuclear flash, the vision lab designed goggles of a new photochromic material which is normally clear but automatically darkens at impact of high-intensity light. As the light diminishes, the lenses return from near opaque to clear. Effects of noise on performance are tested in the reverberation chamber. The subject attempts to level the pitching and rolling equilibrium chair while being blasted by jet-type noise. Performance changes under various noise levels are displayed by electronic readout. Communications effectiveness is tested by a high-intensity sound system. Tape recordings of AF noise environments play through loudspeakers in the reverberation chamber, which ensures a uniform sound field. The subjects listen to and record speech samples from the standard AF airborne communications system. New headset and microphone designs and vibration and weightlessness effects on reception are evaluated.



Altitude Protection

Suit assembly currently in test and evaluation illustrates state of the art in protective garments for use in space missions, such as those planned for Dyna-Soar. It features new joint concepts, a suit-integrated globe-type helmet, and an altitude-sensing device to automatically close the visor at dangerous altitudes. In a high-altitude study, the subject is protected by a partial-pressure suit while his left hand is exposed to the ambient pressures of 63,000 feet and above. Body fluids, mostly water, vaporize at 63,000 feet, and gas bubbles form under the skin. Gas formation in the hand is recorded by motion picture film as well as X-ray.

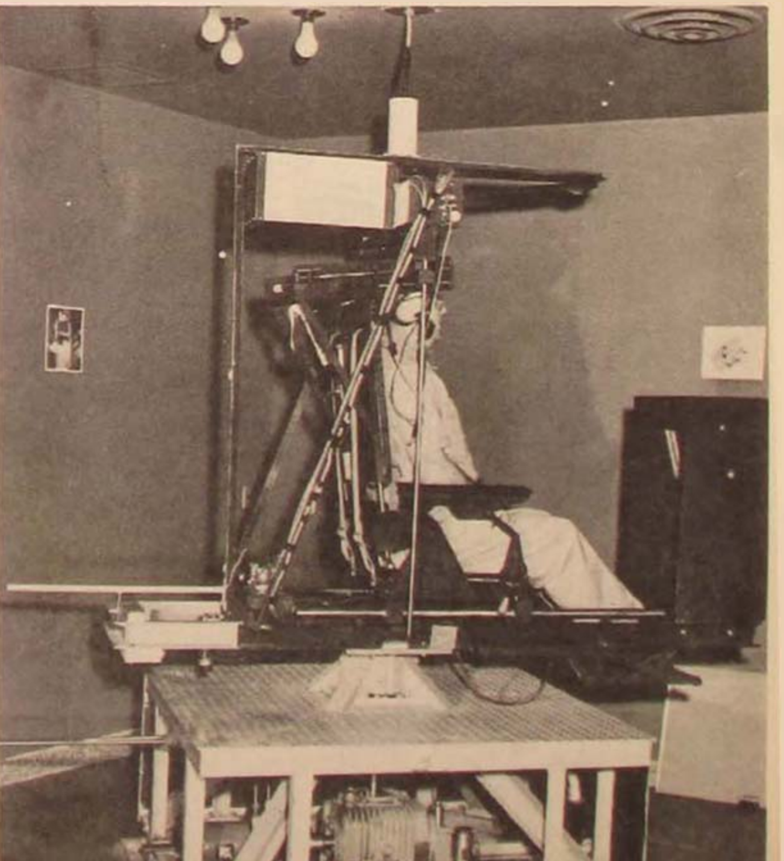


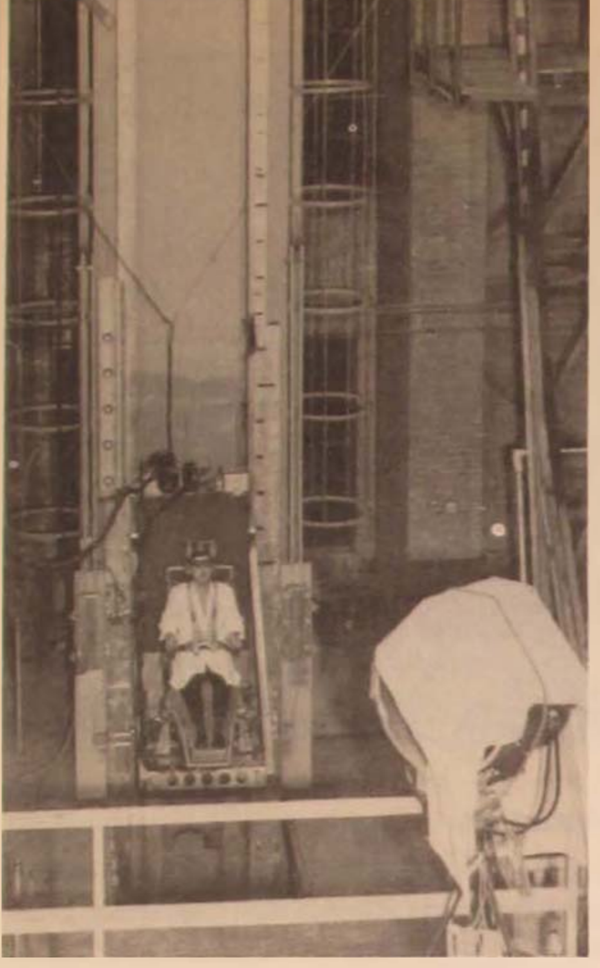


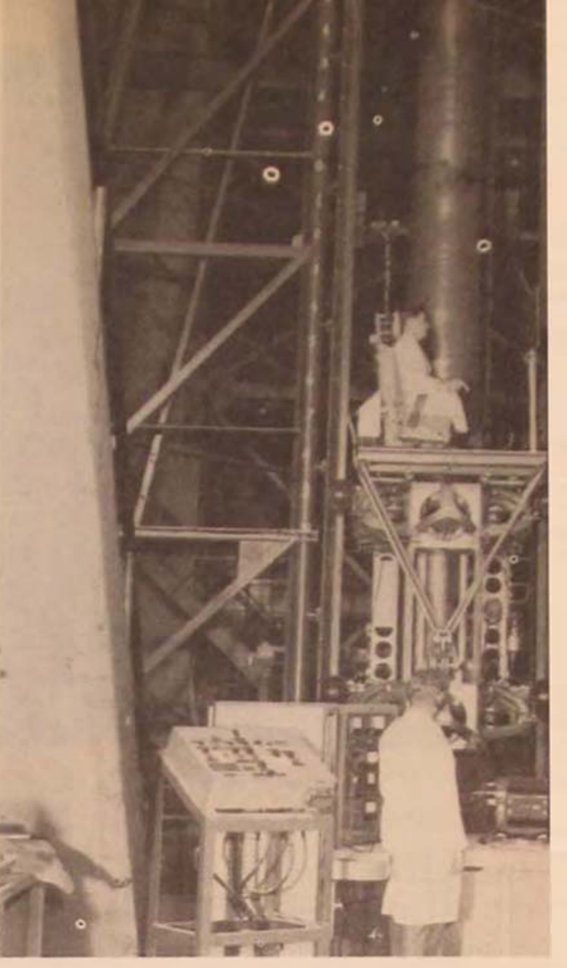
Rotation and Tilt

Postural tilt chair in Vestibular Laboratory, USAF School of Aerospace Medicine. The subject has foam rubber pressing against him to eliminate kinesthetic cues. He is usually blindfolded, and by use of an electrical switch he eliminates any subjective impressions regarding his position. Reactions resulting exclusively from sense of balance can then be studied as the man is tilted at various angles, here at 60°.

The subject about to undergo biaxial stimulation (rotation with tilt) adjusts the goggles while a technician fits the earphones (left). Electrodes around the eyes record the man's vestibular responses. The biaxial chair has a maximum speed of 18 rpm and maximum tilt of 60°. The monaxial rotating chair (right) has a hydraulic accelerating system electrically controlled by a programing unit. Electrodes on the man's head pick up occular displacement caused by the rotational stimulation, which can be linear or sinusoidal.





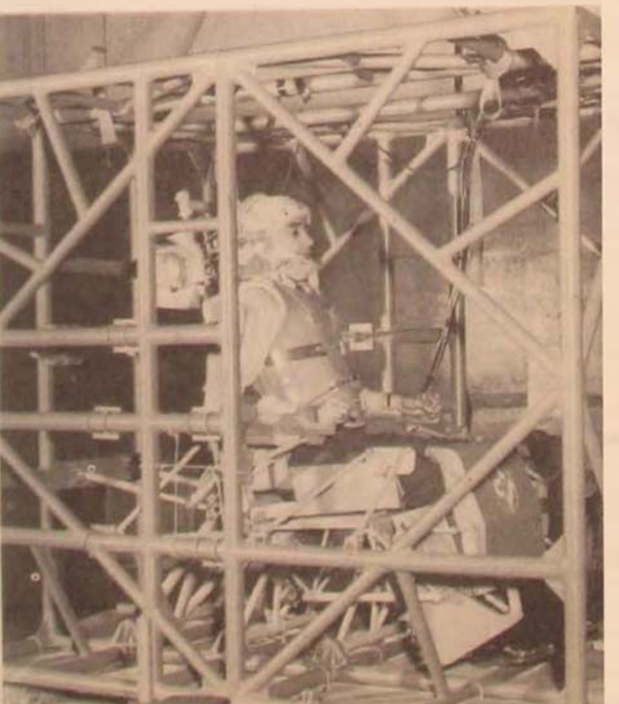


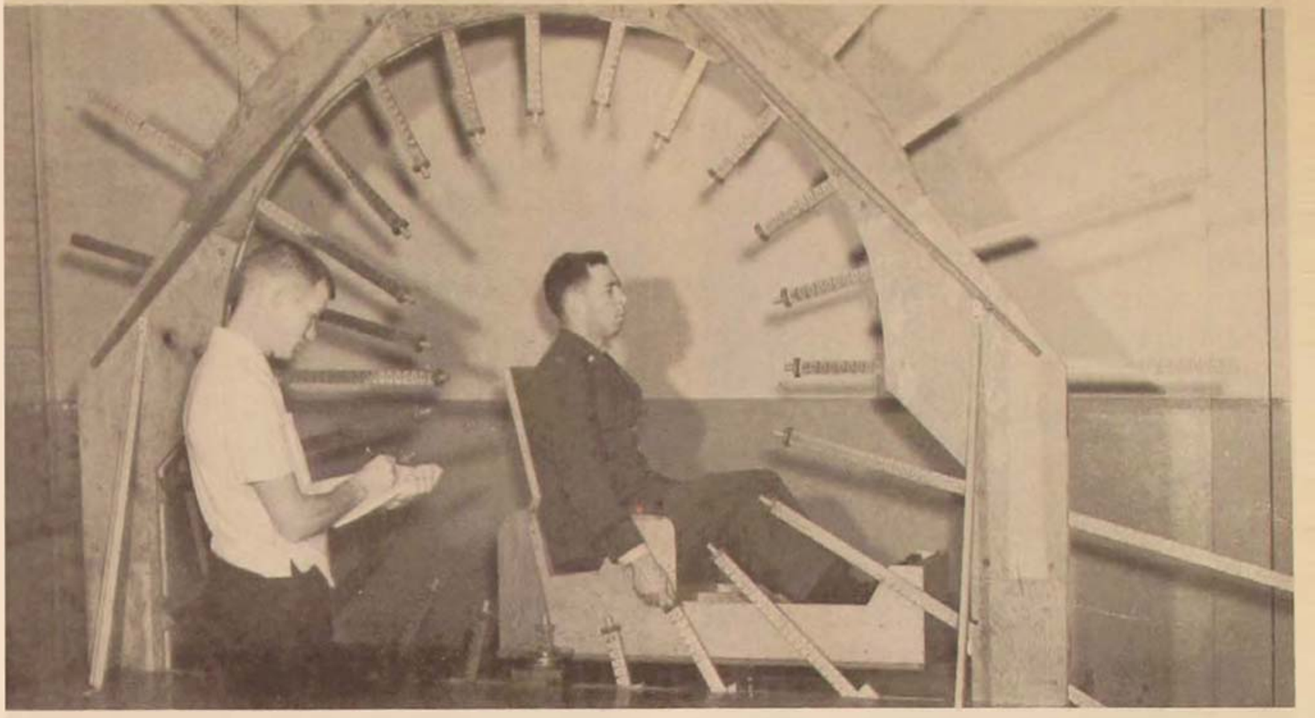
Impact and Vibration

Subjects ride vertical deceleration tower in deceleration patterns with peaks up to 75 g and durations of 100 milliseconds. The platform carries 800 lb at a maximum drop height of 30 ft. Studies lead to protection from impact injuries.

The vertical accelerator subjects the man on the test platform to low-frequency, high-amplitude vibrations. The platform can hold 400 lb and has a total excursion of 20 ft peak-to-peak. The effects of severe buffeting on man, such as he may meet in aerospace and space operations, are studied by Aerospace Medical Research Laboratories.

The whole-body personnel restraint and support system shown mounted within a tubular steel test vehicle was developed in the effort to protect human subjects against impact loads of 60 g in the transverse and lateral directions. System design criteria were derived from analysis of the inertial loadings on the human body, conducted to determine unit pressures exerted on the surface of the body. The system of rigid, molded body shells evolved from this analytical approach.





Reach Measurement

The reach-measuring device indicates the radii of the functional reach envelope at 15° intervals in twelve vertical planes and enables description of arm reach through 360° in the three orthogonal planes. The device helps describe shirt-sleeve and suited arm reach and aids objective evaluation of pressure-suit mobility.

Specific Gravity

The specific gravity of the human body can be accurately determined by weighing the subject under water. Such measurement gives important clues to the mass of muscle and body fat. Excessive fat is associated with hypertension and arteriosclerosis and possibly with the bends also.

(4) USAF School of Aerospace Medicine, Brooks AFB, Texas

Mission: The USAF School of Aerospace Medicine (formerly School of Aviation Medicine) has been recognized since 1918 as the world's outstanding center for aviation medicine. Its mission is to accomplish basic and clinical research, provide education for Medical Service personnel, and furnish specialty consultation in aerospace medicine.

Major research facilities: Anechoic and reverberation chambers; various environmental chambers, including a rapid-decompression, 20-man altitude chamber; 6-man and 4-man parasite chambers; 2 space-cabin simulators; a thermoenvironmental chamber; a cobalt-60 irradiation facility; a deep-therapy unit; and a neutron generator.

(5) Arctic Aeromedical Laboratory, Fort Jonathan M. Wainwright, Alaska

Mission: Conducts an in-house program of research, supplemented by research carried out under contract with various institutions throughout the country, principally universities, on arctic human-factors problems. The laboratory's budget is divided very nearly equally between the in-house and contract programs. Establishes Air Force requirements for clothing, personal equipment, operating procedures, and training programs for use in the arctic; evaluates, under arctic conditions, items of clothing and equipment developed in other Air Force laboratories. Provides laboratory facilities, logistic support, and technical assistance to visiting research teams or field parties.

Major research facilities: Research laboratories and small-animal colony.

▲ Additional bioastronautic functions within the Air Force Systems Command are performed by six other organizations:

(1) Bioastronautics Branch (Flight Test, Engineering Division), Air Force Flight Test Center, Edwards AFB, California

Mission: Performs evaluations of crew work-space design and functional characteristics of weapon systems, manned spacecraft, and personal equipment in the advanced flight test environment (e.g., century-series aircraft, X-15, and X-20 Dyna-Soar). This group also assists in the maintenance and training of military space research pilots.

Major research facilities: TF-102 instrumented aircraft; low-pressure chamber; and central integrated physiological instrumentation system.

(2) Manned Military Space Capability Vehicle Directorate, Space Systems Division, AFSC, Los Angeles, California

Mission: Acts as the Office of Technical Management for all USAF biological space flight programs conducted by the AFSC Space Systems Division; coordinates contributions and activities of contractors and Air Force bioastronautic agencies participating in Space Systems Division flight test programs.

Major research facilities: Bioastronautic test support equipment, costing $1,250,000 to develop and fabricate, consisting of complete mobile (van type) prelaunch preparation, checkout, and launch monitoring facilities.

(3) Biophysics Division (Research Directorate), Air Force Special Weapons Center, Kirtland AFB, New Mexico

Mission: Performs research to determine hazards to personnel of ionizing radiations from nuclear reactor and weapon accidents, weapon tests, radioactive fallout, and from weapon storage and inspection procedures; develops instrumentation, monitoring devices, decontamination methods, and other protective measures; and tests the effectiveness of these procedures with animals. The division also serves as the central AFSC collection agency and repository for information regarding possible hazards of cosmic radiation.

Major research facilities: 256-channel data analyzer used in testing of unknowns for radioactivity; neutron threshold counter; cobalt and cesium sources; 70-acre animal farm.

(4) Deputy for Bioastronautics, Air Force Missile Test Center, Patrick AFB, Florida

Mission: Investigates occupational health hazards associated with missile prelaunch and launch activities. Provides bioastronautic support to Project Mercury.

(5) Operational Applications Laboratory, Laurence G. Hanscom Field, Massachusetts

(6) Human Engineering Laboratory, Griffiss AFB, New York

Mission: These two laboratories conduct research on human performance, with special emphasis on problems of developing command and control systems.

Major research facilities: One medium-sized anechoic chamber; sound-proofed experimental chambers; light-proofed experimental chambers; visual experimental chambers; auditory experimental chambers; tactile-function experimental chambers; and chambers for the recording of physiological responses.

IT IS a formidable task to manage this research program carried on by agencies thousands of miles apart, with a single major command providing guidance, integration, and coordination. Prior to 1 January 1962 the bioastronautic program lacked the unifying command afforded by AFSC, for the scattered components were responsible at different times to various commands—the Air Training Command, Air University, Air Research and Development Command, and the Alaskan Air Command. Obviously, this situation created difficulties in communication and a potential for wasteful duplication of effort, besides standing in the way of a solidly integrated Air Force program. The only means of providing the most efficient management for the entire complex was to achieve complete integration and unification of efforts in aerospace medical research and bioastronautics through consolidation under a single manager.

The major installation conducting bioastronautic research which was not previously under the managerial auspices of the Air Force Systems Command was the USAF School of Aerospace Medicine. Its medical education and training mission had identified it logically with the Air Training Command and, prior to that, with Air University. When the school occupied its new quarters as a part of the Aerospace Medical Center at Brooks AFB in 1959, however, its unmatched laboratory facilities gave it a research potential which could not be permitted to exist independently of the total Air Force program without causing prohibitive dilution of effort.

Accordingly the Air Force Systems Command established its sixth division, the Aerospace Medical Division, which became fully integrated the first day of 1962. Its mission is "to perform the research, development, and testing necessary to provide the required bioastronautic support to the AFSC advanced aerospace systems development mission in terms of both long- and short-range objectives. Inasmuch as these programs have considerable significance to the Nation's civilian and scientific goals in space, the Aerospace Medical Division should be so structured as to be capable of accepting major responsibilities to support Air Force and National objectives in both areas."

The future will surely bear out the wisdom of this reorganization. If present estimates are correct, the school's research potential will be enhanced by more direct participation in the development of major Air Force weapon systems, by easier access to test-vehicle facilities, and by simplified intracommand coordination with sister organizations.

In the final analysis the Nation as well as the Air Force will reap the benefits of this reorientation of the bioastronautic effort. Programing in depth will be possible, as will be the development of a meaningful basis for establishing project priorities in the total bioastronautic program. The implementation of projects—from the idea stage through basic and applied research and systems development to operational status—will be directed by closely associated professional personnel without undue intercommand organizational impedance and with significantly shortened lead time.

Headquarters Air Force Systems Command

Note:

The agencies and facilities described are all within the Air Force Systems Command. The Office of Aerospace Research also conducts research in the biosciences as part of the Air Force basic research program. The objective of the organization is to find new knowledge, and it is not systems-oriented.

part IV

RESOURCES

Technological conflict is as dependent on its resources—its personnel, installations, materiel—as any armed conflict ever was. The "soldiers" of today's technological conflict may be thought of as the scientists, engineers, and technicians engaged in aerospace research and development, the "battlefields" as the laboratories, research centers, proving grounds, and test ranges, and the "weapons" as the knowledge and skills of the "troops" as well as the infinite equipment and gadgetry of scientific reseach and technological development. Historically the Nation's resources have seemed boundless—a continent rich in raw materials as well as inventive minds and expert hands in every workshop and factory. Yet the unprecedented sweep of current technology has highlighted the wisdom of frugality in the expenditure of both our personnel and material resources. In so vast a use of resources with such vital stakes, there is little room for duplication or overlapping of effort and no margin for waste.

FACILITIES

Lieutenant Colonel Clyde L. Wade

RESEARCH and development facilities are the tools by which technical ideas and concepts become realities. This has been especially true in the field of aviation. *Before* building their flying machine, the Wright brothers built a technical facility, a crude wind tunnel. In this tunnel, and with other test devices, they conducted the many experiments which determined the design and performance characteristics of their machine. This scientific approach may very well have been the difference between their success and the cut-and-try failures of some of their competitors. By the middle of World War I it was generally recognized that only the scientific approach ensured good results and, further, that military aviation could tolerate no less than the best.

The first United States military facility for aeronautical research and experimentation was built in 1917 at McCook Field, a few miles north of Dayton, Ohio. By 1919 McCook Field had expanded to 69 buildings, including hangars, shops, laboratories, and a hospital. From these facilities came such advancements as the 400-hp Liberty engine, the first reversible-pitch propeller, aerial photography techniques, leakproof tanks, free-type parachutes, instrument flying, and aerial radio communications. In 1923 McCook engineers developed the six-engine Barling bomber. The first liquid engine coolant other than water and the air-cooled engine also became realities that year. The first all-metal airplane was designed, built, and flown at McCook Field. By 1927 the research activity had outgrown the McCook facilities and was moved to Wright Field, a few miles away.

During the 1930's research and development work in the wind tunnels and laboratories at Wright Field provided the background for the development of World War II aircraft. Some of these technical accomplishments were high-octane fuels, turbosupercharged engines, bombsights, pressurized cabins, and automatic pilots. World War II produced fantastic scientific advances accompanied by a large expansion of technical facilities. This expansion ended with the war. The period between WW II and the Korean War saw little change in Air Force technical facilities even though General Arnold and his perceptive technical officers and leading scientists, such as Dr. Theodore von Karman, were pressing for expanded facilities and advanced military research.

Only the clear challenge at Berlin in 1948 and subsequently in Korea roused the Government to action. In late 1949, after being "studied" and "coordinated" for five years, the complex of advanced wind tunnels advocated by General Arnold and Dr. von Karman was finally authorized and funded for construction on the old Camp Forest Reservation, Tullahoma, Tennessee. These tunnels provided a capability for research and development in speed, altitude, and temperature regimes well beyond those required by the weapon systems of that day. This foresight proved invaluable in the solution of problems that developed in missiles and satellites ten years later.

In spite of the obvious importance of research and technology to the Air Force, it was not until 1950 that a command was established whose primary mission was research and development. The facilities of the new Air Research and Development Command soon included elements at Eglin, Kirtland, Griffiss, and Laurence G. Hanscom as well as those at Wright-Patterson, plus control of the bases at Edwards, Holloman, Patrick, and Arnold Engineering Development Center.

Military R&D facilities provide an extremely diverse capability for research, development, engineering, test, and evaluation. Operational conditions are simulated to permit observation and control of phenomena with laboratory accuracy. Tests are conducted on every scale from microseconds, milligrams, and millimeters to months, hundreds of thousands of pounds, and millions of miles. Viewed in another way, R&D facilities first provide basic scientific knowledge, then apply this knowledge to useful military purposes, develop this knowledge and material into hardware, then test and evaluate the hardware. The hardware becomes part of the prototype of a system. After thorough development of the prototypes, production models of the system are tested and released to operational units. After operational use has identified the remaining weaknesses of the weapon system, these same facilities provide engineering support to correct the deficiencies and upgrade the performance and reliability throughout the service life of the article.

An example of the results of research in Air Force facilities is the "sandwich" construction developed by the Materials Laboratory. The technique was used by the Flight Dynamics Lab to develop strong primary structures. This development was then applied to the latest airframes, such as that of the B-58, and contributes to their exceptional performance. Recent breakthroughs in molecular electronics have provided semiconductor functional blocks in place of transistors, diodes, capacitors, and resistors in airborne communications, guidance, and computer circuitry for missiles and spacecraft. Functional electronic blocks have reduced the size and weight of such circuits to less than .002 of that originally required and have also resulted in greater reliability. Late developments in photographic techniques make possible night photography at heights up to 10,000 feet without illumination from flash bombs or electronic means, the only requirement being faint moonlight. The photographs are so clear that a half-inch-diameter telephone cable is visible from 5000 feet. Other applied research developments are a titanium alloy for use as a structural material; engine materials, primarily superalloys for jet and rocket engines; hydraulic fluids, lubricants, greases, and fuels for weapon systems operating at high speeds and temperatures for extended periods of time.

AFSC Facilities Today

A glance at the accompanying capital investment chart should be sufficient to indicate the impossibility of itemizing within a brief space all the installations and facilities of the Air Force Systems Command. A representative selection must serve to exhibit the range and depth of the resources made available by a capital expenditure of $1.3 billion.

Capital Investment in AFSC Facilities

Air Force Missile Test Center (AFMTC)	$279,083,000
Arnold Engineering Development Center (AEDC)	258,910,000
Air Force Flight Test Center (FTC)	169,826,000
Air Proving Ground Center (APGC)	154,621,000
Aeronautical Systems Division (ASD)	120,000,000
Ballistic Systems Division-Space Systems Division (BSD-SSD)	79,078,000
Air Force Missile Development Center (MDC)	70,363,000
Electronic Systems Division (ESD)	68,026,000
Air Force Special Weapons Center (SWC)	55,979,000
Aerospace Medical Division (AMD)	19,450,000
Rome Air Development Center (RADC)	17,000,000
Hq AFSC	5,200,000
Foreign Technology Division (FTD)	2,893,000
Armed Services Technical Information Agency (ASTIA)	1,827,000
	$1,302,256,000

Structural Test Facility

The largest and most sophisticated flight vehicle structural test facility is operated by the Aeronautical Systems Division (ASD) at Wright-Patterson AFB, Ohio. Here structural testing is conducted on full-scale flight vehicles and major components, simulating the flight loads and environments that act on the vehicle. This facility, sometimes referred to as a "torture chamber," is housed in one of the largest test buildings at Wright-Patterson, with an unobstructed test area 250 feet long by 170 feet wide by 136 feet high. It is not uncommon to find several aircraft in the hangar undergoing tests at the same time. The extreme temperatures associated with today's Air Force vehicles are simulated in this facility, from the –350°F associated with missile propellants up to the 2500°F encountered by manned vehicles re-entering the earth's atmosphere from orbital flight.

To produce these high temperatures, special infrared electric lamps are used–sometimes as many as 3000 on one test. The lamps require 40 million watts of electrical power–enough to run approximately 4000 home cooking stoves at one time. A large automatic data-processing system collects and analyzes data from the tests, using 1928 different channels and collecting up to 114,720 datum points per second. To provide immediate readout of finalized, corrected data, a CDC-1604 digital computer is an integral part of the system.

Electrical Propulsion Test Facility

Prototypes of future space propulsion systems are being developed by the Aeronautical Systems Division. Applied research in this area includes investigation of various types of ion and arc-jet engines as well as power sources to provide propulsion energy, including nuclear energy, solar radiation collectors, and converters. Unique in this effort is the in-house ion engine test facility, which was the first of its kind in the Nation and still is one of the largest. Valued at half a million dollars, it was designed and built by ASD personnel primarily with surplus material salvaged from obsolete test equipment. Its size and pumping capacity permit the testing of all types of ion engines. A specially designed thrust-measuring system is accurate to one pound of thrust at altitudes to 140 miles. The 70-kw, 70,000-volt power supply system will soon be modified to increase the test voltage range, and a new cryogenic pumping system will soon permit testing at even higher altitudes.

To accommodate engines of larger mass flow and higher thrust, a second facility is under construction, again using surplus equipment. This facility will test thermal arc-jet engines with thrust levels as high as 10 pounds at altitudes up to 35 miles. With the completion of this facility, ASD will have an in-house capability of testing and evaluating any electric propulsion engine that is now planned.

Dynamic Analyzer for Advanced Reconnaissance Systems

This ingenious aerospace facility under construction at ASD is designed to test and evaluate advanced aerospace reconnaissance systems, but its versatility permits the evaluation of other types of aerospace systems and equipment as well. In addition to the environments simulated in the normal aerospace test chamber, such as vacuum (altitude simulation), temperature, and radiant energy, this facility will also provide:

(a) Any combination of roll, pitch, and yaw of the test item.

(b) Singular or combined three-dimensional vibration to 5 g from 2 to 800 cycles per second.

(c) Any desired combination of these several environments.

(d) Target simulation that will permit complete evaluation of optical systems (photographic and television). For example, a photographic system designed for installation in a satellite may be evaluated in the facility and its acuity or resolution determined under simulated operational conditions. Planned additions will permit infrared target and electromagnetic signal simulation.

Controlled temperature plates located in the test capsule will simulate the temperature extremes experienced in space. The test temperature range is −100°F to 450°F. Altitude simulation will be up to 150 nautical miles. This facility, with associated equipment and instrumentation, will represent an investment of approximately $7 million when completed.

Sonic Fatigue Facility

Since completion in December 1962, the Sonic Fatigue Facility at Wright-Patterson is providing a unique, much-needed capability for sonic fatigue research, development, and reliability testing. Full-scale aerospace vehicles, experimental structures, and electronic and guidance equipment are tested in the environment of variable high-intensity sound. Complete data recording and analysis equipment are available. The facility consists of (a) a large reverberation chamber providing a random incident sound field of 164 decibels in a volume of approximately 70 feet by 56 feet by 42 feet and (b) a progressive wave field providing approximately 174 decibels sound pressure level over a specimen with a 7-foot dimension normal to the direction of sound propagation. It will develop principles for system utilization so as to produce the highest achievable ratio of military benefit per unit of penalty incurred. Representative studies accomplished include operational analyses on Hound Dog missiles and XB-70 and V/STOL aircraft, system reliability analyses in support of technological force structure planning programs, and analyses of optimum terrain avoidance profiles in low-altitude flight matched against aircraft performance and structural parameters.

computer facilities

In the area of analog computation, scientific problems of many kinds are solved by AFSC's analog computer facility, the Free World's largest. Research and development to advance the state of the art in analog computation are also performed. Characteristic actions include analysis of a scientific problem, establishment of a program for simulation and computation, scheduling and operating the analog computer, data reduction and analysis, and preparation of technical reports. Representative problems solved by the analog computer include analysis and simulation of Vanguard satellite dynamics, self-adaptive flight control systems, lenticular missile guidance and control systems, and drone formation control systems and three-dimensional flight simulation of Bomarc.

The digital computation facility at Wright-Patterson solves a larger variety of scientific problems. Research and development in digital computation techniques are also conducted. The physical facility consists of a large-scale IBM-7090 data-processing system with an IBM-1401 high-speed printer operated as supporting equipment. Representative problems solved include mathematical model of factors affecting solar energy collectors, re-entry heat conduction, radiation effects and measurements, zerogravity trajectories, Skybolt trajectory studies, and X-20 Dyna-Soar optimization.

Holloman High-Speed Track

The 35,000-foot Holloman Track, located at Holloman AFB, New Mexico, is the longest and most precisely aligned test track in the world, the alignment deviation being less than ±0.005 inch. The design and construction were based on knowledge gained through early experience at Holloman and other major tracks. Track testing began at Holloman with the Snark missile in 1949. Since that time dozens of varied programs have been successfully accomplished, building a valuable reservoir of experience.

Sled testing brings together payload, propulsion, instrumentation, and other accessory equipment, and thus it is of major importance in a test program. Years of sled development have produced sled performance ranging from accelerating 200-pound payloads to 4000 ft/sec at 70 g, to boosting 2000-pound payloads to 2500 ft/sec at 15-g acceleration and stopping with 20-g deceleration. Deceleration rates up to 12,000 ft/sec are possible. In addition a monorail sled that can carry a 150-pound payload to over 4000 ft/sec has been developed. There are also various liquid-fueled sleds that can achieve relatively high velocities with a large payload and low acceleration because of a long thrust duration. Instrumentation provides velocity measurement accuracies of better than one part in 20,000.

Because the Holloman Track can closely simulate guided missile free-flight environment and allow closer observation during and after the run, it is an ideal development facility for use between laboratory and free-flight tests of guidance and other systems.

The complex assembly of mechanical and electrical components in a guided missile must work perfectly under the most adverse conditions of high accelerations, extreme vibrations, and rapidly changing temperatures. Inertial guidance systems to be used in ballistic-type vehicles are of such high dollar value that exhaustive preflight tests must be conducted to ensure required flight performance without loss or damage to the system. These tests cannot be accomplished satisfactorily by free-flight testing because of the limited instrumentation possible, the infrequent recovery of the guidance system in an undamaged condition, and the cross-coupling with errors and malfunctions in other parts of the system. In sled tests on the high-speed track, guidance systems and components can be subjected to nearly the same environment a missile provides during its boost phase—or, if desired, they can be subjected to a more severe dynamic environment. Although the boost phase of a sled run is much shorter than that of a missile, the guidance system error has the same nonlinear characteristics during the sled run that it has in an actual flight test. Thus the most important error source in guidance system testing and its cross-coupling effects can be easily and systematically investigated without loss of the experimental system. The Holloman Track played an important part in the development of the guidance system for Minuteman.

Arnold Engineering Development Center

The Arnold Engineering Development Center (AEDC) consists of three major test facilities: Rocket Test Facility, von Karman Gas Dynamics Facility, and Propulsion Wind Tunnel Facility.

- The Rocket Test Facility is designed for development and evaluation testing of propulsion systems for advanced aircraft, missiles, and space weapons, including rocket engines as well as ramjet, turbojet, and turboprop engines. Modifications to the original plant and development of new testing equipment and techniques have made it possible to test both solid- and liquid-propellant rocket units under conditions simulating flight to altitudes above 100,000 feet. Rocket engines that can be tested range from small units of a few hundred pounds of thrust to large, full-scale engines with tens of thousands of pounds of thrust. A vertical test cell now in operation accommodates testing to full-scale rocket engines generating up to 200,000 pounds of thrust at simulated altitudes above 100,000 feet with the engine installed in the cell in its natural upright position. A large new cell provides an altitude simulation capability of up to 350,000 feet with radiation panels for orbital heat flux simulation and full-scale engine propulsion tests. This cell became operational late in 1961.

The purpose of these rocket engine tests is to obtain such information as the burning characteristics of a propellant, the precise amount of thrust an engine generates, and the durability of a rocket engine nozzle case and associated controls. By this means information can be obtained without the costly launch of a complete missile. At the same time altitude tests in these cells can reduce considerably the time element, as well as the number of launches, required in the development of a weapon system.

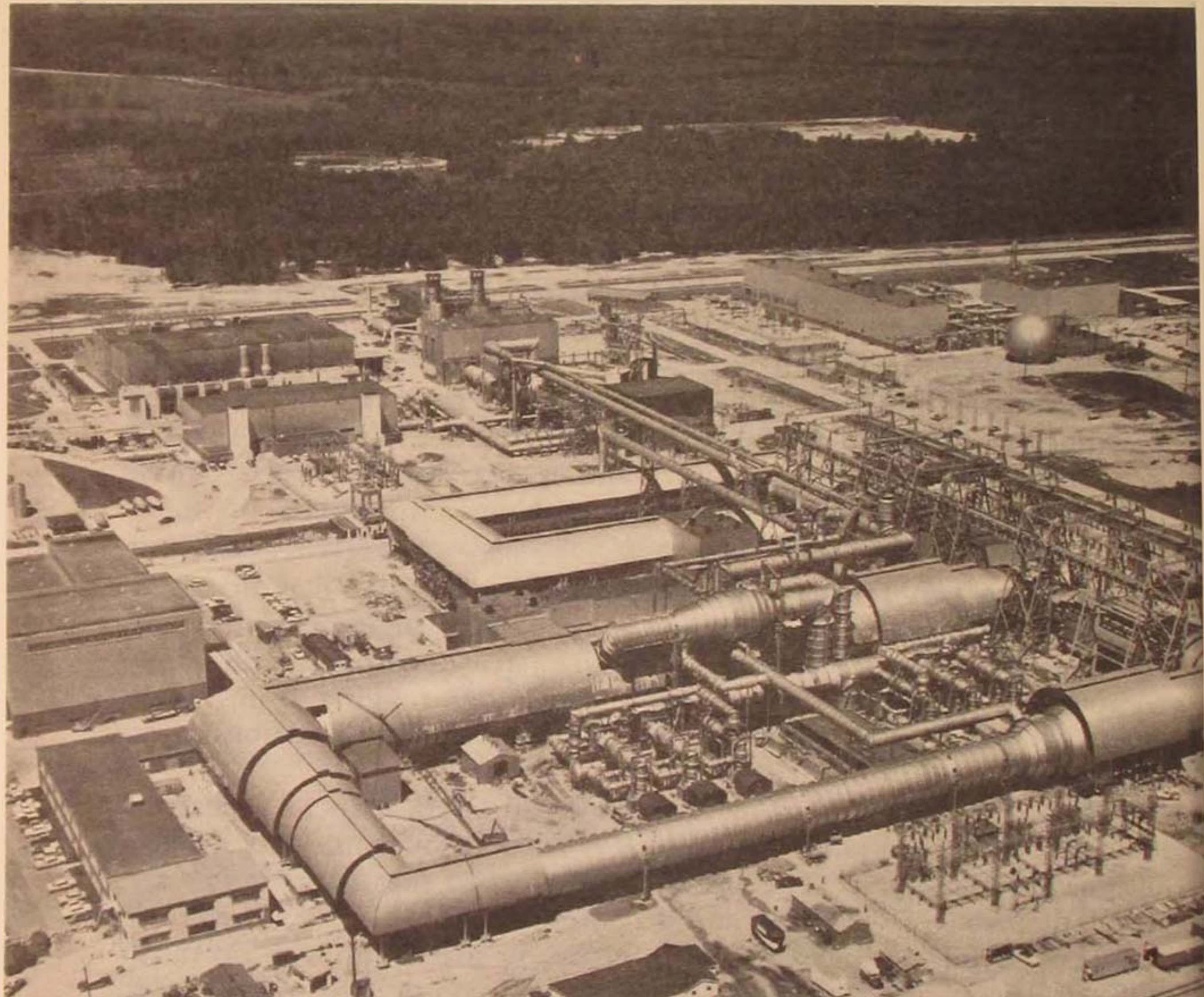
In the same way tests of air-breathing engines can help cut down development time and the number of flight tests required for manned aircraft and certain types of guided missiles. These tests may involve complete flight-type engines or they may involve heavier "boilerplate" versions of an engine in which inlets, compressors, combustors, nozzles, or other sections can be installed for experimental investigations. During test of an air-breathing engine, air that has been conditioned to simulate the desired altitude and temperature is forced into the test cell at the velocity which permits running the engine at the power setting of the desired mach number. One of these test cells is equipped with a variable mach-number and angle-of-attack nozzle which permits changing the simulated speed and angles of climb or descent during the tests.

Testing in this facility is not limited to new and untried propulsion systems. From the start development tests have been run on a number of air-breathing engines and rocket engines which power operational aircraft and missiles, and problems encountered in their operation have been solved here.

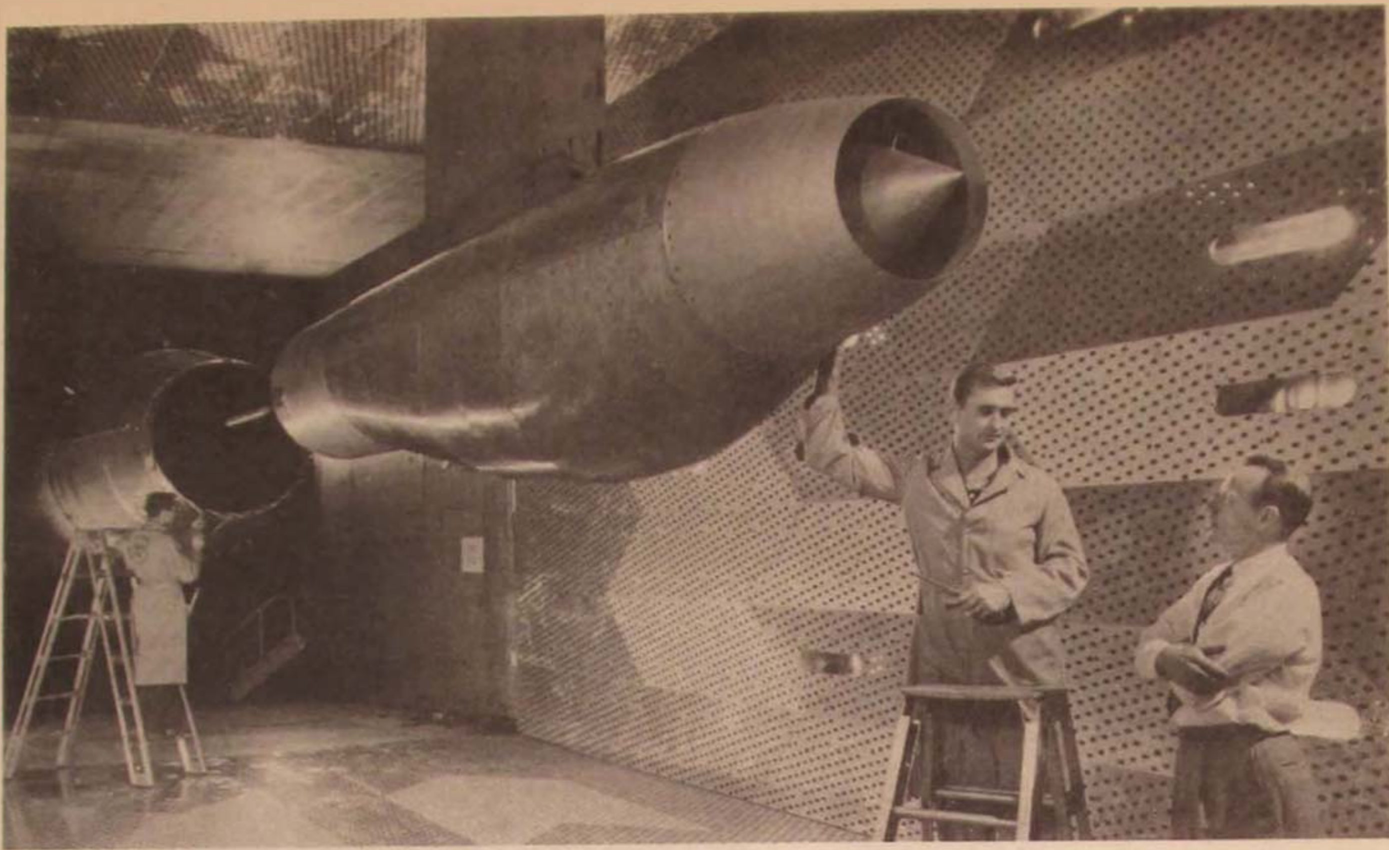
• The von Karman Gas Dynamics Facility (VKF) is designed for the aerodynamic testing (that is, testing to determine the best aerodynamic shape) of aircraft, missiles, space weapons, and their components at highly realistic flight conditions ranging from mach 1.5 to 20 and above. There are eight wind tunnels of various sizes and capabilities in this facility.

Two are intermittent—or blowdown—tunnels. Air for them is stored in a pressure tank, from which it flows through the test section into a vacuum sphere. The pressure tank is 720 feet long. It has an inside diameter of three feet and walls four inches thick. The vacuum sphere is 80 feet in diameter. To prepare for a test run, the pressure tank upstream of the tunnels is filled with compressed air. At the same time air is pumped out of the vacuum sphere downstream of the tunnels. The air pressure in the tank is up to 4000 pounds per square inch, and the sphere can be evacuated to about 1/300 of an atmosphere. When all is ready for the test run, valves are opened at either end of the tunnel, thereby producing airflow through the 12-inch-square test section in which the model is installed. Controls regulate the pressure and density of the air required for the specific test. Duration of the test may range from a few seconds to as long as 15 minutes, depending upon the conditions required. One of the tunnels operates in the range from mach 1.5 to about 5, the other from mach 5 to 8.

The Arnold Engineering Development Center

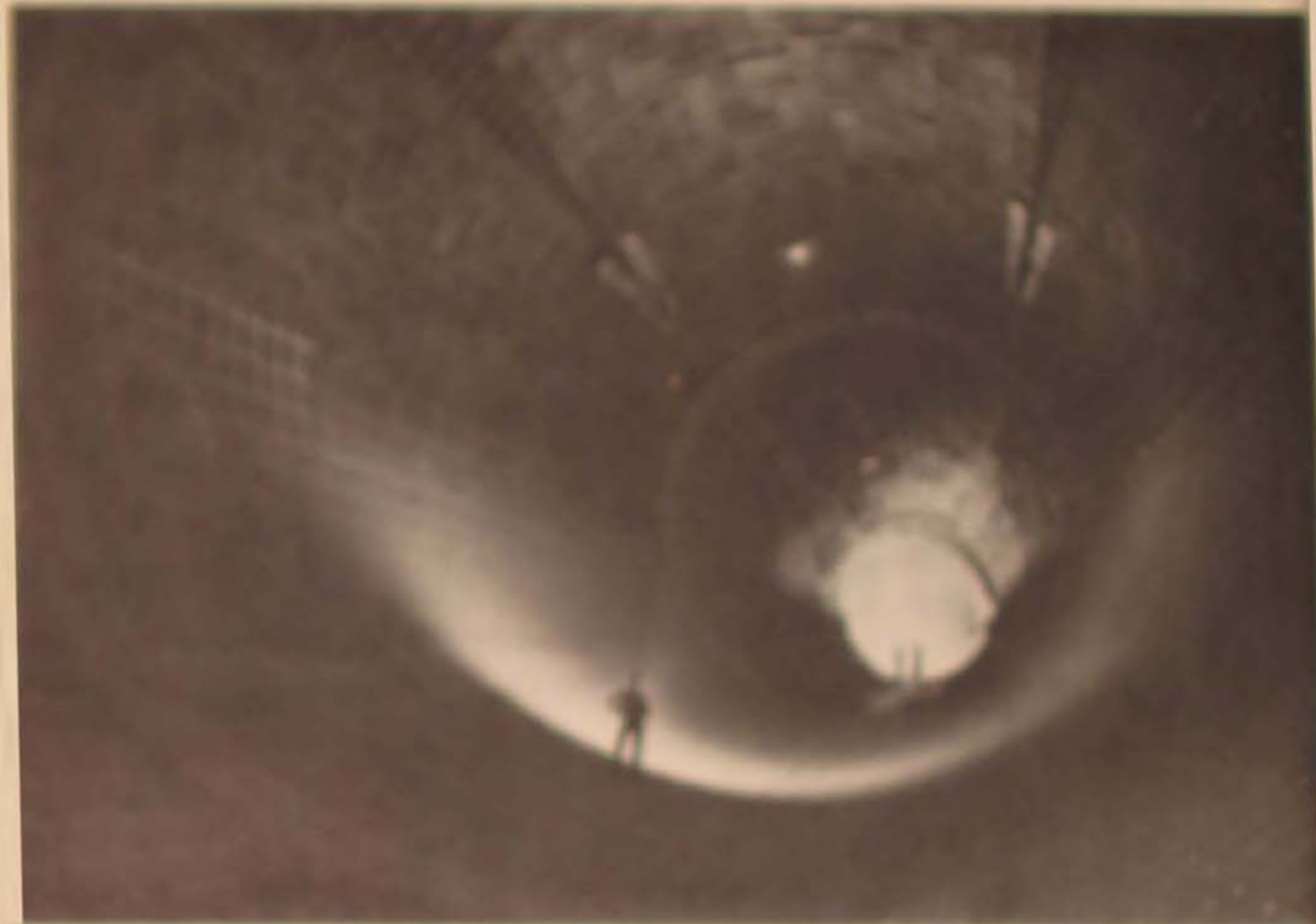


The Arnold Engineering Development Center at Tullahoma, Tennessee, is primarily devoted to the development and testing of propulsion systems and to aerodynamic testing. The 16-foot supersonic tunnel of AEDC's Propulsion Wind Tunnel Facility is in the foreground, the transonic tunnel just behind it. The Rocket Test Facility and the von Karman Gas Dynamics Facility appear in the background.



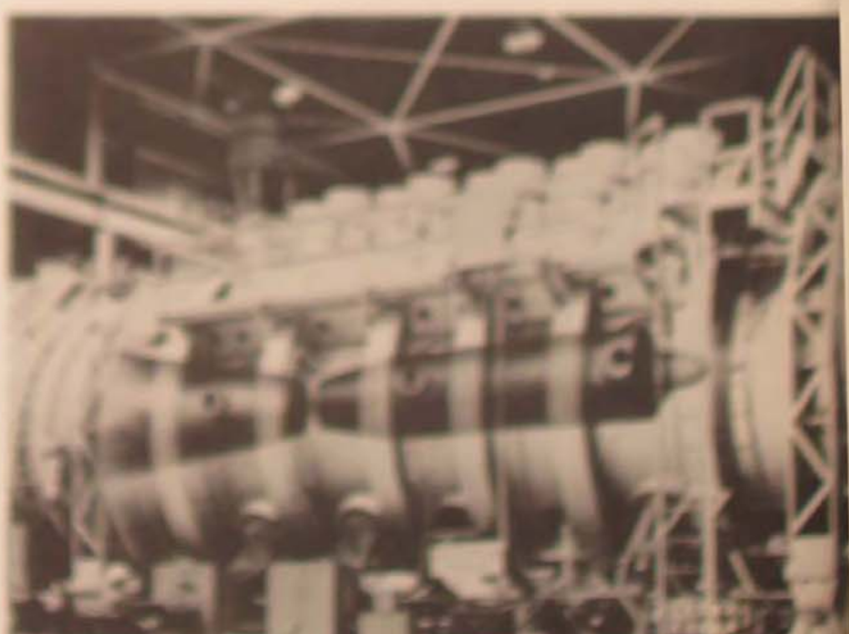
AEDC technicians prepare a jet engine for testing in the transonic circuit of the propulsion wind tunnel. The scavenging scoop (left rear) draws exhaust gases and flames from the engine, ducting them out of the closed-circuit tunnel.

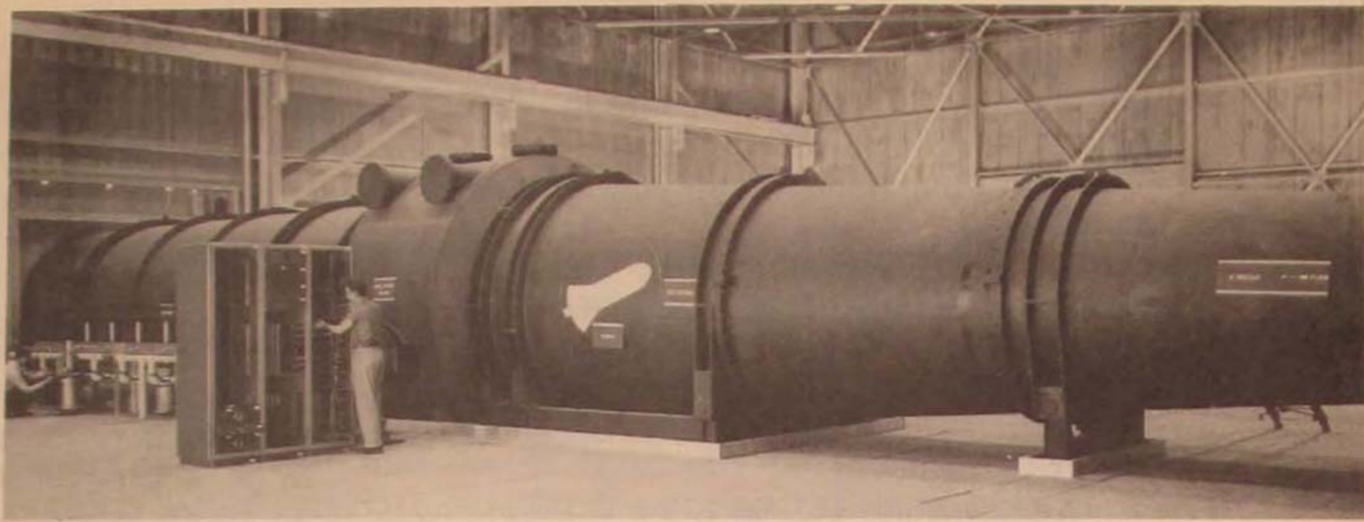
Inside the 16-foot supersonic tunnel. Efficiency improvements in the variable-geometry, second-throat diffuser yielded a 15% reduction of pressure ratio requirements to the main compressor, decreasing main drive power needs by about 25% at a specified test condition.



Ducting in the supersonic tunnel ranges from 27 to 45 feet in diameter. The inner wall is lined with square stainless steel panels stuffed with fiber glass pillows, which provide insulation to maintain any necessary high temperatures. The tunnel simulates altitudes to 200,000 ft, has a mach range from 1.5 to 4.5.

The ghost view shows a jet engine in the 12½-foot-diameter steel test cell of the Rocket Test Facility. The airflow simulates conditions of sea level to 80,000 ft and speeds of 1000-2000 mph; temperatures range from −120° to 650°F. Jet exhaust and flame (4000°F) are pumped out through spray-cooled ducts. More than 250 channels of data may be recorded as the engine undergoes simulated conditions of flight.





The 100-inch-diameter hypervelocity tunnel of the von Karman Gas Dynamics Facility, completed in 1962 at a cost of $3,979,345, is the first hypersonic tunnel large enough to test full-size nose cones, missiles, and rocket components. It can simulate altitudes from 150,000 to 200,000 feet and mach 15 to 20. Tunnel power supply has been operated at one million amperes.

Another link in the VKF continuous hypersonic circuit is the 50-inch-diameter mach-10 tunnel. The model can be pitched through an angle-of-attack range of ±15° with a straight sting and rolled ±180° about the sting axis. Model injection time is about 2 seconds.

Three of the tunnels in the von Karman Facility are continuous-flow tunnels. Air supply is from a nine-stage compressor system that is 1/8 mile long and is driven by electric motors totaling 100,000 horsepower. These tunnels can be run for hours at a time—thus the term "continuous-flow." One continuous-flow tunnel has a test section 40 inches square; the other two are 50 inches in diameter. They can therefore accommodate models much larger than those used in the blowdown tunnels. The mach-number range in the first of these tunnels is 1.5 to 6; the other two operate at mach 8 and mach 10. The first has a flexible nozzle with which the mach number of the airflow can be changed while the tunnel is operating. The other two have fixed axisymmetric nozzles.

Aerodynamic tests at mach numbers from 15 to 20 are made in the electric-arc-driven, hypervelocity-type tunnels of the "hotshot" type, so named by the engineers of ARO, Inc., who developed them. Hotshots 1 and 2 have 16- and 50-inch-diameter test sections respectively, whereas Tunnel F has a 100-inch-diameter test section. The components of a hotshot tunnel are a generator, an electric energy storage unit, an arc chamber, a nozzle, a test section, and a diffuser (vacuum tank).

The operation of a hotshot tunnel is as follows: First, the model is installed in the test section. Then a thin metal or plastic diaphragm is inserted between the arc chamber and the nozzle. Next, all of the tunnel except the arc chamber is evacuated down to near-vacuum conditions. Then the electric storage units are charged with energy. Hotshot 1 has a bank of condensers with a capacity of one million joules; Hotshot 2 has a large induction coil with a capacity of 10 million joules; the capacity of the Tunnel F coil is 100 million joules. When the desired level of the charge in the storage unit has been reached, an arc is initiated in the arc chamber. The resultant discharge raises the temperature and pressure of the gas (air or nitrogen) in the chamber to as much as 8000°F and 20,000 pounds per square inch. The diaphragm bursts, and the air flows through the nozzle into the test section, over the model and into the vacuum tank. Although the test runs in the hotshot tunnels are relatively short—1/20 of a second at most—special instrumentation developed by ARO, Inc., permits recording of the necessary data. In addition the flow over the model is recorded with high-speed motion picture and still cameras. The film is exposed at thousands of frames per second, as compared to 24 frames per second in standard commercial movie cameras.

In another approach to model testing at hypervelocities, experimental work is being conducted in the hyperballistic range. The model in this case can be equipped with telemetry instruments. It is fired in free flight down a closed range at velocities of thousands of feet per second, instead of having the airflow pass over a stationary model as in conventional wind tunnels. The telemetry equipment in the model transmits temperatures and pressures acting on the model during its flight to receivers outside the range. Two prototype ranges are currently being used in this work, and a large-scale range 1000 feet long is now under construction. Simple models have been launched at satellite velocity (18,000 mph) from VKF two-stage light gas guns.

Another VKF test unit is a prototype low-density, hypervelocity, continuous-flow wind tunnel. Its purpose is to provide simulation of aerodynamic conditions encountered by spacecraft at altitudes on the order of 200,000 to 300,000 feet and to help decide the most critical features of advanced test facilities. Rarefied atmospheres of certain other planets also may be simulated. The present tunnel uses a continuous plasmatorch that heats any of a variety of gases to the order of 4000 to 10,000°F. In a typical case nitrogen gas is heated to 8000°F, then expanded through a cooled hypersonic nozzle to a mach number near 10, where the model is mounted. Equivalent density altitude in the test section is almost 50 miles. Models glow cherry-red with heat despite conduction and radiation cooling.

• The Propulsion Wind Tunnel Facility is designed to test large-scale models and, in some cases, full-scale aircraft, missiles, and space weapons whose propulsion systems are in the mach-number range from 0.5 to about 4. In addition a propulsion system can be mounted for testing in its nacelle, pad, wing section, or body of the aircraft, missile, or space weapon, just as it would be mounted in actual flight. Altitude conditions ranging from sea level to well above 100,000 feet can be simulated in the propulsion wind tunnel.

The propulsion wind tunnel, as a facility, has two 16-foot wind tunnels—the transonic circuit and the supersonic circuit—and one-foot model tunnels of each. The transonic circuit operates in the range from mach 0.5 to about 1.6, and the supersonic circuit operates from mach 1.5 to about 4. In over-all design they are basically the same. The two large wind tunnels have removable, interchangeable test sections, which are an integral part of the tunnel when in place. Each circuit has its own compressor. Both are driven by the same system of motors. The interchangeable test sections make it possible to prepare for one test while another is being run in the tunnel. Thus tunnel shutdown time between tests is shortened considerably. The common motor drive system permits operation of both tunnels simultaneously under certain conditions. For peak operation of either tunnel, however, the entire motor drive system is connected to the compressor in the one tunnel.

Airflow, which reaches velocities between 100 and 200 mph in the ducting both upstream and downstream of the test section, is guided smoothly around the corners of the tunnel by giant turning vanes that resemble oversize, vertical venetian blinds. The air, which has been heated by friction and compression, also passes through a bank of water-cooled baffles before it goes into a stilling chamber and thence through a flexible nozzle, which regulates the velocity to the desired mach number, into the test section.

The test section itself has perforated walls in the transonic circuit; that is, the walls, the floor, and the ceiling have thousands of holes in them. And it is surrounded by a plenum chamber. Some of the air flows through the holes in the walls into the plenum chamber and is run back into the circuit downstream of the test section. This arrangement prevents shock waves, inherent to sonic and supersonic flight, from reflecting off the walls onto the model.

Since these two tunnels are closed circuits, a scavenging system was devised and installed to remove exhaust gases from the tunnel air when operating propulsion systems are tested. The scoop for this system is located directly behind the nozzle of the propulsion unit being tested. The scoop leads into ducting which in turn leads to exhausters in the Rocket Test Facility. The exhausters suck the exhaust gases out of the propulsion wind tunnel and through a cleaner before they are forced into the atmosphere. At the same time dry, uncontaminated air is fed back into the circuit through a large silica-gel drier in the same quantity removed by the scavenging system.

The flexible nozzles in these tunnels control only the velocity of the airflow through the test section. The tunnels have movable stings or supports on which the test objects are mounted. To simulate diving and climbing, the sting is manipulated so that the test object itself is rolled or tilted up and down. Just as tests are now run on models in these test sections, so were tests run on models of the test sections themselves before construction began on the actual tunnels. Moreover the two one-foot-square model tunnels—the transonic and the supersonic—are being used today to run tests on small-scale models of aircraft, missiles, and space weapons.

Some of the recent achievements at AEDC include the discovery of the "chuffing" phenomenon which added unwanted thrust to rockets after shutdown, the investigation and correction of numerous nozzle failures, and the discovery and solution of the base recirculation problem. This problem was caused by hot exhaust gases circulating so that they impinged on the missile structure between and just forward of the nozzles to the extent that local structural failures occurred.

Atlantic Missile Range

The Air Force Missile Test Center (AFMTC) at Patrick Air Force Base, Florida, develops, operates, and maintains the well-known Atlantic Missile Range (AMR); conducts missile and space vehicle test flights; and collects and evaluates test data for Air Force, Army, Navy, NASA, and other agencies as directed by the Secretary of Defense. The AMR is a national test facility (rather than an organization) over which AFMTC, as a part of its mission, has been assigned executive management responsibility. Geographically, it encompasses an operational area stretching from the United States mainland at Cape Canaveral, Florida, beyond South Africa to 90° East longitude in the Indian Ocean. AFMTC management and support activities are largely concentrated at Patrick AFB, while actual missile assembly, launch, and flight-test activities are accomplished at Cape Canaveral Missile Test Annex (CCMTA) 18 miles to the north.

When a missile is delivered to the Missile Test Center, it goes through a static test to recheck its operating functions on the ground. In early firings, a test missile contains only the parts needed for it to fly—the airframe, engine, and a guidance system. These tests show how the structure holds up under strain, how the guidance system reacts to instructions, how vibration affects the plumbing, wiring, and other subsystems. After work on the basic elements has been completed, other parts are added until the complete missile is ready for testing. In preparation for actual firing of a missile, all valves, electrical connections, instruments, circuits, tanks, and hoses are checked individually. When the individual part checks have been completed, the testing turns to subsystems and then to the entire system. All these tests and checks are performed before the countdown actually begins.

Cameras play an important part in tracking. The most sophisticated equipment in the camera network is the recording optical tracking instrument used in the ballistic missile and satellite programs. Its function is to photograph the actual performance of the missile—its flame pattern, stability, stage separation, etc. With a 24-inch aperture and 500-inch focal length, it can take a picture of a baseball 8 miles away and has taken one of Sputnik II in space. A system called Azusa is used by AFMTC for high-accuracy measurements of a missile's deviation from the flight plan. This equipment measures direction cosines to an accuracy of two parts per million and can detect change in position of 15 to 30 feet at a range of 500 miles. The Azusa system, located at Cape Canaveral, can collect precision data on missile position and velocity at the rate of ten impulses per second with exceptional accuracy. This information is gathered by eight ground antennas housed in pressurized radomes. It is then fed into high-speed digital computers. In addition to its use in gaining velocity and position information, Azusa is also used for safety purposes, since it provides a continuous prediction on where a missile will impact at any given instant should its flight be terminated.

Facilities of the Future

The requirement for new facilities cannot be safely swept under the rug and forgotten. Despite nearly sixty years of experimentation and millions of flight hours of experience, the point has not yet been reached where even the simplest aircraft can be designed and built to meet theoretical specifications without tunnel and other verifying and corrective tests. The T-37 is only one illustration of the gaps that still exist in our knowledge of aerodynamics. This aircraft was in no way an advanced state-of-the-art model; it was designed for a performance envelope similar to that of the P-51 of World War II or the early P-80. One specific requirement was that it have good spin characteristics. In flight tests it proved to have such bad spin characteristics that recovery could not be accomplished, and both pilot and test vehicle were lost. Extensive tunnel tests of the spin eventually led to a fix, including, among other things, strakes on each side of the nose.

Compared to our knowledge of aeronautics, our knowledge of space sciences is insignificant, and it is also true that the space environment is considerably more unfriendly than the air environment. It should never be overlooked, however, that the common reference point for starting and finishing both air missions and space missions is the earth. This means that space flight does not in any way reduce the requirement for aeronautical facilities; in fact, it requires more advanced aeronautical facilities than ever before because of the hypervelocities necessary to escape and re-enter the atmosphere. Future aerospace facilities must be capable of simulating the atmospheres of other planets as well as of our own, but this must wait until the composition of these other atmospheres is verified.

Civilian aeronautical research and development facilities need only ensure that man and machine make a safe flight—a comparatively simple problem. By contrast, the military mission adds to that requirement all the traditional military requirements—super performance, ease of maintenance, ruggedness, rapid response, reliability, long life, resistance to enemy action, etc. Therefore Air Force technical facilities must be provided to test not only the basic vehicle and power plant but also the combat capability of the entire system. This includes the conventional military reconnaissance devices; detection, tracking, and interception equipment. To provide such facilities is a technical challenge to the United States almost equal to that of the weapon systems themselves.

There are several obvious predictions that can be made about future facilities. They will be expensive, large, and noisy and will use large amounts of power, water, etc., and it will be hard to get them authorized and funded in time to be of maximum value. Less obvious, perhaps, is the prediction that many of these facilities will simulate atmospheric rather than space environments. There are several reasons for this:

(1) All missions start from the earth and must penetrate the atmosphere even on a one-way mission into space.

(2) All manned missions must include a return through the atmosphere to the earth.

(3) Most weapons as well as reconnaissance and communications systems must operate through or in the atmosphere to be effective.

(4) Other planets have atmospheres that will affect military operations there and that must be considered in the development of military systems.

(5) The current aerodynamic technology is not complete for conventional aircraft, and, even if it were, it would not be applicable to the unconventional shapes and power plants of aerospace vehicles.

Specific future facilities have been described in the various long-range plans prepared by the Air Force Systems Command, some of which will be mentioned here as examples.

The Aerospace Systems Environmental Chamber, Mark II, is designed to simulate the space environment and is to be large enough to test complete aerospace vehicles. The main chamber will be a spheroidal vacuum vessel about 200 feet in diameter and about 170 feet from floor to ceiling. The entry lock will be a horizontal cylinder about 70 feet in diameter and about 130 feet long. The vacuum system will include roughing pumps, diffusion pumps, and arrays of helium-cooled cryogenic surfaces. The vacuum system is expected to produce pressures as low as 10^{-8} mm of Hg (torr) or the equivalent of about 250 miles altitude. The heat sink to simulate cold black space will be provided by the liquid-nitrogen-cooled walls (100°K) and the cryopumping surfaces (20°K). Solar simulation and earth radiation and albedo will be provided (130 watts per sq ft over a 60 x 55 ft area and 37 watts per sq ft respectively). The Mark II is expected to cost $156 million.

A series of wind tunnels is planned to cover the flight spectrum from mach 10 to escape velocity (approximately 36,000 ft/sec). These will be designed as rapidly as the state of the art permits. At present the first two are proposed for immediate design and construction. The first, called the TTT (true temperature tunnel), will provide simulation from 3000 ft/sec between 50,000 and 150,000 feet altitude to 13,000 ft/sec at 250,000 feet. This tunnel will be used to test recoverable boosters, the aerospace plane, X-20 Dyna-Soar, supersonic transport, supersonic ramjet, and supersonic combustion, as well as others. The second tunnel planned for the near future is called LoRho. The name is derived from the Greek letter *rho*, which is used to represent pressure, hence a low-pressure (high-altitude) tunnel. LoRho will simulate velocities from 9000 to 28,000 ft/sec at altitudes between 200,000 and 400,000 feet. To provide the heat input, 100 megawatts will heat the air to 11,000°K. From these specifications it can be appreciated that this facility is at the fringe of the state of the art not only in wind tunnel design but in structural materials, electric-arc technology, and instrumentation as well. This tunnel is planned to have a potential to grow with the advancing technology and will eventually extend its velocity range to 36,000 ft/sec or escape velocity. Like TTT, the LoRho will provide test capability for the aerospace plane, Dyna-Soar, and other advanced vehicles. Planned for later is a HiRho facility having a velocity performance similar to that of LoRho but at a lower altitude, actually down to 100,000 feet. This tunnel would have to handle air at 26,000°K at pressures of 2 million psia. Such a tunnel is clearly beyond the current state of the art, but four years from today it may not be.

An orbital laboratory in near space, 100 to 500 miles altitude, will undoubtedly be one of our future facilities. The Manned Orbital Development Station (MODS) program will contribute to this facility.

It is well known that other nations have been working hard to develop a new super weapon, and one has claimed some success. For this he must have had special facilities. Our future facilities for the development of weapons must of course remain classified, but numerous small facilities will continue to be supplied to universities, industry, and others for basic research. The designs of these will follow the trends and breakthroughs in science. Just as the transistor and the laser have had a profound effect on laboratories and equipment, so will other breakthroughs generate a need for gravitational, magnetic, and other types of facilities.

We can be justly proud that Air Force facilities constitute a base for aerospace research that is by far the largest and most capable in the Free World. Since the Air Force mission is vital to the survival of the Nation as well as the Free World, it is mandatory that this capability continue pre-eminent.

Headquarters Air Force Systems Command

PEOPLE

Colonel Marcel Lind and
Major Clifford W. Muchow

In 1908, five years after the Wright brothers made their first flight, the progressive and safety-minded citizens of Jacksonville, Florida, took the first recorded action to make flying safer over their city. They passed an ordinance which read approximately as follows:

> No machine will fly over any part of the city of Jacksonville at a height of 10 feet at a speed in excess of 8 mph, or at a height of 20 feet in excess of 15 mph, or at a height of 50 feet in excess of 30 mph, or at any altitude whatsoever at a speed in excess of 50 mph.
>
> Air machines will be equipped with warning horns, braking devices, safety devices, and a parachute to let the machine down if the engine stops.
>
> No air machine will collide with buildings or structures, public or private.
>
> Funds are authorized to the city constable to purchase an air machine that he may pursue and arrest violators of this ordinance.

On 25 May 1961, in a special message on urgent national needs, the President requested the Congress to provide funds necessary to achieve a new national goal.

> I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.

Between the ordinance and the President's declaration to the Congress were fifty years of tremendous change in man's view of the use of the regions beyond the surface of the earth, and we now propose to move boldly on into an era of spectacular undertakings. An immediate, important question is raised. Are our personnel resources structured to meet the challenge?

In this new era one of the principal personnel resources to which we must direct our attention is the research and development team. Here we certainly no longer have an option of being routine in personnel practices and administration. Adequacy by older standards may be the mark of inadequacy today. The tried and true techniques of personnel management within military commands may have to give way to different approaches in order to meet the more stringent demands of space exploration. Under our new conditions we may well be faced with some imponderables. What new concepts for procurement of military scientists and engineers must be put in practice in the future? What new personnel management techniques are to be inaugurated? Can we borrow certain methods of personnel management from industry? Can we duplicate the policies of recruitment, job satisfaction, employee relationships, and manpower utilization that industry has found so successful? Or does industry have the same inherent problems of personnel management as ours and yet, by virtue of a free market to hire and fire, the ability to surmount them?

Our personnel policies, not only within AFSC but Air Force-wide, need to meet the challenge of the space age and the changing military environment. Attention must be given to different procedures for recruiting officer talent, to different approaches for retaining officers, to the development of new controls for utilizing their skills after training, to the learning of new ways to promote dynamic leadership, and to the growth of new policies for recognition of the individual scientist and engineer.

And these policies will change. Gradually, inevitably, they will yield to a more enlightened over-all personnel management of scientists, engineers, and technical managers. Changes will occur in procurement, in assignment, in tour lengths, in work relations, in promotion, and in recognition. But our purpose here is not to argue for change or omnisciently predict the state of things to come. Rather we intend to provide some of the basic information about the scientific and engineering talent within the Air Force Systems Command, how it is used to support the mission, and how this resource of personnel is trained to the task of research and development. And lastly, we mean to show how this resource, educated to a high level of technical competence and experienced in the many facets of R&D management, provides the base line for those evolutionary changes that must appear in the future personnel system for the scientists, the engineers, and the technical managers. To this end, it will be profitable to review the role of the 70,000 officers, airmen, and civilians in the Air Force Systems Command who are participating in the technological conflict.

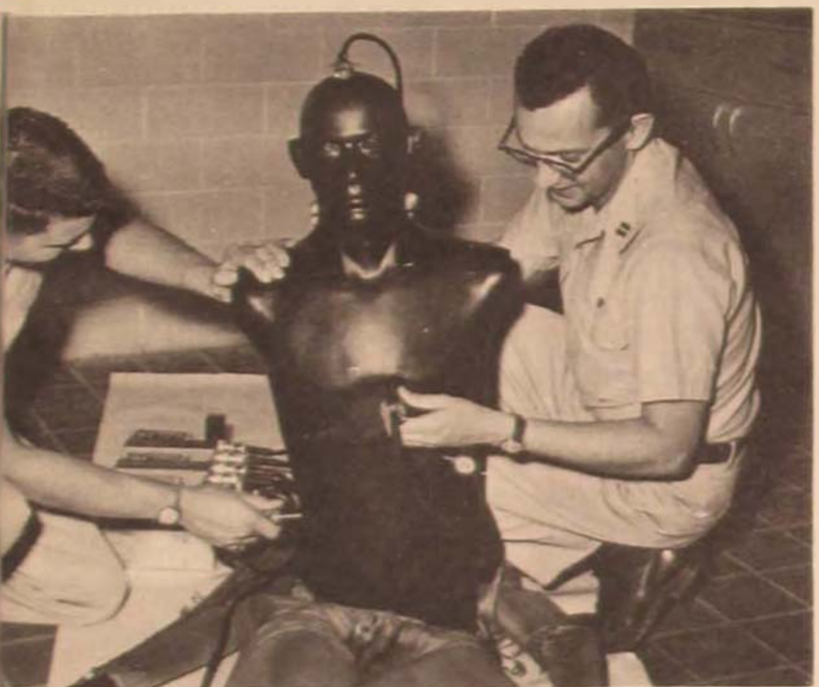
officer resources

There are approximately 8500 officers in the Air Force Systems Command, fairly evenly distributed between research and development officers (26XX, 27XX, 28XX Utilization Fields) and non-R&D officers (all other Air Force specialties).

The transition from the more parochial jobs held by the Air Force officer to an expanded technological practice in space has created the requirement for extensive scientific and engineering

Seventy thousand officers, airmen, and civilians in the Air Force Systems Command carry on the research, the development, the system engineering, and the test and evaluation of the new weapon systems of the Air Force. They may be found—

. . . performing systems checks on Agena B satellite vehicle—



. . . rigging a plastinaut with space-radiation instruments—

. . . sweating out countdown events before launching of an Atlas missile.

background and experience. Whereas the direct operational jobs performed throughout the rest of the Air Force can be accomplished by individuals who have received the bulk of their training and experience on the job, the new technological capability is dependent upon much higher levels of education coupled with military experience and training. The philosophy, policies, and organizational structure of AFSC are founded on clear recognition of the necessity to continue our strong bonds with the industrial and scientific communities and the need for a balanced Air Force/industry/institutional team. But these exterior resources do not negate our requirement for a strong in-house competence. Indeed, AFSC must have an in-house capability to lead, guide, and manage in order to obtain the most from the industrial and scientific potential of the Nation for application to Air Force needs.

Our AFSC research and development officers play a paramount role in maintaining the technological supremacy of our nation. They constitute the most highly trained and most diversified of scientific and engineering talents, the ones most wanted by industry. This role—whether as nuclear physicists or qualified research and development directors—demands the highest academic skills. It is unrelenting in its pressure, and it requires the greatest managerial acumen. The architect of the future Air Force could well be the fully qualified R&D officer, to whom is entrusted the millions of dollars needed to carry on the research, the development, the systems engineering, and the test and evaluation of the new weapon systems of the Air Force.

To provide insight into typical job functions as related to the research, development, test, and evaluation of military systems, it may be helpful to look at a representative research job, a typical development job, a site activation function, and a position in our foreign technology program.

The Research Job. An officer assigned as a nuclear research officer could find himself saddled with the responsibility of planning, programing, and managing the research effort in a nuclear power division within one of the AFSC centers. A typical nuclear research officer performs and supervises the performance of tasks in the application of nuclear power for Air Force requirements. He may work on propulsion, on auxiliary power, or on direct support systems. He concerns himself with adapting nuclear power to ballistic missiles and satellites. He plans applied research and development projects pertaining to nuclear interaction and transformation and resulting radiation, these projects to include scientific studies of isotopes, natural and artificial transformation and radioactivity, cosmic rays, and theory of nuclear structure as it pertains to nuclear power application. He determines the theoretical and mathematical possibilities of a problem and selects a method of approach.

A master's degree in nuclear physics satisfies the educational requirement for his job, and AFSC and Atomic Energy Commission experience is a prerequisite. This highly specialized officer is well qualified by education and experience to analyze advanced Air Force concepts in his area, and through his work he is responsible for an increase in the general store of scientific knowledge. Air Force officers capable of performing these functions are not plentiful. They must be properly identified and husbanded to guarantee the technological supremacy of the United States Air Force.

The Development Job. A typical job related to the development aspects of a future military system is that of research and development director, AFSC 2716. The task imposed on this officer entails over-all program management of a directorate in fulfilling established mission objectives. This includes maintaining management control and direction over Air Force and contractor resources necessary to provide the required ballistic missiles and propulsion systems; over the design changes and system integration of ground support equipment; and over the conduct of launch operations, launch support, communications control, and tracking and data reduction—throughout the development phase. All functions must be properly time-phased according to schedule and integrated with a payload to be furnished by another Government agency. A college degree in guided missiles or astronautics is required for this particular position, plus prior R&D management experience. The incumbent of this job must have the ability to meet with high-level Department of Defense and contractor personnel. He must be proficient in management techniques and well informed in technical areas, and he should have previous experience in vehicle development and launch operations. The qualifications are high, yet the functions to be performed are likewise high. This job has no counterpart in any other Air Force command.

The Site Activation Job. Relatively new among Air Force jobs is the job of preparing and equipping an ICBM site, from design initiation to turnover for operational control to the Strategic Air Command. The tasks for the officer involved in this type of work may range from preparing all site activation documents to participating in the architect–engineer review of concept and design, to evaluating progress of the site activation program, to establishing proper sequence and method of assembling contractors' equipment at a site, to managing the PERT system associated with activation and checkout, to acting as a focal point for approval of costs inherent in site activation as a result of acceleration or time extensions. A project officer's job at a missile site may also encompass responsibilities of maintaining all plans and status of a missile weapon system, primarily concerning installation and checkout. In this capacity he analyzes problems inherent in activation, revises plans and schedules, and refers conflicts to the proper action agency. He prepares reports as necessary to document progress in problem areas. A degree in engineering with some related experience associated with the design, development, installation, and test or analysis of materials, systems, or ground support equipment would be desired.

The Foreign Technology Job. The weapon system engineer working within the Foreign Technology Division performs a role quite different from those of the preceding specialists, for he is concerned with the growth of foreign technology as it relates to our space programs. This officer might be faced with the responsibility of determining and reporting on the characteristics and capabilities of current and future foreign earth satellite exploration systems. He integrates the reported foreign technical information on elementary space systems, including data on launch and powered-flight vehicles, spacecraft, and command and control methods. He investigates the development of subsystems for these foreign space systems and analyzes components in order to determine foreign capabilities to build and operate earth satellite systems. The purpose would be to investigate the methods of operating space systems near the earth and of exploring the space environment. He advises Air Force agencies concerning the extent and type of effort required in support of these systems. In addition he provides intelligence to USAF planning agencies and intelligence evaluation agencies. He must have a definite competence in specific scientific, engineering, and mathematical disciplines, including knowledge of celestial mechanics, geophysics of the upper atmosphere, and geodetics. He should have experience with capsule recovery systems, and bioastronautics experience is desirable.

These four cited research and development jobs call for officers with greatly diversified education and experience backgrounds. Although the R&D and scientific career fields recognize this diversity, they were established in terms of broad general requirements rather than the prerequisites of individual jobs. To ensure that the jobs are filled with capable and knowledgeable officers, many factors besides education must be taken into consideration. The prerequisites for adequate job performance must be determined, spelled out, and subsequently utilized in the management of the officer corps in AFSC. No longer does the Air Force Specialty Code contain in its four digits all the information needed to match the officer to the job. Each supervisor must identify the characteristics needed to perform in the job and must codify or describe them to aid in the selection of officers who meet the unique job requirements. Using the job requirements to screen for the best-qualified officer—one with outstanding experience and education—should result in optimum matching of man to job. This technique has been used in AFSC for several years.

The jobs vary. They become more diversified as new programs develop, as new concepts of military systems materialize, and as new management techniques flourish. Nothing is static. A few years ago an electrical engineer might have been faced with a few problems in basic electrical communications from airplane to ground. Now that same electrical engineer is concerned with reflecting signals off satellites hundreds of miles above the earth. Whereas a contract involving a few thousand dollars may have been quite sizable a few years ago, now the R&D officer is responsible for millions of dollars.

This, then, is the officer corps of the Air Force Systems Command. These officers, along with airmen and civilian personnel, provide our capability to perform the technical analysis of all aspects of research, development, test, and evaluation within AFSC today.

future requirements for officers

A matter of more importance, perhaps, than the use of today's Air Force officers is the need to provide for the required officer abilities in the future. Because of the considerable expansion of the AFSC mission and the tremendous growth in the technical complexities of the command's responsibilities, there is an increasing need for new knowledge and skills and new managerial techniques.

Comparison of AFSC's R&D officer inventory of July 1961 with that of May 1960 shows some gains in younger officers who have studied at the Air Force Institute of Technology. A continued healthy input of officers with less than ten years of military service as well as a high education level is necessary to maintain a favorable manning structure.

If the Systems Command is to continue to satisfy the Air Force's changing requirements, first there must be a plan for the job to be

Civilian and military engineers check figures on aircraft performance evaluation.

done, then the plan must be translated into manpower requirements (how many, what kind, when), and finally a program must be developed to provide the essential officer professional and technical competence. The future security of the Free World and the United States will depend in great part on the mission performance of the Air Force Systems Command and hence on the professional and technical competence of its officer personnel. For the foreseeable future, then, a major problem will continue to be the forecasting of officer requirements and the development of education programs to meet the changing and challenging tasks of the future.

Another major problem, and one that has been widely discussed, is the retention of the young, highly qualified officer. Many surveys have been made of this problem, many opinions advanced. It may well be that we have been in error in thinking of retention as a separate problem. Fundamentally the retention problem is the result of or another facet of a more basic philosophy.

The United States citizenry has not realized that in a cold-war situation the manpower needs have the same urgency as in a fighting war. Consequently the Air Force is attempting to man a deterrent force with men who do not completely understand why. To complicate the problem further, the military service has historically not been accepted as a "way of life" in this country. Thus a retention problem has resulted insofar as the junior officer is concerned. To him the "grass is greener" as a civilian in industry or in Civil Service. In either he feels that he can fulfill his obligation to his country. These questions then arise: Do we really have a retention problem? What is the difference if a person wears a blue uniform or civilian clothes as long as we get the job done?

The difference lies in the fact that the job may not be accomplished unless the Air Force has sufficient in-house technical competence and leadership to guide and direct the R&D effort toward support of the Air Force mission. This in-house technical competence is defined as the Air Force's ability to accomplish technical analysis of all aspects of our research, development, test, and evaluation programs. A long-range, continuing objective is to increase both quantity and quality of the command in-house technical capability to determine and establish requirements derived from advanced planning and systems research and to test the products of those technical programs against Air Force operational requirements.

If we find that the job is not being accomplished, then we must equate the retention problem to tangible incentives. Money or pay is not the whole answer, but a higher standard of living might offer a possible solution. Adequate housing, medical benefits, social and cultural opportunities, and the like are important considerations in the contemporary standard of living. Yet the so-called fringe benefits for the military have deteriorated until they can no longer be considered a substantial attraction to a military career. Problems that face AFSC today in the retention of technically qualified junior officers may well be the problems of other major air commands in the very near future. As systems entering the inventory are becoming more and more complex, there is a concurrent requirement for technically trained officers to maintain and operate them.

To stabilize the officer force through the reduction of officer losses and enhance the benefits of a military career, AFSC has embarked on a program of career motivation. Many actions are being taken to provide personnel orientation and indoctrination, supervisor counseling, application of human-relation factors, professional recognition of the individual, and the role of the Air Force family. It is from the resultant broadened base of young career officers that the bulk of future Air Force leadership in technical development must come. All efforts must be exerted to have a sufficient number of officers available to permit the Air Force through its selective process to choose its future leaders.

airman resources

There are 18,500 airmen assigned to the Air Force Systems Command. Although some of them provide normal support functions, others are in the forefront of the technological race for weapons supremacy. The problem of identification and retention of airmen qualified in these new skills is critical and unique in the development of new weapon systems. The entire concept of intercontinental ballistic missiles was without parallel in Air Force experience. This new military requirement clearly brought to light the need for new skills and techniques in the existing airman career fields. Further, the concept of local on-the-job training into these new skills could not provide the technical competency required. Complete new missile career fields were required.

Today airmen of AFSC are involved in such diversified programs as advanced test and evaluation of aeronautical, ballistic, space, and electronic systems and of bioastronautics. The airman forces are participating in direct mission functions in specific high-priority programs, including Dyna-Soar, Minuteman, Titan II, Blue Suit, and the 465L SAC Control System. Recognition has long been given to identification and retention of airmen possessing the necessary experience and capability to perform functions involving engineering design, development, testing, evaluation, and other specialized work in scientific laboratories. Highly qualified airmen can now be awarded a prefix that will identify their unique qualifications and ability to work beyond the skills called for in their job description. Even if these airmen are reassigned out of Systems Command, the retention of this prefix will provide easy identification in the event they are again required on a research and development project. Faced with a greatly expanded test and evaluation problem on increasingly complex systems, the command has been forced to augment its modest personnel increases by reassignment from its own resources. Intensive factory training, Air Force technical schools, field training detachments, and local OJT keep the airmen current within their assigned duties, and their technical competency continues to rise.

A serious problem exists in that highly technical airmen leave the Air Force for high-paying jobs with Air Force contractors or other civilian industries. Many of these airmen (first-term or career) have received highly selective training at Air Force contractor facilities at considerable cost to the Air Force. On their date of separation or immediately upon attainment of retirement eligibility, many of them go to work for the same Air Force contractor or civilian industry from which they received their technical training. For the airman it is strictly a matter of economics. Relief for this problem can come only through a strong career development program, completely supported by all echelons of Air Force management, and through Congressional action to increase military pay scales.

Recent developments indicate that it would be advantageous to the Air Force to allow career airmen in highly technical skill areas to enter a college training program. After earning a degree, the airman would have a service obligation similar to that of officer AFIT graduates. These airmen would then be placed in positions requiring a high degree of technical competence rather than management ability. Under this program senior airmen would be placed in unit manning document (UMD) positions formerly authorizing captains or lieutenants. Working on the missile pad or in the laboratory, they would greatly enhance the "blue suit" test and evaluation capability. This method of increasing our test and evaluation capability has its counterparts in civilian industry, whose technicians have provided much of the work capability to the engineering staff. Continued development of the airman resource, particularly of those in the higher grades with technical and semitechnical education, can do much to increase the technical competence of Systems Command and the Air Force.

civilian resources

The Air Force Systems Command is the second-largest employer of civilians among all major commands and the largest employer of professional personnel. The 37,000 civilian AFSC employees represent 58 per cent of the personnel resources of the command. They occupy positions in or associated with practically every branch of engineering, science, and administration. Of the total, 13.6 per cent are scientists and engineers, 22.4 per cent are in technical support positions, and 29.2 per cent are in the contract administration function. The remainder perform managerial, administrative, and nontechnical support duties. Though approximately only 5000 in number and a small portion of the command strength, these scientists and engineers represent the major technological resource. Their specialty distribution is as follows:

intelligence & operations research	68
biological science	71
psychology	170
mathematics & statistics	270
mechanical engineering	465
aerospace engineering	505
physical science	569
electrical & electronic engineering	1305
other engineering fields	1344

The experience level of the professional group ranges from the recent college graduate in trainee status to the experienced individual who may be serving as project manager, program director, or system project officer. The last study of educational levels indicated that approximately 71 per cent of the group held bachelor degrees, 11 per cent master degrees, and 4 per cent doctoral degrees. The educational level has risen constantly over the years and is expected to continue to do so.

It is anticipated that AFSC's civilian personnel needs will continue at about the present level for the foreseeable future, and recruitment efforts will be principally on a replacement basis. The critical need will continue to be for experienced scientists and engineers. A recent example of specialized needs was a requirement for ceramic engineers and ceramists. Establishment of a ceramics and graphite technical evaluation center at the Aeronautical Systems Division created an urgent demand for a number of experienced specialists to staff the function. Although the number of ceramic engineers required was not large, the scarcity of qualified individuals in this field made recruitment extremely difficult.

Such new program requirements have not been accompanied by increased manpower authorizations. The result has been a continual evaluation of the composition of the work force, with consequent changes to meet current needs. As an example, program changes at one field division produced a demand for 600 additional scientific and engineering personnel. As this requirement had to be fulfilled within existing resources, the immediate need was met by abolishing 600 nontechnical positions for which the need was less acute.

Most manpower reports indicate that during the next ten years the demand for technical manpower in this country will exceed the available supply. The principal effects on AFSC of the shortage of scientists and engineers have been, and will continue to be, the extensive organization and effort required for recruitment, the extensive utilization of entrance-level engineers to meet requirements for persons with higher levels of training and experience, the un-

Officers study the progress of a satellite launched from Vandenberg AFB while performance data are read out and plotted on central control boards at the Satellite Test Center, Sunnyvale, California. This command and control facility electronically keeps continuous tab on satellites during their orbits about the earth.

favorable competitive position of the command in terms of salaries as compared with industry, and extreme difficulty in filling from outside recruitment sources our positions above the journeyman worker level.

A number of recruiting techniques have been utilized within AFSC in an effort to attract the needed civilian work force. Each year our recruiting officers and technical personnel visit over 100 universities in all parts of the country in a college recruitment program. Approximately 160 graduates a year have been obtained through this program. A related but broader activity is the new AFSC–AFLC Joint Professional Placement Office in New York City. This office maintains effective relations with the professional communities in universities, professional societies, civic organizations, and industry for the purpose of recruiting and placing civilian personnel for professional, technical, and managerial positions throughout the two commands. This activity supplements but does not replace the recruitment programs of individual installations. Some field activities have made use of the new authority to utilize paid advertising in news media. A study conducted by one personnel office indicates such advertising can produce very satisfactory results.

While the competition for scientific and technical manpower has been steadily mounting, the Air Force Systems Command has been constantly on the alert for means other than recruitment of new personnel to meet its requirements. For a number of years AFSC has been developing the existing staff by giving members the opportunity for advanced education through its resident graduate study program. These education programs have been established on base at many of our research and development installations. Under the academic direction of leading universities, it is possible for employees to work and at the same time engage in advanced study. Courses related to the work assignment are conducted during working hours as well as after working hours. When installations are located near universities such as Harvard, Massachusetts Institute of Technology, University of Dayton, etc., attendance in regular classes on campus is arranged. In the past decade approximately 14,000 man-courses were offered under the graduate study program, which included virtually all fields of science, engineering, administration, and management.

The rate of technological change is clearly evident. The necessity for updating even recent college graduates in the state of the art has long been established. Since 1952 the Air Force Systems Command has attempted a program for keeping its personnel abreast of the highly accelerated technological advancements of the day. This program consists of sending individuals to short specialized training courses of one to three weeks' duration offered by universities, technical societies, and consultant organizations. In a typical year approximately 500 AFSC employees engaged in scientific and technical activities have attended 120 such specialized courses given by 29 universities and 7 societies and commercial organizations. College graduates of earlier years very often find it difficult to keep up with the changing technology because of the inadequacies of earlier college curriculums. Therefore it has become necessary for the command to supplement the education of these people through the graduate study program also. For example, most of the individuals who graduated ten to fifteen years ago in the fields of electrical and electronic engineering have not had sufficient mathematics to meet today's requirements and are able to keep abreast of development only by enrolling in special short courses. Earlier mathematics majors lack knowledge of such important subjects as topology and mathematics theory, and earlier students in statistics often need an important course on the theory of probability.

Opportunity is afforded employees of unusual ability and promise to pursue up to a full year of research and study at the graduate level. Some of these programs are sponsored entirely by the Air Force Systems Command while others are cosponsored by the Air Force Systems Command and an outside agency such as the National Academy of Sciences or the Alfred P. Sloan Foundation. The experimental program began modestly in 1956 with 2 individuals attending universities on a full-time basis. In 1961 there were approximately 33 AFSC civilian employees attending universities throughout the Nation. Participants in these programs obligate themselves to remain with the Air Force for three times the period they will be in school.

The importance of bringing our people in contact with scientists and scholars of outstanding national and international reputation is also recognized. Seminars designed to serve this purpose constitute an important integral part of the Air Force Systems Command's special development program. Employees participating in such seminars are afforded the opportunity to come in contact with world-renowned authorities in science and technology.

AFSC considers itself in the forefront of Government agencies and industrial companies that recognize the importance of training their civilian executives of today and tomorrow. We have sought out every available opportunity for internally sponsored programs and have also exploited opportunities for the development of civilian executives at leading universities and other organizations such as the American Management Association and Brookings Institution. Approximately 8.2 per cent of the AFSC civilians of GS-13 and above participated in various executive development programs during the fiscal years of 1959, 1960, and 1961.

To accomplish this command's vital role in national defense, it is necessary not only to obtain but also to retain individuals who possess the capabilities to contribute to the mission to the highest degree. Adequate pay is, of course, a primary factor and one which is beyond the control of the command or the Air Force. Recent legislation adjusting Federal salaries places AFSC in a more favorable competitive position in relation to private industry, however. One means of helping to retain capable personnel and one which can be effected within our resources is to ensure that individuals who do contribute significantly to the mission are accorded the honor and recognition due them. Each AFSC field commander has been directed to provide for a periodic review of the accomplishments of his organization, identification of the individuals who have contributed to the accomplishments, and determination of whether the accomplishment and contributions merit formal recognition.

In further recognition of outstanding achievements by its personnel, the Air Force Systems Command established the AFSC Award for Scientific Achievement in January 1962. The award is given annually to acknowledge outstanding scientific and technical achievements by military or civilian personnel in aerospace research and development or in administrative aspects of research and development programs. In addition, three annual AFSC Management Awards were established in April 1962 for military and civilian personnel. These awards are given respectively to the individual who makes the most distinguished contribution to management in a position of great responsibility, to the individual who makes the greatest contribution to the advancement of any of AFSC's programs, and to the individual who makes the greatest contribution to management entirely in the field of procurement and production.

Other techniques used in the personnel retention program include recognition of the impact of the "man in the job" in the classification of positions; experimentation with the supervisor-centered classification plan whereby line supervisors, under the guidance of personnel specialists, are trained to classify positions they supervise; and utilization of the generalist approach in the personnel servicing of positions. Great stress is placed upon the attitude of personnel specialists in the performance of their function, with the emphasis focusing on application of correct personnel management as one of the important tools that form an integral part of line management.

Increasing sophistication of future weapon systems is the mark of the future. An increasing number of man-years of highly qualified talent within the Air Force, within Systems Command, and within contractor operations will be required for this growing sophistication.

Along with technological sophistication must inevitably come refinement of personnel policies for recruiting, training, and retaining the necessary personnel to develop future weapon systems. Many approaches have been tried on recruitment, pay and housing, career development, education and training, utilization, and prestige for the total personnel force. Some of these have been successful. Yet to be found are remedies for those personnel ills which still face Systems Command and the Air Force. Additional avenues of personnel policy will be explored by resourceful commanders and supervisors.

The personnel resources of Air Force Systems Command, whether on board or programed for the future, constitute the command's most important asset. Upon them rests the future. To them belongs the challenge of the space age and the technical supremacy of the United States Air Force.

Headquarters Air Force Systems Command

part V

THE FUTURE

No crystal ball can illuminate the enigmatic future for us, nor can even a Nostradamus do more than guess what future events man will bring to pass in his world and in the space around it. Were we but wise enough, perhaps by heeding the elusive lessons of history we could glean valuable instruction for the future. Furthermore, if the past was harbinger of today, then in the present we should be able to detect faint glimmers of tomorrow. Accordingly, it seems safe to say man's destiny leads him into deeper reaches of space as his present technologies and near-future programs more and more impel him spaceward. As yet the pathway is only suggested, not defined, but each achievement—each failure too—casts light and helps show the way.

TOMORROW'S ROLE IN AEROSPACE

MAJOR GENERAL WILLIAM B. KEESE

A MILITARY force can be an effective deterrent only if it has the ability to win wars of any scope and intensity. The U.S. Air Force now has that ability. But continuing progress in military technology must continually threaten any current military superiority. The greatest danger from hostile advancements will lie in losing mastery of aerospace. Whatever the changing environment of aerospace operations, the Air Force's prime mission will continue to be maintaining aerospace superiority in support of national policy and providing effective defense of the United States. This means that the Air Force must be able to fight both "big wars" and "little wars." We must not allow the excitement and potential of space operations to overshadow the need to develop and maintain forces for more conventional warfare.

In short-term perspective, we can see the directions in which developments will lead in the familiar areas of aircraft and missiles. For the long-term future, however, one of the most serious threats lies in the technical breakthroughs which will surely occur but which cannot now be identified. Satellites and spacecraft will play increasingly important roles in aerospace operations. Perhaps by the next decade lunar and interplanetary explorations will become routine and affect national military policy. It is a safe assumption that breakthroughs will occur in the realm of space flight, and it must be the United States which achieves the significant breakthroughs.

Yet we must also envision a future Air Force which will be, in part, conventional in present-day terms, its effectiveness ensured through continual modernization and refinement. Manned aircraft will continue much as we know them now, changed only in detail to carry out whatever specialized missions are assigned them. These manned forces will have tactical and support roles as well as a vital part in the strategic mission, but they will be complemented by other different types of weapon systems, both manned and unmanned, and as yet many of these systems are only dimly defined. Future generations of weapons will evolve from space programs which now are assuming ever increasing importance.

Historically the United States has pioneered in the technologically possible. Already we have taken a long jump forward in the progress made by the national space program, which has the mission assigned by the President to "take a clearly leading role in space achievement." A major step will be manned lunar landing in this decade. A revolution has begun which will lead to human advancement as yet undreamed of, and the Air Force without doubt should play a full part in bringing it to fruition.

The technological foundation for all future activity is in fact being laid today. By intelligent planning and by vigorous support of study, research, and development in all fields of scientific endeavor, we can ensure that a broad technological base will exist when needed.

If we are to realize maximum value from our potential, we must consciously take full advantage of the current technological explosion. Historically, as nations have become more highly organized, more thickly populated, and technologically more advanced, and correspondingly more wealthy, they have extended their control over their physical environment. This pattern should also prove true in the space age; and, based upon a scientific foundation, the advances will be beyond the grandest dreams of our grandfathers.

Yet we should remember that many nations have failed to achieve their full potential because they did not recognize the full significance of the state of their technology. Almost 1300 years before Christ the Hittites developed horse-drawn chariots and used them in a mass attack to surprise Ramses II of Egypt. Ramses must have known that his enemy was using horse carts, but he failed to adapt to advanced war methods and adhered tenaciously to the use of mules and oxen. For his lack of understanding of the technology of his day, he paid the high price of a decisive defeat.

In our own day a mistake of great importance influenced the outcome of our struggle with Nazi Germany. The Germans' misunderstanding of the value of air power and their continual misuse of it as a weapon of war contributed much to the Allied victory. Notably Hitler and Goering failed to realize the significance of strategic air and abandoned the battle of Britain at the crucial moment when it was swinging their way. On the other hand Allied use of air power was effective, well planned, and exerted great weight in the strategic victory.

How do such lessons apply to our future? With regard to space we now stand in a position of tremendous power. We have made great progress, militarily, economically, and culturally. Yet our air and aerospace advances have been made possible by technological breakthroughs visualized first by a few foresighted innovators—the Langleys, the Wrights, the Billy Mitchells, the Robert Goddards. Men of their day debated the practicality of theories then unproved but which in a short time came to fruition. As late as February 1939 the great Enrico Fermi said, "Whether the knowledge acquired of the possibility of a chain reaction will have a practical outcome, or whether it will remain limited to the field of pure science, cannot at present be foretold."

Is not a similar situation now before us? One needs only to consult a few scientists to receive opinions poles apart concerning the significance of space exploration, the value of lunar colonies, or the possibilities of manned flight to Mars. Yet who today can certainly affirm, for example, that planetary colonization is absurdly impractical? Or who can positively deny that other planets might furnish a vast wealth of raw materials to replenish the sometime exhausted stores of the earth?

Space Exploration

The exploitation of space will most probably alter the political and military as well as the economic and cultural alignments of our present world. Each of these potential aspects of change has widespread significance for the Air Force.

political-military aspects

The political-military potentials clearly lend great urgency to the United States space effort and have led to a national space program on a high-priority basis. In some respects the future already is here. Space systems which only five years ago were labeled fantastic now are possible. And after an innovation becomes technically possible, practical application usually follows quickly.

The first major step in the space age was the development of ballistic missiles with intercontinental range. The logical progression would lead to indefinite extension of today's ICBM range. Whether the Soviets now have such an orbital bombardment system is not known, except as implied by Mr. Khrushchev's veiled remarks. Many Americans of great scientific stature strongly urge that we develop such a system ourselves; others of equal stature disagree as to the value of such a development. The important thing is that we recognize the possibility, investigate fully the potential, and then base the actual decision upon firm scientific evidence and sound military judgment.

One contingency now is historic fact. The early development of an ICBM by the Soviet Union had a decided impact on the balance of power, political and military. Possession of the IRBM, and the potential possession of the ICBM, complemented with practical nuclear warheads and brash propaganda exploitation, enabled the Soviet Union to improve substantially its strategic position relative to the West. The recent Soviet development of higher yield weapons coupled with large booster capability has provided the means of an additional significant improvement in strategic capability. In the meantime the Soviet Union had gained a political-military advantage by winning a technological first with Sputnik and went on to enhance that advantage by the manned orbital flights of the Vostok series. The prospects multiply.

Future bases in space may indeed become essential insurance for the survival of both our strategic force and our command and control. Manned satellite systems could provide command and control, and satellite-based bombardment missiles could provide global coverage. The uses of satellite systems for reconnaissance, surveillance, mapping, navigation, and meteorological forecasting are well recognized. Variations of space-based systems might include those which have been assembled in space for long-term flight. Such space bases probably would be manned. Rather than being purely operational bases, they could be used in peacetime for component testing under realistic conditions, for crew training, or as departure points for voyages into deeper space. While the significance of an effective force "hidden in the vastness of space" is yet to be evaluated, the potential of military operations in space using true spacecraft cannot be denied important implications.

Can one yet truly speak seriously of flight into deep space where distances are measured in light-years? A staggering scientific development would be required. Yet what hidden military capabilities may become possible by the solution of the multitude of problems attendant to many new concepts? Radiation weapons effective against any threat, coming either from the atmosphere or from space itself, may appear, perhaps as stationary devices directing an intense energy ray toward hostile spacecraft, with sufficient energy to destroy them in fractions of a second over ranges of thousands of miles.

The question is, are such developments technically feasible? Maybe, maybe not. Yet in this as in other potential projects the mandate is clearly summarized in the words of one scientist: "No one can say that we will or won't make discoveries. There is only one thing that can be stated definitely: We can't afford the risk of not trying." These words are in fact pertinent whether applied to the more conventional weapon system coming in the near term or a future concept which might include manned space stations in permanent orbit, complete with spacecrews, an arsenal of weapons, and the ability to rendezvous with other spacecraft.

In studying the political and military aspects of future operations in space one should consider the possibility that if armed conflict does occur it could conceivably be limited to space. Many feared that the Korean War eventually would escalate into general war. It did not because none of the participants was willing to permit it to do so. Might not deep space become the Korean battlefield of the next century? The capability to conduct space warfare need not be contrary to the American desire to continue to use space for peaceful purposes, for nations going into space must be prepared to stand up for their space rights or surrender them abjectly. We are not prepared to surrender.

economic aspects

The economic aspects of space exploration are of vital concern to the military services as well as to the Nation as a whole. One of the values of advancing space technology will be its effect of speeding the national development. Nothing will suffice but national planning on a tremendous scale. Already the budget for space research, including both the civilian and military components of the national program, is about $5 billion. Add to that figure the bill for procurement of missiles, and it increases substantially.

This is merely the first installment. It already has resulted in an astronautics industry equal in economic importance to the automotive industry. Even the most conservative estimates today lead one to believe that it will double in a decade or less. Yet before there can be a monetary profit (from devices such as commercial communications satellites) the national investment will probably be at least $100 billion. Even such an amount would be a reasonable price if that is what we must pay to maintain our own values. There is, of course, no sense in planning systems which the Nation clearly will not be able to afford. Current plans should be periodically re-evaluated in terms of cost of alternatives and projection of available funds.

Such expenditures, with corresponding investments of manpower, require the marshaling of national resources on an unprecedented scale. However, economics and techniques are changing. The day of the production line may have passed as far as space is concerned. Traditionally, several production workers have been employed for each engineer on the payroll. This ratio is in the process of reversal. Increasing emphasis upon quality of personnel and the need for fewer items of hardware—but items that are infinitely more complicated and sophisticated—are leading to greater cultural development of the entire American people.

cultural aspects

The cultural impact of the space program has two aspects: the effect upon Americans as a people and the effect upon the rest of the world and our relationship to it.

Increased technical complexities require higher levels of education for military personnel in all echelons. A future weapon system will be practical only if it can be supported by normal maintenance and operating personnel. We will meet this problem in two ways: by trying to reduce operational complexity of weapon systems and by increasing educational facilities within the military establishment.

The Air Force long has recognized the need for greater educational development, especially in scientific and technical areas. Today there are over 700,000 persons employed in the aerospace industry. Twenty-five per cent of these people possess a technical skill of some kind and ten per cent are qualified scientists or engineers. By 1970 the total employment in the aerospace industry may well have to be doubled, and it is estimated that more than 50 per cent of the total employment will be technical personnel. One result of the increased demand will be the requirement for a higher level of education for the average American as well as for the military services. The great potential danger in solving this problem is the temptation of introducing mass-production techniques into our university system, with probable deterioration in quality of graduates. This can be avoided only by stringent quality control.

The cultural impact of space developments upon international relations will be substantial also, both for nations which participate actively and for those profiting indirectly. From these developments will come new communications systems, improved geodetic mapping and navigation systems, and improved weather prediction on a global scale, as well as other equally important capabilities. All peoples and all nations can profit to some degree. Consider the impact of communication developments alone upon the newly developing nations of Asia and Africa and upon peoples in remote portions of Central and South America and Oceania. If especially selected television programs could be broadcast from the United States and received in all parts of the world, a great advantage could be gained in the battle for men's minds.

Mention of cultural values to be derived from space explorations must include the advancements being made in understanding the human being and how to make him function better. Substantial contributions to the health and longer useful lives of human beings could be an early and welcome product. Another important accrual comes from the development or perfection of materials for use in the space age. Some are old friends made more usable; others are newly discovered or fabricated in the laboratory. They will serve many purposes. One pattern for achieving orbital space stations of substantial size, for example, is suggested by expandable materials that can be boosted into space and inflated there. In one way or another it is quite probable that future spacecraft will be designed to permit aerodynamic re-entry and flight after returning to the atmosphere from orbital missions.

The Air Force and The Future

Soviet technological and military capabilities have unquestionably influenced the size and composition of the present-day U.S. Air

Force and the direction of its development programs. Now the demonstrated Soviet competence in space technology has application to many military systems and is a clear signal of danger ahead. We must be prepared to respond to a variety of threats without delay.

This continuing state of readiness can be derived only from a broad program of basic and applied research pressed forward into the widest possible exploration of potential solutions for numerous requirements. These investigations should be oriented to provide maximum useful information for military purposes. During the infancy of space technology the Air Force and the National Aeronautics and Space Administration and the rest of the community engaged in space work have had many identical concerns in such areas as propulsion, guidance, and re-entry. In the future the Air Force should be concerned with providing military capabilities on a routine basis, using military personnel, employing large numbers of launches, and perhaps performing in relation to noncooperative objects in space. Interchange of data with NASA will continue, but the Air Force and NASA do not have common planning objectives. NASA is concerned with space as its focus of interest. The Air Force is concerned with space only insofar as it is a medium for meeting threats and maximizing required military capabilities, not as a challenge in itself.

The Air Force Systems Command has the responsibility and the capability in its Government industry team to find the technological solution to military space problems. The balance and integration of R&D efforts constitute its gravest mission. The resources available to the Air Force are not unlimited. Only the most promising pathways can be followed among the vast range of development feasibilities. Which developments then are to be supported by the Air Force? In the Nation's interest the choices must be systematically made to cope with the rapid rate of technological progress, the great variety of subjects, and the large number of possible applications. The chosen developments must anticipate the structure of the Air Force of the future and ensure that there are no gaps in capability. We must be prepared to cope with the anticipated and the unanticipated. And there's the rub—the unanticipated. Today it appears most likely that the unanticipated will occur in space. The most critical examination must be made of each new Soviet space accomplishment to minimize the possibility of surprise.

PREPARING for the future is a large order. The future is but dimly defined, especially beyond the first generation of space vehicles now on the horizon. We should have the ability to project into the future new systems of satellite inspectors, early-warning satellites, and space stations to continue military tasks now recognized. We take with us a firm conviction that man must learn to function in space efficiently and that he must be so incorporated into the systems that his powers of deliberation, evaluation, and decision are exploited. Above all, we know also that in the space programs of the future the Air Force must continue its vital contribution to the national security. It must not be otherwise.

We must respect the scope and the difficulty of the problems we face, but we should not minimize our ability to handle these problems.

Headquarters Air Force Systems Command

The Quarterly Review Contributors

Colonel Raymond S. Sleeper (USMA; M.A., Harvard University) is Deputy Chief of Staff, Foreign Technology, Hq AFSC. After graduation at West Point in 1940 he was assigned to the 11th Bombardment Squadron, 7th Bombardment Group, with which unit he served in Java and Australia during the war. In 1943 he was transferred to General MacArthur's staff as Chief of Military Personnel. In 1944 he became Deputy Chief, Enlisted Branch, Personnel, Hq USAF. He studied personnel administration and social psychology at Harvard, 1947-48. Subsequent assignments have been as Deputy Chief, Strategic Vulnerability Branch, ACS/Intelligence, Hq USAF, 1948-1950; as student, then as a faculty member, Air War College; as Deputy Commander, 11th Bombardment Wing, later Commander, 7th Bombardment Wing H (B-36), 1955-1957; as Chief of War Plans, CINCPAC, from 1957 until he became Assistant to the DCS/Foreign Technology in 1960, leading to his present assignment on 1 January 1963.

General Bernard A. Schriever (M.S., Stanford University) is Commander, Air Force Systems Command. After completing flying training in 1933, he served as a bomber pilot at March and Albrook Fields before reverting to inactive reserve status in 1937 to fly for Northwest Airlines. Re-entering the service as a regular 2d lieutenant in 1938, he served a year with the 7th Bombardment Group, then was assigned as a test pilot at Wright Field. There he attended the Air Corps Engineering School in 1941, then studied advanced areonautical engineering at Stanford. In 1942 he joined the 19th Bombardment Group, Southwest Pacific Theater. In 1944 he assumed command of the Advance Headquarters, Far East Service Command. Postwar assignments have been as Chief, Scientific Liaison Section, DCS/M, Hq USAF; as student, National War College, 1950; as Assistant for Development Planning, DCS/D, Hq USAF; as Assistant to the Commander, ARDC, and Commander, Air Force Ballistic Missile Division, ARDC, 1954-1959; and as Commander, Air Research and Development Command until his assignment as Commander of the newly created Air Force Systems Command on 1 April 1961.

Colonel Florian A. Holm (B.S., Fort Hays Kansas State College) is Director of Development Planning, DCS/Plans, Hq AFSC. He was commissioned from flying school in 1939, and during World War II he commanded the 461st Bombardment Squadron (B-29), Okinawa. Postwar assignments have been as Commander, Radar Experimental Squadron, Boca Raton, Florida, 1946-1948; Technical Intelligence Attaché, American Embassy, Stockholm, Sweden, 1948-1952; Chief, Operations Armament Laboratory, Wright-Patterson AFB, 1952-1955; student, Air War College, 1956; Chief, Navaho Missile Division, 1956-1958; and Director of Advanced System Planning, Aeronautical Systems Division, AFSC, Wright-Patterson AFB, from 1958 until his present assignment in 1961.

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COLONEL EDWARD A. HAWKENS (B.S., Carnegie Institute of Technology) is Chief, Propulsion Laboratory, Aeronautical Systems Division, AFSC. During World War II he was project engineer on the R-2600 engine and Chief, Engine Projects Unit, Air Corps Power Plant Laboratory. In 1948 he headed the Air Force Cold Weather Engine Test Group in Alaska. In 1949-50 he served as the first USAF exchange officer with the RAF assigned to the Director of Engine Research and Development. From 1952 through 1958 he held staff assignments in the Directorate of Laboratories, Wright Air Development Center, and with the Deputy Commander for Research and Development, Hq ARDC. He has been with the Propulsion Laboratory since 1959.

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COLONEL CHARLES G. ALLEN (M.S., Purdue University) is Vice Commander, 6595th Aerospace Test Wing, AFSC, Vandenberg AFB, California. He entered the Air Corps in 1940 and served in initial cadres establishing five flying training bases in the Southwest. He commanded the 5th Bombardment Squadron and was Deputy Commander, 9th Bombardment Group, Tinian and Philippine Islands, 1946; was in Operations, Hq Far East Air Forces, 1947; and was Operations Officer, 28th Bombardment Group, 1948. After attending Purdue University 1949-1952, he became Chief, Fighter and Experimental Aircraft Division, Weapon Systems Directorate, Wright-Patterson AFB, 1952-1957. He attended the Air War College, 1958, and then commanded Vandenberg AFB until his present assignment in 1960.

MAJOR GENERAL W. A. DAVIS (B.S., Texas Technological College) is Commander, Ballistic Systems Division, AFSC. After earning a degree in mechanical engineering, he completed flying training in 1937 and served with the 17th Attack Group, March Field. He attended the Photographic School, Lowry Field, was Photographic Officer at Brooks Field, and then became Assistant Director, Photo Lab, Experimental Engineering Division, Wright Field, in 1941. He attended the Air Corps Engineering School, then became Chief, Subdepot Operations, Oklahoma City Air Depot, and later Commander, 5th Photo Group, Peterson Field, Colorado. During World War II he was Commander, 5th Reconnaissance Group, later Operational Engineering Officer, Twelfth Air Force, Mediterranean Theater, 1943-1945. At Wright Field 1945-1950, he was successively Chief, Bombardment Branch, then Fighter Branch, and Chief, Aircraft and Missiles Section, Air Materiel Command. He was AF plant representative at the Boeing Airplane Company, Seattle, 1950-1953. At Hq USAF he was Director of Procurement and Production until 1956, Assistant for Production Programing, DCS/M, until 1958. Again assigned to Hq AMC, he was Deputy Director for Weapon Systems, Directorate of Procurement and Production, then Director of Procurement and Production, until 1960, when he assumed command of the Aeronautical Systems Center. He was Commander, Aeronautical Systems Division, AFSC, from 1961 until his present assignment.

MAJOR GENERAL ROBERT G. RUEGG (B.S., Oregon State College) is Commander, Aeronautical Systems Division, ASFC, Wright-Patterson AFB. During World War II he served in the Philippines and Southwest Pacific as flight leader and as deputy and acting squadron commander, 1941-42. Then assigned to the Flight Test Division at Wright Field, he completed his tour in 1947 as Chief, Operations Subdivision. Subsequent assignments have been as Deputy Chief of Staff, Operations, Alaskan Air Command, 1948-1950; Chief, Aircraft Laboratory, Wright-Patterson AFB, 1950-1953; Senior AF Liaison Officer, Office of the Assistant Secretary of Defense, Research and Development, 1954-55; Director of Procurement and Production, Hq USAF, 1957-1959; Deputy Director for Logistics, J-4, Joint Chiefs of Staff, 1959-60; and Director of Procurement and Production, Air Force Logistics Command, from 1960 until his present assignment in 1962. General Ruegg has attended the Army Air Corps Engineering School, Air Command and Staff School, Industrial College of the Armed Forces, and the Advanced Management Program, Harvard Graduate School of Business Administration.

MAJOR GENERAL CHARLES H. TERHUNE, JR. (M.S., California Institute of Technology) is Commander, Electronic Systems Division, AFSC, Laurence G. Hanscom Field, Massachusetts. After graduation from Purdue with a degree in mechanical engineering, he completed flying training in 1939. He served with the 1st Pursuit Group, Selfridge Field, and as Range Officer with the Armament Laboratory, Materiel Division, Wright Field, until entering Cal Tech in 1940 to study aeronautical engineering. Back to Wright Field in 1941, he was for two years Chief, Design Development Branch, Aircraft Laboratory, and for two years in the Fighter Branch, Aircraft Project Section. He served in the Pacific Theater from May 1945 to June 1947, as Executive Officer, 58th Fighter Group; Commander, 3rd Air Commando

Group; Commander, 49th Fighter Group; and Chief of Maintenance, Far East Air Forces. Subsequent assignments have been as Deputy Chief and Chief, Guided Missile Branch, Hq USAF, 1947-1951; AF Assistant to Director of Guided Missiles, OSD, 1950-1952; Assistant Director and later Director of Development, AF Special Weapons Center, Kirtland AFB, 1952-1954; then until 1960 he was with the AF Ballistic Missile Division, ARDC (or its predecessor, Western Development Division), as Deputy or Vice Commander. Since August 1960 he has been with the Electronic Systems Division (or its predecessor, Command and Control Development Division) as Deputy or Vice Commander and as Commander since February 1962.

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Colonel Marcel Lind (M.A., George Washington University) is Director of Military Personnel, Hq AFSC. Commissioned from flying school in 1941, during the war he served with the 15th Antisubmarine Squadron, American Theater of Operations. Subsequent assignments have been as commander of a B-29 squadron and in various personnel jobs through major command level in SAC, 1947-1954; as Chief, Operational Training Branch, Hq USAFE, 1954-1956; as Commander, Air Base Group, Landsberg, Germany, 1956-57; and in the Directorate of Personnel Planning, Hq USAF, from 1957 until his current assignment in 1961. He is a 1954 graduate of the Field Officer Course, Air Command and Staff School.

Major Clifford W. Muchow (M.S., University of Southern California) is Acting Chief, Officer Assignment Division, Directorate of Military Personnel, DCS/P, Hq AFSC. During World War II he served with the 90th Bombardment Group, Fifth Air Force. Recalled to active duty in 1951, he has served with the Personnel Laboratory, Lackland AFB; in the Titan Program Office, Ballistic Missile Division, Inglewood, California; and as Chief, R&D Manning Branch, BMD.

Major General William B. Keese (B.S., Cornell University) is Deputy Chief of Staff, Plans, Hq AFSC. Commissioned in the Field Artillery Reserve from ROTC, he then took flying training, 1933-34, and served with the 20th Pursuit Group, Barksdale Field, until 1935 and in the Canal Zone until 1937. He served six years in the Training Command at Randolph, Perrin, and Lackland Fields, took B-24 transition training in 1943, and then commanded the 484th Bombardment Group, MTO, until April 1945. Subsequent assignments have been as DCS/O, Eastern Flying Training Center, Maxwell Field, later Director of Training, Western FTC, and then Chief, Plans Division, AF Training Center, Randolph Field, 1945-1947; as Chief of Staff, Antilles Air Division, later Commander, Ramey AFB, Puerto Rico, 1948-1950; Chief, International Branch, Policy Division, Hq USAF, 1950-1953; Director of Plans, Hq USAFE, Wiesbaden, Germany, 1955-1957; Director, Military Personnel, DCS/P, Hq USAF, 1957-1960; and Director of Development Planning, DCS/R&T, Hq USAF, from 1960 until his current assignment in 1962. General Keese is a 1948 graduate of the Air War College and attended the British Imperial Defense College in 1953-54.

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