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shadow shield. A shield, other than the reactor shield, that is interposed between the radiation source and a specific area to be protected. Useful in space, it is less effective in the earth's atmosphere because air scattering deflects radiation around it.

shield, or shielding. Any material, such as concrete, lead, or water, used to reduce the intensity of radiation.

SLAM. Abbreviation for supersonic low altitude missile. An ARDC project on which three aircraft contractors (Chance Vought, North American Aviation, Inc., and Convair) are working on conceptual designs to make preliminary determination of basic requirements of the nuclear ramjet missile system.

technology. 1. In modern military usage, one of the five elements of national power, along with the military, political, economic, and psychosocial elements. 2. As used in sense 1, the total complex of science, research, engineering, industrial potential and techniques, and imaginative employment of the end products of these efforts. 3. Restrictively, the engineering and industrial sciences and their capabilities and techniques, as opposed to the physical or social sciences.

power sources for instrument packages in satellites and space probes. The Snap effort, which serves both Air Force and NASA needs, follows two heat-source avenues: the development of small, compact-core reactor-powered systems and the harnessing of the energy from decay of radioisotopes. The Atomic Energy Commission is responsible for developing both nuclear-heat sources and the conversion equipment into an integrated, electricity-producing power package.

solar batteries. Batteries which utilize large areas of photoelectric cells that are activated by the sun to produce electricity.

specific heat. The ratio between the amount of heat that it takes to raise the temperature of a given substance one degree and that required to raise an equal mass of water one degree.

specific impulse. A performance parameter of a rocket power plant or rocket propellant equal to the pounds of thrust developed per pound per second of propellant flow. Also the thrust in pounds divided by the propellant consumption rate per second.

specific power. The energy delivered per pound of fuel in a reactor or in a radioisotopic power source.

stagnation temperature. The "ram" temperature created on the leading edges of an aerodynamic vehicle traveling through the atmosphere. Refers to the complete standstill of air molecules on the leading edges of the craft.

static conversion. Energy conversion in which no moving parts of equipment are utilized.

steady state. The stable operating condition of a reactor in which the neutron inventory remains constant; that is, the effective multiplication factor (k_e) is equal to one.

Stefan-Boltzmann law. A law of heat transfer by direct radiation in which the amount of heat rejected from a given surface is proportional to the area of the surface and to the absolute temperature of the surface raised to the fourth power.

Stirling cycle. A thermodynamic cycle in which heat is added at constant volume, followed by isothermal expansion with heat addition. The heat is then rejected at constant volume, followed by isothermal compression with heat rejection. If a regenerator is used so that heat rejected during the constant-volume process is recovered during heat addition at constant volume, the thermal efficiency of the Stirling cycle is the same as for the Carnot cycle, with less compressive work needed.

stoichiometric ratio. The law of chemical composition whereby elements will only combine with each other in definite, established ratios which are whole numbers of each constituent element.

strategic mission profile. A profile of a specific mission. See **mission profile.**

structure activation. Radioactivity induced in the structure of the aircraft, ground vehicle, building, etc., in which the reactor is operated.

subcritical. The status of a reactor that has slipped below just critical, the number of new fissions being less than the previous generation. If not regulated with control rods, the reactor will shut itself down on an exponential decrease.

substrate. Of a coated material, the material which is protected by the coating.

supercritical. The status of a reactor that has proceeded past the just-critical point, generating one new fission per previous fission. The added fissions increase exponentially, power going up in the same proportion. If not contained with control rods, the reactor will run away.

target materials. Materials selected for irradiation by neutrons or gamma rays or both within a reactor or gamma-radiation test facility.

thermal mw-year. A power of one megawatt of thermal energy produced continuously for one year.

thermal shock. The stress developed by rapid heating or uneven distribution of temperature in a material.

thermionic conversion. The process wherein electrons released by thermionic emission are collected and utilized as electric current. The simple example of this is provided by a vacuum tube, in which the electrons released from a heated anode are collected at the cathode or plate.

thermionic emission. Direct ejection of elec

Nuclear Weapons and Limited War

General Frederic H. Smith, Jr.

SINCE the delivery of atomic weapons on Hiroshima and Nagasaki a few days before the termination of World War II, the world has come to recognize the probable use of nuclear weapons in any general war, with a somewhat lesser appreciation of the immediate and long-term effects upon civilization as a whole. It is safe to say that knowledgeable people in every nation rightly construe an all-out nuclear war between the Communist powers and the free world as being destructive beyond real comprehension, a horror to be avoided if at all possible.

There is, however, little widespread knowledge of the application of nuclear firepower in limited war. In limited war relatively small-yield weapons can and should be used selectively in such a manner as to avoid the destruction of the countries or populations involved and still achieve military objectives at nominal cost. As a result of ignorance and in the absence of clear-cut tactical doctrine, the general feeling of horror engendered by the prospect of a world holocaust, which is reasonable, has been applied to any employment of nuclear weapons in limited war, which is unreasonable.

This confused thinking is not confined to the man in the street but is unfortunately shared by many men in scientific, governmental, and military circles. We in the Air Force have been remiss in our failure to explore fully the wide range and flexibility now available to us in the family of weapons and to enunciate clearly our doctrine for tactical application of these weapons in limited war. We cannot afford to lose friendly nations and territories to the U.S.S.R., Red China, or their satellites under any circumstances. It certainly would be inexcusable if we were to lose them simply because we failed to capitalize on our great potential through a basic lack of understanding or lack of imagination as to how to use the weapons we now have.

The purpose of this article is to demonstrate that not only can the intelligent use of nuclear firepower in limited war give us the greatest possible opportunity to win such wars at minimum cost to us and to the country we may be defending against aggression, but that it is highly probable that without the use of such weapons our chances of winning in many areas are slim indeed.

The Threat and Our National Objectives

Any lengthy treatment of the subjects involved under this heading is certainly unnecessary here. The teachings of the Communist ideology are well known to all readers, as well as the vast disparity between the pure manpower resources available to Soviet Russia, her satellites, and Red China on the one hand and to the organized free nations of the world on the other. In the application of this manpower in limited wars the Communist hegemony has the advantage of operating on interior lines and of being able to expend a great number of lives and a large commitment of currently obsolescent material without any sensible reduction of its over-all capacity to wage global war.

On the other hand the industrialized nations of the free world, in opposing aggression, must operate on exterior lines in most parts of the world and can ill afford heavy loss of life or heavy commitment of modern equipment without a reduction in the capability to wage global war. It follows, therefore, that if we are to prevent further Communist expansion at the expense of friendly or neutral nations we must find an economical method of waging successful limited war.

What Do We Mean by Limited War?

Classically a limited war might be defined as any armed conflict short of direct combat between the great powers. If this article is to avoid generalities and clear up misunderstandings through a frank discussion of specifics, this definition needs further explanation.

In the first place we must realize that both the U.S.S.R. and the United States possess ample force to erase any small country as an effective sociological or industrial unit. It would be possible for their air forces to eliminate opposition within and bordering such a country by indiscriminate bombing with nuclear weapons of the sections held by the enemy. Such a defense of an ally obviously would not only be unattractive to that ally but would negate any political advantage to be gained by waging this kind of a limited war.

By extension, there is a very definite upper limit to the destruction of life and property that is consistent with the successful attainment of our objectives. While we cannot specify a general cutoff point at which the tactical advantages of further destruction would be outweighed by the political disadvantages, it is patent that there will be one. The achieving of tactical objectives with a minimum application of force will be a serious factor in selecting targets and in determining tactics. These considerations are the very ones that have been used in the past as arguments against the employment of nuclear weapons in small wars. The considerations are real; the conclusions that have been drawn are invalid.

Whether armed resistance to Communist aggression by the United States and its allies can in effect be limited to local areas and not spread to global conflict depends not only upon the will of the combatants but upon geography and geopolitics. The nations in the European economy are alike enough in culture and interdependent enough economically (and in a sense politically) that it is difficult to visualize a limited war being fought in that area. But in the Far East a limited war has already been fought in Korea, and in Southeast Asia one has been fought in Indochina. In the Middle East actions taken by the United States and Great Britain in Lebanon and Jordan might well have resulted in limited-war situations. In each of these examples neither of the chief antagonists desired global war; and in Korea and Indochina their wish to avoid it was strong enough to have permitted the tactical use of selected nuclear weapons without serious danger of all-out war, with peculiar and distinct advantages accruing to the United States, her allies, and the free world.

It is clear that nuclear weapons cannot be used haphazardly if we are to keep the war limited and avoid undue destruction to the friendly countries we are defending. Certain very clear-cut restrictions must be placed upon their use—restrictions in targets, in yields, and in character of bursts. The objectives of a limited war must be explicitly defined by higher authority and should include a restriction on strikes outside a delimited zone of hostilities. A limited aggression can be effectively countered under such conditions, and we should develop plans and concepts on this basis.

New criteria for the selection of appropriate targets for nuclear weapons in limited war need to be developed. These must admit a new class of targets, categorized as "situation-control" targets. Typical situation control would be the use of nuclear weapons to destroy forest cover and thus to deny the enemy concealment or passage. Another would be the closing of narrow gorges in mountains by causing extensive land slides. The commander on the spot must have the option of expending weapons in the zone of conflict within his allocated stockpile in accordance with his judgment of the situation, at the same time remaining within the explicit policy guidance concerning the acceptable categories of targets and methods of weapon employment placed upon him by

One of the most frustrating aspects of the entire cold-war period for the military commander or planner has been the host of unpredictable factors involved in possible limited wars. The location, the enemy, the size, the political conditions, the weapons, and the tactics of such a war have all seemed fated to be left unspecified until the last moment. General Frederic H. Smith, Jr., Commander in Chief, United States Air Forces in Europe, feels that much of this uncertainty would be removed if the United States should publicly reserve the right to use nuclear weapons in limited wars, just as it has already done for general war. Further, he details a concept for the effective use of such weapons. Under this concept, difficult terrain features would become the targets for nuclear attack, with the tactical intent of denying to enemy troops the cover and camouflage offered by these features and of blocking the passage of troops through critical areas.

higher authority. Counter-air-force targets would of course be brought under attack within the designated confines of the conflict, but in most instances this would require careful selection of weapons and a high precision in delivery to obviate undue loss of life to the indigenous peoples.

Historical Situations Favoring Nuclear Firepower

World War II situations

During World War II in the Southwest Pacific, conditions prevailed which made attainment of Allied military objectives—and, in fact, containment of aggressive Japanese forces—an extremely difficult proposition. The battlefields in New Guinea, New Britain, the Philippines, Indonesia, and the Solomons were covered to a large extent with dense forests, including rain forest, dense bamboo, mixed bamboo and deciduous forest, and mangrove swamps. Much of the area was hilly or mountainous. Our forces had little experience or capability to cope with this battlefield environment. The Japanese troops were experienced, had been jungle-trained, and could take utmost advantage of all opportunities afforded by the terrain.

To complicate matters, at least at first, air support by Allied air forces was ineffective. The enemy forces were able to assemble, to move, and to fight in such a way that Allied forces were rarely able to see them or accurately estimate their capabilities. Targets in the classical sense of the word, i.e., concentrations of personnel and material that could be pinpointed, were extremely limited. Eventually napalm became a primary weapon in close support in the Southwest Pacific as it became available in quantity late in the war. Used in conjunction with demolition weapons, napalm became one of the most effective means of driving enemy forces into the open for subsequent attacks with fragmentation bombs and strafing. This combination of tactics not only was employed against jungle-concealed objectives but was used very effectively against enemy troops entrenched in caves.

The Ipo Dam. Coincident with the cleanup of Manila, elements of the XIV Corps were penetrating to the edge of Laguna de Bay to divide enemy forces to the southeast and southwest of the city. The 6th Infantry and 1st Cavalry Divisions pushed into the mountains north of Laguna, where the former captured Montalban by the end of February 1945. Both divisions then reached Japanese defensive lines, consisting chiefly of elaborate cave positions. The positions were fairly well stocked with equipment, weapons, and food, and the advance became necessarily slow.

The usual method of attack was to smother the caves with air and ground bombardment so that demolition parties could approach and seal the tunnel entrances. Heavy bombers struck every significant target, especially enemy concentrations in the vicinity of Antipolo and Ipo. On 6 March, 98 B-24's dropped 250 tons of bombs on Antipolo. Some 450 fighter attacks in the area between 8 and 11 March further lightened the task of the 1st Cavalry, which reported that the terrific bombing had literally blown the enemy out of his defenses.

The XI Corps gradually overcame the Shimbu force's southern pocket. By early May it had surrounded 4700 combat troops at the juncture of the Ipo and Angat rivers. Another force of about 2700 men was cornered in the vicinity of Santa Maria–Bosoboso, and 6200 more were holding the Mt. Oro–Mt. Pamitinan–Mt. Purro area. The corps expected desperate opposition. Late in April General MacArthur had called attention to the inadequate water supply reaching Manila and directed that the Ipo Dam be captured as a priority objective. It was seen that if this reservoir continued in enemy hands or was destroyed Manila faced an epidemic of enteric diseases. New and speedier tactics of attack were in order.

The V Fighter Command accordingly prepared for the largest mass employment of napalm in the Pacific war. On 3–5 May 1945 a total of 238 fighters saturated the outlying defenses of the Ipo area with napalm and demolition bombs. These attacks proved very destructive and extremely demoralizing to the enemy, driving them into the open where they were easy targets for other forms of attack. The V Fighter Command repeated the same general pattern of attack on 16–18 May. Operations officers divided the five-square-mile area held by the Japanese into sectors and then sent 673 Lightnings, Thunderbolts, and Mustangs to turn it into a sea of flames. Napalm-laden P-38's and P-47's, flying at 50 to 100 feet, attacked first, followed by P-51's which strafed and bombed the terrified Japanese. On the second day A-20's with frag bombs aided the Mustangs. As our 43d Division moved ahead against negligible resistance, it estimated conservatively that 650 Japanese had been killed by air action alone. Approximately 1500 other fatalities among the enemy in this action were attributed to machine-gun and mortar fire by ground forces.

The Ipo Dam, although prepared for demolition by the enemy, was captured without damage.

The employment of napalm in the liberation of this objective drew comment in the United States Strategic Bombing Survey:

> Napalm became a primary weapon in close support in the SWPA as soon as it became available in quantity late in the war. In the Ipo Dam area west of Manila, the Japanese were holed up in five strongholds embracing almost a square mile. Five fighter groups delivered a total of 646 sorties, dropping 200,000 gallons of napalm to enable our ground troops to walk, standing up, into the enemy strong points where weeks of probing prior to the fire bomb attacks had failed to show a soft spot.

Korean War situations

Destruction of Sinuiju. In the air battle for the Yalu during the early stages of the Korean campaign, the mission of the Far East Air Forces was to effect a complete interdiction of North Korean lines of communication and the destruction of North Korean supply centers and transport facilities, North Korean ground forces, and other military targets bearing immediately upon the current tactical situation. In a USAF historical study on Air Force operations during that campaign the fulfillment of the mission is recorded:

> In recognition of the massive destruction capabilities of the B-29 medium bombers, much of this effort was delegated to the FEAF Bomber Command. Fifth Air Force would provide fighter escort and combat air patrols so as to maintain air superiority, would under-

take such destruction of hostile supply centers and interdiction targets as was practicable with its fighter bombers and light bombers, and would maintain reconnaissance over enemy lines.

Because of the urgency of the task and the reduction of medium bomber strength to three groups, FEAF secured a relaxation of the policy preventing use of incendiaries against Korean targets, directing FEAF Bomber Command (P) "to employ any type of ordnance . . . which will best accomplish its object." Lt Gen Earle E. Partridge was similarly authorized to "utilize any ordnance available." [Not to include nuclear weapons.—Ed.] High-explosive general-purpose bombs were recommended for attacking the approaches to the main bridges across the Yalu and the marshalling yard at Sinuiju.

FEAF target planners had given careful attention to the North Korean city of Sinuiju on the south bank of the Yalu directly across from the Manchuria city of Antung. A bombing attack would provide an additional restriction to the movement of military supplies from Manchuria into Korea and would destroy warehousing and accumulated stacks of military goods. In October, FEAF had directed Bomber Command to conduct on 7 November 1950, a maximum effort B-29 strike designed to destroy the key enemy communications and supply center at Sinuiju. The Fifth Air Force would provide fighter escort and combat air patrol for the bomber force.

As a warm-up on 5 November, Bomber Command sent 22 B-29's to drop incendiaries on barracks and warehouses at Kanggye, a north central Korean town at the apex of transportation routes leading southward to Sinanju and Hamhung; the attack destroyed more than 65 percent of Kanggye's built-up area.

On 8 November, 79 B-29's dropped on Sinuiju 584.5 tons of 500-lb incendiary clusters and 1,000-lb bombs, the latter being aimed at approaches to the international bridges. Comparison of pre-strike and post-strike photographs showed that over sixty percent of the 20,000,000 sq ft built-up area of the city was destroyed. Fifth Air Force provided a fighter escort, and a preliminary fighter bomber strike against flak installations which considerably reduced the volume of enemy ground fire. Other enemy guns on the Manchurian shore threw up a heavy volume of fire, but the bombers came over Sinuiju at 18,000 to 21,000 feet and escaped damage.

This Bomber Command strike against Sinuiju virtually eliminated the first of ten priority communications and supply centers designated by General Stratemeyer.

A consideration of the type of ammunition employed, the quantity in tons expended, and the area covered in these actions prompts the observation that, had atomic bombs of infinitely smaller weight but almost incalculably higher yield been dropped upon these targets, greater destruction would have been achieved and the neutralization of enemy potential would have been more lasting. A further advantage would have been gained in that the drops could have been made from altitudes beyond the range of enemy antiaircraft.

The bombed areas were suitable as atomic targets, since they were clearly defined in intelligence dossiers and well depicted in reconnaissance photography.

Battle for the Yalu bridges. The United Nations air interdiction effort ordered the destruction of the first span out from the Korean bank of the Yalu River bridges and marked for destruction every major bridge structure between the Yalu and the battle line. Concurrently the Fifth Air Force was laying an all-out armed reconnaissance, by night and day, against everything moving on North Korean road and rail routes.

In all, there were 12 international bridge crossings of the Yalu. The most important of them to the tactical situation were those in northwestern Korea: the combination rail and highway bridge and the double-track railway bridge at Sinuiju, the highway bridge at Chongsongjin, the railway bridge at Namsan-ni, the highway bridge and railway bridge at Manpojin. Across the Sinuiju, Chongsongjin, and Namsan-ni bridges the Communists could run forces to oppose the Eighth Army. The Manpojin bridges would permit the Chinese to march down the center of North Korea and split the Eighth Army from X

Corps. Other bridges of lesser importance to the tactical situation were the highway structures at Ongdmdong, Linchiang, the two at Hyesanjin (this town was occupied by U.N. forces on 20 November), at Samanko, and near Hoeryong.

In deference to the fact that these bridges were major steel structures, built by the Japanese to withstand great natural adversities, the Yalu bridges were assigned as FEAF Bomber Command targets. Effective 8 November Bomber Command was directed to destroy the bridges at Sinuiju, Namsan-ni, Chongsongjin, Manpojin, and Hyesanjin, and by 17 November the entire list of bridges had been authorized for attack. On 12 November, noting that much of its B-29 effort had to be committed to the destruction of enemy communications and supply centers, FEAF requested that Navy-based air assist in the destruction of the international bridges. FEAF medium bombers had developed a high degree of proficiency during the bridge-interdiction campaigns in South Korea, bombing from an altitude of 10,000 feet with little or no opposition. But even under these favorable circumstances the 19th Bombardment Group had been hard put to destroy the steel cantilever west railway bridge at Seoul, an effort which ultimately consumed 86 sorties and 643 tons of heavy demolition bombs.

Bombers of the 19th Group began attacking the Yalu River bridges on 8 November under cover of the massive attack against the Sinuiju bridges. Following this attack, medium bombers did not again return to the Sinuiju bridges until 13 November, when nine 98th Group B-29's walked their bombs across the bridge approaches and covered both bridges well out to midstream. With three flights in close trail, the 98th Group passed over the target within ten seconds, thus minimizing the time of exposure to antiaircraft fire. On the following day Bomber Command sent a normal three-group effort against the Sinuiju and Manpojin bridges. Twenty-one B-29's of the 19th and 307th Groups fought off Mig and Yak attacks to drop 111 tons of 1000- and 2000-pound general-purpose bombs in good pattern on the Sinuiju bridges. But the damage was slight, probably because of the flak and fighters, which badly damaged two 307th Group B-29's, and because of the drift caused by a 95-mph crosswind.

On 24 November weather improved, and all three medium bomber groups went out on interdiction missions, ranging from the Yalu to the bomb line. The 98th Group, with eight B-29's, laid down its 1000-pound bombs at the Manpojin railway bridge. While most of its bombs were accurately aimed, flak-evasion maneuvers and 17° drift caused some eight bombs to fall in the mud flats on the Manchurian side of the river. Seven 19th Group planes dropped 2000-pound bombs on the international highway bridge at Chongsongjin. Next day four 19th Group B-29's had disappointing results at Chongsongjin, but eight other planes of the group reported destruction of at least one span of the Manpojin railway bridge. Enemy antiaircraft fire at Manpojin (a great proportion of it coming across the Yalu) was now so severe that Bomber Command was authorized to suspend attacks on the bridges and instead effect multiple cuts on the railways and highways south of that city. On 26 November eight 307th Group B-29's reported two spans of the Chongsongjin highway bridge in the water, but the status of this bridge remained in doubt. The 307th Group sent eight more B-29's there on 29 November to score hits on two spans. The 19th Group repeated the raid on 30 November with eight B-29's, which reported destruction of one span of the bridge. Because of a rack malfunction the 19th Group let one 4000-pound general-purpose bomb slip across the border to the Manchurian shore.

Meanwhile the planes of the aircraft carriers *Leyte, Valley Forge,* and *Philippine Sea* had gone into action against the international bridges on 12 November. The Sinuiju railway bridge proved as invulnerable to the Navy dive bombers as to the B-29's. "Knocking down that Sinuiju railroad bridge," commented the *Leyte*'s air group commander, "was like tackling San Francisco's Golden Gate." The Sinuiju cantilever-span highway bridge was more vulnerable: a three-day attack dropped its Korean approaches. Navy strikes also damaged the Manpojin railway bridge and cut single spans out of the two bridges at Hyesanjin. Navy pilots reported severe antiaircraft and enemy fighter opposition; they too were forced to attack targets from inopportune bomb-run angles lest they violate Manchurian territory.

By the end of November the U.N. air effort had succeeded in cutting at least four of the international bridges and had damaged most of the other bridges, but it was becoming increasingly evident that the returns were not commensurate with the effort expended.

Here again, the superiority of atomic ordnance over the types of weapons considered conventional at the time of the Korean campaign suggests itself. Precisely what expenditure of nuclear bombs would have equaled the destructive effect of the high explosives (HE) dropped upon the Yalu River bridges could be readily computed, given the exact tonnage and type of HE used. But it becomes apparent without such computations that with nuclear weapons the total effort required to launch the Yalu sorties could have been very greatly reduced and the CEP's (circular probable errors) more accurately controlled to conform to the restrictive limitations imposed by high authority.

Action in the Pusan perimeter. On 5 July 1950, less than two weeks after hostilities had begun in Korea, the Commander in Chief, Far East (CINCFE), ordered the establishment of a joint operations center (JOC) at the 24th Division headquarters in Taejon as well as a tactical control center (TACC) near that city. Within two days of the setting up of these facilities enemy troops and armor had advanced into this general area and were building strength along a line between Pyongtaek and Wonju. Faced with this situation, CINCFE directed that medium-bomber missions originally planned against Wonsan, Seoul, and Pyongyang be devoted to attacks on bridges in the battle area in an attempt to reduce the flow of troops and supplies to the front.

Soon afterward the enemy launched drives against Taegu, where the JOC and TACC had been compelled to locate by the suddenly deteriorating situation, and immediately initiated a pincer movement on Taejon, forcing U.S. units to set up defensive positions facing the enemy attack. On 19 July the enemy opened the assault on Taejon with artillery and mortar fire, forcing U.N. troop withdrawal three days later to positions along the east bank of the

Naktong River. On 7 August the enemy crossed the Naktong at several points, suffering heavy casualties as U.S. forces resisted. Nevertheless within three days enemy bridgeheads east of the Naktong were reinforced with additional troops and supplies. For the rest of August enemy patrol action along the river was extensive. On 1 September the enemy launched a general offensive, making his deepest penetration north of the junction of the Naktong and Nam rivers. It was not until mid-September that U.S. units reduced the threat of his offensive in that sector. The turn in the tide was largely attributable to "carpet bombing" tactics of the B-29's of FEAF's Bomber Command in troop assembly areas.

The troop concentrations in the Naktong valley during the Communist thrust of July and August 1950 would have afforded profitable targets for atomic attack had the weapons been available in their present assortment and had other conditions been permissive. Circumstances prohibiting nuclear warfare during the Korean campaign are still recent enough at this writing to recall that considerations against its practice were more political than military and that the political implications were international, since the United States, the possessor of the atom bomb, was allied with several other of the United Nations in the Korean expedition.

Atomic weapons in the Korean War. During December 1950 there was some thought as to the practicability of using atomic weapons in Korea. The Eighth Army staff was reported to be in favor of their employment, and the Fifth Air Force saw no reason why it could not mark targets for an atomic strike, provided that proper targets could be located.

A theoretical study undertaken by an Army research organization later claimed that lack of ground and air intelligence at that time regarding Communist troop movements and concentrations would have limited the destructivity of atomic weapons had they been tactically employed against hostile personnel targets. Had intelligence been better, atomic weapons might have taken a terrible toll of hostile troops.

The study estimated that, if one 40-kiloton airburst weapon had been exploded over the dense enemy concentration in the Taechon area on the night of 24–25 November 1950, 15,000 of a total enemy force of about 22,000 troops would have been destroyed. It was estimated that casualties from six 40-kiloton airburst bombs over the fairly extensive enemy assembly in the Pyonggang-Chorwon-Kumhwa triangle on 27–29 December 1950 would have amounted to some 30,000 to 45,000 of a total enemy force of about 65,000 to 95,000, had intelligence regarding enemy numbers been exact and timely. Had six 40-kiloton bursts been laid along the enemy lines north of the Imjin River on the night of 31 December–1 January 1950–51, an estimated 28,000 to 40,000 of a total enemy force of 70,000 to 100,000 in the area preparing for a jump-off assault against the Eighth Army would probably have been destroyed.

Logistics

In the preceding discussion the figures given for various battles and campaigns indicate even to the uninitiated the tremendous logistic effort required to support the air operations. The World War II examples were drawn from experience in fighting an all-out war against the Japanese. The Korean War required a major effort on the part of the United States, and it was a war we did not win.

In any future conflict with the Communist powers we must anticipate that logistics as well as political factors will be considered and that our antagonist will throw the greatest possible load upon the logistics system supporting our activities. It is easy to envision a number of places in the world, perhaps in Southeast Asia, where we would be forced to operate from the equivalent of bare strips. One can readily visualize the tremendous effort simply to supply fuel, oil, bombs, and ammunition if we were to fight such a war as that in Korea or such as any of the major engagements in the war against Japan, utilizing only napalm and high-explosive bombs and ammunition. Competent studies clearly indicate that it would take a period of several days to be able to mount more than a double handful of sorties a day, considering only the provision of fuel. We really compound our logistic requirements if we must provide iron bombs and napalm tanks and jelly.

To be more specific, a single nominal-yield nuclear weapon, airburst, will clear an area of forest about 8000 feet in radius. To achieve a similar effect with napalm would require 8000 sorties of F-100 aircraft, each carrying four 120-gallon drop tanks. Not only would 32,000 tanks have to be transported to the operating base but 25 million pounds of napalm would also have to be provided, over and above 8000 sorties' worth of fuel. In the Ipo Dam campaign the Fifth Fighter Command dropped just under 700 tons of napalm in two days of intensive operations. One atomic bomb of nominal yield with an airburst would have been more effective in destroying cover, would have left no lingering radiation hazard, and, other than animals in the jungle and forest, would have killed only enemy troops.

Nuclear weapons were not available to us in World War II except at the tag end of the war. Nor did our stockpile contain sizable numbers and varieties of them during the Korean conflict. This situation does not obtain now nor will it in the future. Furthermore our assumed superiority over the Communist powers is qualitative, not quantitative. In any future limited conflict we must maximize our effectiveness and minimize the strain upon our economy. This can only be done through the intelligent application of nuclear firepower. That such firepower can be employed with no more—and perhaps with less—inhumanity than there was in wars of the past I hope to demonstrate in the following discussion of targets.

Limited-War Targeting

Geographical, geopolitical, economic, and cultural factors affect the likelihood of a Communist-instigated limited war. The geographical area we have chosen for a treatment of targeting considerations in limited war may be a no more likely one than many another. Because of the writer's familiarity with the terrain and because of its relatively wide variety of land and vegetation forms, Southeast Asia has been selected as a hypothetical example to illustrate the application of nuclear firepower against a variety of situation-control targets. The basic principles would apply to any geographical area.

Communist forces have shown again and again that in both large-scale invasion operations and limited guerrilla activities they take maximum advantage of the concealment offered by forest cover. This was beautifully demonstrated in the war against French Indochina, where the Communists were able to assemble, to move, and to fight under cover so that the French forces were rarely able to see them or to estimate accurately their capabilities.

In Southeast Asia standard interdiction targets, including roads, bridges, railways, and rivers, will be few in number and low in value. In most cases the Communists will have the advantage of nearby vegetation cover for concealment. They have repeatedly demonstrated the capability to move under cover while minimizing their use of standard transportation routes and facilities. Air targets of the standard communications-center type will play a relatively minor role in Air Force limited-war operations in Southeast Asia.

The basic Air Force operational problem in most limited-war tactical situations will be that of weapons delivery against an enemy who can almost always operate under vegetation cover of such density and extensiveness that detection and precision bombing are almost impossible. In addition to vegetation cover, areas of eroded limestone, karst areas, provide earth cover in the form of caves and extremely rugged terrain. Detection by aerial reconnaissance can generally be avoided by enemy forces. Air Force preplanning, in the sense of standard lists of fixed targets against an enemy in this environment, is next to impossible. Since standard communications-center and interdiction targets —targets that can be preplanned—will play a relatively minor role in limited war in Southeast Asia, this study is addressed to the special problem of "situation-control" targets.

The major targeting consideration will be that of providing for the delivery of nuclear weapons on areas involving enemy assembly, movement, and actual combat, where in almost every situation he will be afforded the advantage of concealment. Very little targeting will be possible in terms of preplanning against fixed or pinpoint locations. Targets will usually be discernible and locatable only in terms of general areas in a fluid situation, even where pinpoint objectives are involved. Area saturation of such situation-control targets will be the rule, pinpoint or precision being required only in terms of safeguarding friendly troops and indigenous personnel.

Such targets will require continuing action on a combat necessity basis, where timeliness in weapons delivery is of overriding importance. Nuclear weapons are a critical requirement against such situation-control targets where political considerations permit their use. Timeliness requirements will usually be of such a nature and urgency that the proper or maximum degree of situation control can be effected only if the local commander can use nuclear weapons at his own discretion, as modified and controlled by the ground rules prescribed by competent authority.

Target analysis reveals that Southeast Asia presents generally eight categories of situation-control targets. The eight situations have been described as:

- rain forest
- valley route (rain, deciduous, or bamboo forest)
- mangrove forest
- bamboo grove
- karst area
- mountain defile
- close-contact siege or redoubt
- beach or amphibious landing

Within the above categories an almost infinite number of individual target situations can be visualized in terms of specific situation-control targets and opportunities for weapons application. Here we will analyze general terrain and weather combinations so that plans for any specific tactical situation can be developed as necessary under one of the above general categories. Nuclear weapons against such targets will usually produce the double effect of (1) disrupting enemy assembly, movement, or battle activities; and (2) clearing away jungle or forest concealment, thus ensuring increased effectiveness from continued nuclear attacks against enemy positions.

The examples we shall present are not to be construed as actual targets or associated with probable courses of action by an enemy. They were selected purely as examples of the general categories of situation-control targets to be found in Southeast Asia and are used to depict weapon effects in various terrain and forest-cover situations. In applying sample weapons to these targets, zero winds have been assumed in most cases. Fallout must always be considered in connection with the safety of friendly troops, but in relation to the enemy is a bonus effect. For ground-burst weapons the fallout pattern will vary with type of weapon, wind direction, and velocity. Airburst will usually be recommended so as to minimize fallout. Figures reflecting personnel casualties are based on the assumption that troops are under forest cover or in the open. In neither case have they taken passive protection measures.

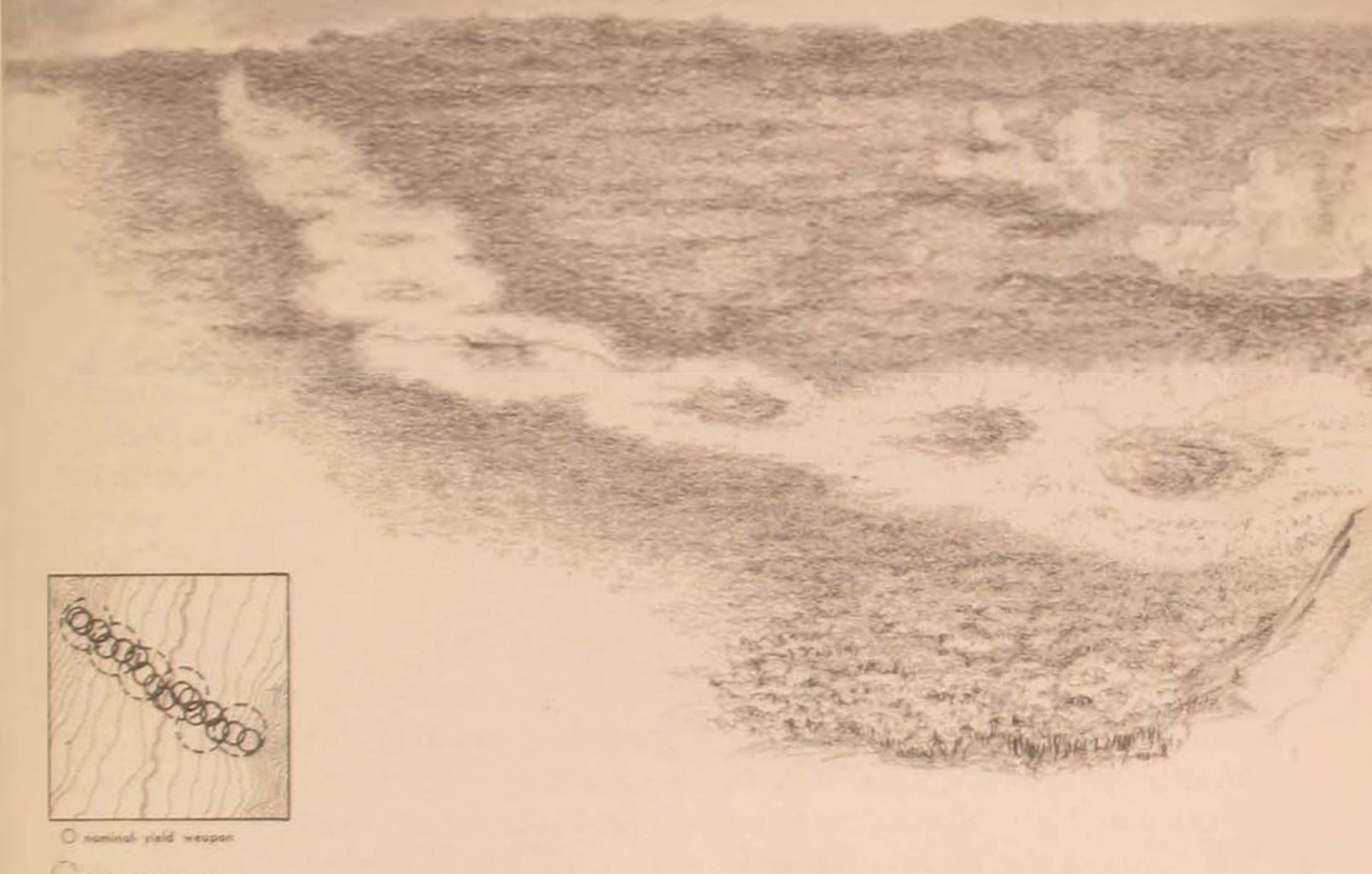
Examples of Situation-Control Targets

A summarized example, with illustration, of one type of tactical control situation is presented for six of the general categories mentioned earlier. Of course many variations in situation are possible under each general category in such items as weather, terrain, forest cover, tactical situation, and weapon-effects requirements. The six typical examples are offered as a basis for planning in terms of specific combat situations.

Rain Forest

1. Description: Rain forests are dense and the trees generally tall. Crown canopy is thick and storied in varying layers. Unlike jungles, the rain forest often has sparse ground vegetation, involving a carpet of ferns, a tangle of canes, or groves of creeping bamboo and palms where the sun reaches the

Rain Forest



forest floor or at the edge of the forest. Such undergrowth replaces the high forest as canebrake along streams and is insufficient to deter jungle-trained troops.

2. Situation: Enemy forces have invaded a friendly country and are regrouping. A vast irregular-shaped rain forest is located between the enemy and his attack objectives, i.e., population centers of the friendly nation. The indigenous air force, using nonnuclear weapons, has destroyed a concentration of small boats and rafts on a major river flowing through the jungle into the friendly nation. Small indigenous naval forces patrol the river. Combat air

patrols over the river have further discouraged logistical support of the invasion by this means. Preliminary nonnuclear strikes by the indigenous air force have caused the enemy to disperse into the periphery of the dense forest. Intelligence reports indicate that the enemy is planning to continue invasion through the forest, without the assistance of vehicles and with each soldier carrying his own ammunition and food.

U.S. Air Force elements have arrived and attempted reconnaissance of the forest. The excellent cover afforded the enemy prevents locating him or collecting information concerning the disposition of any of his forces known to have invaded the country.

The vast forest covers several hundred square miles. Photo interpretation and intelligence studies of the forest for possible choke points eliminate large areas as likely penetration routes because of steep ridges and other natural barriers. Final analysis reveals a corridor 60 nautical miles wide which the enemy must cross to reach his objectives. Intelligence indicates that the invading forces have not had sufficient time to reach this corridor. Action is initiated either to block his progress through this area or to trap him in a concentrated area for purposes of direct nuclear attack on his forces.

3. Nuclear Weapons Application:

a. Blast Effects:

A single nominal-yield weapon, airburst, has significant blast effects over approximately a 3.7-NM diameter. Sixteen of these weapons, airburst with minimum overlap, would create a debris belt in excess of 58 NM in length and effectively block the forest corridor. Since a zero circular error is unlikely and overlap and gap of weapons effects are probable for any delivery method, the requirement for 16 nominal-yield weapons to block this rain-forest corridor represents a conservative estimate.

Six high-yield weapons would cover an area greater than that covered by 16 nominal-yield weapons. Also there is less probability of gapping and overlapping. With a single high-yield weapon burst at optimum altitude, a circular area approximately 11 NM in diameter would be subjected to blast damage, i.e., limb breakage in the center and denuding of stems and leaves at the outer edges. Six such weapons would create a 67-NM-long debris belt. An additional uncalculated bonus effect when applying the larger-yield weapon results from the "K" factor, an intensifying blast effect associated with the longer duration of the positive phase of larger nuclear weapons. Depending on the nature of the target, more damage can be achieved with less or equal overpressure if the overpressure lasts for a longer period of time, as is the case with high-yield weapons. The degree of blast intensification from K-factor effects cannot be predicted for forest stands, since experimental data are not available.

Jungle-trained troops moving on foot would experience great difficulty in crossing the debris-belt barrier. Even if such an attempt were made, they would be exposed and interdiction would be easier. Attempts to clear a path or road through the debris would require such a concentration of manpower and machinery or elephants (used extensively in forestry activities in Southeast Asia) that another lucrative nuclear target would be provided. Creating

Valley Debris Barrier

such a belt behind as well as in front of enemy forces might provide a trap, thus presenting lucrative troop targets.

b. Thermal Effects:

Plants seldom burn vigorously when plant moisture exceeds 16 per cent, regardless of wind conditions. The natural vegetation of a rain forest, having a moisture greater than 16 per cent, will smoke and char from thermal effects but will not ordinarily ignite or sustain combustion.

Valley Debris Barrier
(Deciduous Forest)

1. Description: A valley is approximately 50 miles long and 20,000 feet wide at its narrowest point. Mountain walls of the valley are characterized by

deeply dissected ridges, making movement on them impossible. The valley floor is cut by a small river fringed by coarse, sharp-bladed marsh grass and reeds 3 to 7 feet high. A multistoried forest of dense broadleaf evergreen and deciduous broadleaf trees, interspersed with groves of bamboo, covers the remainder of the valley. The forest has a high, closed canopy; trees are 75 to 90 feet high; trunks 2 to 4 feet in diameter are clear of branches 35 to 60 feet from the ground. Undergrowth varies from a heavy mantle of low ferns and herbs to dense, tangled masses of vines, tree ferns, tall bamboo thickets, and small trees intermingled with thorny shrubs or coarse grass.

2. Situation: A numerically small, poorly equipped friendly force is attempting to defend the valley entrance into strategic territory. Organized enemy guerrilla forces, resupplied by native bearers and small river boats, are in the area in advance of an anticipated invasion, and they control the valley. Because of the concealment afforded the guerrillas by dense forest canopy, they cannot be detected through the use of aerial reconnaissance.

3. Nuclear Weapons Application:

a. Blast Effects:

A nominal-yield weapon, airburst at the 20,000-foot choke point of the valley, would break branches from trees to an effective diameter of approximately 15,000 feet. Trees stripped of leaves and stem breakage would extend out to approximately 22,200 feet, leaving little or no cover to enemy forces. Thus a strategic length of 3.7 NM and the entire valley width at this point would be exposed to reconnaissance and interdiction.

b. Thermal Effects:

(1) Marked dry season: During the dry season undergrowth ignited by thermal effects is susceptible to conflagration. An estimate of the area that could be cleared from resulting fires would depend on wind velocity and atmospheric conditions at time of attack.

(2) Rainy season: During the rainy season or at times when the moisture content of vegetation exceeds 16 per cent, extensive fires would not result. Debris several feet thick would carpet the 3.7-NM length and the entire width of the valley choke point. The area would become impassable to vehicles and very difficult to negotiate on foot. The advantage of concealment would be lost to the invading force, and supply and personnel buildup routes of guerrilla forces would be exposed.

Mangrove Forest

1. Description: Mangroves are tidal swamp forests usually found at river mouths and deltas. Water is brackish, and silting is continuous. The dense, intricate root network and deep mud render these areas virtually impassable. Mangroves are formidable barriers to landing operations. Sluggish and winding river channels offer the best possibility for penetration. Mangrove forests also occur along coast lines and around many of the islands in tropical areas.

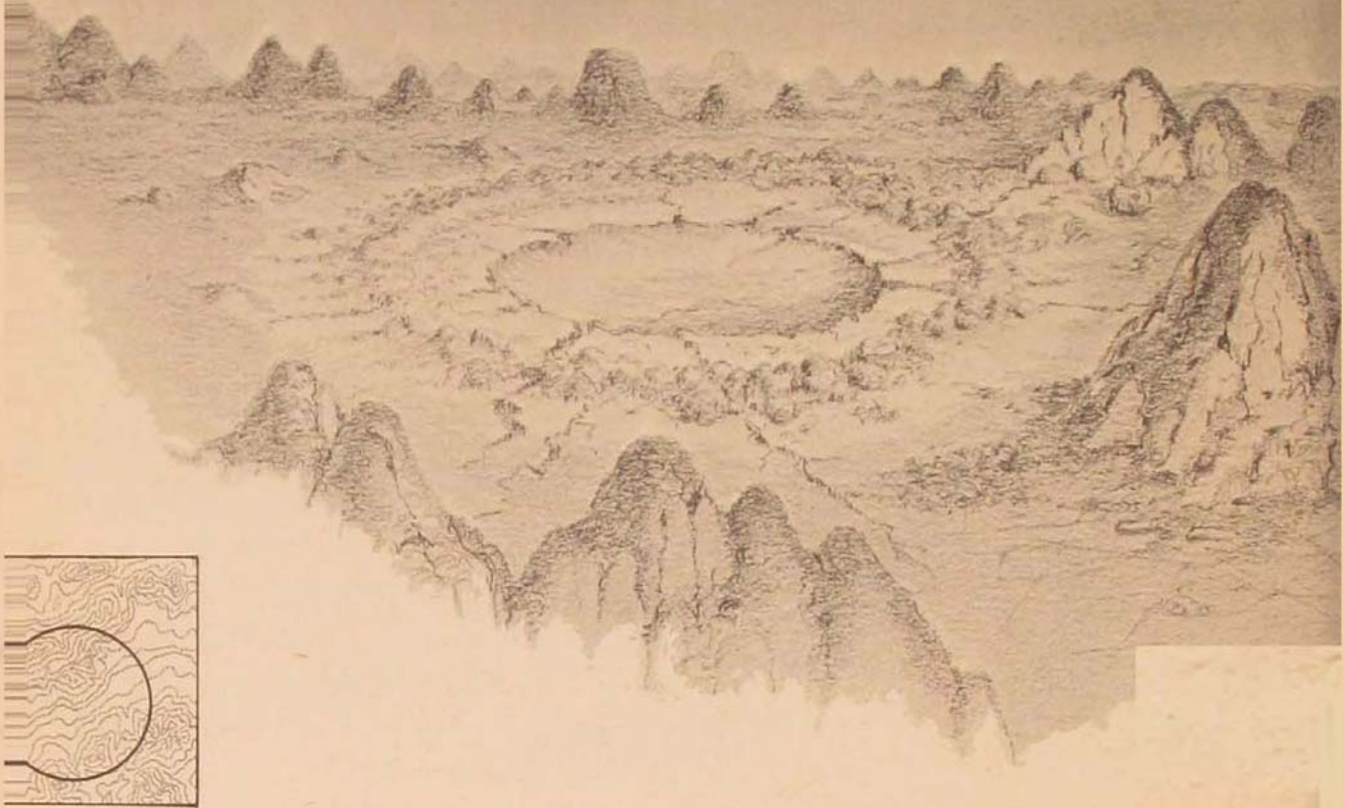
2. Situation: Enemy troops have infiltrated a mangrove forest from which they are making repeated forays in flat-bottom boats against a nearby friendly city. Indications are that their base of operations is being resupplied with

Mangrove Forest

material and reinforced with personnel. Because of the dense vegetation canopy and because of his mobility, the enemy cannot be located with sufficient accuracy to permit attacks with nonnuclear weapons. Efforts by friendly ground forces to push the enemy out are causing prohibitive losses to the friendly forces.

3. Nuclear Weapons Application: The toughest forests for which data are available are tropical rain forests. In these forests a nominal-yield weapon will strip tree branches over a diameter of approximately 2.5 NM and limbs and leaves over a diameter of approximately 3.7 NM. To maximize blast and thermal effects, an airburst is recommended. Since a mangrove forest is somewhat tougher than a rain forest, the diameters of effects listed above are probably a bit large. Seasonal variances probably are not significant in mangrove forests.

Karst Redoubt Area



Karst Redoubt Area

1. Description: Karst is eroded limestone soil containing caverns or caves capable of concealing and sheltering men and equipment. Limestone is light colored and thick bedded, with widely spaced joints (fractures smaller than faults and not accompanied by dislocation). It forms plateaus characterized by jagged pinnacles and caves, and often forms steep-walled islands fringing coastal areas. Limestone areas generally have scrub-forest vegetation, with isolated clumps of grass. Karst areas are found over large sections of Southeast Asia.

2. Situation: Enemy ground forces have taken advantage of caverns found in limestone formations. Flame throwers, napalm, and other nonnuclear weap-

ons have proved ineffective in the amounts available. It is estimated that ground assault would result in unacceptable losses to friendly forces.

The objective is to eliminate enemy concentrations in karst "cave-cavern" sanctuaries.

3. Nuclear Weapons Application: A nominal-yield weapon with a surface burst is illustrated. If available, a penetration-type weapon is preferred because it would increase crater diameters and subject larger adjacent areas to underground disturbance. The underground disturbance or rupture area is approximately 1.5 times the diameter of the crater. Crater diameters for the nominal-yield weapon burst at the surface and below the surface are as follows:

Height of bomb when detonated	0′	−10′	−20′	−30′	−40′
Crater diameter	460′	540′	630′	725′	800′

The lips resulting from these craters create an additional unusable surface equal to the crater diameter.

A bonus effect of surface burst (assuming zero wind) is residual radiation extending over approximately a one-mile diameter. Within this circle survival is possible only if exposure is limited to one hour and if personnel decontamination procedures were accomplished. This pattern would be elongated to windward, depending upon wind conditions. Because of residual radiation, only one nominal-yield weapon per square mile is required to deny a karst area to enemy forces.

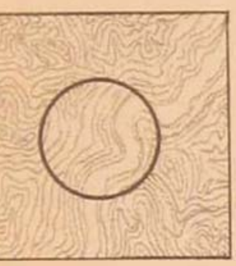
Mountain Defile (Pass)

1. Description: Mountains, hills, and plateaus are common terrain features throughout Southeast Asia—or any other world area, for that matter. Vehicular movement often is limited to defiles in these rugged mountain chains and plateaus. A typical mountain defile may be 3000 feet above sea level and 500 feet wide, located between peaks that are 7000 feet above sea level.

2. Situation: It is indicated that large enemy forces intend to pass through a 400-foot-wide mountain defile to reach their objective. The friendly objective is to block the mountain pass to vehicular traffic and compel enemy forces either to retreat or to attempt a virtually impossible advance along the rugged mountain slopes.

3. Nuclear Weapons Application: One nominal-yield weapon, surface burst, will block a 400-foot rocky defile with a crater approximately 450 feet wide. This crater is a lingering "hot spot." The surface burst results in residual radiation, approximately 50 per cent of which falls out around the target in a one-mile circle. This radiation hazard, lethal if exposure exceeds one hour in four, is an effective personnel barrier for approximately 40 hours after the

Mountain Pass



) nominal-yield weapon

burst. A penetration weapon is preferred because of increased crater diameter and area of underground disturbance (see karst situation).

Close-Contact Situation

1. Description: A close-contact situation may be mobile or relatively stable. In each situation, common denominators are proximity of some hostile forces and access requirements for material resupply and reinforcements.

2. Situation:

A limited-war situation has existed for some time in a heavily wooded, mountainous country in Southeast Asia. Enemy guerrilla forces, trained, equipped, and supplied from outside the country, have had increasing success. Operating in small groups, taking advantage of the almost ideal cover provided them by the terrain, avoiding the main arteries of transportation, maintaining their front-line supply by portage on the backs of coolies, the guerrillas have been extremely difficult to counter with the conventional ground and air weapons available to the indigenous friendly forces. As the guerrillas have gained in strength they have increased the size of their attack forces from units of tens to units of hundreds. This has enabled them to attack more valuable and more heavily defended military targets. Massing silently in the forest, they overwhelm a strongpoint or a defended village, then melt back into the forest and disperse before reinforcements can arrive.

When the success of these tactics rolls back the friendly outposts dangerously near vital delta country, the friendly forces mount a major counteroffensive. They move some 40,000 men into the forest-covered high ground that rims the delta. The first objective is to block entry into the delta; the second is to establish a fortified forward base from which friendly troops can counterattack.

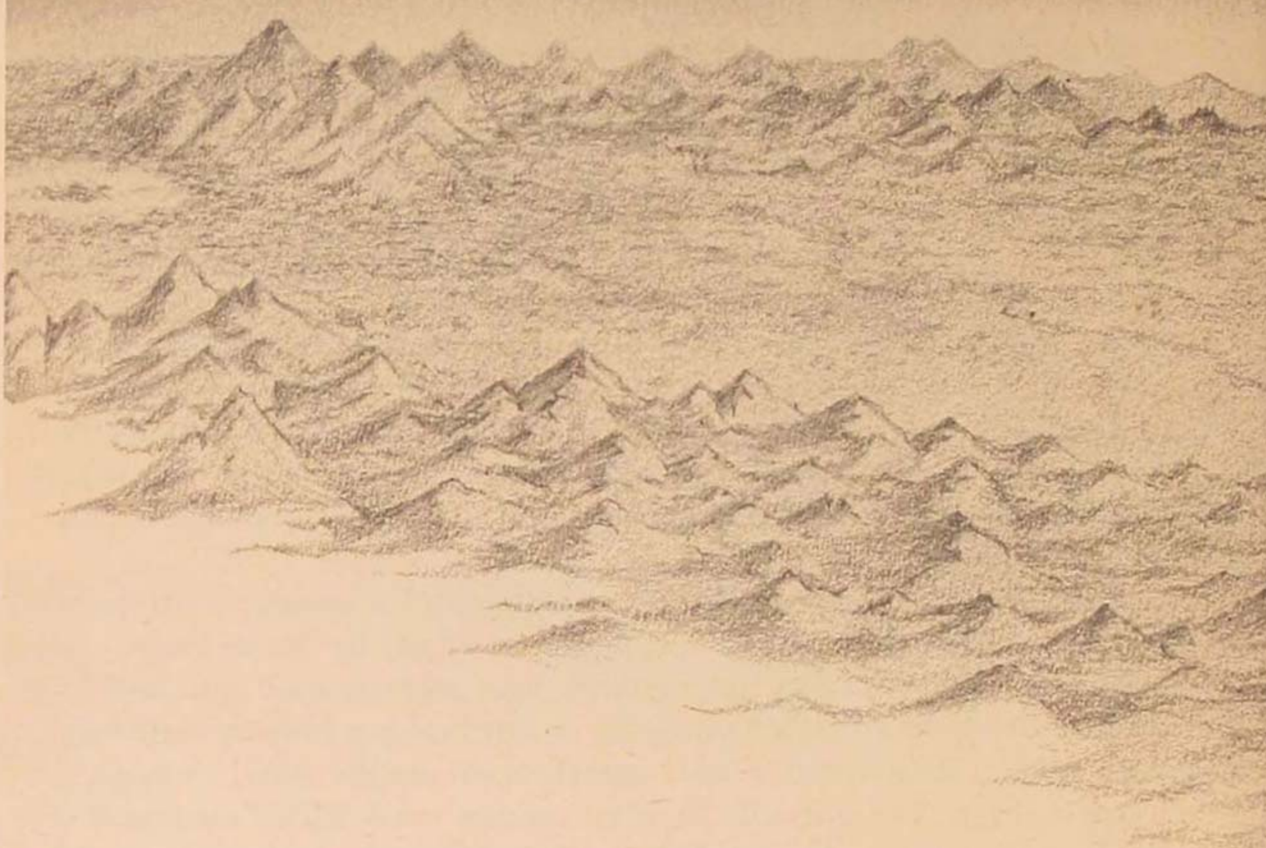
Enemy guerrilla forces infiltrate the mountainous country surrounding the friendly troop concentration and under cover of the dense forest bring up increasing numbers of troops, together with mortars and light artillery. Friendly air attacks are unable to stop the enemy buildup because their reconnaissance cannot identify troop concentrations or supply routes through the heavy forest cover. The guerrilla buildup reaches some 50,000 men, and the friendly force is surrounded. Resupply of the beleaguered forces becomes possible only by air, and as the enemy ring slowly closes, the friendly defenders are forced back into a constricted area which can be raked with enemy mortar and artillery fire. Friendly air attacks fail with conventional armament and napalm, again because of the dense forest cover. With air resupply and reinforcement becoming more and more hazardous as the defense area constricts, it is apparent that the friendly force must surrender unless nuclear weapons are used to break the encirclement. If the force surrenders, the decisive battle of the war has been lost and the delta forfeited to the guerrillas.

3. Nuclear Weapons Opportunities:

a. General:

Many target situations offered by this example appear as profitable nuclear targets, many of which are comparable to those outlined in the other examples. The targets selected in these situations are called situation-control targets because the primary objective is control of a tactical situation rather than destruction of defined amounts of definitely located personnel and material. In the early stages of the war, key enemy transfer supply points near the border could have been destroyed with nuclear weapons. If such action had not been considered expedient, the enemy "jungle trail" logistical support system could have been interdicted by use of nuclear weapons, with some measure of success. This interdiction might have prevented the siege situations which developed later, effectively supported by mass coolie transport despite intensive nonnuclear interdiction.

Close Contact

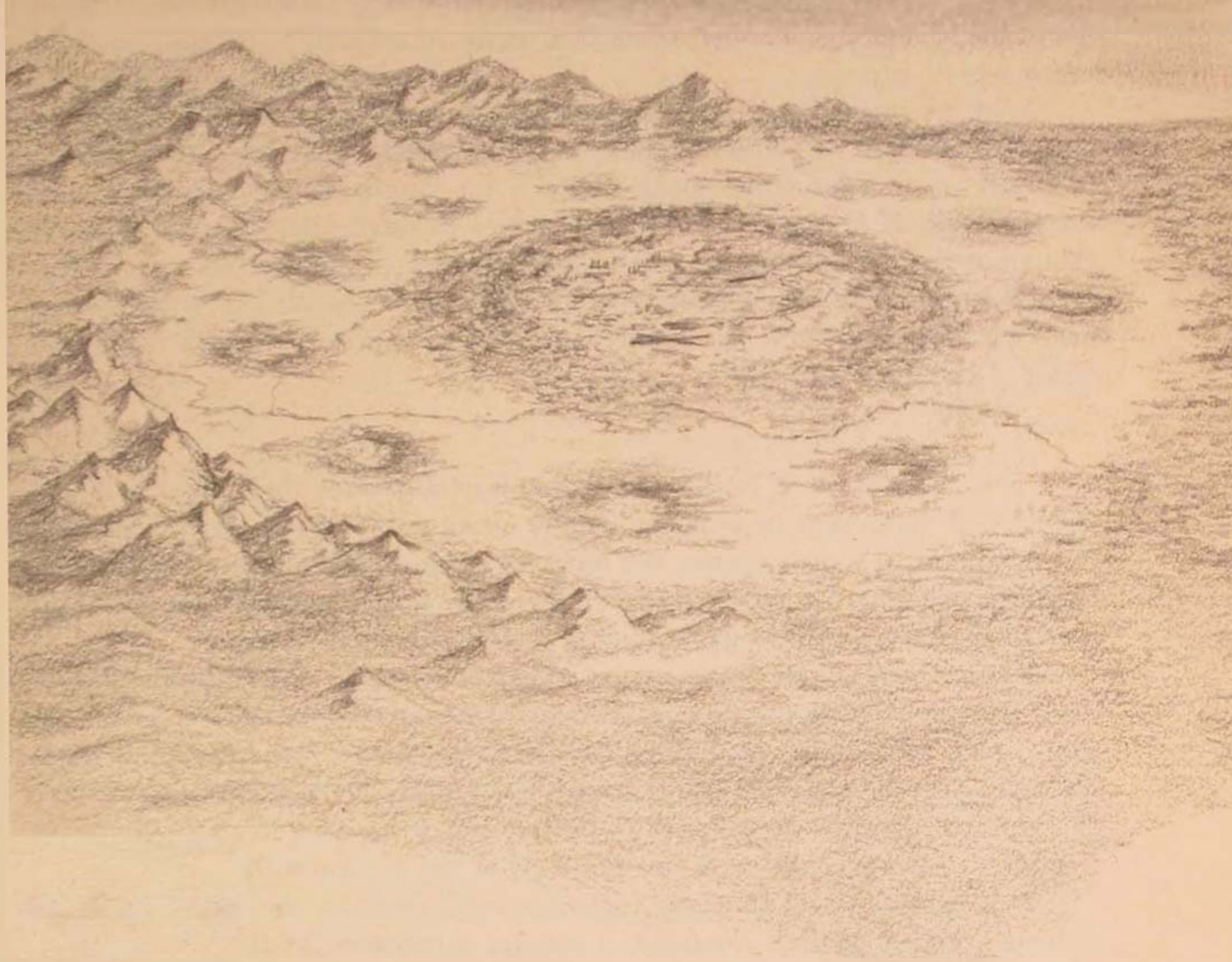


Even after the over-all tactical situation had deteriorated to the situation of siege, there were still lucrative opportunities for the application of nuclear weapons. Resupply of the enemy's two-week supply level of artillery shells could have been impeded. Small nuclear weapons could have been used in very close support. Somewhat larger-yield nuclear weapons could have been applied profitably at points more distant from friendly troops. This latter point is especially true as regards the 40–45,000 hostile troops beyond the range of friendly artillery.

It has been demonstrated that nonnuclear weapons are difficult to apply in adequate numbers when hostile personnel and supplies are so camouflaged and dispersed that pattern bombing of huge areas is required. While destruction of enemy personnel and supplies is an aim in such operations, control of the tactical situation and fighting environment is of paramount importance. The use of nuclear weapons in this type of situation would immediately deny the enemy a favorable tactical environment and impede his further use of a desirable or advantageous siege area.

No preconceived personnel-materiel minimums can be established as cri-

Situation



teria for nomination of this type of situation-control target. The overriding consideration is that a favorable tactical environment be denied the enemy before he is able to use it to advantage. Preplanning should include the identification of logical choke points for weapons application.

b. Specific:

The siege situation. The friendly forces have and plan to use nuclear weapons. Since the enemy forces are in close contact with friendly units, surface bursts with characteristic residual radiation fallout are eliminated as a possible delivery tactic. For airburst, a minimum distance of 4500 feet separation of friendly troops from the perimeter of weapon effects is advisable. Air-ground coordination is necessary. Friendly troops must be forewarned of the nuclear attack and adequate safety precautions taken.

The terrain around the siege point is scrub-forested hills. The rainy season has not started, although it is expected within a few weeks. An elongated area allowing a minimum cushion of 4500 feet between friendly forces and the perimeter of weapon-casualty effects is drawn. Ten nominal-yield weapons are dropped at this relatively safe distance. They strip the forest cover away and reveal the enemy routes for logistical and personnel buildup. They inflict heavy casualties and destroy stockpiled materiel in every direction around the besieged garrison.

With personnel and logistical reserves destroyed and the area exposed to more effective use of either nuclear or conventional weapons, the enemy is suddenly in an untenable position. He is no longer able to support a protracted siege. If he gambles on quick victory through all-out attack, friendly ground and air firepower can pin him down long enough for friendly troops to pull back and for smaller nuclear weapons to be applied to enemy troop concentrations. In short, the enemy has lost any option that could bring him victory. The siege is broken.

In the wide variety of limited-war situations that might confront the United States and its allies, no single weapon or weapon system can meet the full range of requirements. We must, in conjunction with our allies, maintain a broad range of capabilities in conventional and nuclear weapons. This is essential for both the deterrent value and combat flexibility.

By the same token, we must not deprive ourselves of the unique advantages offered by imaginative employment of nuclear weapons. We have been quite clear and firm in expressing our determination to use nuclear weapons in total war. Now we need to speak out with equal clarity in affirming that we can and will use nuclear weapons in limited war when such weapons best serve our broad interests and meet the demands of the tactical military situation.

We must achieve, through education and through the development of clear-cut, logical tactical doctrine, a general acceptance by the United States of the requirement for the use of nuclear weapons in limited war. This country cannot afford the tremendous outlay in dollars, resources, and men needed to defeat aggression by man-to-man combat on the ground, supported only by high-explosive bombs and rockets, napalm, and machine-cannon fire delivered from the air.

While considerable work has been done in joint exercises involving ground and air units simulating the employment of nuclear weapons, there are many fruitful avenues yet unexplored in the development both of suitable weapons and of specific doctrine for their employment. Much better equipment and techniques for the air defense of isolated areas must be evolved, for we cannot assume that we will be allowed the great advantage of unilateral application of nuclear firepower. Aid programs to threatened nations should emphasize as much as possible the importance of creating a ground environment for air defense and air control of offensive strikes that is superior to that available to the other side. This work can and should be done prior to any outbreak of hostilities and would make its own contribution to our over-all deterrent posture.

We have successfully deterred war with the Soviet empire by convincing its leaders that we shall not hesitate to employ all nuclear weapons at our disposal if such employment is necessary to prevent the enslavement of the free world. I believe we can prevent future limited aggression by the Soviets or their satellites if they become equally convinced that we can and will employ nuclear firepower from the outset.

Headquarters United States Air Forces in Europe

Basic Research for National Survival

Brigadier General Benjamin G. Holzman

BASIC research is the "Cinderella" of military and industrial technology. Until recently an ill-fed, ill-housed stepchild, basic research is now enjoying its greatest popularity in American history. The date on which this transition began is 4 October 1957, when Sputnik I joined our natural moon in orbit around the earth.

Today basic scientific research is recognized in Congress, optimized in the Executive agencies, and eulogized in the press. Unfortunately it is still almost as widely misunderstood as it was before and not much better supported.

A large part of the misunderstanding arises from the myriad definitions. Basic research has almost as many definitions as definers. We in the Air Force Office of Scientific Research have resolved this difficulty by ignoring all definitions except that contained in the Department of Defense "Policy on Basic Research." This defines it as "that type of research which is directed toward increase of knowledge."

I speak of AFOSR and not of the entire Air Force Research Division because my topic is basic research. AFOSR is the Air Force agency with primary concern for basic research conducted outside Air Force laboratories and facilities. There are valuable contributions to basic research from other Air Force agencies and from other departments of the Government. But the primary interest of these other Air Force agencies is in something else. Basic research discoveries are apt to be almost incidental bonuses in the developmental or applied research directed toward specific applications. Because of my subject, I am also leaving out the other components of the Air Force Research Division, whose research programs are largely "in house." Thus, I speak only of the AFOSR programs, since they are at the heart of the Air Force's basic research endeavor.

If a research proposal has a potential payoff for the Air Force and arouses no interest anywhere else, we will support it to the extent that we are able. In many cases the decision as to whether a given project is basic or applied research is an arbitrary one, on which two equally eminent scientists might disagree diametrically. Our attitude is not to worry about a line which is so indistinct. This attitude has resulted in substantial dividends to the Air Force in AFOSR's brief existence.

The origin of AFOSR was reported in the Winter 1953–54 edition of *Air University Quarterly Review* by its first commander, Dr. Oliver G. Haywood, Jr., then Colonel, USAF. At that time it was an integral part of Headquarters

Air Research and Development Command. It was elevated to center status on 8 August 1955 and opened its own headquarters in Washington, D. C., on 1 July 1956. Between that date and October 1957, despite innumerable evidences of its value, AFOSR led a precarious existence and often was rescued from extinction only by the efforts of my predecessor, Brigadier General Hollingsworth F. Gregory (now retired), and the faith of Generals Thomas S. Power and Samuel E. Anderson, as successive commanders of ARDC.

Now, thanks to the interest generated by recent space probes by both American and Soviet scientists, and thanks also to the dynamic philosophy of ARDC's present commander, Lieutenant General Bernard A. Schriever, AFOSR has become the nucleus of an expanded Air Force Research Division, one of the four major operating divisions of ARDC.

It is not my purpose to dwell on AFOSR's philosophy or operating technique, both of which are roughly similar to that outlined in Dr. Haywood's article. Rather I should like to review AFOSR's contributions to the Air Force to date and the trends in basic research as we see them.

One of the hard truths we must live with is that tangible results from basic research seldom become visible very quickly. The atomic bomb is credited with saving untold days of war, many thousands of lives, and millions of dollars. It was made possible only by the basic research on the atom performed decades earlier by scientists who had no conception of, or interest in, its war potential; and the total cost of all the basic research would hardly have come to one per cent of the cost of the Manhattan Project.

Many of the projects we are supporting today will uncover knowledge of natural laws whose full value may not be known until 5, 10, or 20 years from now, but which may then spell the difference between life and death for our Nation. I feel strongly that the Air Force, in its aerospace operations, is bound to benefit from the results of *any* investigation conducted by competent scientists into *any* unknown area of *any* field of science and that the only wasted research is that which is not properly supported.

Fortunately some AFOSR-supported projects have already produced important results and others have reached the point where important contributions

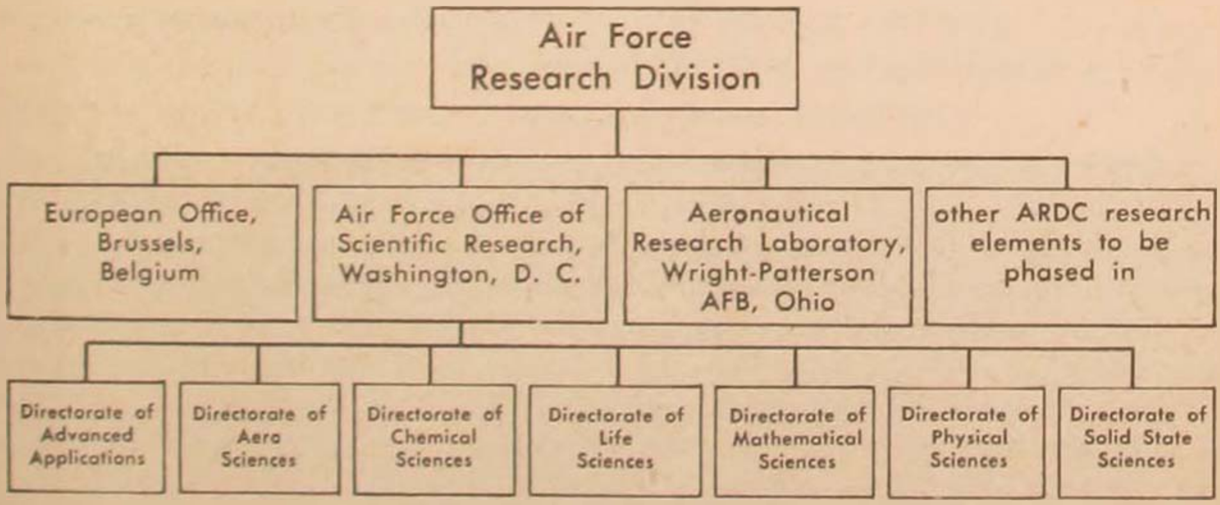


Figure 1. Organization of Air Force Research Division.

to our military strength are clearly discernible. The best way to give the broad picture is to describe briefly the work of the individual directorates and divisions that supervise AFOSR's research operations and to select a few of their actual and potential payoffs to date.

solid-state sciences

AFOSR recognized very early that the most fruitful investigation in metallurgy, ceramics, semiconductivity, and magnetism would require cooperative contributions from each of these areas, rather than separate efforts. From this realization was born the concept of a new solid-state sciences discipline over seven years ago. Today the acceptance of this as a new integration of the research effort is everywhere evident. Universities and other research administrators have followed our lead in encouraging experts in physics, chemistry, metallurgy, ceramics, electronics, and high polymers to view their research on the solid state of matter as part of a unified scientific problem area. Investigation is profiting in a way which might have been impeded by the previous departmentalization, and the striking achievements of our solid-state sciences team validate AFOSR's novel departure from tradition. This in itself can now be listed as a major Air Force contribution to science.

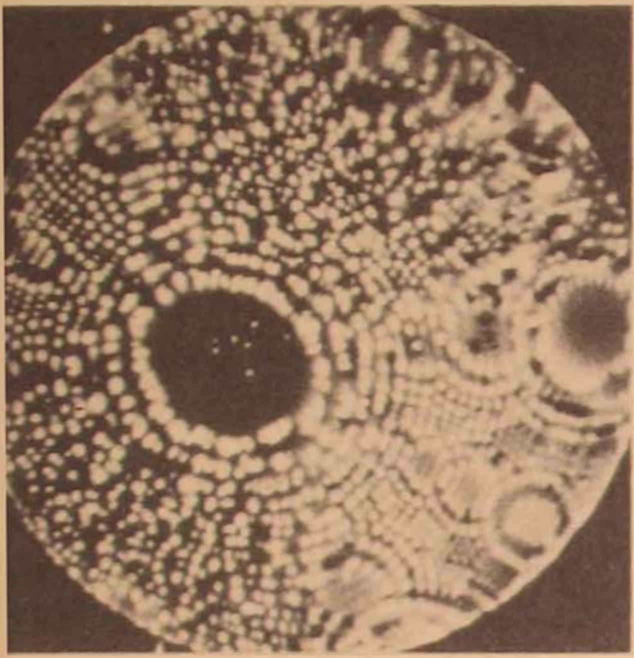
The Solid State Sciences Directorate has, from its inception, had two major objectives: (1) to clarify existing fundamental knowledge on which many present applications rest, and (2) to explore unusual phenomena which may result in significantly new ideas with respect to metals, alloys, ceramics, all the electronic materials (e.g., semiconductors, ferrites, ferroelectrics, magnetic materials, and dielectrics), phenomena occurring on the surface of solids and especially on interfaces (the points at which different materials come together), and low- and high-temperature properties of solids. The implications to the Air Force of any new discovery in these areas are obvious.

The discoveries of scientists supported by AFOSR in this area include:

- Field electron-emission and field ion-emission microscopy which first enabled scientists to "see"—and actually photograph—individual atoms and to study their important role in the ultrastructure of solid materials.

- High-purity indium antimonide crystals, which possess greatly enhanced sensitivity as an infrared photodetector.

Recently the statement has been often made that air weapons must be constantly rethought and replanned to achieve breakthroughs in performance and reliability rather than the incremental improvement to be gained from piecemeal redesign of components. Perhaps even more than the developmental engineer, the researcher in basic science can provide the new, fundamental knowledge of natural processes from which such breakthroughs often proceed. Brigadier General Benjamin G. Holzman, Commander of the Air Force Research Division, ARDC, shows how the Air Force is pioneering in such research with contracts let to civilian universities, research laboratories, and individual scientists that enable them to probe the unknown and the poorly understood. Out of basic research on the beetle's eyes, for example, comes a new, sensitive groundspeed indicator for century-series aircraft.



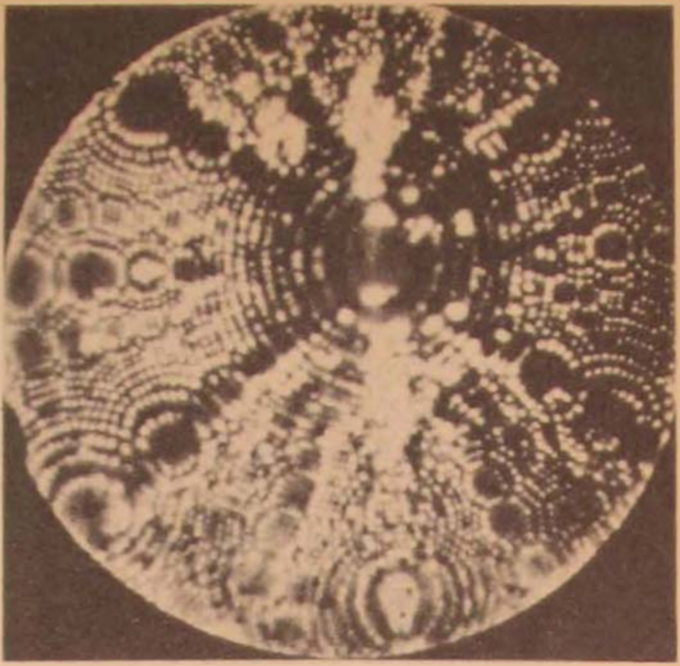


Figure 2. Photographs of a single atom on the tip of a tungsten needle. Taken by a field emission microscope, the photo at left is magnified 4,300,000 times, the one on the right 2,750,000 times.

• MASER (microwave amplification by simulated emission of radiation) action in synthetic ruby and other solid-state crystals, which may greatly simplify long-distance microwave and infrared communication.

• Synthetic, room-temperature, ferroelectric crystals (lithium trihydrogen diselenite), which offer a new class of solids for converting electrical energy into mechanical energy and vice versa.

• Methods of controlling the purity and surface conditions of normally brittle, refractory crystals so that they become ductile and may be bent and twisted at room temperatures. This may lead to an important new class of materials for high-temperature applications in future Air Force weapon systems.

• Electron-microscopical and precision X-ray-scattering techniques that can depict the role of atomic dislocations and the migration of dislocations in crystals in various phenomena in structural metals and alloys.

• High-vacuum instrumentation for precise measurements of metals over a wide range of low and high temperatures under controlled atmospheric conditions, which has made possible the study of many metals of special interest to the Air Force (e.g., titanium, zirconium, hafnium, thorium, uranium, and the rare earths). Such study has been hampered in the past by the ready contamination of these substances by oxygen and nitrogen.

At the present time our solid-state scientists are emphasizing:

1. *Crystal growth.* Most solids are found, under microscopic examination, to consist of crystalline units. The study of how these crystals grow should lead to the achievement of a facility for producing materials with unusual mechan-

ical properties and greatly enhanced electronic utility. The value of high purity and crystal perfection has been demonstrated in the past with the invention of the transistor.

2. *Surfaces.* The mechanical properties and corrosion behavior of solids have been found to depend largely on their surface condition. This discovery suggests strongly that prolonged interplanetary travel will significantly influence the properties of metals and ceramics.

3. *Superconductivity.* The infinite conductivity of some intermetallic compounds at low temperatures and other low-temperature characteristics are not well understood. Such mystery areas often prove to be highly important, because the present lack of understanding is indicative of a need for radically new concepts.

4. *Deformation and flow processes in solids.* Understanding of detailed mechanisms in this area, which includes fatigue and fracture, should provide a key to successful development of materials to meet unprecedented demands being placed on solids.

physics

AFOSR's physicists are concerned with the expansion of our fundamental knowledge of matter and the processes of nature. Among the most important areas of investigation under their support is expansion of research on the MASER techniques, one of which I mentioned under solid-state sciences. Since the original demonstration of very-low-noise, narrow-band amplification in the ammonia gas MASER, research in the generation and amplification of extremely high frequencies has proceeded in many new directions, both basic and applied. One dividend thus far from some of our researchers is simpler equipment operable at room temperatures. Another group of investigators has succeeded in providing substantial bandwidth in a MASER. Under another contract (this one a joint-services contract), a millimeter-wave MASER was developed which is being used for radio astronomy. MASER research is being extended into the lower millimeter wave lengths, as well as to infrared and optical frequencies, under current AFOSR contracts.

Other research under our physicists' sponsorship includes:

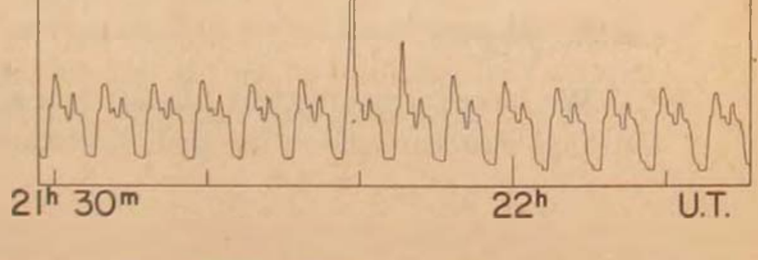
1. *Extraordinary radio-wave transmission.* Low-frequency, audiolike signals, a class of atmospheric electrical disturbances popularly known as "whistlers," were observed with low-frequency receivers and on telephone lines several years ago. They were identified as natural phenomena associated with atmospheric electrical discharges. The unusual method of transmission of these signals was verified under one of our joint-services contracts and has proved capable of providing directed signal transmission over long distances. Two additional "whistler" variants have been identified under recent AFOSR contracts. Study of these various "whistler" phenomena is giving us an improved understanding of the interactions of electromagnetic radiation with magnetic fields in ionized regions. Besides being important for improved communications, this research provides a means of probing the earth's magnetic field and of measuring ionization in the upper atmosphere, all of which are of obvious and vital Air Force interest.

2. *The spectroheliograph* This apparatus, built at Stanford University under AFOSR contract, consists of 32 trainable, 10-foot-dish antennas along two intersecting, 375-foot arms of a cross. It provides a narrow beam capable of scanning the sun's surface to give us, to a degree of precision not previously obtainable, continuous information as to the formation, development, and motion of the solar flares responsible for auroral displays, intense magnetic storms, and other communications-disrupting phenomena. The high resolution of this spectroheliograph has made it possible to scan other celestial energy sources to obtain readings on temperature distribution. This is a valuable supplement to optical telescopic information about electromagnetic, solar, and astrophysical phenomena.

3. *Statistical mechanics.* The techniques of statistical mechanics have been successful in dealing with materials in thermal equilibrium and with simple systems such as dilute gases and perfect crystals. The AFOSR-supported research in this field is attempting to develop methods of more general applicability. Thus far techniques have been worked out for more precise calculations of the properties of fluids. This is important in working at very low temperatures where all gases become very dense and certain properties, such as conductivity and viscosity, change radically. In a related area, another AFOSR-sponsored researcher has derived formulas for describing the heat flow in gases which are valid from extremely dense gases to almost individual particles. Other work is going on in this field under our support, both in the United States and in Europe.

The Air Force implications become clear when we consider that aircraft

Figure 3. Spectroheliograph, or radio telescope, built at Stanford University under AFOSR contract. Composed of 32 dish antennas mounted on two intersecting lines and synchronized for simultaneous tracking, the radio telescope (left) can receive on a narrow beam and with great resolution the radio energy emissions from the sun. The graph (below) is a sample reading from the spectroheliograph. The left axis of the graph indicates the strength of the received signal in empirical units. The high points on the graph are caused by sun spots.



and missiles move through atmospheres of varying densities which are not made up of hard spheres, are not in equilibrium, and have varying viscosities, among other factors. Also these vehicles are propelled by the combustion of fluids that are subject to all the same qualifications and whose effectiveness depends both on the rate at which the fluids can burn and on the subsequent interactions of charged particles of combustion products. Out of this research undoubtedly will come improved aircraft and missiles and better fuels.

4. *Atomic and molecular research.* Fortunately the funds and manpower resources of the Physics Division match to the extent that the major portion of the program areas is covered by the selection and monitoring of related or complementary research problems. For example, in the area of the energy-exchange processes for molecules and atoms from their normal states, studies of initial activation at low energies have clarified basic chemical processes, including reaction rates. At intermediate energies, investigations of cross sections for interactions of molecules with atoms and of radiation with atoms have led to a better understanding of the way the upper atmosphere is composed and why certain molecules, ions, and free radicals are produced in discharge tubes and during chemical reactions. Correspondingly, investigations of completely ionized atoms which occur under stellar conditions are also carried out. It is from studies such as these, ranging from low to high energies, that vital information is obtained for engineering studies of fuels, communications, and extreme flight conditions, as well as the more fundamental processes occurring on the sun and other stellar bodies, such as sustained and cyclic thermonuclear reactions.

Unexpected scientific results are obtained in this area of investigation, as in most others. For instance, a study of the selective absorption of soft X rays by the outer electron shells of the light metallic elements led to instruments that can also measure the mass or weight of objects as small as animal cells a few millionths of an inch in diameter and with weights in the micromicrogram region.

As in other sciences, in physics no one can predict with certainty which of our basic programs will produce significant new knowledge, either in the purely scientific sense or in terms of fruitful application to future Air Force requirements. However, the projects mentioned above have already shown more than mere promise and imply similar success in other areas of physics. If I were to mention only one area in which a breakthrough could give really startling results, it would be field theory. Understanding the relationship among the electromagnetic field, the gravitational field, and the nuclear field, to the point where each could be controlled by causing interactions with the others, would give a tremendous boost to our ability to control energy release from nuclei, as well as in our ability to use electrical fields to overcome gravitational fields.

nuclear physics

We have set up nuclear physics as a science in its own right in our organizational structure. Even in applied research it is becoming extremely difficult to compartmentalize science—to say arbitrarily that a given project belongs to general physics rather than to nuclear physics, or to chemistry, or to solid-state science. In basic research this often becomes impossible. Therefore we have consistently tried to avoid setting up rigid classifications. We do not say to any of our staff scientists or to any of our contractors that their interests lie in a given narrow field and must not intrude on a neighboring field.

The success of AFOSR's support of basic research is due largely, I believe, to our philosophy that an investigation is best carried out by a qualified scientist who has a strong desire to conduct that investigation. Similarly we encourage our staff scientists to select proposals in which they see a definite possibility of a contribution to the Air Force, regardless of whether it seems to fall just within or just outside their specific field. Several contracts in any given directorate or division might be equally at home in one of three or four other units, but our scientists do not worry about labels, nor do we. It was this philosophy that led my predecessors to set up solid-state science as a separate field, and the same philosophy indicated that nuclear physics was important enough to warrant its own staff.

Our nuclear-physics program concerns itself primarily with (1) the properties and structural details of nuclei and elementary particles, (2) the composition and energy spectrum of cosmic radiation, and (3) methods of mathematical physics applicable to complex physical systems.

AFOSR's modest investment in studies of low- and medium-energy nuclear physics is oriented toward problems which our staff believes are not receiving specific or sufficient attention from other research agencies. For instance, a vast amount of data has been accumulated on neutron cross sections. A model exists which, from the engineering viewpoint, can explain qualitatively the interactions of the neutron with various materials, at least in the small-energy range of concern in the weapons and reactor technology of today. We support investigations that start where the applied programs leave off, because our present qualitative understanding is not sufficient for the advancement of pure science and its eventual applications to future technological requirements.

One objective is to develop a universally applicable mathematical description of the nucleus, which will permit quantitative prediction of the dynamical behavior and properties of fissionable isotopes and all other nuclei over an energy range from a few kilo electron volts to billions of electron volts. An important by-product of such a description will be found in its application to the shielding problem. At present, lack of understanding of the pertinent parameters requires the use of design techniques that are based on only empirical constants and arbitrary factors of safety.

The small AFOSR program in high-energy particle physics is the entire support given by the Air Force to a field that represents the greatest unknown in the whole area of physical science. (This illustrates my conviction that there is no conceivable discovery of natural law that would not be of interest to the Air Force, since in this instance our support is based on what we do not know, rather than on what we do know.) No real unification of ideas as to the fundamental particles has yet been established, nor do we have more than a superficial understanding of the nuclear forces and their interplay with the electromagnetic and gravitational forces. These are beyond doubt important areas to explore, if only to safeguard the Air Force against possible technological surprise and expensive obsolescence. As long as no other element of the Air Force is concerned with the potential discoveries of scientists studying these particles, we shall continue to support them to the extent that we are able.

It should not be inferred, however, that our nuclear-physics program has not come up with tangible results. One of its projects has produced new knowledge on the electromagnetic structure of the proton and the neutron. Results from another joint-service-supported investigation of high-energy photon interaction with matter provide information that is directly related to the shielding capabilities of various materials for gamma-ray radiation.

Some of the techniques developed by the theoreticians under our support promise application to problems in fields not directly related to those that prompted their undertaking. For example, a subject of great interest to nuclear physicists has been the dispersion relations and their application to high-energy phenomena. In April 1959 an AFOSR contractor placed a powerful new tool in the hands of fellow theorists by extending dispersion relations to permit treatment of reactions in systems where two particle transitions are involved and both energy and momentum transfer must be considered. This method, already internationally known among quantum theorists, will be welcomed by researchers in many other fields of interest to the Air Force. As one instance, it is safe to predict application of this new technique to problems of radiation propagation in the atmosphere.

A question which has plagued cosmic-ray physicists is why some solar flares produce low-energy cosmic rays while others do not. An AFOSR-sponsored scientist resolved this question by means of a very-short-time constant, high-counting-rate cosmic-ray telescope with which he detected and recorded variations in the flux that last for only a minute or two and that had not previously been noticed. This information fills an important gap in our knowledge of natural law.

In viewing future research proposals, our nuclear scientists will continue to emphasize research in theoretical nuclear physics, with particular attention to the development of a theory that will permit prediction of the utility of a nucleus for specific purposes. Until a quantitative description of nuclear forces and other properties is available, we cannot satisfactorily predict such suitability and must determine the matter empirically, often at considerable expense. Studies of general relativity theory and quantum field theory will be supported, for it is certain that greater comprehension of these theories will drastically influence future developments in modern physics.

The relatively small AFOSR program in the rapidly unfolding field of high-energy physics will be expanded as quickly as more funds become available for it. Another program similarly marked for expansion when we have the money for it is low- and medium-energy particle spectroscopy, because of our urgent need for more precise data on nuclei. Better equipment for this type of investigation is coming into operation, such as the 12-million-electron-volt Tandem Van de Graaff (popularly known at AFOSR as the "tandegraaft") at Florida State University. This is one result of our current effort in this area. This machine is expected to come into operation in the spring of 1960 and will be the third of its kind in the world.

Investigations of cosmic radiation will continue because of the obvious importance of this phenomenon to the related fields of high-energy physics, geophysics, and astrophysics, all of which have high Air Force significance. In 1959 we started a small program of support to cosmic-ray and solar physics in South America, where the unique combinations of altitude and latitude make these studies especially important. Among the organizations we support is the world's highest year-round laboratory. Located in the Andes and also virtually on the geomagnetic equator, it is ideal for cosmic-ray variation and asymmetry studies.

information complexes

Besides supporting research in pure and applied mathematics, our Directorate of Mathematical Sciences sponsors a vigorous program in information complexes. Small as it is, this may well be one of the most important of our projects in the furtherance of the pursuit of scientific knowledge. This investigation into the fundamental aspects of information storage and retrieval includes theoretical studies to determine optimum ways of organizing scientific information so that the answers to specific questions can be found rapidly and efficiently. Such fundamental studies can yield information suitable for all information complexes, from conventional libraries to the most modern computers.

The *practical* purpose of the information studies is, of course, to reduce

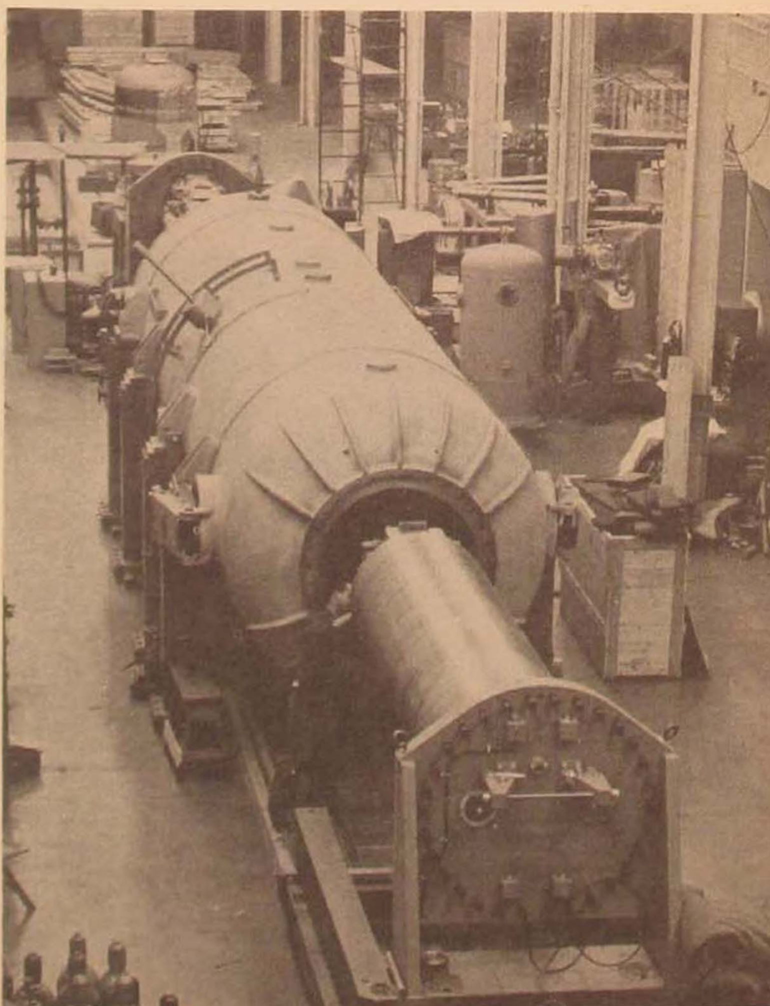


Figure 4. Tandem Van de Graaff positive-ion accelerator at Florida State University. Operating at 12 million electron volts, the "tandegraaff" is a new, precisely controllable source of charged particles. It permits extension of precision nuclear research to higher energy ranges, unexplored areas.

the need for human labor in the handling of information. Ultimately it should be possible to translate, index, abstract, store, and retrieve scientific and technical information without any human intervention at all. On the other hand, the *scientific* purpose is to gain more knowledge about scientific knowledge itself, as it is displayed in an ordered array of symbols, by analysis of the grouping, interrelationships, and properties of the symbols.

Although this program has been in existence for only about two years, it has already produced about twenty scientific papers of sufficient value to have been presented at important national and international scientific meetings. One paper so presented by an AFOSR contractor led to the commercial development of a working model of an information-retrieval device in less than one year, at no cost to the Government and with no profit to the original contractor. This is perhaps the fastest translation of basic research into practical application in history.

Of particular significance to this organization, as well as to all other science-supporting institutions, is a mechanized information control system. With it we expect very soon to be able to digest pertinent details on each of our over 1000 current contracts and give us not only quick information on specific projects but also answers to such complicated questions as: "Which of our contracts in universities involve infrared detection systems operating at cryogenic temperatures, and which of these will expire during the first quarter of the next fiscal year?" Or: "How many contracts do we have in basic research on materials in Massachusetts outside of Harvard and MIT?"

This part of our mathematical sciences staff has a contract with the Library of Congress. This is now producing the first complete bibliography of abstracts of all research supported by AFOSR since its beginning. Over 8000

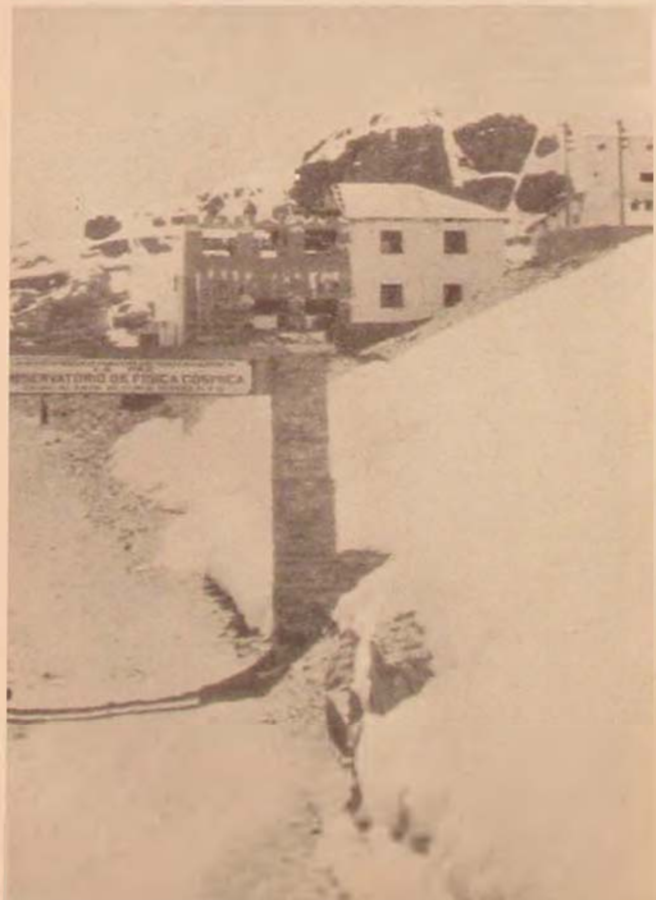


Figure 5. The world's highest year-round laboratory, the Observatorio de Fisica Cosmica of the Universidad Mayor de San Andres. Perched at an altitude of over 17,000 feet among the towering peaks of the Andes and near the geomagnetic equator, the laboratory is uniquely situated for study of cosmic-ray variation.

abstracts and literature references, dating back to 1950, have already been compiled and we expect to issue our first working volume in a short time. As far as we have been able to determine, AFOSR will be the first agency supporting a large program of basic research to produce a reference work which will provide comparatively easy access to all research papers produced under its auspices.

AFOSR's program in research information has become so widely recognized in its short existence that its director is an invited member of the Federal Advisory Committee for Scientific Information and is an invited speaker or panelist in almost every important meeting dealing with this area of science. We are, I believe, justly proud of the leadership the Air Force has gained through a very modest program of AFOSR.

mathematics

The "pure" mathematical sciences are of interest to the Air Force because of their function of developing techniques for describing, controlling, and predicting physical events. Mathematical techniques are designed in terms of specific mathematical systems which serve to characterize them and determine their range of application. AFOSR's program includes analytic and algebraic methods and the "nondeterministic mathematics" of probability theory and statistics.

Our mathematics program is oriented toward important problem areas of air technology and is developed in close coordination with our objectives in the other science programs. The rapid development of science and technology in recent years has had a very marked effect on the mathematical sciences by reducing substantially the "lead time" between a mathematical discovery and its utilization. This of course emphasizes AFOSR's great requirement for mathematical research. An important contemporary concern in mathematical research is that formerly the only equipment a mathematician needed was paper and pencils and occasional use of a small calculating machine. This is no longer true. The use of modern, high-speed computing equipment has now become an integral part of research in some areas of mathematics.

A recent report from an AFOSR-sponsored research mathematician summarizes the formulation of a new type of computer designed to execute simultaneously an arbitrary number of subprograms or computations. It is distinguished by a structural design composed of a number of identical subnetworks and a special organization for each subprogram to facilitate the simulation of "similar" systems. It can become a very useful tool for investigating new problems in automata theory, as, for example, von Neumann's scheme for self-reproducing automata. If current component research is successful, this formulation may lead not only to really practical computers but also to such distinctly Air Force purposes as new, automatic guidance and control systems for missiles and spacecraft.

On another mathematical plane, let us consider the phenomenon of light. Generally speaking, light travels in a straight line; precisely speaking, it does not. Light tends to "creep" around the sharp edges of an object so that the actual shadow is somewhat less than the geometric shadow. This diffraction of light plays an important part in the design and use of optical equipment and also in the examination of the gaseous envelopes that surround the sun and planets of our solar system.

Diffraction is appropriately formulated in a mathematical context. The diffraction of a plane wave by a circular aperture is exactly equivalent to the mathematical treatment of certain (Fredholm) integral equations which depend on a parameter P. P is the product of the radius of the aperture and the wave number of the incident wave. When P is a positive real number, the integral equations have a unique solution. A significant research goal is to prove that the equations have a unique solution for all finite values of P. It would then be possible to show that the solution of the diffraction problem could be expanded in a mathematical power series in P which would converge and hence give a definite result for all P. One AFOSR contract mathematician has examined certain of the Fredholm integral equations for such complex values of P. He has obtained results for which the inhomogeneous Fredholm equation always has a unique solution and consequently for which the diffraction problem can be solved. His report concludes with discussion of some practical considerations for practical application of his results.

If the reader will recall his early studies in mathematics, he will remember that as he progressed from arithmetic to algebra and thence to geometry, trigonometry, and calculus, he became a member of an ever-diminishing elite. It is safe to say that if arithmetic were considered the base of the mathematical mountain the work of the theoretical mathematicians sponsored by AFOSR would represent the highest pinnacle of that austere monolith.

Our mathematics research program has produced definite accomplishments in such areas as ordinary and partial differential equations, nonlinear techniques, approximation techniques, fluid flow, electromagnetic theory, and statistical design. Since mathematics is the basis of all the physical sciences, Air Force support of the inhabitants of this select realm has potentially the highest payoff imaginable in terms of real offensive and defensive power.

propulsion

The reason for Air Force support of basic research is perhaps nowhere more obvious than in the field of propulsion. With aircraft and missiles already operating at the edge of the atmosphere, with satellites already venturing thousands of miles from earth, and with interplanetary spacecraft on the visible horizon, we have for practical purposes gone beyond the potential usefulness of so-called conventional fuels. New means of propulsion must be discovered and applied at a rate of progress never before approached by science and technology. This is the mission of our Propulsion Research Division.

The work supported by our propulsion scientists can be broken down broadly into three categories: energy sources, energy release and transformation, and conversion of energy to propulsive work.

Again very simply, the studies in energy sources include thermodynamic and thermophysical properties, activation energies, atomic and molecular binding energies, and composition of propellants. The second category includes study of chemical kinetics and dynamics of gaseous, liquid, and solid propellant combustion processes ranging from ignition, through flames and detonation, to quenching. Also included is fundamental work on ionization and de-ionization, dissociation and recombination, and chemical regrouping of atoms of propellant working fluids. The third part of our propulsion research program concerns the acceleration of working fluids such as ions, colloids, and plasmas, by nozzles or electromagnetic means.

Our annual program in propulsion consists of about seventy contracts costing about $4.5 million, including about $1.5 million provided by the Advanced Research Projects Agency of the Department of Defense. I believe that the dividends already reaped from this program far exceed this modest investment. We must add to these the intangible value of our growth of understanding of the complex phenomena involved in the natural laws of propulsion.

A constant part of the work of this division is making sure that the theoretical and experimental work done by our sponsored scientists is not left to gather dust in some scientific archives. Its results are delivered as promptly as possible to potential amplifiers and appliers via technical and semitechnical journals, papers at scientific meetings, and seminars and symposiums. Last October we cosponsored our Second Symposium on Advanced Propulsion Concepts, which drew over 600 of the free world's leading propulsion scientists and engineers to Boston for a full two days of meetings on both the classified and unclassified levels.

Studies of detonation in air-breathing combustion by two AFOSR contractors working separately resulted in the production by each of them of a standing detonation wave in a flowing system. The knowledge derived indicates such promise for flight in the mach-7 regime that we have recommended that the Wright Air Development Center conduct feasibility studies to evaluate engine possibilities.

Our emphasis in liquid-rocket combustion has been placed on scaling and high-frequency combustion instability. A model of the fully developed instability based on experimental data produced under our sponsorship has been of practical use in the design of large engines, particularly in the second-stage rocket of the Titan.

In solid-propellant research, an AFOSR contractor developed a hot-plate device for studying surface decomposition of solids. This has proved useful in simulating solid-propellant combustion. The technique was adopted to resolve the mechanism of combustion of ammonium nitrate propellants on a WADC contract and is now being applied to study ammonium perchlorate propellants and detonation.

In ion-plasma research, we have projects to study the details of ionization, plasma behavior, and means of accelerating mass to high velocities. AFOSR-sponsored work on arc jets has led to their wide use as laboratory tools. Exploratory studies on ion propulsion by one of our contractors formed the basis for our recommendation to start development of the ion rocket, on which competitive bids are now being received by ARDC and on which contracts will probably have been awarded by the time this article appears. Work in the field of

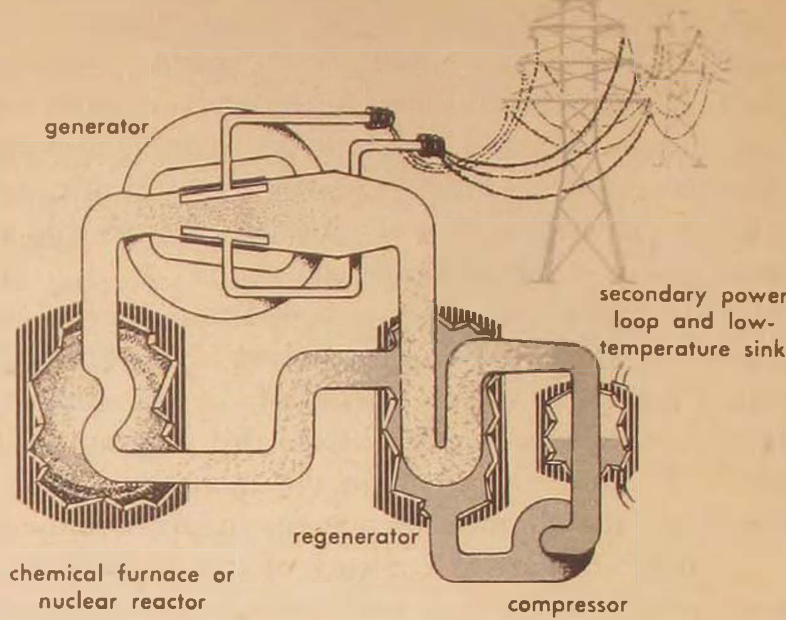


Figure 6. A system chart of a magnetohydrodynamic cycle for generating electrical power in commercial quantities. This concept is based on research sponsored by AFOSR. A chemical furnace or nuclear reactor (lower left) heats and ionizes the working gas, which then flows through a magnetic field in the generator. Direct current is tapped off the ionized gas by electrodes in the generator. The working gas is then cooled in the regenerator and the heat sink, compressed, and reheated in the regenerator before re-entering the furnace for heating and ionization, to repeat the cycle.

magnetohydrodynamics has begun to show great promise of fruitfulness for the Air Force. One contractor has demonstrated lift, simulated the propagation of shock waves in interstellar space, and evolved several means of plasma acceleration which are significant contributions to propulsion.

We have several projects concerned with the synthesis of fuels, the kinetics of propellant reactions, and thermochemical and thermodynamic properties of fuels. One study of the reactions in a high-temperature arc resulted in a means of synthesis for high-energy propellants. Another contractor determined that the delay of oxygen in going from one equilibrium state to another was 1000 times shorter than had been predicted by Teller. Since this information is significant to the re-entry problem, it was furnished promptly to industries concerned with nose cone designs.

As in the other AFOSR technical areas, the work in propulsion is under constant evaluation to ensure that present and promising successes do not blind us to the need to scan the far horizons for ideas that require our peculiar kind of encouragement and nourishment to produce potent possibilities for the kind of Air Force that the Nation will need in the decade or more ahead of us. When we have brought an idea to the edge of practicality, it becomes the project of one of our sister divisions in ARDC and we turn our time and funds to new raw ideas that need "proving out."

mechanics

It is probably here that AFOSR comes closest to applied science, but even here we manage to stay within the "blue area" which is AFOSR's special forte.

Under mechanics, we support basic theoretical and experimental research in such phenomena as boundary layers, gas flows, composition and properties of air at high temperatures, magnetofluid mechanics, orbital mechanics, nonlinear mechanics, unsteady aerodynamics and gas dynamics associated with flutter, structural interactions and thermal effects, and plasticity, creep, and fatigue in vehicle structures.

Our Mechanics Division plays a leading role in defining and suggesting new areas of research, both within and outside AFOSR. Thus its technologists have a wide range of literal exploration as well as of sponsorship. For the purposes of this discussion, I will confine my report to brief acknowledgment of a very few specific accomplishments.

We have sponsored studies on reduction of drag by means of favorable interference. At supersonic speeds the predominant portion of the total drag is the wave drag induced by shock waves emanating from the moving vehicle. Results which we have obtained in substantially reducing this wave drag by proper arrangement of "interference" surfaces have been made available to the aircraft industry and have been incorporated into existing and planned supersonic aircraft.

Studies by an AFOSR contractor of the strong interaction between shock waves and boundary-layer flow have led to an understanding of the detailed mechanism of this phenomenon. The results of this investigation were recently applied to the development of an accurate static-pressure probe for transonic aircraft and led to a speed-indicator device for use on the USAF Century series of fighters (the F-100, 101, 102, 104, and 106).

One class of problems arises in connection with very-low-density flows, such as those found in flight at very high altitude. Slip flow and the interaction of high-speed and high-energy rarefied gas molecules with solid surfaces constitute challenging problems whose solution would be of practical importance in missile and satellite design. Also these studies may shed useful light on the structure of solids and the energy level of the bonds that hold atoms within the crystal lattices. The first low-density tunnel promising full simulation of altitude (20 to 90 miles), temperature (about 3000° Kelvin), and speed (up to mach 12) will soon be available for research in this important field. It is being built under AFOSR sponsorship at the University of Southern California.

One of the more promising techniques for surviving the high heat flux

Figure 7. The new low-density wind tunnel at the University of Southern California, built under AFOSR sponsorship. The photo at right shows an experiment on a pilot model with the high-frequency electrical discharge (electrodeless heater) used for preheating the air that will become the "wind" in the low-density tunnel.

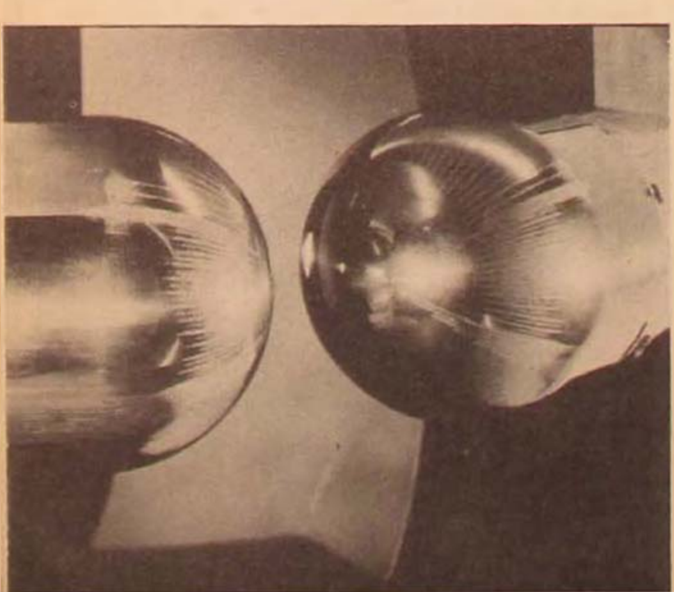
encountered in hypersonic flight is the use of ablating materials as part of the skin of surfaces exposed to the airstream. It is important to the use of this technique to have a firm theory available against which experimental results can be checked. Immediately upon release of the first report on such a theoretical development, the theoretical technique was employed by two industries, one in the design of nose cones and the other in the solution of heat-transfer problems in advanced propulsion designs.

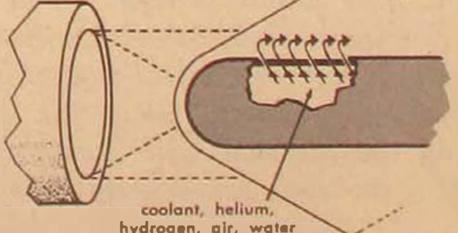
The shock tube, virtually unknown a decade ago, has become one of the most important research tools in use today. Predetermined conditions of high-temperature, high-pressure, and high-speed flows of controlled purity can be produced conveniently in shock tubes to a degree unequaled in any other laboratory environment. In a shock tube terminated with a proper nozzle, a model immersed in the flow can experience conditions, for instance, similar to those encountered by an ICBM in free flight. Under Mechanics Division sponsorship, the first hypersonic shock tunnel employing a tailored interface technique was developed at Cornell Aeronautical Laboratory, with steady-flow durations of over five milliseconds at mach 15. This tunnel has been in such demand since its completion that another is now being constructed to permit basic research to continue without impediment.

Until recently the duration of a test could be measured only in milliseconds. Under AFOSR sponsorship, the same contractor has produced a hypersonic shock tunnel in which models can be tested under rigorous environmental conditions for several seconds of continuous flow. A shock-tube arrangement, based on the principle of the Gatling gun, permits such testing for up to 15 seconds of flow time. After successful demonstration of the pilot model this year, ARPA recently authorized construction of a larger version which it has funded for $3 million.

Under the flight conditions made possible by modern propulsion techniques, the structural designer faces problems many times harder than those experienced by his predecessors. Aerodynamic heating, for example, adds a

Figure 8. Transpiration, or water-film cooling, of a hypersonic, hemispherical, cylindrical body at a speed of mach 8 in the wind tunnel at the University of Minnesota. The coolant is ejected through porous wall coolant jets and directed upstream through orifices. The foreshortened cylinder of the two is the mirrored image of the test cylinder. The small sketch below shows how the principle of transpiration operates.





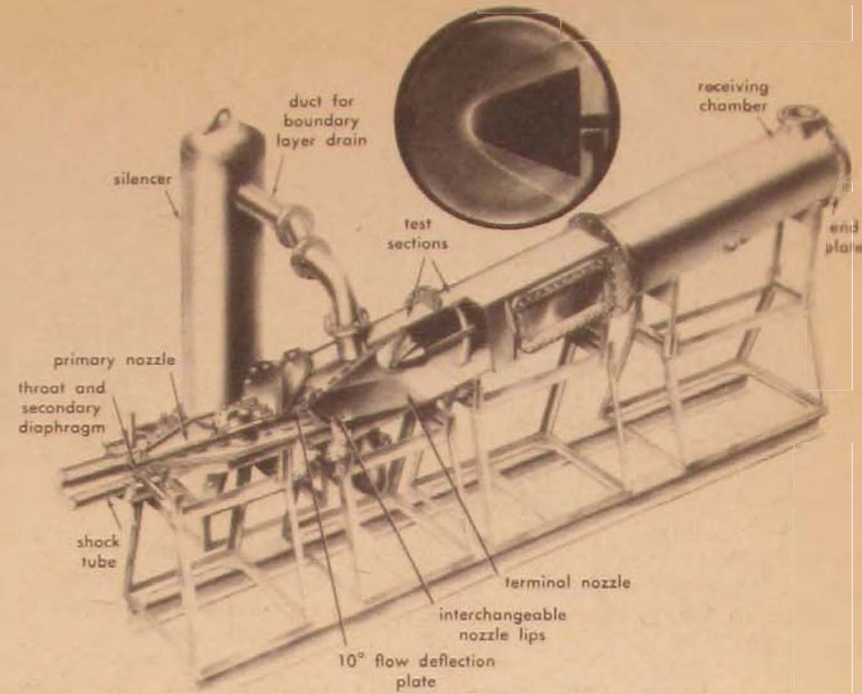


Figure 9. A drawing of the 11-by-15-inch tailored interface hypersonic shock tunnel, built at the Cornell Aeronautical Laboratory under AFOSR sponsorship. The inset photograph shows ionized flow around a blunt-shaped model being tested in the tunnel.

severe complication to the problem of aeroelasticity. Present practice is to treat these problems separately. This may not always be a valid procedure. AFOSR's Mechanics Division is supporting a university research program, the first of its kind, on the effects of studying the two problems together. One early result of this project predicted that the inclusion of thermal stresses, which occur primarily during accelerated flight, alters significantly the flutter characteristic of a wing in a manner not predictable from earlier methods. The prediction was later verified in experimental work in a supersonic wind tunnel.

An AFOSR survey about two years ago revealed that little effort was being made in this country in nonlinear mechanics, particularly compared to the major effort in the Soviet Union. We have tried continuously since then to expand our support in this field. We were the first agency to support a major group activity in nonlinear mathematical techniques in this country.

Other problems receiving some AFOSR funds at this time include plasma dynamics, especially with respect to the flight of bodies through the ionosphere, the use of magnetofluid mechanical principles to reduce heat transfer and drag and perhaps to provide lift, and the flow of molecules and particles over bodies. Marked for support as funds become available are investigation of the effects of extremely high vacuums on structural material properties and behavior,

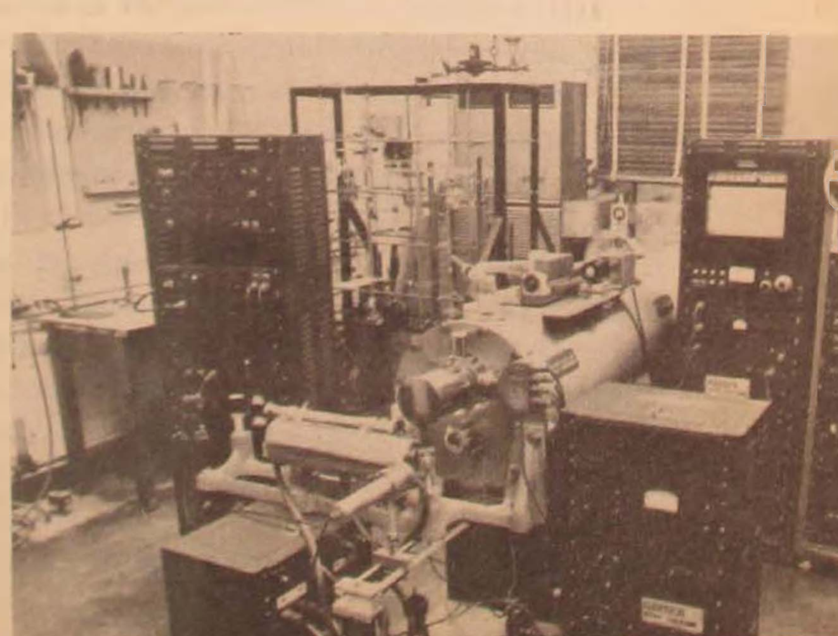


Figure 10. How far chemistry has left the test tube is illustrated in this modern chemistry laboratory. It contains apparatus for spectroscopic study of the transient processes that involve reacting chemical species.

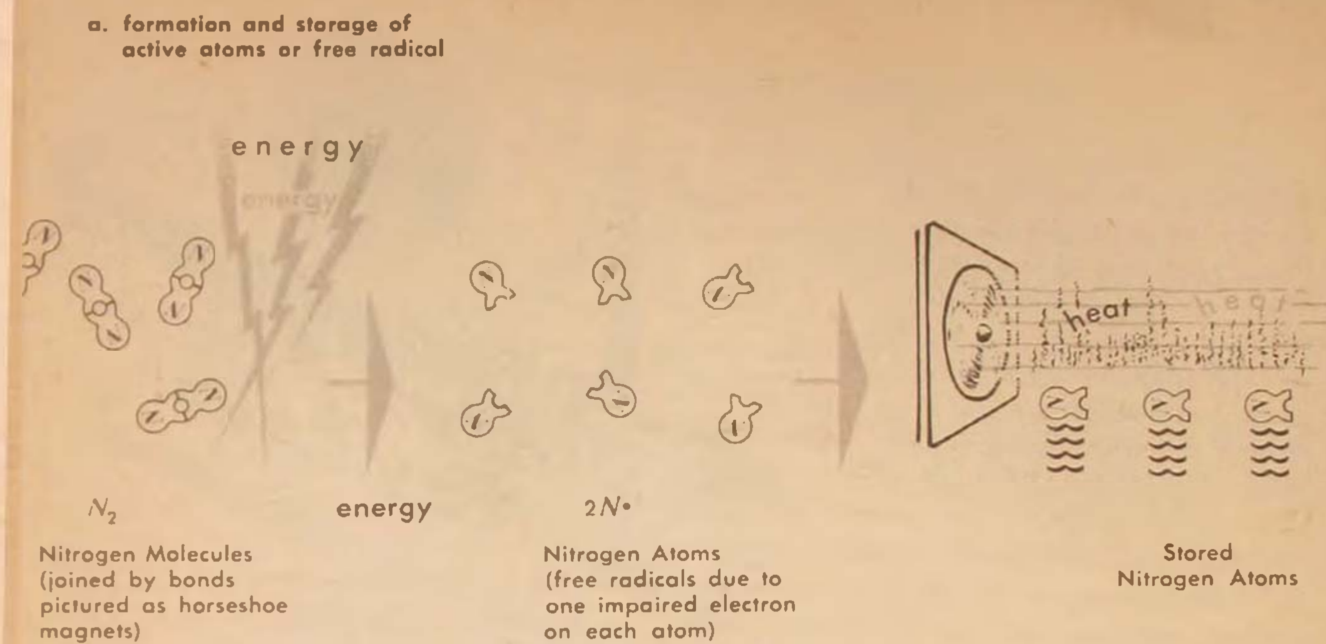


Figure 11. The free-radical process. In the formation and storage phase, shown in (a), nitrogen molecules—or many other varieties—are energized to the point that the bonds tying the molecules together are broken. This frees nitrogen atoms (free radicals), which can then be solidified by removal of heat. In the recombination

and application of analytical mechanics to the dynamics of a body in motion at very high speeds and altitudes. These studies would be directed to the end that the vehicle will be fully maneuverable and controllable by its occupant, whether human or servomechanism.

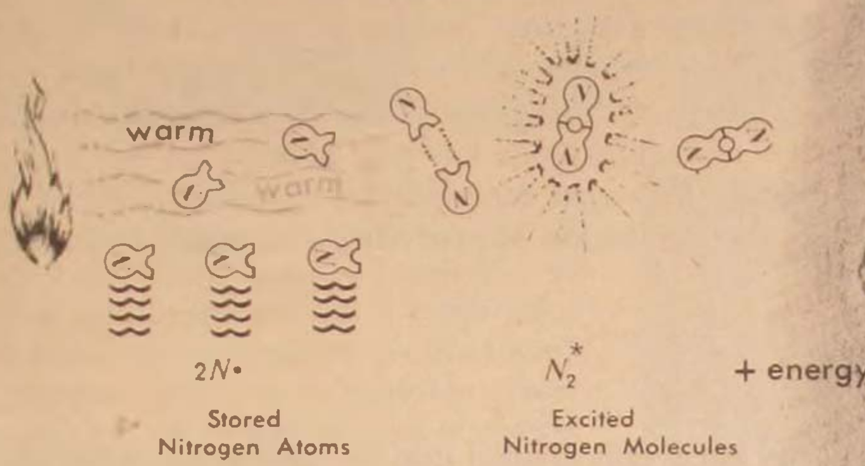
chemistry

AFOSR's basic research program in chemistry is focused on the combinations and interactions of atomic and subatomic particles in the gaseous, liquid, solid, and colloidal states. The Air Force has a natural and profound interest in all aspects of chemistry, since all materials are direct products of chemistry and are capable of improvement through the application of chemical principles. For practical reasons, our chemical monitors limit their efforts to the filling of gaps in our understanding of natural chemical phenomena that may be retarding the Air Force in carrying out its mission. Some significant knowledge has been added to our stockpile in recent years.

An AFOSR contractor discovered a new principle in making polymers (large molecules in plastics, fibers, and rubbers) stable to heat. His results are being applied to the Air Force materials program at WADC, while his research continues under our support. His reports have triggered work by other investigators as well, illustrating how a single discovery in basic research expands work going on in a number of directions.

Another scientist, with our support, produced a hydrogen-fluorine flame that has the highest burning velocity known. We expect this to be valuable in studying flow patterns produced in exhaust gases from missile propulsion systems. Another flame produced by the same scientist from cyanogen and oxygen found an unlooked-for home in medical pathology at Harvard Medical School, which acclaims it as virtually the first new spectroscopic flame source in half

b. recombination, energy release (thrust)



phase (b), a little warmth loosens the free radicals from the solid, returning them to the gaseous state. The free radicals then have a strong affinity to recombine. In recombining, they release great amounts of energy. This energy is in the form of heat, which, if harnessed, can be focused to produce rocket thrust.

a century. By means of the flame burning at 4500° centigrade, Harvard Medical School can analyze as little as one third of a drop of body fluid for 17 different trace metals.

Quartz fibers have been produced with tensile strength greater than that of steel and with a melting point near 2000° centigrade. Both uncoated and metallic-coated quartz fibers are now being evaluated for use in high-temperature materials by the WADC Materials Laboratory.

One contractor's studies on the effect of light on various dyes uncovered the fact that 25 per cent of the absorbed light energy is released in darkness. This suggested a system for the economical utilization of solar energy, which he is now pursuing in a WADC applied-research program.

Basic discoveries in the photographic chemical field have led to important applications of great interest to ARDC. Among them are a unique developer and a method for making usable prints from overexposed negatives, such as might be obtained from shooting into the sun or toward a nuclear explosion.

Pioneering work on highly energetic atoms and molecular fragments, generally known as "free radicals," led directly to the extensive work being done in this area now throughout the Department of Defense. It was started some three years ago with a very modest investment and in the face of very critical evaluations from a number of highly respected sources. AFOSR underwrote the small program because *if* free radicals could be stabilized in sufficient quantity they *could* become a very useful fuel. The work soon progressed to the point where the Department of Defense considered it worth expanding to a rate of $1 million a year. While free radicals have not yet been proved practical for fuel purposes, the work we supported had the important side effect of interesting many researchers in the possibilities of promising results from investigations in low-temperature chemistry and physics.

Our Chemistry Directorate, like our other units, views all incoming proposals (all unsolicited, incidentally) with an eye to the new, the novel, and even the startling. It is now particularly interested in studies on the nature of the chemical bond—including interactions between atoms and molecules, their sizes, bond angles, bond energies, electrical and magnetic properties; surface chemistry, in which comparatively little progress has been made; research areas such as photochemistry, nonequilibrium kinetics, phase transformation and reactions at both extremely high and extremely low temperatures, and other studies that will ensure the production of needed new materials for future Air Force needs.

life sciences

Our program in life sciences is divided into two principal categories—biological and behavioral, both of which have the predominant mission of enhancing the usefulness of man in the future Air Force. Many of the investigations we sponsor in this area appear at first glance to have little application to man, and are thus more subject to hasty misevaluation by both friends and critics of our work than perhaps any others we support. Our experiences, many of them unfortunate, have tended to make us perhaps unduly sensitive and reluctant to discuss what may prove to be our greatest contribution to the military posture of our country. This feeling makes it doubly incumbent on our life scientists to view proposals for research objectively.

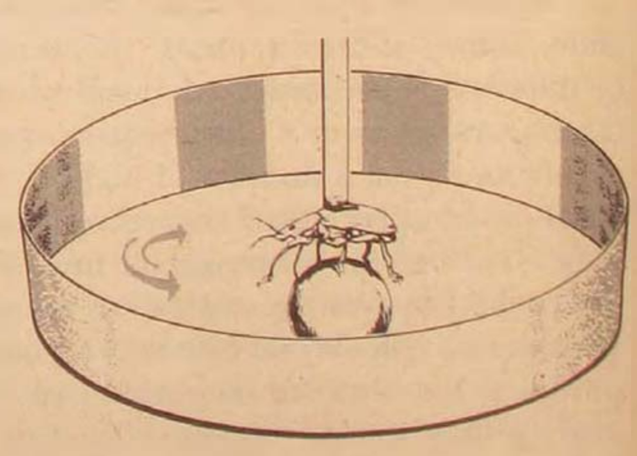


Figure 12. One of the experiments with beetles that led to the development of the most accurate groundspeed indicator for aircraft yet devised. In the experiment the beetle is rigidly suspended in the center of a rotating drum. The walls of the drum have alternating panels of black and white. As the drum revolves, the beetle's eyes respond to the brightness of the white panels. It was discovered that the beetle's eyes performed a continuous autocorrelation of a random pattern of light. His responses were measured by the movement of a rounded object that he clutched with his feet and turned in response to the stimulus from the patterns of light. The movement of the object indicated the direction of movement the beetle would have taken if he had been free. When this autocorrelation was worked out mathematically, it became apparent that an analogous mechanical system could be devised. Each biological unit involved in the perception of motion was translated into an electronic counterpart. Thus photoelectric cells placed at front and rear of an airplane were substituted for the beetle's ommatidia. Appropriate integrators and other electronic units completed this highly accurate groundspeed indicator. The sensory cells or receivers on the aircraft register passage over the same point on the earth and, using a light source, measure the length of time between the passage of the first and second sensors over the point on the ground, giving the groundspeed.

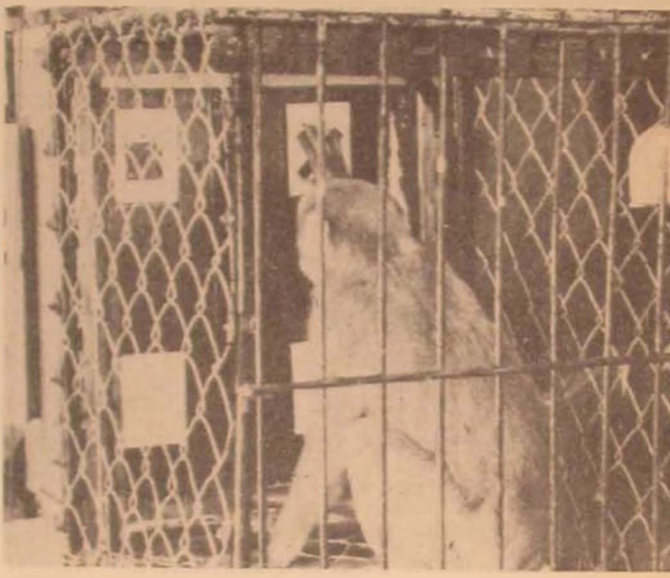


Figure 13. AFOSR-sponsored research in behavioral problems is being carried on in England, using trained primates. In the first photo, the animal is performing a delayed-response problem. In the second he is performing a discrimination learning problem, in which to earn a reward from behind the bottom panel, marked X, he must press the unmarked panel above it. The third photo shows the second part of the discrimination learning problem. He now must press the X, which has been moved to the upper panel, to get his reward from behind the same bottom panel. The experiment attempts to determine whether discrimination functions best with cues located at place of response or at place of reward. Primates are also used in determining the effects on behavior of brain lesions, electrical stimulation, and psychotropic drugs.

A few months after I assumed command of AFOSR, an outline of some of our research activities was presented in a talk before the Air Force Association. Mention was made of a scientist under our support who was training octopuses (the correct plural, by the way) to respond to certain signals. Immediately this was raised to the dignity of headlines even in one of our most eminent newspapers as indicative of a waste of research funds. A few days later I walked into a meeting of high-level Air Force officers and officials and was greeted by queries as to how my training school for octopuses was coming along. The heavy implication was that I had held the Air Force up to ridicule.

Fortunately I was able to explain our interest in octopuses to this important group and to emerge with their full support. It became clear to them that before we can hope to learn very much about the brain of so complex an organism as man, we must begin with that of a much simpler creature. By studying the changes that occur in the brain of the octopus when it undergoes a learning process, we fill in important blanks in our knowledge of how living brains gather information, interpret it, arrive at conclusions, and direct definite actions and reactions by other parts of the organism. But how do we get the correct story now to the millions of people who read the erroneous news stories and whose support of our research efforts may have been seriously undermined thereby?

How do we acquaint them with the fact that an equally unlikely research project involving study of the eye of a beetle has now been translated into the most efficient airspeed indicator ever devised for aircraft? How do we explain to them that another life-sciences project concerning electric eels may enable us in the future to protect our airmen and spacemen from such potent hazards as nuclear energy, cosmic radiation, and similar phenomena that will certainly be part of their environment?

Our biological program supports studies that may lead to advances in aviation and space medicine, in the ecology of closed environments (such as that in a spacecraft), and in military engineering as it is applied both to vehicles and to munitions. Until this program was established less than five years ago, the Air Force had made almost no contribution to basic biology. After such a short time, it would be presumptuous of me to claim that we had made many outstanding accomplishments. But we are supporting work whose implications, I firmly believe, are so far-reaching that we can hardly begin to forecast them.

The principal areas of our biological interest include study of brain mechanisms and the central nervous system; the environmental tolerances of man, the limitations imposed on him, and the adjustments his body must make when he invades unusual environments; the important biochemical and biophysical processes that govern the molecular organizations and transformations that are unique to living cells; the study of communications within an organism, including visual perception, function of special sense organs, and animal navigation; and the biosynthesis of materials, such as in algae.

On the behavioral side, we seek to acquire fundamental knowledge that will facilitate the prediction and control of human behavior. We believe the

Figure 14. Basic research into man-machine relationships in the decision-making process. An AFOSR contractor at the University of Michigan is using a Simplified Dynamic System Simulator in research on a logistics transportation problem. The man in the foreground is assigning cargoes to different destinations, using a pictorial and tabular display of the locations of supply sources and sinks. The movement of vehicles is represented by the bank of counters in the left background. The operator controls these vehicles by operating lighted pushbuttons. The experimenter (right background) determines vehicle speeds and records data on the efficiency of problem solutions. Several men can work jointly at this task, which combines elements of planning, decision making, monitoring, and communicating. Principles of information display and team organization are being studied.

Figure 15. Electroencephalographic cap developed by an AFOSR contractor to help determine the effect of psychotomimetic drugs on human behavior. The project scientists are developing and refining electronic methods for measuring normal behavior, as well as for determining the relationship of various drugs and other stimuli to the state of arousal and readiness to respond.

fields of investigation that offer the greatest Air Force potential include analysis of human performance in complex man-machine systems; analysis of requirements for human operators, both individual and in terms of available manpower for progressively automated weapons; development of mathematical and electronic models of human behavior to provide analyses of human capabilities; studies of decision processes utilizing mechanical and electronic components to facilitate or substitute for human linkages in man-machine systems; investigation of the environmental factors in ground, air, and space operations that result in human stress; studies in the motivational aspects of human performance; research on organizational factors influencing the quality of performance; investigation of techniques for acquiring and utilizing intelligence from or about human sources in hostile areas; methods for protecting personnel from enemy influences while on duty in foreign countries or in the event of capture; and a wide range of others.

In brief, it is the purpose of this division to identify critical areas where different levels of human performance will have a major effect on the accomplishment of the mission of the Air Force.

THE foregoing gives a very brief account of some of the things that AFOSR has done and is doing to bring the greatest potential of basic research to bear on the Air Force of the near and distant future. A wide range of scientific disciplines and vast experience in scientific appraisal and evaluation are represented on the staff of my organization. This has enabled AFOSR to produce a record of accomplishment and a basis for future accomplishment that are, I believe, far beyond what might ordinarily have been expected from less than forty scientists, augmented by less than eighty administrative, clerical, and other supporting personnel.

The record becomes even more impressive when one remembers that only a short time ago much of the energy of the staff had to be devoted to defending the Air Force's basic research program from those who had budgetary authority but little understanding of science. Many of us vividly recall the days, not so long ago, when "research" was a dirty word in the Air Force, to be avoided at all costs. Whatever research projects were undertaken were hidden under the blanket of "technical development," with funds provided for them by far-sighted military leaders who knew that they ran a real risk of severe censure and possible premature retirement if their encouragement of this "long-haired stuff" were exposed. In this light, the courage and judgment exhibited by Generals Power and Anderson and Gregory, which I cited earlier, become truly remarkable. We who pursue military scientific research in these more enlightened days owe them a heavy debt.

I began this article by calling basic research the "Cinderella" of science. To carry the analogy a bit further, we are now enjoying the novel experience of being the belle of the ball, with the Prince Charming of public opinion apparently ready to grant our every wish. I can only earnestly hope that we will escape reversion to rags at the stroke of midnight. Because basic research offers three important values:

1. Basic research has the value of serendipity—the unique ability of the researcher to uncover again and again principles of worth and information of consequence that are far beyond the limits of reasonable expectation. Our investigators are constantly discovering data they were not seeking. The dividends that accrue to our Nation and our Air Force from this quality alone are incalculable.

2. Basic research has the value of economy. It is the cheapest commodity we can buy. The costs associated with research begin to mount in orders of magnitude only after basic research has proved the application to be practical. Many of our most potent weapon systems and many of our civilian industries are based on the results of a basic investigation which itself cost less than a two-ton truck.

3. Basic research has the value of open visibility. One proof of this is that over 95 per cent of the research supported by AFOSR is on the unclassified level. One simply cannot classify a law of nature; it is there for anybody to find. The history of science is full of discoveries that were made more or less contemporaneously by two or more scientists working not only independently but completely unaware of each other's efforts. A natural phenomenon is there for us to see and to interpret, just as it is there for the scientists of the Soviet Union or any other nation to see and interpret.

This leads to my final and firmest belief: if America ever again fails to encourage her scientists to explore the unknown, in whatever direction the unknown may lie, the effect may be nothing less than disaster for the way of life that America has come to represent to all the free peoples of the world.

Headquarters Air Force Research Division (ARDC)

Outer Space and National Sovereignty

Major Charles A. Roberts

UNTIL just a few years ago the height to which a nation's sovereignty extended above its territory was primarily an academic question. It is true that as early as 1900 international lawyers were speculating on whether states enjoyed an extension of national sovereignty into the superjacent airspace, but their speculations were based on only the most fragmentary knowledge of the embryonic science of aeronautics. They were actually more legalistic exercises than attempts to solve contemporary problems.

Indeed the liberality of the views of these early authorities was in inverse proportion to the degree of progress in the science of aviation. Before international flights became a regular occurrence there were strong tendencies to be very liberal and to declare the air to be free to all, much like the open seas. When international flights became a reality, the free-air theories were discarded as the various nations extended their sovereignty into the airspace by means of regulations, statutory enactments, treaties, and international agreements.

The rejection of the doctrine of freedom of the air was based not only on the fact that it impinged upon the inherent right of a state to protect itself but also on the fact that it had not had the benefit of sustained national practice and therefore lacked historical and juridical soundness. One of the earliest authorities on international air law noted that the doctrine of freedom of the air "rests on no solid rock of past development and on no solid rock of consistent principle."[1]

evolution of international air law

This same "past development" and "consistent principle" have largely determined the subsequent course of international air law through international agreements. For this reason the doctrine of full sovereignty in national airspace did not assume the proportions of a true international principle until its adoption as a guiding rule of international conduct by belligerents and neutrals alike during World War I. In the case of the belligerents, exclusive sovereignty was taken for granted. When enemy aircraft appeared in national airspace, there was no doubt as to the action that would be taken. The matter was not so clear-cut for the neutrals, as there was no authoritative precedent upon which to draw. Taking their cue from the belligerents, the neutrals developed through custom and practice the principle that any aircraft violating their airspace were interlopers. In many cases they were pursued, fired on, or shot down and their crews interned. The question of air sovereignty during wartime was answered unequivocally. National airspace came to be considered as sacrosanct as sovereignty itself and was no less jealously guarded. Thus theory was crystallized in the practice of states. Once established, there was little logic to suggest that these principles would be abandoned when the war was over.

At the peace conference an aeronautical commission was formed to draft the air clauses of the peace treaty and to prepare a peacetime international aviation convention governing postwar international aviation. The commission was composed chiefly of military officers of the Allied Powers, including several who had had considerable experience in wartime cooperation as members of the Interallied Aviation Committee.

The outstanding work of the Aeronautical Commission resulted in the Convention Relating to International Air Navigation, known as the Paris Convention of 1919.[2] The convention recognized that every state had complete and exclusive sovereignty over the airspace above its territory. The territory of a state was understood to include the national territory of both the mother country and its colonies and the territorial waters adjacent thereto. When the parties to the convention agreed on the principle of complete and exclusive sovereignty, they were not creating a sovereign right but were merely affirming its observance as between the states that were parties to the convention.

Although the United States never ratified the 1919 convention, this was not a reflection on the political philosophy of the convention or on the excellence of its technical annexes and the International Commission for Air Navigation which was to administer them. The 1919 convention did serve as the model for subsequent United States legislation. Section 6 of the Air Commerce Act of 1926 stated in part:

> The Congress hereby declares that the Government of the United States has, to the exclusion of all foreign nations, complete sovereignty of the airspace over the lands and waters of the United States, including the Canal Zone.[3]

The principle was established, and no significant change was to be made in the legislation that followed. Section 1107 (i) (3) of the Civil Aeronautics Act of 1938 amended the above passage to read:

> The United States of America is hereby declared to possess and exercise complete and exclusive national sovereignty in the airspace above the United States, including the airspace above all inland waters and the airspace above those portions of the adjacent marginal high seas, bays, and lakes over which by international law or treaty, or convention, the United States exercises national jurisdiction.[4]

At the Sixth Pan-American Conference twenty-one American states signed the Havana Air Convention of 1928.[5] The sovereignty question was settled in the first article of the convention. The high contracting parties recognized that every state had complete and exclusive sovereignty over the airspace above its territory and territorial waters—almost the identical statement made in the Paris Convention of 1919.

The 1944 Chicago Convention on International Civil Aviation superseded both the Paris and Havana conventions. Again the treatment of air sovereignty was unequivocal. In Article 1 each contracting state recognized that every state had complete and exclusive sovereignty over the airspace above its territory. In Article 2 the territory of a state was deemed to be the land areas and territorial waters adjacent thereto under the sovereignty, suzerainty, protection, or mandate of such state.

In this very brief sketch of the evolution of the air sovereignty concept in international law it may be seen that the regime of the air has followed the classic pattern of development of international law in other fields. In this evolution writers on the subject have always led the way, with their often conflicting theories. Just as the law of the sea had its Grotius and Selden with their conflicting views of whether or not the high seas should be open to all, so also did the law of the air have its Fauchille and Westlake with their opposing views of whether or not airspace should be free to all.

Of course it is not the writers that make international law. It is the usage and the practice of states that begin the real determination of what international law is. Actually international law is as much political as it is juridical. For the most part international law is a system of jurisprudence which is a result of the experience and necessities of situations that have arisen in the past. It has developed "with the progress of civilization and with the increasing realization by nations that their relations *inter se*, if not their existence, must be governed by and depend upon rules of law fairly certain and generally reasonable." [6]

In short, following after the writers and the establishment of usage and custom, the ultimate expression of international law comes in the treaty or international convention. The first principles of international air law were established in the Paris Convention of 1919, were reaffirmed in the Havana Convention of 1928, and collated in the Chicago Convention of 1944.

from air law to airspace law

In this evolution through the two world wars and three conventions, the complete and exclusive sovereignty of the subjacent state in its airspace was never questioned. "Airspace" in the normal context was taken to mean, by its nature alone, that portion of a state's three-dimensional territory which was neither underground nor on the surface of the earth but was above

As in the early years of the air age, the dawning space age has led nations to ask "How far up is ours?" The answer must come from international law, and yet traditionally international law arrives at answers much more slowly than today's technology poses new problems. Major Charles A. Roberts, Chief, Political and Economic Branch, Directorate of Air Intelligence, Headquarters United States Air Forces in Europe, argues that the legal foundation for "free space" has already been laid in the series of uncontested orbiting flights by IGY and other satellites. If this is so, then the burning question becomes "At what altitude below orbital height should national sovereignty end?" Major Roberts urges that it end at the 53-mile limit proposed by the Karman primary jurisdiction line.

national territory in which that state exercised sovereignty and control of all human conduct. By common consent it has always been recognized also that all states possess complete and exclusive sovereignty in their airspace, regardless of their intentions or ability to exercise effective control.

Until recently it was as unnecessary to define airspace as it was to define land area. Common consent and understanding gave universal acceptance to the postulate that airspace was that portion of a state's territory which could be seen and which extended upward indefinitely. By "indefinitely" here is not meant the illogical extreme of extending sovereignty into outer space beyond the planets and galaxies. In the past there was never any real need or purpose in attempting to delineate the end of air sovereignty.[7] The rationale for the development of international air law in this respect was expressed in succinct terms by Hans Kelsen. He defined the territory of a state as being three-dimensional and stated that the efficacy of the national legal order extended not only in width and length but also in depth and height; further, a state could enforce the provisions of international conventions only within that part of the airspace over which it had effective control.[8] This principle of "effective control" was visualized as a dynamic concept in which further technical progress meant further extension of control beyond the airspace. But theory collided head-on with national practice when the first satellites were launched.

Since the very first day that a satellite was placed in orbit, the question of the extension of sovereignty into the airspace has no longer been merely academic. The satellites are there for all the world to see and hear. Their very existence demands an answer to the sovereignty question.

For several years before the first satellites were launched it was common knowledge that the theory of sustained orbital flight was soon to be tried, since the prerequisite ballistic missile assets were rapidly improving. As was to be expected, the writers on international law were ready to lead the way at their own level of abstraction. They were soon formulating propositions as to the political and juridical implications upon international law that an extraterrestrial vehicle might have.

concepts of airspace

Of the many writers in this field two must be mentioned here: John C. Cooper, formerly director of the Institute of Air Law at McGill University, and Andrew G. Haley, president of the International Astronautical Federation and general counsel of the American Rocket Society. Both have been intimately associated with the progress of international air law and the evolution of space law. Both have made significant and lasting contributions to the discipline of public as well as private international air law.

In 1951 Cooper's views tended toward the "effective control" theory, but he was not satisfied with this approach. He also believed that, if effective control determined the extension of sovereignty into outer space, the only rational approach was that the limit claimed by the most advanced state should be enjoyed by all states, regardless of their strength.[9] In 1956 Cooper abandoned this earlier view because of the almost insuperable difficulties in applying such a concept. Rather he proposed a trizonal concept. This would recognize a "territorial space" upward to the ceiling at which aircraft may be operated; a second zone up to 300 miles called "contiguous space," with certain rights for the nations of the world; and a final area above contiguous space called "free space."

While this proposal would have the advantage of establishing a set of limits, technical progress in aircraft and missiles is inevitable and sovereignty propositions based on these dynamic factors are bound to falter. Cooper is his own best critic, pointing out that "it would be unfortunate if international rules of future high altitude flight control were adopted, and if it were then found that they were based on incorrect theories as to the physical characteristics and usefulness of various areas in the upper atmosphere and beyond."[10] In 1957 Cooper thought that perhaps the 300-mile zone should be extended to 600 miles.[11] By early 1958 he was no longer willing to give specific recommended heights to sovereignty, though he did assert that, legally, the word airspace covers only that portion of the atmosphere where there is sufficient air to provide some aerodynamic lift for airplanes and balloons.[12] He then indicated that the best scientific opinion was coming to favor the altitude of 53 miles as the last point where the air was dense enough to give any aerodynamic lift. Although Cooper still favored his trizonal theory, the elusive and evanescent character of the atmospheric regions and his zonal boundaries which are not susceptible of inspection by definition suggest that Cooper himself saw its questionable usefulness, as evidenced by his reluctance to state precise boundaries.

Gaining in favor with the theorists is the bizonal concept. This would demarcate a lower area of contiguous airspace subject to full sovereignty and control of the subjacent state and an upper zone of outer space which would be *res communes* or *res extra commercium*. Many words have been written on where the upper limits of airspace should be. These views range from as low as 30 miles to the suggestion that, if the term "atmosphere" is used, it might extend upward as high as 60,000 miles.[13]

The 53-mile figure mentioned by Cooper is growing in favor and is frequently quoted. This altitude is the same as that originated in 1957 by Haley. To establish a sound base for the demarcation of air and space jurisdiction, Haley utilized a scientific study prepared by Dr. Theodore von Karman of the University of California. Haley constructed a diagram showing the earth orbital satellite regime and the Kepler regime (earth escape velocity) and plotted what he called the Karman primary jurisdiction line.[14] For a vehicle to circle the earth at a constant altitude, the weight must be counterbalanced by aerodynamic lift plus centrifugal force. The aerodynamic lift decreases with altitude because of the decreasing density of the air. If flight is to continue, inertial forces must take over. In the corridor of continuous flight, when the vehicle reaches the altitude of 275,000 feet and is traveling at a velocity of 25,000 feet per second, the aerodynamic lift is gone and the vehicle passes into a Keplerian trajectory. This phenomenon, occurring at a given altitude and speed, is what Haley calls the critical jurisdictional boundary or the "Karman" line, the line at which airspace terminates.[15]

If a purely scientific approach were to be taken to the problem of determining where airspace ends and outer space begins, current astronautical findings and parameters lend a high degree of credence to Haley's "Karman" line of critical jurisdictional boundary. But it is an unassailable fact that neither scientific exposition nor semantic maneuver will provide an unequivocal answer to what is primarily a political problem.

The physical characteristics of the airspace would certainly be pertinent to any discussion and will undoubtedly influence the evolution of international air law into space law. But all writers since Fauchille (including Fauchille) who have attempted to set arbitrary boundaries based upon man's activities in the airspace have eventually been mouse-trapped by the dynamic character of this new regime. Other writers may attempt to delineate boundaries as functions of altitudes, mass velocity, heat, distance, and other physical variables combined. Their views may seem more sophisticated technically and may have more appeal because of increasing scientific knowledge and engineering technology. But their boundaries may well be just as vulnerable to developments such as the X-15, and it remains questionable whether they are even relevant for purposes of human control and planning.[16]

development of space law

There are two schools of thought regarding the Paris-Havana-Chicago evolution of space law and at least the sovereignty aspects of it. The first view would accept the premise that the sovereignty declarations were extensible into outer space and that terms such as "atmosphere" and "the ability to support a flight instrumentality" were sufficiently valid to use in determining the law of space. The second view is the opposite, that these conventions are not applicable to outer space by any stretch of the imagination.

The arguments are many and forceful, but little useful purpose may be served in attempting to accommodate old conventions to a new dimension. These conventions have served their purpose in the past and are still doing so in the present. To attempt to use definitions from one document in the context of another argument is to distort their meaning and to encourage fallacious reasoning. When the original discussions for these conventions were held, it was under a certain set of conditions (postwar settlement, for instance), with a certain set of objectives, which do not lend themselves to the luxury of logic by mutation. It is not a very persuasive argument that the air sovereignty concepts of fifteen or thirty years ago were identical to those of the space age. While the international law that came out of the Paris, Havana, and Chicago conventions was based on both security and commercial aspects, and while each convention contained declarations of air sovereignty, these declarations were made in the matrix of their contemporary technological progress.

The launching of the first satellites neither influenced nor affected existing international conventional air law. The fact that the U.S.S.R. was not a member of the Chicago convention had no bearing on the universally accepted principle that each state possessed complete and exclusive sovereignty in its airspace.[17] No claims of any kind have been made by any government concerning sovereignty over the airspace traversed by satellites. But at the same time that satellites are circling the earth in indiscriminate orbits as far as surface territory is concerned, a dozen or more complaints, protests, and international incidents have arisen from claims of violations of national airspace at lower altitudes.

As recently as October 1958 the U.S.S.R. publicly charged the United States with "flagrant and inadmissible" violations of Soviet airspace when high-altitude weather research balloons drifted over Soviet territory at an altitude of approximately 100,000 feet.[18] A few days later the allegation was formalized in a note handed to the United States chargé in which the Soviets complained of a "continued violation of the airspace of the U.S.S.R."[19] Another series of incidents occurred in November 1958 when the Soviets alleged violation of their airspace in the Sea of Japan and in the Baltic. The latter case involved a USAF RB-47 flying at 33,000 feet, 66 miles from Soviet territory![20]

The foregoing situation—unprotested satellite overflights in the same time period as protested lower-altitude flights—is not the paradox that it might at first appear to be. These concurrent situations are a positive affirmation of the existence of a body of international air law insofar as sovereignty in the airspace is concerned. They also affirm the existence of a developing custom in space law which declares that that portion of the airspace in which an orbit can be maintained is actually free space and that no extension of sovereignty therein will be recognized.

The Karman 53-mile line. The international incidents referred to (and there were similar cases on the continent of Europe) all occurred within the envelope of airspace below the so-called Karman primary jurisdiction line of 53 miles in altitude. All satellite activity about which there were no sovereignty protests was carried out in the space above the 53-mile line.[21] The Karman or 53-mile line in and of itself cannot and should not constitute the boundary between the regimes of air law and space law, nor can the line in itself determine the extension or the end of a nation's air sovereignty. But the fact is: (1) Regular and frequent satellite orbits in the envelope of space beyond the 53-mile line are a *fait accompli.* (2) The original satellite programs were under the auspices of the International Council of Scientific Unions, which sponsored the International Geophysical Year, and were therefore not arranged on a strictly intergovernmental basis. Yet it was the governments of the United States and the U.S.S.R. which cooperated and announced in advance that during the IGY they intended to place objects in orbit around the earth. (3) Since no nation protested these arrangements, the only rational conclusion is that there is an implied agreement, at least for satellites launched during the IGY, that they would be allowed to circulate freely in outer space. As Haley has stated:

> The launching by the United States and the U.S.S.R. of earth-orbiting unmanned satellites in connection with the International Geophysical Year is legally possible for the sole reason that no nation has voiced objections, although the satellites in describing their orbits may violate the municipal law of half a dozen nations.[22]

(4) Although the IGY ended in December 1958, this fact per se has no relevance in the determination of the law of sovereignty in outer space. Adequate authoritative precedent has been established for this concept to take its rightful place in the corpus juris of international relations.

This precedent, coupled with the fact that transit agreements for satellite flights have never been sought from other nations by either the United States or the U.S.S.R., lends a persuasive argument to the acceptance of the postulate that the first phase of the sovereignty aspect of space law has been settled by custom.

limits of national sovereignty

Assuming that the foregoing hypothesis is correct, the second phase of the sovereignty problem in the law of outer space is that of establishing the limit of national sovereignty.

Heretofore it was neither necessary nor possible to determine with any degree of logic where national sovereignty should end. While many of the previous views expressed by publicists, scientists, lawyers, and laymen were challenging, until space penetration was an accomplished fact they could not be based either on positive verification of scientific theory or on an analysis of the subsequent actions of the first two nations to penetrate outer space.

Both these components are essential to the development of this branch of customary space law. By their nature they will grow on a case-to-case basis, since our knowledge of outer space is increasing in direct relationship to the degree of sophistication of the satellite vehicles and their instrumentation. For example, data from satellites have pointed to a core of heavy radiation which was previously unknown, 1100 miles or more above the geomagnetic equator. The data also suggest heavy radiation areas over the zones of maximum aurora near the poles.[23] Other scientific theories, such as orbit velocities and thrusts necessary to achieve orbit, have now been confirmed. As this scientific knowledge grows, there will probably be a similar growth in the body of custom as evidenced by the practices of states in their space explorations. Herein lies the rationale for the determination of national sovereignty.

the U. S. should act now

The fact that the upper limit of air sovereignty has never been set, either in statute or in treaty, presents the problem which now demands an immediate answer. Every nation is supreme in its territory. It can unilaterally determine for itself what foreign aircraft may enter its airspace and under what conditions. This is a property or characteristic of sovereignty which does not change. As Chief Justice Marshall noted so long ago:

> The jurisdiction of the nation within its own territory is necessarily exclusive and absolute. It is susceptible of no limitation not imposed by itself. . . . All exceptions, therefore, to the full and complete power of a nation within its own territories, must be traced up to the consent of the nation itself. They can flow from no other legitimate source.[24]

Since it is our prerogative within our inherent rights as a sovereign nation, we must establish the limits of national sovereignty for ourselves, even if on a unilateral basis. This premise is advanced because it is firmly believed that in so doing we will be adding to the practice of nations by establishing custom and setting a precedent which would be in the national interest of the United States. This proposal is put forward not on a chauvinistic basis but in the sincere belief that we cannot afford to "wait and see" until it is too late and customs have been started by other nations which may be inimical to our interests.

Neither logic nor the future course of events can allow an anomalistic equilibrium, such as exists at the present, to continue forever. Where is the rationale in a system wherein the nations of the world declare that they have sovereignty and exercise effective control in their superincumbent airspace without limitation, and yet just a few miles beyond the area in which sovereignty has previously been exercised no nation asserts sovereignty in the airspace, all nations tacitly recognizing the regime as free space? We certainly know where sovereignty ends on the high seas. Why can we not know where it ends in the air? Where is the line over which we may say to anyone, "Go not one step farther lest you infringe upon the sovereignty of this nation"? The lack of such a line of demarcation is a denial of the very essence of sovereignty.

We know that intruders could not overtly penetrate the aerial borders of a great power at an altitude of 10,000 feet—or at 30,000 or 50,000 feet—without causing an incident. We recall that the United States balloons which the Soviets protested so vehemently were stipulated to have flown at an altitude of over 100,000 feet. Would there be a protest or an international incident if highly sophisticated vehicles were to penetrate or cross a national border at 150,000 feet?—200,000 feet?—279,840 feet? We must reach an answer to this question in order to have a rational base line from which future development in the law of outer space can proceed. Unless we have this foundation, the further orderly development of astronautics runs the risk of foundering on the rocks of international tensions. There are no automatic self-limiting factors to national aspirations or international tensions which preclude their extension into outer space.

While the outstanding authorities in this field may disagree on details, there is a reassuring consensus on the basic principles from which they believe space law must evolve. In his recent appearance before the House Select Committee on Astronautics and Space Exploration, Cooper testified that until the upper boundary of a nation's airspace has been fixed and the status of the area beyond fully determined "all future plans for space flight will run the hazard of serious international complications."[25] Haley's position during the same hearings was no less unequivocal: "We cannot leave the question of establishing the limits of sovereignty and the boundaries and jurisdiction in a perpetual vacuum. . . ."[26] This has always been the predominant theme in Cooper's works—not the importance of the criteria he suggested nor the efficacy of the various zonal concepts, but the clear necessity for establishing a set of limits regardless of the method used.

Failure to take the first steps in the development of custom may find us in an untenable position should another state enact regulations controlling or prohibiting the flight of space vehicles across its territory and, in so doing, unilaterally extend the upper limits of its sovereignty to any height it desired or was capable of controlling. There is no necessity or justification for the United States to be placed in a position such as this. If through the use of exceptionally well-developed interceptor techniques that state were able to maintain positive and effective control over the airspace so claimed, the lack of any customary international law on the matter would only enhance the frustrations of the offended state or states.

It may reasonably be presumed that the present two-nation monopoly of outer space will not always obtain.[27] In this new context, if there is no moral custom established as a precedent by those who pioneer in space, amoral actions by those who follow afterwards should not be any great surprise. As President Eisenhower has publicly stated, the motives of the United States in this regime are directed toward the use of outer space for peaceful purposes only.[28] We are therefore committed to take the first steps in the moral order to which we subscribe.

acceptance of the 53-mile limit

To this end, it is suggested that the United States announce acceptance of the principle that national sovereignty ends at an altitude of 53 miles. This altitude is neither an arbitrary nor an *ipso facto* scientific choice. It is selected on the basis of *de lege ferenda,* or what the law should be to properly reflect a presently existing reality of international relations. By this is meant a reality in the sense of reflecting a condition with an objective existence in time and space apart from any observer.[29]

To establish this limit would not be a question of extrapolating abstract legal principles into outer space but would be a frank recognition of fact. In doing this we would not be jeopardizing or compromising our position or stature in the world, nor would we be unnecessarily limiting a sovereignty that should not be limited. It has been one of the main purposes of this exposition to show that sovereignty has already been effectively limited by custom and that to acknowledge this fact would only be to acknowledge a *fait accompli.* Sovereignty cannot be held in abeyance. The acknowledgment of its nonexistence above 53 miles is the only rational base line from which the conventional law of outer space can proceed.

The critics of such an approach may feel that this position would derogate from the inherent right of this nation to reserve all rights and privileges in outer space for a future period. The only reply is that to do nothing can be as dangerous or more so than taking action, a priori, based on a rationale which would enhance its acceptance by the rest of the nations of the world community. Perhaps the present position of the State Department, to "wait and see" and to treat this problem much like the sovereignty problem of the Antarctic, may have already served its full useful period.[30] Since the problem must inevitably be faced, it appears more reasonable to face it from a tenable position in advance than to risk facing it defensively in a manner or at a time not of our own choosing.

The argument may also be heard that this action would impinge upon this nation's security. Under the United Nations Charter all nations possess the right of self-defense. The inherent right of a nation to protect itself from harm knows no particular locus. Should this nation be threatened from or through outer space, our response would be immediate regardless of the regime in which the threat originated. This is the precise context in which General White was speaking when he said that air and space are indivisible.[31]

international cooperation

For the future of outer space, we can assume it would be possible to continue unabated the technical cooperation on an international basis that was highlighted by the work of the International Council of Scientific Unions during the IGY. This same group recently formed a special committee for the purpose of directing space research.[32] This kind of scientific cooperation could easily lead to international agreement on an intergovernmental basis. In this respect a recent staff report of the House Select Committee on Astronautics and Space Exploration proposed the formation of an international body to promote the peaceful conquest of outer space. This report urged the United States to take the initiative, along with the other Western nations, in the hope that the U.S.S.R. would find it advantageous to join. The new organization, in contrast to that proposed by the International Council of Scientific Unions, would include government as well as scientific representatives.[33] As Dr. Lloyd Berkner, president of the ICSU, pointed out, during the IGY all scientists had complete congeniality and free discussion in their projects and, with the exception of Red China, "all other nations have laid politics aside on the grounds that genuine scientific enterprises should have no political implication of any kind."[34] If this type of cooperation is to continue, these scientists must know the political context of the medium within which they carry out their investigations. To this end, a nonsovereign area is a nonpolitical area.

THE last theme in this very abbreviated treatment of a complicated problem is to emphasize the difficulty of attempting to establish the beginnings of a code of space law by agreement *before* custom has had a chance to be tested in the crucible of experience and acceptance. As they have in the past, so also in the future international discussions on outer space may bog down by being inextricably linked to extraneous issues. Such has been our experience in the United Nations discussions on outer space. Also, premature agreements may be worse than no agreements at all. We have only to review the actions of the U.S.S.R. in respect to its international obligations to see that its compliance with previously signed agreements is completely unpredictable, as witness the present Berlin difficulties.

It is firmly believed that in the normal course of events international law, whether it be terrestrial or extraterrestrial, follows a natural and sequential evolution which will not be diverted. The publicists have had and will continue to have their say. Custom is in its gestation period and will not be hurried. Here, it is only urged that there be a significant contribution to this developing custom. Convention will inevitably follow in due time, but the time is not yet here. Only after we have entered the "cold caverns of infinity" on a solid foundation of custom will we be ready to allow the international law of space to reach its full fruition in international convention.

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References

1. Harold D. Hazeltine, *The Law of the Air* (London: University of London Press, 1911), p. 142.
2. U.S. Congress, Senate, *Convention Relating to International Air Navigation*, 66th Congress, 1st Session, 1919, Senate Documents, Vol. 8.
3. U.S., *Statutes at Large*, XXXXIV, Part 1, 568.
4. U.S., *Statutes at Large*, LII, Part 1, 973.
5. U.S., *Statutes at Large*, XXXXVII, Part 2, 1901.
6. Green H. Hackworth, *Digest of International Law* (8 vols., Washington: U.S. Government Printing Office, 1940-1947), I, 1.
7. *United States* v. *Causby*, 328 U.S. 256 (1946).
8. Hans Kelsen, *General Theory of Law and State*, ed. Anders Wedberg (Cambridge, Mass.: Harvard University Press, 1945), p. 217.
9. John C. Cooper, "High Altitude Flight and National Sovereignty," *International Law Quarterly*, IV, No. 3 (July 1951), 418.
10. John C. Cooper, "Legal Problems of Upper Space," *Proceedings of the American Society of International Law*, 50th Annual Meeting, Washington, D.C., 25-28 April 1956, p. 92.
11. *The Times* (London), September 2, 1957, p. 9.
12. John C. Cooper, "Missiles and Satellites: The Law and Our National Policy," *American Bar Association Journal*, XXXXIV, No. 4 (April 1958), 321.
13. Richard T. Murphy, Sr., "Air Sovereignty Considerations in Terms of Outer Space," *The Alabama Lawyer*, XIX, No. 1 (January 1958), 34. See also: Remarks of P. K. Roy, *Proceedings, American Society of International Law*, 1956, p. 94.
14. Andrew G. Haley, "Law and the Age of Space," *St. Louis University Law Journal*, V, No. 1 (Spring 1958), p. 3.
15. *Ibid.*
16. Myres S. McDougal and Leon Lipson, "Perspectives for a Law of Outer Space," *American Journal of International Law*, LII, No. 3 (July 1958), 425-26.
17. "Air Code of the U.S.S.R. Approved by the Central Executive Committee of the U.S.S.R. April 27, 1933," *Journal of Air Law*, IV, No. 3 (July 1933), 441. See also: I. S. Peretерski, "The Air Code of the Union of Soviet Socialist Republics," *Air Law Review*, IV, No. 1 (January 1933), 153.
18. *New York Times*, October 12, 1958, pp. 1, 11.
19. *New York Times*, October 14, 1958, p. 72.
20. *New York Times*, November 18, 1958, pp. 1, 5.
21. James J. Haggerty, Jr., "Assignment Space," *Planes*, May 1958, p. 3.
22. Andrew G. Haley, "The Rule of Law in the Space Age," *Foreign Policy Bulletin*, XXXVII, No. 24 (September 1, 1958), 190.
23. *New York Times*, October 27, 1958, p. 1.
24. *Schooner Exchange* v. *M'Faddon*, 7 Cranch (U.S.), 116 (1812), at 136.

25. House Select Committee on Astronautics and Space Exploration, *Hearings on H.R. 11881*, p. 1266.
26. *Ibid.*, 1434.
27. See the testimony of Dr. Lloyd V. Berkner regarding Red China: House Select Committee on Astronautics and Space Exploration, *Hearings on H.R. 11881*, p. 1043.
28. *U.S. Department of State Bulletin*, XXXVIII, No. 970 (January 27, 1958), 122.
29. Quincy Wright, *The Study of International Relations* (New York: Appleton-Century-Crofts, Inc., 1955), p. 11.
30. Loftus Becker, "United States Foreign Policy and the Development of Law for Outer Space," *JAG Journal*, February 1959, p. 29.
31. Thomas D. White, "Air and Space Are Indivisible," *Air Force*, March 1958, p. 40.
32. *New York Times*, October 2, 1958, p. 30.
33. *New York Times*, October 19, 1958, p. 18.
34. House Select Committee on Astronautics and Space Exploration, *Hearings on H.R. 11881*, p. 1044.

The Ordering of Technological Warfare

Colonel William O. Davis, AFRes

DURING the week that technological warfare became an unquestionable reality for the Department of Defense, I was on active duty in Washington and had the good fortune to be an active observer of the event.

A few days before the launching of the first Soviet satellite I was privileged to discuss the subject with officials very high in the Department. A few days after the first Soviet satellite I had the interesting experience of discussing the same subject with the same people. In the interim I had attended a meeting of the International Astronautical Federation at Barcelona, Spain, where I had seen firsthand the impact of the Soviet achievement on our European allies.

There was no question that our allies were frightened by the Soviet technical victory and that our ability to influence affairs in Europe had been seriously damaged. Although there was still some expression of the philosophy that the only important factor was the force in-being and not "technical stunts," there could be no doubt that the full political impact of the loss of the first major battle in technological warfare was felt in the highest levels of government. It suddenly had to be faced that the United States was at war and had been for some time—a technological war rather than a military war but nonetheless a war in which the ultimate survival of the nation might hang in the balance.

If this indeed be the case, what then is technological warfare? How did we get involved in it? What constitutes victory and defeat, and what are the overall effects on our national survival?

What is technological warfare?

First of all, we cannot define war as consisting solely of the application of military force to achieve national objectives. With the launching of Sputnik I, we saw major political results achieved by the application of a force that was nonmilitary in nature. Even prior to Sputnik many important forms of warfare were not covered by the classical definition. To provide a working definition for the sake of discussion, let us tentatively define war as the application of national resources to achieve national objectives in competition with other nations. Fundamentally the outcome of any war is determined when one of the contestants decides to yield to the wishes of his adversary. Thus the true object of warfare is not to destroy the materiel and to occupy the territory of the enemy but to influence the enemy government and population to adopt the pattern of action desired.

The most obvious form of war, of course, is direct military action, corresponding roughly to the adolescent forms of competition in the individual. Just as the individual discovers upon reaching maturity that there are more subtle ways of achieving his objective than fighting with his fists, so a maturing civilization discovers far more subtle ways of influencing its fellow members in international society, although unquestionably the threat of destruction remains the most impressive form of influence and no nation dares present a weakened military posture to the outside world.

Second only to the threat of physical destruction is the threat of economic destruction. Economic warfare has been an important alternative to military action since early history and has been raised to a high pitch of industrial competition by the great nations of the world. The third method of influence popular in warfare is direct applied psychology, perhaps the most fundamental of all. In pure psychological warfare the objective is to influence directly enemy populations and governments without the deployment of either military or economic force.

Technological warfare to some extent represents a combination of all three types of influence. For example, development of the atomic bomb and the long-range bomber provided a direct military threat to potential enemies. The demonstration of a continued high level of technical achievement, particularly if this level is higher than the enemy's, provides a direct psychological influence against his seriously considering an attack upon you. Perhaps the most important threat of technological warfare is the economic one. It is here that tactics and strategy may be stated most explicitly and that maximum results are achieved in times of military peace.

In other words, the object of technological warfare should be not only to exceed the enemy technically but also to influence or coerce him economically in the process. Thus technological warfare may be defined as the strategic and tactical employment of scientific and engineering discovery to influence adversely the enemy's economic, political, and military posture.

The environs of warfare since the middle of the twentieth century have moved spectacularly toward the realms of science and space. In this aspect of national power, laboratories are advance bases, blueprints are battlefields, scientists and engineers are troops, and victories are measured in the orbits of satellites and the trajectories of missiles. This is technological war. Its outcome is dependent upon technological progress and new space-age concepts. Its tactics and strategy—not to mention political impact—are imperfectly understood and will not be advantageously pursued by the United States until we substitute positive direction for reliance on chance. Col. William O. Davis, AFRes, scores failure to accord technological warfare the necessary emphasis and calls for reorganization and better management of resources to meet this challenge to national survival.

How did we get involved?

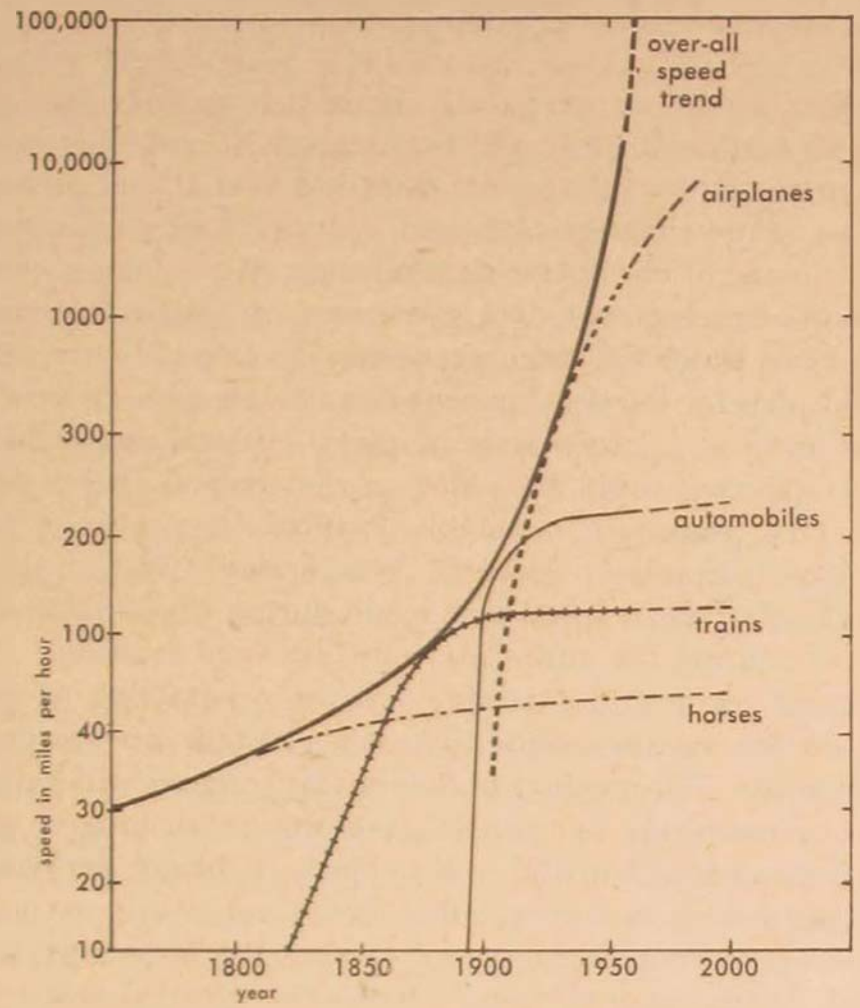
As the beginning of the current technological conflict took this nation largely by surprise, it is worthwhile to consider how it was possible for the Soviet Union to have gained so much headway. For the most part the best technical minds in the United States failed to foresee the rapid development of the field of space technology. This is not surprising. Of even the most imaginative science-fiction writers it can generally be said that they have predicted events too far in the future. Jules Verne, writing in 1890, forecast television, 600-mile-per-hour passenger travel, the atomic bomb, and many other modern discoveries, but in general he forecast such discoveries for nearly one thousand years in the future. Looking at forecast after forecast, one is forced to the conclusion that new scientific discoveries usually occur much sooner than anyone has expected.

This factor is of obvious importance in the waging of technological war. A knowledge of the true rate of progress in a given field of technology would constitute a potent offensive or defensive weapon. The characteristics of a weapon determine the strategy and tactics of its application. Let us, then, consider those characteristics of technical progress which dictate the strategy and tactics of technological warfare and proceed to a discussion of the factors affecting doctrine in this area.

The accompanying figure is a plot of speed records for various modes of transportation over approximately the last hundred years. This curve has been included because it graphically presents the principles to be discussed; curves for a number of other parameters of progress have presented those same characteristics. On a rectangular plot a straight line represents a situation in which the same amount of progress occurs each year. On a semilogarithmic plot a straight line indicates that the percentage rate of progress —unlike the amount of progress on the rectangular plot—is constant each year. Thus since this is a semilogarithmic plot, the speed capability of a given type vehicle tends to increase by a constant per cent each year during the period of active development. This represents a dramatic growth pattern in the case of the more modern modes of transportation, such as the airplane. (The figure is unclassified; if classified data were presented, the trend would probably be somewhat nearer to a straight line.)

Even more remarkable than the trends of individual modes of transportation is the over-all trend of speed. Speed, in common with many other parameters of progress, is actually increasing at an exponential rate on this semilogarithmic plot. In other words the percentage rate of progress is not only high but increasing every year. This observation has most serious consequences in the conduct of technological war.

Another very important observation from these trend curves is that there appears to be very little correlation between technical progress and economic cycles. So the rate of technical progress appears to be independent of the amount of financial support provided or even the amount of effort. If greater effort is applied, the most important result is a shortening of the interval between discovery and production rather than a hastening of discovery. Thus one might conclude that, regardless of the level of effort, an attempt to increase the rate of technical progress within a given concept of a vehicle will normally be fruitless. The continued development of an airplane per se can only bring an increase in speed along the straight line of the airplane



speed curve. To increase the percentage rate of progress, it is necessary to develop new vehicle concepts. The same general type of conclusion can be drawn from most of the other relevant trend curves, such as altitude, horsepower per pound of vehicle, etc.

What is victory in technological warfare?

In summary, we find that the evolutionary development of existing concepts in general follows the line of constant percentage improvement, whereas the introduction of new concepts may lead to a revolutionary increase in capability. The fact that we cannot increase the evolutionary rate of progress merely by increasing the effort in the field leads to one important conclusion with regard to the strategy of technological warfare. The prediction of a discovery does not imply that the scientists of any particular nation will make it. Once a nation has gained the advantage—is ahead on the trend curve —it is very difficult for an adversary to catch up. To do so, the adversary must make a discovery still further in advance and therefore less probable. He can never retrieve his position by merely attempting to duplicate the achievement of another nation after the fact. Increasing the national effort may expedite the more rapid production of new weapons, but it will not usually bring about new discoveries any sooner. Thus when a nation has fallen behind in technological warfare, it must seek new concepts if it is to retrieve its position.

In the past, before we were really aware that we were fighting a technological war, we had usually followed two methods of planning and developing military weapon systems. To the end of World War II and perhaps for some years after, we were primarily concerned with purchasing military weapons in quantity for the use of our operating commands. We did not generally attempt to program the development of a given weapon system but rather bought off-the-shelf items which had been previously developed by the manufacturer. When we did plan for the development of a new weapon, in most cases it was done on the basis of a frozen state of the art. It was assumed that no new technological changes would be added to the weapon system during its development. This procedure inevitably resulted in a weapon system obsolescent the day it became operational. As a matter of fact, in the case of the B-52 as much progress in speed was made during the development time of the airplane as during the entire previous history of aviation.

The second method of planning was the programing of developments based more or less on the assumption of a constant percentage increase in the state of the art. This method presumes that progress will have been made by the end of each year but only that evolutionary progress predicted in advance will be included in the new weapon. Although perhaps realistic in terms of a given weapon concept, this method of development programing leads to almost constant reprograming during the fiscal year as a result of the constantly changing prediction. It has been estimated that approximately 85 per cent of all resources of Air Research and Development Command have been reprogramed during some years.

The ideal situation from a technological warfare point of view would, of course, be one in which all efforts were concentrated on the discovery of new concepts. Unfortunately this approach would not lead to a proper preparation of the nation for armed conflict. In practice, even today we must use all three approaches. A portion of our resources must go into the attempt to discover new concepts so as to score a victory in the technological war over the enemy, a portion must go to the rapid evolution of existing concepts so that a continuing supply of new weapons is becoming available to the armed forces, and finally at some point that state of the art must be frozen so that actual hardware may be produced. It is with the proper distribution of resources into these three areas of interest and with the proper strategic and tactical application of new discoveries and weapons that the management of a technological war must concern itself.

Let us first consider the problem of division of resources. Several years ago, while a student at the Air War College, Colonel Oliver G. Haywood, Jr., made an analysis of a simple tactical problem by the von Neumann theory of games. He considered the case of a commander who, having limited resources, had to choose between estimating the enemy's capabilities and estimating his intent. If he chose the estimate of the capabilities and attempted to deploy a portion of his force to counter each possible capability, he could not apply sufficient resources to any capability to ensure victory. On the other hand, if he attempted to estimate the intent of the enemy and guessed wrong, he ran a risk of total defeat. In analyzing this problem Colonel Haywood came to the conclusion that approximately one third of the commander's resources should be applied in accordance with his estimate of the enemy's intent and two thirds according to his estimate of the enemy's capability. This distribution optimized his chances for victory while minimizing his possibilities of total defeat.

Something of the sort could well be applied in the present struggle between the United States and the Soviet Union. I would hesitate to suggest that one third of the nation's defense resources should be committed to the development of new concepts in technological warfare, but certainly something like one third of the effort and interest, if not dollars, should be applied in this direction. The remaining two thirds of effort and interest and a larger proportion of dollars should, of course, go to the continuous development of new weapon systems and their production for possible military warfare.

A general in charge of fighting a technological war would be concerned not only with the development of new concepts but also very strongly with the problem of communicating the new concepts to system engineers and ultimately to production engineers, so that the products are of concrete military value in the event of armed conflict as well as of psychological and economic value in the technological war. In other words, his primary function would be that of communication and translation between people who think in different ways.

I believe that one of the greatest reasons for our failure to anticipate the success of the first Soviet satellite lay in the fact that for the most part the advocates of space activities were zealots rather than practical politicians. In times past the responsibility for new concepts has generally been assigned to small organizations and has been in the hands of younger men. Although such preparation for the age of space as had been achieved was largely due to their efforts, had there existed a manager or general officer concerned primarily with establishing communications between those having new ideas and those who produce them, I believe we would be in a very much better position today. In the struggle for funds and resources in the American democracy, this general's maturity of approach and practical knowledge of how to influence people and sell programs are at least as essential as his technical knowledge.

If he could solve the communications problem, the next major duty of our general in charge of technological warfare would be mapping tactics and strategy. When the British were faced with the problem of defeating Napoleon at the time when he had the greatest land force in the world and also benefited from internal lines of communication, they resorted to the flexibility of their sea power to achieve their purpose. By landing small forces and stimulating local rebellion in widely scattered areas, they forced the continuous deployment of Napoleon's troops from one end of Europe to the other, thus exhausting him economically and paving the way for Waterloo.

The analogous strategy in technological warfare is shown in the present situation with the Soviet Union. For example, the enemy breaks out in the satellite field and forces a complete redeployment of our resources in that direction. Once we have committed ourselves to this course, the next action of the enemy is to make a breakout in the field of nuclear-powered aircraft with the hope that this would force a redeployment of our economic and technical resources. This process could be repeated almost indefinitely as new concepts became available.

This, then, is the primary strategy of technological warfare: to force the enemy to compete at a technological disadvantage while recommitting his resources as frequently as possible to his own economic disadvantage. When a nation is ahead in a given technical field, it is very difficult for an adversary to catch up without the development of a new concept. Thus a victory immediately places the enemy on the strategic defensive, and the trends are all in favor of the victor.

As to our objective in the current technological war, it is obviously essential that we regain the initiative as soon as possible by the effective application of new weapon concepts. Having achieved a favorable position in the technological struggle, we should then concentrate on changing emphasis in technical fields when this can be done to our economic advantage and the enemy's disadvantage.

The tactics of technological warfare as opposed to its strategy are perhaps best illustrated by the timing of Soviet announcements at the time of the launching of the first satellite. It will be remembered that the Soviets, within a few days of the launching of Sputnik I, announced that a very-high-altitude nuclear explosion had been set off over Siberia. It is probable that this explosion was balloon-borne, although it may have been rocket-borne. In any case there was no military relationship between the two events. But to the uninformed public in Europe and Asia the juxtaposition of these two technical events seemed to imply that the Soviets had the ability to place a satellite over any point on earth and to release a hydrogen bomb from it at any time they pleased. This was a completelv false conclusion, but nonetheless the psychological effect upon the European people and even upon the European military was quite profound, as those of us who were in Europe at the time can testify. The tactics of technological warfare consist of the manner in which new discoveries are displayed to the enemy and to the neutral populations of the world, either singly or in combination with other technical achievements.

If we are to fight this type of war, then clearly some agency or individual must have the responsibility for fighting it. The tactics and strategy of any war cannot be trusted to chance but must be carefully coordinated and planned with other activities at the national level. In my opinion this is perhaps the greatest deficiency in our national structure at this time. Such an operating agency would have to have certain characteristics. First of all, it would of necessity contain a combination of technical and military personnel, although it should be strongly emphasized that the technical personnel should not be specialists and the military personnel should not be tactical in their thinking. What is required for this organization is the best strategic thinkers of both professions. Furthermore it should not be an advisory group but an operating agency. For such an organization to operate, the military and scientific thinking must be closely integrated at all times, and the agency should have the authority to influence directly the timing of United States technical-publicity releases. Such an agency should eventually report directly to the President. In the meantime, however, it appears that there would be great value in undertaking a consideration of the problem immediately even at the level of the Department of Defense or, perhaps, of the Air Force.

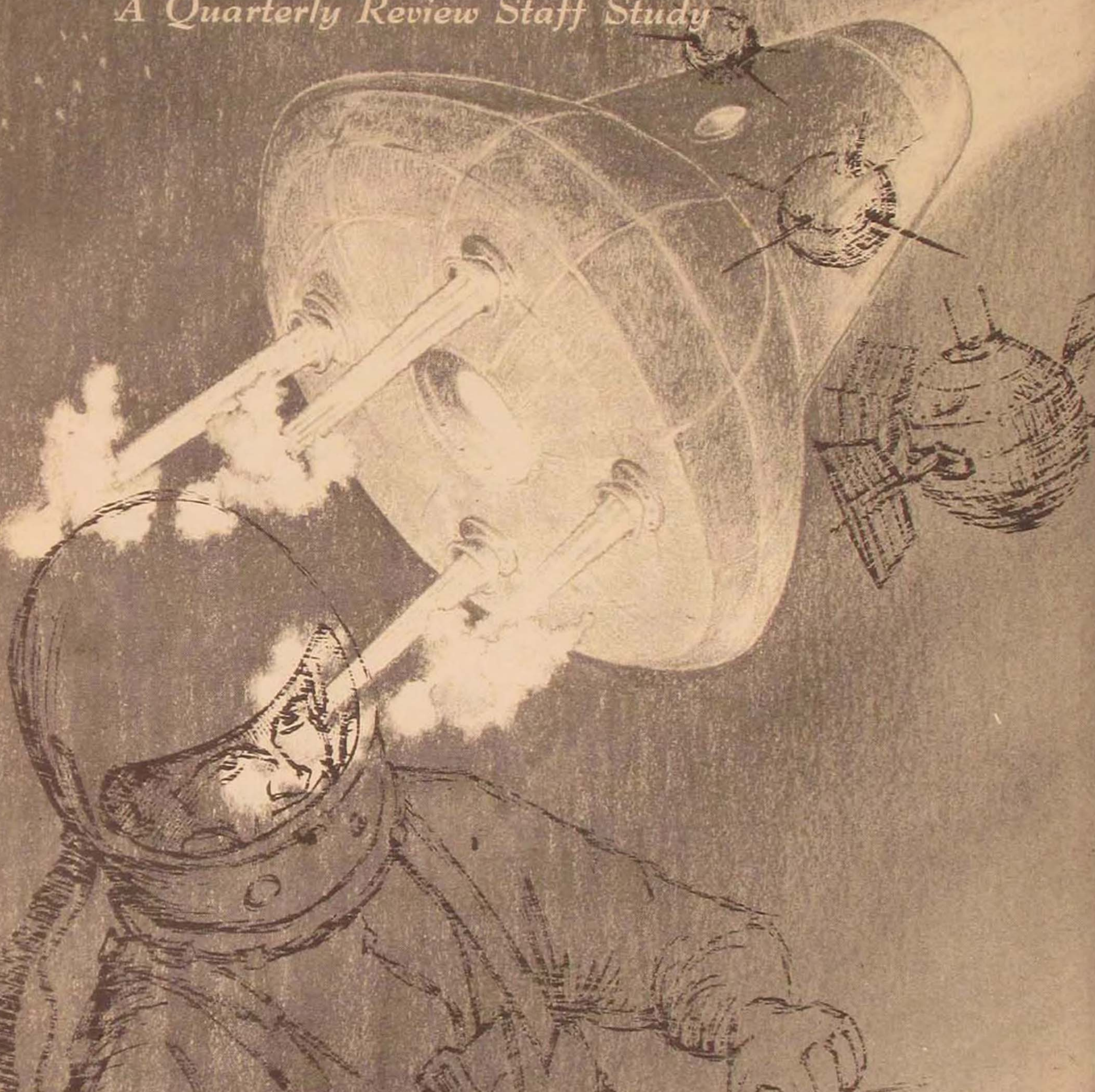
Technological warfare is here to stay. As a matter of fact I would estimate that already more time and money are probably being spent for this form of war than for military warfare. All the great missile and satellite programs now under way must be presumed to be of much more significance in technological warfare than in military war at the present. We may reach the time when general military war may be suicidal for any nation. The substitution of technological warfare, although costly, cannot compare to the cost of fighting an all-out nuclear war whether we win or lose. Furthermore technological warfare has the advantage of offering an arena for important competition in which to release international tensions and provide for the healthy development of societies.

We are engaged in such a war now, and yet our entire organization is designed around the fighting of a potential military war. Should we not seriously consider, as a nation, the necessary reorganization to permit us to compete at an advantage in what is likely to be the most popular and potentially decisive form of warfare during our generation?

Minden, Nevada

Technology in Orbit

A Quarterly Review Staff Study



LOOKING back over the decade of the 1950's, one must conclude that the single factor of greatest military importance was the tremendous surge of technology. In future historical consideration, with the advantage of greater perspective, it may well be that the rise in technology is adjudged the dominant factor in world affairs during this decade. Certainly at no other time in history has appeared any such combination of momentous technological advances that found surging, far-reaching employment within the decade and other technological advances, some of them equally momentous, that immediately promise limited employment with eventual prospects of revolutionary effect.

For this was the decade of the hydrogen bomb, of jet against jet in combat, of supersonic speeds in level flight, of intermediate-range and intercontinental-range ballistic missiles, of orbiting satellites, of man's first contact with the moon, and of man's first dim view of the reverse side of the moon. In this decade the speeds of manned vehicles rose from about 600 miles per hour to more than 1500 miles per hour. The speed of his fastest weapon system rose to 16,000 miles per hour. The altitudes with which man had practical concern rose from about 20 miles to some 300,000 miles, and he probed out some 120,000,000 miles with vehicles orbiting around the sun.

While manned aircraft made spectacular advances during the decade, and the X-15, nuclear flight propulsion, and impending increases in rocket thrust promise to put manned vehicles back into the forefront by the end of the 1960's, the 1950's were essentially the decade of the ballistic missile. It was the missile that brought the bounding technological revolution of the mid-century into the world limelight and kept it there. For it was with the ballistic missile that prescient technology became recognized as a dominant factor in the power struggle between the free world and the Communist world. From 1952, when the successful hydrogen bomb gave the ballistic missile the warhead potential that made it an ominously significant strategic weapon, the race for operational ballistic missiles was on between the United States and the U.S.S.R. Then when the first Soviet Sputnik flashed into orbit, the ballistic missile began its second career as the booster for satellites and space probes. From that day in October 1957 until the close of the decade in 1959 the dual contest for operational missiles and space triumphs continued in a zigzag of world headlines.

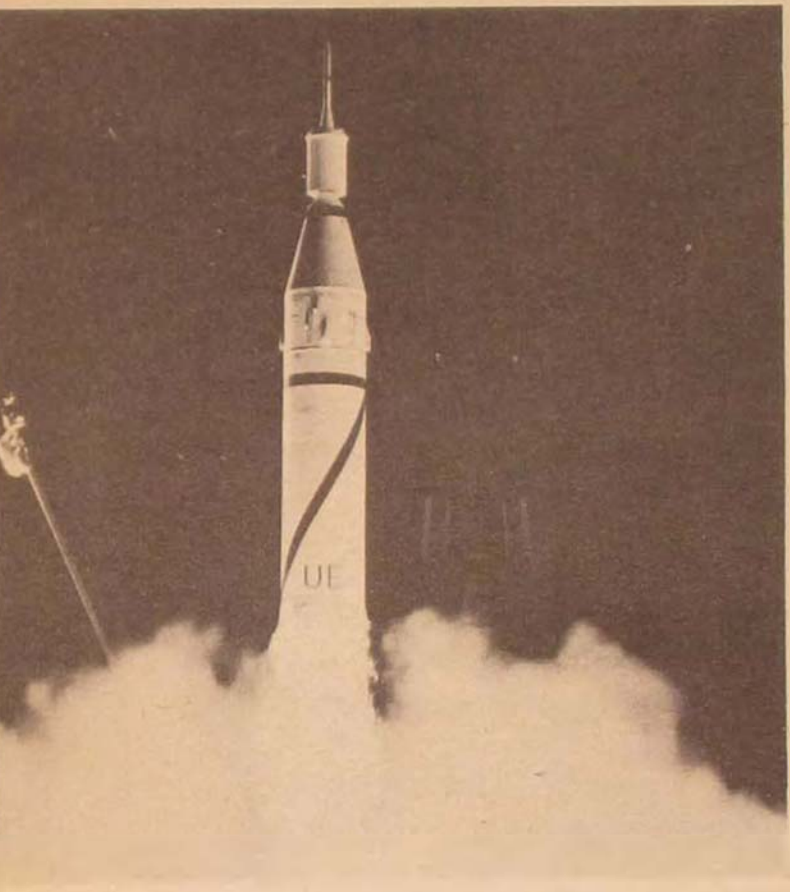
For many reasons the space ventures have attracted and held world attention. There is the sheer spectacle. There is the feeling of participation as man attacks the great frontier that moves out from his own planet toward contact with other worlds. But as technological achievement centered itself firmly in the arena of man against space and of nation against nation, a feeling began to grow, though still nebulous in form, that the whole matter of space exploration had much more meaning to the United States than might reside simply in a new area of scientific exploration. The venture into space had become the showcase for advanced technology, in which the relative strong points and weaknesses of United States and Soviet progress stand out more boldly than elsewhere along the broad technological front.

As a result of this interest and concern, the year 1960 has opened with many-sided debate and examination of American progress in space: its relative success, its relative importance and urgency, its organization, and the scope and kind of exploratory program that is planned for the future.

Hardly with expectation of answering any of these debated points or even of encompassing them all but with hope of offering some modest synthesis of the rather scattered scientific record concerned, the Editors of *Air University Quarterly Review* have assembled a factual summary of U.S. and Soviet space explorations through December 1959.

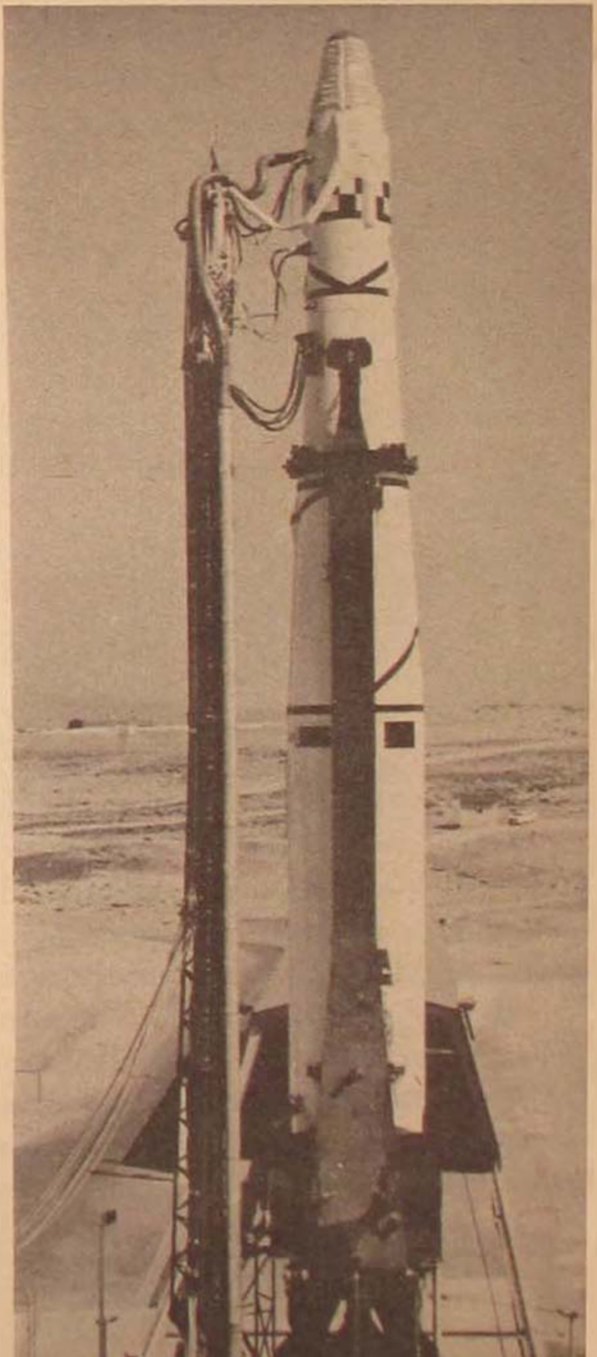
Boosters for U.S. Space Projects

Launching power for the U.S. satellites and space probes during the 1950's came mainly from the four boosters and the three-stage Vanguard rocket shown here. With the exception of the Vanguard rocket, which was developed solely for IGY scientific experiments, all launchings used military-developed "first-generation" missiles as boosters. For space use, these missiles were modified to carry additional fuel and to accommodate upper stages.



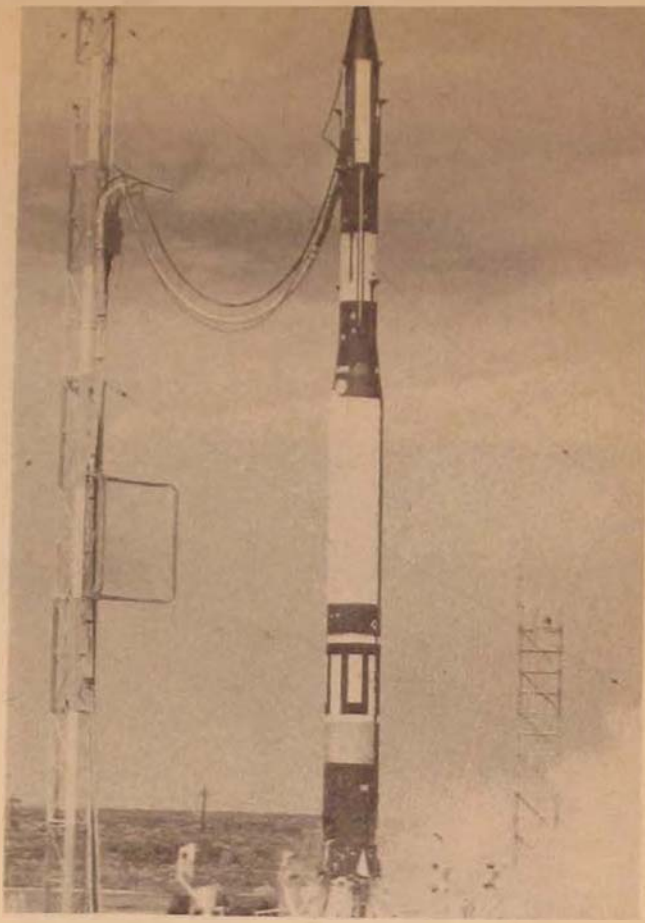
Redstone

Army-developed . . . . . ballistic missile
69 ft high . . . . 70-in diameter
launch weight . . . . 61,000 lb
thrust . . . . 75,000 lb



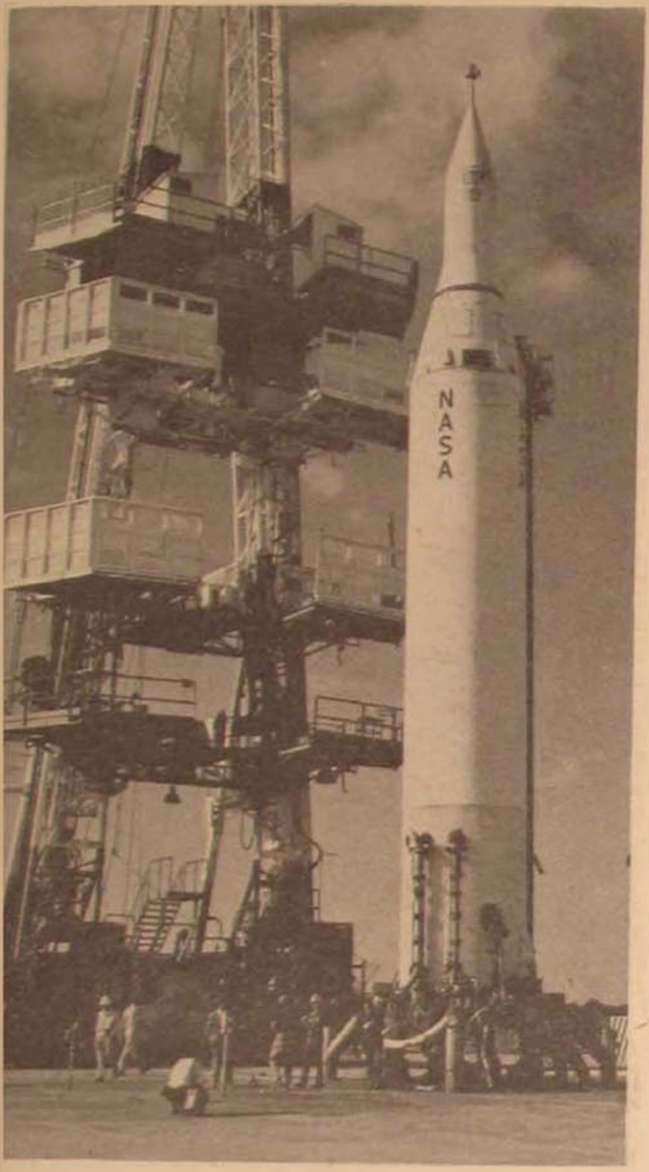
Thor

Air Force-developed . . . . IRBM
65 ft high . . . . 96-in diameter
launch weight . . . . 110,000 lb
thrust . . . . 150,000 lb



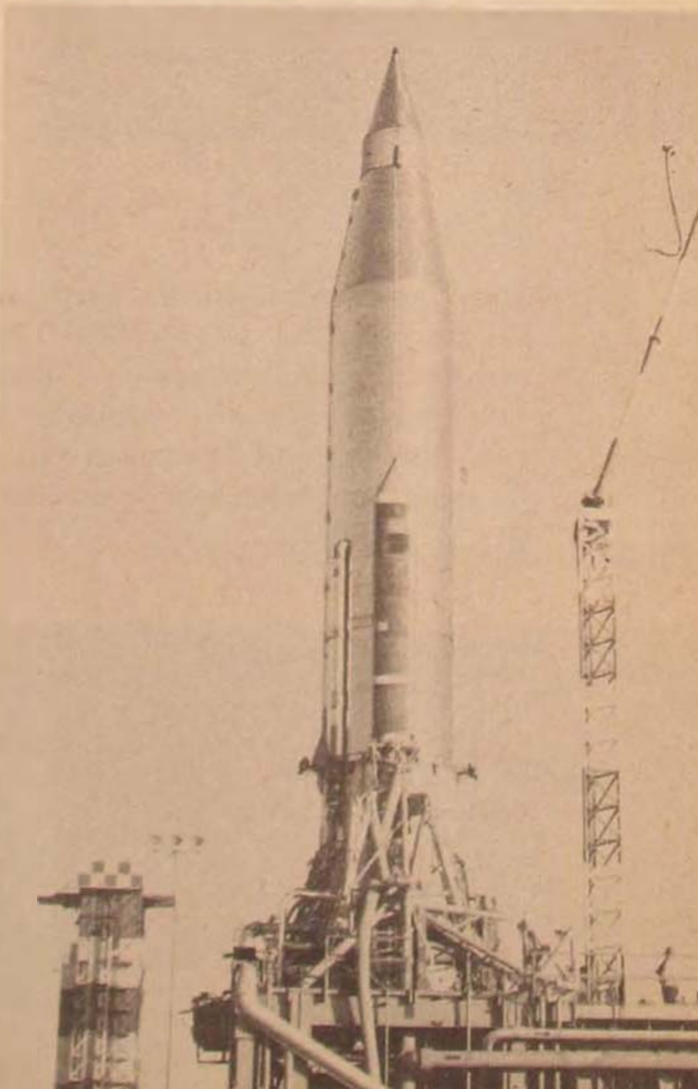
Vanguard

Navy-developed...... NASA rocket
72 ft high........... 45-in diameter
launch weight............ 22,600 lb
thrust.................. 35,940 lb



Jupiter

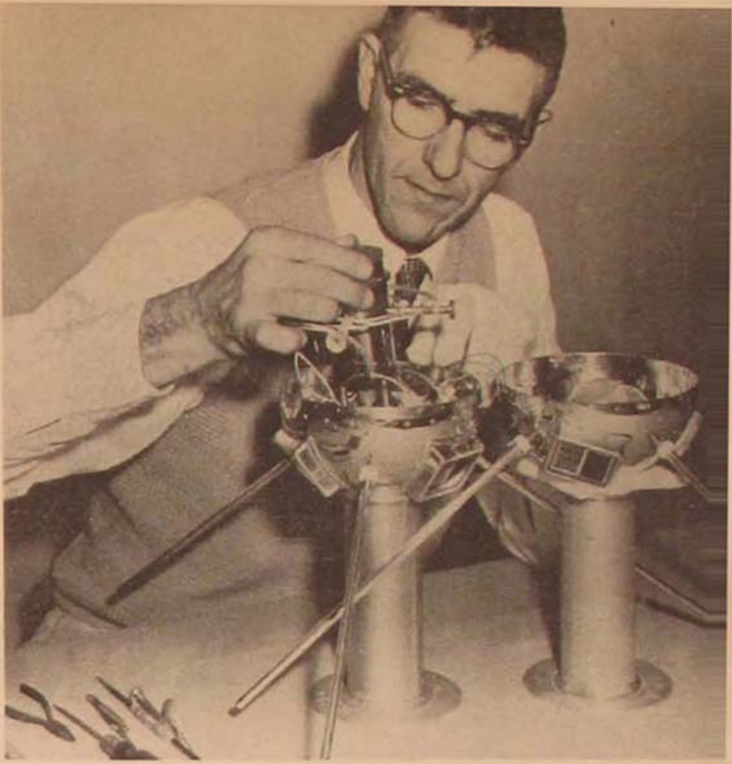
Army-developed..... Air Force IRBM
60 ft high.......... 105-in diameter
launch weight........... 110,000 lb
thrust.................. 150,000 lb

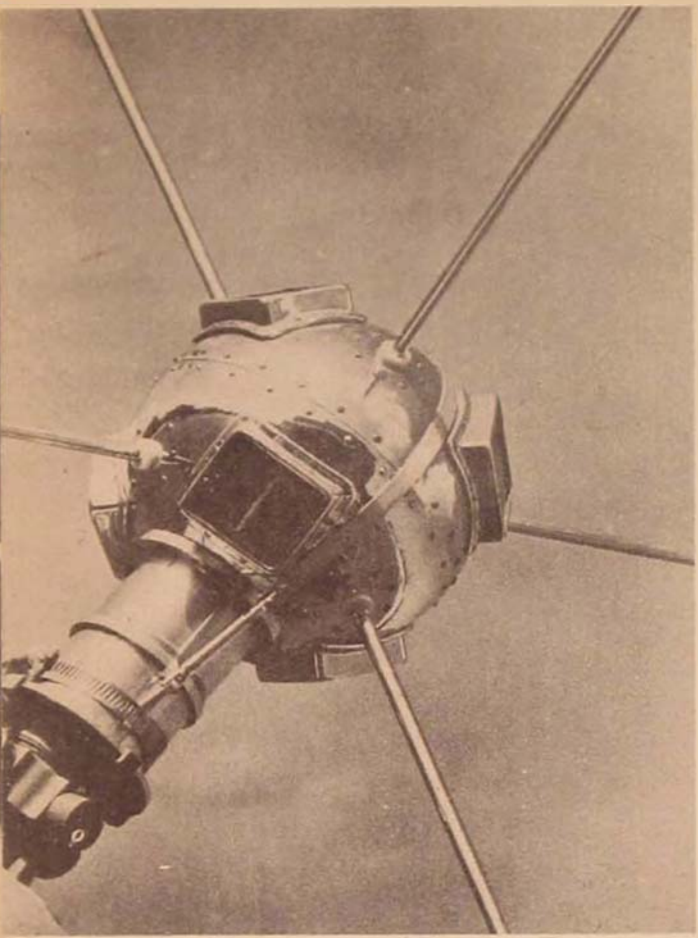


Atlas

Air Force-developed......... ICBM
82½ ft high........ 120-in diameter
launch weight........... 260,000 lb
thrust.................. 360,000 lb

Project Vanguard





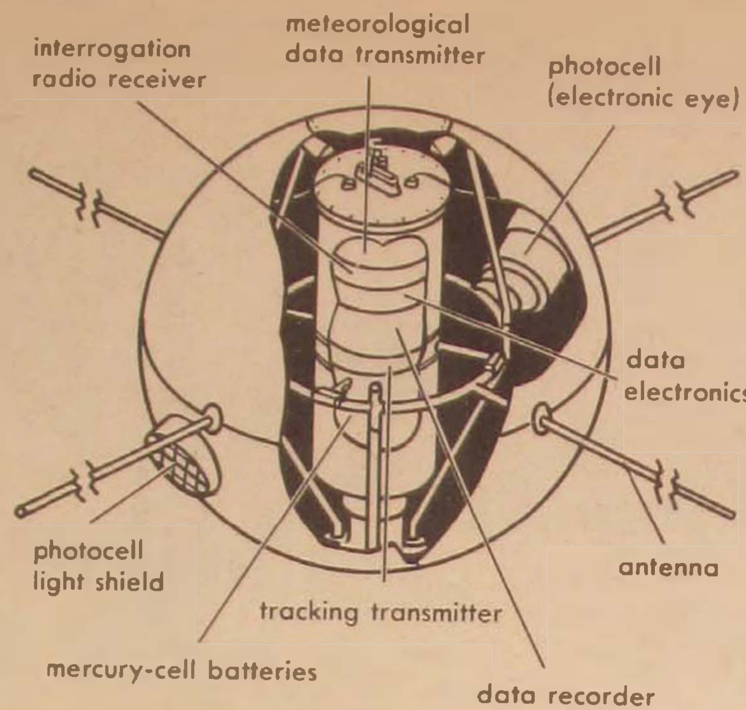
Instruments are inserted in Vanguard I (above). Antennas and solar cells are on the satellite (left).

The Vanguard scientific earth satellites were part of U.S. participation in the International Geophysical Year (IGY). Of 11 launchings for the trouble-plagued Project Vanguard, three satellites achieved orbit: Vanguard I, a small test sphere with minimum instrumentation; Vanguard II, the weather-eye satellite; and Vanguard III, measuring the earth's magnetic field, solar X rays, and space-environment conditions. All three remain in orbit.

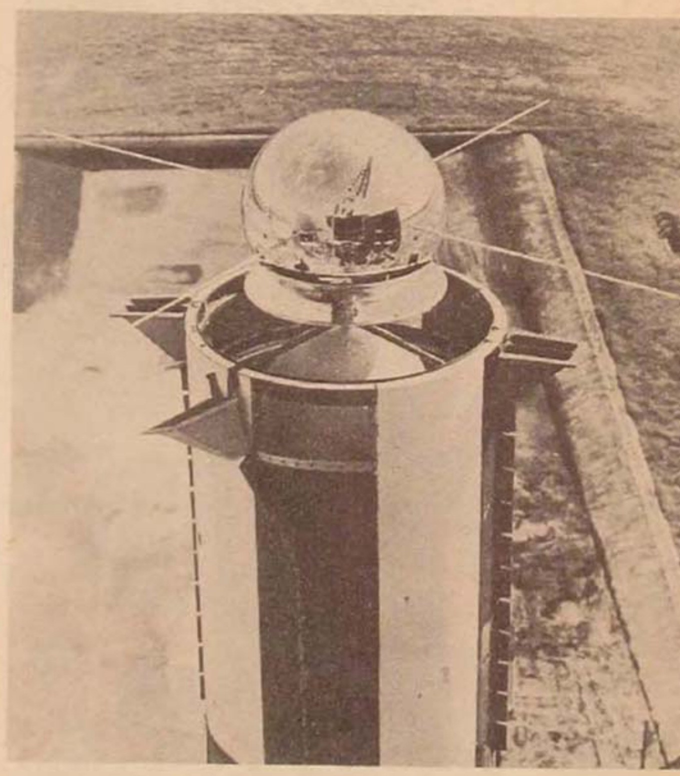
Vanguard I

Launched: 17 March 1958
From: Air Force Missile Test Center, Cape Canaveral
By: Naval Research Laboratory
For: Department of Defense, acting for U.S. National Committee—IGY program
Diameter: 6.4 in
Weight: 3.25 lb

Perigee: 409 mi
Apogee: 2453 mi
Orbital period: 134 min
Angle to equator: 34.25 deg
Estimated lifetime: 200–1000 yr
Launching vehicle: Vanguard rocket TV 4
Stages: 3



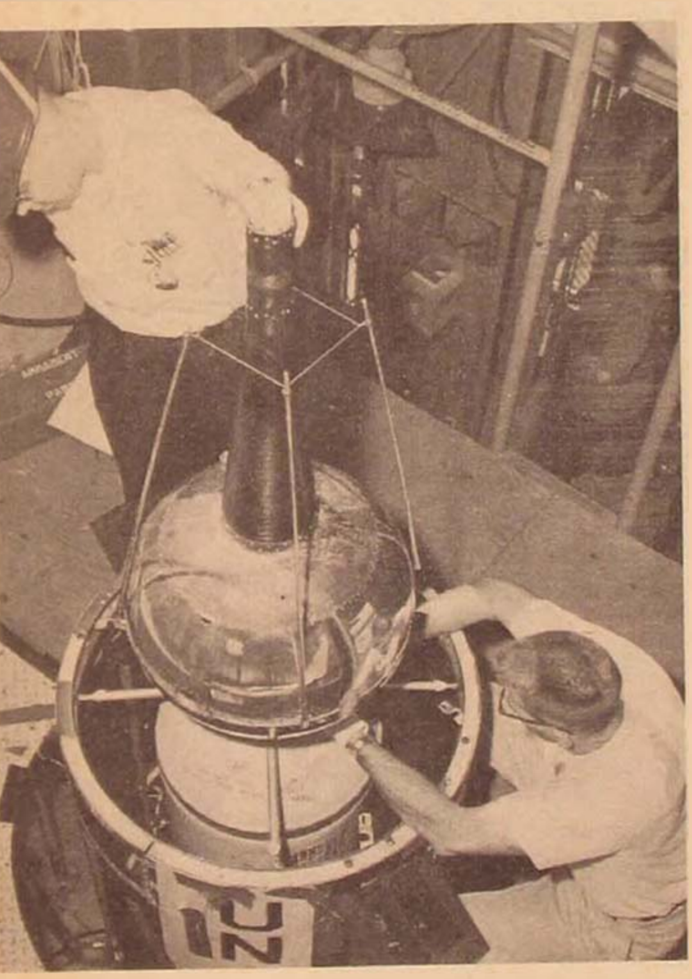
Vanguard II satellite: cutaway (above); instrument-deck insertion (left); atop launching rocket.



Vanguard II

Launched: 17 February 1959
From: Air Force Missile Test Center, Cape Canaveral
By: Naval Research Laboratory
For: U.S. National Committee—IGY program
Diameter: 20 in
Weight: 20.74 lb

Perigee: 347 mi
Apogee: 2064 mi
Orbital period: 125.85 min
Angle to equator: 32.88 deg
Estimated lifetime: 10—200 yr
Launching vehicle: Vanguard rocket SLV 4
Stages: 3



Spread before the Vanguard III shell and magnetometer tube (above) are battery packs, electronics for space experiments, and transmitters. This last satellite in the Vanguard series is mated (left) to a Vanguard launching rocket, modified by NASA.

Vanguard III

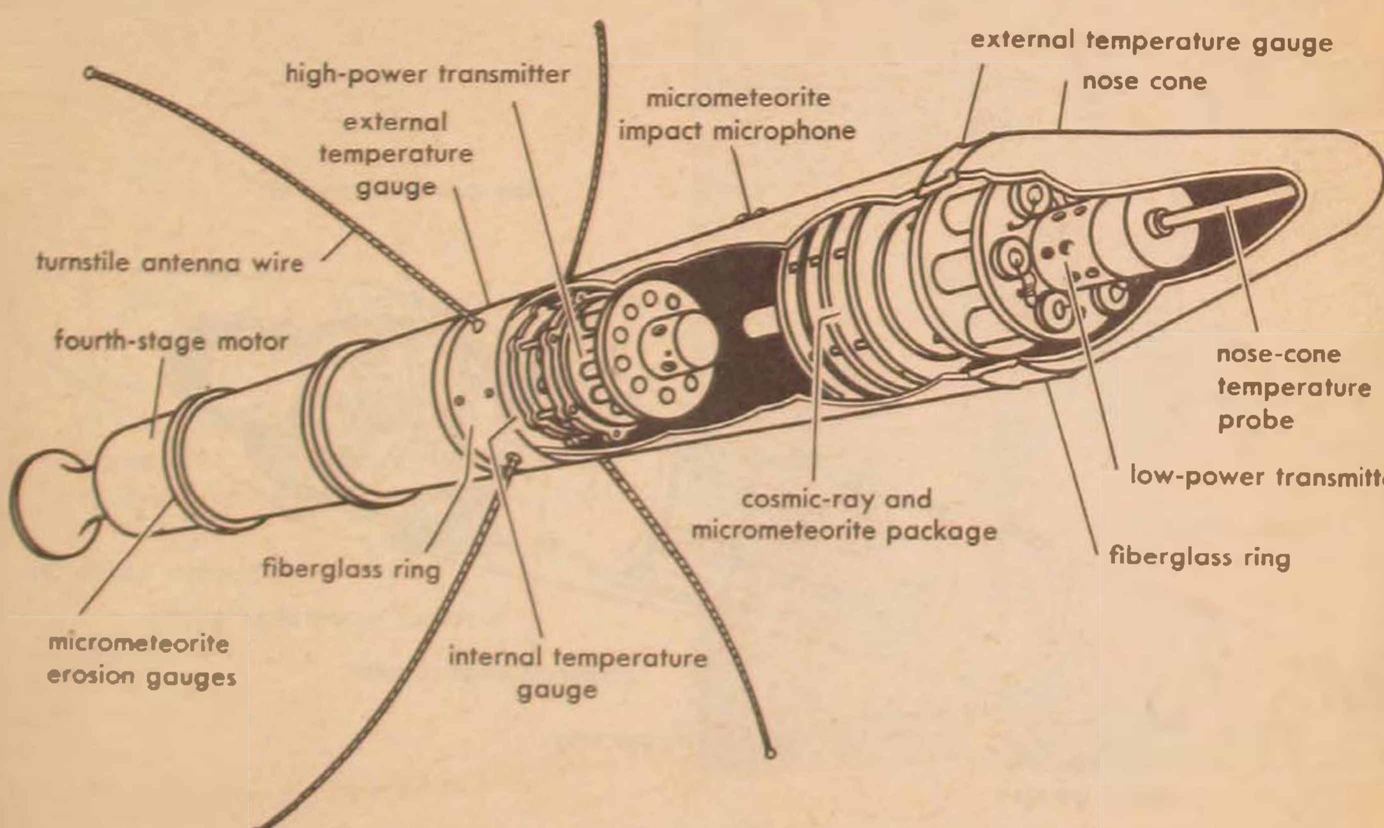
Launched: 18 September 1959
From: Air Force Missile Test Center
By: NASA
For: U.S. National Committee—IGY program
Diameter: 20-in sphere, 26-in tube
Weight: 50-lb scientific payload, plus attached 50-lb third stage

Perigee: 319 mi
Apogee: 2329 mi
Orbital period: 130 min
Angle to equator: 34 deg
Estimated lifetime: 30—40 yr
Launching vehicle: Vanguard rocket SLV 7
Stages: 3

Explorer Satellites

Precision instruments are assembled for Explorer I. Below is a cutaway drawing of Explorer I satellite.

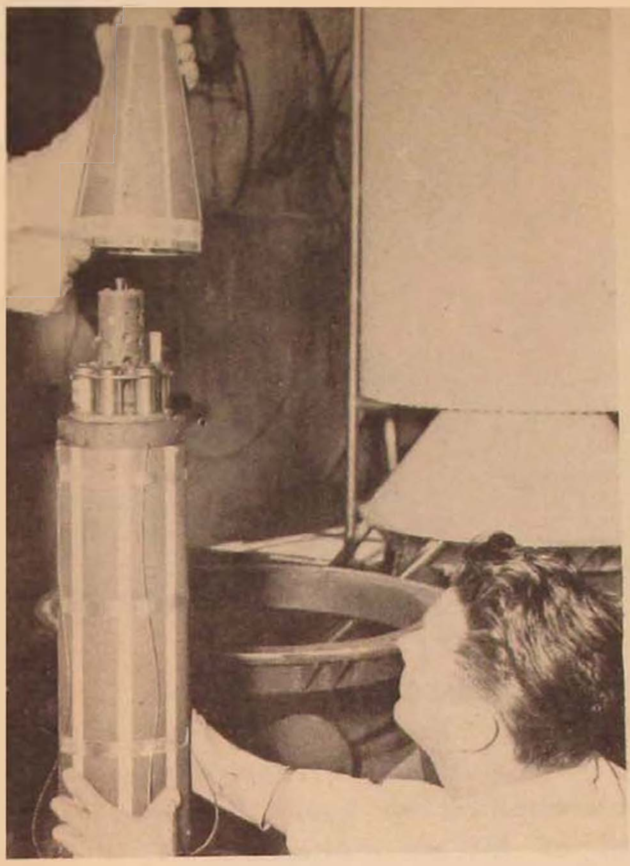
U.S. participation in the IGY program was further implemented by the Explorer scientific earth satellites. Explorer I, first U.S. satellite to go into orbit, made the most important satellite discovery of the IGY: the first of two radiation belts (the Van Allen belts) surrounding the earth. Later, Explorer VI detected a third, closer-in band of intense radiation. Of seven Explorers launched, Explorers I, III, IV, VI (the paddle-wheel satellite), and VII achieved orbit; of these, I, VI, and VII remain in orbit.

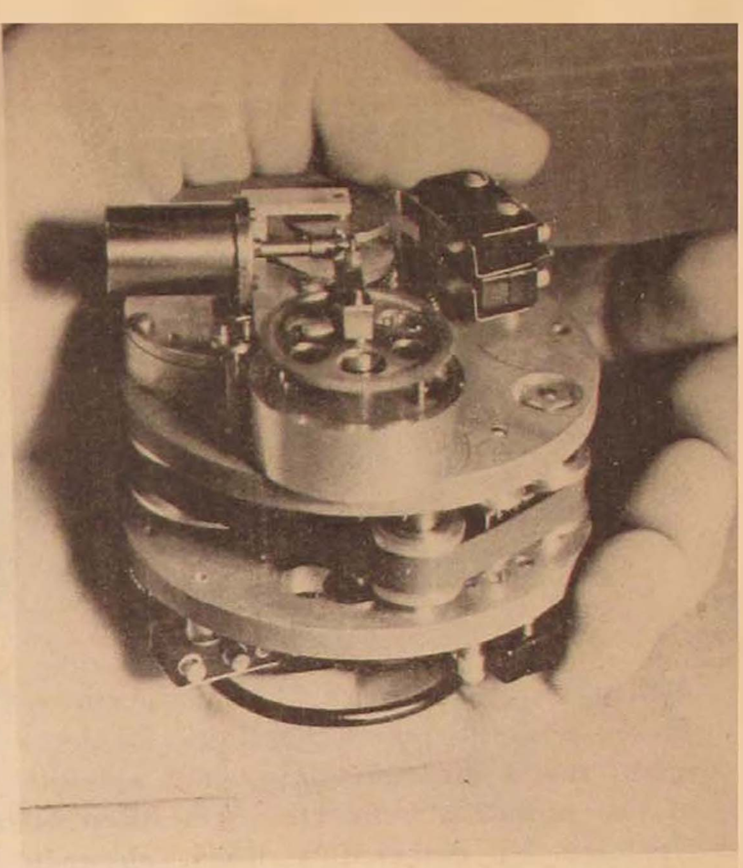


Explorer I

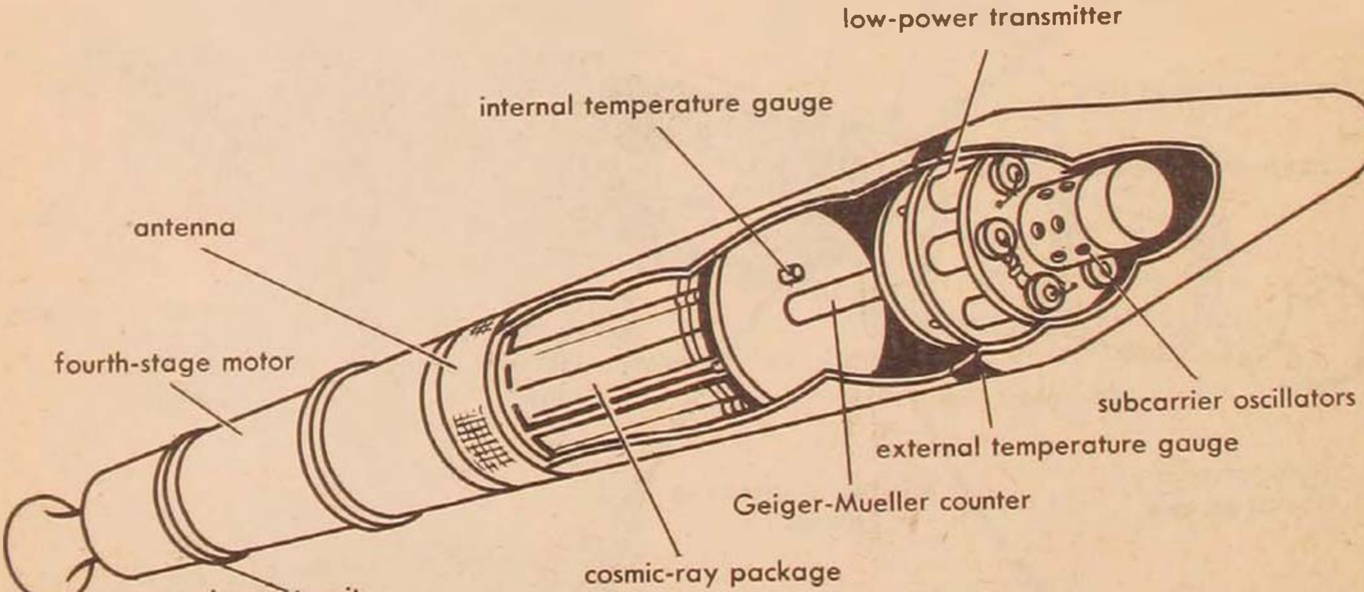
Launched: 31 January 1958
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: DOD, for U.S. National Committee—IGY program
Dimensions: 6-in diameter, 80-in length
Weight: 30.8 lb of which 18.13 lb scientific

Perigee: 224 mi
Apogee: 1573 mi
Orbital period: 114.8 min
Angle to equator: 33.34 deg
Estimated lifetime: 3–5 yr
Launching vehicle: Jupiter-C rocket
Stages: 4





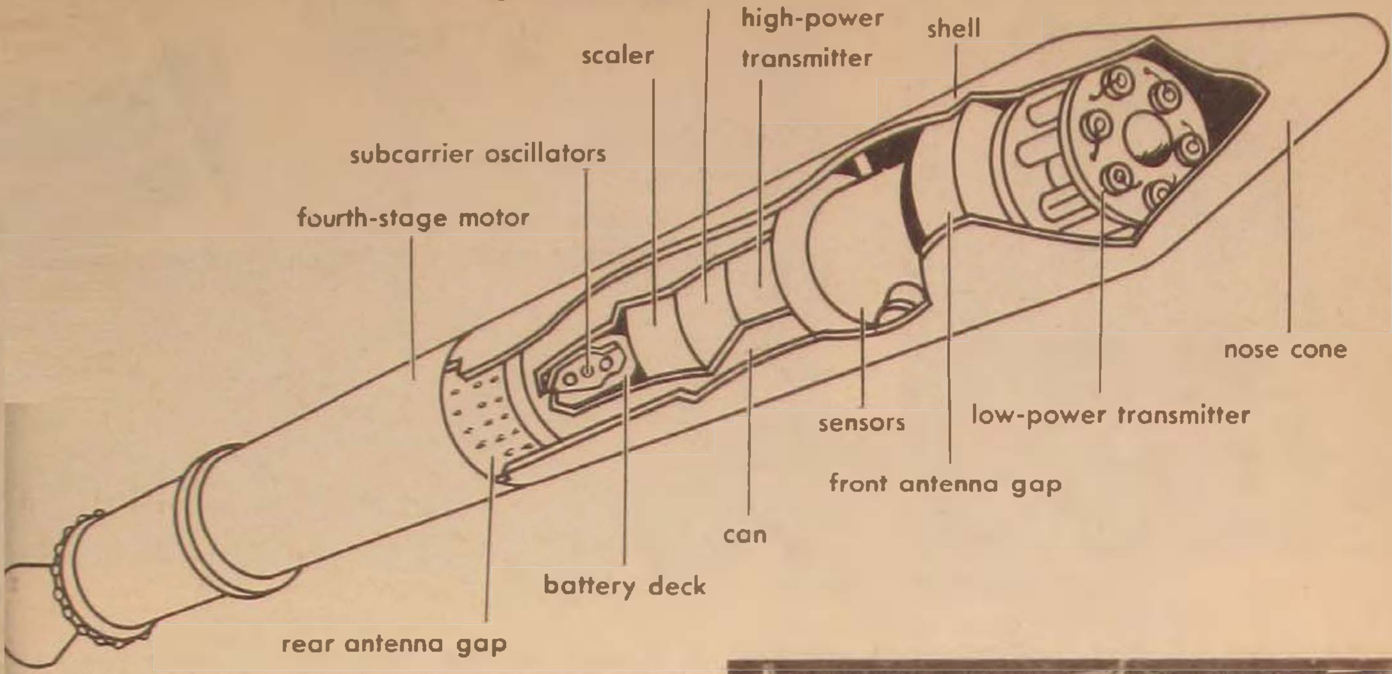
Protective nose cone (left) is lowered over Explorer III's instrumentation, which included a miniature tape recorder (right). Explorer III (cutaway below) transmitted data on temperature, cosmic-dust erosion, and intensity of cosmic radiation.



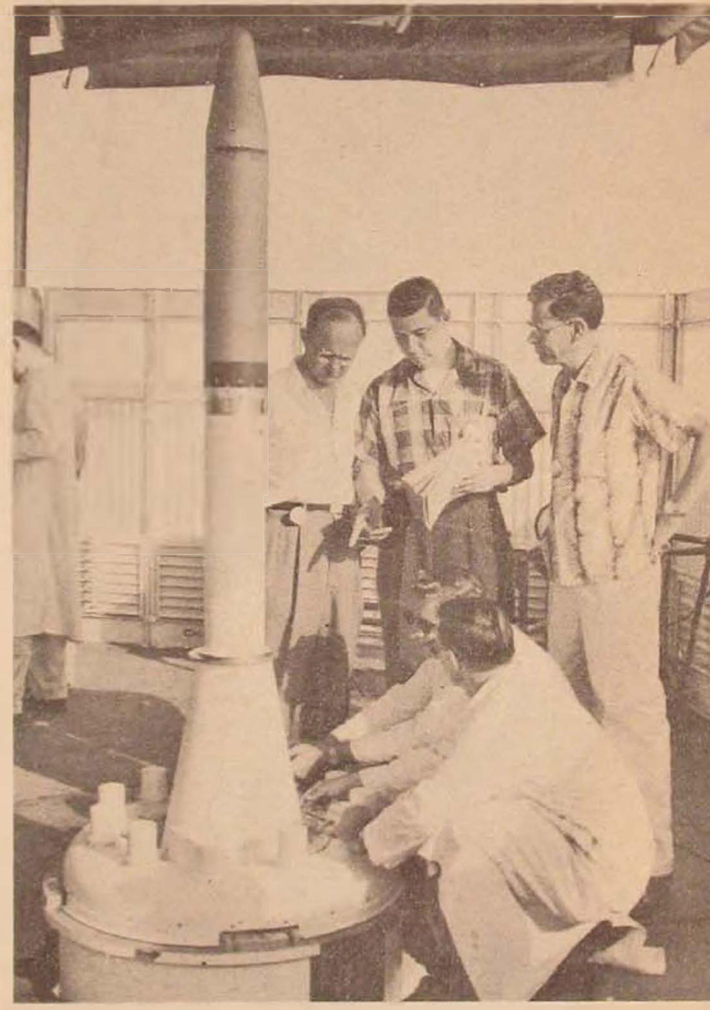
Explorer III

Launched: 26 March 1958
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: DOD, for U.S. National Committee—IGY program
Dimensions: 6-in diameter, 80-in length

Perigee: 121 mi
Apogee: 1746 mi
Orbital period: 115.87 min
Angle to equator: 33.4 deg
Lifetime: Disintegrated 27 June 1958
Launching vehicle: Jupiter-C rocket



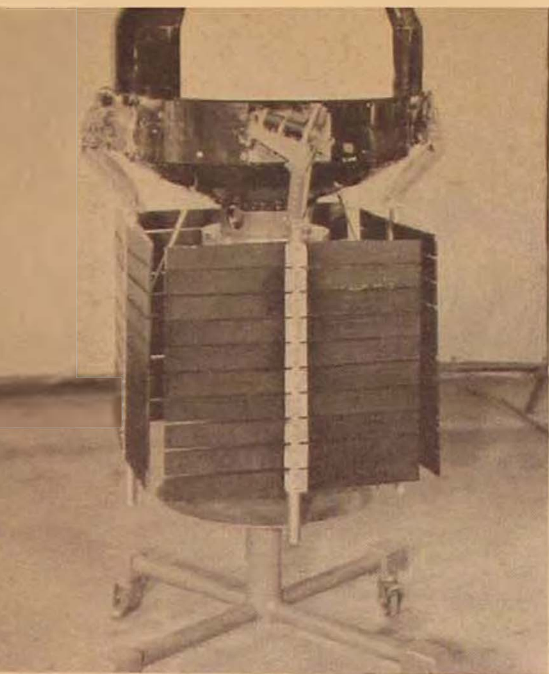
Explorer IV, shown in cutaway above, is installed on a Jupiter-C rocket. It was designed and instrumented to investigate high corpuscular radiation intensities detected by Explorers I and III.

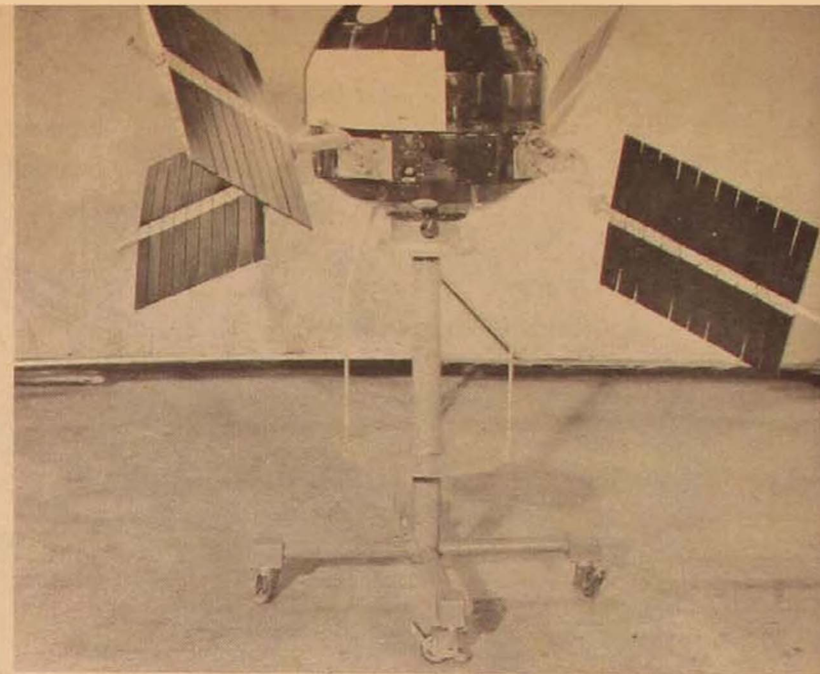


Explorer IV

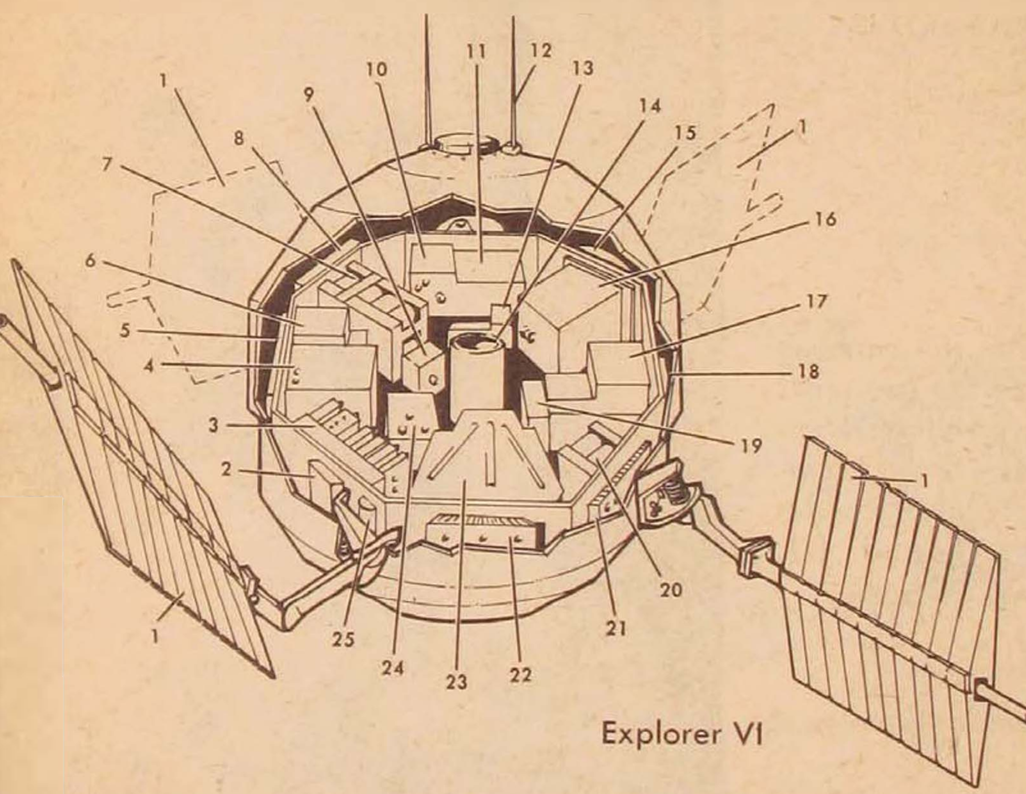
Launched: 26 July 1958
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: ARPA
Dimensions: 6.25-in diameter, 80.39-in length
Weight: 38.43 lb, of which 25.8 lb was scientific instrumentation

Perigee: 163 mi
Apogee: 1380 mi
Orbital period: 110.27 min
Angle to equator: 50.29 deg
Lifetime: Disintegrated 22 October 1959
Launching vehicle: Jupiter-C rocket
Stages: 4





Explorer VI, the paddle-wheel satellite, is unique in two respects: its four solar paddles, and its TV scanner to take the first crude pictures of the earth from space. The paddles are in launching position (left), orbiting position (right).

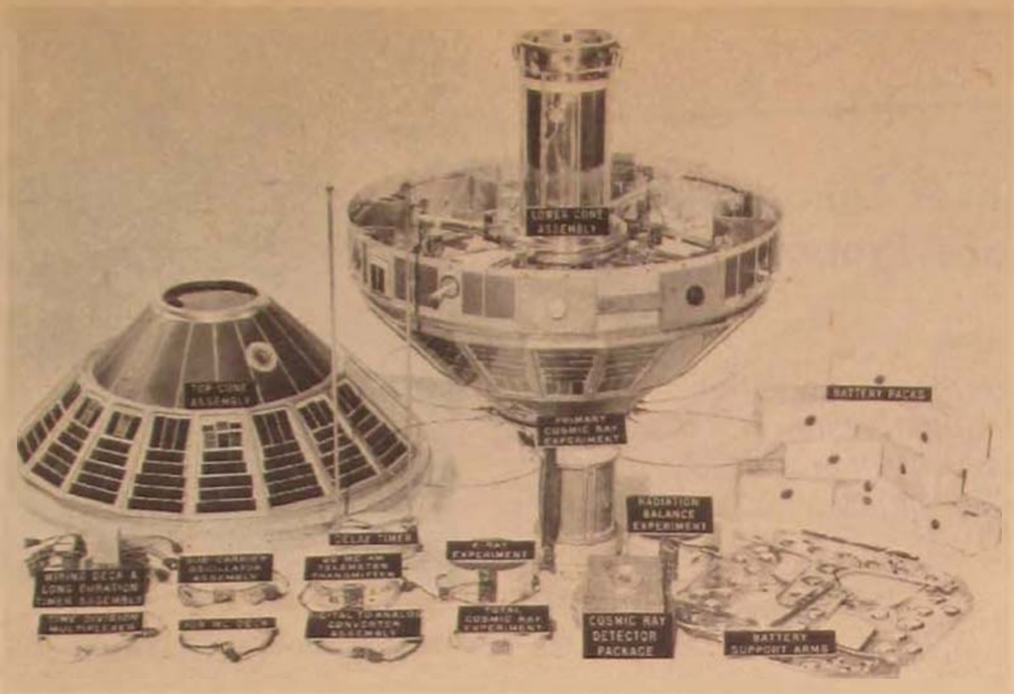


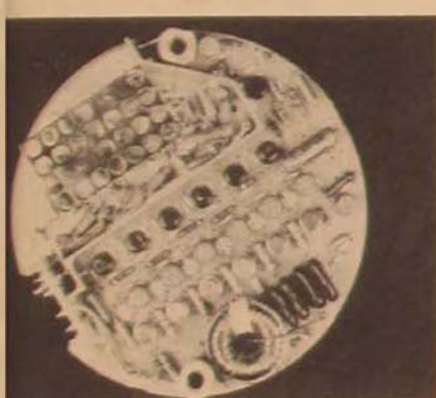
1 solar cells
2 solar-cell current monitor
3 command receiver
4 ion chamber Geiger-Mueller counter
5 temperature range reference
6 digital decoder
7 batteries
8 command box
9 aspect indicator
10 40-second timer
11 converters No. 2 and No. 3
12 antenna
13 accelerometer batteries
14 injection rocket
15 heat sink
16 5-w transmitter
17 proportional counter
18 static converter
19 108-mc transmitter
20 batteries
21 subcarrier oscillator and multiplexer "A"
22 subcarrier oscillator and multiplexer "B"
23 digital telemetry
24 television logic circuit
25 flux gate magnetometer

Explorer VI

Launched: 7 August 1959
From: Air Force Missile Test Center
By: U.S. Air Force
For: NASA
Dimensions: 26-in diameter, 29-in depth, with four 18-in-square solar vanes
Weight: 142 lb

Perigee: 156 mi
Apogee: 26,357 mi
Orbital period: 12½ hr
Angle to equator: 46.9 deg
Estimated lifetime: 10 mo—2 yr
Launching vehicle: Thor-Able III
Stages: 3





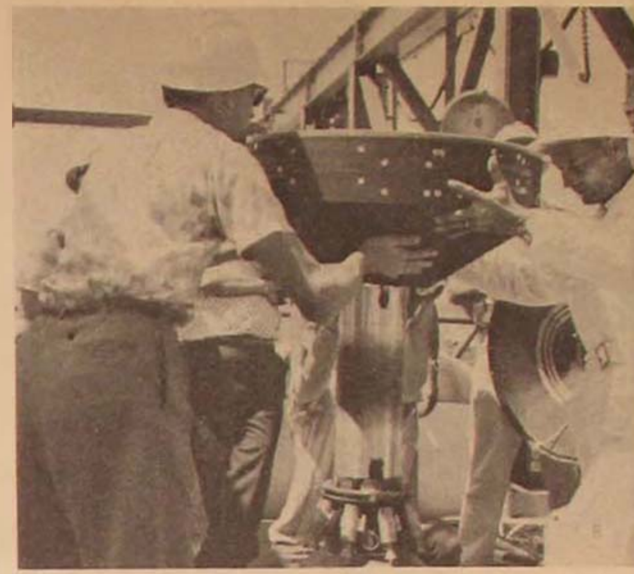
Explorer VII, the composite radiation satellite and last IGY shot, undergoes final prelaunch inspection (right). The partially disassembled Explorer VII (top) and its 108-megacycle transmitter (above) show miniaturization of components.

Explorer VII

Launched: 13 October 1959
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: NASA, for IGY
Dimensions: 30-in diameter, 30-in height
Weight: 91.5 lb

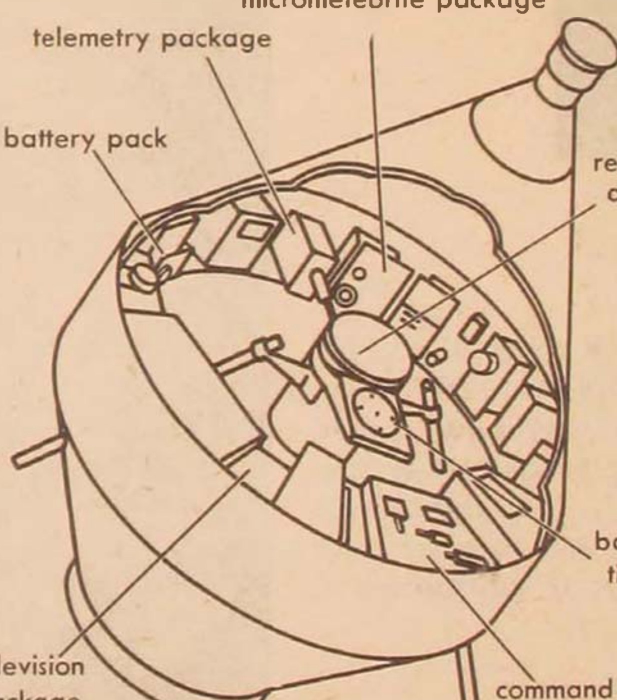
Perigee: 342 mi
Apogee: 680 mi
Orbital period: 101.33 min
Angle to equator: 50.3 deg
Estimated lifetime: 20 yr
Launching vehicle: Juno II rocket
Stages: 4

Pioneer Lunar and Space Probes



After decontamination by ultraviolet lights, Pioneer I is positioned atop the Thor-Able I launching rocket. Cutaway is of Pioneer I.

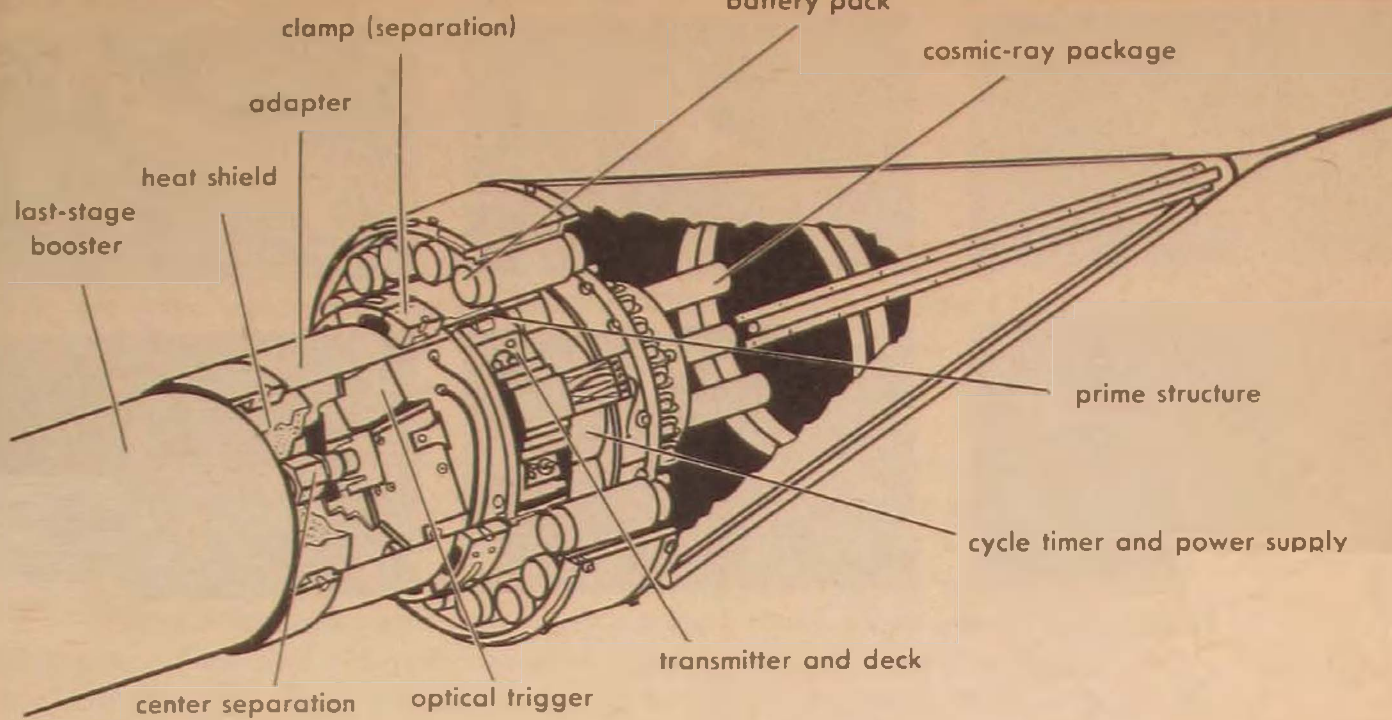
The Pioneer series of lunar and space probes was another part of the U.S.—IGY program. Of three moon probes (Thor-Able I, Pioneer I and II) fired by the Air Force for ARPA, only Pioneer I achieved partial success. Of two space probes (Pioneer III and IV) fired by the Army for NASA, Pioneer III was also a partial success, and Pioneer IV attained solar orbit. Pioneer III discovered a second, outer band of radiation around the earth.

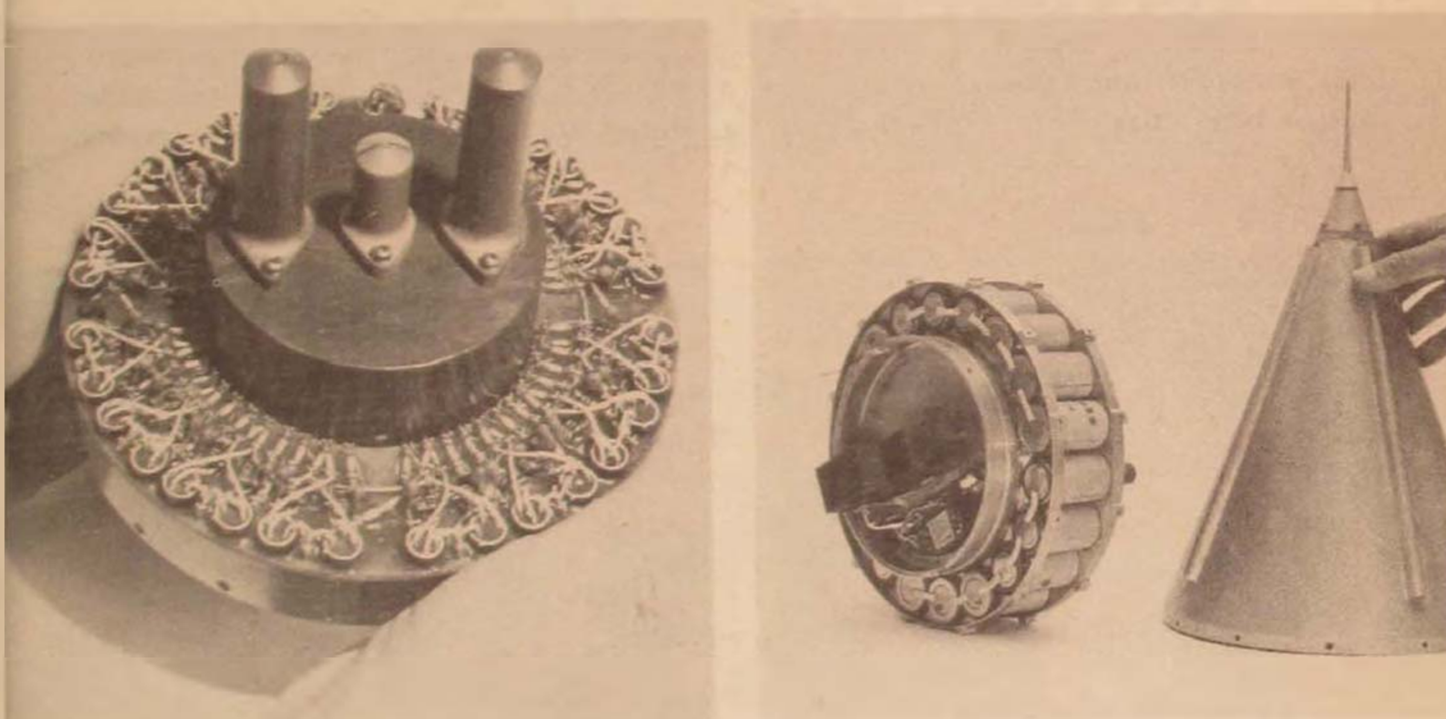


Pioneer I

Launched: 11 October 1958
From: Air Force Missile Test Center
By: U.S. Air Force
For: ARPA, for IGY
Dimensions: 29-in diameter, 30-in length
Weight: 84.4 lb, including 39 lb scientific instrumentation and 4th-stage terminal

Maximum altitude: 70,700 mi
Duration of flight: 43 hr 17½ min. Re-entered atmosphere over South Pacific 12 October 1958.
Launching vehicle: Thor-Able I
Stages: 3 firing stages, plus rocket-equipped terminal vehicle



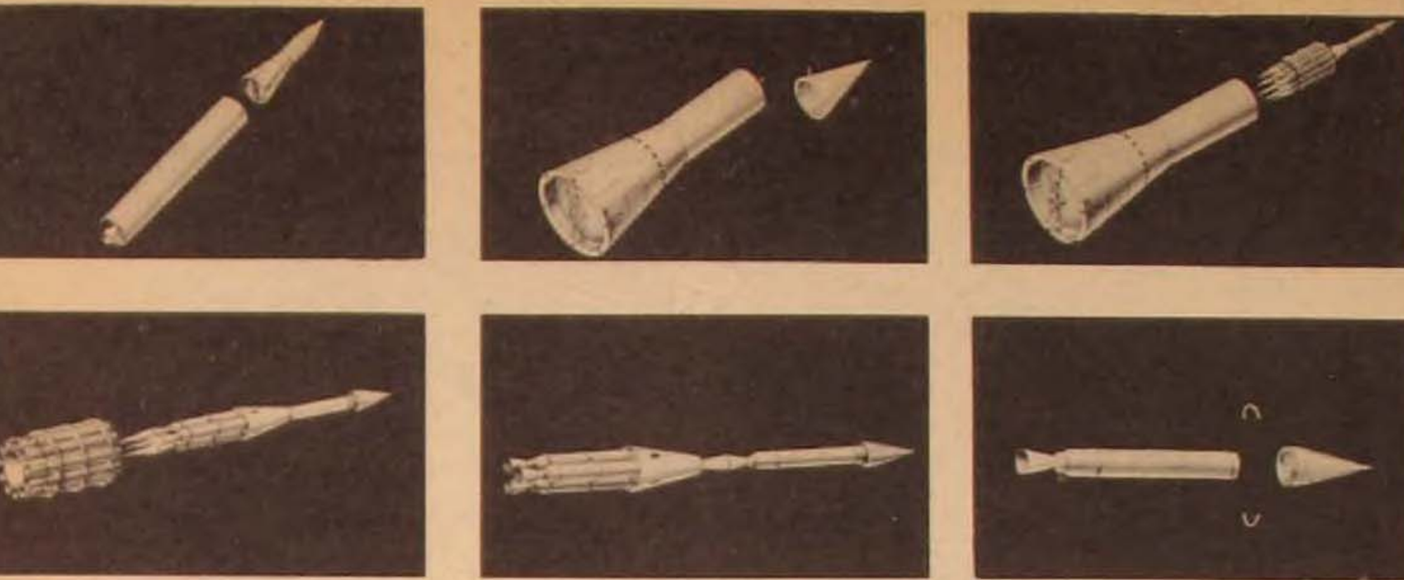


Pioneer III's radiation deck (left) has two Geiger-Mueller tubes and a voltage supply tube. An underside view (right) shows the photoelectric scanning device and batteries for radio beacon and cosmic-ray experiment. The cone, gold-washed for electric conductivity, serves as antenna. Pioneer III is shown in cutaway above.

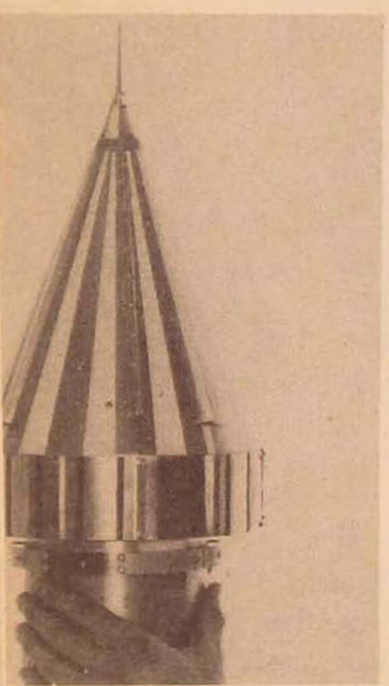
Pioneer III

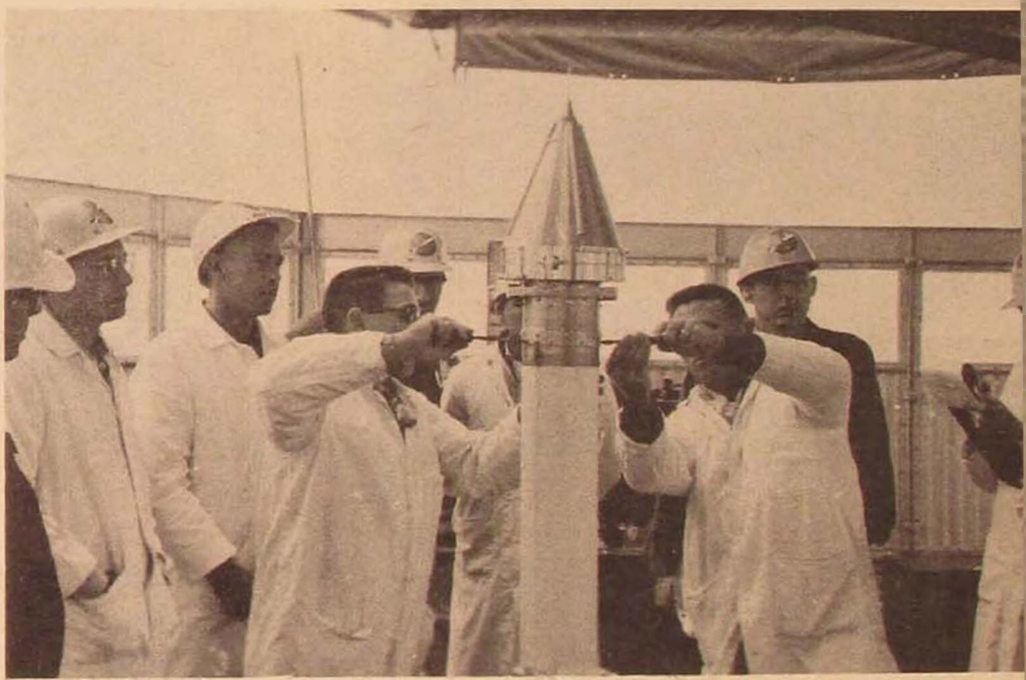
Launched: 6 December 1958
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: NASA, for IGY
Dimensions: 10-in diameter, 23-in length
Weight: 12.95 lb

Maximum altitude: 63,580 mi
Duration of flight: 38 hr 6 min. Re-entered atmosphere over French Equatorial Africa on 7 December 1958.
Launching vehicle: Juno II rocket
Stages: 4



Pioneer III and IV used the Juno II launching vehicle, whose firing and separation sequence during launch is shown above. Pioneer IV's striped pattern (below, left) provides temperature control in space. In preparation for its successful launch into solar orbit, Pioneer IV is positioned atop the Juno II (below, right).





Pioneer IV

Launched: 3 March 1959
From: Air Force Missile Test Center
By: Army Ballistic Missile Agency
For: NASA, for IGY
Dimensions: 9-in diameter, 20-in length
Weight: 13.4 lb

Perihelion: 91,700,000 mi
Aphelion: 106,100,000 mi
Closest distance to moon: 37,300 mi
Orbital period: 392 days
Estimated lifetime: millions of years
Launching vehicle: Juno II rocket
Stages: 4

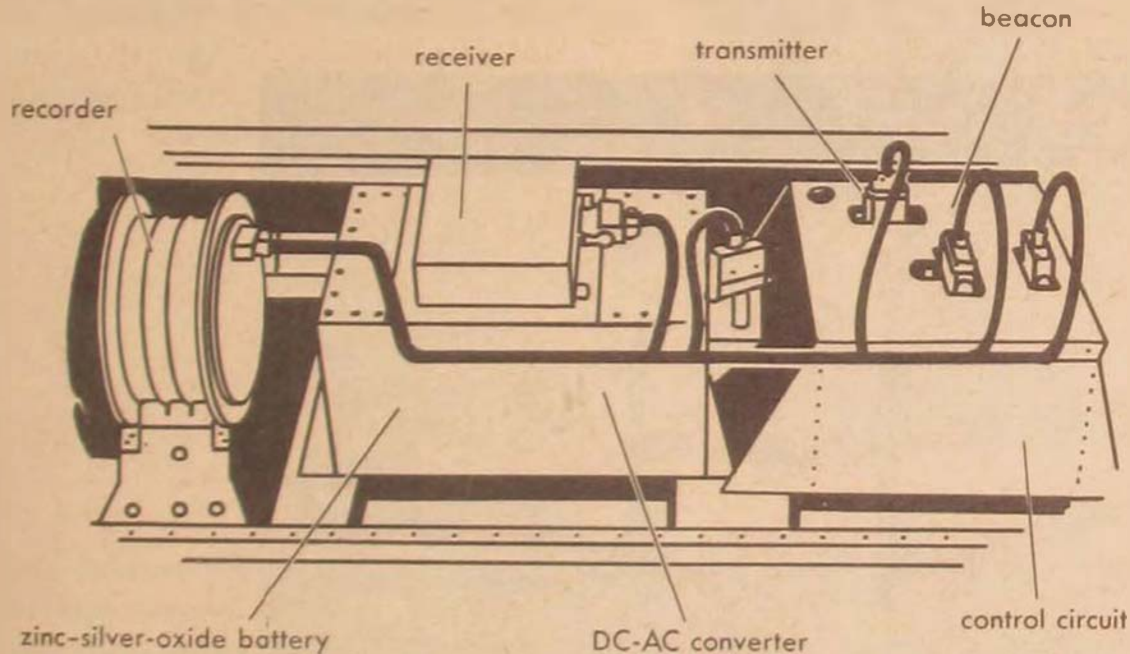
Project Score

THE instrumented Atlas missile put into orbit on 18 December 1958 was the first test of a communications satellite. Titled Project Score (for "signal, communications, orbit, relay experiment"), both the 150-pound payload and the 4.5-ton final rocket stage went into orbit. This largest of U.S. satellites was a military experiment and not part of the U.S.—IGY program.

The satellite's communications equipment consisted principally of twin 35-pound packages, each containing a transistorized receiver, 8-watt transmitter, and tape recorder. Recorded on tape at lift-off was a goodwill message from President Eisenhower, which was transmitted the following day—the first time a human voice had been beamed from outer space. Later the satellite accepted and relayed messages from ground stations in Texas, Arizona, and Georgia. After 35 days in orbit it came down near Midway Island.

Although payload was light, the orbiting of the 8750-pound Atlas shell evidenced great progress in satellite launching and guidance capabilities.

Present military requirements for rapid, accurate, and secure communications demand minimum antenna and transmitting equipment, least possible interference from changes in solar conditions, and freedom from jamming.



Cutaway diagram of one of the twin communications relay systems carried in Project Score Atlas satellite to receive, store, and relay messages from ground stations.

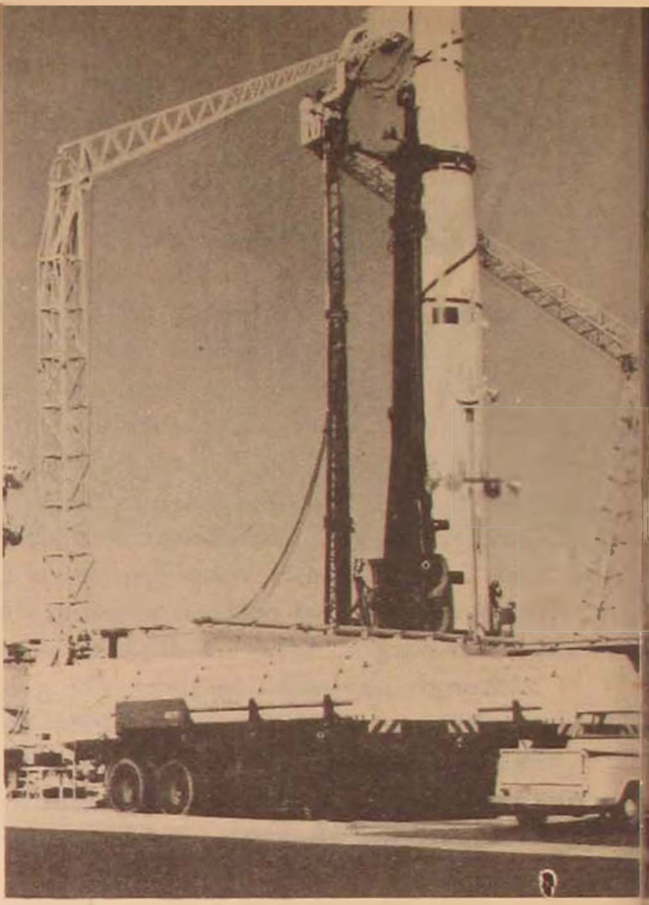
Project Score

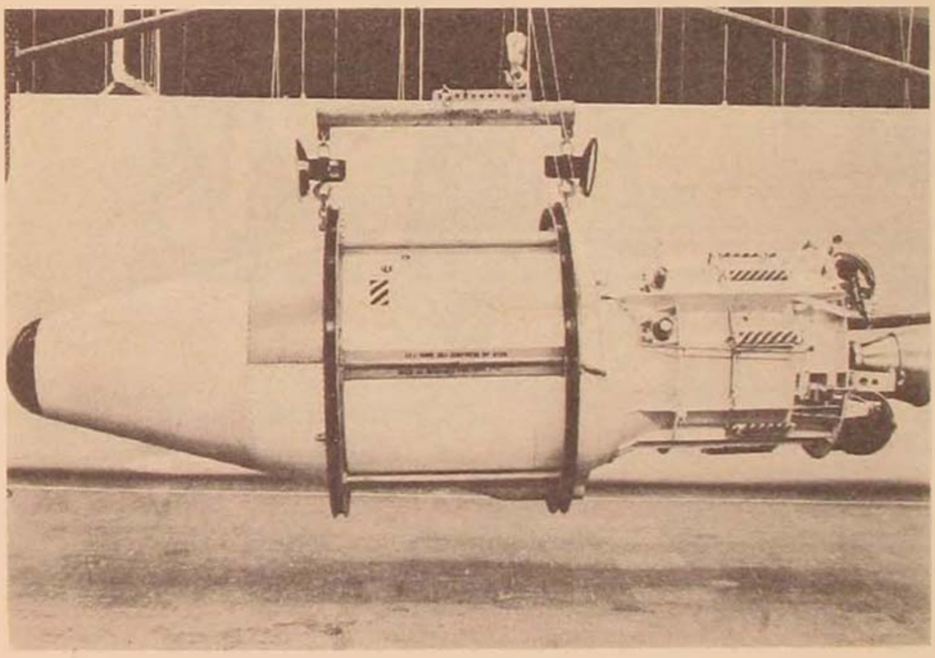
Launched: 18 December 1958
From: Air Force Missile Test Center
By: U.S. Air Force
For: ARPA
Dimensions: 10-ft diameter, 85-ft length
Weight: 8750 lb, including 150-lb scientific instrumentation

Perigee: 110 mi
Apogee: 920 mi
Orbital period: 101.46 min
Angle to equator: 32.3 deg
Lifetime: Came down 21 January 1959
Launching vehicle: Atlas
Stages: 1 (2 boosters, 1 sustainer engine)

Discoverer Project

Discoverer I satellite, atop its first-stage Thor IRBM, is prepared for launching (right). This satellite gets final thrust from its second-stage Agena engine, which is contained within the terminal body (below).

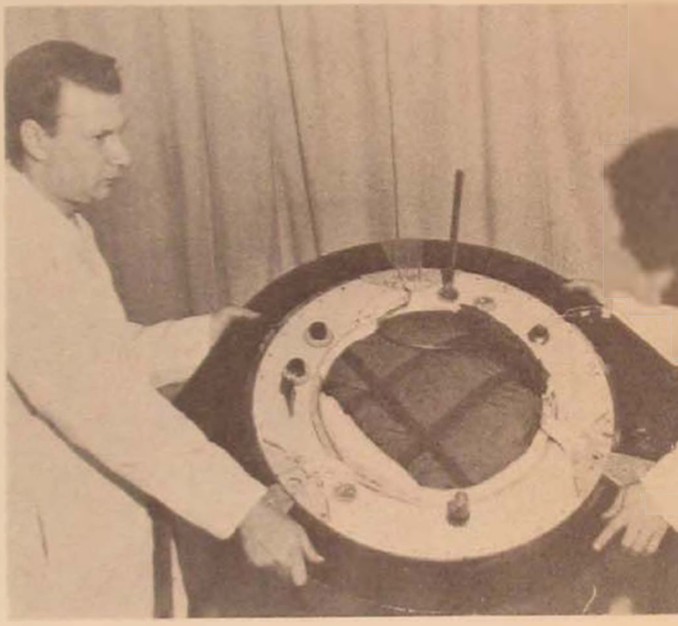




Discoverer I

Launched: 28 February 1959
From: Pacific Missile Range
By: U.S. Air Force
For: ARPA
Dimensions: 5-ft diameter, 19.2-ft length
Weight: 1300 lb in orbit, including 245 lb of instruments

Perigee: 99 mi
Apogee: 605 mi
Orbital period: 95.9 min
Inclination: 3 deg off north-south axis o[f] earth
Lifetime: Disintegrated 5 March 1959
Launching vehicle: Thor, Agena second stag[e]
Stages: 2



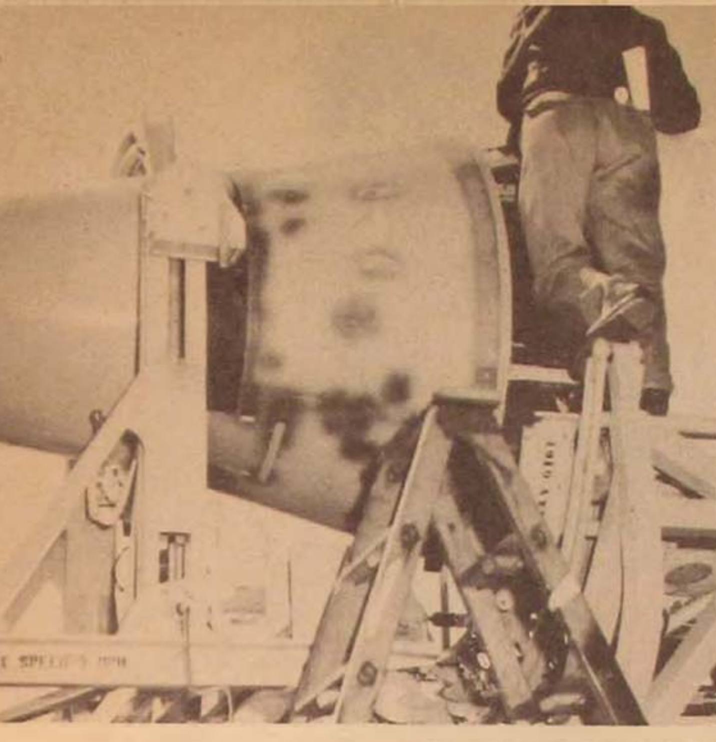
The environmental capsule is placed in Discoverer II's re-entry capsule (top). At right is a rear view of the completely assembled re-entry capsule, containing a parachute.

The Discoverers have aided the development of military satellite techniques. Of eight launched, all but Discoverer III and Discoverer IV attained orbit. The Discoverers have differed from other satellites in that they were launched into polar orbits, they stabilized themselves in orbit, their entire second stage became the satellite, and they carried (except Discoverer I) a re-entry capsule. Not all was perfection, however. Technical malfunctions prevented the ejection of some capsules, and others ejected were not recovered.

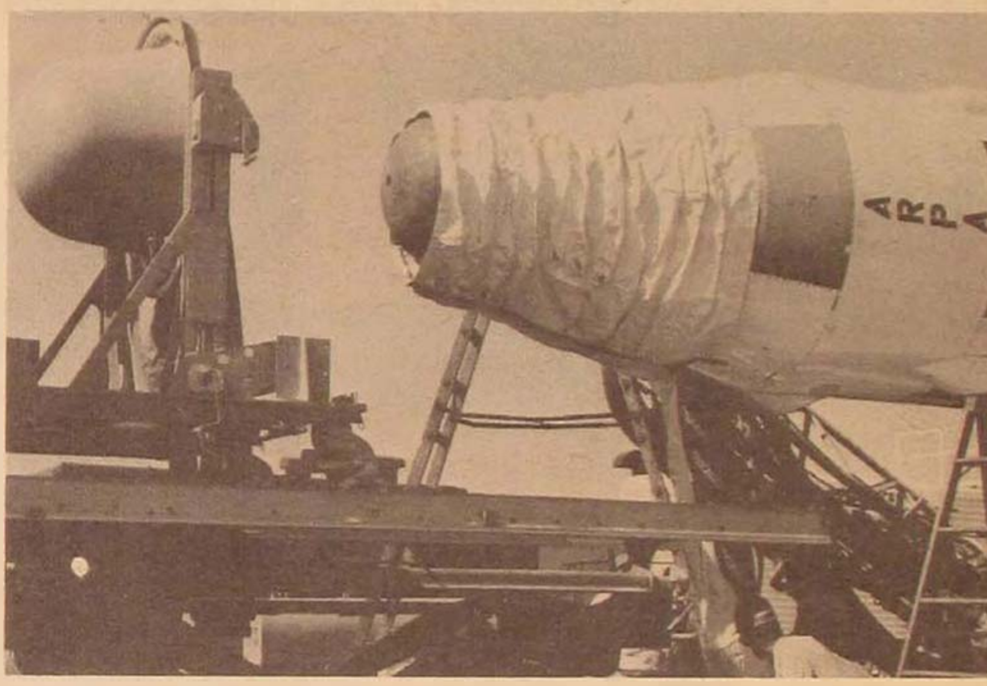
Discoverer II

Launched: 13 April 1959
From: Pacific Missile Range
By: U.S. Air Force
For: ARPA
Dimensions: 5-ft diameter, 19.2-ft length
Weight: 1610 lb, including 195-lb recovery capsule and 245 lb of instrumentation

Perigee: 142 mi
Apogee: 220 mi
Orbital period: 90.5 min
Inclination: 0.2 deg off north-south axis of earth
Lifetime: Disintegrated 26 April 1959
Launching vehicle: Thor, Agena second stage
Stages: 2



Before and after views of mating the nose cone (containing the re-entry vehicle) to the Discoverer satellite. The cloth cover helps maintain prelaunch temperature.

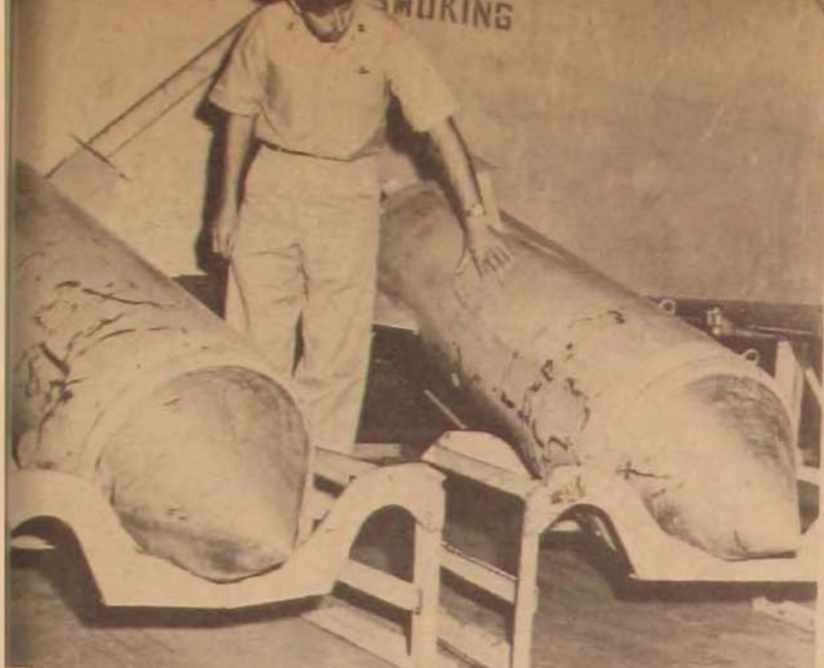


The Discoverers represent several firsts in satellites—one being their polar orbits, another the attempt to attain near-circular orbits. They are the first satellites able to change orbital attitude. On the 17th pass around the earth, a command-activated timing device triggers gas jets, reversing the satellite in orbit and angling it 60 degrees down from horizontal to permit ejection of the recovery capsule. This proving-out of systems for polar orbit, re-entry, and guidance and stability of an orbiting satellite is essential to the future reconnaissance and man-in-space satellites.

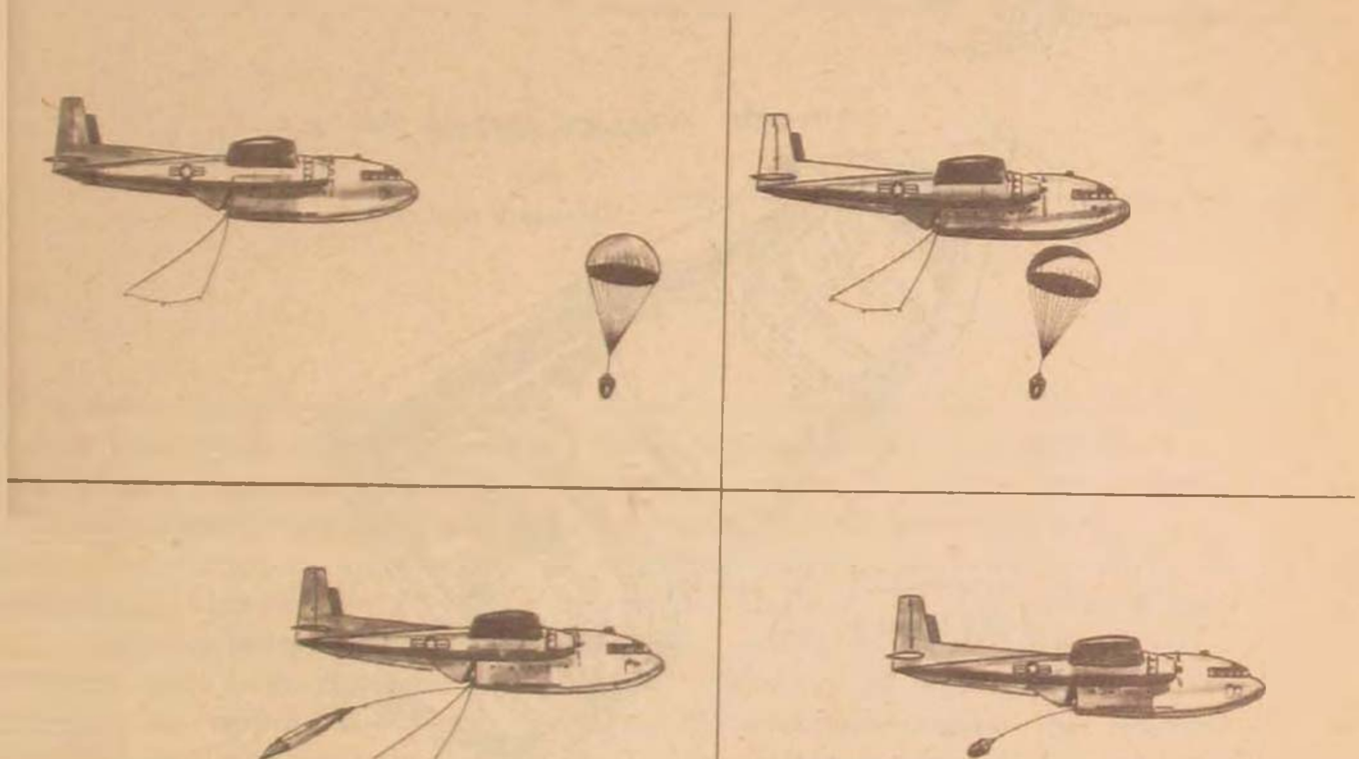
Discoverer V and VI

Launched: 13 August and 19 August 1959
From: Pacific Missile Range
By: U.S. Air Force
For: ARPA
Dimensions: Both, 5-ft diameter, 19.2-ft length
Weight: Both, 1700 lb including 300-lb re-entry capsule

Perigee: 136 mi and 139 mi
Apogee: 450 mi and 537 mi
Orbital period: 94 min and 95.3 min
Inclination: Both, polar orbits
Lifetime: Disintegrated 16 September and 20 October 1959
Launching vehicle: Both used Thor, Agena
Stages: 2



Mid-air recovery of Discoverer space capsules over the Pacific has been assigned to the USAF 6593d Test Squadron of Hickam AFB, Hawaii. Practice missiles (left) are used in operations (right) training aircrews to air-snag the space capsules. Below is the planned sequence of C-119 recovery of the parachuting capsule.



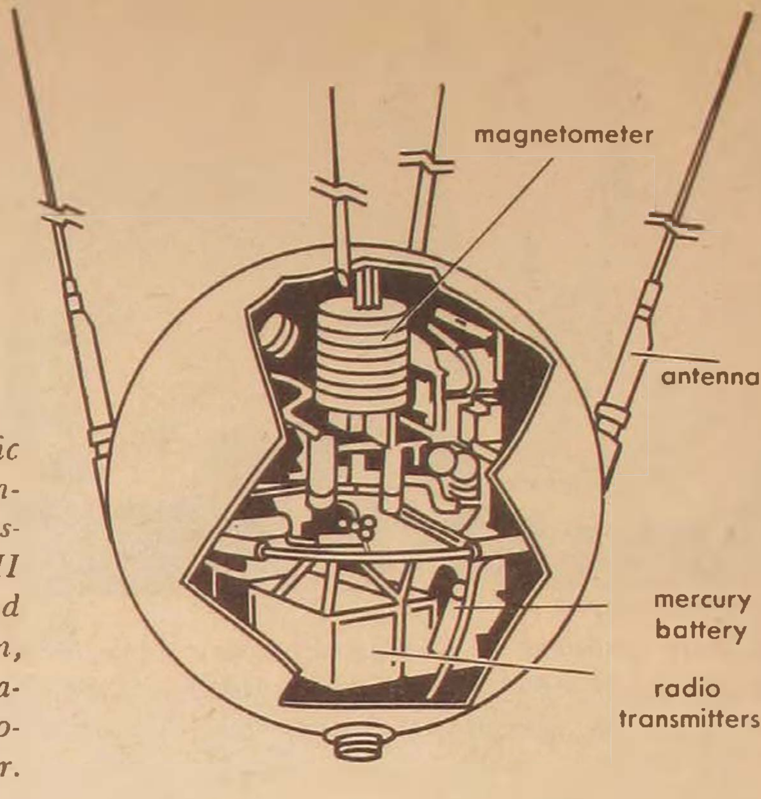
Discoverer VII and VIII

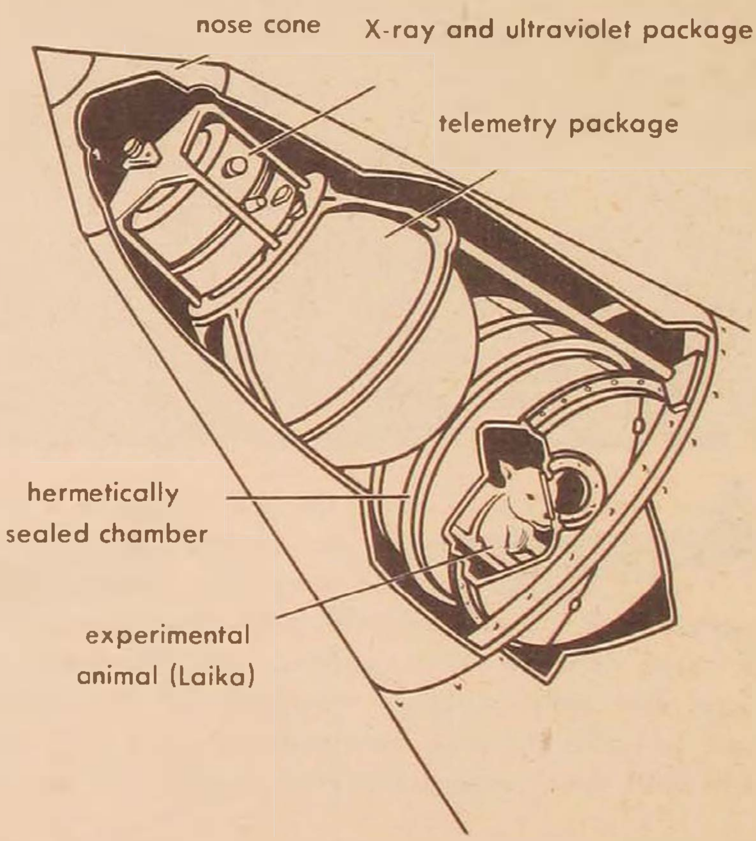
Launched: 7 November, 20 November 1959
From: Pacific Missile Range
By: U.S. Air Force
For: ARPA
Dimensions: Both, 5-ft diameter, 19.2-ft length
Weight: Both, 1700 lb including 300-lb re-entry capsule

Perigee: 100 mi and 130 mi
Apogee: 520 mi and 1035 mi
Orbital period: 95 min and 103 min
Inclination: Both polar orbits
Estimated lifetime: 2 wk and over 12 wk
Launching vehicle: Both used Thor, Agena
Stages: 2

Sputnik Satellites

Sputnik I (right) carried scientific instruments to measure and telemeter internal temperatures, pressures, and "other data." Sputnik II (below) investigated cosmic rays and solar ultraviolet and X radiation, and telemetered satellite temperatures, pressures, and certain physiological data on its dog passenger.

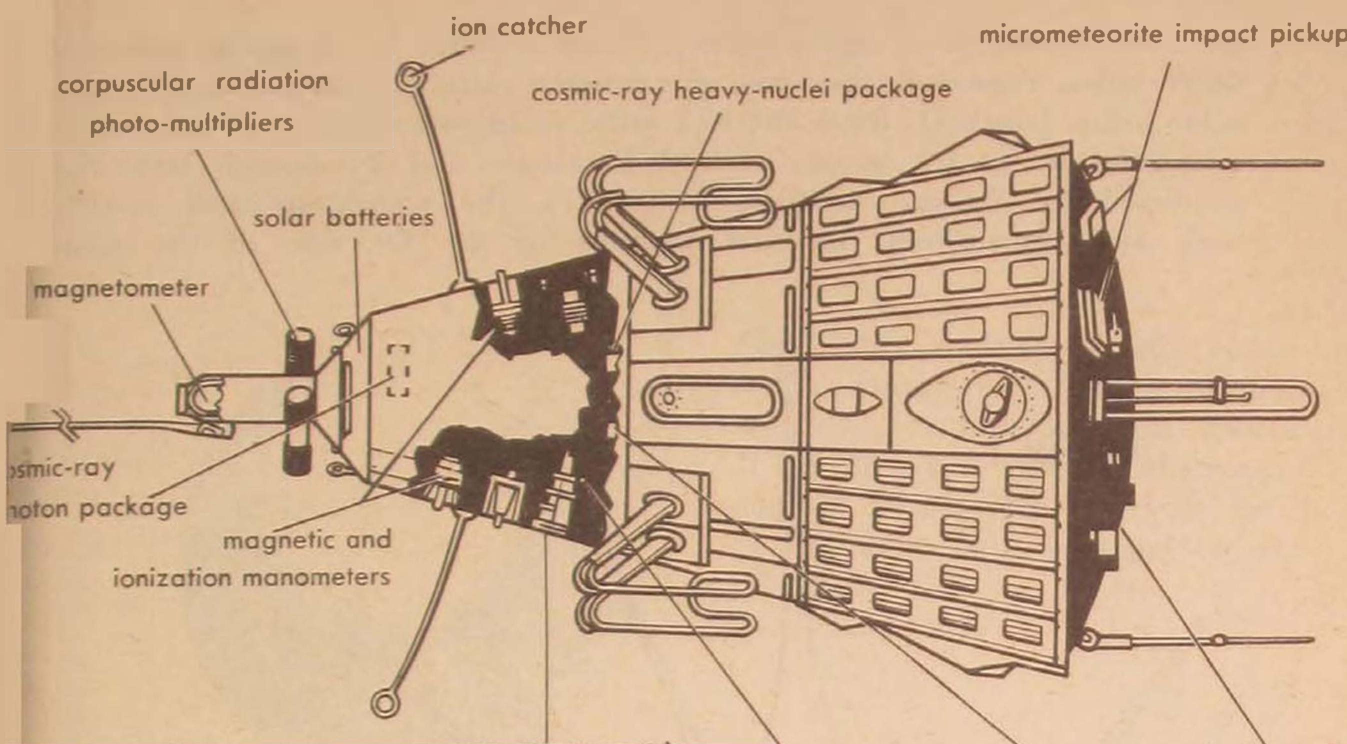




Sputnik I and II

Launched: 4 October, 3 November 1957
By: U.S.S.R. for Soviet Commission on Interplanetary Communication
Dimensions: 22.8-in diameter; Sputnik II (by optical measurement) 64-in diameter, 32-ft length
Weight: Both 4 tons (unofficial estimate) of which 184 lb and 1120 lb were instrumentation

Perigee: 142 mi and 140 mi
Apogee: 588 mi and 1038 mi
Orbital period: 96.17 min and 103.7 min
Angle to equator: Both 65 deg
Lifetime: Disintegrated 4 January 1958 and 14 April 1958
Launching vehicle: Undisclosed
Stages: 3



Sputnik III

The three Sputniks, launched under Soviet participation in the IGY, brought large returns in political prestige. Their launch angle was such that little velocity was imparted from the earth's rotation, indicating great thrust from the launch vehicles. Sputnik I, first man-made object to orbit the earth, found air drag at an altitude of several hundred miles to be three to five times higher than formerly computed. Sputnik II's dog behaved normally during launch and bore up well under prolonged weightlessness. Acceleration data from Sputnik II led to the discovery of significant solar influence on upper-atmosphere densities. Sputnik III carried the heaviest scientific payload yet sent aloft. Sputnik data also reported outer space to be a dazzling, multicolored brightness rather than the accepted black void.

Sputnik III

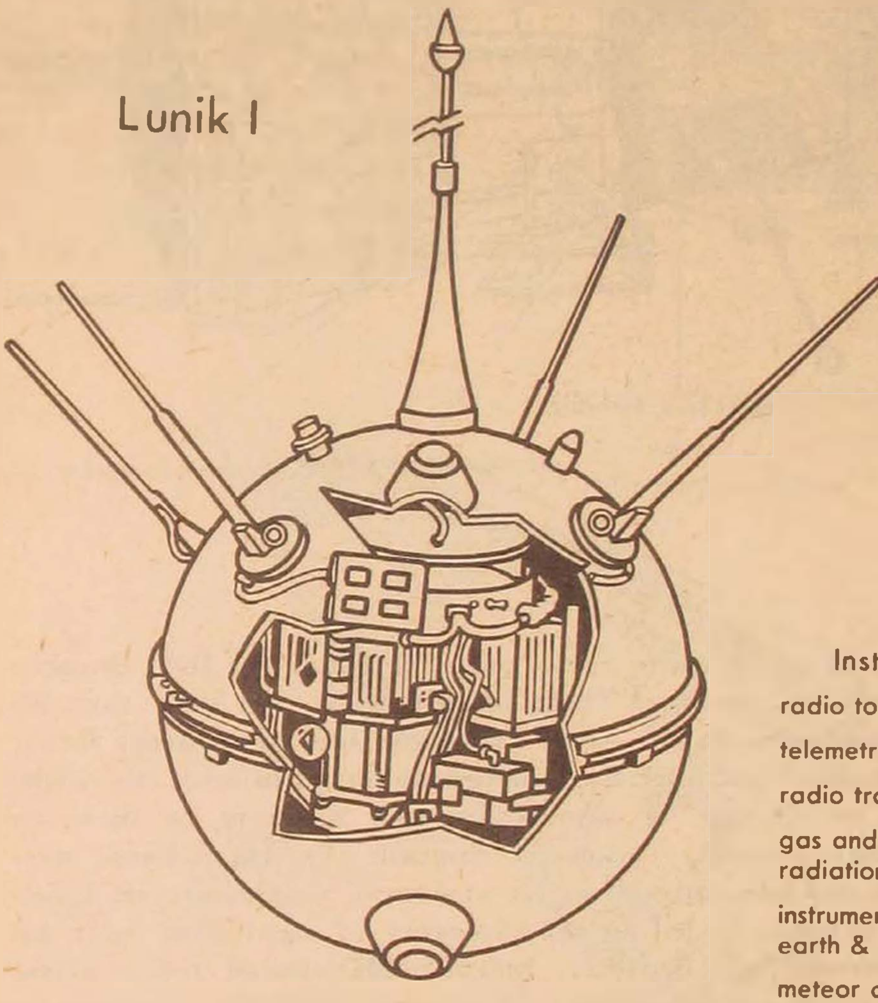
Launched: 15 May 1958
From: Undisclosed
By: U.S.S.R.
For: Soviet Commission on Interplanetary Communication
Dimensions: 68-in diameter at base, 141-in length
Weight: About 7000 lb in orbit of which 2925 lb scientific instrumentation

Perigee: 135 mi
Apogee: 1167 mi
Orbital period: 106 min
Angle to equator: 65.3 deg
Estimated lifetime: 2 yr
Launching vehicle: Undisclosed
Stages: 3

Lunik (Lunar) Probes

Of three known Soviet lunar probes, Lunik I, aimed at the moon, missed by 4660 miles, reportedly because of excessive velocity, and continued into a solar orbit. Lunik II, fired 236,875 miles to impact within a predetermined triangulation on the moon, arrived 1 minute and 24 seconds later than predicted by Soviet scientists. Lunik III, the translunar-earth satellite, took and transmitted the first pictures of the far side of the moon.

Lunik I



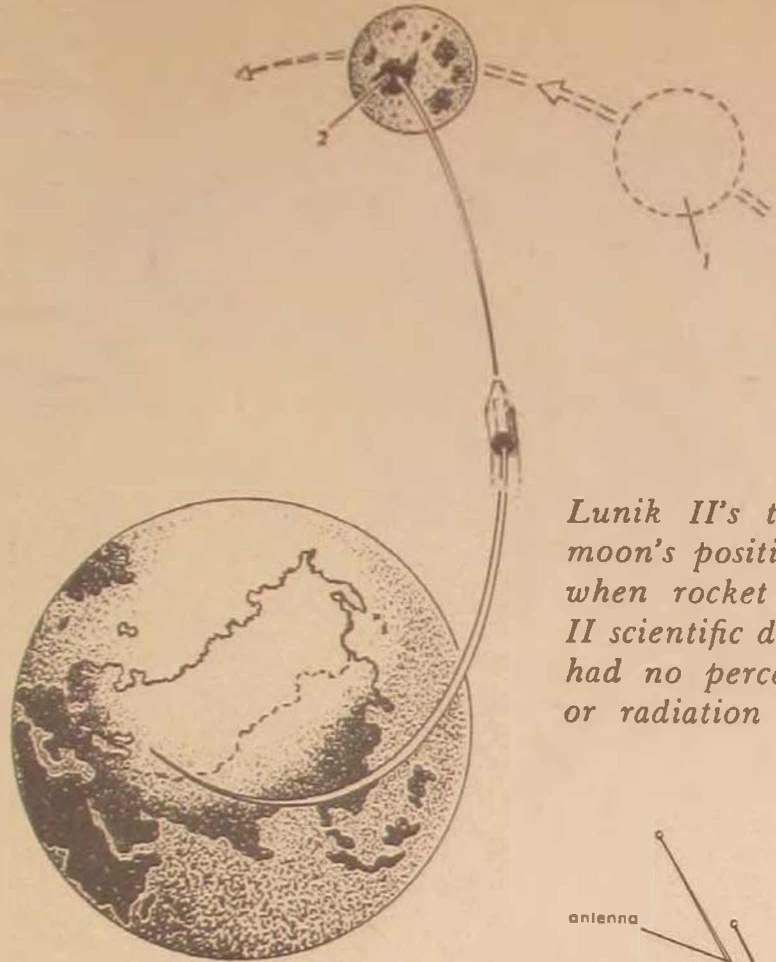
Instrumentation

- radio to verify trajectory
- telemetric radio
- radio transmitter
- gas and sun corpuscular radiation detector
- instruments for measuring earth & moon magnetic fields
- meteor detectors
- radiation detectors
- cosmic-ray detectors
- silver-zinc and mercury batteries
- magnetometer

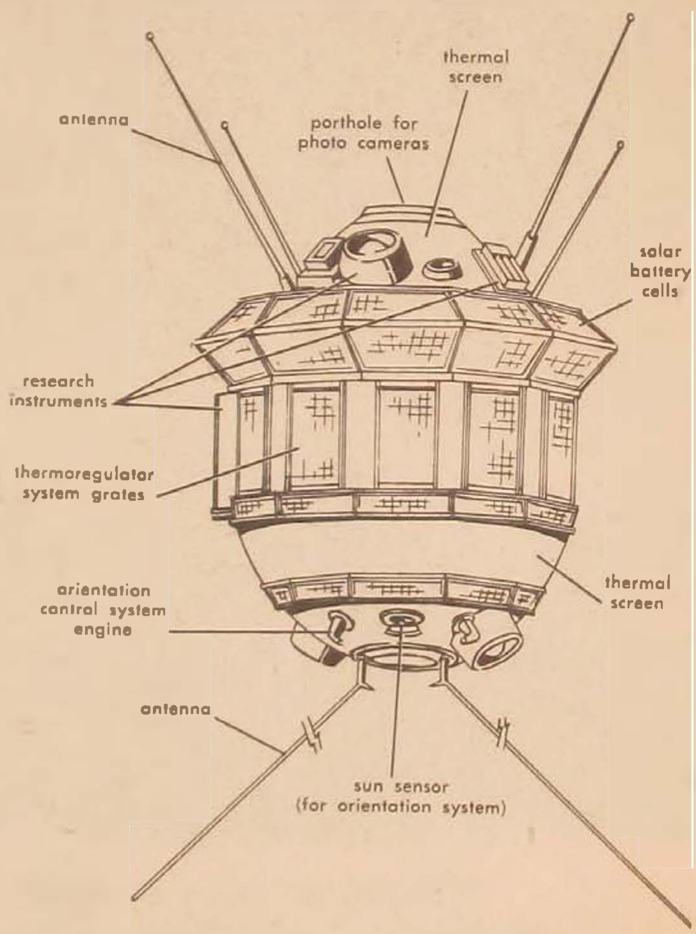
Lunik I

Launched: 2 January 1959
By: U.S.S.R. for Soviet Commission on Interplanetary Communication
Dimensions: Undisclosed
Weight: 3245 lb in flight (last-stage rocket including 796 lb instrumentation)

Perihelion: 91,000,000 mi
Aphelion: 123,000,000 mi
Closest distance to moon: 4660 mi
Orbital period: 15 months
Estimated lifetime: millions of years
Launching vehicle: T-3
Stages: 3



Lunik II's trajectory (left) shows moon's position at launch (1) and when rocket impacted (2). Lunik II scientific data revealed the moon had no perceptible magnetic field or radiation belts surrounding it.



Lunik III (right), termed an "automatic interplanetary station" by the U.S.S.R., carried TV that transmitted 40 minutes of lunar photography up to 300,000 miles.

Lunik II and III

Launched: 12 September, 4 October 1959
By: U.S.S.R. for Soviet Commission on Interplanetary Communication
Dimensions: Lunik II, undisclosed; Lunik III, 47-in diameter, 51-in length
Weight: Lunik II, 858.4 lb including a 58.4-lb lunar probe; Lunik III, 614 lb; last-stage rocket (including 345 lb equipment) also in orbit
Perigee and apogee (Lunik III): 24,840 mi and 292,000 mi
Estimated lifetime (Lunik III): Very long
Closest point to moon (Lunik III): 4373 mi
Orbital period (Lunik III): 15 days
Duration of flight (Lunik II): 35 hr—impacted moon 13 September 1959
Distance of flight (Lunik II): 236,875 mi
Launching vehicle: Multistage rocket
Stages: 3

the balance sheet

What, then, can be said of the balance sheet for the first two years and three months of man's venture into space? In numbers of successful satellites and probes, the United States is well ahead, with eighteen against six for the Soviets. In total weight of orbiting vehicle, the two are about even, the heaviest U.S. satellite weighing 8750 pounds against "about four tons" for the U.S.S.R. But this includes the final stage of the rocket. In actual instrument payload the U.S. lags behind, with 245 pounds against the Soviet 2925 pounds.

In the most-limiting factor to enlarged space exploration, propulsive thrust in the rocket boosters, the United States seems to be well behind. But the Saturn project now under development is expected to bring the U.S. into the same one-million-pound-thrust range that is expected for the Soviet in the near future. Guidance systems seem to be about equal in accuracy, the moon shots of the U.S.S.R. having conclusively demonstrated Soviet capability in this field.

As to the amount of scientific information that has been received from the two space programs and the relative value of that information, the results are almost impossible to determine. Thanks to U.S. emphasis on miniaturization, the U.S. probes have given high information return per pound of instruments. The U.S. has published more and fuller information more promptly than has the U.S.S.R. Even in some of the Soviet shots that were in support of the IGY, there is a general feeling among Western scientists that the information released by the Soviet Government has been fragmentary. In general, the larger number of U.S. satellites and the variation in their heights and orbits would seem to have charted a more complete pattern of the first 1000 miles of the space envelope around the earth—the most complex and troublesome layer of space and the one of most immediate importance.

Stepping back from the details of the two space programs and looking at the broader effects, there can be little doubt that space exploration has become a very important element of national prestige for the United States and the Soviet Union. There are those who argue that the decade of the 1950's has already elevated technology to the position of an equal partner with the four traditional elements of national power—the political, the military, the economic, and the psychosocial. Certainly its effects have penetrated all four of the other elements and yet have not been confined to any one of them nor even described by any combination of the four.

In assessing how far this trend in elevation of technology as a component of national strategy has gone, it is perhaps more pertinent to look at the Soviet situation than at that of the United States. The United States has occupied somewhat the position of the odds-on favorite in a horse race. As the greatest industrial nation in the world, with the solid reputation of some seventy years of technological attainment behind it, the United States was expected to do no less than run at the front, after a fast start at the post.

The Soviet Union, while hardly a dark horse by now, was in the more pleasant position of being expected only to place. Yet by the end of the decade the Soviets had run up a startling record: the first satellite in orbit, the largest payloads, the first impact on the moon, the first photographs of the far side of the moon. These triumphs had tremendous impact on world opinion. In all four of the areas of national power Soviet international gains as a result of exploits in space have been impressive. Indeed several American authorities have claimed that the U.S.S.R. has gained firmer and wider recognition as a first-rate technological power from such ventures in this short period than from all their previous attainments in industrialization and in military hardware. If this evaluation should be accurate, then their relatively modest investment in space exploration is one of the best deals the Soviets have ever made.

One of the great challenges of the 1960's will be found in the essential question raised during the last two years of the 1950's: Is the initial success of the U.S.S.R. in space due only to a considerable lead in rocket development, and will the United States effort pull even with and then pass Soviet attainment? A second question is closely related: Are some of the Soviet spectaculars such as their moon shots more spectacular than real, and will the more-solid scientific aims claimed for the U.S. space programs pay off in the form of more-substantial gains toward putting man in space and other advanced requirements?

For the military services the answers to these questions are vital. Once the problems of greater and more sustained thrust and of manned space vehicles have been met, the military aspects of space will assume sharper focus and greater urgency. In the airman's understanding, the space barrier must fall as surely as the oxygen barrier fell years ago. One of the principal jobs of the military in the 1960's will be to convince the American people that, in military science and ultimately in the national posture, the transition from air to space has no more artificial ceilings or boundaries than does national security itself. Until mankind develops other sure means of settling international differences, we must be able to fly a little higher, a little faster, with a little more firepower more effectively employed than can any possible enemy.

Air University Quarterly Review

In My Opinion...

NUCLEAR-POWERED DETERRENCE

LIEUTENANT COLONEL DONALD F. MARTIN

THERE is lack of agreement among the military as to the importance of aircraft nuclear propulsion (ANP). If ANP is of extreme importance, then it follows that such importance can be clearly established and evaluated.

Aircraft nuclear propulsion will provide a weapon system of practically unlimited endurance or range. Air forces have always sought to extend the range of their aircraft. Many air campaigns of World War II were compromised by limited range. Although the effort to increase range has been continuous, all aircraft flying today are still limited in range by their fuel capacity. Added range has been purchased at the price of increasing aircraft size and thereby fuel capacity. We have also resorted to an expensive and complex air-refueling force whose sole contribution to our strategic offensive capability is to extend the range of our nuclear-armed bomber force. ANP will eventually end our quest for increased range by supplying virtually limitless fuel.

The application of nuclear propulsion to manned aircraft means that a single weapon system will possess:

- very low vulnerability to surface attack;
- residual strategic offensive capability after an aggressor's initial nuclear attack; and
- ability to perform postattack reconnaissance to ensure precise application of our residual capability.

Thus, in effect, ANP will provide the means for locating and destroying the enemy's remaining military capability after a missile barrage. Our remaining weapons can, after reconnaissance, be applied against the enemy's surviving weapons that could strike our country. We do not have to use our remaining weapons against the aggressor's cities and people whose destruction cannot influence the outcome of the war.

ANP and the ALBM

When a nuclear-powered aircraft is equipped with the air-launched ballistic missile (ALBM), a weapon system is created that combines the advantages of the manned airborne aircraft with the superior ability of the ballistic missile to penetrate to the target.

In general characteristics a first-generation Camal (continuously airborne missile launcher and low-level penetration bomber) might well be subsonic with a maximum operating ceiling of 40 to 50 thousand feet. Because of nuclear power, it could also cruise indefinitely at low altitudes. Some people who are otherwise enthusiastic about Camal are troubled by such an aircraft's subsonic speed. In a combination with the ALBM, the importance of the aircraft's speed is reduced because the ALBM does not now have a penetration problem nor is it likely to encounter one for quite some time.

ANP and deterrence

Since our national policy is to deter war, how will ANP contribute to more effective deterrence? During the period of expanding SAC capability and U.S. nuclear-bomb monopoly, deterrence approached the absolute. Our margin of deterrence has been steadily lessening since the Soviet Union achieved a significant and ever-increasing nuclear-weapon capability. Within the very near future a condition of parity in strategic nuclear-offensive capability will exist between the U.S. and the U.S.S.R. This means that if a nation commits aggression and starts a war, that nation cannot prevent the U.S. from launching a significant retaliatory blow. Under this nuclear parity, deterrence will exist only if the U.S. has an actual, credible ability to survive a nuclear attack with sufficient residual capability to end the war in our favor. The key is residual capability, which poses the question of vulnerability of U.S. strategic forces.

Today the Polaris-launching submarine promises ,to be an effective strategic weapon system. It is easy to visualize how difficult it would be for the enemy to destroy our Polaris submarines hidden under the seas. This concealed deployment and other advantages are to be found—in some cases more abundantly—in a nuclear-powered aircraft missile launcher: invulnerability to enemy missile pinpointing, instant readiness for attack, and practically unlimited range from nuclear propulsion.

The mobile Minuteman missile, using our railroads to vary its launching site, will also be largely invulnerable to attack. A nuclear-powered aircraft missile launcher adds to the impressive capability of Polaris and Minuteman the means for much wider dispersion "on station," since it operates in the air. Communications, a problem for submarines, is not a problem for Camal. ANP will also provide something of the utmost importance that is lacking in both Polaris and Minuteman—that is, detailed postattack reconnaissance of bomb damage, which is positively essential for subsequent effective counterforce attacks. The relative invulnerability of these land-, sea-, and air-based systems will give us a diversified residual capability regardless of the magnitude or effectiveness of an enemy attack upon our surface installations. The surviving hardened, fixed missile sites would also become a part of our residual capability.

If we assume that our nation and the aggressor nation have achieved a similar state of technology, the factor of vulnerability (as modified by quantity) will determine how much remains of our strategic force after a nuclear ballistic-missile exchange. Airborne aircraft are practically invulnerable provided they stay beyond range of the enemy's radar and air defense weapons. Since invulnerability is attained merely by being airborne, subsonic flight is adequate. An altitude ceiling should not concern us unduly. As radar operates on line of sight, aircraft can avoid detection and proceed much closer to an enemy's territory by flying at low altitudes.

if deterrence should fail

A concept has been advanced that envisages a number of nuclear-powered aircraft missile launchers cruising subsonically at, say, 20,000 feet above land, sea, or arctic regions. A ballistic-missile nuclear exchange between fixed ground targets can have no effect upon the operational capability of the airborne aircraft. This independence of action is enhanced if the airborne force has its own airborne command post. Such a post must be capable of assimilating intelligence, programing restrikes, and transmitting a restrike program to the remaining land, sea, and air missile units for their use. Even the loss of the airborne force's air base with all its complex ground environment will not detract from the immediate offensive capability of this force.

Camal would probably not be assigned an active role until a day or two after initial attack against known, fixed bases. There is no valid reason for expending ALBM's against preselected fixed targets that can be destroyed equally well by less flexible ICBM's and IRBM's. The inherent flexibility and mobility of ALBM's become predominant after an initial nuclear exchange. Then is the time to use our invulnerable residual force to destroy the enemy's remaining capability. By waiting until after the initial exchange, we capitalize on Camal's reserve missiles and ensure acceptable attrition on its vital reconnaissance missions. Since reload of Camals will be difficult, we must expend our ALBM's with utmost effectiveness. They must be used to do those jobs that no other missile can do.

The main objective during the first few hours of global war is to inflict as much destruction as possible on the enemy's offensive capability while preserving sufficient residual capability of our own to ensure, beyond question, that we will ultimately bring about the conclusion of the war on terms favorable to us. The all-important residual capability will be composed of surviving hardened missile sites, unused Polaris missiles aboard submarines, mobile Minutemen, and airborne Camals.

reconnaissance by Camal

Postattack reconnaissance is vital. We should not be misled into believing that a secure, invulnerable, residual capability alone constitutes effective deterrence. It does not go far enough. The ability to destroy cities and people is an unlikely deterrent if it is known by both sides that we can not ultimately prevail. After an attack we might have a sizable number of nuclear weapons still intact under the seas, on land, and in the air; but unless the location of the enemy's surviving force is known, our weapons would be expended blindly against previously determined targets—or not expended at all. The practical military value of our remaining weapons without postattack reconnaissance is greatly reduced. There exists, then, the vital task of reconnaissance.

Some preliminary reconnaissance can be provided by our bomber aircraft, which must be airborne as soon after the war starts as possible. Since their fuel is limited, we can safely assume that within 12 hours after the war has started our bombers will be withdrawing from the enemy's territory. During that first 12-hour period our bombers will provide us with fragmentary reconnaissance—fragmentary because the rapidly changing situation will prevent systematic reconnaissance. It is obvious that only a large and well-equipped airfield can "turn around" a B-52 for a restrike or reconnaissance mission. And it is doubtful that many large airfields will remain operational —in any event we cannot plan on their use. Our bomber force, then, will give us some measure of reconnaissance during the first few hours of the war only. When their fuel is exhausted, even our fragmentary reconnaissance will cease.

The Camal, on the other hand, having unlimited fuel, can provide the precise postattack reconnaissance we need to locate targets for our residual force. Subsonic speed during the reconnaissance mission is permissible—

- because of the widespread destruction of the enemy's defense force by our ICBM's, IRBM's, and bombers.
- because some ALBM's can be expended against surviving air defense targets during penetration, and
- because of the capability for low-level penetration provided by limitless nuclear fuel.

At least one half of the initial number of airborne missiles could be retained until reconnaissance has been completed and a counter-force restrike plan devised. Maintenance of a deliverable reserve is essential to conclusion of the war. If the Polaris submarines and mobile Minuteman units have a reload capability, these reloaded missiles also could be effectively brought to bear on the enemy with the help of Camal reconnaissance. Such a reconnaissance would eliminate reliance on vastly inferior and essentially blind preselected targeting.

reconnaissance by earth satellite

Since reconnaissance is so essential to applying our residual capability precisely, effectively, and in exactly the right amount, we must discuss the value of earth satellites as reconnaissance vehicles. Prior to initiation of war, satellites will provide invaluable intelligence. But satellites travel in a highly predictable orbit, and after several circuits of the earth their precise location at any given instant can be computed with a remarkable degree of accuracy. Development of an antisatellite missile will be a much easier task than development of an antimissile missile. If we plan to use satellites for reconnaissance after hostilities commence, we must launch new satellites from relatively invulnerable launching and monitoring sites or develop a maneuverable satellite. The difficulties and expense of the first alternative are apparent. As to the second, the energy requirements for significant and repeated alteration of a satellite's orbit are of an order considerably beyond today's technology. The guidance and programing for a maneuverable satellite will also present extreme difficulties.

Camal force structure

What could be the approximate size of an effective Camal force? The yardsticks used are admittedly general. The first consideration is the number of ALBM's we desire to have airborne every minute of every day of the year —say, 200 missiles. Next let us assume that each Camal will carry five missiles. Then I think we would require 40 operational aircraft airborne at all times. If we assume a utilization rate of 67 per cent (not at all unreasonable for this type aircraft), then our operational force must total 60 aircraft. To this figure we must add 17 aircraft for training purposes and an estimated 10 per cent or 8 aircraft for major modification, depot overhaul, etc. Our total requirement is now 85 aircraft, exclusive of aircraft for research and development. The total aircraft buy would be perhaps 100 units and be spread over several years.

Camal crews. How many crews would be required? The combat-alert sortie length could perhaps be as much as seven days (168 hours), with each crew performing one alert sortie every two months. We would then need about eight crews for each of the 40 airborne aircraft or 320 crews. Adding 15 per cent to our required crew strength for leave and duty not involving flying, and approximately 10 per cent for a normal crew upgrading load, means an additional 80 crews. This brings the total to 400 crews needed to keep 40 aircraft continuously airborne in combat-ready status.

Because of the long period of time airborne on combat alert, the crew will be large, similar to what we today call "augmented." But we cannot know how much it will be augmented until we run actual tests simulating a seven-day flight. Perhaps in excess of two individuals, on the average, will be required for each crew position. This figure of 2+ is too high in terms of the aircraft commander; it may be too low for individuals whose duties require extreme concentration or who must pay close attention to detail while on duty.

Camal bases. Because ANP provides unlimited fuel and because the aircraft is airborne for a long period, Camal will need very few air bases. Two ZI bases, perhaps one in the Northeast and one in the Northwest, could handle the 85 aircraft and generate 500 sorties per month. With only two air bases, savings in real estate, facilities, runways, highly skilled maintenance personnel, and expensive ground environment are apparent.

The air bases should be located on the seacoast in order to minimize flight time over populated areas. Dr. Miles C. Leverett, Manager of the Development Laboratories of the Aircraft Nuclear Propulsion Department of the General Electric Company, has found that, assuming no fission product release, the principal radioactive exhaust material from nuclear-powered aircraft would be argon-41. A radioactive form of an inert gas that is one of the minor components of air, argon-41 emits gamma rays that are potentially hazardous but have a halflife of only 110 minutes. The possibility of damage being done by argon-41 released from a plane at high altitude is nil. According to Dr. Leverett, nitrogen, the chief ingredient of air, might be transformed occasionally into radioactive nitrogen-16, but after a few seconds this would decay into ordinary atmospheric nitrogen.

A force of the size depicted represents a large dollar investment. However, its low vulnerability and the enemy's certain knowledge that we possess the means to utilize effectively our residual capability would certainly add immeasurably to our deterrence.

A strategic offensive force with a credible residual capability would constitute—even under the most adverse conditions—an effective deterrent for years to come. The nuclear-powered ALBM-carrying aircraft contributes to this deterrent in two unique ways:

- It would extend the area of our strategic force's invulnerability from the land and seas into the air.
- It would provide vital photo, visual, and electronic reconnaissance to ensure proper application of all our remaining weapons.

With a possible loss of missile superiority by the U.S. already predicted, the potentialities of a nuclear-powered aircraft missile launcher become extremely important. Authorities resist it with the argument that the first Camal would be big and slow by B-58 or B-70 standards. If we wait, they say, we will surely have a much higher-performance vehicle because of our advancing technology.

failure of U.S. to have operational Camal force first

What could happen if a potential aggressor nation possesses a first-generation Camal in operational numbers before we do? In addition to the tremendous prestige factor, there are even more important considerations. Visualize a massive enemy nuclear attack against the free world. Our ZI and overseas missile and bomber bases are brought under attack simultaneously. The enemy's long-range air force follows the missile attack. Our BMEWS and Midas provide the alarm of ballistic missile attack by which we ready our own ballistic missiles and actually launch our SAC alert force. The alert force is on its way to targets in enemy territory. These aircraft may be launched without Executive decision, since they operate under conditions of "positive control." Executive decision to fire our ballistic missiles will probably be made only after enemy missiles strike U.S. targets. This is understandable because of our extreme reluctance to strike at an aggressor with any chance of error. Then, and only then, preselected enemy targets would be struck by our surviving land- and sea-launched missiles. After several exchanges we would still have usable weapons under the seas and on land, but the problem would be knowing what enemy targets remain unhit.

After the enemy's long-range air force withdraws and with our air defenses greatly disrupted, to say the least, the aggressor's nuclear-powered aircraft can perform bomb damage assessment and photo and electronic reconnaissance of the U.S.

Let us assume that Westover, Hunter, and Travis Air Force Bases received only near misses during the initial exchange, as did several other strategic-force bases and fixed missile sites. Dobbins, Malmstrom, and several other air defense installations are still operational. With this type of intelligence, effective enemy restrike against fixed sites is now possible. Usable U.S. airfields and missile sites are brought under the enemy's restrike attack. Systematic destruction of our residual fixed-site capability is now inevitable.

Against this, lacking detailed reconnaissance, we would have to rely on preselected targeting. Our remaining operational missiles in and on the earth and under the seas would be impotent against the enemy's surviving military targets. How could we continue to apply intelligently our weapons against a military force that is destroying us when we have no idea how effective our own weapons have been or what portion of his force still survives? Would we continue to apply our residual capability indiscriminately until it was exhausted? The threat of indiscriminate application of nuclear weapons has some deterrent value; however, it can only lose a conflict against an enemy who has a postattack reconnaissance capability.

The enemy could resort to ultimatums of unconditional surrender and threaten systematic destruction of our population centers while we would be unable to apply effectively our residual weapons against his offensive force.

In the final analysis, it appears that only the measured, precise application of our residual force against the enemy's extant force would ensure conclusion of any future global war in our favor. ANP will provide such a capability. The nation which still has deliverable weapons and the will to apply them when the other nation's weapons have been exhausted or destroyed will ultimately prevail.

It is rather difficult to explain a lethargic attitude toward development of aircraft nuclear propulsion. It should be a matter of grave national concern.

Headquarters United States Air Force

The Fallacy of the Concept of Minimum Deterrence

Brigadier General Robert C. Richardson III

A NEW concept of deterrence has recently appeared. Known as "minimum deterrence," this concept offers a panacea for the grave economic and strategic problems of our time. Like most panaceas it is easily stated, for it is based on generalizations and oversimplification.

The concept of minimum deterrence holds that a large counter-force capability is not necessary in our strategic offensive forces and, in fact, is ineffective as a deterrent to general war. This premise is based on two assumptions:

- First, that our strategic offensive forces will be used only in response to an enemy attack; and
- Second, that the enemy will have flushed his offensive forces in the initial attack and hence our counter-force systems will go against empty air bases and missile sites.

As a corollary to this second assumption, the concept of minimum deterrence states that a large counter-force capability which is not usable against the enemy's strategic offensive forces is excessive to our needs—that it can kill many times the number of enemy targets which will be available after the enemy's initial attack.

Proponents of minimum deterrence have maintained that an adequate deterrent posture can be had with a small, secure, strategic force capable of annihilating area targets. In other words, the idea of minimum deterrence is based on maintaining a Free World strategic offensive capability that is composed of bombers and missiles in numbers adequate to destroy an enemy's major centers of population but not adequate, either quantitatively or qualitatively, to destroy his dispersed and hardened offensive forces. The threat to an enemy's centers of population and industry is presented as adequate to prevent him from initiating general war. Nothing is said about deterring lesser acts of aggression.

This attempt to reduce the present strategic counter-force capability by settling for the less costly job of "city busting" is clearly motivated by budgetary considerations. Some proponents of minimum deterrence seem to fear that one full conversion of the strategic offensive forces from existing weapon systems to advanced bombers and intercontinental missiles that are adequate to deal with the current target system would mean reductions in other forces and capabilities.

Others would like to see the primary strategic target system changed from counter-force targets to cities, since area targets better fit the relative inaccuracies, slow reaction times, and quantitative limitations of some missile systems.

Finally there are some who recognize that a minimum-deterrent posture will provide little deterrence to aggression in peripheral areas and so would maximize justification for building up limited-war forces.

Let us examine minimum deterrence as a strategy for security of the Free World. Is it the most effective means of deterring the Communist bloc from initiating general war? Could it defeat aggressor forces if deterrence should fail? Could it provide effective deterrence to limited war? Would it, in fact, be cheaper than a deterrent based on counter-force capabilities? Unless these questions can be answered affirmatively, the endorsement of a minimum-deterrent concept could have serious consequences for the United States and its Free World partners.

what is deterrence?

Of all the threats we face today, it seems incontestable that general war is the most serious. General war is clearly more likely in the future than it has been to date. This stems from the great increase in the Soviets' relative general-war capability. The ensuing possibilities are that the Soviets might rationalize a valid "win" strategy which would warrant premeditated initiation of general war, or that their improved general-war posture might lead them to taking greater risks in cold- or limited-war aggressions, any of which could progress to general war.

Defeat in a general war would end the independent existence of this nation—probably of the Free World. Only the cumulative effects of defeat in several limited wars could have a like effect. A national policy dedicated to deterrence of war, or to victory if deterrence should fail, must therefore be concerned first with the problem of general war and secondly with lesser

Born of budget considerations and fostered by "small war" protagonists, the concept of "minimum deterrence" is now contesting for national acceptance. Its supporters argue that, since the United States will not strike first, we need only enough retaliatory force to destroy the enemy's area targets. These targets, the reasoning runs, will be all that are militarily worthwhile, since the enemy's missile and bomber forces will already be airborne. To Brigadier General Robert C. Richardson III, Chief of the Long-Range Objectives Group, DSC/Plans and Programs, Headquarters USAF, this means a deterrent force capable only of extracting from the enemy a high cost for his victory rather than one that confronts him with a credible threat of defeat. General Richardson analyzes the concept of minimum deterrence, finds it fallacious, and points out the consequences if it were adopted.

wars. An ideal solution would be a security system that could deter effectively all types of war.

Deterrence is basically a cold-war goal. Obviously if there is a war, deterrence has failed. Deterrence seeks primarily to influence the enemy's intentions. Since we can never know with absolute certainty what the enemy's intentions are or how our actions have affected them, deterrence of an enemy whose military forces are of the same order of magnitude as ours can never be certain. But differently constituted military forces will have varying degrees of deterrent effectiveness.

Military forces that will extract from an enemy a high price for victory *do* constitute a deterrent. Their degree of effectiveness depends on the enemy's willingness to pay. On the other hand, military forces that confront the enemy with a credible threat of defeat under any circumstances provide a much higher degree of deterrence.

This second type of deterrent force is designed to support completely the only sound military and national policy—that of winning a war should deterrence fail. A force which can do no more than make the enemy pay a high price for victory is clearly not fully responsive to the best interests of the Free World.

It might be said, then, that deterrence is achieved by a combination of military and nonmilitary measures, actions, and capabilities designed to dissuade a potential enemy from deliberately initiating war by convincing him that the cost and the risks involved outweigh his chances of gain. A force adequate to deter under some circumstances is not necessarily a force adequate to achieve victory. But a force adequate to achieve victory under any likely circumstances is also a deterrent force to the highest achievable degree.

relationship to stalemate concept

The advocates of minimum deterrence argue that a force adequate to destroy 100 or more cities will deter an enemy from initiating general war. Since both the Communists and the Free World have forces adequate for destruction of cities on this relatively modest scale, it is clear that minimum deterrence is associated with the so-called stalemate concept.

In brief, the stalemate–minimum-deterrence thesis holds that since general nuclear war could never be initiated by the United States, even if provoked by every means short of a direct attack on the homeland, general war can only begin with an initial enemy attack (also assumed unlikely). In this case the enemy forces must have inevitably "flown the coop," so that there are no useful strategic military targets left to hit.

Thus, by combining the argument that premeditated general war will never occur with the argument that if a general war does occur the U.S. will be hit first, one arrives at minimum deterrence as being an adequate strategy.

The fallacy of the "stalemate" theory has been recognized for some time in professional Air Force circles. There are other considerations that deny the validity of minimum deterrence and the resulting "city busting" strategy even more forcefully.

minimum deterrence evaluated

General war. On the face of it a counter-city strategy is suspect. It violates two basic principles:

- The only rational military objective in war is the enemy forces, or targets that affect the forces;
- Destruction which does not affect the outcome of the war in one's favor is irrational and politically and morally unjustifiable.

The proponents of minimum deterrence, while accepting the above in principle, counter with several interlocking arguments:

- Total atomic war can only result from miscalculation or an irrational act: it cannot be conceived of as serving a valid political aim. The classical principles therefore do not apply. The only purpose of total-war forces is to deter total war, and they can do this as effectively by possessing a "revenge" potential as by possessing a valid war-winning potential.
- In the nuclear-missile age there is no prospect of destroying enemy forces—even with the initiative—since missiles can be easily concealed or fired on warning of any attack en route.
- Even if we could find and destroy the Soviet long-range threat, we cannot afford the quantity of sophisticated strategic systems required and still meet other threats which may prove equally dangerous in the long run.

The net effect of accepting the above premises is to concede that Free World survival will be gambled solely on our ability to deter or prevent war and that, should deterrence fail, defeat or at best mutual destruction is inevitable. In our present military environment, dominated by high-yield nuclear weapons delivered over global ranges by missiles or manned aircraft, one cannot show how the capability associated with a minimum-deterrent force can contribute to a satisfactory military outcome, should deterrence fail. This being true, it is not even the best deterrent strategy, since it does not confront an enemy with a credible threat of defeat.

In addition, destruction of centers of population and industry as a means of defeating an enemy in the atomic era is both anachronistic and inhumane. It is a vestige of an era in which the key to victory lay in mobilization of a nation's *potential* for delivering destruction—its industry and population. Even in World War II strategic bombing was limited to targets that were presumed to affect the military capability, as evidenced by the U.S. daylight pinpoint-bombing of industry. Where cities were attacked, the cities selected as targets were production centers of war materiel. The attacks were justified on the grounds that they disrupted the workers and, hence, war production.

In atomic war it is recognized that post-D-day production and mobilization would contribute little or nothing to the outcome. If true, it is hard to see what benefit is to be derived from wanton attack of cities, people, and real estate. Today, victory lies not in the ability to destroy the enemy industrial and manpower potential but rather in the ability to destroy his *existing* capability for delivering destruction. Hence a minimum-deterrent force is not an effective general-war deterrent against a nation which has on hand, prior to the opening of hostilities, a large stock of nuclear weapons and the means to deliver them; which has made some provision for the security of an industrial nucleus for recovery purposes; and which has demonstrated willingness to sacrifice human life on an extravagant scale in the attainment of political objectives.

The possessor of a minimum-deterrent force may not take the initiative in general war under any circumstances, including receipt of unequivocal warning of attack. To do so would only guarantee his complete destruction by the enemy's untouched forces in-being.

It is also true that a minimum-deterrent force could not respond rationally to initiation of general war by the enemy, for response would be no more than an act of revenge. Annihilation of the enemy's major cities could not prevent the enemy from completing destruction of the attacked nation to the extent and on a time scale which suited his need and convenience.

A minimum-deterrent force will restrain an aggressive nation from initiating general war only so long as the aggressor feels that conquest by means short of general war is a more advantageous course of action. Thus a minimum-deterrent force sets a price for victory, but one which the Communist bloc may consider reasonable for the attainment of world domination. This concept should perhaps be labeled "partial deterrence" rather than "minimum deterrence."

Limited war. Next, let us see how effective a minimum-deterrent strategy and force may be in relation to limited war.

If this country were to tailor its strategic forces to a philosophy of minimum deterrence, we could not prevent the Communists from launching limited wars in areas of their choosing. They would be well aware that our minimum-deterrent force would be used only as a last resort, if at all, because attack of enemy cities without an accompanying ability to destroy his offensive forces would be national suicide. A Twilight of the Gods philosophy is not part of our heritage.

What has deterred aggression in Europe and in other vital areas for the past ten years has been primarily the counter-force aspect of the general-war capability, backed up by the expressed willingness to use any and all forces to defend the Free World if it should become necessary. An enemy nation is most effectively deterred from attempting major acts of limited aggression if he is made to realize that we have both the *will* and the *physical capability* to retaliate with general-war forces and that, should we do so, our possession of the initiative and a counter-force capability will lead to our destroying his general-war retaliatory capability.

We must therefore answer our question, "Could a minimum-deterrent force deter limited war?" in the negative.

Relative cost. It is perhaps pointless to pursue a discussion of whether a minimum-deterrent force is cheaper than a strategic offensive force with a counter-force capability. A force which cannot deter either general or limited war and which cannot achieve victory is not a wise choice at any price.

We would not attempt to challenge the assertion that a minimum-deterrent force would be cheaper in dollars than a counter-force capability if the purchase cycle ended there. But a minimum-deterrent force creates a requirement for *unlimited forces to fight limited wars*. If our strategic general-war forces can neither deter limited war nor participate in it, we must then create limited-war forces in quantities adequate to meet the Communist threat at any point along a 15,000-mile periphery or at several points simultaneously.

This drain on Allied manpower and resources would more than offset the apparent saving in general-war deterrent forces realized by conversion to a minimum-deterrent force. Another effect of adopting minimum deterrence in the U.S. force structure would be to raise the cost of Allied security, since U.S. mobile forces—even if augmented—can never meet the demands of a limited-war capability to defeat the Soviets in the NATO area alone.

counter-force targeting

It is often argued that in the missile age we shall be unable to locate enemy force targets even if we had the strategic initiative. What are the prospects of finding lucrative force targets in the 1965–1970 time period? Obviously a counter-force capability has little meaning if we cannot find or hit the forces.

The claim that ICBM's can be so concealed that their location will be unknown to us is exaggerated. Intelligence techniques should provide knowledge of the location of hardened sites during the construction period, and they won't move far thereafter. Concealing a completed site is easy compared to hiding the building process, which requires access to roads or rails, labor, heavy equipment, etc.

While the exact location of mobile missiles may not be known, their great vulnerability to slight overpressures should allow us to target these on an area basis with the help of reconnaissance.

Finally, we shall have constant satellite surveillance in the time frame of concern to us. This should provide intelligence on ICBM movements or site construction. We assume that the Soviets know all about our ICBM sites. I see no excuse for granting them a decisive advantage in this respect.

The Free World's strategic force structure and strategic concepts need not be influenced by an assumed unsymmetrical intelligence, reconnaissance, or surveillance capability. We must base our plans on the assumption that we can both find and reach all major Soviet missile and bomber bases by one means or another. We must then see to it that this assumption is validated by giving adequate attention to this problem.

This leaves the question of whether or not any nation's warning, decision, and reaction systems can respond quickly enough to save the force from surprise attack. Here we can only rely on judgment. Theoretically it is possible to build a fully automatic response to a missile attack. In practice I doubt if either side can do so or would accept the liabilities of doing so in the foreseeable future.

The enormity of the damage involved in unleashing a nuclear war precludes decentralization of the decision to fire ICBM's to the extent necessary to eliminate substantive delays. The lack of reliability of warning and identification devices and the possibility of spoofing will require unequivocal knowledge of the attack before responding. And fear of accidents will keep the human control factor in the firing sequence.

We must be ready to respond quickly if an enemy's poor timing or premature firings should clearly motivate our decision to retaliate. But if a real case could be made for survival by quick response, there would be no requirement for hardening, mobility, or concealment of strategic missile sites.

In summary, our strategic forces for the foreseeable future cannot rely solely on survival through automatic reaction. Nor should our strategy be unduly influenced by the doubtful assumption that any attack on enemy forces will be frustrated by the enemy's ability to unload his sites and bases while our attack is en route.

From the above analysis it seems clear that a minimum-deterrence, counter-economy strategy and the related force structure make no sense in the 1965–1970 period.

minimum deterrence weakens NATO

In the years since World War II, the bastion of Free World security has come to be the series of international alliances in which the United States accepted a key role either as a formal partner or as an informal supporter. A series of bitter experiences in the postwar years showed clearly that Communist encroachment, with its bag of tricks ranging from fifth columns through Communist-sponsored guerrillas to open aggression by Communist satellites, could only be stemmed by tying the smaller and more exposed countries into alliances with the stronger powers of the West. The final ace in these alliances has always been the strategic total-war forces of the United States.

One of the most far-reaching implications of the minimum-deterrence concept is the disastrous effect it would have upon these alliances. For the sake of brevity, I will discuss this aspect only in relation to NATO. As the strongest and the most vital to Free World defense posture, this alliance is the bellwether.

In a recent presentation on the Berlin situation Dr. Hans Speir discussed Soviet aggressiveness. The extent to which the Soviets are prepared to push the West towards war in this instance can be attributed in part, he states, to pronouncements by responsible American officials to the effect that we would probably no longer honor our commitments to use, if necessary, our strategic forces in defense of our allies.

Numerous public statements in recent months have questioned the willingness of the U.S. to perform its retaliatory role in the NATO defense strategy, should the Soviets attack Europe. Most of these statements claim that the Soviet long-range nuclear capability will, from now on, deter the U.S. from using its strategic forces, except in a case of last resort—that is, a direct attack on America. Hence, these statements conclude, our commitments should be reduced to a level commensurate with minimum-deterrence philosophies.

Effective deterrence is composed of two elements. First, a reasonably credible and demonstrated military capability to inflict unacceptable damage upon the enemy should he engage in aggression; and second, the declared *will* to use this capability. It appears today that many individuals are openly challenging the will to use our principal deterrent force in defense of NATO.

Soviet planners, in considering the extent to which they can conduct limited aggression with impunity in the NATO area, are obviously taking into account these public statements, made by Americans, which discredit the validity of our approved national security strategy with respect to the NATO area. These statements are, at the very least, irresponsible in that they *invite* limited aggression by increasing Soviet confidence that we will not retaliate against their homeland, notwithstanding our commitments.

Whether the U.S. NATO strategy of "the shield and the sword" is valid at this time seems beside the point. If this strategy needs to be revised, then it should be revised within the councils of NATO and the National Security Council, not in the market place.

Today the European public and European leaders count on the U.S. strategic retaliatory capability and on our promises that we will use it in their defense to offset the larger Soviet forces threatening West Europe. Based on the current shield and sword strategy and on faith in American commitments, the NATO forces have been deployed and organized so as to best complement the strategy of forward defense in Germany and strategic retaliation from the U.S. and U.K. The present efforts would publicly "pull the rug" out from under the retaliatory half of the strategy by advocating minimum deterrence and stalemate. Nor do they attempt to solve the resulting problem of how one is to provide an effective deterrent or a truly credible military capability to defend NATO without the support of the strategic air arm. These efforts can only lead to insecurity throughout Europe and the exploitation of the resulting weakness by the locally superior Soviet forces.

It may be useful to recall that NATO force goals have never been downgraded or reduced because of anticipated returns from the U.S. strategic air undertaking. Since the very inception of NATO our Government has sought to obtain the maximum military contribution that the countries concerned could raise and support, given as much U.S. assistance as could be justified to the Congress and the American people each year.

The first NATO plans established the minimum forces required to defend Europe without support from the strategic forces. Following the North Atlantic Council meeting in Lisbon, it became clear to the Western world that these minimum force requirements for a local defense of Europe could not be generated. The necessary choice, now and at that time, was the adoption of a global strategy which combined strategic retaliation with the maximum NATO capability to provide the strongest possible defensive shield in Europe. The alternative was to admit inability to defend Europe at all.

Had the military leaders of the various NATO countries been compelled to advise their political masters that only the forces that could be generated or maintained locally would be available to NATO and that in their opinion there was no prospect of defending their lands with these forces, the political leaders would have quickly appreciated the fact that there was little purpose in making a partial effort. They would have selected a policy of neutrality or compromise with the Soviet Union in the face of no prospect for a successful military defense.

The contribution of the Free World's strategic retaliatory force to the security of Europe must be looked upon as an increment which reinforces the maximum forces that can be maintained locally to the level of military effort required to provide both the military and the governments of Europe with confidence that a defense effort is worthwhile.

Acting in the capacity to fill the gap between capabilities for local defense and force requirements, the Free World's strategic air contribution spans a wide range of differences. At the same time it in no way prevents a continuing effort to maximize the local capability wherever possible into a completely self-sufficient defense.

The very fact that NATO force goals constantly exceed the ability of the nations concerned to build the forces is evidence of the effort being made towards self-sufficient defense in Europe.

If, by reducing the strategic retaliatory forces to a point where they could only be used as a last resort, we admit we have no "will" to use the forces in defense of Europe, then we must reassess the security of our NATO partners on the basis of their local capabilities to deter or defend against Soviet attack. If the local capabilities still prove inadequate to deter or fight aggression without strategic air support, the leaders of the countries concerned will quickly recognize this. They then might seek to reorient their foreign policy to seek protection through agreement with the Communist bloc, being unable to find security in any strategy that NATO can afford.

What if it were found possible ultimately to generate a truly effective local defense and deterrent capability around the entire periphery of the U.S.S.R.? Even so, the Soviet Union would certainly take advantage of the gap between the time we could build such a capability and our earlier declarations that the strategic air forces can no longer be counted upon to protect our friends.

In capitalizing on the budgetary attraction of the offensive element in defense, proponents of a reduced and diversified SAC go so far as to rationalize that the classical prewar concept of the shield and the sword is now reversed. The new twist sees SAC as the "shield" which prevents either side from using strategic forces. Behind this "shield" the front-line, limited-war conventional armed masses become the "sword" and can return to the classical land warfare of attack and counterattack.

The minimum-deterrent strategy sought by critics of the existing counter-force deterrent capacity is one which would lead to unlimited requirements for limited war. Such a strategy would eventually become a far greater drain on the taxpayer than the present one—if Europe survived long enough to implement it in the first instance.

Headquarters United States Air Force

...Air Force Review

IS A SONIC BOOM AN EXPLOSION?

Dr. James A. Fraser

We shall approach this problem by considering three important phases of the chain of events which are associated with a sonic boom and with an explosion. First, we shall consider the origin. Second, we shall consider the mode of transmission of the energy from the place of origin to the place where the effects occur. Third, we shall consider the effects.

Since most definitions of explosion emphasize the origin, the origin is not only the first consideration but also the most important. *Webster's New International Dictionary*, Second Edition, 1958 printing, defines explosion as: "Act of exploding; detonation; a violent bursting or expansion, with noise, following the sudden production of great pressure, as in the case of explosives, or a sudden release of pressure, as in the disruption of a steam boiler; also the noise made by such bursting." Notice that this definition is exclusively concerned with the origin of the energy involved. Funk and Wagnalls' dictionary, 1952, defines explosion as: "The act of exploding; rapid combustion, decomposition, or other similar process resulting in a great and sudden development of gases, and consequent violent increase of pressure, usually accompanied by a loud report." The *Van Nostrand Chemist's Dictionary*, 1953, defines explosion as: "A chemical change that produces large quantities of energy or an increase in the volume of the system, or both at a rate sufficiently rapid to have considerable effects, often destructive, upon the surroundings." This definition discusses both origin of energy and effects, but it emphasizes origin. The *United States Air Force Dictionary*, 1956, defines explosion as: "A sudden outburst of particles or gases from a substance that has undergone detonation. Detonation precedes explosion, although the two events are so closely related as to be identified as the same event in loose or elliptical usage."

While all these definitions are satisfactory, I prefer the one offered by Webster because it is more general. In it a pressure difference is assumed as the necessary condition for the initiation of an explosion. This pressure difference may come about by the sudden production of gases under pressure through chemical reaction of an explosive, or it may come about by gradual buildup of pressure in a confined place, such as a steam boiler. The important point is that before an explosion can take place there must be produced by some means a pressure difference. The second necessary condition for an explosion is that this pressure difference be neutralized or eliminated *suddenly*. In fact this action must be almost instantaneous—time being measured in milliseconds. Within this definition an automobile tire blowout is an explosion, but a slow leak is not. In both cases the pressure difference was relieved, but in the slow leak the action was not sudden.

This definition should also include the production of gases under pressure by nuclear and thermonuclear reactions. In these cases tremendous pressures of hot gases are produced with very great speed and released to the surrounding atmosphere with a suddenness measured in microseconds.

It should be noted that within this explanation of an explosion, and within all the definitions of an explosion, the explosion is over when the act of exploding destroys the pressure difference which is a prerequisite for explosion. The train of events initiated by the explosion may continue for some time after the explosion, but these definitions imply that the explosion is the initiating act rather than the succeeding consequences of that act.

In spite of this, to get a means of comparison with the sonic boom which will be described in the next section, we shall consider the first consequence of the explosion. The suddenly expanding gases bursting forth from their place of origin press against and compress the surrounding air. This then forms a sphere of compressed air, if we assume that the burst has taken place in free air. The spherical shape of the pressure wave may be modified by obstructing substances if they are in the vicinity. This compressed air is the start of a shock wave, which in the case of an explosion is often called a blast wave. Three more definitions are now in order:

> *shock*—a finite pressure disturbance having a discontinuous front followed by a variation in pressure, the whole of which propagates as a wave.
>
> *shock front*—the discontinuity at the head of a shock wave.
>
> *blast wave*—the pressure wave resulting from an explosion, usually consisting of a shock front and a positive phase followed by a negative phase.

The sonic boom has received much public notice in recent years. From both a legal and a public relations standpoint the Air Force has felt it important to inform the public on the nature of this phenomenon of supersonic flight. Court cases involving the sonic boom have begun to crop up. The Air Force has at least the indirect interest of clarifying the facts. Insurance companies, for example, insure buildings against damage from "explosions." If damage is claimed as the result of a sonic boom, the question of whether a sonic boom is an explosion becomes central. One such case was recently concluded in the Circuit Court, Montgomery, Alabama. The judgment was that "the phenomenon known as the sonic boom is not an explosion within the wording of the policy issued by the defendant to the plaintiff." While this one case is perhaps not definitive, particularly since it is being appealed, it does suggest a need for information on the origin, transfer of energy, and effects of a sonic boom compared to conventional and nuclear explosions. Dr. James A. Fraser, Physical Science Analyst, Warfare Systems School, defines the physical distinctions between a sonic boom and an explosion.

The origin of the sonic boom is best explained by considering the difference between subsonic and supersonic flow. To do this we will first examine a pressure wave formed by a disturbing center that is at rest with respect to the atmosphere, then a pressure wave formed during subsonic flow, and finally a pressure wave formed during supersonic flow. Figure 1 is a cross section of a spherical pressure wave emanating from a disturbance at a point O in the center. The pressure wave is transmitted at the speed of sound in the air. Let this speed be represented by the symbol a. Notice that in time t, the pressure wave will travel a distance $r = at$. This situation would pertain if the medium in which the pressure wave is propagated (air) is at rest relative to the source of the disturbance.

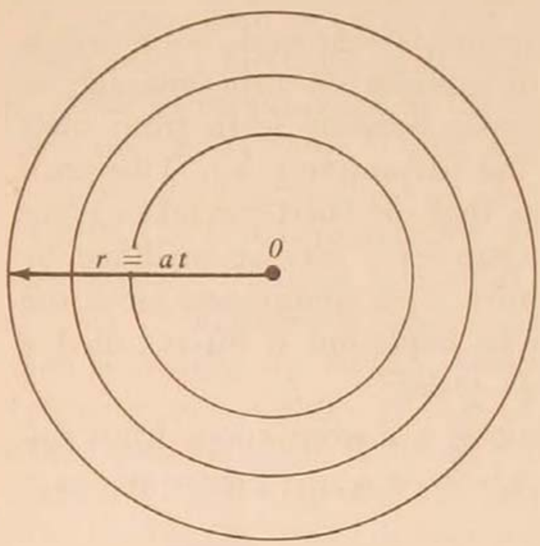


Figure 1

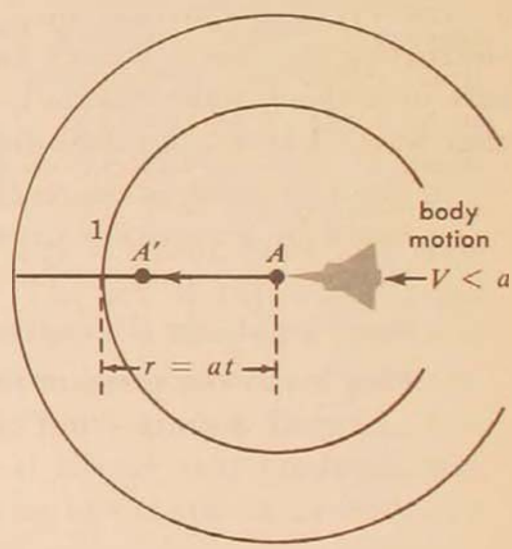


Figure 2

Now consider a body traveling with a subsonic speed in air, as illustrated in Figure 2. At the start of the discussion, let the body be at the position A, moving in the direction of the arrow, with a velocity V which is less than the speed of sound a. It will create a disturbance in the air which will start a pressure wave. After a time, t, the pressure wave will have moved in a sphere to the line represented at 1 (a cross section of the sphere). The distance from A will be at. But in this same time, t, the disturbing body will have moved only to A'—a distance which is less than at because it is moving slower than the speed of sound. The same sort of argument could be repeated for a number of time intervals. Because V is less than a, the pressure wave or pressure front always moves away from the disturbing object, and the disturbing object always remains inside the spherical waves it creates. Thus when a body moves with a subsonic speed the disturbances created by it clear away from the body.

Figure 3 illustrates the conditions where a body travels with supersonic speed. In time t the pressure wave caused by the disturbing body will move on a spherical wave front a distance of at. But in this same time the body itself has

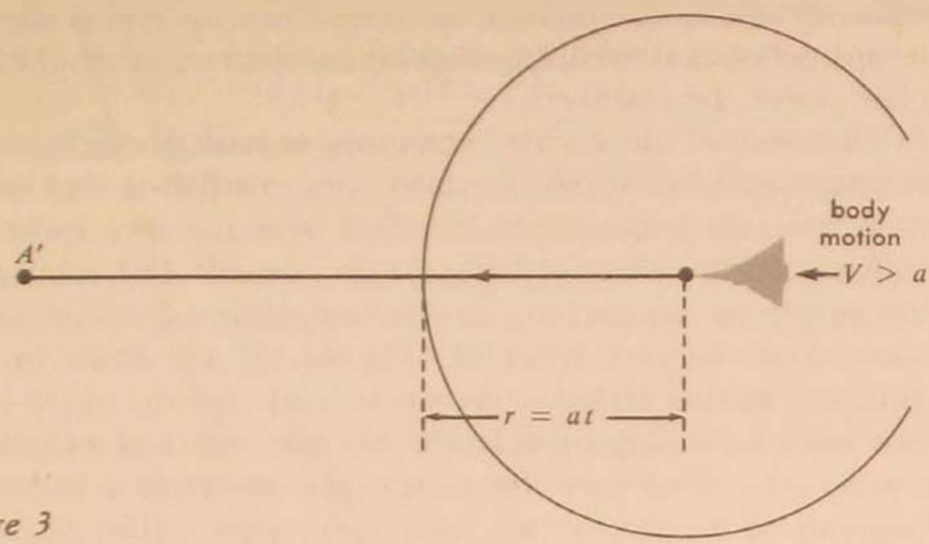


Figure 3

moved farther than this distance to a point marked A'. In other words, the body will have overtaken and traversed the disturbance it created; thus the disturbance wave front is always *downstream* from the body. As the body moves it will be creating disturbances in the air *continuously*. In Figure 4 five successive points of disturbance are shown with their associated expanding, spherical pressure wave: A, B, C, D, and E. Notice that all the disturbance

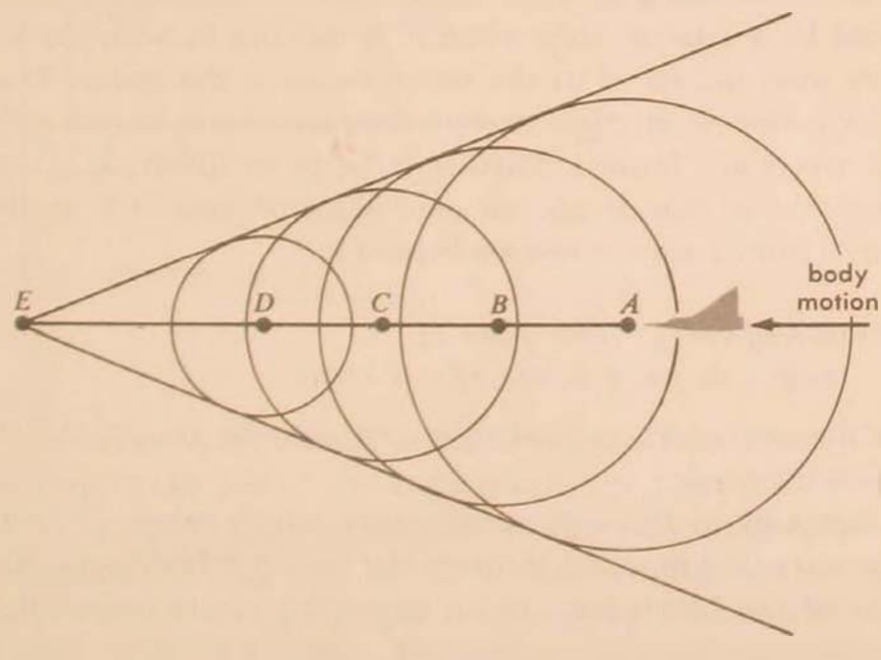


Figure 4

wave fronts merge along the surface of a cone, the cone starting at the disturbing body and trailing behind it. This is a cone bounded by a pressure greater than the ambient pressure, and this pressure has been built up by the addition of many small increments of pressure from each of the merging pressure waves. This bounding cone is a *shock wave*. It has a shock front, but it is not a blast wave, except in loose usage.

It should be clear that one of the essential differences between subsonic and supersonic flow is that downstream disturbances can be propagated upstream with the speed of sound when the flow is subsonic, but downstream disturbances cannot be transmitted upstream when the flow is supersonic. For example, a supersonic aircraft approaching an observer cannot be heard until after it has passed the observer.

The discussion of shock wave formation, or sonic boom formation, could now be complicated by introducing modifying conditions, such as supersonic flow into a concave corner, supersonic flow into a convex corner, the effect of body diameter, the effect of body length, the effect of many local shocks from various parts of an aircraft, the effect of changes in speed, etc. This will not be attempted, because it would only obscure the forest to look at the trees. The presentation already developed shows that the origin of the shock waves in a sonic boom is quite different from the origin of a shock wave from an explosion. The shock wave from an explosion resulted from the sudden, almost instantaneous equalization of a gas pressure difference. It happens once per explosion. When the pressure difference ceases to exist, the explosion is over. These shock waves are not *continuously* propagated. With the shock wave originating from supersonic flow, the wave is continuously propagated. There is no sudden, precipitous equalization of a previously developed gas pressure difference. In fact the mechanism for producing a shock wave in an explosion is not even analogous to the mechanism for producing a shock wave by supersonic flow. If an analogy is necessary or illuminating, then the shock wave produced by supersonic flow is analogous to the big bow wave produced by a boat or ship when it is moving in water at a speed equal to or faster than the speed of the water waves in the water. The mechanism of wave formation is similar, except that transverse waves rather than longitudinal waves are formed. Further it helps to illustrate that the shock wave from supersonic flow is not an explosion, because it is easily seen that the bow wave from a ship is not an explosion.

transmission of energy from place of origin to place where effects occur

In the case of an explosion, energy may be transported in any or all of the following ways:

1. Fragments of the case or structure which originally confined the high pressure may be propelled through the air. In a bomb, the fragments may be portions of the bomb case; in an exploding steam boiler, they may be fragments of the boiler. These fragments contain kinetic energy of motion and will do damage when they impact against another substance.
2. A blast wave with a shock front may be formed.
3. Thermal radiation may be formed. This thermal radiation may fall upon an object and raise its temperature sufficiently to damage it. Combustible materials may be set on fire and living materials killed or severely damaged through cell destruction.

4. Radiation of wave lengths other than those known as thermal energy may be formed. For example, gamma radiation or light may be formed.

5. In nuclear explosions some of the energy may be transported in the form of fallout.

6. Some of the energy may couple directly with the ground, if the explosion takes place on the ground, and thus dig craters or holes by movement of the soil; or in the case of nuclear weapons, there may even be vaporization of the soil.

7. Energy may be transported as sound.

In the case of a sonic boom most of these modes of energy transportation are absent. Energy is transported by the formation of a shock wave and by the formation of sound. There is no energy transmission by means of fragments, thermal radiation, radiation other than thermal, or fallout, nor are craters formed. Thus it is clear that the only similarity between the explosion and the sonic boom in regard to energy transmission is that they both produce a shock wave and that they both produce sound. However, there are distinct differences in the shock waves produced. Figure 5 is a typical graph of the pressure–time relationship in a blast wave produced by an explosion.

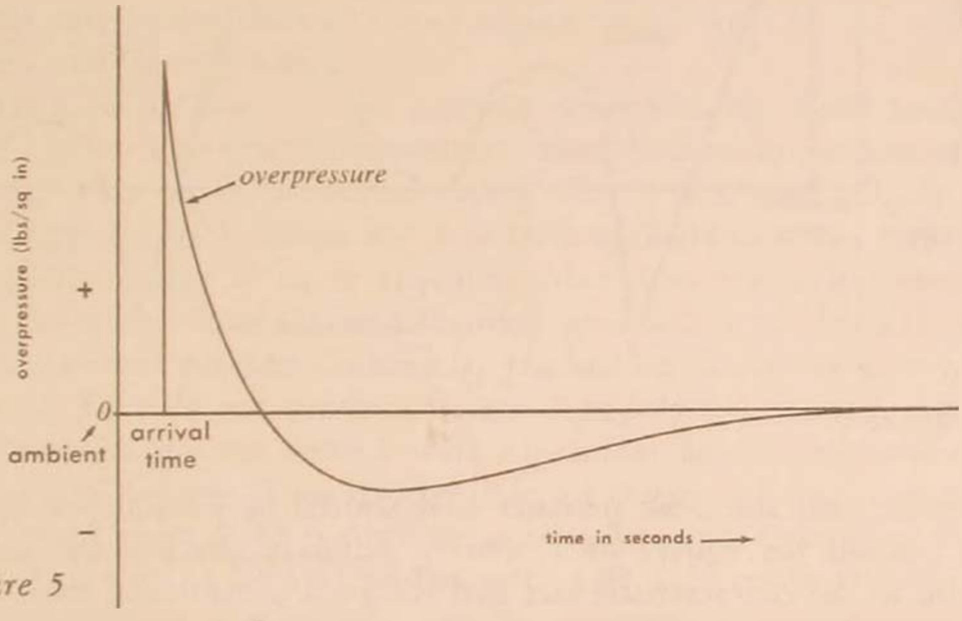


Figure 5

Notice that the time is measured in either fractions of a second or in whole seconds, depending upon the size of the explosion. The pressure is measured in units of overpressure, pressure over and above the prevailing or ambient atmospheric pressure. Notice also that the unit chosen is pounds per square inch. The graph is not the actual graph from any specific explosion but rather is a typical graph that would be produced by the blast wave from any explosion. The first event is a very rapid, precipitous, almost instantaneous rise in the overpressure. This is the shock front. Immediately the pressure begins to fall and continues to fall until it reaches the prevailing ambient pressure. It then continues to fall, so that there is a phase of negative pressure where pressures are below the ambient. The peak pressure is the highest overpressure attained. The portion of the blast wave where pressures are greater than ambient is the positive phase of the blast wave, and the portion of the blast wave where pressures are less than ambient is the negative phase. Accompanying this blast wave will be a wind which will be in one direction during the positive phase and will reverse itself during the negative phase. This blast wave is not a sound wave. It travels with speeds much greater than the speed of sound. A sound wave is not characterized by a precipitous rise in overpressure at its onset. Thus a blast wave is characterized by an abrupt discontinuity in pressure which has a time of rise measured in microseconds, while the sound wave has a gradual and repetitive rise in pressure.

Figure 6 is a typical pressure–time graph of a sonic boom. The pressures are measured on the ground and are produced by an aircraft in supersonic flight. Notice first that this pressure wave starts with a precipitous rise to a peak pressure in a manner somewhat similar to that of the blast wave. How-

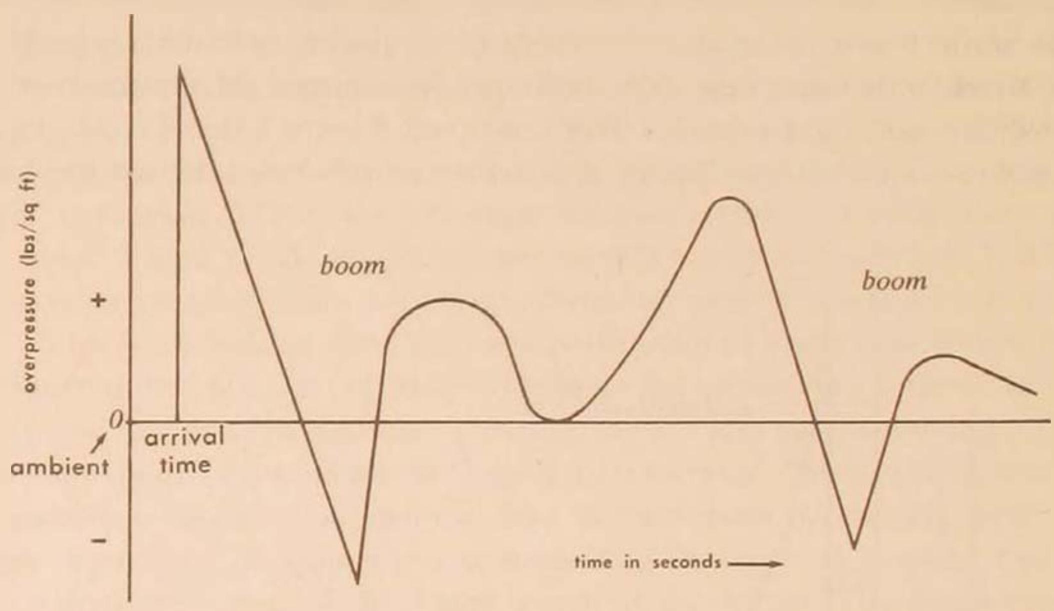


Figure 6

ever, notice that the peak pressure is measured in pounds per square foot, not in pounds per square inch. This is standard practice and merely calls attention to the characteristic fact that the peak pressures of sonic booms are usually much less than the peak pressures of explosions. After the peak pressure has been reached there is a negative pressure followed by a second peak. This series really constitutes one shock wave. Notice that there are two peak overpressures and two booms may have been heard. Following this first shock wave there is a second, less energetic shock wave in which two booms may again be heard. Sometimes no booms are heard.

The only similarity between an explosion and a sonic boom in the mode of energy transmission is in the formation of a sound wave and the formation of a shock wave. There is no doubt that the sounds are similar. The shock waves, although similar, are certainly different in at least two respects:

1. They have a different time–pressure history.
2. The order of magnitude of the peak pressure is generally much less in the shock wave produced by supersonic aircraft flight.

effects produced by explosions and sonic booms

Explosions, depending upon whether they are nuclear explosions, chemical explosions, boiler explosions, or other explosions, may cause one or more of the following effects:

1. Impact damage through fragments hitting a target.
2. Damage when the shock front causes movement of a body which in turn may shatter it.
3. Damage when a large blast wave entirely encompasses a building and crushes it.
4. Damage when the wind accompanying a blast wave causes objects to be picked up and moved in the manner of missiles. This flying debris may cause damage.
5. The blast wave may cause vibration of a structure in such a manner that its own vibration causes it to shatter.
6. The thermal energy may set fires, weaken a structure, kill or damage living things.
7. Initial radiation, such as gamma radiation, may kill or damage living things.
8. Fallout may kill or damage living things.
9. Craters may destroy targets.

In a sonic boom, most of these methods for producing effects upon other objects are absent. The sonic boom cannot cause damage by producing flying fragments from its casing. It has no casing. There is a wind accompanying the shock wave of a sonic boom, but it is most unlikely that this wind would be of sufficient velocity to cause anything more than minor inconvenience. Sonic booms cannot cause damage through production of thermal radiant energy. They cannot produce damage by production of radiant energy other than thermal. They do not produce fallout. They do not crater the ground. They do, however, produce a shock wave which may have sufficient energy to do some forms of damage. Thus it is possible for the sonic boom wave to have an energy in the order of 33 pounds per square foot at a distance of 280 feet from an aircraft moving with a speed of mach 1.02. One could get even closer to an aircraft moving at supersonic speeds, and one could consider greater speeds than mach 1.02. In these cases it is conceivable that peak pressures in the order of 144 pounds per square foot might be encountered. These are indeed unlikely.

Even if a pressure of 144 pounds per square foot were encountered on the ground, we would only be talking about one pound per square inch, translating these figures to the figures used when talking about explosions. One pound per square inch can certainly do damage. It can shatter windows; it might crack plaster. It would not be of great military importance because the damage accomplished would be insufficient for military purposes. It might indeed be sufficient to cause significant civil destruction. The mechanism by means of which this damage is caused is not always clear. In the case of breaking glass it may be that the natural period of vibration of the glass is matched by the frequency of the shock wave and thus the glass is destroyed by its vibration rather than by the translational pressure imposed upon it. Regardless of how the damage is accomplished, it is true that the shock wave from a sonic boom can cause some damage which will be considered minor or major depending upon the point of view of the people involved.

It is thus clear that a sonic boom again differs quite markedly from an explosion in that it is limited to doing damage through two possible effects instead of the numerous possible effects of an explosion.

From the above discussion it is concluded that a sonic boom is not an explosion. If the dictionary definition of an explosion is accepted, then clearly a sonic boom is not an explosion because its origin is much different from the origin of an explosion. If the argument is based upon the means by which energy is transmitted from the source of disturbance to the target, then clearly there are major differences between a sonic boom and an explosion. If the argument is based upon the effects produced, again there are major differences. Where similar effects may be produced, the order of magnitude of the effects from a sonic boom is very much less than from typical explosions.

Warfare Systems School

Reference

Daum, Fred L., and Norman Smith. *Experimental Investigation of the Shock Wave Pressure Characteristics Related to the Sonic Boom*. Wright Air Development Center, August 1955.

The Quarterly Review Contributors

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Brigadier General Benjamin G. Holzman (B.S., M.S., California Institute of Technology) is Assistant Deputy Commander for Research, ARDC, and Commander, Air Force Research Division (ARDC). He was on the faculty of California Institute of Technology for three years, a meteorologist with airlines and the U.S. Department of Agriculture for three years, then Meteorologist-in-Charge, Master Analysis Center, U.S. Weather Bureau, 1939-1942. While on special assignment in Labrador he was commissioned a major in the U.S. Army and commanded the weather squadron at Goose Bay. In 1942 he was selected for research and intelligence work with the Soviet Hydrological and Meteorological Mission in Washington. In 1943 he became Chief, Long-Range Forecasting Section, Hq AAF. From January 1944 to May 1945 he served as Deputy Director, Weather Service, Hq U.S. Strategic Air Forces, first in London, then in Paris. He was Meteorological Adviser for atomic bomb tests at Alamogordo, Bikini, and Eniwetok. Other assignments have been as Research and Development Officer, as Chief of the Geophysical Sciences Branch, and as Assistant for Atomic Energy, at Hq USAF; as Deputy Commander for Research and Development, then Chief of Staff, at the Air Force Special Weapons Center. In 1955 he became Director of Air Weapons and later Director of Research, Hq ARDC. He assumed command of Air Force Office of Scientific Research in October 1958. A 1952 graduate of the National War College, General Holzman has served as Vice President of the American Meteorological Society and as President of the American Geophysical Society. He is the author of numerous and widely published technical papers.

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Lieutenant Colonel Donald F. Martin is assigned to the Office of the Assistant for Coordination, DCS/Plans and Programs, Hq USAF. After completing flying training in 1943, he was assigned to the Eighth Air Force and flew thirty combat missions. Postwar assignments have been as a student at the Statistical School, Harvard University; in the Comptroller's Office, Hq AMC; again in England 1948-1951; in the Directorate of Flight Safety Research, Norton AFB, 1951-1954; as a student, Air Command and Staff School, 1955; and as Deputy Director of Operations, 38th Air Division, Strategic Air Command.

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Dr. James A. Fraser (M.A., Ph.D., Columbia University) is Physical Science Analyst, Warfare Systems School, Air University. Born in the Union of South Africa, he moved to Canada, graduated from the University of Alberta, completed his advanced degrees at Columbia University in 1939, and in 1941 enlisted in the Royal Canadian Air Force. He was commissioned the same year and attended the Navigation School, RCAF, then served as Navigation Instructor and Assistant Chief Instructor at Malton, Ontario. In 1944 he attended the British Empire Central Flying School, Hullavington, England, then was Chief Ground Instructor in the Centralia Training School for Pilots and in the Uplands Flying Training School, Ottawa, until his discharge from the RCAF in 1945. In 1949 while head of the Science Department, State Teachers College, Troy, Alabama, he was commissioned in the USAF Reserve. He served on active duty with the Evaluation Staff, Air War College, 1951-1953, and was appointed to his present position in 1955. He is a graduate of Air Tactical School, Air Weapons Course, and Air War College.

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