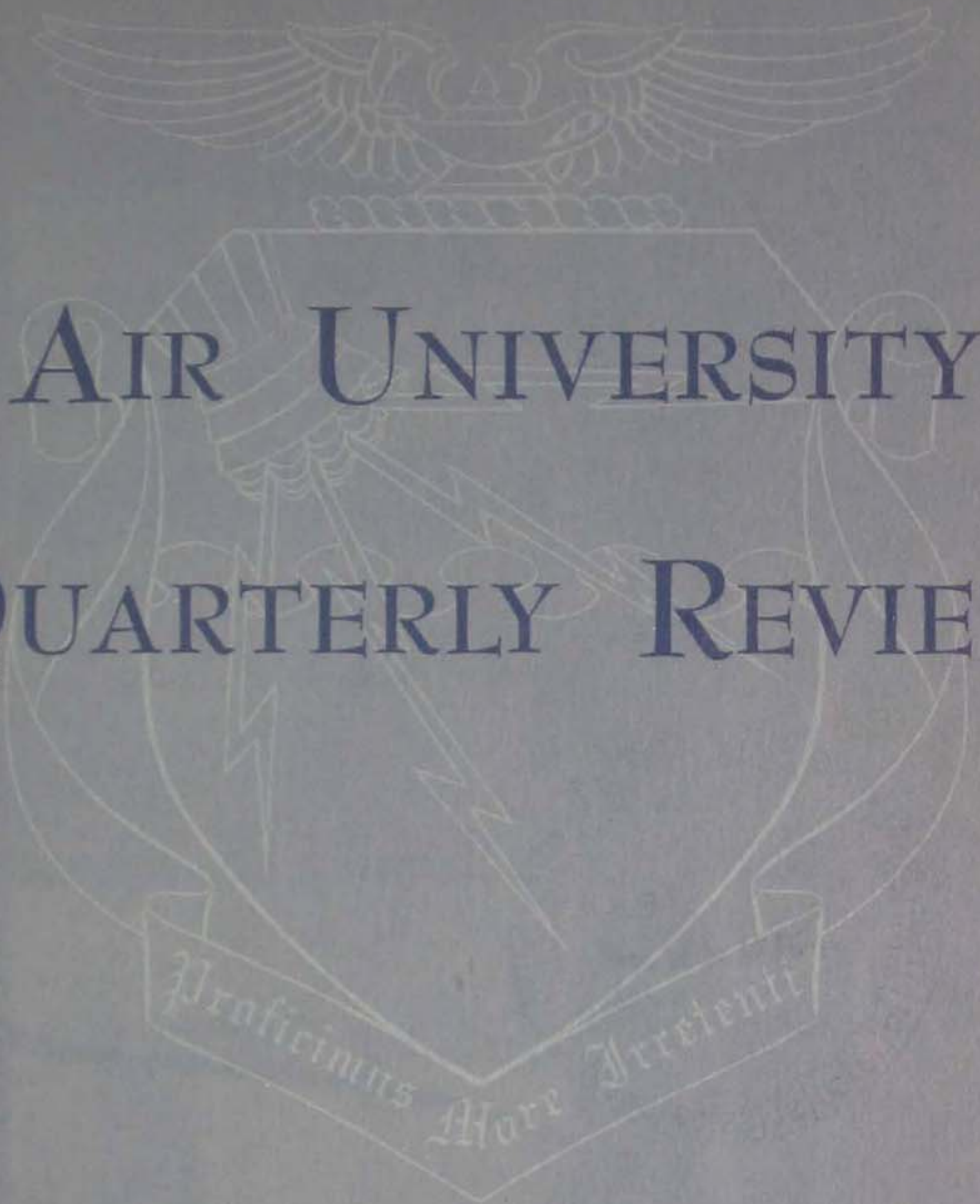
AIR UNIVERSITY QUARTERLY REVIEW



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IN MY OPINION

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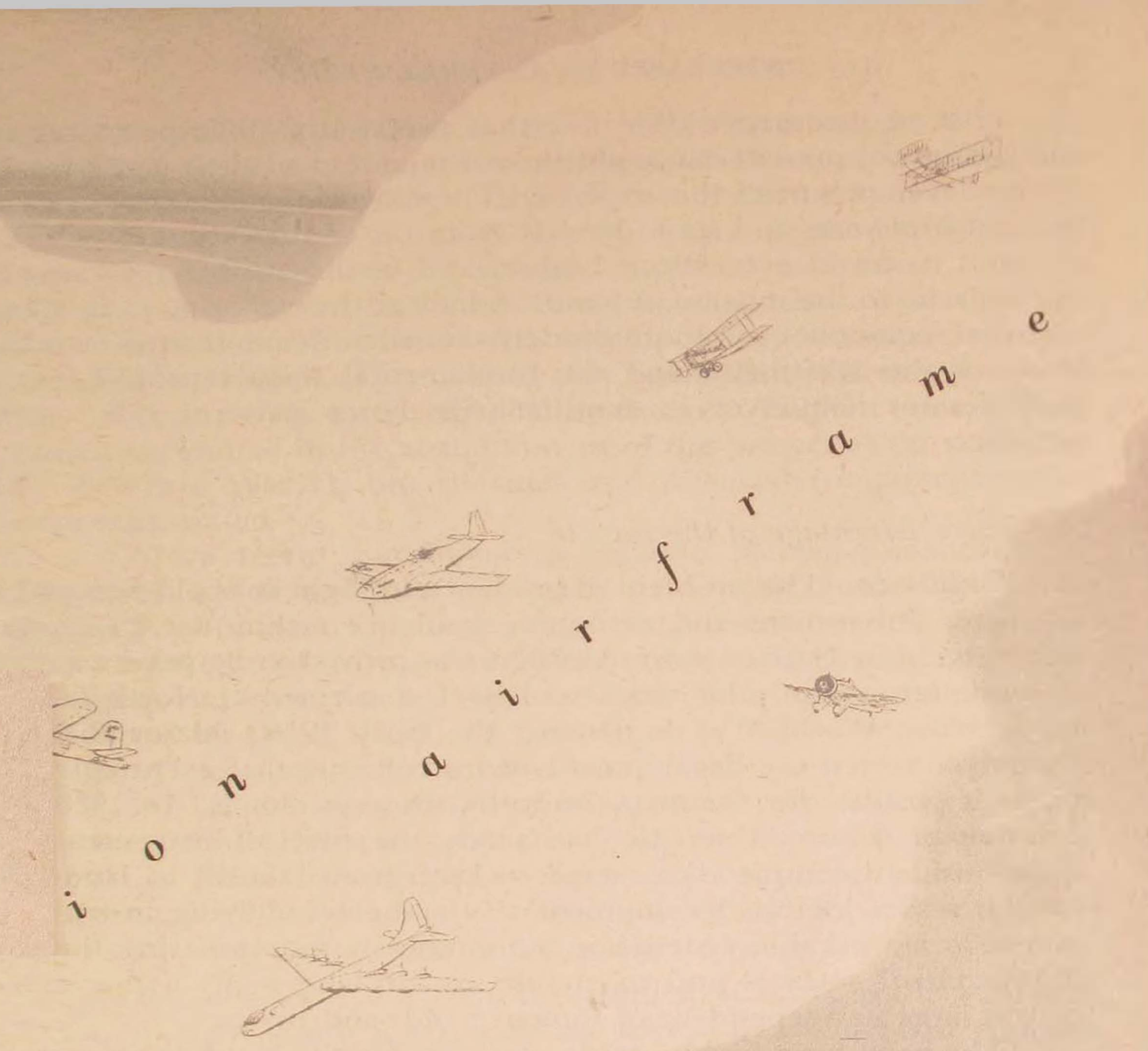

Missiles in Perspective

COLONEL CLAUDE E. PUTNAM

PRACTICALLY everyone has read and heard a great deal lately about missiles—both ballistic and aerodynamic—constituting the ultimate weapon systems, about fighters and bombers becoming obsolete, and even about the death of the flying Air Force. We must agree that missiles are welcome and compatible additions to the Air Force family of weapons, but it is incumbent on all airmen to keep them in perspective. One useful method for doing this is to consider factually and dispassionately the kinship between aircraft and missiles—where they came from and where we go from here—in the evolution of the military art.

It is an incontrovertible fact that practically all important components of present-day sophisticated missiles had their genesis in the development of the airplane. These developments cover a span of fifty years and stem directly from the airman's insatiable demand to travel ever faster, higher, and farther with payloads appropriate to the mission at hand. A look at the evolution of the essential components of all modern missiles demonstrates the truth of this statement, and the fundamental missile problems thus frame themselves in familiar Air Force patterns of experience.

Air Force parentage of the missile

Guidance. The problem of guidance in flight is as old as the airplane. Instrument and automatic guidance techniques began to emerge shortly after powered flight was proved to be practical. A crude automatic pilot was tested by U.S. airmen at North Island before World War I. During the early 1930's Major Bill Ocker pioneered the development of instruments that eventually made it possible for the airplane to fly through clouds. In 1929 Lieutenant Jimmy Doolittle had made the first all-instrument flight inside a completely covered cockpit, from take-off to landing. It was a logical development to tie the blind-flying instruments to a workable system for automatically manipulating the flight-control surfaces and to enable an airplane to fly a preset course largely independent of human hands and brains.

The need for a highly stable platform for the Norden bombsight of the mid-1930's spurred development of more versatile automatic pilots, and the electronic autopilot provided a satisfactory solution to this problem. Parallel developments in radio-control techniques enabled remote control of this more sophisticated autopilot. The radio-controlled drone was born in the early

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1940's, enabling airplanes for the first time to be maneuvered and landed without a human being aboard. These very same techniques were soon applied to guided bombs during World War II, e.g., the tarzon and razon. Thus we clearly see the emergence of the guidance and control systems employed in modern missiles. It is a little-known fact that "Boss" Kettering had a pilotless airplane, which could have been developed into a weapon carrier, flying at Muroc Lake at a time that preceded the development of the German V-1 by a very healthy margin. Higher priority programs resulted in the abandonment of the project at the outbreak of World War II, but the idea and essential components were demonstrated.

More recent developments include inertial-guidance techniques, which had their inception in the Air Force Navaho in 1946, and star-tracking techniques which were developed for the Air Force Snark in the late 1940's. Also in 1946 guidance techniques employing rocket engines which swiveled on gimbals were evolved for the MX-774, the forerunner of the Atlas missile. Advanced electromagnetic wave control techniques were conceived in 1947 for the air-to-surface missile Rascal. Advanced swiveling engine control systems were developed for the surface-to-air Bomarc in 1951. It is significant to note that all these developments sprang directly from the aircraft industry and its subcontractors to meet operational requirements laid down by the Air Force.

Propulsion. Here again the problem is as old as the airplane. The Wright brothers perfected the first practical airplane propulsion system, permitting their epic flight at Kitty Hawk, North Carolina, on 17 December 1903. More advanced engines emerged hand-in-hand with the development of airframes that could carry and utilize the increased powers. One need only cite the Liberty engine of World War I and the turbosupercharger of 1928 to demonstrate the Air Force's long history of experience with propulsion problems. Refinement of Englishman Frank Whittle's jet engine introduced the jet age to U.S. aviation. Rocket engines followed closely on the heels of World War II with our dramatic improvement in the design and thrust output of the German V-2 rocket engine. The development of the first successful American large liquid rocket engine was initiated for the Air Force Navaho in 1946. The Navaho also spurred the development of the first practical ramjet engines which, after painstaking improvement, became the sustainer power for the operational Bomarc.

Manned airplane applications for the rocket engine were not ignored. On 14 October 1947 USAF Captain Charles E. Yeager blasted the Bell X-1 rocket-powered research plane through the sound barrier for man's first attainment of supersonic speed. Major Arthur Murray in the X-1A sister ship attained the then unprecedented altitude of 94,000 feet in 1954. In September 1956 Captain Milburn G. Apt took the X-2 to a speed of 2178 miles per hour before structural failure cost him his life. This aircraft had previously established an altitude record of 126,000 feet. The X-2 provided the first continuous throttling of high-thrust liquid-oxygen-alcohol engines and made important contributions to missilry. These spectacular achievements demonstrate how airmen have traditionally operated at and beyond the very threshold of knowledge. Another example is the Rocket Engine Advancement Program. Initiated in 1951, it has provided the basis for all large oxygen-hydrocarbon engine work in the United States. Future refinements and new developments are sure to follow. Probably before the end of this year Captain Iven Kincheloe will have a look at our old planet from an altitude of some 100 miles, and it is no secret that the X-15 which will take him there and its follow-on aircraft will be striving for orbital speeds.

Airframes. Airmen have been wrestling with the knotty problems associated with obtaining required structural strengths at the lightest possible weights since the very inception of the airplane. They progressed through the wood, fabric, and wire of the earliest airplanes, through the all-metal monocoque construction of the 1920's, to the extremely efficient weight-strength ratios found in modern missiles. They have also long been in the forefront of adapting new materials—new metals and new bonding techniques—to the peculiar requirements of the airframe construction. Solving the strength and vibration requirements for transonic flight and progress made toward developing heat-resistant materials for operational speeds close to the heat barrier attest to the success of their endeavors. Indeed in this area it appears that we may have approached the practical ultimate in strength of materials. Experts state that no important advances have been made in developing new materials during the past ten years. Rather the advances have been in ingenious design and fabrication techniques, which of course have largely stemmed from the airframe industry. Work on the MX-774, initiated in 1946, and its successor the Atlas in 1951, provided the basis for all ultra-lightweight tank structures employed in modern missiles.

General Orval Cook, President of Aircraft Industries Association, disclosed recently that there are 43 Department of Defense missile projects now under development or in production; and in every missile the aircraft industry supplies the airframe, propulsion, guidance system, or a major component. To do this, it draws on the same hard-won and laboriously accumulated reservoir of scientific and technical knowledge that brought manned aircraft to their present advanced state, as well as on the one-hundred-million-dollar production facilities which the industry has built for the ballistic missile alone. All told, the aircraft industry has spent a billion dollars on research and test facilities since World War II and plans to spend another billion during the next five years. Airmen everywhere should keep these facts in mind as a partial but telling answer to the question of where the modern American missile came from.

Concepts of Employment. The foregoing has attempted to demonstrate how the development of missiles is a natural evolution from the airman's quest for greater speeds, ranges, and altitudes. The concept for the operational employment of these new weapons likewise finds the airman in a familiar environment, backed by years of experience with the subtle problems involved. The resources, skills, and techniques for the production of necessary target data have long been available in the Air Force. Calculations of required weights of effort to achieve acceptable probabilities of success, problems of reaction times, and the complex timing of world-wide operations to attain maximum tactical advantages are familiar exercises to the airman. Another prerequisite to successful missile application is reconnaissance—prestrike, poststrike, and follow-on surveillance. In this important field the airman has been active since the first utilization of the airplane as a military instrument. He has evolved techniques for prehostility reconnaissance, postattack damage assessment, and data processing which exist nowhere else. Of course the capabilities to employ long-range missiles have resulted in new requirements in this field, such as refinements in the geodetic datum plane and investigations of gravitational anomalies. The Air Force has long had an active interest in these studies.

Airmen pioneered and refined concepts of the three-dimensional and global nature of modern warfare. Strategic bombardment of vital elements of an enemy's heartland to end his capability to conduct effective military operations was conceived by forward-looking airmen. The possibility of a counter-nation—as distinguished from a counter-force—strategy was early recognized. These concepts are entirely compatible with the nature of missiles.

The Air Force concept for the operational employment of missiles is that they will be assigned specific tasks in emergency war plans just as soon as they have demonstrated a reliable capability to perform a given task better than the older weapon system which they replace or supplement. This inevitably means that we will have an evolutionary rather than a revolutionary change in concept. The first strategic missiles will be directed against relatively soft, heavily defended targets where extreme accuracies and yields are not stringent requirements and where fast reaction times and invulnerability to enemy defenses are important. The smaller, harder targets will still be left to the manned bombers, which can destroy them more efficiently.

As future developments in missiles improve their reliability, accuracy, and yield, they will be programed against targets that are consistent with their capabilities at any particular point in time. As for tactical missiles it appears that their inherent inflexibility must be complemented by the flexibility of manned airplanes for as far as we can see into the future. Defensive missiles will provide a powerful addition to the capability to defend against air attacks, but for a considerable period into the future they will complement the manned interceptor. Surface-to-air missiles cannot operate beyond contiguous radar coverage. On the other hand manned interceptors with their own airborne radars can perform effectively against targets that have been spotted by early-warning techniques but that have not yet entered the zone where continuous radar tracking is possible.

complementary nature of the missile

Missile applications fit quite naturally and logically into the framework of the traditional Air Force roles and missions. This is not to say that the airman fails to recognize the formidable problems involved in integrating operational missile systems into the active inventory. The Air Force is charged with the grave responsibility for maintaining an ever-ready combat capability that can be put into action literally on only moments of notice. Our offensive forces must be capable of instant retaliation in the event of attack. This is the deterrent to war which is the cornerstone of our national policy. Our defensive forces must be ready every minute of every day to inflict maximum attrition on enemy attacking forces. Any gaps in these capabilities caused by faulty phasing of new weapons into the active inventory could well be fatal. Likewise a failure to maintain continuously a force structure that embodies the proper balance between offensive and defensive capabilities and the required degree of flexibility could have disastrous consequences.

These considerations suggest two important conclusions: First, that for an indeterminate period the Air Force will have a mixed complement of more or less conventional manned vehicles and unmanned and manned missiles. The inherently limited flexibility of missiles must be offset by the more flexible manned airplanes, and programs must be implemented in such a way that missiles are integrated without creating even a temporary hiatus in our day-to-day combat capability.

The second conclusion stems directly from the first: The commander charged with the operational control of this mixed system has a tremendous responsibility as well as some tough problems. His judgment in determining how best to employ the most effective combination of manned airplanes and missiles in a given situation will be of crucial importance. He should be accorded an appropriate freedom of action in determining when an older weapon system becomes obsolete and when a new weapon system achieves all the necessary prerequisites for being phased into the active inventory. He must also have at his disposal the vast communications and control facilities to enable him to conduct operations on a global basis. And perhaps most important, he must be able to draw freely and almost automatically on a broad background of experience in three-dimensional global war.

human factors

The adaptation of man to the new and still somewhat mysterious environment high above the surface of the earth has proceeded along with other aeronautical advances. As soon as it was discovered that it is cold up there and that keen eyesight and certain psychological attributes are necessary to the successful operation of airplanes there, the flight surgeon entered the picture and has been doing stalwart service ever since. The list of his contributions is quite as impressive as those of the propulsion and airframe engineers. They range from protective clothing in the very infancy of flight, through safety devices during World War I and oxygen equipment in the 1920's, to air conditioning and pressurized cabins in the 1930's. The jet age saw the evolution of anti-G suits, crash helmets, and continuous refinements in the earlier equipment.

The flight surgeon's exhaustive investigations into the physics of the upper atmosphere and man's physiological reactions to this hostile environment furnished a sound foundation for the development of the equipment required to enable man to probe the limits of the sensible atmosphere and to invade space itself. Air Corps Captains Orvil A. Anderson and Albert W. Stevens set the world's altitude record of 72,395 feet in a hermetically sealed balloon on 11 November 1935. They were followed in 1957 by Major David G. Simons who attained a height of 102,000 feet and stayed above 100,000 feet for almost 24 hours.

Current Aeromedical Laboratory studies involve such problems as weightlessness and its nutritional, circulatory, and psychological implications. Their people are also investigating the effects on the human being of confinement in a small container for the extended periods which space flight will involve, as well as shielding against cosmic rays and nuclear radiation. Air-conditioning requirements to counter the blistering heat of the ionosphere have received intensive attention. Colonel John P. Stapp's widely publicized experiments on the tolerance of the human body to acceleration and deceleration constitute important contributions.

WHAT should all this suggest to the airman? The answer seems quite clear: Man is headed for outer space, and the missile is just another step in the long process of evolutionary development which will allow him to get there. Just as the evolution of the airplane furnished the basic technology for the missile, so will the art of missilry make important contributions to the development of the space vehicle. This is not to imply that the airman will in any way disparage the military implications of the missile or fail to continue its vigorous development and improvement to achieve the benefits of its maximum capabilities. It is to suggest that while doing these things to the best of his ability he should direct his aspirations toward the higher achievements and never lose sight of the farther horizons. This is part of the tradition and heritage of the airman.

There is indeed something symbolic about that dead dog hurtling overhead at the fringes of outer space which should be portentous for all airmen. Relatively soon it will be replaced by a live human being with a very conscious mission in mind, and the end is not yet in sight. Technology is rapidly reaching for the moon, Mars, and Venus, and the mysteries of our universe are sure to unfold. This is a dazzling prospect for the airman and a magnificent duty for the Air Force, for which it is soundly prepared by virtue of the building blocks painstakingly and laboriously accumulated during fifty years of progress.

Air War College

Missilemen—Present and Future

COLONEL ALLEN W. STEPHENS

WHEN General Nathan Twining was Air Force Chief of Staff, he once laid before the Congress and the taxpayers a new military fact of life that cannot be circumvented:

> In the past, we have kept modern by replacing obsolete and obsolescent aircraft and associated equipment with newer models of the same general type. In other words, we have gone down one road. Today as we develop and prepare to introduce guided missiles into our primary combat units, we have no choice but to go down two at the same time.
>
> The introduction of missiles causes this kind of difficulty with all three services, but it is a particularly acute problem for the Air Force. Development and introduction of guided missiles into each of our major force areas must be done in order to gain the tremendous advances in strategic, air defense and tactical weapon capabilities that missiles provide.

General Twining's testimony before the members of the Senate Appropriations Committee was in the nature of a plea for funds to sustain the entire Air Force program, including research, weapons, equipment, facilities, and people. His proposition promised to be inescapably expensive, but there is obviously no alternative to the "dual road" responsibility of the Air Force. With international tensions continuing as they are, the Air Force cannot afford to drop its guard by weakening the Strategic Air Command. Yet the potential threats posed by Soviet scientific breakthroughs in missile development make it mandatory that more missile power go into our deterrent punch. The deterrent capability of SAC must be kept and improved while the Air Force goes full blast ahead toward development of a "Sunday punch" with operational ballistic missiles.

It is not my intention here to explore the political or economic impact of this circumstance, as fascinating and tempting as such a venture would be. It is necessary, however, that any discussion of men and missiles, as we know them both today, take its departure from the "two road" fact of Air Force life as stated by General Twining.

His premise has the most vital significance when applied to the people that make up our Air Force—aircraftmen or missilemen. The laws of nature are such that it still takes nine months to produce a new-model human being. It takes a little longer to produce an original ballistic missile prototype. But the original production time for human or missile is much less than the time involved in teaching a new airman recruit all he must know to become a full-fledged missileman.

The same has been true for a long time in training the people who make SAC the war-deterrent force it is today. It has been a giant struggle to find and train enough technicians to maintain and operate the complex equipment and weaponry of our B-47 and B-52 manned-aircraft force. It has been an even greater struggle to keep these technicians in uniform after they are fully trained.

Ralph J. Cordiner, President of General Electric Company and Chairman of the Defense Advisory Committee on Professional and Technical Compensation, had this to say about the problems of technology and the demand for technically skilled people in his report to the Secretary of Defense:

> Research, development and innovation on an expanding scale have become a way of life, not only in industry but in the military field as well. The dramatic technological changes symbolized by nuclear energy, electronics, supersonic aircraft and missiles systems are causing an explosion of change and growth in almost every social, political and economic institution, including the military establishment. . . . The Armed Forces are competing with the civilian economy for a relatively scarce resource. Technically skilled personnel are in great demand in this expanding, technically-powered economy . . .

This competitive demand for expert technicians is the point of departure for any analysis of the human element and its impact

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on operational performance of unmanned ballistic missiles. And it prompts some perplexing questions about the missileman resource:

- Where do we stand today in development of the missileman?
- What qualifications must the missileman have?
- From what source do we get the missilemen of tomorrow?
- How many must we have and how soon must we have them?
- How long can we keep them after we get them trained?
- What will be the conditions of service for the missileman, compared to Air Force life as we know it today?

The Air Force literally has been running a carrousel, with thousands of trainees going round and round after one another and with all too many skilled and experienced technicians dropping off at the first opportunity into the more lucrative jobs offered by industry. Thus the second road promises to be at least as rocky as the older, well-traveled one. And there is the added complication that, at least in the beginning, the people for manning of both systems must come from the same existing resources.

Lead time for training has always been a limiting factor in developing and employing new weapon systems, particularly in recent years with the rapid advance of technology and the resulting complexity of modern military hardware. The problems of complexity and training lead time are compounded in the ballistic missile program because organization and training of operational units must proceed simultaneously with research, development, and testing of the missiles. Most of the missile know-how is now concentrated in the laboratories, production plants, and test facilities. Research, development, and testing must go on, however—even after the first and subsequent operational "birds" are pointed upward and cocked for potential firing in anger.

To establish the earliest operational capability with ballistic missiles, therefore, the Air Force must breed its missilemen and its missiles at the same time, so to speak. Officers and men of the Air Force are now sprinkled throughout all contractor plants to learn what can be learned only by "over-the-shoulder" training. Many more will be entered into training at these facilities in the next few months. They will work in the laboratories, on the production lines, and at the test sites alongside engineers who themselves are still studying and experimenting with techniques of rocketry, guidance, fuel systems, and the like. There is no other way to produce the missilemen for our initial operational units. There is not time to wait until the full cycle of research, development, and testing has been completed, as we would do normally with a new aircraft model.

The most significant human limitation on operational performance of ballistic missiles, then, is the incubation time from no missile knowledge to perfected technical competence for the many missilemen we need. The Air Force is well along, after months of preparation, toward General Twining's second road—the creation of an operational ballistic missile force.

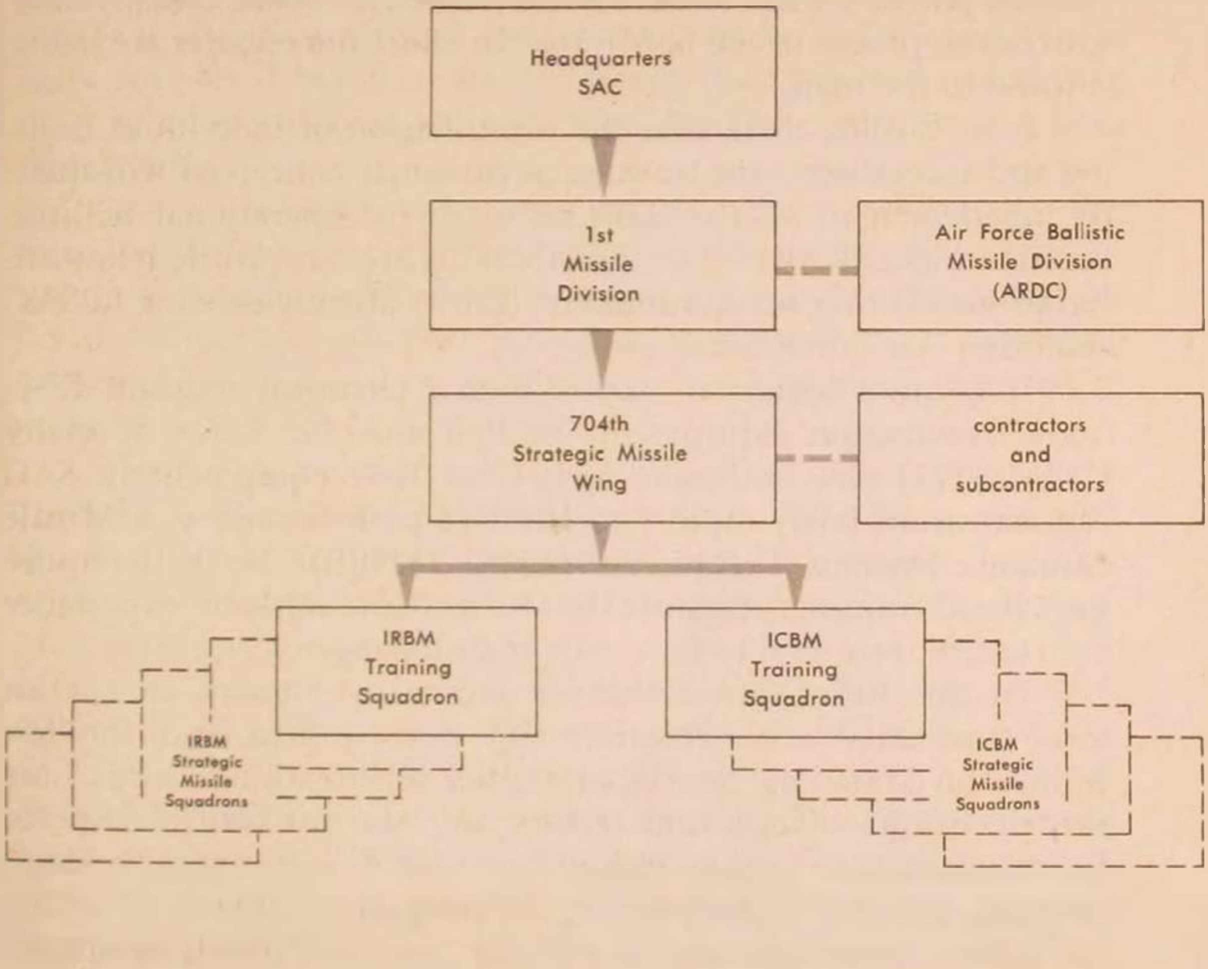
The 1st Missile Division was organized at Cooke Air Force Base, California, in July 1957 by the Ballistic Missile Division of Air Research and Development Command. This first-of-its-kind organization was given the dual mission of training Air Force missilemen and developing an initial operational capability with intermediate-range and intercontinental ballistic missiles. In July 1957 the 704th Strategic Missile Wing was organized, also at Cooke, as the "incubator" unit for the first ballistic missile squadrons. The plan was that ARDC would create operational units concurrently with development and testing of the hardware and turn the fully trained units over to SAC coincident with delivery of fully tested, ready-to-fire operational missiles.

Events overtook this plan, and on 1 January 1958 the 1st Missile Division and its fledgling units were transferred to Strategic Air Command, under the command of Major General David Wade, formerly Chief of Staff at SAC Headquarters. With assistance from ARDC's Ballistic Missile Division at Inglewood, California, Strategic Air Command is pulling out all stops to expedite training of missilemen and to accelerate creation of the first operationally ready ballistic missile units.

An IRBM training squadron has been activated at Cooke Air Force Base. It is the task of this squadron to supervise training of all IRBM units. The first two operational Air Force IRBM squadrons also have been activated, the 672d Strategic Missile Squadron (Thor) at Cooke AFB and the 864th Strategic Missile Squadron (Jupiter) at Huntsville, Alabama. Personnel for all these squadrons have been selected and are now in various stages of training. The ICBM training program has not progressed quite as far, but it will follow along in similar manner in phase with delivery of the first ICBM weapons to launch sites.

In a combined effort with the missile contractors and the Ballistic Missile Division of ARDC, the 1st Missile Division will supervise the training of all IRBM units and will train and command all ICBM units. The IRBM units will be deployed overseas by Strategic Air Command upon completion of training. Most of the training in the early stages will be done by the contractors in their plants. This is the training of individuals in the variety of special skills required. As soon as facilities are completed and missiles and associated equipment are delivered to Cooke AFB, unit training for Thor, Atlas, and Titan missiles will be accomplished there. Individual training on the Jupiter missile will be conducted in part at the Army Ballistic Missile Agency at Huntsville, Alabama. Ultimately it is expected that a substantial portion of the Jupiter training will be done at Cooke AFB.

Ballistic Missile Training Organization



The individual-training program has been developed to a large degree by the contractors concurrently with development of the missiles. This is standing procedure, for the design of the missiles and their component parts is predominantly influenced by the ability of ordinary people to maintain and operate them.

During a recent visit to the Convair plant at San Diego, 1st Missile Division officers asked Jim Dempsey, Chief Atlas Project Engineer, this question: "The general idea seems to prevail that all missilemen must be in the genius category—what is your view as to the kind of people we will have to have in our operational units?" Mr. Dempsey's answer was that missilemen could and would be of the same ilk as those we have trained by the thousands in the maintenance and operation of B-47's, B-52's, and other modern aircraft. He reiterated that design criteria on the Atlas and other missiles are oriented to personnel qualifications and limitations and that qualitative personnel requirements are being developed jointly by the contractors and the Air Force concurrently with development of the hardware. In effect the missiles are being tailored to the man.

It is feasible, then, that the combination of individual training and specialized unit training as presently conceived will qualify missilemen in all the skills required for operational ballistic missile units. Many of these missile skills are new, while many are variations of other occupational specialties already existing in SAC and other Air Force commands.

It is quite logical to expect that a technical sergeant Electronic Navigation Equipment Technician (Air Force Specialty Code 30171) now maintaining B-47 or B-52 equipment in SAC can transition fairly rapidly to effective performance as a Missile Guidance Systems Technician (AFSC 31170B). He will require specialized training, of course, but his existing skill and experience are readily transferable to missile maintenance.

At the outset our military missilemen of today, except for those associated with research and development and the few trained on Matadors, Snarks, and other air-breathing "birds," are the electronics officers and technicians, the fire-control experts, the mechanics, and other technicians now in our inventory, most of whom are in SAC keeping the manned aircraft flying. They are the best we have been able to get and keep, and they have already proved themselves. These trained and experienced aircraftmen, both in SAC and elsewhere in the Air Force, are the only *immediate* resource of people to be retrained into ballistic missile skills.

Here, of course, we run head-on into the crucial aspect of the "two roads" dilemma: How can we avoid weakening our existing manned-aircraft deterrent force in the process of manning ballistic missile units? Our only recourse is to nurse along our existing manned bomber and fighter force, weaning some of its offspring gradually to make up a nucleus for fledgling ballistic missile units. But for every man we take out of SAC bomber units, we must train a replacement—at least until ballistic missiles actually begin to supplement manned bombers in the SAC emergency war plan.

Where do we find the many other missileman candidates we must have to build up the ballistic missile operational force? The answer is the same place we found the SAC men—on the streets, on the farms, or wherever Air Force-motivated youngsters come from. The missilemen of the future are the ordinary, but alert and trainable, young men who stop and read the recruiters' signs. There is no other resource. But if they can master the intricacies of the thousands of gadgets that make a B-52 capable of delivering an H-bomb to Soviet targets, they can learn what they need to know to boost ballistic missiles off the ground and onto target track.

So now we come back to the laws of nature and science. We can raise the manpower and we can produce the missiles. We can teach the men to do all the things that have to be done to countdown and fire the missiles. But we must have them in vast numbers, and we must allow for the training lead time required to make them reliable and competent.

The trick comes in keeping them once we have trained them. It has been difficult to hold them in uniform up to now, even with the traditional challenge, excitement, and satisfaction that have always been inherent in preparing for and taking off with a flight of bristling B-47's or B-52's. In missile units the atmosphere is certain to be one of even greater challenge. But the training launches will be much less frequent than aircraft flights, and each firing will be preceded by long periods of tension and strain. Crews will find themselves sitting at consoles and working in isolated underground facilities where everything is done by remote control. Boredom and monotony will be a constant companion except for the times when missiles are actually being fired. Multiple-shift operations will be required to maintain a state of constant readiness. In many cases the men will be separated from their families.

All these things will have to be overcome by an enlightened, new approach to the problem of individual motivations. We cannot afford to stand by and hope that trained missilemen will stay with us. We must be able to attract thousands of officers and men into a missile career and keep them there for at least an eight-year tour. To do so we must make their life as missilemen the best the country can offer.

How do we do this? We do not know the complete answer yet. We do know that we cannot expect intelligent, technically qualified experts to submit to the privations and restrictions of a missileman's life for pay that is less than they can get right on the same launch pad in civilian status from any one of the contractors. We know also that the man of missile caliber will not tolerate shabby, overpriced quarters for his family when he can provide decently for them by shucking his uniform. Nor will he submit to prolonged separation from his family without suitable compensating reward. We know these things from recent and vivid experience.

We believe, on the other hand, there are plenty of men who can be motivated to follow the career of a missileman if they are offered conditions of service and life that measure up to alternative civilian standards. This has been the guiding philosophy behind all that has been done to develop the first ballistic missile operational and training facility at Cooke Air Force Base. Army mobilization-type barracks for airmen that once housed 74 men have been converted into modern, highly attractive dormitories, with separate two- and three-man rooms. Bachelor officer quarters have been converted into comfortable, spacious apartment units that will assure young bachelor officers of value received for their forfeited quarters allowance. Some 880 new three- and four-bedroom Capehart family quarters are under construction on the base, with 525 more to follow. Cooke will have the Air Force's first three- and four-bedroom quarters for airmen—more than 600 of them. In short, everything possible is being done to make the standard of living at Cooke AFB second to none and thus enhance the life of our first operational missilemen.

But will these physical innovations be enough without realistic attention to the primary motivating influence on missilemen and their families—their economic standing? I believe they will not.

The case for an improved military compensation system and other military career enhancements has been well documented by the Defense Advisory Committee on Professional and Technical Compensation (Cordiner Committee). It appears likely that the Congress will enact some kind of legislation to steepen the military pay curve. But there appears much less probability of legislation to make quarters allowances more realistic, to establish some form of isolation or remote-duty pay, or to bring into reality the other improvements recommended by the Cordiner Committee.

If the Air Force is to build and maintain ballistic missile units up to the required level of operational readiness, the missileman's career must be brought up to standards more competitive with those available in the civilian economy.

THAT is for the future units. At this early stage there is great enthusiasm and pride among the officers and men of the 1st Missile Division. We are charging ahead in preparation for the day when the first operational "bird" will stand upright and be counted in SAC's emergency war plan capability. "Hangar flying" sessions produce all sorts of strange but fascinating new lingo. Altitude to the missileman becomes "apogee," peak of the missile's flight path arc. Fuel is "propellant," a combination of kerosene and LOX (liquid oxygen). The hangar has been replaced by a "RIM" building, the building where the missiles will be received, inspected, and maintained.

Every man at Cooke AFB is a missileman, from the general commanding to the cook in the mess. It is an exciting experience to be traveling down General Twining's "second road" with the country's first operational ballistic missile command.

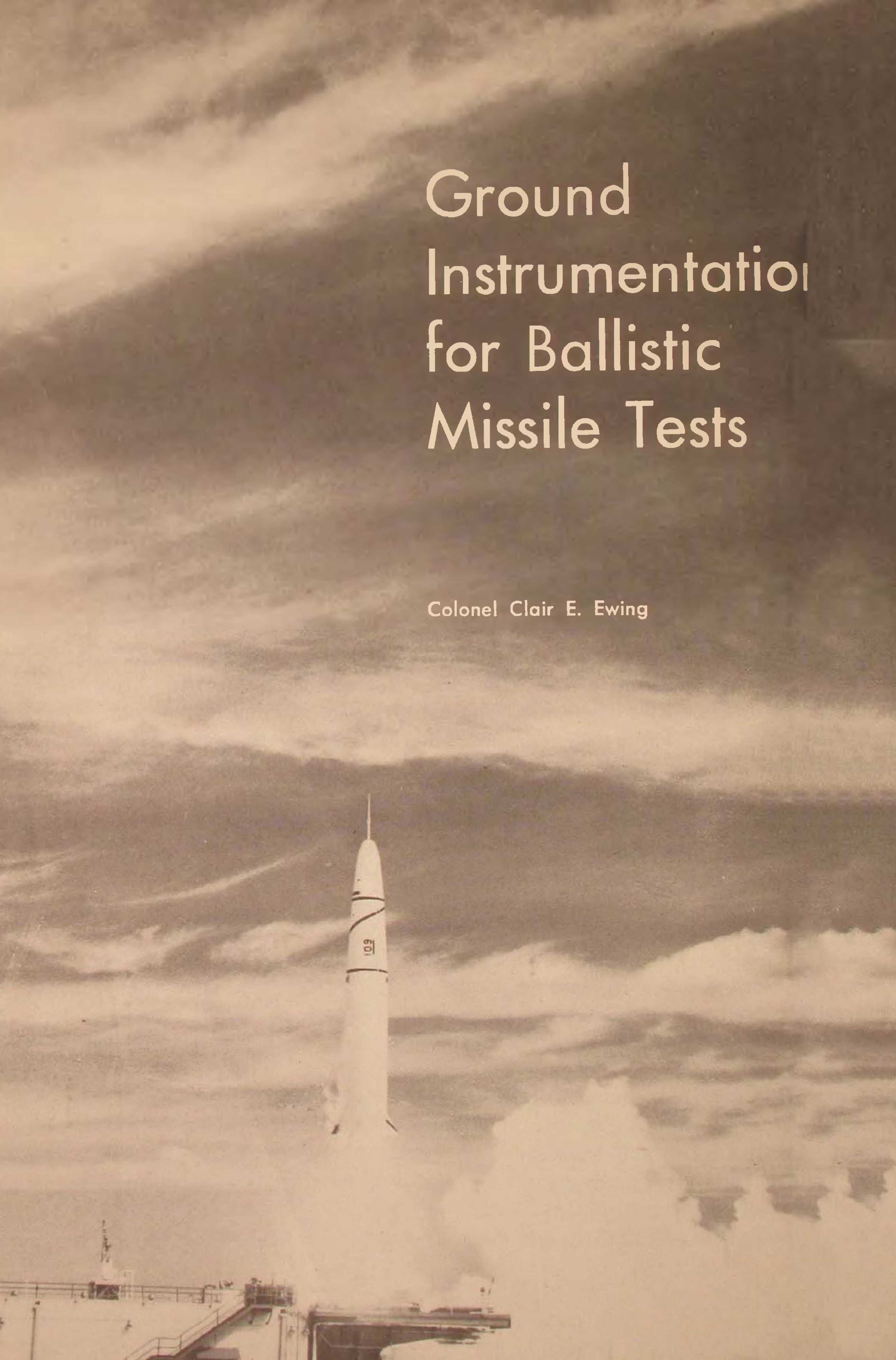
The atmosphere is loaded with challenge for the missileman of the future. As Author Albro Gaul in his introduction to *The Complete Book of Space Travel* says: "The first space pilot has already been born. He is probably between ten and 16 years old at this moment . . . "

The line forms to the right.

Headquarters 1st Missile Division (SAC)

Ground Instrumentatio for Ballistic Missile Tests

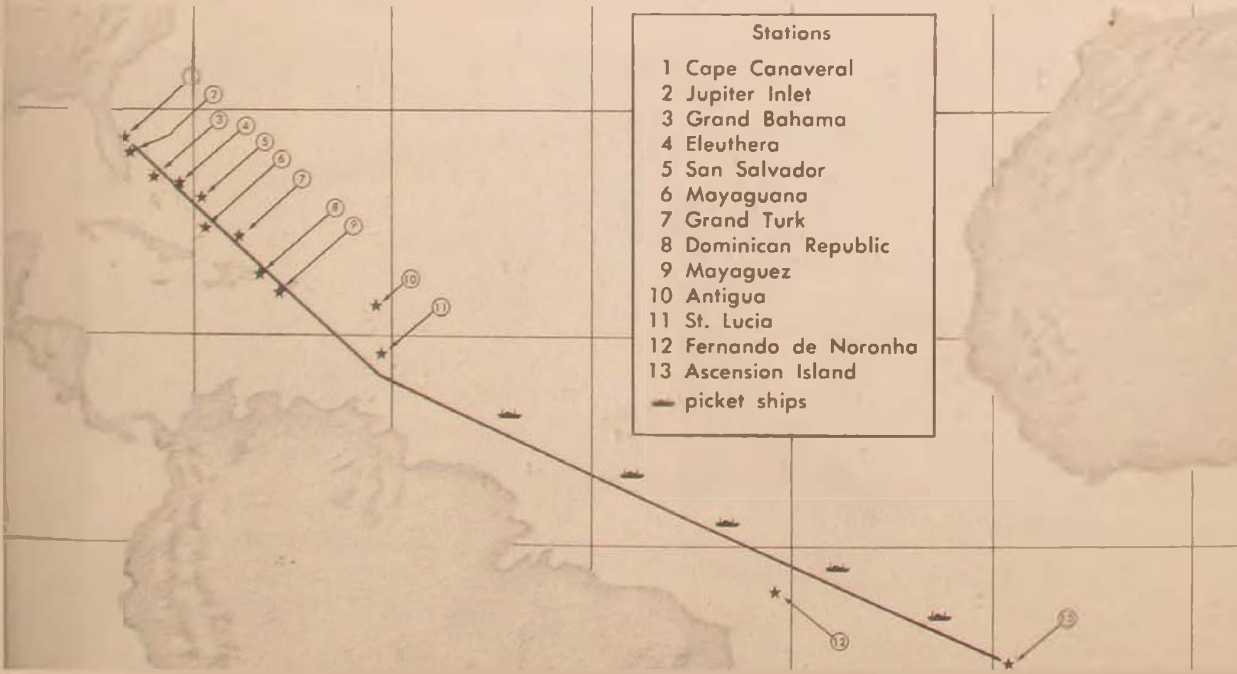
Colonel Clair E. Ewing



THE instrumentation plan for the Air Force Missile Test Center range is derived directly from the test requirements generated by the various missile test agencies.

Before the ballistic missile programs came into being, the range instrumentation plan was designed to support cruise missiles (formerly called aerodynamic missiles) such as the Matador, the Snark, and the Navaho. Thanks to geography and the cooperation of the down-range governments, a chain of island stations provides continuous corridor coverage of telemetry, radar, and command/destruct frequencies for the first 1400 miles of missile flight. Throughout the next 2800 miles the only coverage is telemetry obtained from six picket ships spaced at equal intervals along the flight path. Instrumentation based on Ascension Island, 4400 miles from Cape Canaveral, provides land-based coverage of telemetry, radar, and command/destruct frequencies for the last few hundred miles. Throughout this distance there are specified impact areas for the various cruise missiles. This range has been used in its entirety, the first missile to go the full route being the Snark flight of 31 October 1957.

Beginning in 1955 the influx of ballistic missile programs brought about a major change in the concept of range planning. Within a few months test requirements were received for the Thor, Jupiter, Polaris, Vanguard, Atlas, and Titan programs. For the testing of these missiles there would have to be down-range facilities to accommodate ballistic missiles with ranges varying from a few hundred miles to five thousand miles. Nor was variation in distance the only problem. Unlike the cruise missiles, which can be maneuvered close to the chain of down-range islands, the ballistic



missile must take a straight path from launch to impact. After leaving the mainland of Florida the missile is at all times several hundred miles or more from the nearest instrumented station. These great distances from the tracking stations, coupled with the high velocities inherent in ballistic missiles, present unusual problems in range instrumentation.

To analyze these problems, we can quite logically divide the ballistic missile trajectory into three portions:

- **The powered-flight portion—from launch to burnout**
- **The mid-course portion—from burnout to re-entry into the atmosphere**
- **The terminal portion—from re-entry to impact.**

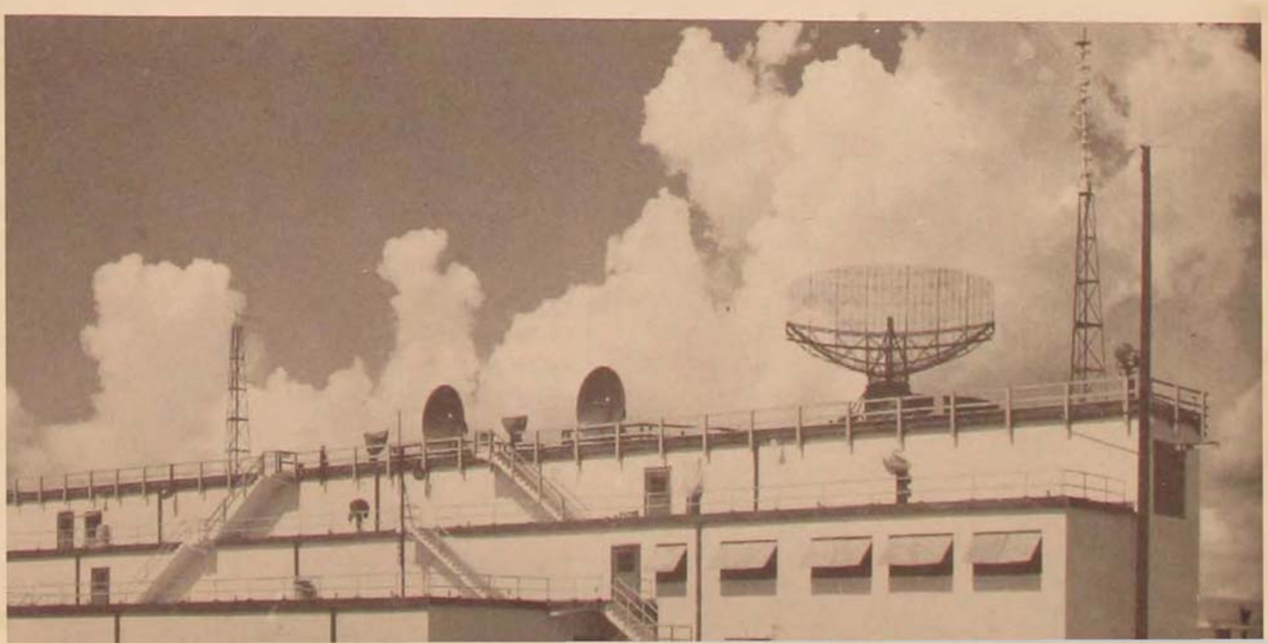
Looking at each portion in turn, we can review the major test requirements, the purpose of the requirements, and the AFMTC instrumentation plan for meeting the requirements.

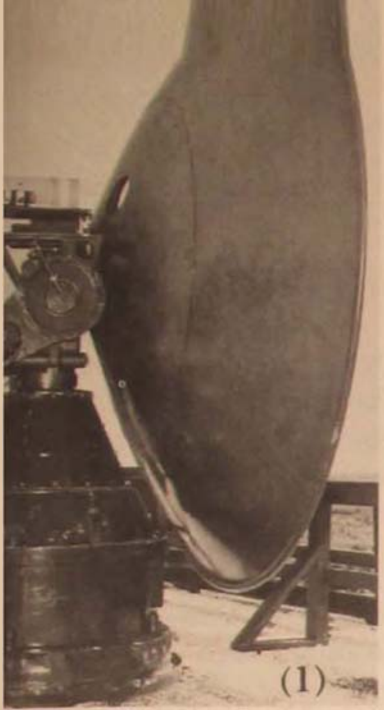
powered flight

In the powered-flight portion there is the requirement to determine with extreme accuracy the position of the missile at all times. These data are needed to establish the shape of the ascending portion of the trajectory.

To meet this requirement, Cape Canaveral has an overlapping sequence of optical and electronic equipment. For the first few thousand feet of missile rise, fixed plate and tracking cameras, as well as tracking radars, provide coverage. Then beginning at a few thousand feet after launch and

Central Control at Cape Canaveral is the nerve center of the AFMTC missile test program. In addition to the administrative offices, the building houses the air operations room. For all missile flights this room coordinates and controls range instrumentation, clearance to fire, range safety, and continuous display in real-time of the missile's position and point of impact in event of fuel cutoff. Equipment on the roof, from right to left: a communications antenna, a helical telemetry tracking antenna, a Gabriel command/destruct antenna, a CPS-5 surveillance radar antenna, two SCR-584 Mod II radars, and communications and timing antennas.




(1)


(2)

Whether a missile test is successful or not, the missile's azimuth, altitude, and attitude must be known second by second after launch. One reliable tracker is the Mod II radar, which with the boresight camera (1) has an angle-data accuracy of 1 mil. For the first few hundred feet of missile flight, radar tracking is hampered by ground clutter and multipath. With the Navy MK-51 gun director (2) modified as an optical tracking aid to the Mod II radar, early tracking can be done visually. High-speed recording of azimuth and elevation scale data is provided by Askania cine-theodolites (3), as well as position of target with respect to direction of aim. Several, synchronized in timing, photograph the flight from different positions at frame rates up to four per second. Triangulation of these films provides the missile's position. Cine-theodolites are dispersed in seven towers on the Florida coast. Each tower (4) has a power-driven astrodome, timing, electronic control, darkroom, and air-conditioning equipment. Other coverage is provided by the CZR-1 ribbon-frame camera on a 3-axis gimbaled mount (5), taking 1-by-5-inch pictures at 30, 60, 90, or 180 frames per second. Measurements of the position of the missile frame by frame and comparison with synchronized pictures taken at other sites reveal the missile position, velocity, acceleration, and attitude.

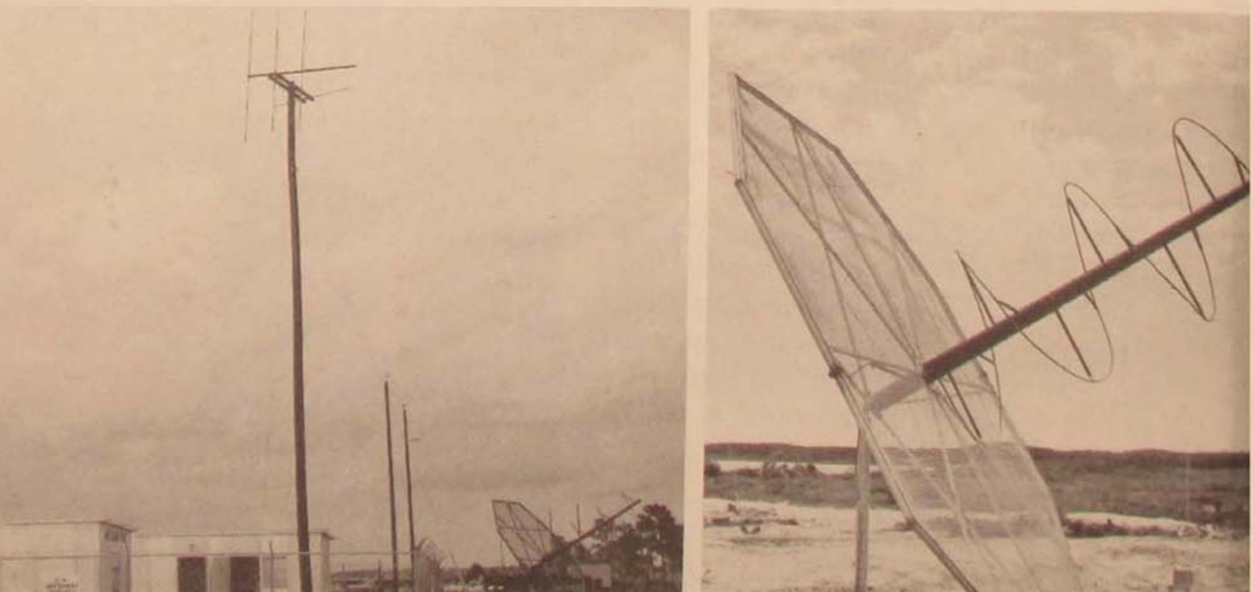
continuing to burnout and even beyond, several electronic tracking systems are available. Three of these systems will be discussed.

One such system is Dovap (Doppler Velocity and Position). This is based on measurement of the Doppler shift, made possible by a law of physics that the wave length of emissions from an object appears to grow greater or less as the object approaches or recedes in relation to an observation point. Just as the rate of approach and recession of a distant star may be determined by the Doppler shift in the visible spectrum of the star and just as the approach or recession of a locomotive may be determined from its whistling by the Doppler shift in an audio frequency, so also may the component of velocity of a missile toward or away from a receiver site be measured by the Doppler shift in a radio frequency. Three or more receivers are required in order to obtain the absolute velocity. One initial position on the trajectory must be obtained by some other method, such as ballistic cameras. Having an initial point and the velocity, the shape of the trajectory can be established.

Another electronic tracking system is the Azusa. This device measures two direction cosines and slant range. From these data the missile's position can be computed. It operates on the principle of phase comparison. Slant range is measured by the phase difference between the transmitted signal and the transponded signal received from the missile. Direction cosine is measured by the phase difference between signals received from the missile at antennas located at the ends of a base line of known length. An Azusa system is located at Cape Canaveral and a second system is planned for down range.

The Dovap and Azusa systems are now the workhorses of the AFMTC range. Under development is a system of great promise known as Secor (Sequentially Correlated Ranging). This, in principle, is a very simple

On the Florida mainland there are four Dovap receiver stations, one of them shown at the left below. At the right of the photo is the $3\frac{1}{2}$*-turn helix antenna that gathers a signal from the missile-borne transponder. The signal is recorded at this site with 15-bit range timing and reduced at Patrick AFB to yield precision data on velocity and position. Similar Dovap receiver antennas also operate down range, as the one shown at lower right on Walker Cay in the Bahama Islands.*



The Azusa tracking station at Cape Canaveral (left) has eight 4-foot parabolic antennas on two mutually perpendicular base lines. At the center is a conical scan direction-finding antenna. The system measures two direction cosines and range. The two cosine reference antennas are on the right and in the foreground. The coarse direction cosine antennas are immediately adjacent to these, the fine direction cosine antennas on the other end of the line. The transmitting antenna is on the far extension of the fore and aft line. The Secor system is shown (right) at its field test site. The helical antenna at left is the standard Secor antenna.

device. If, from a point in space, distances can be measured precisely to three points of known geographical position, that point in space can be fixed. Although three stations will furnish a position, the Secor system at AFMTC utilizes four stations for redundancy and to ensure that three stations will be on while the station change-over is made. The planned Secor chain will consist of 10 stations dispersed along the trajectory from back of launch to beyond burnout. As the missile rises from the launch pad, the four stations on the Florida mainland will acquire the missile. As the missile progresses down range, the change-over process will cause the missile to give up the rearmost station and pick up one ahead. This leapfrogging is continued until burnout is reached.

Another requirement in the powered-flight portion is to obtain the velocity vectors to a high degree of precision. These data are needed to provide an independent determination of the azimuth and elevation tracking errors associated with the guidance system.

Colonel Clair E. Ewing, B.S. in Civil Engineering, Kansas State College; M.S. in Civil Engineering, University of Colorado; Ph. D., Ohio State University, is Director of Range Development, Air Force Missile Test Center, Patrick AFB, Florida. During World War II he served for two years in the Aleutian Islands as an intelligence officer. In the Korean War he commanded the 1st Shoran Beacon Squadron, and later the 5th Shoran Beacon Unit, Strategic Air Command, Forbes AFB, Kansas. Colonel Ewing's Ph.D. is the first in Geodetic Science ever granted in the Western Hemisphere. He is a graduate of the Air Command and Staff School.

Essentially the same equipment is used for velocity measurement as was mentioned in connection with position measurement. The two functions of position and velocity are related by the element of time. Precise timing signals are transmitted from the timing central to the instrumentation systems.

A special case of velocity measurement is presented by the satellite programs. When the rocket bearing the satellite has ascended to altitude, it is necessary to determine the exact instant when vertical velocity is zero. At that moment the path of the missile is parallel to the earth's surface. This is the proper time to fire the final stage, thus placing the satellite into orbit.

So far in this discussion of the powered-flight portion of the trajectory, the requirements for position and velocity data have been mentioned. A third major requirement is to provide in-flight photographic surveillance for the purpose of observing such phenomena as the flame, structural integrity, tumbling, and staging. To meet this requirement, the AFMTC has developed a Roti (Recording Optical Tracking Instrument). Roti is a reflecting telescope of the Newtonian type. It has a focal length ranging from 100 to 500 inches in increments of 100 inches. The aperture is 24 inches. Just how far Roti will see these phenomena is a function of missile coloration, illumination, and visibility. The system was designed to obtain such data up to a range of 200 miles. Experience thus far has confirmed the design objective.

A special problem in the powered-flight portion is flame attenuation. The chemical process in the combustion of some fuels in long-range ballistic missiles yields, as a temporary by-product, free electrons. These are expected to be present in such density that they cause severe attenuation of electromagnetic propagation. It is therefore advantageous to avoid viewing the missile through its cone of combustion gases. To achieve a better viewing angle the AFMTC has dispersed its radar, telemetry, and command/destruct equipment along 160 miles of the east Florida coast, from Spruce Creek on the north to Jupiter Inlet on the south.

Finally, in the powered-flight portion, a requirement exists to protect life and property against hazards arising from missile test activities. An errant missile could jeopardize the mainland, the down-range islands, or even go so far astray as to fall undetected. To control the point of impact, AFMTC has developed a comprehensive range safety system. This system consists of two categories of equipment. The first contains those devices used to detect, during the first few thousand feet of missile rise, the changes in the velocity vectors. These changes are compared with the programed changes. If they exceed previously selected limits, the flight-termination system will be activated. Historically this category of equipment has progressed through the simple wire sky-screen, the optical sky-screen, the electronic sky-screen, the tracking radars, and, most recently, closed-loop television. These instruments are used to confine an initially errant missile to the vicinity of the launch area.

For missiles that become errant after the launch phase an impact predictor has been developed. This consists of three devices: a tracker, a computer, and a display. The Azusa is used to determine the six parameters of position and velocity. An IBM-704 general-purpose digital computer is used for calculating what the position of impact would be if thrust were

Another device used to track ballistic missiles in flight is the Roti MK II (Recording Optical Tracking Instrument). This is a large tracking telescope with local aided tracking controls and remote positioning from range radars through a data-transmission and parallax-computation network. Roti includes a Newtonian telescope 24 inches in diameter and with 100-inch focal length. The primary image is re-imaged by a turret-mounted lens transfer system that can change the effective focal length from 100 inches to as much as 500 inches in 100-inch increments. Roti obtains recorded images of missiles at slant ranges of up to 200 miles. At right is a photo of a Thor taken by Roti from a distance of 35 miles with the 500-inch focal length.

terminated instantaneously, necessarily considering a rotating earth and the applicable laws of gravity and motion. By use of this real-time display of the impact point the range safety officer may with confidence delay destruct action until a safe area is reached.

mid-course flight

The requirements mentioned so far have dealt with the powered-flight portion only. The second portion is mid-course. Relatively speaking, this is the simplest portion of the trajectory. Only three of its requirements will be mentioned.

The first is to receive and record the telemetered internal performance parameters, such as fuel flow, fuel cutoff, skin temperature, missile attitude, etc. This requirement exists in the powered-flight and terminal portions as well as the mid-course. Telemetry reception is a must from the time the missile is standing on the launch pad until it impacts into the ocean. The AFMTC plan is to use standard and high-gain antennas on land, supplemented by picket ships and aircraft near the impact area. The Missile Test Center has developed an automatic-tracking, high-gain, parabolic-dish antenna of Kennedy design with a gain of 28 decibels above isotropic. The dish is 60 feet in diameter and mounted on a 400-ton concrete pedestal. It has been designed to withstand winds up to 135 knots. One antenna will

Aside from the external coverage of missile test flights provided by radar, cameras, and recording telescopes, there is the equally important requirement of picking up the data telemetered from the missile throughout its flight. This is the job of the antennas shown here: left above, the 7-turn helical telemetry receiving antenna, with a frequency range of 215-245 megacycles, a gain of 7-10 decibels, a beam width of 45°, normally used at all telemetry receiving stations where moderate gain is acceptable. Right above, the tri-helix telemetry receiving antenna, frequency range 215-245 mc, gain 15-17 db, beam width approximately 20°, normally used at telemetry receiving stations where high gains are necessary. Left, the high-gain, automatic-tracking telemetry receiving antenna, frequency range 215-245 mc, gain 28 db, beam width approximately 4°, polarization right-hand circular, installed at 4 stations to cover ballistic missile trajectory.

be located at Cape Canaveral, one at Antigua, one at Fernando de Noronha, and one at Ascension Island.

Another requirement during mid-course is to determine a series of position points following burnout. These data are required in order to compare the trajectory as actually flown with the theoretical trajectory as derived from known physical laws. To meet this requirement, ballistic cameras are used in pairs at the end of a known base line. The spatial orientation of the optical axis of each camera is determined by reference to the stellar background, which is recorded on the plate along with the flashing light from the missile.

The intensity of the gravity field must be known throughout mid-course. This information is necessary because the ballistic missile responds to the acceleration of the earth's gravity just as does any other free body in space. Since the gravity field varies from point to point on the earth's surface, it must be measured. Approximately 25,000 miles of submarine track have been logged during the past year for gravity measuring operations. These data are corrected to the earth's surface, then extrapolated to missile altitude.

terminal flight

The third or terminal portion of the trajectory is comprised of re-entry into the atmosphere and impact into the ocean. The shape of the trajectory and the impact position are requirements in this terminal portion.

To establish the descending portion of the trajectory, several instrumentation devices are used. When the missile is several hundred miles up range from the impact point, it will be acquired by Cotar (Correlation Tracking and Ranging). This is a tracking system almost identical to Azusa. It measures two direction cosines and slant range by phase-comparison techniques. Though less accurate than Azusa, it is omnidirectional, which is an asset during the terminal portion. Also the Cotar will act as an acquisition device for placing the long-range, monopulse AN/FPS-16 radar on target. Both the Cotar and the radar will track to impact into the ocean.

THE test requirements that have been outlined are by no means all of them. There are a multitude of lesser ones. Also each missile program has its own numerous requirements peculiar to that particular program. The test requirements mentioned here are the major ones and are representative of the problems to be overcome in instrumenting a ballistic missile test range.

Air Force Missile Test Center

The USAF Reports to Congress

A Quarterly Review Staff Report

In August 1957 the Soviet Union announced that it had an intercontinental ballistic missile. This claim created a ripple of interest. Reactions varied from mild alarm to scepticism. Two months later, in October, came the big shock. The Soviets put into orbit around the earth a satellite vehicle weighing 184 pounds. One only had to watch the night sky at the appointed time or tune in on the proper short-wave frequency to have proof of the basic fact that the satellite was there. The international debris was still settling a few weeks later, in November, when the second Russian satellite arced into orbit—this time one weighing 1100 pounds and carrying a live dog.

December sharpened the dismay of the free world when the U.S. Navy's much-publicized Vanguard rocket collapsed on take-off and its small, shiny satellite lay amidst the wreckage on the launch pad. January 1958 brought the first ray of sunshine. The Army succeeded with its Jupiter-C test vehicle, and the first American satellite was in orbit—apparently better instrumented than the Russian ones but at 30 pounds a meager payload in the face of the Russian achievements.

In the United States public debate has been troubled and points of view have been many and varied. Still, out of the welter of opinion two facts have emerged as incontrovertible:

- the Soviet Union has gained a major technological and propaganda triumph through the launching of the first earth satellites;
- the state of the art which they represent constitutes an urgent technological and military challenge to the United States.

Estimates vary as to the relative positions in the race of the Soviet Union and the United States, from the more pessimistic ones of our being five to two years behind the Russians to claims that we are neck and neck. But since the first two sputniks no responsible voice has claimed that the United States is clearly in front. For impressive as the satellites themselves may be, behind them lurks the ever more impressive military implications of the powerful missiles that put the big satellites into orbit.

Of the many responses triggered by this situation one of the most important has been the inquiry into the status of the U.S. missile and satellite programs by the Preparedness Investigating Subcommittee, a standing subcommittee of the Committee on Armed Services of the United States Senate. Members of the subcommittee under the chairmanship of Senator Lyndon B. Johnson of Texas are Senators John C. Stennis (Mississippi), Stuart P. Symington (Missouri), Leverett Saltonstall (Massachusetts), Ralph E. Flanders (Vermont), Estes Kefauver (Tennessee), and Styles Bridges (New Hampshire). More popularly known as the Johnson Committee after its chairman, the subcommittee has been holding extensive hearings in an effort to determine what needs to be done to bolster the missile program and the related research and development programs on space vehicles and space weaponry.

In his opening statement Senator Johnson expressed his belief that the facts the hearing might disclose would not "invite our people either to a siesta or to a hysteria" but that they would "inspire Americans to the greatest effort in American history. And this committee seeks only to determine what can be done, what must be done now and for the long pull."

Many of the views expressed by leaders of the United States Air Force in response to the questions of the subcommittee members and their Chief Counsel, Mr. Edwin L. Weisl, are of absorbing interest and importance to airmen. From the thousands of words of testimony the Editors of *Air University Quarterly Review* have selected representative passages and statements bearing on certain prominent issues of immediate concern to professional understanding. These passages have been chosen wherever they were found throughout the unclassified portions of the testimony and have been assembled into a continuity with a minimum of summary in the hope of fairly representing the opinions of our own leaders on these topics of professional concern: the status of our Air Force programs, the quality of our incoming weapons, and our march forward into new weapon systems that bear on the exploration and the control of space.

The cited remarks are in most instances brief selections from larger blocks of direct testimony in the verbatim give-and-take of the questioning. To preserve both flavor and authenticity, editing has been limited to the process of selection in view of the space available and the voluminous transcript of the unclassified statements made during the sessions of 17 December 1957, and 8 and 9 January 1958. Only Air Force testimony is included.

First Priority—Maintain the Deterrent Force

The anchor view of the USAF testimony was an absolute need for a force capable of certain counterattack under which no enemy might hope to profit from his war or find victory in sudden attack. This force is the Strategic Air Command. At present its strength is in the manned bomber forces, which are, in professional opinion, currently quite capable of performing the counterattack mission. Missile forces are beginning to phase into the Strategic Air Command to supplement the manned bombers and diversify the counterattack capability. Ultimately astro forces will phase in for manned operations in space. But whatever weaponry and combinations of bombers, missiles, and spacecraft the Strategic Air Command may assume from year to year, its deterrent force must be kept strong year in and year out. It cannot be allowed to peak and slump as the new weapons and capabilities phase in and older weapons phase out of its operational units. This, said Lt. General Donald L. Putt, Deputy Chief of Staff for Research and Development, USAF, "it is essential that we do . . . we have got to take care of today's deterrent force. We have also got to do the things that need doing today so that when we get to tomorrow we have not slipped back then."

General Curtis E. LeMay, Vice Chief of Staff, USAF, concurred and commented on the ultimate superiority of manned systems in air-space warfare. In response to Committee Counsel:

Mr. Weisl. "Do you believe that our manned bombers with nuclear weapons today constitute the major military deterrent against Soviet aggression and our major weapon system of retaliation?"

General LeMay. "I don't think there is any doubt about that, Counsel.

"That is true."

Mr. Weisl. "How long have we got to keep that strength?"

General LeMay. "It is rather difficult to pick out a definite date when we could absolutely say that unmanned vehicles or weapon systems would take over the mission now performed by the manned vehicle.

"I expect it to be a gradual transition, and I have serious doubts whether we will ever see the time when there will be no manned vehicles in our weapons inventory.

"I believe that there will always be a place for them, and while they may not look like the airplanes that we now operate, they will be manned weapon systems nevertheless, and I think any force that has manned weapon systems at its disposal will certainly have the advantage over one that chose to go to an unmanned system."

Secretary of the Air Force James H. Douglas agreed: "Today, our principal concern is to maintain the military strength which provides an effective deterrent against an aggressor. . . . The Strategic Air Command is a main element of our deterrent force. With the swiftly moving technological development the maintenance of a deterrent force has required a rapid succession of new weapons, with the old phasing out as the new are phased in. SAC, for example, since World War II has gone successively from the B-29 to the B-50; B-36; B-47 and now to the B-52. Each one of these weapons followed a familiar evolutionary pattern—a first phase of limited operational usefulness caused by exasperating mechanical failures, a second phase of weapon maturity with improvements designed to increase effectiveness, and a third phase of gradual obsolescence as a more advanced weapon system became available.

"Ballistic missiles are viewed by the Air Force as continuations of this evolutionary process. Three principles must be constantly kept in mind.

"First, we must push the development and integration of the weapons of tomorrow at a pace which permits our scientists and technicians to operate effectively.

"Second, while a new weapon system is being phased in—whether it is the B-52, B-58, or a ballistic missile launched from the ground or an aircraft—we must maintain the deterrent force with the weapons of today.

"Third, we must press forward with projects for the weapons of day after tomorrow even though we cannot clearly see precisely how those weapons will operate."

To maintain the deterrent capability of the manned bomber forces of SAC will take bases, men, and new generations of aircraft. All are expensive to acquire and maintain, and funds will have to be found, if a strong and alert force is maintained.

. . . bases

Mr. Weisl. "General LeMay, . . . you have stated to the Subcommittee on Air Power of the Armed Services Committee* that you need a greater dispersal of SAC bases.

"Has anything resulted from that testimony?"

General LeMay. "Since I last appeared before the Committee, I believe there has been one more base assigned to the Strategic Air Command.

"However it is only capable of taking tankers at the present time and needs some more construction before bombers can move on it."

. . . men

General White. "We are definitely short of manpower in the coming year, and I have requested an increase of 10,000 personnel. . . . 850,000 is our present schedule end strength by 30 June 1958, and I have asked that that be raised to 860,000."

Senator Saltonstall. "If you have 860,000, will you have enough manpower to put crews on the Thors and the Jupiters?"

General White. "That is one of the major reasons for asking for the additional 10,000."

Senator Saltonstall. "If you put on additional manpower on the Thors and the missiles, how will your crews be on the B-52's and B-47's?"

General White. "You mean, as to numbers?"

Senator Saltonstall. "Yes."

General White. "We expect to be all right as to numbers."

Senator Saltonstall. "Will you have, what, 2½—"

General White. "1.6 crew ratio per aircraft."

Senator Saltonstall. "On B-52's?"

General White. "On all strategic aircraft."

Senator Saltonstall. "Will that be enough to keep—"

General White. "That is all strategic bombers."

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*[In 1956. For a report on USAF testimony before this committee see "U.S. Air Power Today," *Air University Quarterly Review*, VIII, 4 (Fall 1956), 60-78.]

Senator Saltonstall. "Will that be enough to keep your crews, to keep sufficient crews alert?"

General White. "That is the ratio required in order to keep alert."

Senator Saltonstall. "And how much of your force can you maintain on alert or keep on alert?"

General White. "That works out to one third of the force."

Senator Saltonstall. "One third of the force?"

General White. ". . . It is not only a question of personnel, but you have to have the adequate runways, the taxiways, the alert shelters and the ground handling equipment and the ground crews to keep the aircraft in commission, and you have to have more flying time in order to compensate for the aircraft that are kept on the ground."

Senator Saltonstall. "And if you had your own way 100 per cent, would you have more on the alert than one third, or is that enough?"

General White. "I would think it would be highly advisable to have more. It gets exceedingly expensive in manpower and in aircraft. You have to have more aircraft, and a great many more crews."

Senator Saltonstall. "So that you have asked for 10,000 more men?"

General White. "Yes."

Senator Saltonstall. "And if you get those 10,000 more men in all different categories, that would carry you in a satisfactory or optimum way?"

General White. "It would carry us on a very austere basis."

Senator Saltonstall. "On a very austere basis?"

General White. "That is correct, sir."

. . . new generation aircraft

In a sense all weapons are interim weapons. All weapons in the inventory in quantity verge toward obsolescence in view of those under development. But the fight must be fought with the inventory, and the old and the new must overlap. General LeMay brought out that some SAC wings are still equipped with the B-36. General White agreed that the B-47 wings are losing their effectiveness in the face of improvements in aircraft and air defense. The 603 programed B-52's, better than 600-mph heavy bombers, are not yet all out of production and into inventory for "interim" modernization. The B-58, a medium bomber with speed approximating mach 2, is in final testing but not yet quite ready to enter quantity production. More KC-135 tankers will be needed for the full B-52 force. And looking immediately ahead, planners see the supersonic, very-high-altitude X-15 rocket plane, a forerunner of the spacecraft, and the chemical-fuel B-70 hypersonic bomber. The X-15 experimental plane Secretary Douglas characterized as one of the "radical" USAF projects: "It does include a man. It has a good many characteristics of the missile, and is able to reach altitudes of something like a hundred miles. It has almost all of the re-entry problems of the ballistic missile and ultimate problems of returning it, a satellite, to the earth after it has been on orbit.

"It really requires all the characteristics that one would find in a manned satellite to take care of the man. It does not require the propulsive force."

The Sputnik Acceleration—Programs Leading to the Missile Phase-in

Much of the Committee's inquiry centered on the adequacy of the post-Sputnik speedup of the USAF missile program. The trend of Air Force testimony called for a faster pace and amplification of funds.

Senator Johnson. "Do the present authorized plans for the development of the Thor, the Atlas, and the Titan represent the fastest rate of progress that you think can be made?"

General Schriever. "Does your question also include the operational force buildup?"

Senator Johnson. "Yes."

General Schriever. "The total program?"

Senator Johnson. "Yes, sir."

General Schriever. "The answer to that is no."

Senator Johnson. "Would you specify specifically in what respects you are dissatisfied with each of them, if that is so, for this permanent record?"

General Schriever. "In the Thor program we have complete authority to move as fast as we can possibly move insofar as completing the development.

"We have a much greater capability in building or producing Thors and building operational units faster and getting deployed faster."

Senator Johnson. "If there is nothing fundamentally wrong with the design, should not it be possible to step up the rate of development a great deal by working faster and longer and harder, and isn't that advisable in the light of the situation as we know it to be?"

General Schriever. "We are working as fast right now as far as the development program itself is concerned, putting together all of the pieces that are involved in the development. There is no restriction on overtime at the present time or multishift operations."

* * * *

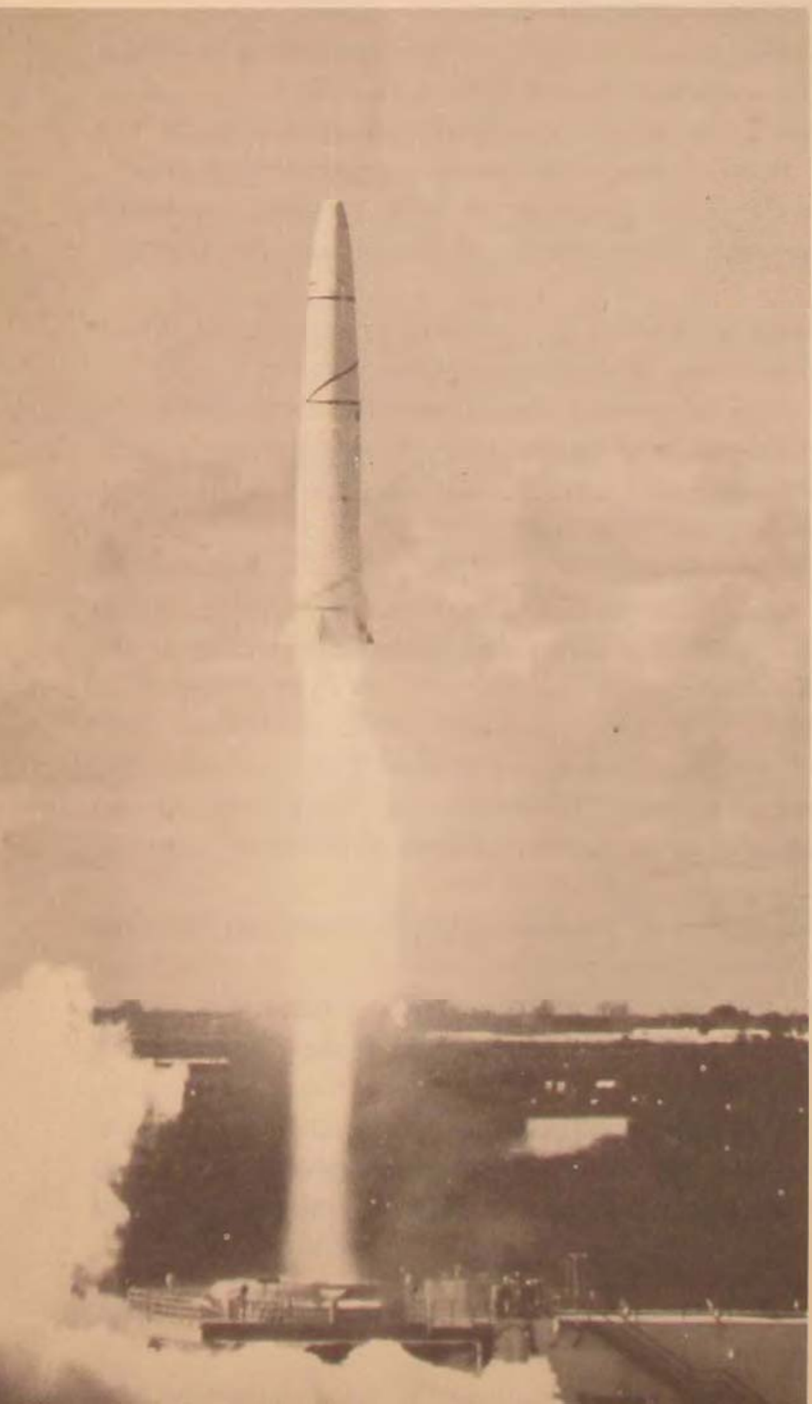
Senator Johnson. "Have you got anything else you want to say about the Atlas and the Titan, General, so far as the present authorized plans for development are concerned?

"Are you making the fastest rate of progress that you think can be made and should be made?

"I want to tie you into this record for history to see what our expert told us ought to be done, and if you think more ought to be done, I think you will say so."

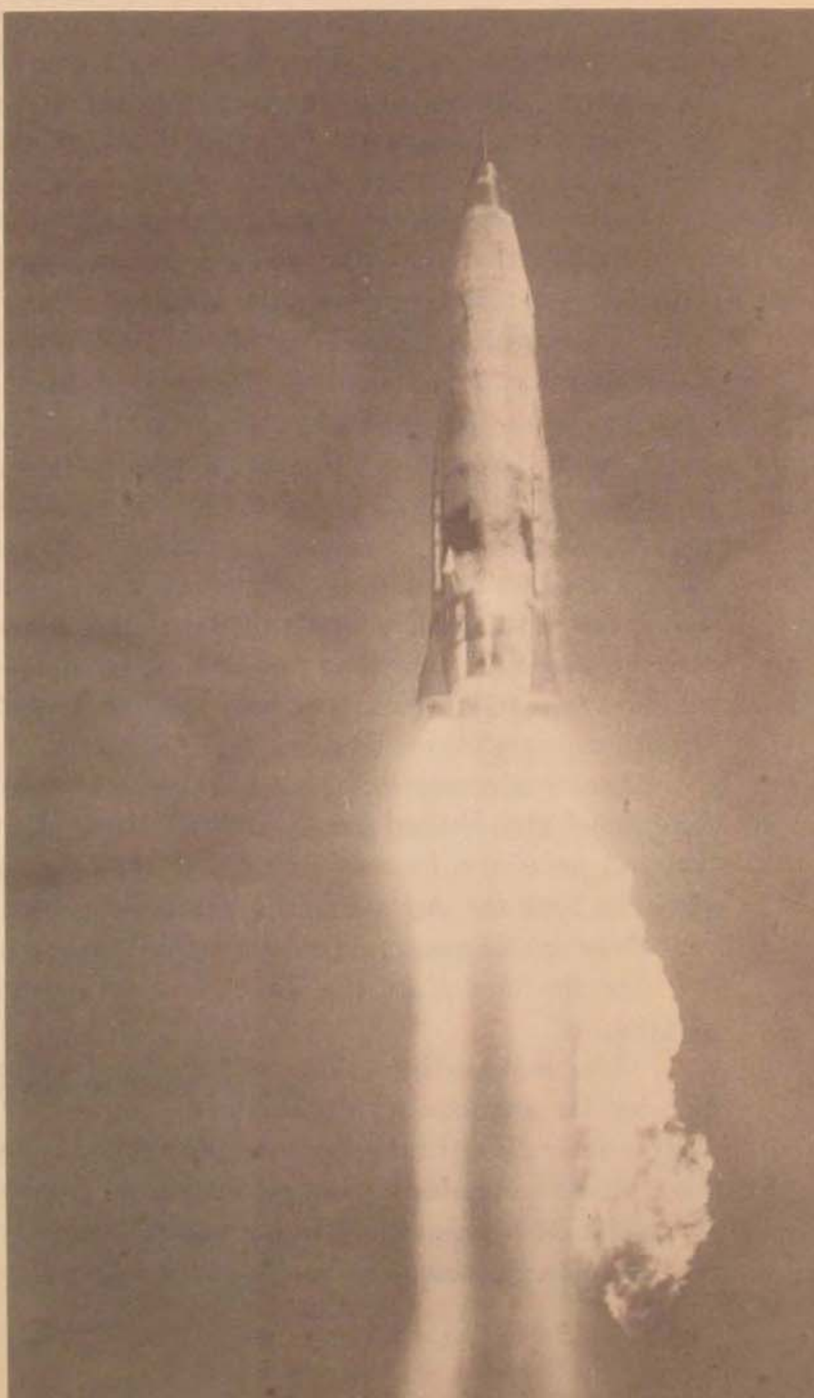
General Schriever. "In the Atlas program the development phase of it with all overtime restrictions now removed, . . . there is agreement I think between myself and Convair that we cannot accelerate the development program.

Thor unloading from C-124 at Patrick AFB



Thor in test

Atlas trucking from factory to Patrick AFB



Atlas in test

"There is also agreement that we can do more in terms of production and we can get more units, more groups in the same period. . . ."

Senator Johnson. "And your view is that we should?"

General Schriever. "We should at least—"

Senator Johnson. "And that we can?"

General Schriever. "Yes."

* * * *

General Schriever underscored the importance of bringing Titan along.

Senator Saltonstall. "May I ask a question on the Titan?

"The evidence was that there was no new money or no extra money put in for the Titan, is that correct?"

General Schriever. "That is correct."

Senator Saltonstall. "How far along in the development stage are you with the Titan?"

General Schriever. "The Titan is about a year behind the Atlas. . . ."

Senator Saltonstall. "In your opinion, General, is it more valuable to go forward faster with the Atlas in the stage that it has now reached than to perhaps speed up the Titan?"

General Schriever. "No, sir. I think that you have to go both ways.

"I think that the Atlas you can get into operational units sooner, . . .

"That actually increases the number of squadrons as compared to the present program . . . the Titan, as General White pointed out yesterday, the Air Force has recommended that instead of the . . . squadrons that are presently in the program, that we go to. . . ."

Senator Saltonstall. "In the Titan?"

General Schriever. "In the Titan in the same time period, and this we can also do.

"The Titan should go because it is built around the hard base, and I think you need to take the calculated risk now, because if we do this, we have to make the decisions now and select the site location and initiate our whole construction program because the hard base is a considerable construction program. . . ."

Senator Saltonstall. "May I ask you this: from the point of view of the defense of the United States and the United States security, is it in your opinion necessary, looking forward to the long range of 1961 and 1962, that we have both the Atlas and the Titan in operational stages?"

General Schriever. "Yes, sir, I think so.

"In the first place the Titan is a follow-on, it is a more sophisticated weapon. . . .

"Also looking into the space age and astronautics age, the Titan is a booster for astronautics development. . . ."

Senator Saltonstall. "So that the Titan is valuable not only as a missile for defense purposes but also as a booster for space programs."

General Schriever. "That is right."

Senator Saltonstall. "Satellites?"

General Schriever. "And so is the Atlas."

Lt. General Clarence S. Irvine pinpointed program obstacles in the Thor-Jupiter duplication and perhaps in overregard of the missile as an end in itself rather than a way stop to yet more sophisticated weapons.

Mr. Weisl. "Now, General Irvine, what bottlenecks can you tell the committee are present which impede or obstruct the acceleration of the development of ballistic missiles?"

General Irvine. "As I told you, on the Atlas, the program, I think, is pretty well on schedule. There it is really a question, at this point, of time. Maybe we could accelerate it a little with a little more money in key spots.

"The real question is how many do we want? We need to make that decision fairly soon.

"In the case of the Titan, there we are running essentially a development program. We are not ready for the production order yet. Since that is a real backup in that it is considerable improvement over the Atlas, I think we would be better off if we accelerated that weapon system.

"Again, in the case of the existing Thor and Jupiter, there is a question of getting authority for sites and really making a determination of the ultimate requirements that are necessary. . . ."

Mr. Weisl. "You were not consulted, either, were you?"

General Irvine. "No, I was not.

"However, I learned about fifty years ago from my Scotch father how to take orders and I have got orders and am carrying them out. . . ."

Mr. Weisl. "Are there any other obstacles?"

General Irvine. "In the missile, the ballistic missile area, I do not think that there is sufficient awareness, outside of the long-haired types like General Putt and myself, that the ballistic missile is only a short step in the evolution of a weapon system; that we feel out of it comes things like a ballistically boosted manned machine, whether this is made as an airplane to not quite go in orbit, or whether it is a true orbital type machine.

"There is too much feeling, I think, in the people in this country and in Government, that we are perhaps just a little bit crazy when we talk about this sort of machine. And as far as I am concerned, I have been accustomed to this, having been in engineering a little bit, that I think this is a very high compliment when a lot of people in this country think the Air Force is trying to go too far and too fast."

Mr. Weisl. "Well, according to General LeMay, we neither have gone too far nor too fast. Do you agree with General LeMay's testimony?"

General Irvine. "I do."

The Jupiter IRBM Weapon System Is Examined

The unqualified opinion of Air Force missilemen and production experts was forcefully expressed. The cost of putting two missiles into production and establishing the weapon systems to operate them is justified only by the insurance value of different designs, by sending the message to Garcia over two different routes. The Jupiter intermediate-range ballistic missile is similar in concept and design to Thor, unlike the pairing of the quite different designs of Atlas and Titan. Jupiter prospects are already available in Thor.

Mr. Weisl. "General Irvine, you know, of course, about the decision to manufacture both the Thor and the Jupiter?"

General Irvine. "Yes, sir."

Mr. Weisl. "Do you think there is any substantial difference from an operational standpoint between the Thor and the Jupiter?"

General Irvine. "They are about as alike as the Ford and the Chevrolet."

Mr. Weisl. "Do you think the Jupiter is the backup for the Thor?"

General Irvine. "No, not to any real engineering degree. The laws of nature are the same for the Army and the Air Force, and they have equally skilled people working on the job, except in this area I think the Air Force got started sooner with a more thorough understanding of what we are trying to do. And that was not just to build a missile, but to build a weapon system with a complete environment including the people, the operational concept, the fitting of this weapon system into the over-all SAC war plan, this last probably being the most important of all."

Mr. Weisl. "Has the Air Force sufficient facilities to manufacture as many Thors as can possibly be needed in the foreseeable future?"

General Irvine. "We are in the interesting position on this as we are in many other weapon systems of being able to build more than we could justify to meet military requirements or that we think the country ought to buy."

Mr. Weisl. "Since the Air Force will be charged with the responsibility of operating both the Thor and Jupiter, do you as an expert feel that you need both the Thor and the Jupiter?"

General Irvine. "This is a question of buying insurance. This to me is the difference between the 65-year-old man buying insurance to send his kid through school or buying insurance on the child. I mean you can pay a high price for insurance if you buy the wrong kind.

"If this were a missile which had an advanced engine, an advanced airframe—"

Mr. Weisl. "If you will pardon the interruption and will forgive me, does this have an advanced airframe? Does this have a different engine? Does this have a different propulsion?"

General Irvine. "It has the same engine, an Air Force-developed engine at North American, with somewhat different installation devices, but relatively the same installation procedures; so actually the facts of life in this case are that the accent on the development of the Jupiter has been toward developing a missile, not a complete weapon system. And this is perfectly understandable, because the people who are working on it did not have the entire environment and were not the people that had the problem of solving the entire military problem.

"Therefore, the ground environment and the operational concept and many other things are not—they do not quite fit. So that this to me—and I think if you have got some Fords coming out—this is like starting some Chevrolets, too. To meet our requirements it is going to be late, certainly after the middle of next year, before a missile that has all the apparent requirements in it to meet the Air Force mission—"

Mr. Weisl. "You are talking now of an intermediate missile?"

General Irvine. "Yes, I am talking about the IRBM. In other words, they have been flying prototype missiles and the work that has been done on them has been fine. The difference between that and the Air Force concept is like our feeling that new and modern high-performance airplanes we build on so-called hard tooling and we build enough of them so we have a production run.

"The Thor, built by Douglas with Air Force thinking behind it, was built on production tooling. So if you get a good one, we are in a position to go ahead and build a lot of them."

Mr. Weisl. "You have got a good one in your opinion in the Thor, have you not?"

General Irvine. "Yes, sir."

Mr. Weisl. "And you are in a position to build as many of them as the Air Force can possibly use in the foreseeable future?"

General Irvine. "More."

And General Schriever, answering assistant counsel:

Mr. Vance. "Speaking of backups, do you agree with General Irvine's testimony, as I understood it, that Thor and Jupiter are not necessarily backups for one another?"

General Schriever. "Yes, I agree that at this stage of the game I do not think that they are backups of the kind that we should pay that much insurance for."

. . . identical movability

Senator Flanders. "A fundamental difference, as I have observed it, between the two is that one is at least being used with the fixed launching platform, or is it, as it was explained to us, movable but not mobile launching platform, while the other is intended to have a mobile launching equipment mechanism.

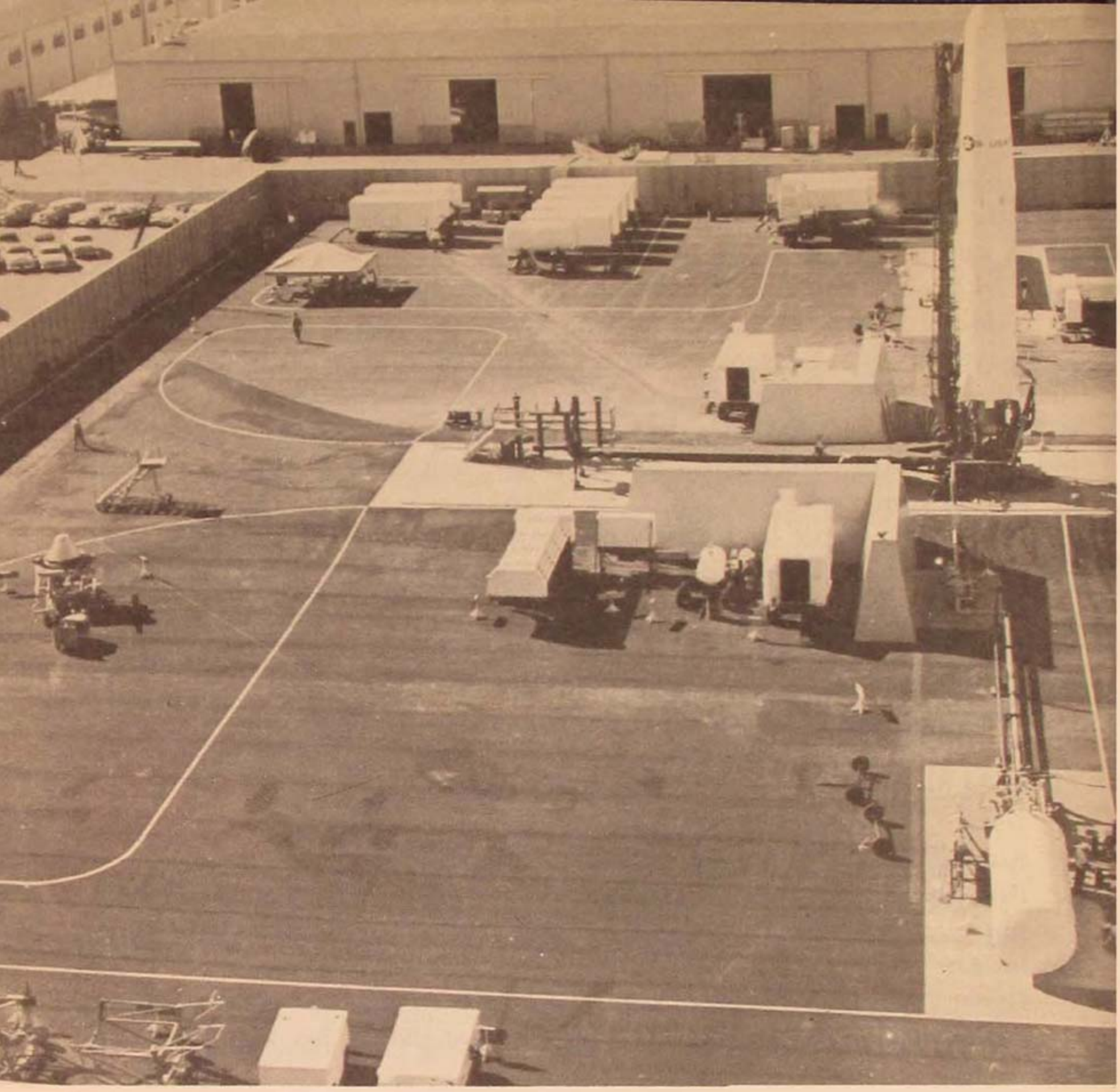
"Now, is the Air Force sold on the notion of the fixed platform?"

General White. "The two weapons, as far as mobility—and that is, I think, an overstatement—movability, are identical, in our opinion, and there is no real difference between the Jupiter and Thor as far as their movability is concerned."

Senator Flanders. "Well, we saw fixed—we saw ground installations out in California which certainly were not mobile."

General White. "They can be, though. The same kind of a launching platform that one—on trucks, and so on, can be applied to the other. The real key—"

Senator Flanders. "Apparently it had not been developed. I did not



Thor with its movable ground equipment

Thor in its portable maintenance hangar

know whether you had any feeling that there was a definite reason for the fixed platform."

General White. ". . . Even to move them even a few miles, they have to go over roads, and the narrow standard roads in Continental Europe are going to force a tremendous problem.

"I can only say the Air Force has an open mind upon it, and a great deal of the determination will be the desires of the nation to which these will eventually be turned over. . . ."

Senator Flanders. ". . . Now, the ICBM is of necessity launched from a fixed launching spot."

General White. "Yes, sir."

Senator Flanders. "I have not heard of anybody who has suggested making that mobile, have you?"

General White. "Yes, sir, that is right, sir."

. . . quick reaction time vs. movability

Mr. Weisl. "General Irvine, you undoubtedly have either heard of or read the testimony of General Gavin and General Medaris to the mobility of the IRBM. Do you agree with their views as to mobility?

"Let me put it another way. You do agree that mobility is desirable, do you not?"

General Irvine. "We have—that is really a question—we had an inspection by our Secretary and Secretary Brucker from the Army out on the West Coast, a development engineering inspection of the ground handling equipment for the Thor. All the equipment was in place. The real materiel, not pictures, not ideas, but the materiel that would be used was set up in place and demonstrated. And this equipment is on wheels, and we are in a position to put this stuff on trucks and drive it around the country if that seems like a good idea.

"However, when you start talking about that sort of thing where you are going to move a train of 150 or 160 trucks around the country, I think some people ought to take a look at some World War II pictures of what—I was in a P-38 outfit a little while myself—is a demonstration of what you could do to a bunch of trucks on the road with a bunch of fighters, and the Russians have lots of fighters."

Mr. Weisl. "You heard or read the testimony of General Medaris, I believe, who said that this equipment is just as easy to move as an 8-inch gun."

General Irvine. "I have never experienced moving 8-inch guns, but I think the best answer to that question is, we design our materiel so that we can drive it around and set it up and tear it down and move it. We have five different plans which go from a completely mobile solution to where we would have a large number of sites, unoccupied sites, maybe some we would not use at all in time of peace, that we could move to, have our equipment so we could place all of it on wheels.

"From that through various gradations to a hardened site where there would be nothing for the enemy to look at if we decide to bring it out, shove the missile on a launcher, and shoot it.

"So we have those five different variations, and we feel they are necessary, from relatively thinly populated areas where the deployment plans could be carried out, to heavily populated areas where some places, anybody who has driven around some of the narrow roads in England, moving a 25-ton truck along, it sounds a little sporty.

"Should we decide to put this equipment in a place like Alaska, there it seems sort of sensible to dig in."

* * * *

General Irvine. "In the Air Force, we have some pretty big chunks we move around, and we think we know something about them.

"As I said before, the laws of nature are the same for everybody; whether it is an Army truck or an Air Force truck, it sinks in the sand just the same.

"If you set up a hundred-thousand-pound missile, we have the idea that maybe you ought to lay out a little piece of concrete about 20 feet square to put it on.

"But I would like to say one more thing about the real fundamental difference of opinion about the handling of these two missiles, the difference between Irvine and Gavin.

"Gavin is thinking in terms of equipment, quite properly, to chaperon an army in the field, as an extension of artillery. And with this concept there is nothing wrong with what he proposes to do.

"Our philosophy with these missiles, from the very beginning, was to create another weapon system which would fit into the SAC war plan; and therefore, among other things, we wanted fast reaction, the ability to shoot quickly, the same as in SAC we want an alert system to get the airplanes in the air quickly, while the people who fly them are still alive; and in the case of the missiles, while there is still a man there to push the button.

"This is the real difference in philosophy."

. . . cost

Senator Symington pointed out that "the principal extra cost of producing both Thor and Jupiter" had been stated to be the cost of "continuation of two research and development programs instead of one. Do you agree with that?" he asked General Putt.

General Putt. "No, sir."

Senator Symington. "Why not?"

General Putt. "Well, in addition to the added costs of two development programs, you have the additional cost of tooling up a different line, production line, a somewhat different set of ground handling equipment, the training of people in additional—not necessarily additional skills, but to handle different systems.

"The number of parts and pieces that go into your supply system are doubled, which is a headache in itself.

"So that I think there is considerably more than just the increased cost of two research and development programs."

Secretary Douglas estimated the extra cost of proceeding with Jupiter

Men of USAF
1st Missile
Division
learn Thor
assembly at
the factory

into operational units: "I think that it is reasonable to say that if we could proceed and were justified fully in proceeding with Thor at the present time without Jupiter, the present operational program could be accomplished for perhaps as much as $200 million, perhaps more, less than in going ahead to equip the presently planned units with both missiles. As the program increases in size, if it does, the difference will become relatively smaller, at least in relation to the whole program."

Air Force Uses Broad Resources To Pair Development and Production Planning

Questioning of General Schriever brought out the Air Force concept of weapon development. Design-development contracts let to achieve performance specifications create a development-production team of experienced industrial organizations with regard to each of the component systems of a missile. Solution of tooling and production problems is an integral part of design development. Testing puts production facilities in being to manufacture the test missiles and readies them for quantity production. Over-all direction is provided by a contract systems manager under close technical supervision by the Air Force Ballistic Missile Division headed by General Schriever. In this regard Senator Bush brought up the much-publicized German scientists at the Army's Redstone Arsenal, who have done the research work on the Army's Redstone and Jupiter missiles. General Schriever was invited to comment on the "arsenal" system of weapon development as contrasted to the USAF concept.

Senator Bush. "Just as I was very much impressed at your establishment when we paid a visit to you recently, so I was very much impressed at Redstone by the people we met there and the operations which we viewed and I am sure you must agree there are wonderful people down there and they have done some wonderful things just as you have, too.

"Outstanding, I suppose, is this group of German scientists headed by Dr. von Braun who testified up here, and when one sees an organization like that, here is a man who has a team which has been engaged in rocket research and development for twenty years or close to it, I just wonder whether we are making all the use, getting all the use and value out of that kind of a team and that kind of a plan with his team, so to speak, that we should, in this very important work that is just going on in this country. . . .

"I don't want to embarrass you by asking you to answer any question that you don't think is appropriate and I won't insist on any answer from you on this but I wondered whether you would care to make any observation from your own experience and contact with the Von Braun group, and the Army arsenal work down there as to whether a good deal more value could not be gotten out of them at all levels of research and development in the rocket field or not, or do you have any general comment to make in connection with this broad question?"

General Schriever. "Well, first of all, I would certainly agree that they have a very competent group of people there.

"I think that the fact that they have a very competent group there, however, is sort of an accident.

"In other words, I don't go along with the arsenal philosophy of doing development and then turning it over to industry for production.

"I think the Air Force philosophy of having industry do development and having the capability of planning for production simultaneously is a much better way of doing it.

"The Air Force had quite a number of German scientists right after the war at Wright Field, and made, deliberately, the decision not to try to retain that group of scientists as a group, similar to what they have done at Redstone, and they have been, most of them have gone into American industry and a lot of them are in industry today; they are at Convair, they are at Bell, and a number of other companies, and although this is a matter of opinion, my feeling is that these people distributed to American industry, are doing equally as good a job for the United States. . . .

"I don't want to take any credit away from the group of people there [at Redstone]. . . ."

Senator Bush. ". . . In other words you don't feel that we are handicapping ourselves as a defense organization by not making broader use of the talents of the Von Braun group."

General Schriever. "Well, I think, as I say I think they are being used well up to the hilt now."

Senator Bush. "Yes, and you don't feel that there is a very much broader field in which they—to which their talents might be applied which would be the over-all field to affect not only the Army but the Navy and the Air Force too in the field of missiles.

"Are you getting as much benefit as you think you are entitled to from them or that you can use effectively?"

General Schriever. "Well, I think you have to put it this way: the group is in existence, it is a good group, so that is a fact."

Senator Bush. "Yes."

General Schriever. "And as far as whether my organization or the Air Force is getting as much use out of them as we could, I think we are getting as much benefit from what they are doing as is possible, as long as they are an agency under the control of another organization."

Senator Bush. "Oh, yes."

General Schriever. "Now we get complete information on their technical progress.

"We have a liaison office there and we get all information as to what they are doing technically."

Senator Saltonstall. "Is that mutual?"

General Schriever. "Yes, I have a couple of their officers right stationed with me and they get all of our reports."

Senator Bush. "Perhaps what I am getting at is this question, as to whether we could have a closer unification of effort in the missile field than we have right now, and that we have had in the recent years. It is a difficult question, I know."

General Schriever. "Yes, it is a difficult question to answer because fundamentally, I have, as I have said, I feel that as a country, we are better off by going to industry for our development. I don't think we should have Governmental agencies carrying out development in the manner that Redstone does.

"I don't mean to say we should not test and evaluate them."

Senator Bush. "I mean right up to the point where it is tested and manufactured."

General Schriever. "They actually assemble and test—they get the engines from North American, they get their guidance from Ford Instrument Company, which is part of Sperry, but they do all of the detailed engineering, of assembling the total missile, and they actually carry out the test firings, they prepare the over-all drawings and specifications and finally turn them over to a company say like Chrysler to do the final assembling and production."

Senator Bush. "There appears to be a difference of opinion between yours, let's say, and General Medaris?"

General Schriever. "That is right, there is."

Senator Bush. "As to the economic philosophy or the efficiency of these respective approaches. He appears to be quite as convinced that theirs is better as you are that yours is better; that is very interesting, and I am sure you and he must know that you differ on that."

General Schriever. "Oh, yes. He knows what I think and I know what he thinks."

Senator Bush. "Yes. Well, that is pretty difficult for an amateur to get into it and decide who is right."

Senator Saltonstall. "Would the Senator yield on that?"

Senator Bush. "Just for a question."

Senator Saltonstall. "Is that not based, General Schriever, on history, the Army is the oldest in existence, they had to build their rifles and everything else in arsenals, so they adopted the arsenal theory.

"You fellows came along later with the airplanes and you adopted the industry theory."

General Schriever. "Yes. In the early days it actually was tried, the business of building airplanes in the government arsenal type of arrangement, and it did not work very well, and you can get all kinds of pros and cons on this, but I think that philosophically it is true that regardless of party, the policy of this country is to have private enterprise do the job for the government instead of having the government do the job; and I think if private enterprise can do it, and I think they can, in the case of developing these weapons, then we ought to tend to that direction."

Application of Air Force Missiles to Space Operations

Most significant of all the facts emerging from the hundreds of thousands of words of testimony heard by the Johnson Committee was the readiness, now, of the Air Force to begin major space operations. The reconnaissance of lunar and interplanetary space is possible with the Air Force missile power now in existence, with Thor, Atlas, and Titan. Added to the manned space experiments now beginning with the X-15 rocket plane and to long-standing Air Force research in the physiology of space travel were capabilities for the attainment of the moon within months, the dispatch of reconnaissance probes to Venus and to Mars, and manned flight around the moon and back to Earth. These ventures became, under the weighed testimony of Air Force leaders, ventures of today's devices and today's work. Involved is control of space.

. . . control of outer space

Senator Johnson. "Now would you give the committee what things you believe are essential to control outer space?"

General White. "Well, I think the number one thing is to get some things in outer space, sir.

"The first thing you have to have is the means for firing objects into space.

"One of the most important, I say, projectors in this case in that field is the Titan, and that is one of the reasons not only because of its operational value to the ballistic missile inventory but because of the future growth in that booster for outer space projection, I am anxious to have the Titan expedited. It is a more sophisticated booster than the Atlas. It is a more rigid construction, and is the prime vehicle in the hands of the United States today for getting large vehicles and apparatus into outer space.

"You have to start with the booster and in my opinion the Titan is just over the horizon in that field."

* * * *

Senator Johnson. "Do you want to go ahead and discuss some other things?"

General White. "The human factors, if you want to get a man into space, we certainly do that, and we have done a great many experiments in the Air Force with that sort of thing. We have space suits actually developed to enable a man actually to live in getting to and from the moon.

"We will undoubtedly have to develop all sorts of communications equipment, guidance equipment.

"I actually foresee the use of weapons in space, both on offensive and defensive.

"I can imagine a satellite being a missile launching platform. It is possible to put one of those things in space, and have it go over any given spot on earth and at a given signal, and mind you of course this is not a simple proposition but I am told that it is possible, have that fire a missile at a given point on the earth, a certain city, for example.

"I think that if that is possible, that concomitantly there should be developed a defense against that kind of a satellite.

"The reconnaissance is one of the—probably one of the earlier developments that will take place.

"You will have a vehicle that will map enormous areas of the earth frequently and perhaps by television and other means get the actual photographs down on earth.

"Another way to do observation would be to put a vehicle in space which would be motionless with respect to the earth's surface, because if you fired high enough, and under certain conditions, the speed of that vehicle at the greater radius from the center of the earth can be made to equal the rate of rotation of the earth so in effect it relatively—relative to the earth's rotation it is stationary, and that can be used for many things, for observation of all the earth within the range, sight range of that particular vehicle, for communications purposes, and so on.

"I think you can even go on further, and I think it is within the realm of possibility that we can reach the moon within a very short time, by relatively short, two, three, four years.

"I think it is possible that man can go there. I am told, and I certainly have no personal knowledge or have any personal expertness in the matter, that by various combinations of stages with boosters such as that of the Titan it would be possible to actually reach one of the other planets in our solar system.

* * * *

"We have done a great many developments in this area.

"The Titan itself, the rocket engines for practically all of the ballistic missiles are Air Force engines.

"We have sent many instruments into the high altitudes to study cosmic rays, temperatures. We have sent people in balloons to very high altitudes to learn all we can about the reaction of the outer space, as near as we can reach it, on the human body. There are just an enormous number of such experiments we have done, sir."

. . . *an extension of Air Force mission*

Senator Johnson. "I want to ask you, what about the Air Force role of putting the Air Force into outer space?"

General Schriever. "Well, my feeling is this: that from a mission point of view, there is a great similarity in operating in the air, in the atmosphere above the earth, and in operating in space, and so that is No. 1.

"I think that it normally follows mission-wise.

"No. 2, from a technical standpoint, these ballistic missiles you see here, and what they represent in terms of resources, facilities, know-how, people, is the platform for going into space, not only the boosters but the guidance, the re-entry, all parts of it.

"I made a statement a year ago that at least 90 per cent of what we are doing in the Air Force ballistic missile program, 90 per cent of all of this work can be directly applied to an astronautics or space program.

"And so, from a technological standpoint, it is, I think, a normal transition to step from these ballistic missiles into satellites, moon rockets, going to planets.

"Of course, from a personnel standpoint, physiological standpoint, we have had the department* at Randolph Field for quite a long time. Dr. Strughold has been working there on manned space flight. You are familiar with the balloon flights we have had, high-altitude aircraft. We are practically operating in a space environment when we get up to altitudes of 100,000 feet or so."

Senator Johnson. "And you consider control of outer space extremely important to the free world, do you not?"

General Schriever. "Well, I certainly do, although I would not be able to give you exactly why in tangible terms, again, a year ago, that I thought perhaps the future battles would be space battles instead of air battles, and I still feel that way about it."

. . . the reconnaissance satellite

General Schriever disclosed plans to use the Thor as a booster for a satellite with a recoverable reconnaissance device.

General Schriever. "Let me say this, that there was a lot of interest at different sources in the government for an advanced reconnaissance system. . . . Now since sputniks, there has been of course a desire to accelerate this program, and we have been looking at means for accelerating it and I have given verbal instructions and this will be carried out in contractual terms, to bring into this program the Thor as a booster to expedite getting orbiting vehicles and we think, based on our studies to date, and we have made rather exhaustive studies both in house and in Lockheed, that we can get before the end of this year, say some time around perhaps as early as July, but more likely about October, we can get an orbiting vehicle with the Thor as a booster, which would be a boost to this program here, in other words, we would be getting experience, we would be getting some of the components in flight and so forth, . . .

"Now the actual system that would be orbiting, the dry weight of that after you have used the fuel would be about . . . pounds, and there are several different existing engines that you could use for a second stage.

"One of them is the present Vanguard second stage engine.

"Another one is the Bell engine that we are using for this particular program now, it was used for the Hustler air-to-surface missile. . . ."

Senator Symington. "So you could make and by what date do you think you could have a functioning weapon as a satellite?"

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*[Department of Space Medicine, School of Aviation Medicine, USAF, Air University, located at Randolph Air Force Base, Texas. The Department is headed by Dr. Hubertus Strughold, famous pioneer in the physiology of the space man. Dr. Strughold was Director of Aeromedical Research Institute and Professor of Physiology at the University of Berlin, 1935-1945, and Director of The Physiological Institute, University of Heidelberg, 1947-1949, before coming to America in 1949 to assist in establishing the Air Force Department of Space Medicine. He is the author of an excellent study, *The Green and Red Planet* (Albuquerque: University of New Mexico Press, 1953), concerning the possibility of living forms on Mars.]

General Schriever. "I think that we could have a reconnaissance capability, using the Thor booster, by the spring of next year, with a recoverable capsule."

Senator Bush. "Spring of what?"

General Schriever. "Spring of next year, 1959."

Senator Carroll and General Irvine discussed photo reconnaissance by satellite, with ICBM power for the booster.

Senator Carroll. "Can you have under planning—you do not have to answer this if it is classified—did you, as sort of the production manager of the Air Force, did you have under consideration a sort of a reconnaissance satellite?"

General Irvine. "We have been working toward that end in General Putt's department for a long time, and in this area we have been interested in that problem because we knew in the engine required for the ICBM, we had the fundamental element required for the first step in the satellite."

Senator Carroll. "In other words, the ICBM engine—"

General Irvine. "Yes, sir."

Senator Carroll. (continuing) "—could be used to launch this reconnaissance satellite?"

General Irvine. "Yes, sir."

Senator Carroll. "Mr. Chairman, I have had brought to my office about —a while ago, a photograph, and this is certainly not classified, taken by the Boston University Physical Research Laboratory, which I understand is doing some research work for the Air Force, a picture taken from Pike's Peak of Denver, Colorado, 63 miles away, and taken evidently by a mirror camera, photographed with a red filter, and I am able to pick out with my eye, without the aid of a magnifying glass, the State Capitol, the Martin plant that is doing some military work, and many military installations.

"The thought occurred to me whether or not, if you take a picture with a camera on a horizontal plane at 63 miles, is it classified, can you tell us how far you can photograph down?"

General Irvine. "I think there again that Mr. Horner* can tell you more positively about this than I can, but we have cameras that will take pictures from a satellite in orbit."

Senator Carroll. "Pictures from a satellite in orbit?"

General Irvine. "Yes, sir."

Senator Carroll. "Well, there has been some talk, as I remember, that—"

General Irvine. "A lot of work on it."

* * * *

Senator Carroll. "If we could launch such a satellite, reconnaissance satellite, I assume the Russians, being ahead of us, could launch one, too, and—"

General Irvine. "Yes, sir."

Senator Carroll. "And by having such photographic cameras function-

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*[Honorable Richard E. Horner, Assistant Secretary of the Air Force for Research and Development.]

ing, perhaps each of us would know what each other is doing; is that possible?"

General Irvine. "I think this would be very healthy. This is the first step toward peace."

Senator Carroll. "Is that what you meant when you said a little while ago, if we would use some of our money or devote our money to some of the research programs, is this one of the programs you have in mind?"

General Irvine. "We have three Air Force programs with three different companies, one of which we have recommended for implementation."

. . . the manned satellite

General Schriever. "There is no manned satellite program authorized at this time. I would prefer not to say anything more about the program that has been under discussion, which Mr. Horner covered, because of its classification."

Mr. Weisl. "I think the Senator is talking about the X-15 which was discussed."

General Schriever. "Oh, this is not a satellite. This is a rocket-propelled experimental airplane."

Senator Barrett. "Yes, I understand that, General, but I was thinking about an extension of the X-15, and it would be perfectly agreeable to wait for executive session."

General Schriever. "Well, I think I can say something about certain things that appear possible in the not too distant future with the hardware that is now in the ballistic missile programs."

Senator Barrett. "That is what I had in mind."

General Schriever. "You can take the Thor, the Jupiter, the Atlas, and the Titan, and they all make perfect boosters, some of them better than others, and there is existing hardware for second stages available today that would put into orbit considerably greater weights than we are talking about in our current satellite programs.

"And these could then be followed by experimental recovery flights initially. You could even get to the moon by 1959."

. . . costs of astronautic research

Mr. Horner pointed out that the program of astronautic research disclosed by testimony to be within Air Force capabilities was not enormously costly: "I noticed throughout all of the testimony a thread which seems to indicate to me the general opinion that what we have called our astronautics program, what might be called space exploration, is something that is really quite expensive, and really relatively expensive.

"Relative to the efforts we now have in other fields, and specifically in the ballistic field, it can be really quite cheap, quite reasonable indeed.

"I say this because we have a large part of the industrial plant that is needed. We have a large part of the test facilities that are needed. We have a lot of the techniques fairly well in hand.

"What is left to do now is to put these things together, and there are any number of different things that can be accomplished, a list that would be truly challenging, for a relatively small investment over the next few years."

. . . the ten years ahead

The big investment for the first generation of space vehicles has already been made, General Schriever said. The exploitation of this generation of vehicles in space flight is ample for a wide range of projects over the next ten years. Sizably increased power is not presently needed.

General Schriever. "Present Atlas, Titan, and Thor provide booster capacity for space missions of primary interest for the next ten years. Principal investment in first generation space vehicles has already been made.

"Two. The development of a few added stages of small size, as building blocks, can provide, in proper combination with the boosters, vehicles for all space missions for the next ten years. . . .

"Three. The guidance systems for the present and second generation ICBM and IRBM are basically adequate to perform the space missions, in other words to hit these, the moon, . . . planets; you need a guidance system to do it.

"Four. The development of payloads for some of the various missions, including payloads for animals and manned experiments, can be defined and initiated now. In other words, we can start work on these things now.

"Five. Research and technical development required on critical problems and on basic space phenomena can be defined and initiated now for the second generation of space vehicles and space missions.

"In other words, we are not just groping around. We can actually specify things."

Senator Saltonstall. "Are these your conclusions or conclusions of people who have submitted them to you?"

General Schriever. "These are the conclusions we have reached after many months of study in my organization where there have also been inputs by industry.

"These have been reviewed just a couple of weeks ago by the Ballistic Missiles Scientific Advisory Committee, headed by Dr. Millikan. They essentially agree with all of the major conclusions we have reached."

Senator Saltonstall. "And you believe in them personally?"

General Schriever. "I believe in them personally, yes. . . ."

Mr. Vance. "General, General Medaris testified that unless we developed an engine of a million-pound thrust by 1961 we would be out of the race.

"Do you agree with that?"

General Schriever. "No, I do not. I think that we need to develop larger engines, and I do not disagree that we should not develop a million-pound engine, mind you, but I do not agree we would be out of the race if we have not got one developed by 1963."

Mr. Weisl. "You do agree we should be working on such an engine?"

General Schriever. "Yes, I agree."

Mr. Vance. "Have you so recommended it?"

General Schriever. "No, I have not recommended it. . . ."

Senator Stennis. "I want to be sure we understand it. You really think we ought to be building this large engine?"

General Schriever. "I think we should be developing this large engine; yes, sir."

Senator Stennis. "With a million pounds' thrust, anyway?"

General Schriever. "In the order of a million pounds."

Senator Stennis. "But you do look upon it as kind of secondary necessity, that is, something to fall back on, rather than a primary necessity; is that right?"

General Schriever. "I think we need these kinds of engines. We need to have them by 1965 or so for the next generation of space vehicles.

"I have carried you through 1965 with basically the boosters we now have, plus these . . . second stages which, I think, will do everything that you want to do for the next ten years."

The Coming of Astro Power

At the conclusion of his testimony General Bernard Schriever made a formal prepared statement to the Committee. The few typewritten pages he read for the record make up one of the prime documents of our age. Passing through the intermediate realm of the ballistic missile weapon systems to look forward into the dawning age of manned space operations, General Schriever dealt America her first hand as an astro power. These are the cards we have to draw to. This is the probable play. Facing war, the stakes are high; and in peace the adventure is on into a new age of man. We stand therefore at a time for "bold decision."

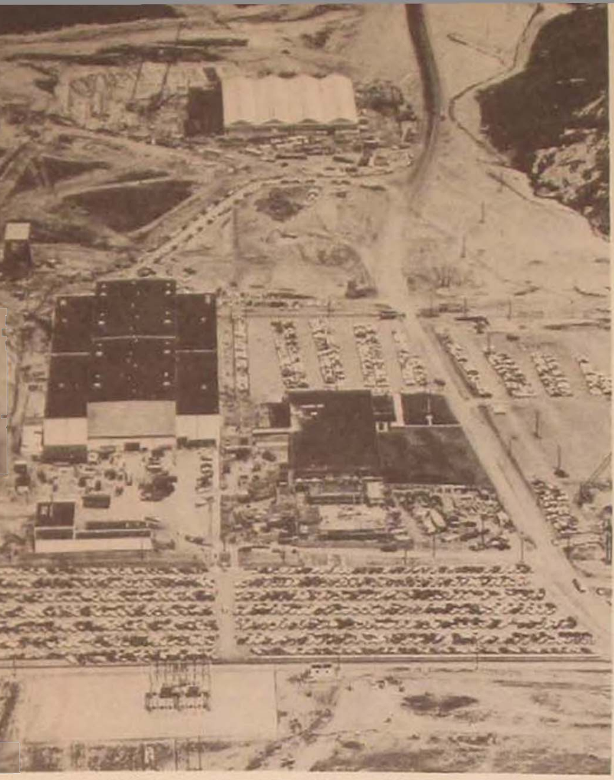
Statement of Major General Bernard A. Schriever
Before the Senate Preparedness Investigating Subcommittee
9 January 1958

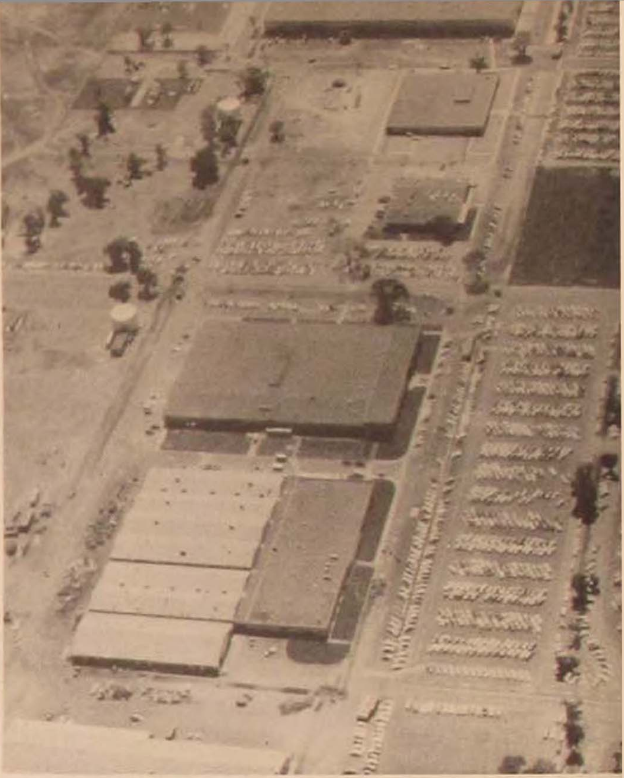
My purpose here today is to assist your subcommittee in defining and evaluating the kind of future performance and programs which are required if we are to give our country undisputed leadership in the fields of ballistic missiles and astronautics.

As I see it, we face two challenges: one immediate, the other long-range. Meeting each one successfully is vital to the maintenance and strengthening of our national security.

In seeking to provide you with what in my opinion are concrete answers to these questions, I am not going back over past history. The concern we all share now is with history in the making—and what we can do to make that history lead us toward the security we require.

In looking now to the future, the immediate question is, what can be

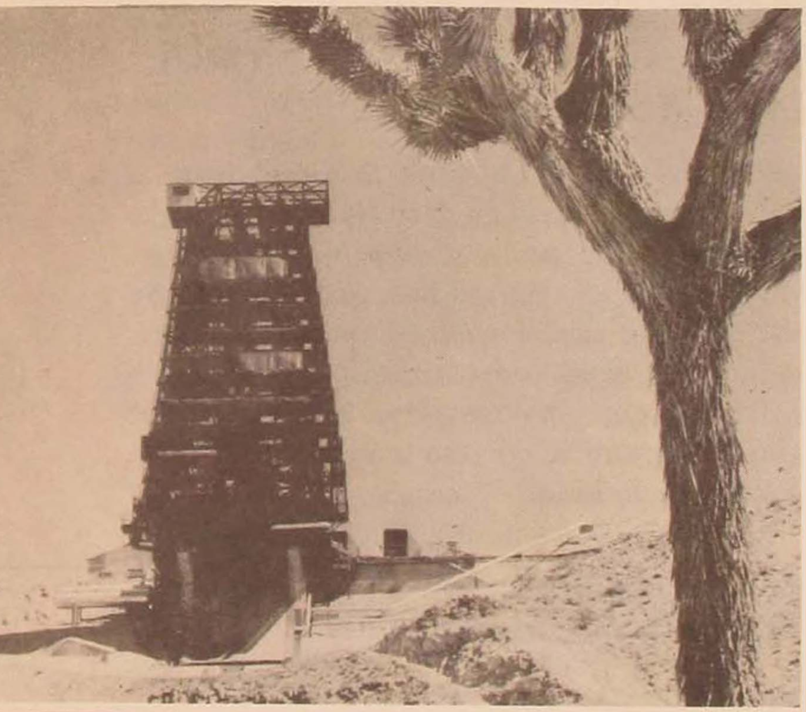




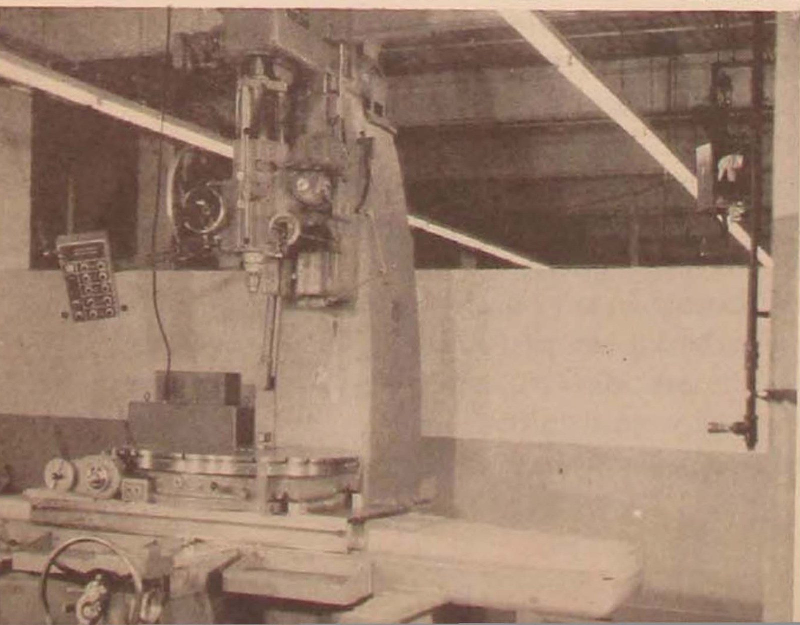
l. Martin Co., Denver

r. Aerojet-General

Industry Facilities in Air Force Ballistic Missile Program



Convair



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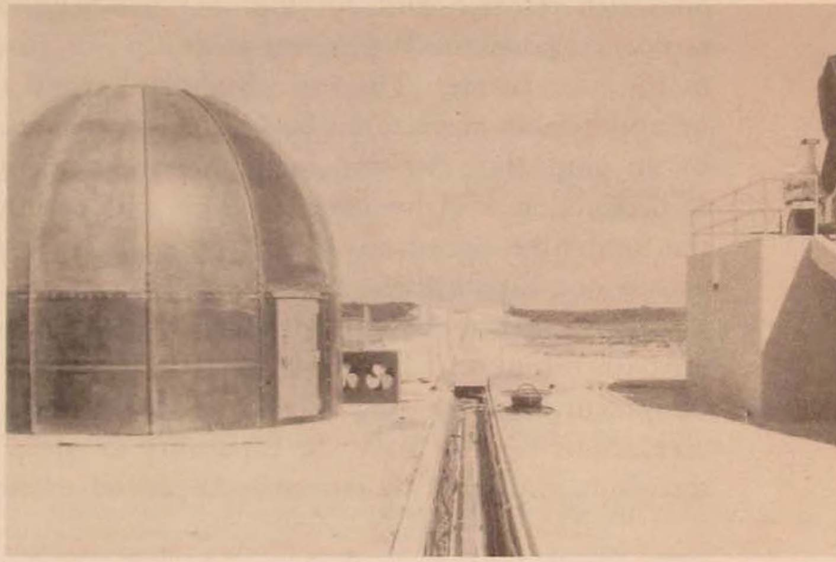
Air Force Facilities in Ballistic Missile Program



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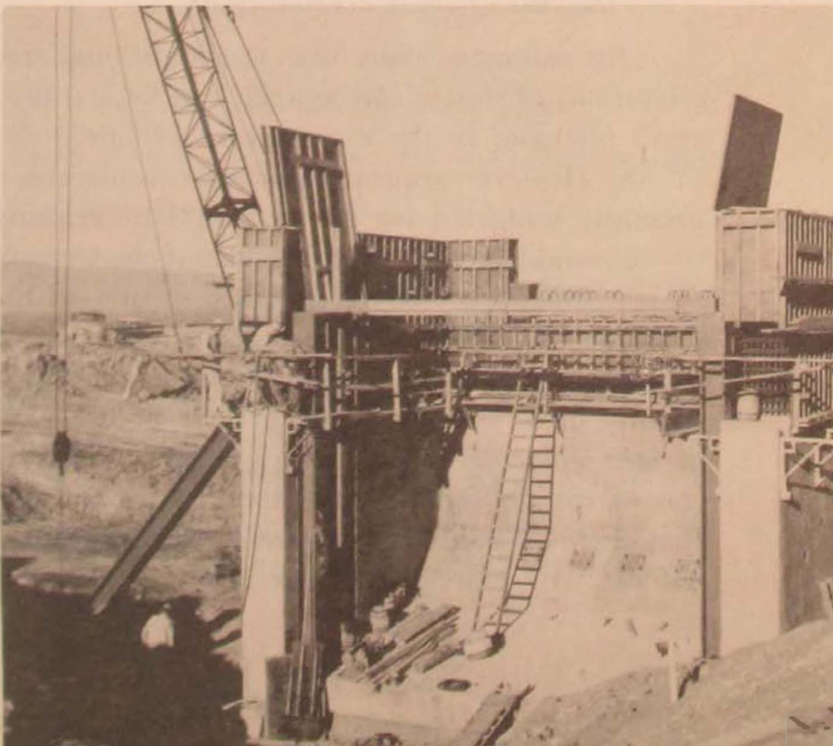

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done to further compress the time within which we will achieve significant operational forces of intermediate-range and intercontinental ballistic missiles? How can we close the gap that now exists between our country and the Soviet Union with respect to the availability of these weapon systems?

. . . our ballistic missile potential

The Thor IRBM will be the earliest operational ballistic missile. Our planning now stipulates 15 missiles per squadron.

The present Department of Defense directive, which calls for both Jupiter and Thor squadrons, does not achieve at the earliest date the deterrent power which is well within our capabilities. If a decision is made immediately to increase our rate of production over the currently approved maximum rate, by early 1960 we can deploy twice as many operational IRBM squadrons, all Thor-equipped. The first two Thor squadrons would be overseas by the end of calendar year 1958.

The next addition to our ballistic missile force will be the Atlas ICBM, on which research and development has been, and is, proceeding about as rapidly as possible. We expect to equip our first Atlas operational complex in the near future. The force buildup beyond that first unit, however, can be appreciably accelerated beyond current plans. This can be accomplished by an immediate decision to double the currently approved maximum rate of production of Atlas missiles. This will permit us to equip almost double the total Atlas squadrons called for in the next few years. This also is well within our capabilities.

The third, and most advanced ballistic missile in our force of the immediate future will be the Titan ICBM. Here again our research and development is progressing at a rapid rate. Our most recent assessment, however, shows that we have the capability to equip twice the number of Titan squadrons indicated by currently approved schedules.

. . . the cost of these accelerations

Our estimates show that the additional strength provided by these accelerations of our missile systems can be accomplished by means of relatively small increases in the expenditure of funds allocated for the remainder of FY 58. However appropriation of considerable additional funds over those presently budgeted for FY 59 would be required.

It would be a colossal blunder if we were not to plan beyond the point of matching every Soviet ballistic missile with one of our own. We must continue to refine and improve this first generation of ballistic missiles, in effect progressing to a next generation of missiles. We can provide in the slightly more distant future greater accuracy, greater destructive potential, greater range, greater simplicity, greater mobility, but at less cost. All of this we can do and are now planning, and all of this demonstrates once again that there is no fixed, final and frozen solution to the problem of national defense, any more than there is any ultimate weapon.

. . . our astronautics potential

The second challenge, as I analyze the future, is in the longer-range field of astronautics. Here the military requirements are at present less clearly defined, but are no less demanding of an immediate, vigorous program designed to surpass Soviet capabilities in this field.

Fortunately we are already a long way down the road. The original investment for preliminary projects in space flight has already been made in our present Air Force ballistic missile programs.

We have already provided for approximately 500 million dollars worth of new facilities designed for development, testing, and production of ballistic missiles—facilities nonexistent only three years ago. We have a vast military, scientific and industrial organization experienced in the design, development, testing and production of ballistic missiles. Moreover, this organization is staffed by personnel of the greatest competence who have mastered many new fields of knowledge which can be springboards to substantial short cuts in our mastery of astronautics.

In my opinion, these presently existing assets provide our best steppingstones for every advance we can expect to make into this new age of space science and technology. Our studies have shown that by using our presently existing rocket engines and missiles, we can provide both at the earliest date and at the greatest economy not only unmanned reconnaissance of the moon, but also a basic vehicle for manned space flight. I believe that any program to develop a separate astronautics agency would result in duplication of capabilities already existing in the Air Force ballistic missile programs, and at a cost in funds and time similar to that already expended on these programs.*

*Following the prepared statement, further questioning took place in which General Schriever's position relative to the proposed new Department of Defense Space Agency was clarified:

Senator Saltonstall. "General Schriever, may I first say that this is an awfully interesting and important statement, and I certainly appreciate, and as one member of the committee, you appearing as a witness today. Certainly, it is comforting to have men like you around.

"My question is this: You were critical in that statement just now of a new satellite agency, so to speak."

General Schriever. "Yes, sir."

Senator Saltonstall. "As I understand it, if they set up a new satellite agency in the Department of Defense, that would not mean that the present Air Force facilities, the Air Force personnel and the Air Force research could not, under the direction of that agency, go forward and go forward along the lines that you are saying.

"I would not interpret a new agency to mean that you would put on the shelf and throw away all, discard all, that you people have done, discard your efforts.

"Now, isn't that your understanding?"

General Schriever. "Yes.

"Let me clarify that point. I will read that again where I say that a separate astronautics management agency, and by that I want to clarify the word 'management,' I mean an operating management organization which has a large technical staff, and has its own procurement agency.

"I think we do need an agency which will formulate policy and approve total program for the Defense Department, and give direction."

Senator Stennis. "And give you the job to do; is that right?"

General Schriever. "But I think the existing—that is right, in part. I am not saying I should have it all."

Senator Stennis. "I know. But hand it down to you, and you take it from there."

General Schriever. "That is right. But we will be directed by that agency; I expect that.

"I think earlier I said we ought to have a strong direction agency that makes decisions . . . if that is the way it is set up, I am all 100 per cent for it.

"But if it attempts to set up a procurement staff and do the contracting out of the Pentagon and set up a big technical staff there and make all the technical decisions, I say you are not going to set up a very good thing."

If we are to take full advantage of our present astronautics potential, these are some of the projects we can immediately initiate:

1. Our present Thor missile with existing second stage hardware can place a satellite in orbit with a respectable payload.
2. By adding existing third stage hardware, this vehicle can perform unmanned reconnaissance of the moon at a relatively early date.
3. A slightly modified Thor plus a high-energy fuel stage which we have been developing can make possible initial unmanned reconnaissance of Mars and Venus.
4. The Titan booster when developed plus high-energy second and third stages could put much greater weights into orbit and could provide extended manned satellite missions. This vehicle could provide manned flight around the moon and back to the earth.

Many far-reaching potential capabilities are apparent as we look more into the future and develop the possibilities of thermonuclear propulsion and payloads up to hundreds of tons. These few specific examples of capabilities now at hand and their times of realization, however, strongly emphasize the requirement for initiating these projects immediately if we are to have any chance of leading in space technology in the 1965-1970 time period.

The entire astronautics development program which I have touched upon can be initiated at once with no dilution or diversion of our ballistic missile programs.

As I analyze the future, if we are to meet the challenging requirements of either ballistic missile acceleration or of astronautics, we must recognize where our strongest capabilities lie today, and make certain decisions now. The decisions we make today will exert momentous influence on where we stand tomorrow, and must point to well-planned, clearly-defined objectives. Today's situation calls for bold decision and calculated risk and funds.

Air University Quarterly Review

The Ballistic Missile and Its Elusive Targets

MAJOR KENNETH A. SMITH

A BALLISTIC missile is hurtling through space at fantastic speed. The many thousands of parts in the missile are working to perfection. As the shrunken world spins beneath the high arc of the flight path, the missile's guidance system automatically but delicately performs the small corrections that keep the huge missile on its preset trajectory. At the correct point in space the engine suddenly burns out. The aft section separates cleanly and the warhead streaks on alone, up and on over the apogee. Now it slants earthward toward the selected target. Will the missile hit the target?

The survival of the free world may well depend on the answer being yes. Assuming that the missile is functioning perfectly in every detail as the designers intended it to, we should also be able to assume that the answer is yes. One small detail could change the answer to no—even though the missile components function perfectly. Is the target actually where we thought it was—that target 5500 miles away from the launch pad, separated from it by broad oceans and vast land areas for which we have no accurate maps? Geographical and political boundaries may have prevented our mapping the target area accurately and tying in precisely the geographic coordinates of launch pad and target.

For hundreds of years map makers have been attempting to pinpoint one given place in relation to others across the face of the earth. The slight inaccuracies have always been an annoyance to navigators, but until recently the slow speed of the means of transportation allowed ample time to correct for the errors. With the coming of high-speed, long-distance aircraft the difficulty became somewhat aggravated, but still there was some time to make computations and a crew was along to correct navigational errors by taking visual sightings. Even in bad weather the radarscope or radio and radar navigational aids were available to the crew. With all these checks available the error to worry about was the human error of the navigator rather than the reference errors in the maps.

But with the coming of the ballistic missile the problem has suddenly assumed critical importance. All traditional navigation devices for correcting map error have no use here. The only things that matter are the validity of the information set into the guidance system before launching and the faithfulness of the missile's guidance system in keeping the missile on its trajectory. Of course such a system assumes that the location of the target in relation to the launch pad can be plotted precisely. It is this assumption that we must make come true by finding means to link our North American Datum system to those for other continents. This is one more science in which we are operating under an informational handicap, for the details of the North American Datum have been available to the rest of the world, including Russia, while comparable detail from the Russian datum has not been available to us. Presumably the Russians have been able to tie their datum into ours and can now pinpoint targets on this continent. We do not necessarily have to have their information to achieve the same accuracy ourselves. We do need more geodetic data than we have as well as more detailed information on the location of targets. But with some additional geodetic data there are methods that will enable us to extend our own datum system to cover other continents.

The purpose of this writing is to review what has been accomplished toward compiling the geodetic information for use in the ballistic missile program and to discuss the methods that can be used to supplement the mapping information in areas now inaccessible because of political or other obstacles.

what has been accomplished

Since World War II there have been considerable advances in the reduction of different national surveys into large, unified geodetic systems. This was done by readjustment of existing continuous surveys and by direct connection between different systems. In general the connection systems have been limited to continental boundaries because of difficulties imposed by large bodies of water that separate most of the continents and by certain borders that have been closed for political reasons. The relationship between the North American Datum, the European Datum, and the Russian datum can only be estimated when comparing plotted positions on the separate datums. Estimates of the amount of error vary from hundreds to thousands of feet. Errors can also be introduced when trying to tie two surveys together even though they are on the same continent. The Russians attempted to join the Pulkovo and Svobodny Datums near Krasnoyarsk and found an error of about 2700 feet. Recently the Army Map Service reported a correction in the placement of the Palau Islands in the Pacific Ocean. The islands' position has been moved 4000 feet northwest of their previously recorded position.[1]

problems of mapping and surveying the world

If the world were a perfect sphere many of the mapping and surveying problems would not exist. The fact remains there are hills and valleys on the warped surface of the earth and a slightly shorter axis runs through the earth pole to pole than through it at the equator. It is these odd qualities that complicate our problem of referencing points accurately on the face of the earth. As a basis for starting a survey or datum a sphere must be developed which is as representative as possible of the actual shape of the earth. For this purpose an ellipsoid is chosen, the equatorial axis measured, and the flattening effect introduced by the shorter pole-to-pole axis determined.

There are five quantities that must remain constant when developing a datum. There must be an initial point from which to start the survey. The ellipsoid must be defined by length of the equatorial axis and flattening effect on the meridian. The initial point coordinates and the azimuth direction from which to start the survey must remain the same throughout the development of the datum. Change one quantity and the whole datum will have to be recomputed.

North American Datum. The 1927 North American Datum is the result of readjusting the triangulation of the United States and then tying into it the geodetic datums of Mexico and Canada. The initial point is located near Meades Ranch in Kansas. The datum is referenced to the Clark Ellipsoid developed in 1866. Information from the North American Datum is available to all nations of the world.

Russian geodetic datum. Russia at one time had two independent geodetic datums in progress. An attempt was made to link the old Pulkovo Datum with the Svobodny Datum at several points near Krasnoyarsk. There was a discrepancy, as previously stated, in plotted positions on the two datums of about 2700 feet. Since each datum has a different initial point the error was unavoidable. Investigation revealed that the error was caused by using separate initial points referenced to the Bessell Ellipsoid developed in 1841. In 1946 the Russians stated that a new datum called the 1942 Pulkovo Datum would be computed and referenced on an ellipsoid developed by Krassowiski and Izatov in 1938.[2]

Single world geodetic datum. A single world geodetic datum would certainly be the most ideal situation for computing the target coordinates for use in the ICBM guidance system. In order to establish accurate information between two or more geographical positions, the points must be referenced on the same geodetic datum using the same ellipsoid. The main difference between the various computed ellipsoids lies in the length of the equatorial axis and the flattening effect on the meridian. The following table lists most of the important earth ellipsoids:

author	*year*	*a*		*1/f*
Everest	1830	6,377,276	meters	1/300.8
Bessell	1841	6,377,397	"	1/299.15
Clark	1880	6,378,249	"	1/293.5
Bonsdorff	1888	6,378,444	"	1/298.6
Helmert	1907	6,378,200	"	1/298.3
Hayford	1910	6,378,388	"	1/297.0
Heiskanen	1926	6,378,397	"	1/297.0
Krassowiski/Izatov	1938	6,378,245	"	1/298.3
Jefferies	1948	6,378,099	"	1/297.1
Ledersteger	1951	6,378,315	"	1/297.0

NOTE: *a* = equatorial axis
1/f = fractional value for flattening of meridian

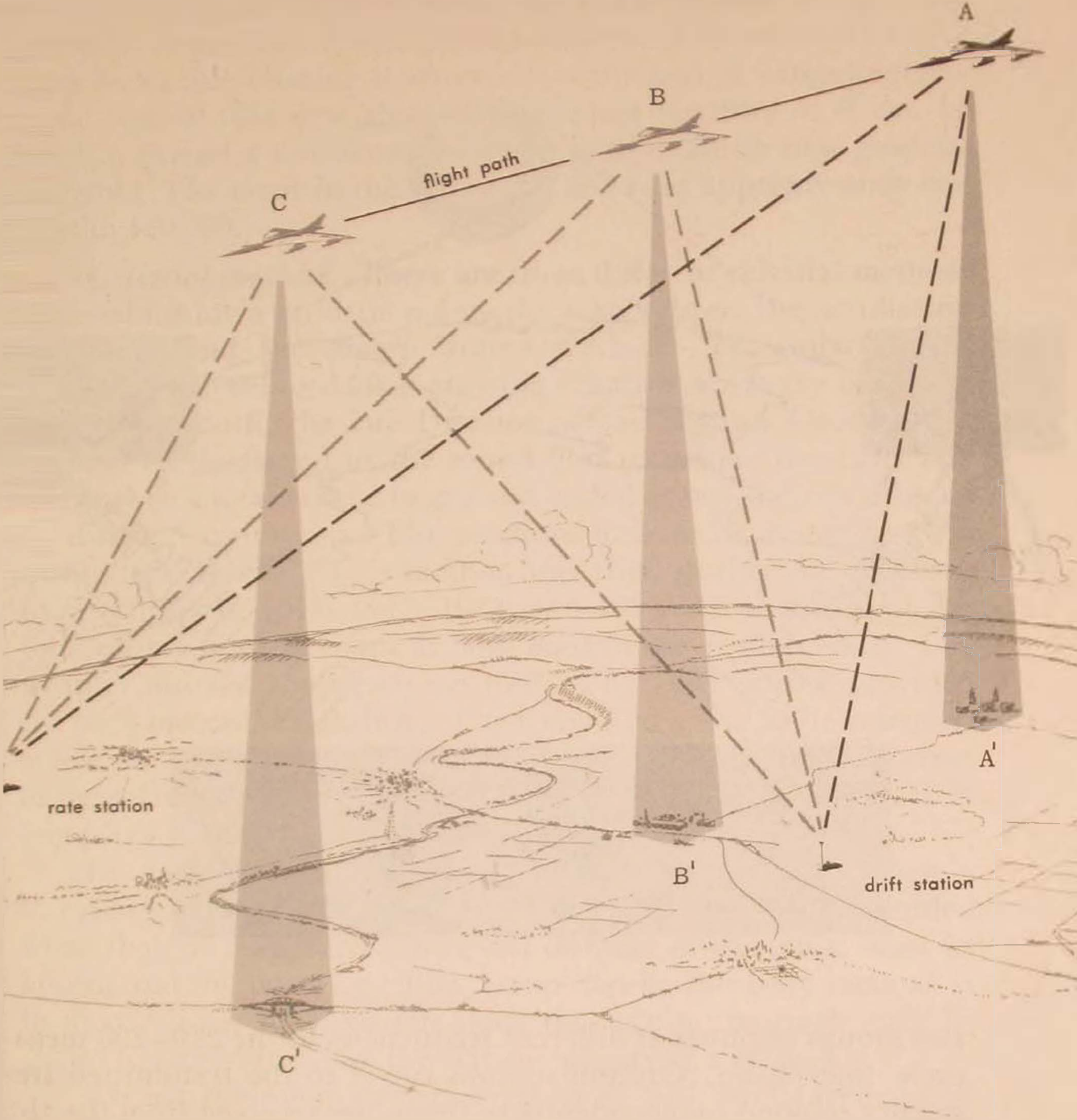
Of these ellipsoids, the Everest, Bessell, Clark, Hayford (now known as the International Ellipsoid), and Krassowiski/Izatov are the surfaces of the most important and extensive surveys.

methods of extending geodetic control

There are several methods of extending geodetic control. These methods are capable of spanning large bodies of water and in some cases land areas that are otherwise inaccessible. The geodetic methods are:

The Hiran, or direct method;
The celestial, or semidirect method;
The gravimetric, or indirect method.

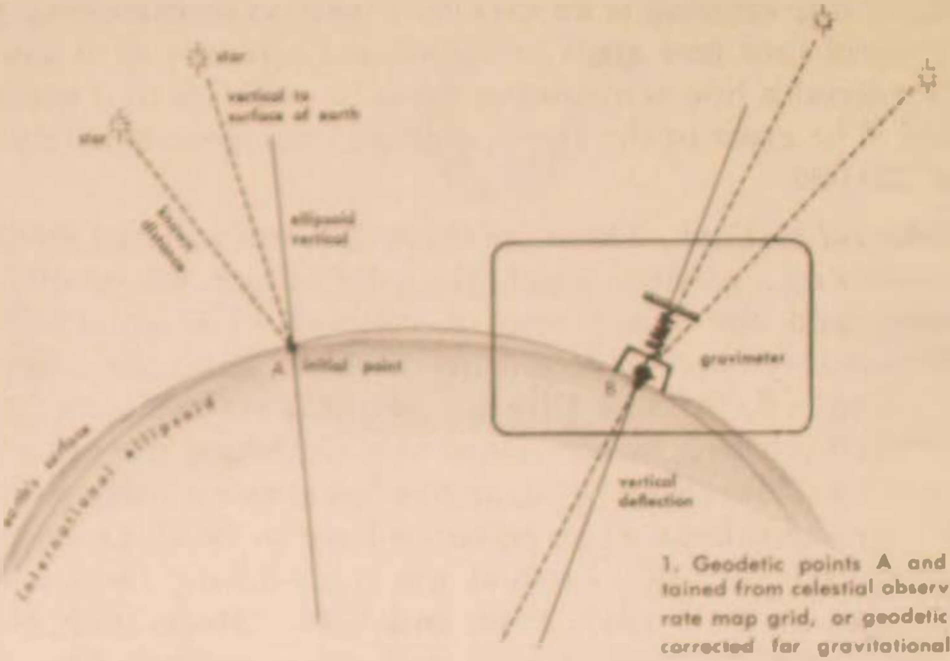
Hiran Geodetic Mapping



Each method of extending geodetic control has a definite use. Each provides an acceptable accuracy—defined by the U.S. Coast and Geodetic Survey as error in line extension of less than one part in 50,000. The gravimetric method offers an excellent procedure for developing a world geodetic datum and can be used to establish geodetic controls in land areas that are closed for political reasons.

Hiran method. Hiran (High Precision Shoran) operates on the transponder-responder principle and can be considered a radar beacon system. The airborne transponder alternately transmits

Gravimetric



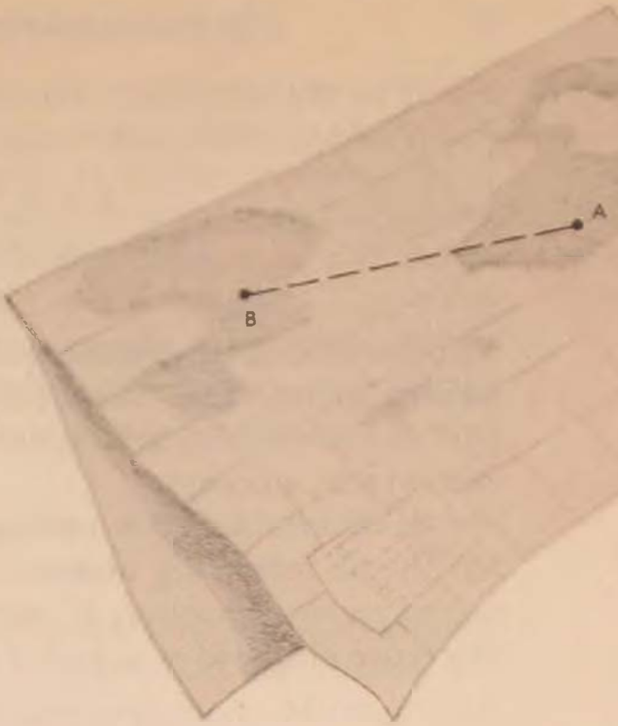
1. Geodetic points A and B are obtained from celestial observation, accurate map grid, or geodetic datum and corrected for gravitational deflection.

moon and surrounding stars from several distant points at the same exact time. By comparing the moon's position in relation to the surrounding stars and measuring the angular differences in position of the stars, then knowing the direction of the moon from the observatories, the distance between the observatories can be quite easily computed. According to Markovitz, the accuracy of 40 meters can be obtained for the positions.[6] The over-all error of the celestial method is less than one part in 50,000.

Gravimetric method. The gravimetric method is essentially a procedure of reducing the shape of the earth geoid configuration to an ellipsoid shape so that we can measure distance and direction between any two points on the earth's surface. The undulations and the deflection of the vertical are determined by measuring the gravity anomalies which exist over the surface of the earth. The smoothing out of the undulations gives a more representative shape of the earth and the deflection of the vertical provides information needed to correct positions of latitude and longitude that have been determined astronomically and to reference these corrected values directly to the chosen ellipsoid without recourse to triangulation.

Dr. Heiskanen of the Ohio State University Mapping and

2. Corrected points are transferred onto the international ellipsoid.



3. These points may then be transferred to any map or datum that is based on the international ellipsoid.

Charting Research Foundation has outlined a method for establishing a world geodetic datum using the gravimetric method.[7] In order to arrive at a world geodetic datum—or world system of coordinates—there must first be a reference ellipsoid that can be used world-wide. The International Ellipsoid, developed in 1910 by Hayford, seems to be one of the best available. Also there will have to be a suitable gravity formula with which to compare the representative gravity measurements. The international gravity formula suggested has the following value:

$$\gamma = 978.0490\,(1 - \phi.0052884 \sin^2 \phi - \phi.0000059 \sin^2 \phi)\,.$$

In order to get the gravity values as representative as possible the observed gravity reading must be reduced isostatically to sea level and compared to the above theoretical international value. From this comparison we get the needed value of gravity anomalies Δg_1 which can be used to calculate the deflection of the vertical plumb ξ and η. In addition to this method of calculating the value of ξ and η Dr. Heiskanen explained another method which was adaptable to short triangulation nets. The astronomical observation values of latitude ϕ', longitude λ', and azimuth A′ and the corresponding values of ϕ, λ, and A are computed geodetically and re-

ferred to the ellipsoid. From the observed values and the computed values, ξ and η are found by the following formula:

$$\xi = \phi' - \phi$$

$$\eta = (\lambda' - \lambda) \cos \phi, \text{ or}$$

$$\eta = (A' - A) \operatorname{cotan} \phi$$

This method of determining the value of ξ and η can be used over limited areas. The measured arcs cover only a relatively small part of the earth's surface, and such triangulation nets cannot be carried across oceans.

If the problem is turned upside down and the formula rewritten in the following manner, we can convert astronomically observed quantities of ϕ', λ', and A' to the quantities needed for a reference ellipsoid ϕ, λ, and A:

$$\phi = \phi' - \xi$$

$$\lambda = \lambda' - \eta \sec \phi$$

$$A = A' - \eta \tan \phi$$

This gives the quantities of ϕ, λ, and A which can be referenced directly to the ellipsoid selected without recourse to triangulation. Here indeed is a method of computing a world geodetic datum utilizing all the observations recorded to date regardless of the referenced datum or original ellipsoid used.

It must be remembered that the use of gravity anomalies to determine the value of the vertical deflections ξ and η is no magic method. It is an elastic tool in the hands of the geodesist. It is also possible to transfer the coordinates of latitude and longitude taken from an accurate map directly to the gravity datum by applying the recorded values of the vertical deflection for the mapped area. The mapped area must have a reliable grid of latitude and longitude. One additional advantage can be utilized in the gravimetric method of using isostatically reduced anomalies: it is possible to obtain an acceptable value of the gravity anomalies by using the average value to compute the needed vertical deflection ξ and η. While some error will be introduced, the error will not be large enough to prevent the calculation of the target position when using weapons of a large blast radius. Using the tools of gravimetric datum the following results can be obtained:

- The determination of a general world geodetic datum—or world system of coordinates—using the information of the many existing datum systems, such as the Russian, Swedish, and European, in the gravimetric datum without the task of recomputing all the datums.

- The computation, based on the world geodetic datum, of the geographic coordinates of any important point in the world where astronomical observations exist. It is also possible, using the coordinates of a point taken from a reliable map having an accurate grid, to compute the coordinates directly to the gravimetric datum if the gravity anomalies are available. The error between two points, computed gravimetrically using celestial observations and accurate vertical deflection measurements, should be no greater than 50 meters. This is well within the accuracy of Hiran or celestial methods.
- The accurate computation of the distance and direction between launch point and selected target of ICBMs.

Considerable work has been accomplished on the gravity measuring requirement. Some parts of the world have thousands upon thousands of gravity measurements recorded. Much of the world still remains to be worked, but certain parts of the world of interest to the ICBM program are well covered. In 1950 the Air Force Cambridge Research Center established a world-wide gravity measuring program. No less than 30 countries, many leading oil companies, and prominent geodesists from all over the world are cooperating in this program to solve the problem of gravity data collection.[8]

About one fourth of the world has been mapped accurately to the scale of 1/250,000. Approximately two fifths of the world has been mapped to the scale of 1/1,000,000 or larger. The areas that have been mapped and the gravimetric measurements offer an excellent source of information on which to base a datum computed gravimetrically. Celestial observations taken from available datums such as the Pulkovo, European, and others will furnish additional information.

the future

The Hiran method of extending geodetic control has been used extensively by the armed forces. Hiran is limited in its range over land areas, since United States aircraft are not allowed to fly over many parts of the world because of political differences. The celestial method has been used, but the observations of solar eclipse, star occultation, and moon camera methods are all dependent on visual sighting of the celestial bodies. The weather does not always cooperate. When using the celestial method observers have to be in place at both ends of the line to be extended. Here again certain areas are inaccessible and cannot be covered by the celestial method. The gravimetric method of extending geodetic control presents the best method of developing a world geodetic system because it references any available geodetic information to the reference ellipsoid without recourse to triangulation. The gravimetric method is the only one that can extend geodetic control to areas that are now totally inaccessible to the United States.

Can the ICBM hit the target? If we get the proper distribution and density of gravimetric readings and use the gravimetric method to establish a world geodetic datum—or a world system of coordinates—for calculating the precise relationship between the launch point and the target, the answer can and must be yes.

Air Command and Staff College

NOTES:

[1] *Military Engineer*, No. 332, November-December 1957, p. 469.

[2] B. Szabo, *Geodetic Datums and an Estimate of Their Accuracy*, Aeronautical Chart and Information Center, April 1956, p. 28.

[3] Air Force Manual 100-1, Vol. 2, *Communications and Electronics*, Department of the Air Force, December 1952.

[4] W. A. Heiskanen, *Intercontinental Connection of Geodetic Systems*, Ohio State Research Foundation, May 1955, p. 8.

[5] *Ibid.*

[6] *Ibid.*

[7] W. A. Heiskanen, *The Geodetic Significance of World Wide Gravity Studies*, Ohio State Research Foundation, Technical Paper Number 124, November 1950, pp. 41-42.

[8] Heiskanen, *Intercontinental Connection of Geodetic Systems*, *op. cit.*, p. 16.

Officers and Missiles

LIEUTENANT COLONEL WILLIAM L. ANDERSON

"WHEN in doubt, do the right thing." General Spaatz offered this counsel to the City of Los Angeles during a public forum on the necessity for jet-age airport expansion. His advice was accepted in that case because the circumstances of jet transport handling were sufficiently clear-cut to enable an affirmative decision. Unfortunately the factors in some departmental-type decisions are not so sharply defined. Where the decision must encompass a series of increments, perhaps even to the point that at the time of the decision the nature of the more distant increments cannot be too clearly seen, the problem becomes one of finding certain principles that seem to hold maximum validity under changing circumstances. This is exceedingly difficult.

The planning for the officer personnel requirements in the ballistic missile program involves this kind of decision. Laying down principles for it would be difficult at best. But the problem is being even further complicated by partisan debate: who is to be the backbone of the ballistic missile force, the rated or the nonrated officer? The rated officer sees a new weapon family, abetting manned aircraft, which demands the experience of the pilot-commander for effective use. The nonrated officer sees the opening of new opportunities. He senses the great career leverage offered by missile duty. As is so frequent in such debates, both groups are arguing on the basis of generalized and often mistaken information or assumptions, and both have some truth on their side.

For the Air Force the risk in this imagined conflict of interest is that it will invoke unrealistic personnel policies designed to settle an empty issue. This would be most unfortunate, for the ballistic missile force ought to be manned not in terms of how we split up the new pie among interest groups but rather in terms of an understanding of what the missile needs and in what direction this new weapon is likely to evolve in the future.

The intent of this article is to relate what the experience has been thus far in officer manning of the missile force, what the requirements for the initial force seem to be, and what general direction is portended for the future. When this is understood there is no real conflict of interest. Rather there should be abundant opportunity for the fullest use of both rated and nonrated officers. More than opportunity, there will be an insatiable demand for competent officers with diverse skills.

how missile units have been manned thus far

Since the activation of the first ballistic missile operational units, personnel requisitioning has never been in terms of rated versus nonrated officers. Many of the special skill requirements of ballistic organizations could best be satisfied from groups of nonrated officers. A number of pilots have been assigned, but the total has been considerably less than expected. This does not mean that only a handful of pilot officers will be used in this program. It is simply that many early requirements for specialized officers were circumstantially filled from nonrated sources. Several command positions were filled from rated groups. Again this has not been by design. It is simply that there are more experienced commanders available from rated sources as a result of past assignment policies.

It has been interesting to observe rated and nonrated officers working together in a ballistic missile organization. On the whole it has been a very harmonious arrangement. In some areas of planning the special and often unusual training of nonrated officers has been irreplaceable. For example, computer programing and supervision of the preparation of target guidance material represent areas where the abilities of certain nonrated officers are especially noticeable. On the other hand rated officers have been particularly active in such areas as emergency war planning and

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crew rotation. These areas of interest overlap, and of course such conclusions are of the broadest nature. There are exceptions. In general the question of whether an officer is rated or not is of little interest in this organization. It is just a case where both rated and nonrated talents find an abundance of opportunity. Any debate over rated qualifications is beside the point.

missile manning and AF officer requirements

As a background to qualifications for missile posts, we need to take a look at officer requirements of the past decade. Previous requirements must be compared with ballistic missile needs and the points of difference marked. At the end of World War II an Army general stated that the AAF needed "fighting first lieutenants" in the postwar era. And that is what we got in the several integration cycles. The first lieutenants fell under a policy which estimated that 70 per cent of Air Force officers should be rated. There was never an enthusiastic acceptance of this policy, and arguments have rumbled on through the intervening years. One air base was even manned largely with rated officers, each performing some nonflying additional duty. The fact that this particular base evidently was operated satisfactorily testifies either to the impotence of personnel policies or to the remarkable malleability of the average officer.

Historical validation of rated requirements for manned systems has usually been on the basis of:

a. Equipment-Inventory Positions—a relatively fixed requirement factored by a staff determination of number of pilots or crews per unit of equipment.

b. Emergency War Requirements—the customary mobilization figure. Usually considered in light of production potential after M-day. Tends to vary inversely with complexity of manned systems.

c. Rotational Positions—provides periodical interchange of officers between command-operational and staff assignments. Provides an undetermined portion of emergency war requirements.

d. Staff and Command—positions where aeronautical ratings lend effectiveness to the performance of the incumbent. Often the same requirement as the preceding one.

Spectacular improvement in manned aircraft performance since 1945 has profoundly altered the true requirements for rated personnel. New performance levels in equipment justify new emphasis on rotational assignments. Too much staff activity goes on without sufficient appreciation of the true nature of high-performance aircraft operations. The conditions of extreme alertness and dispersal under which the manned force must operate can best be understood through an assignment policy which brings large numbers of field-grade officers to operating-level duties in the combat wing. Hence there is an immediate validation, not for more pilots, but for recognition that rated personnel must be increasingly fed into the combat and operations field. An example of the present lag is that about two thirds of the regular officer group are currently serving outside the combat and operations area. This results in large numbers of rated officers becoming tagged as specialists in some administrative area where they may stagnate. Ultimately this degenerates into a system of arms and services, with all the attendant disadvantages of a strictly partitioned organization.

Acceleration of rotational assignment procedures for rated personnel ought to be accomplished in light of a new major influence: requirements for an emergency war utilization of staff crew members are steadily diminishing. Production potential of current aircraft following an M-day will be limited indeed. Part of this limitation may be caused by strike damage from enemy forces. But the duration of a future major conflict will no doubt be less than the lead times required to accelerate production. Since only a limited number of additional aircraft will be available following an M-day, rated personnel in the emergency war requirements category must be both able and adaptable individuals. The ability of an officer to satisfy an emergency requirement quickly is generally correlated to his recent experience in high-performance aircraft. This lesson has not been lost. The current reviews of flying status have been considerably stiffened and effectively act to cull the marginal performer from this category.

need for rated officers in ballistic missile force

Now consider the nature of requirements for operations and combat types in the ballistic missile force. First, there is the same need for satisfying the equipment-inventory positions as in the case of a manned system. Routine rotation between staff and missile operating posts is similarly necessary. Indeed it is urgent, for few major staffs have enough knowledge of missile operating techniques at present. Knowledge of missiles will also, as in the case of aircraft, lend effectiveness to the performance of individuals in staff positions. These are abiding requirements. One striking difference with missiles is that no emergency war requirement exists. Neither time nor circumstance will allow ballistic missiles to be manned with a view to strengthening the crew after some projected M-day. Nor is it likely that such a requirement will be justified in the future. Ballistic missile units are planned as a totally ready force capable of extremely quick reaction. This reaction follows a hard rule: launch preparations must be quicker than the flight time of the enemy missile. This rapid launch capability may alter a number of operating procedures and policies, ranging from handling of bench stocks to use of reserve forces. The first effect, however, is the requirement for complete crew manning on a regular duty-shift basis to provide a quick reaction time around-the-clock.

Strategic Bomber Pilot Versus Launch Control Officer

Pilot, Strategic Bomber	Function or Requirement	Launch Control Officer
yes	plans missions	no
yes	pilots aircraft	no
yes	supervises crew training	yes
yes	directs flying activities	no
yes	must know theory of flight	no
yes	must know radar bombing	no
no	graduate of launch control course	yes
no	mandatory technical undergraduate training	yes

The debate concerning the actual need for pilots in local missile operations may be settled quite easily. Missile officers obviously do not need to be rated officers.

If it is irrefutable that actual missile operation does not require a rated officer, it should be equally plain that this applies only to a very local situation within missile units. Several influences make it essential to consider the role of the rated officer above the crew level of missile operations. Foremost is the case of the planner in most staff functions. In the foreseeable future the USAF will use both manned and unmanned systems. Effective planning from the wing level upward requires a familiarity with the operational use of both missiles and aircraft, for the two types of weapons cannot effectively be employed separately. Secondly, there is the question of availability of officers with command experience. Notwithstanding the numbers of excellently qualified nonrated officers, it will doubtless be necessary to turn to the rated resource because of the numbers of commanders required for missile organization. Here is a case where the demand for effective commanders probably outstrips future availability. Weapon for weapon, ballistic officer requirements in the near future will exceed those for manned systems by over 200 per cent. It is important to remember that instantaneous availability of operational ballistic missiles cannot be equated with manpower economy.

Use of the rated officer in ballistic organizations should not only be a matter of necessity, but must enhance the experience of the individual. It ought to be practiced to a considerable extent on a rotational basis. Certainly such assignments must never be allowed to sever the relationships of an officer with manned-force employment. For it is the dually experienced officer who offers the elite planning and management capabilities for the future. We need to be particularly sensitive about the relationship of the manned and unmanned forces; otherwise interim missile developments may tend to produce a fissured officer corps. This could be doubly unfortunate, since interim missile developments may be quite uncharacteristic of the future.

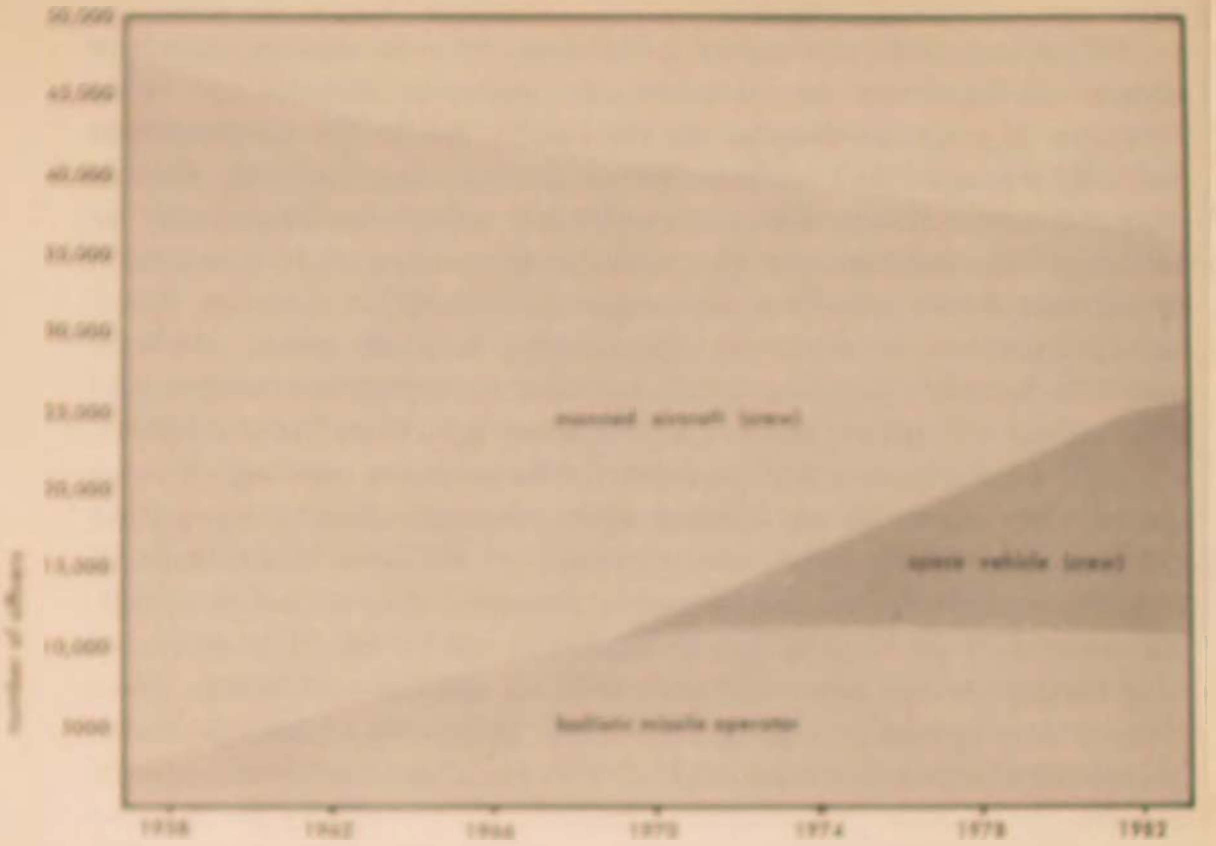
operational missiles and beyond

Missiles mean all things to all men, or so it seems. The public imagination has been sufficiently captured by missile news so that we have a popular conception that here at last is the means for push-button war. So a word of caution is in order. A ballistic missile is not an all-purpose weapon. Despite its obvious destructive power, its value may be limited by the very fact that it is an all-or-nothing device. At the end of diplomacy road, and sometimes before the end, armed force is useful in varying degrees to attain national objectives. A ballistic missile is essential for existence; for some time it will be the quiet big stick. Yet it lacks the visible international glamour of a White Fleet or the undeniable influence of a nonstop, around-the-world flight by strategic aircraft. It also lacks "presence," in the sense that deployment is necessarily a somewhat remote undertaking. Picture for example the paucity of interest or even knowledge on the part of the typical Asiatic about the existence of an ICBM complex in northwestern United States. Totality is the leading characteristic of a ballistic missile force.

The fact that a weapon lacks complete versatility does not mean that its development is frozen. Ballistic missiles are today weapons of singular destructive capability, while the airplane was initially a specialized reconnaissance device. But ballistic devices may become extraordinary surveillance vehicles. They may be mutated into fantastic travel conveyances so that what is regarded as a dream today will be commonplace within this century. Commercial uses of ballistic techniques are sure to come. Diverse military benefits ranging from logistics to weather research and forecasting are anticipated. Despite these promises for the future, all such performance will necessarily be slow in coming. Consequently there can be no wanton abandonment of existing specialized forces, for the fundamental reason that there must be functioning replacements. Moreover a manned system has a special dimension in its "option-performance" capability. The presence of a man provides a special potential in system operation. Here then is an impressive argument for the inclusion of man in many high-performance systems of the future. And it is the special benefit of the man-machine relationship that leads to the conclusion that aircraft, or manned air vehicles, will ultimately make use of the extraordinary propulsive force characteristic of the ballistic missile.

A most dramatic element of ballistic developments is the engine. In this component lies the key to future development involving the role of man in military vehicles. Man has always sought to associate himself most intimately with his scientific products. Whether for war or peace, he has always been the central beneficiary in the development of a means of conveyance. In improving his travel methods, he has usually improved his ability to conduct a war. Abundant objectives justify these developmental efforts, for combat success usually has as critical ingredients the velocity and performance of a vehicle. We need then to look ahead and see what sort of intimate relationship man might conceive so as to take advantage of new propulsive forces.

It is the coming juncture of aircraft and missiles that justifies the closest current relationship between crews of present manned systems and the array of ballistic missiles. For unmistakably we may expect a coincidence in engine performances in manned and unmanned vehicles so as to produce essentially a single group of vehicles, adaptable to a variety of performance objectives. This promises not the exclusion of man or of an aircrew, but rather


Future Operator Requirements

the imminent demand for their presence. An estimate of this development is contained in the accompanying chart. It is a crude projection, largely based on thrust growth since 1945. This does not mean that it is necessarily optimistic. The chief conclusion is that we shall have manned space vehicles operating in less than 10 years. Weight considerations as listed by experts would seem initially to limit the vehicle crew to a single operator. Solid-fuel propulsion for engine simplicity appears a logical probability. Flight conceivably would vary from a few hours to perhaps a day or two. Since the residual vehicle weight at re-entry would be low, no special landing problems are envisaged. Of course the pilot would be concerned with weather at his chosen destination, so he would require a reliable homing procedure for the final navigation phase and for the selection of alternate landing places.

A second conclusion drawn from the requirements projection is a long-term reduction in manned vehicle crew requirements, including aircraft. This is essentially due to the correlation of cost and performance, which provides something of a limit. Moreover, as in the case of present-day transport planes, future vehicles of all classes may be expected to provide an increasing functional yield. Compare, for example, the value of a single reconnaissance vehicle in orbit with the massive World War II efforts in reconnaissance.

National interests demand that the Air Force achieve a capability to deny a potential enemy the military use of space. This may require an unprecedented national effort. Certainly the need for decision is near, for international competition has already drawn the issue of survival in the space age. It is against this background that the specialized potential of a ballistic missile ought to be considered. Combat during the space era requires action aloft, and surface destruction may become so incidental as to be unnecessary. Space vehicles, manned and unmanned, will ultimately exceed the usefulness of ballistic missiles. Moreover gross manpower requirements for space vehicles will eventually exceed requirements for operation of ballistic missiles by a wide margin.

We can either regard the ocean of space as open and free to all or as a medium that must be controlled by some method. Either alternative automatically excludes a number of lesser nations, because of the capital costs of space activities. So it boils down to an issue between the large, industrialized countries. Since mutual confidence is uncharacteristic of international relations, there really is no option. The taking of the necessary steps to acquire a space capability is essential to our national survival. It is against this unfolding age and challenge that the trivial argument of roles for rated and nonrated officers is heard. It is heartening to realize that the demands of the space age will shortly drown out this minuscule debate. There is as much scope as all of them can handle, and the roles of the nonrated specialist and the pilot are going to become so interdependent, each so indispensable to the other, that grounds for argument will be inconsequential.

Headquarters 1st Missile Division

Fundamental Equations of Force Survival

Colonel Robert D. Bowers

As a democracy dedicated to peace the United States has traditionally held the policy of fighting only in retaliation to blows struck against her by an enemy. So deeply rooted is this policy that we have clung to it even in this age of nuclear weapons and high-performance, globe-girdling delivery vehicles. We have acknowledged the high degree of national peril involved in this free choice by building and maintaining in peacetime large, combat-ready retaliatory forces. Deterrence, and the ability to retaliate if the deterrence fails, are dependent on the ability of our retaliatory force to survive initial attack and still have the capability to inflict an unacceptable degree of damage on the enemy.

Such a force must of course be developed, built, trained, and its employment planned long before the outbreak of war. Of the many new factors involved in this process one of the most critical is the computing of the portion of the retaliatory force that will survive the enemy's initial attack. All persons engaged in national defense may encounter this problem at one time or another. It is encountered often these days by the military planner. What factors are important in force survival? How do they interrelate? How much emphasis should be put on each?

Although there are professional operations analysts and study organizations such as RAND to turn to, planners are often faced with the necessity of estimating answers to questions such as these in advance of the completion of rigorous analyses. The equations developed here are the tools for making such estimates, and they can also be used to better understand and define problems preliminary to more detailed analyses.

The term "fundamental" is used to describe these equations because certain simplifying assumptions are made in the derivations. This procedure may not be sophisticated enough to satisfy the strictest mathematicians but it is adequate to show the general relationships among the various survival factors. These in turn should be accurate enough for broad military planning where many of the parameters—particularly those under control of the enemy—can never be precisely known or controlled by the planner. Because the equations are somewhat bulky they may appear formidable at first glance to those not normally confronted with mathematics in the exercise of their daily duty. Closer inspection will show that the terms are easy to understand and that the equations can be solved by anyone familiar with slide-rule fundamentals. For those who are not, a graph is included which allows the equations to be solved by longhand arithmetic.

The assumptions used in developing the equations are:

a. For purposes of terminology it is assumed that the target for enemy attack is the U.S. ballistic missile force. For application to the U.S. aircraft force, simply substitute "aircraft" for "missile" and "base" for "site" in the terminology.

b. The U.S. sites present point targets to the enemy. This assumption is probably more valid for ballistic missile sites than for aircraft bases, but it should be sufficiently valid for air bases under most circumstances.

c. The enemy initiates the war by an attack which arrives nearly simultaneously all over our missile force. There is no launching of U.S. missiles during this short period when enemy weapons are impacting. This does not rule out the possibility of launching on the basis of warning prior to attack.

d. All errors contributing to the enemy circular probable error (CEP) are normally distributed.

e. All targets are of equal importance to the enemy, and he distributes his attack in an optimum fashion. The enemy has no advance knowledge of which U.S. missiles may be launched or how many may be launched before his weapons arrive at target.

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f. The lethal, or damage, radius of the attacking nuclear weapon is the distance at which a specified static overpressure will be exerted. Any target within this radius and vulnerable to the specified overpressure will be destroyed. Any target designed to the specified overpressure and which is outside this radius will escape.*

g. Sites (or missiles) hardened to a given static overpressure are also designed to withstand all the other weapons effects associated with that overpressure.

h. The U.S. sites are separated by a distance such that a single attacking weapon cannot destroy more than one site and will have a negligible probability of hitting a site other than the aiming point. This distance can easily be determined when yield, accuracy, and site hardness are known.

i. The enemy attacking weapon has no alternate target capability after it has been launched.

For a U.S. missile to be destroyed by enemy attack, all of the following conditions must obtain:

- The enemy must know the location of the U.S. missile at the time he launches his attack;
- The missile must not be launched prior to arrival of enemy attack; and
- The enemy weapons must impact within the lethal radius.

The probability that a missile will be destroyed is the product of the probabilities that each of the above conditions will obtain. Stated mathematically the probability that any one missile will be killed or destroyed by enemy attack is:**

$$P_k = P_I (1 - P_L) (1 - P_M) \qquad (1)$$

where P_I is the probability that the enemy knows where the missile is;

$(1 - P_L)$ is the probability that the missile is not launched prior to arrival of the attack; and

$(1 - P_M)$ is the probability that the attacking weapon (s) will destroy the target.

The probability that a missile will survive enemy attack is:

$$P_s = 1 - P_k$$

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*This is known as a "cookie cutter" distribution. While it is true that some targets inside the lethal radius may escape and some outside may be destroyed, the approximation is adequate for our purposes.

**See accompanying summary of symbol definitions.

Definition of Symbols

P_k = probability of destroying any one missile; also the expected fraction of the force that is destroyed.

P_s = probability of survival of any one missile; also the expected fraction of the force that survives.

P_I = probability that the enemy knows the location of U.S. missile(s) or that he knows there are missiles at any particular site.

P_L = probability that a U.S. missile is launched before arrival of enemy weapons.

$1 - P_L$ = probability that a U.S. missile is not launched before arrival of enemy weapons.

P_M = probability that weapon(s) will miss the target, i.e., the weapon(s) will all fall outside the lethal radius.

$1 - P_M$ = probability that weapon(s) will hit and destroy the target.

R = lethal radius (or radius of destruction) of an attacking weapon.

C = circular probable error (CEP) of attacking weapon.

n = number of enemy missiles impacting in each target area.

W = yield of attacking weapons in megatons (MT).

H = site hardness in pounds per square inch (psi) of overpressure.

E = number of enemy weapons assigned to attack the U.S. missile force.

r = over-all reliability of enemy weapons. i.e., the fraction of the enemy missiles that will function adequately so as to impact in the target areas.

a = attrition rate of enemy weapons by U.S. active defense.

N = number of missiles in U.S. force.

k = concentration of U.S. missiles, i.e., number per site.

NP = the number of U.S. missiles expected to survive.

Substituting this expression into (1):

$$P_s = 1 - P_I (1 - P_L)\ (1 - P_M) \tag{2}$$

The probability $(1 - P_M)$ that weapons aimed at a point target will hit it depends upon the lethal radius, accuracy, and number of attacking weapons.

If one enemy weapon impacts in the region of each site $(n = 1)$, the probability of site destruction is:

$$1 - P_M = 1 - (\tfrac{1}{2})^{R^2/C^2}$$

When n is greater than 1, $(n > 1)$:*

$$1 - P_M = 1 - (\tfrac{1}{2})^{R^2 n/C^2} \tag{3}$$

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*This is mathematically precise only when n is an integer, but is an adequate approximation for any other value of n greater than 1.

When n is less than 1, $(n < 1)$:

$$1 - P_s = n \left[1 - (1/2)^{R^2/c^2}\right] \tag{4}$$

The lethal radius (R) can be expressed in terms of the target hardness (H) and weapon yield (W) as follows:*

$$R = \frac{6W^{1/3}}{H^{1/2}} \tag{5}$$

where R is nautical miles, W is megatons, and H is pounds per square inch (psi).

An expression for n in terms of the quantities previously defined can be derived as follows: The number of enemy weapons assigned to attack the U.S. missile force is E. The number of assigned enemy weapons successfully launched and functioning properly is Er. The number of assigned enemy weapons launched, functioning properly, surviving air defense action, and reaching the target is $Er(1 - a)$. The number of U.S. missiles is N. If these are concentrated with k missiles per site, then the number of sites (or targets to the enemy) is N/k. Therefore by definition:

$$n = \frac{Er(1 - a)}{N/k} = \frac{Er(1 - a)k}{N} \tag{6}$$

The probability that any given missile in the U.S. force will survive (which is also the expected fraction of the force surviving) can now be found by substituting equations (3), (5), and (6) into equation (2). The result is:

$$P_s = 1 - P_l(1 - P_L)\left[1 - (1/2)^{\frac{36W^{2/3}Er(1-a)k}{c^2HN}}\right] \tag{7}$$

Equation (7) is for the case where at least one attacking weapon reaches each site, i.e., the term $Er(1 - a)k/N$ will be equal to or greater than 1.**

For the case where there are more sites than there are enemy weapons reaching the sites, (i.e., the term $Er(1 - a)k/N$ is equal to

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*This expression is for a surface burst and has been derived empirically from the unclassified DOD-AEC publication "The Effects of Nuclear Weapons," June 1957 (AFP 136-1-3). Somewhat more precise expressions could be derived for limited ranges of hardness. For an airburst and 10 pounds per square inch (psi) or less hardness, the expression $10W^{1/3}/H^{0.5}$ can be used.

**The form of equation (7) will vary with the assumptions as to how the enemy assigns targets to his missiles and the information the enemy has (and uses) about the reliability and survivability of his missiles after the launch operation begins. Equation (7) represents the best the enemy can do without bomb-damage assessment.

or less than 1), equation (4), instead of (3), should be substituted into equation (2), resulting in the following expression:

$$P_s = 1 - P_I (1 - P_L) \frac{Er(1 - a)k}{N} \left[1 - (\tfrac{1}{2})^{\frac{36W^{2/3}}{c^2 H}} \right] \qquad (8)$$

All the major factors in force survival are now related in these expressions. By use of the appropriate one of the equations the expected fraction of the U.S. force surviving can be determined for any given set of the parameters. In using the equations the assumptions under which they are derived must be kept in mind and the survival probability modified to account for any change in the assumptions. For example, if the U.S. missiles are launched while enemy weapons are arriving (which is contrary to assumption "c"), the survival probability would tend to be raised because some missiles would be launched before being attacked; but at the same time the survival probability would tend to be lowered since the missiles (if initially in hardened sites) would be exposed and more vulnerable during the period preparatory to launch. These could be offsetting factors, but they would need further examination in any particular case to determine the effects on survival.

The equations are intentionally made general to cover all the major factors in force survival. In particular cases or under particular circumstances they can be considerably simplified. For example, if the force is based at fixed sites rather than mobile,* it can be assumed the enemy will know the location. Then the term P_I equals 1. If there is no launching prior to enemy ICBM attack** the term P_L equals 0. Equation (7) then reduces to:

$$P_s = (\tfrac{1}{2})^{\frac{36W^{2/3} Er(1 - a)k}{c^2 HN}} \qquad (9)$$

and equation (8) reduces to:

$$P_s = 1 - \frac{Er(1 - a)k}{N} \left[1 - (\tfrac{1}{2})^{\frac{36W^{2/3}}{c^2 H}} \right] \qquad (10)$$

As an example of the use of the survival equations and the

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*In a mobile system the missiles would be moving from place to place so that the exact location of some fraction of the force is unknown to the enemy at any time. This may be good from a survival standpoint, but it has practical logistic, operational, and reliability limitations, plus the fact that the fraction of the force on the move is not available for immediate retaliation.

**Launching missiles prior to manned bomber attack may be feasible, but launching prior to enemy ICBM attack has practical limitations of short warning time and national decision time. These limitations are more thoroughly discussed by Colonel H. W. C. Shelton, "Impact of the Ballistic Missile on Defense," *Air University Quarterly Review*, IX, 3 (Summer 1957), 131 ff. It should be pointed out that these limitations do not necessarily apply to launching manned bombers on warning of ICBM attack. The bombers can be called back if the warning turns out to be false.

accompanying graph, take the case where the number of assigned enemy weapons is equal to the number of U.S. missiles; the over-all reliability of enemy weapons is 80%; there is no combat attrition of enemy weapons; there is no launching of U.S. missiles prior to enemy attack; the U.S. missiles are based at fixed sites hardened to 75 psi and dispersed to 5 missiles per site; the enemy CEP is 3 nautical miles and the yield is 1 megaton (MT).

The parameters then have the following values: $E = N$, $r = .80$, $a = 0$, $P_I = 1$, $P_L = 0$, $k = 5$, $H = 75$, $W = 1$, $C = 3$, $Er(1 - a)k/N = 4$.

Since $Er(1 - a)k/N$ is greater than 1 (each site is attacked by more than one enemy weapon) and since $P_I = 1$ and $P_L = 0$, equation (9) should be used.

When these figures are substituted, the numerical value of the exponent becomes:

$$\frac{36W^{2/3}\,Er(1-a)\,k}{C^2HN} = \frac{36 \times 1 \times 4}{9 \times 75} = .214$$

and from equation (9):

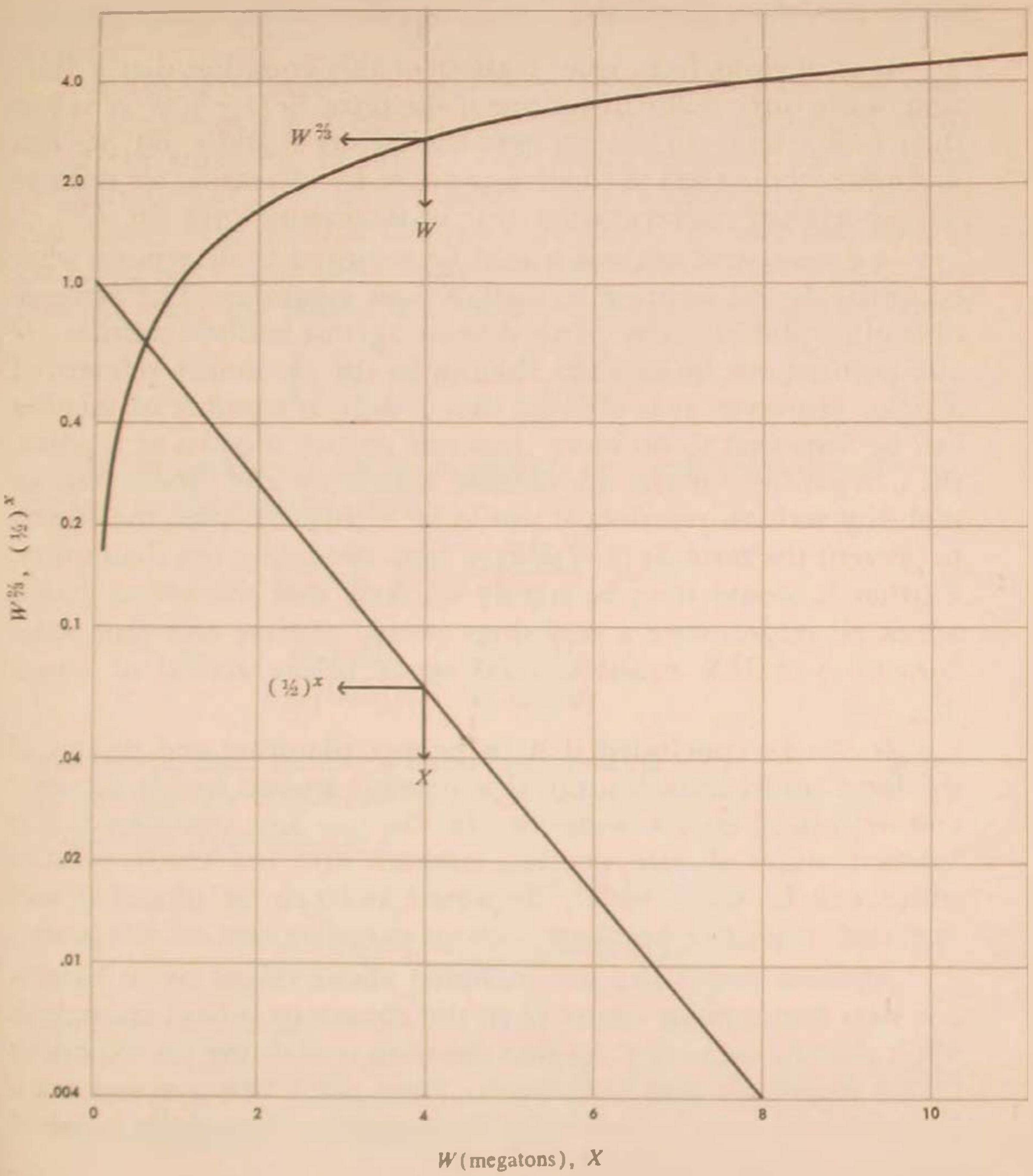
$$P_s = (1/2)^{.214}$$

From the accompanying graph, when $x = .214$, then $(1/2)^x = 0.86$. Therefore $P_s = 0.86$. Under these conditions 86% of the U.S. force would be expected to survive the enemy attack.

These calculations can be repeated for various values of the parameters to determine the alternatives between hardness (H), dispersal (k), active defense (a), reaction time (P_L), force size (N) and enemy capabilities (E, r, C, W), for fraction of force survival (P_s), or number of surviving missiles (NP_s).

When costs of the various alternatives are known, the particular combinations and degrees of hardness, dispersal, active defense, reaction time, and force size can be chosen that will provide maximum survival at given cost or given survival at least cost.

THE question is often asked: Can our force survive highly accurate or high-yield weapons if it is based at fixed sites and makes no launchings prior to enemy attack? Further examination of equations (9) and (10) will throw some light on this problem. If the CEP becomes very low (approaches zero) or the yield becomes very high, then, for reasonable values of the other terms, the exponent in the equation becomes very large and the term containing the exponent vanishes. The survival according to equation (9) then becomes zero. But this is for the case where



there is one or more attacking weapons per site. When there are fewer attacking weapons than sites, equation (10) is applicable and, under these circumstances, becomes:

$$P_s = 1 - \frac{Er(1 - a)k}{N}$$

It is obvious from examination of this equation that a fraction of the force will still survive if the term $Er(1 - a)k/N$ is less than 1. We have no control over the factors E and r, but we can make the whole term as small as possible by increasing air defense (a), decreasing concentration (k), or increasing force size (N).

A careful cost analysis would be required to determine what emphasis should be given to each of these measures. The extreme difficulties and high cost of air defense against ballistic missiles are also pointed out by Colonel Shelton in the previously referenced article. However, it is obvious that if a great number of missiles can be dispersed to no more than one or two missiles at a point, then, regardless of the air defense capability and limitations of mobility and fast reaction, it would be highly costly for the enemy to prevent the term $Er(1 - a)k/N$ from becoming less than unity. Further it would then be highly unlikely that the enemy could attack all targets over a very short period of time and thus some launching of U.S. missiles could occur before arrival of attack $(P_L > 0)$.

It can be concluded that by proper planning and design of the force configuration survival is possible against highly accurate and high-yield enemy weapons. In the case just considered, this survival might dictate smaller, simpler, and less costly missiles which can be more widely dispersed and can be procured and operated in greater numbers without excessive cost or manpower.

Another possibility not included above might be to harden our sites to the point where H in the equations is high enough to offset the low value of C, so that the term containing the exponent in the equations does not vanish. Here again the cost and feasibility of such a measure must be determined and carefully weighed against the other measures.

ANOTHER comparison that can be made by using the equations and substituting typical values is the relative cost and military value of hard and soft bases. A good measure of merit in designing a missile force is the cost per surviving missile rather than the cost per initial missile in the force. A force configuration which will give a low cost per surviving missile is obviously better than a configuration resulting in a high cost per surviving missile —other things such as logistics and operating simplicity being equal.

It would be useful to know how the cost of a hard base compares to that of a soft base if they have equal measures of merit (cost per surviving missile). The following steps will give an indication. Let D equal the dollar cost of a missile force. It does not matter here whether this is a yearly cost, ten-year cost, or cost on some other time basis, since the time factor cancels out. The cost per surviving missile is D/NP_s. For equal measures of merit:

$$\left(\frac{D}{NP_s}\right)\text{soft} = \left(\frac{D}{NP_s}\right)\text{hard}$$

If the number of initial missiles is assumed to be the same for the two configurations, then:

$$\left(\frac{D}{P_s}\right)\text{soft} = \left(\frac{D}{P_s}\right)\text{hard}$$

$$\frac{D\,(\text{soft})}{D\,(\text{hard})} = \frac{P_s\,(\text{soft})}{P_s\,(\text{hard})}$$

As a typical case, assume a fixed-base concept $(P_I = 1)$ and a surprise attack $(P_L = 0)$ of one weapon per target, $Er\,(1 - a)\,k/N = 1$. Then from equation (8):

$$P_s\,(\text{hard}) = (\tfrac{1}{2})^{36W^{2/3}/c^2 H(\text{hard})}$$

$$P_s\,(\text{soft}) = (\tfrac{1}{2})^{36W^{2/3}/c^2 H(\text{soft})}$$

The ratio of costs is:

$$\frac{D\,(\text{soft})}{D\,(\text{hard})} = \frac{P_s\,(\text{soft})}{P\,(\text{hard})} = (\tfrac{1}{2})^{\frac{36W^{2/3}}{c^2}\left(\frac{1}{H(\text{soft})} - \frac{1}{H(\text{hard})}\right)}$$

Substituting values from the previous example of $W = 1$, $C = 3$, H (hard) = 75 psi and taking H (soft) = 3 psi as a typical soft base:

$$\frac{D\,(\text{soft})}{D\,(\text{hard})} = (\tfrac{1}{2})^{\frac{36}{9}\left(\frac{1}{3} - \frac{1}{75}\right)} = (\tfrac{1}{2})^{1.28} = .41 = \frac{1}{2.44}$$

$$D\,(\text{hard}) = 2.44\,D\,(\text{soft})$$

or, under these conditions a 75-psi site would need to cost more than twice as much as a 3-psi site for equal measures of merit. In other words a 75-psi base would be better than a 3-psi base unless the 75-psi base cost more than twice as much as the soft base. Although no conclusions can be drawn from this one example, repeating the analyses and assigning various values to the parameters should provide a good feeling for the payoff in hardening missile sites.

Another way in which these expressions may be used is to determine the relationship between hardness and dispersal for given survival. For example, take the previous case where $P_I = 1$ and $P_L = 0$ and equation (9) applies. If the survival is to remain the same under two separate conditions of hardness and dispersal (call them conditions 1 and 2), then the value of the exponent of ½ must not change. If all the other terms in the exponent remain the same under the two conditions, then:

$$\frac{k_1}{H_1} = \frac{k_2}{H_2}$$

$$H_2 = H_1\left(\frac{k_2}{k_1}\right)$$

Thus if the first condition is 5 missiles per site ($k_1 = 5$) and the second condition is 10 missiles per site ($k_2 = 10$), then for equal survival:

$$H_2 = H_1\left(\frac{10}{5}\right)$$

$$H_2 = 2H_1$$

and, under these circumstances, a 10-missile site must be twice as hard as a 5-missile site for equal force survival.

Only a few examples of the application of these fundamental equations of force survival have been shown. The equations can be used in many other ways to produce an indication of the relationships and relative worth of the measures contributing to force survival. It is obvious that all the factors entering into force survival planning cannot be put into mathematical equations. But intelligent application of the relationships presented here will go a long way toward providing broad planning guidance.

Air Force Ballistic Missile Division, Hq ARDC

In My Opinion...

CONTROL OF OUTER SPACE

Colonel Martin B. Schofield

GROWING interest in the exploration of space above the earth's atmosphere has raised the question of what limits, if any, should be imposed on the use of outer space by reason of national sovereignty. While international lawmakers have slowly pondered this question, science has been busy creating the potential trespass with little regard for its legal acceptance. Now that scientific earth satellites, protected by mutual agreement, have already successfully penetrated the assumed space boundaries of all states on earth, the question of legality arises concerning similar penetration by other forms of space vehicles not covered by specific agreement. From a military point of view, unrestricted use of either atmospheric or nonatmospheric space by military vehicles of other states would undoubtedly pose a serious threat to our national security.

Extension of Sovereignty into the Air Space

As far back in history as four and one-half centuries before the Christian Era reference was made to "air space" as a question of law. One quotation appears:

> The air should be open to the free use of all, and that it might be used freely as might the flowing water, the sea shores, and the sea.*

In those early days the air was thought of merely as a human commodity, unrestricted and available to all. Much later in history, near the turn of our century when the air was found to serve an entirely different function, restrictions as to its use appeared. The introduction of lighter- as well as heavier-than-air conveyances made evident the need for international air boundaries.

Prior to controlled flights of Von Zeppelin in 1900 and the Wright brothers in 1903, free balloon ascents were rather commonplace. Their unpredictable and irregular flight paths became the cause of the first international convention called to discuss state rights in the air space. A convention called by the French in 1889 as a result of German balloons descending on French territory revealed two schools of thought, one of which may be accredited as the basis of today's international air law.

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*John Cobb Cooper, "Roman Law and the Maxim *Cujus Est Solum* in International Law," *McGill Law Journal*, I (Autumn 1952), 16.

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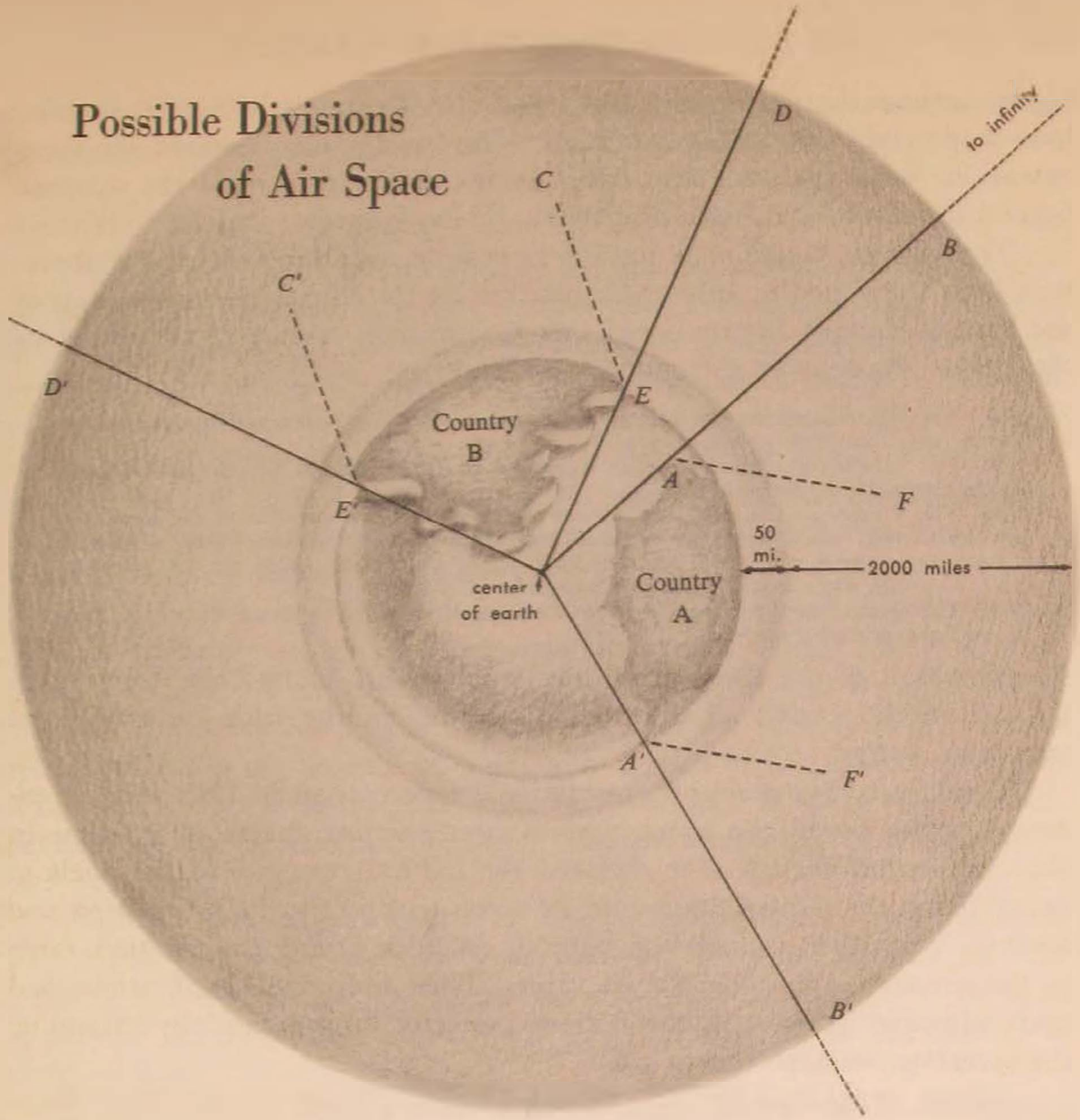

Possible Divisions of Air Space

Two possible methods of segmenting space according to territorial boundaries of states or continents have been considered. One is by projection upward of the geographic boundaries (dotted lines A—F and A'—F' for Country A; E—C and E'—C' for Country B) on parallel to a vertical halfway between them. The other is by radial verticals from the earth's center through the geographic borders to infinity (solid lines A—B and A'—B' for Country A; E—D and E'--D' for Country B). Under the first method the cross-section area of a nation's air space would remain the same to infinity, leaving wedges of unowned space between that claimed by contiguous nations. Within that "no man's space" a bomb could be dropped from 1000 miles up and fall gravitationally 250 miles inside another nation's borders. Under the second method each nation's air space would expand congruently as the radial boundary lines flare, leaving unowned space only above the open seas. Under any method of segmenting space according to earth boundaries, a space vehicle would pass at will through the changing ownerships—unless of course it achieved the feat of staying within its own nation's space borders, perhaps by spiraling and necessarily by taking into account the earth's spinning. Obviously the observing or enforcing of boundary lines in space is difficult up through the 50-mile zone, impossible 2000 miles up, and ridiculous to the stars and galaxies.

eignty beyond the maritime league. Some in Central and South America have made claims exceeding 200 miles. The basic practical reason for these extensions is an apparent firm belief in the ability to control the seas out beyond the traditional limits and to the limits claimed.

The greatest single spur toward large-scale abandonment of the three-mile limit developed in 1956 at Geneva during the Eighth Annual Session of the United Nations International Law Commission. Article 3 submitted to the United Nations by the commission reads:

> 1. The Commission recognizes that international practice is not uniform as regards the delimitations of the territorial sea.
> 2. The Commission considers that international law does not permit an extension of the territorial sea beyond 12 miles.
> 3. The Commission, without taking any decision as to the breadth of the territorial sea up to that limit, notes on the one hand that many states have fixed a breadth greater than three miles and, on the other hand, that many states do not recognize such a breadth when that of their own territorial sea is less.
> 4. The Commission considers that the breadth of the territorial sea should be fixed by an international conference.

Abandonment of the three-mile limit is apparently in its final stages. Less than 25 of the world's 59 littoral nations are holding with the traditional territorial waters.

The United States set off international repercussion in 1945 when President Truman issued two proclamations strengthening American interests in the Continental Shelf.* One declared the natural resources of the Shelf to appertain to the United States and to become subject to its jurisdiction and control. The other asserted the right to establish fishing conservation zones in the sea areas adjoining the coastline. Thus additional justifications had been advanced other than the national security for substantially extending the sovereign interests out to sea.

Recent extensions of U.S. air boundaries seaward by erecting "Texas towers" and by employing airborne early-warning aircraft along the coastal areas are examples of extensions of sovereignty in the interest of national security. Some of the towers are erected as much as 100 miles off the coast, yet are not viewed as additional assertion of territorial sovereignty in the sea. Airborne early warning exceeds this distance. Such extensions, however, are classified as assertions only of "special-purpose control." In other words, they are directed toward a single, specific purpose and do not amount to a blanket claim of jurisdiction. Hence they are not presumed to affect U.S. recognition of the extent of its territorial waters, which continues to be three miles.

The "specific purpose" of the Texas towers is the extension of U.S. air boundaries for the purpose of more effective air defense control. In the interests of national security, detection and identification of high-speed modern aircraft are required at distances of several hundred miles from U.S. coastal areas. Such extensions are made to satisfy state interests. They give consideration to decisions of international law only as a secondary reflection. Similarly, extension of sovereignty above the earth's atmosphere will un-

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*The Continental Shelf is fixed by the so-called "100-fathom curve" and may extend anywhere from 5 to 120 miles off shore.

doubtedly be made either to enhance scientific progress or to meet the threat of advanced weapon systems of greater speeds and altitudes.

space law and state sovereignty

The extensions of state sovereignty beyond the air boundaries and geographical limits of a state have not thus far been known to conflict appreciably with the rights and boundaries of subjacent states. Neither have they been known to overlap the extensions of adjoining states except in instances of assuring both parties in their mutual interest. However the appearance of a new form of vehicle, the earth satellite, has created an entirely different problem because of the nature of its trajectory. Such trajectories display tremendous speed in an orbital flight path about the earth to attain sufficient centrifugal force outward to offset the force of the earth's gravity. This form of flight requires no reaction from the air except during the initial stage of trajectory in approaching orbital altitude. Once the vehicle or object is established on its orbit in space, it may be said to be in a state of free fall, and control in relation to its track over the surface of the earth is relinquished. In the absence of a guidance system such a space object pays little respect to sovereign state boundaries, as its orbit in space remains independent of the earth's rotation and it thereby establishes a new track for each revolution in orbit.

Although very little thought may have yet been given to the question of state sovereignty above the earth's atmosphere, it may be expected that the introduction of numerous objects passing at random over all sovereign states at varying altitudes and directions will raise questions as to the legality of their trespass.

The distance at which an object passes above a state's national air space appears to be one of the main factors which will determine its legality. An individual earth state would not likely consider an object orbiting about the moon as an encroachment upon its particular territorial sovereignty or national air space. At the other extreme it might regard an object passing over its territorial boundaries at an altitude of only 20 miles as a quite different matter—that at least during the time the object passed within its particular national air space boundaries the threat was localized and related only to its own peculiar interest.

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> This interest is not sufficient to establish a special relationship in the previous sense between outer space and the territorial limits of a state. Nor can outer space from a constructive legal point of view form a part of that territory in which the sovereignty of a state extends. The exercise of sovereignty over its territory by a state is based on two prerequisites: It must deal with a space with delimitable—even if not visible—borders. In the second place, the possibility of exercising "effective sovereignty" must exist. Neither prerequisite is applicable to outer space. In the present state of the arts it would be impossible to establish definitely whether an occurrence in outer space had transpired over the boundaries of a specific state even if the presumed boundaries of the state were delineated in a plane in outer space. The boundaries of a state cannot be definitely established as one moves outward into space from the surface of the earth, as would be the case in outer space.*

In summary, the limitations that have been encountered in air travel by the recognition of state boundaries and unquestionable existence of state sovereignty in air space lose their identity somewhere in the upper limits of the earth's atmosphere. Although the dividing line is not yet clearly established, the absence of state sovereignty in space is easily comprehended when examining a state's jurisdiction in remote areas of space that are contiguous to other planets rather than to the earth.

Limits of sovereignty as expressed here are in no way related to the rights of a state to defend its sovereignty through action outside its recognized boundaries. This is a common practice among states today and will always be considered an inherent right of a sovereign state regardless of the location of the threat in space, in the earth's atmosphere, or on the surface of the earth.

In general then, the absence of state sovereignty in international space merely restricts a state from exercising control over vehicles of another state unless matters of national security are involved. If safety is to be provided for in the free use of space and if international disputes are to be resolved, it is apparent an effective international body should be organized to determine the type of control needed in regulating the use of space. The agency given this responsibility should have not only the authority to regulate the use of space but also have the collective force, militarily capable of enforcing the international regulations adopted. Actually time is running out for the formulation of such collective security. International agreements must be reached before space capabilities are so commonplace that a belligerent nation could stand in the way of forming harmonious controls.

Military Implications of Unlimited Use of Space

Long-range ballistic missiles and the scientific earth satellites have stimulated the imagination as to what the future may hold in the way of advanced weapon systems. The advent of these systems has drawn serious attention to their potential as long-range nuclear weapon carriers. Several applications of advanced systems have been envisioned:

- The use of an earth satellite as a reconnaissance vehicle would provide intelligence data of the highest order of coverage and reliability. Reconnaissance in the form of constant surveillance would provide military information heretofore beyond capabilities. Weather and electronic recon-

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* *Ibid.*

referred to as a world balance of power; yet, as the term deterrence suggests today, it represents a balance between the two major powers which leaves the lesser powers to join with and be guided by the will of whichever dominating leader they choose or are forced to join.

At the same time it is within the imagination to foresee the day when technology will permit lesser powers to equip themselves with nuclear space-weapon systems providing significant influence upon the larger powers. This will become possible as the ratio of destructive force per dollar continues to increase. Without reaching too far into the future it may even be assumed that the more or less insignificant military powers of today may reach some form of parity with the larger powers through their war-deterring capability. The capability, if attained by the smaller states, may not necessarily constitute a major threat, but it may be entirely adequate to permit a participation in power politics approaching that of the major military powers. This possible future situation might then be referred to as a true world balance of power. Assuming such a balance is feasible, the situation then suggests the desirability of establishing a form of control early in the era of space travel while but a few powers carry the weight of international influence.

An early-day monopoly in the field of aviation inspired the French to advocate "freedom of the air space" regardless of territorial sovereignty. A comparable feeling of leadership in the air today has inspired the United States to advocate strongly the policy of "open skies" in which to employ aviation to its greatest advantage. This position, presently held by the United States, when translated into the free use of space might not be wise under the assumption above that a true balance of power may exist sometime in the future. In plainer words, the presence of a variety of devastating military forces, of many sovereign states, constantly deployed throughout international and outer space, may not be conducive to peaceful living. Such a condition of balance might then be comparable to the situation in the old West where aggression appeared attractive for the "fastest gun."

Such a balance is too critical. It might be sounder for the United States, while it is an early contender in the exploration of space, to use its position to influence to the best advantage by strongly advocating a form of international control over the use of space. A form of control should prove attractive to states that possess little military strength but a strong desire for national security. If the feeling is prevalent, even the Soviet Union might find the proposal attractive after appreciating the collective military force that could be brought to bear against it. Full realization of this collective power might force the Soviet Union to be content with other means of seeking world domination.

A Position on the International Use of Space

Our position regarding the international use of space must be realistic rather than Utopian and consistent with established national objectives.

Definitions of Space Strata

Three practical definitions for the division of space are proposed for adoption by the Air Force and by any international body concerned with the use and control of space:

national air space — the area bounded by the geographic borders of a state extended along radial lines considered to originate at the earth's center to terminate at a height of 50 nautical miles above mean sea level. The figure of 50 miles was arrived at as the useful altitude at which aircraft may operate that depend on reaction of the air for lift and control and which is adequate to permit free operation of air contrivances of advanced design around the earth's surface without serious restriction as to speed and navigation. Also by this limit a portion of atmospheric density above national air space is available in which free-fall vehicles can decelerate and assume a glide path comparable to that of powered aircraft before re-entry into the national air space of a sovereign state. State sovereignty is implicit in the term "national air space." All air space above international waters would remain international as now recognized by the International Civil Aviation Organization.

international space — that area of space between 50 and 2000 nautical miles above mean sea level, without regard to national boundaries. Within this layer will fall the great number of vehicular and orbital trajectories. Ballistic missiles aimed halfway around the earth need not exceed an altitude of 2000 miles. This height is sufficient for trajectories incident to the launching of orbital vehicles of a permanent nature. Powered space vehicles could establish orbits or flight paths within international space and depart outward or return to earth as desired. Operations within this space are considered more pertinent to earth than to other planets or to interplanetary space travel.

outer space — that area of space beyond 2000 miles, to infinity. This definition is useful militarily as meaning the region where operations are not closely earth-associated but are more related to interplanetary transit.

groundwork of common understanding and mutual interest has been laid and the nature of the new threat is generally understood by all. Therefore a proposal by the United States for international control should prove attractive to a majority of states.

What would be the position of the controlling agency toward those states not in agreement to a form of international control? Here the decision to forcibly protect the security interests of the majority would have to be made. It is questionable whether such a decision could be reached in the United Nations, but it is becoming increasingly apparent that the threat of the employment of satellites and other space vehicles in military roles soon after the International Geophysical Year may alter the resisting side of world opinion, as it is known today, and produce a different concept of cooperation.

Evaluation Staff, Air War College

DEFENSE IS NOT PROFIT AND LOSS

Colonel Albert S. Raudabaugh

THERE is an old story in the Air Force about a base commander whose unit was having more than its share of aircraft accidents. Higher headquarters was on his back. Finally in desperation he put out an order: "There will be no more aircraft accidents on this base." The story is probably fiction. At least it ought to be. Yet in an extreme form it does illustrate the human tendency to solve a problem by applying some sort of controls or law that worked very well for another problem in another kind of environment but that is completely unsuited to this problem in its environment.

Nowhere has this tendency been more evident than in the area of fiscal controls procedures in the military establishment. During the past eight to ten years much pressure has been put on the military establishment to use business principles and procedures. No one can question the worth of these procedures in the business world. The growth of American industry has been phenomenal during the past decade. However there are certain fundamental differences between a military organization and a business organization. These fundamental differences must be recognized. The premise that "what is good for business is good for the military" is not necessarily valid in all instances.

Recently the Air Force, along with other Government departments, has been required to install an accrual accounting system in addition to its other accounting and fiscal procedures. The primary argument in its favor was that it had been an indispensable tool of business management in reflecting profit and loss.

The fundamental financial control system of business is accrual accounting. It is a calculative service that records, classifies, and periodically summarizes activities in terms of dollars, the fundamental requirement being to place income and expenses in a time period, generally monthly, in which they are consumed or used. Accrual accounting has served business well. But this does not necessarily mean it can be transferred in total to the military with the same end result. In fact the direct transfer of a business-type accrual accounting system to the military may have unfavorable results because it could cause personnel to be needlessly assigned and could provoke erroneous conclusions that would have a harmful effect on the military.

What are the major deficiencies in a business accounting system when applied to the military? What is the minimum financial accounting system necessary for the Air Force? Any person assigned to military accounting who is not materially productive is wasteful to the Air Force and, consequently, to the defense of our nation when manpower is limited.

the pressure for accrual accounting

When dollars enter into the operation of any organization, an accounting requirement is established. At the same time, because accounting is a service, the minimum of effort should be devoted to it, with the maximum effort going to the operational side of the organization. An accounting service should be productive and furnish definite assistance to the operational side.

The first pressure on the Air Force is to account to Congress for the money appropriated. These are taxpayers' dollars and are held in trust by the Air Force. An accounting system has been in use for many years to account for these funds. This system is known by various names, such as an appropriation accounting system, a fiscal accounting system, or an accounting system on a cash basis. Appropriated funds are obligated at the time a firm contract is assumed by the Government. The funds are then expended at the time the contract is completed or at such other times as may be specified in the contract. This system accounts for all the dollars expended by any Government department. Once an item is paid for this dollar-accounting system drops the item, which is then picked up as a line item in a supply or equipment account.

The present procedure is for Congress to appropriate money to the Air Force in two broad categories. One is termed "no year money"—money appropriated that will be available to the Air Force for obligation until it is expended. This category includes major programs or items of equipment which have long lead-time requirements, such as aircraft, other major procurements, and the research and development program. Congress can control these expenditures on a line-item basis. For example, the number of B-52's to be purchased at the price per aircraft can be shown as a line item. But because of the long lead time the actual requirement for funds may extend over a period of several years.

The second major category of money appropriated to the Air Force has to be obligated during the fiscal year in which it is appropriated. The two major activities covered by this type of money are the operation and maintenance of the activities and installations of the Air Force and the pay of military personnel. The dollar requirements for Air Force operations, maintenance, and military personnel are periodically summarized for Congress on an annual basis at the time the annual budget is submitted. In addition, numerical and grade ceilings for both the military and civilian personnel paid from these two appropriations are placed on the military by the appropriation act. These limitations afford Congress an additional control over military expenditures.

As indicated above the fiscal accounting system drops an item once it is purchased. It does not provide a dollar control over inventory. Once an item has been purchased it becomes a stock number and quantity in the bin of some supply warehouse. The Air Force has corrected this deficiency by installing a system that accounts for all the inventory of the Air Force by dollars.

So the Air Force has, under the fiscal accounting system, a method whereby the dollars appropriated to it by Congress are accounted for. This is the minimum accounting system considered necessary to discharge the Air Force's responsibilities to Congress for the dollars entrusted to it. To this minimum has been added a monetary control system over the Air Force inventory.

A second major pressure is to make over the military in the image of business, at least from an accounting point of view. What this means is that an item of material is obligated or bought, put in an inventory account, and then finally accounted for when it is consumed or used. The activity consuming or using the item is charged with the expense. Until that time the item is considered an asset. The accountant follows the item to the activity actually using it. In the Air Force for example a carburetor will be purchased and placed in supply, but not until it is put on an aircraft will the

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cost of that carburetor be charged to the activity using the aircraft or to the maintenance squadron repairing it. Many additional people and much additional paper work will be required to follow the item to this point.

how accrual accounting serves business

The accrual accounting system which so effectively serves the businessman is based on a relatively simple formula. This formula makes possible a comparison of the efforts of the corporation with its accomplishments. Professor A. C. Littleton, in his book *Structure of Accounting Theory,* states: "The central purpose of accounting is to make possible the periodic matching of costs (efforts) and revenue (accomplishments). This concept is the nucleus of accounting theory, and a benchmark that affords a fixed point of reference for accounting discussions." Stated as a formula it is: income minus expense equals profit (or loss). The civilian accountant must have available these two elements, expenses and income, in his accounting system in order to determine the net profit of the enterprise. Costs are arrived at by internal accounting procedures. Income is determined by the external and impartial judgment of the consuming public.

The civilian accountant establishes various accounts containing dollar information which support the income and expense activities of his company. This information he summarizes periodically, generally monthly, for the use of management. The investors reading this article are familiar with the profit and loss statement of a corporation. In general, this statement deducts the expenses from the income of the corporation and arrives at the net profit of the corporation for the period.

Management receives information from the accountant on a periodic basis. Using this information management compares one month with the next to determine progress and to see how profit and expenses compare with past performance. In measuring his corporation's efficiency, the accountant prepares various ratios: income per dollar of gross plant and equipment; income per dollar of gross equipment only; income per square foot of floor space; income per dollar of working capital; ratio of salaries and wages to income; and ratio of operating profit to income. Research indicates that the income element is the basis for measuring the efficiency of the operation. Using these ratios from month to month the manager is able to control his business. If expenses measured against income are increasing steps are taken to correct the situation. Thus the manager of a business corporation sitting at any echelon or level of management can determine the efficiency of any portion of his business. The accountant furnishes the businessman the primary quality measurement with which he controls and operates his business.

accrual accounting in the Air Force

In determining whether accrual accounting can serve the Air Force, we must take a closer look at the civilian accountant's equation. You will recall that this equation is: income minus expense equals profit.

The military establishment is not a "profit-making" organization. Webster defines profit as "accession of goods, valuable results, useful consequences, avail, gain, excess of returns over expenditures." Only in a broad sense can this expression apply to the military, if it is assumed that the American people expect "a valuable result" and "useful consequences" out of a military establishment when needed. In particular, they may expect an "excess of returns over expenditures" when wartime military results are aggregated. When the military establishment is spoken of as not being a profit-making organization, a restricted and narrow interpretation of the word "profit" is being used, profit in a dollar sense. Proponents of wholesale introduction of business methods into the military may not fully appreciate this distinction. The dangerous aspects of applying the business accountant's yardstick make their entry here. The military, in war or in peace, cannot make the type of profit that is understood by the civilian accountant. Its product, or "profit," is not subject to the precise standards and measurements available to the civilian businessman, although the same interactions are present.

To fully understand the fact that the military establishment is not a profit-making organization in the restricted sense, it is necessary to take a further look at the civilian accountant's equation. As indicated previously, this equation is composed of two parts: income and expense. There is no question that the military accountant can precisely measure the cost of any military operation. All that is required is the accounting know-how and the necessary reports flowing from the operation itself. The income part of the equation is a different story. When an American businessman sells a product he has produced, he receives dollars as income in return. The purchaser exercises his judgment as to the quality of the product he is buying and the number of dollars he is willing to exchange in return for the product. It is granted that the purchaser may be influenced by a superior advertising or salesmanship campaign. But in the final analysis each purchaser's judgment of the quality of the product he is buying in comparison with the price and quality of similar articles on the market determines which businessman receives the consumer's dollars as income. This income, basically determined by the quality judgment of the consuming public, then is incorporated into the profit and loss statement of the corporation concerned. This becomes the sales income for the corporation. The civilian accountant receives his qualitative measure of the corporation's accomplishments or efficiency almost gratis. Without this factor the formula, of course, would become meaningless.

The National Security Act of 1947 specifies the basic mission of the United States Air Force. It shall be organized, trained, and equipped for prompt and sustained offensive and defensive air operations, for effective prosecution of war, for expansion to meet the needs of war. This mission determines the basic difference between the USAF and a civilian business enterprise. The USAF spends money to organize, train, and equip to meet some undetermined future war. The product of this expenditure is not put on the market with its value or income determined as a competitive product during peacetime. The competition to be met is an enemy—possibly in active combat competition. Then and only then will the "sales or income" value of the USAF be determined, and then only in the broadest general terms. It does not lend itself to any dollars-and-cents type of evaluation to serve as entries in the accountant's ledger.

The civilian manufacturer would be faced with a somewhat similar situation if he stored or warehoused his production. Assume that a company manufactures automobiles. All its production is placed in a warehouse and not on the consumer market. Periodically the latest company modifications are made on all the stored automobiles. Assume further that the manufacturer has only very limited knowledge concerning the automobiles that competitors are manufacturing and selling. Known production costs have been incurred. Now what will be the sales value of the automobiles when placed on the market at some future unknown date? Will they result in a net profit or loss to the manufacturer? Although these questions are absurd from a civilian manufacturer's point of view, the situation is far from being so when analyzed in the light of the mission of the USAF.

The automobile-manufacturing analogy points up the basic difference between civilian and military operations. Both incur cost for labor and material in producing a product. The civilian manufacturer immediately places his product on the consumer market. He is able currently and progressively to measure his accomplishments. He receives income from sales as a definite and immediate index of the cost he has incurred to produce his product.

The product of the USAF is combat potential. It cannot be "put on the market" until war is declared. Men are organized, equipped, and trained. Training is the perennial peacetime mission of the military. The result of this training may be said to be in "dynamic storage." Consequently there is no specific qualitative valuation available in peacetime to measure the military product. Sales income available to the civilian producer as a measure of accomplishment is not available to the military producer. The civilian accountant receives the sales figure in his profit and loss statement as a basic element in measuring the accomplishments of his company's enterprise. The military accountant is faced with the problem of finding a substitute for this sales figure. A closer look at the military operation will indicate that the income side of the civilian accountant's equation is not available. The military accountant cannot provide a qualitative dollar measurement. Several examples that follow will explain why the "income minus expense equals profit" formula is meaningless when applied by the military accountant.

Take for example the perennial peacetime mission of the military, training. A student is sent to school for a period of time. During the course of instruction many Air Force dollars are expended for salaries of instructors, textbook material, and facilities. The costs are finitely and definitely measurable. But what benefit has the Air Force received for this expenditure? Is it measurable? It cannot be, because the benefit received is the increased knowledge of the individual. No known method is available to finitely measure in dollars the increased knowledge that the student has obtained. It is generally assumed that he will be of greater benefit to the Air Force.

But it is impossible to put a dollar tag on knowledge. Even industry cannot include in its inventory the dollar value of its employees.

Another example: a pilot flies an aircraft. He is trained to intercept enemy bombers attacking the United States. Many dollars are expended for gasoline, spare parts, his salary, and many other things to provide this training for the pilot. Again dollars are expended. What definite, finite value is measurable from this training? Value has been received but what is the dollar estimate of that value? What entry may be made in "accounts receivable" because of the millions of dollars of property destruction averted by a successful intercept?

Another example in which the military is not comparable to civilian industry lies in the fact that military personnel are "captive customers." Take the food service operation. The enlisted personnel of an organization are required to eat at the mess hall if they are not on separate rations. No charge is made for the food consumed; also, no estimate of the quality of the food is obtainable. Can the food's quality be based on the number of enlisted men eating in the mess hall? They have no other place to eat, except at their own expense. In contrast any civilian restaurant manager, within a very short period of time, would be aware of the fact that the quality of his food had fallen off. Customers would not patronize his restaurant. His dollar income would be considerably reduced and he could immediately start checking to see what was wrong. About the only methods available to the military commander for checking on the quality of food served in a dining hall would be gripes or inspections. The dollar income or qualitative measurement of the operation that is available to the civilian restaurant owner is not available to the military.

attempted solutions

Much effort and money have been spent attempting to find solutions to the problem of measuring accomplishments from military expenditures against the dollar cost. Several suggested solutions have been put forth. One is to compare cost with budget. A second compares actual cost with some cost standard.

First, what is involved in comparing the cost expended by a military organization against the amount of funds budgeted for that organization? A budget is merely an expression of the dollar cost required to operate an organization during a period of time. Therefore all that is being measured is costs against previously estimated costs, or, in other words, the commander's ability and accuracy in budgeting and estimating. There are no black or red figures in the commander's ledger as there are in the business accountant's.

A further consideration. What in this instance would determine the efficiency of a commander? Would it be his ability to zero out his budget? Would it be his ability to "save" money in these days of austerity? If to be efficient the commander must zero out to his budget estimate, that can very easily be accomplished on a dollar basis. If he is to "save" money, is it assumed that his original estimate was "fat" and because of it he showed definite dollar savings as compared with his original estimate? Again, whose budget is to be considered? Normal rotations would place each commander under the domination of his predecessor. The predecessor's ability to budget would determine the efficiency of the commander that succeeds him.

The second solution has been to use cost standards as a basis of comparison for accrued costs. Example standards are cost per flying hour, cost per line item of supply, and cost per meal served. But again this appears to be unfair to the base commander. He has little control over which military personnel are assigned to him. Their ranks and abilities are, in a large measure, predetermined by higher headquarters. He has little control over the fixed facilities with which he is operating. Such things as the type of material in his runways, the availablity of rail facilities to haul in his supplies, the distance he is from his ration point, all enter into the cost although he has little or no control over them.

The income side of the equation is not available to the military accountant. Also it does not appear that suitable comparisons to take the place of the income side of the equation are available either. Consequently the military accountant is placed in the position of finitely measuring costs but not having any suitable measure with which to compare them. The question might be asked the civilian accountant, "How much accounting would you be doing today for your industrial concern if you could not use the basic accounting equation?"

the solution

To solve this dilemma, the fundamental difference as between military and civilian accounting in the accrual area must be recognized. Once this difference is recognized, the basis for decision should follow.

The necessity for dollar information in the military is not questioned. The expenditures in the military establishment are enormous. But by the same token resources should not be put in any area from which definite benefits will not result. Under the limited personnel ceiling of the Air Force every man in the accounting area is one less man maintaining an aircraft on the line. There is much good management information in the present fiscal expenditure system. Utilization of this information should be fully explored. When coupled with an accounting system for the inventories in the Air Force it will provide a wealth of usable information.

This article has pointed toward the necessity of finding some kind of qualitative measurement for the effectiveness of a military operation. The military would have been derelict in their duty if they had not developed and used such a system through these many years. This is an inspection system. A person qualified in any particular area makes an on-the-spot visit and report as to the quality of the operation being inspected. While this is a judgment measurement not subject to the finite measure of dollars, it would appear to be the best and only system available to the military. Dollars do provide a general measure of effectiveness. They can measure the relative merit of two plant managers. But they cannot judge the relative merit of two base commanders.

It is believed that the maximum financial accounting system for the Air Force should consist of two main elements. The first is a fiscal accounting system—which accounts to Congress on the basis of the appropriation account structure. The second element is a system that will account for the inventory of the Air Force on a dollar basis. Concentration on these two elements will provide to a commander the maximum of useful financial information with a minimum of personnel and effort assigned to the financial area.

Headquarters Air University

Orbits of Satellites

COLONEL JOHN F. BABCOCK

WITH the advent of the ballistic missile as a weapon delivery system, the need of airmen for mathematical understanding of this new military art took a decided spurt. Many, initially at least, believed that the principles involved in the computation of missile flight paths must be one of the newer, and abstruse, branches of mathematics.

But as one begins to probe into a few fundamentals, he soon finds that many of the problems of the satellite trajectory and their solutions are over three hundred years old. Maybe even more surprising is his discovery that a number of the basic laws governing the orbits of planets, which are very similar to satellite orbits, were developed with only the simplest of mathematical theory and the crudest of the scientific instruments. The great pioneers who formulated the laws of planetary motion had no high-speed electronic computers to perform their calculations or to test their theoretical computations of the rigid paths they postulated by scientific law for the ancient "wandering" planets.

In the 1957 Summer Issue of the *Air University Quarterly Review* appeared a very timely article, "Notes on Technical Aspects of Ballistic Missiles." Reactions from students and faculty alike at the Air Command and Staff College of the Air University indicated that the theories it related to the ballistic missile were of extreme interest and well presented. Some felt in addition that the accelerated interest in astronautics might justify a brief review of the more fundamental aspects of analytical geometry to assist in understanding missile trajectories. Accordingly an attempt will be made to present the basic conic section formulas bearing on these trajectories, together with a few of the laws of physics and concepts of astronomy illuminating the orbits of missiles.

Most of the material presented here* has been digested from various textbooks in mathematics, physics, and astronomy, and no originality is claimed for the stated formulas. It is hoped, however, that what is offered may act as a catalyst for airmen in stimulating them to become more knowledgeable in mathematics, and particularly the mechanics phase of physics. For any genuine understanding of the ballistic missile or satellite orbits the fundamentals of their mathematics and physics must be understood.

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*The author wishes to express his appreciation for the valuable comments and suggestions given by Dr. J. A. Greenwood, Mathematician, Physical Vulnerability Division, Directorate of Intelligence, Headquarters USAF; and Dr. Vladimir Rojansky, Physicist, Space Technology Laboratories, The Ramo-Wooldridge Corporation, Inglewood, California, in their review of the original draft of this paper.

The sequence of the material to be presented will be:

a. A discussion of conics or conic sections from both a mathematical and a graphical standpoint.
b. A brief discussion of the laws of Newton and Kepler.
c. A discussion of basic formulas relating to principles of astronautics.
d. A brief discussion of physical constants which are of major importance in astronautics.
e. A series of problems with which the reader may try his hand in the application of the mathematics and physics discussed.

Conic Sections

First we shall consider the various types of conic sections. By definition, conics or conic sections are formed when a plane intersects a right circular cone. These sections can be a straight line, a circle, a parabola, an ellipse, or a hyperbola.

In order to minimize discussion and details many diagrams and illustrations will be shown. In the development of the mathematical formulas only the key points will be stated, and the reader will be left to complete the derivations from standard texts, if he desires.

Analytical geometry is the branch of mathematics which assembles the fundamentals of algebra, geometry, and trigonometry for detailed analysis in various types of equations. One of its most important tools is the rectangle coordinate system, as a means of locating points in a plane or three-dimensional space. To locate points accurately in the rectangular frame, coordinate or plotting paper is used.

Rectangular Coordinate System

Figure 1 shows two axes, the horizontal or X axis and the vertical or Y axis, drawn perpendicular to each other and intersecting at the point O,

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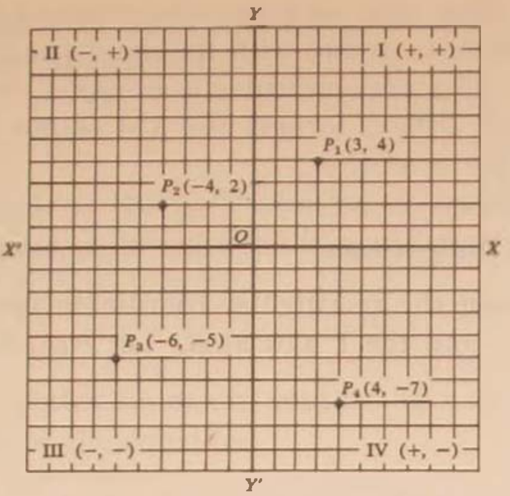


Fig. 1

called the origin. These axes divide the plane into four quadrants, starting with Quadrant I in the upper right-hand corner and moving counterclockwise for Quadrants II, III, and IV.

The point $P(3, 4)$ indicates that this is a point in the first quadrant, three units to the right of the Y axis and four units above the X axis. The reference $P_2(-4, 2)$ states that point P_2 lies four units to the left of the Y axis and two units above the X axis. By inspection other points can be identified easily from their respective positions in relation to the origin, as indicated by their coordinates.

. . . rectangular coordinates

In many cases specific numerical coordinates are not known; however,

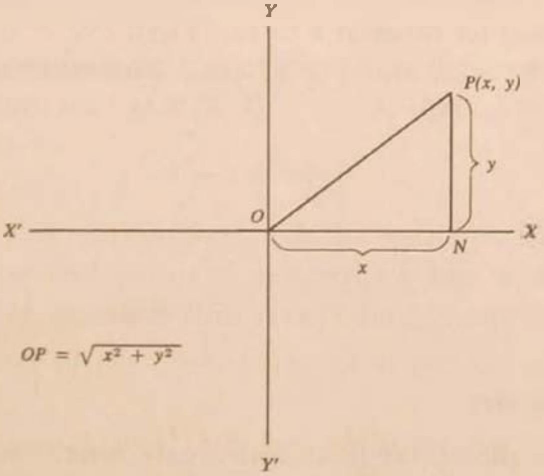


Fig. 2

the symbol for a point P can be written as $P(x, y)$ as shown in Figure 2. This notation means the point P is located x units to the right of the Y axis and

y units above the X axis. The sign preceding x or y may be either plus (+) or minus (−); therefore in accord with the signs, point P could lie in any of the four quadrants. If a perpendicular is dropped from point P to the X axis, the right triangle OPN is formed and it is readily seen from the Pythagorean theorem that $OP = x^2 + y^2$.

. . . *equation of a straight line*

In Figure 3, using the rectangular coordinate system, the line L intersects the X axis at A and the Y axis at B. Let $P(x, y)$ be any point on the line L as shown. The line L makes the angle theta (θ) with the X axis. Now draw a line T through point O, the origin, parallel to line L. Next draw PN perpendicular to the X axis. PN will then be parallel to the Y axis.

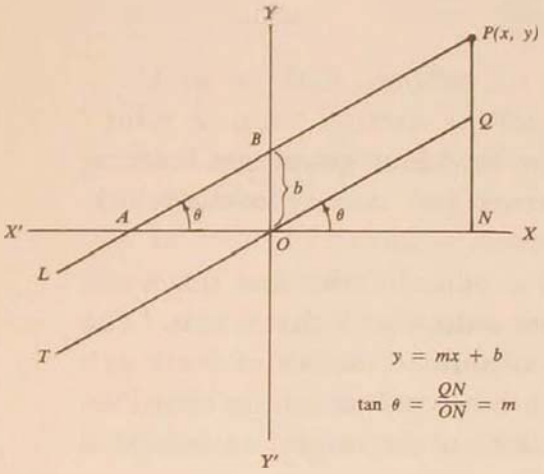


Fig. 3

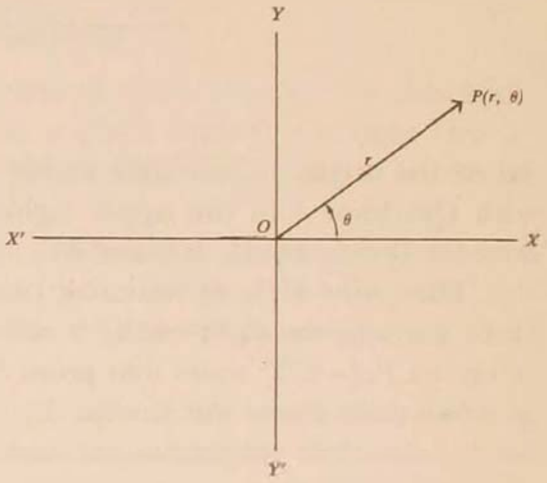


Fig. 4

Let $OB = b$ and let tangent $\theta = m$. Then $PN = QN + PQ$, $QN = ON \tan \theta$, $PN = y$, $ON = x$, and $PQ = OB$. Therefore by substitution in the equation $PN = QN + PQ$:

$$y = mx + b$$

This is the general equation of the straight line L. Notice this is a first-degree equation, as x and y appear in it to the first power. This means the line L can intersect the X and Y axes only once.

. . . *polar coordinates*

In addition to the rectangular coordinate system another and sometimes more convenient system known as polar coordinates is used, as illustrated in Figure 4. It is apparent that any point P in the plane can be described by giving its distance r from the origin O and the angle θ the line OP makes with the X axis, measured in a counterclockwise direction. The X axis is then referred to as the initial line and O as the origin or pole. The line r

and the angle θ are called the polar coordinates of the point P. The length of OP or r is called the radius vector.

Circle

By definition a circle is the path of a point (called the locus) which moves in a plane so as to maintain a constant distance from a fixed point called the center.

. . . with center at origin

If in Figure 5 the center lies at the origin O of a rectangular frame, the circle can be expressed by the equation

$$x^2 + y^2 = r^2$$

To demonstrate a use of this equation, consider what will be the radius of a circle when its center is at the origin O in the rectangular frame, if a point on the circle is located at $P(3, 4)$:

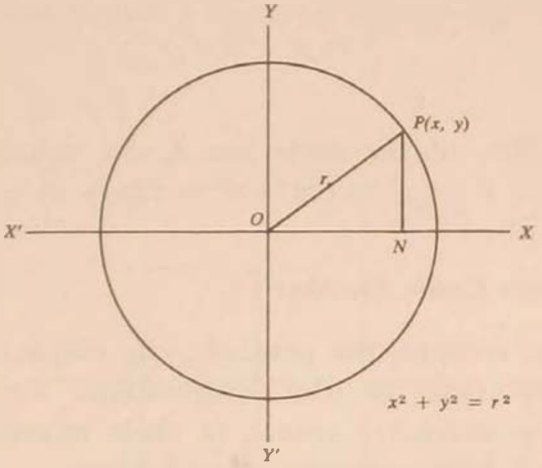


Fig. 5

$$r^2 = x^2 + y^2$$
$$r^2 = 25$$
$$r = 5$$

. . . with center not at origin

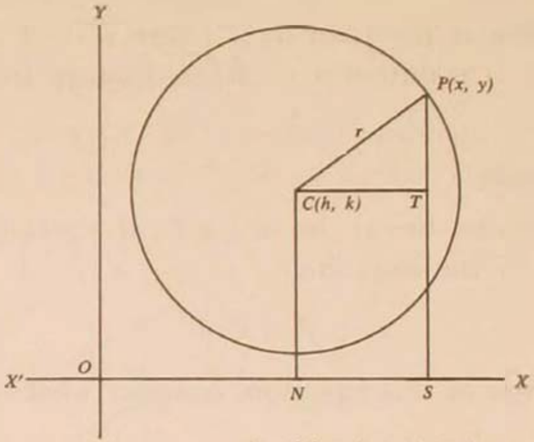
Suppose the center of the circle is not at O but is located at some other point, $C(h, k)$.

As seen from Figure 6, $P(x, y)$ is any point on the circle with its radius r equal to PC. By inspection of the figure, $PS = y$, $OS = x$, $ON = h$, $CN = k = TS$. Further, $PT = PS - TS$ and $OS - ON = NS = CT$. In the triangle CTP we have $\overline{PT}^2 + \overline{CT}^2 = r^2$. By substitution in $\overline{PT}^2 + \overline{CT}^2 = r^2$, we obtain the following:

$$(PS - TS)^2 + (OS - ON)^2 = r^2$$

$$(y - k)^2 + (x - h)^2 = r^2$$

This equation is the general equation for a circle when its center is not at the origin. Suppose the center of the circle $C(h, k)$ was located at the point $P(5, 6)$ and the radius of the circle was 4. Its equation would then be $(y - 6)^2 + (x - 5)^2 = 4^2$, or $x^2 - 10x + y^2 - 12y + 45 = 0$.



$(x - h)^2 + (y - k)^2 = r^2$

Fig. 6

Similarities of Certain Conic Sections

The three conic sections, the parabola, the ellipse, and the hyperbola, are of particular importance in orbit computations. Certain like terms (*focus, directrix,* and *eccentricity*) appear in their respective definitions and should be understood before proceeding with them.

Focus. The focus is a fixed point of reference with respect to the conic section and is located on its major axis.

Directrix. The directrix is a fixed straight line which is also used as a reference and is perpendicular to the major axis of the conic.

Eccentricity. The eccentricity is a numerical constant designated by the letter e and is determined by the following formula:

$$e = \frac{\text{distance of any point on the conic from the focus}}{\text{distance of the point from the directrix}}$$

It will be seen that the shape of the conics is determined by the value of the eccentricity e. When

$e = 1$ the curve is a parabola

$e < 1$ the curve is an ellipse

$e = 0$ the curve is a circle (special case)

$e > 1$ the curve is a branch of a hyperbola

. . . parabola

The parabola is the locus of a point which moves so that its distance from a fixed point called the focus is equal to its distance from a fixed straight line called the directrix.

In Figure 7 let F be the focus and YY' the fixed line or directrix. Let $OF = 2a$ and $P(x, y)$ be any point on the curve. Draw the line PP' perpendicular to XX' at N and draw LL' perpendicular to XX' at point F. Also draw the lines LK and PM perpendicular to YY'. By definition of a parabola the eccentricity e equals unity and is a constant ratio. From the figure, $e = PF/PM$ or $PF = PM$, since $e = 1$. In the right triangle PNF, $\overline{PF}^2 = \overline{PN}^2 + \overline{NF}^2$. Since $PF = PM$, then $\overline{PM}^2 = \overline{PN}^2 + \overline{FN}^2$. By substitution, $x^2 = y^2 + (x - 2a)^2$. Simplifying the equation, we now have $y^2 = 4a(x - a)$.

This curve cuts the X axis at point $A\,(a, o)$. The point A is known as the vertex of the parabola. The curve can be moved to the left so that the origin A lies on point O, and the equation will then become $y^2 = 4ax$. The focus of the transferred equation is at (a, o) and the directrix is the line $x + a = o$.

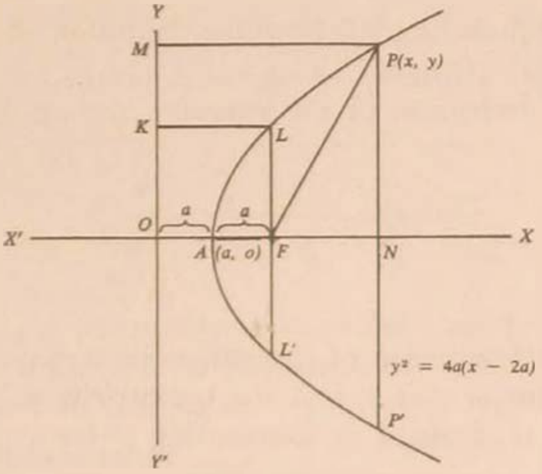


Fig. 7

It is noted that this equation is second degree with respect to y and first degree with respect to x. The equation for a parabola can also be derived such that $x^2 = 4ay$. The curve would then be symmetrical with the Y axis.

. . . ellipse

The ellipse may be defined as the locus of a point which moves so that its distance from a fixed point called the focus maintains a constant ratio e, which is less than unity, to its distance from a fixed line called the directrix.

The equation for the ellipse will not be derived, but pertinent points will be noted which should assist the reader in dealing with the standard equation of the ellipse. In Figure 8, F and F' are the foci. The line KL is the directrix and F' and line $K'L'$ are symmetrical to F and line LK. $OA = OA' = a$, the semi-major axis of the ellipse. $OC = b$, the semi-minor axis.

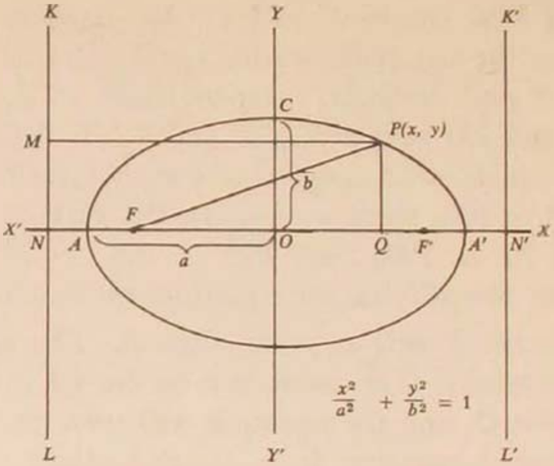


Fig. 8

The eccentricity e equals PF/PM, from the definition of the ellipse. The eccentricity e also equals AF/AN.

In the formal derivation of the equation for an ellipse the following results:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2(1 - e^2)} = 1$$

This equation is an expression of the ellipse in terms of point $P(x, y)$, the length of the semi-major axis a, and the eccentricity e. The standard equation for the ellipse is obtained by substituting b^2 for $a^2(1 - e^2)$, which gives

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

The equation now expresses the ellipse in terms of point $P(x, y)$, the semi-major axis a, and the semi-minor axis b.

This is one of the most important equations in determining the path of a planet as it makes an elliptical orbit around the sun. It is also of extreme value in missile computations in determining the path of a satellite when its orbital velocity varies from 5 miles per second to 7 miles per second.

. . . hyperbola

The hyperbola is defined as the locus of a point which moves so that its distance from a fixed point called the focus maintains a constant ratio, which is greater than unity, to its distance from a fixed straight line called the directrix.

In Figure 9 the focus is F and the directrix is line MZ and the eccentricity $e = FA/AZ$ or PF/PM. The line $M'Z'$ and point F' are symmetrical to line MZ and point F.

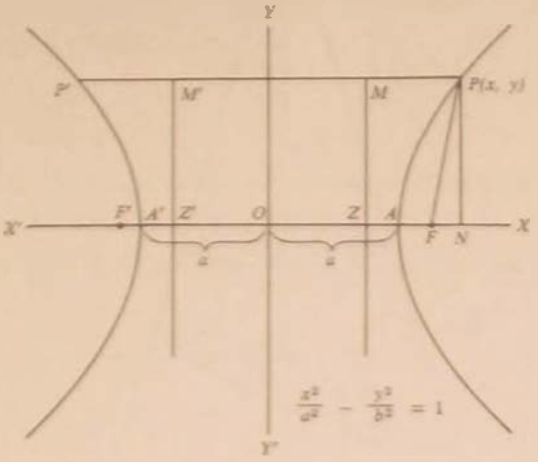


Fig. 9

In the formal derivation of the equation of the hyperbola the following expression is obtained:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2(1 - e^2)} = 1$$

Since by definition the eccentricity e is greater than 1, by inspection $a^2(1 - e^2)$ is negative. Therefore $-b^2$ is substituted for $a^2(1 - e^2)$, and the standard equation for a hyperbola is formed:

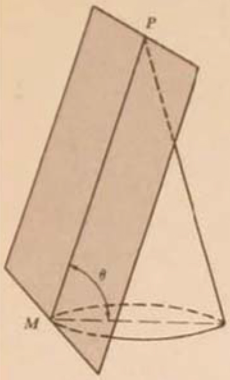
$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

This equation has considerable significance in missile computation, particularly when a satellite is given a velocity in excess of 7 miles per second.

The Sections of a Circular Cone

So far we have discussed the conics or conic sections more or less abstractly. A clearer picture of the formulas that have been derived may result from an exhibition of their relation to a three-dimension geometrical figure, the right circular cone. In Figure 10 let lines L and M intersect at a point P. With PL as an axis, rotate the line PM so that a right circular cone is generated as in the figure. In the right circular cone, PL is the altitude, ML is the radius of the base circle, and the line PM is called an element.

Conic Sections



$y = mx + b$
(straight line)
Fig. 10a

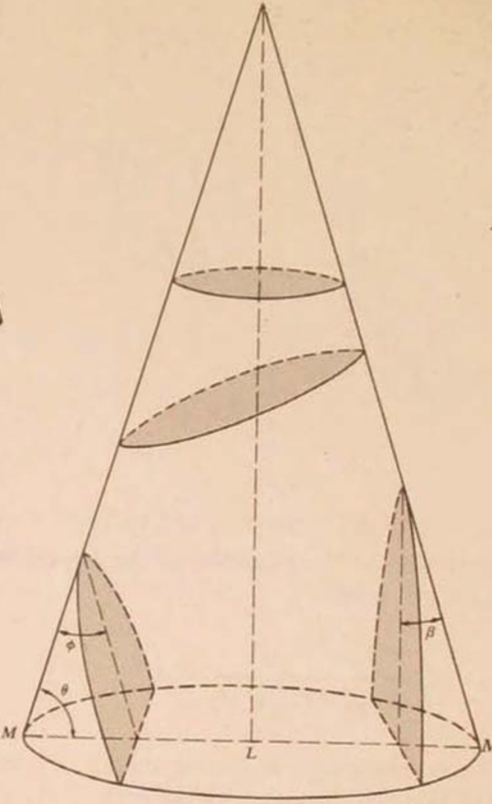
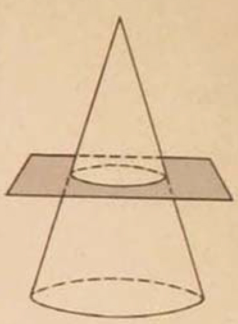
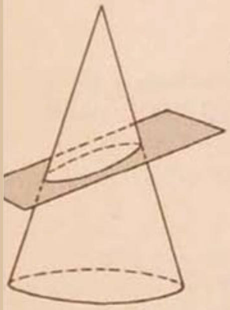


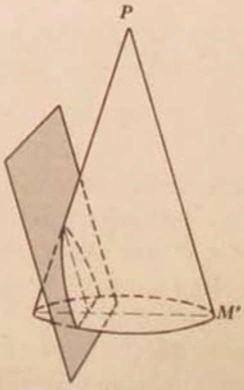
Fig. 10



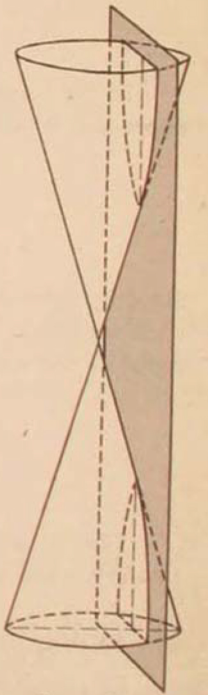
$x^2 + y^2 = a^2$
(circle)
$e = 0$
Fig. 10b



$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$
(ellipse)
$e<1$
Fig. 10c



$y^2 = 4ax$



$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$
(hyperbola)
$e>1$
Fig. 10e

If we were to imagine a plane intersecting the right cone in such a manner that it passes through only the element *PM*, as in Figure 10a, the intersection of the plane and the cone would be a straight line. This line *PM* could then be defined mathematically in terms of its length *PM* and the tangent of the angle θ it makes with the line *ML*. Or, as we defined previously, $y = mx + b$.

The *curve* of intersection of a right circular cone by a plane is called a conic section, or simply a conic.

. . . the circle

Let us pass a plane through the cone perpendicular to the line *PL*. As is seen from Figure 10b, the section cut is a circle, or, as is usually said, the cutting plane generates a circular section, or circle. This circle can be expressed by the equation

$$x^2 + y^2 = r^2$$

. . . the ellipse

Next pass a plane through the cone at other than right angles to *PL,* in such a manner that the section generated is closed, Figure 10c. This section is an ellipse and can be expressed by the equation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

. . . the parabola

If we pass a plane through the cone in such a manner that it is parallel to an element of the cone, i.e., the line *PM'*, a parabola is generated, as in Figure 10d. This section can be represented by the equation

$$y^2 = 4ax$$

It will be noted that this section is open. If the curve generated in this way is extended toward infinity, the ends of the curve will approach parallelism.

. . . the hyperbola

Finally if we cut the cone at still a smaller angle, Figure 10e, it will generate a curve called the hyperbola, i.e., angle β is smaller than angle ϕ. This curve, like the parabola, is open and can be expressed by the equation

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

It will be noted that a second cone has been added to Figure 10e. This upper cone has been generated by extending the lines *PL* and *PM* through *P*. It will be further observed that the upper cone may be considered a mirror image of the lower cone. Consequently when the plane is passed through the lower cone, it will in turn intersect the upper cone, and a second hyperbola, symmetrical and equal to the lower hyperbola, will be formed.

. . . importance of the ellipse

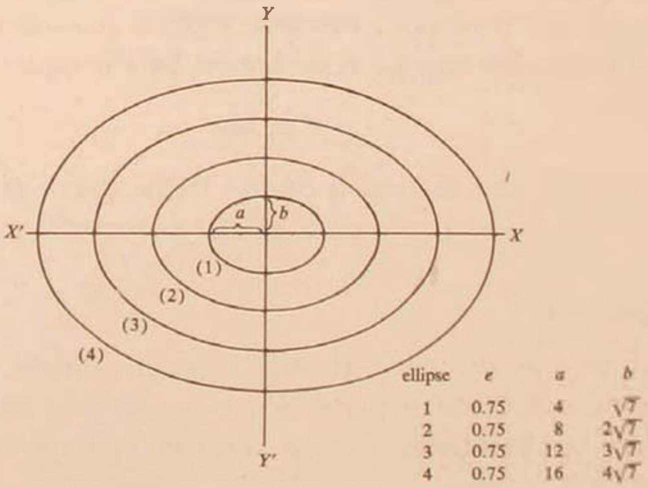
Although the detailed derivations for both the ellipse and hyperbola have been omitted, it is recommended that the complete derivations of these formulas be obtained from any standard text on analytical geometry. From the standpoint of computing the trajectory of a missile that is to be fired from a given point *A* on the surface of the earth to another point *B* (the target), the ellipse and its basic equation will be of maximum interest to the missileman.

Size and Shape of the Ellipse

From the discussion so far of conic sections it should be obvious that the particular size or shape of an ellipse is a function of its major axis, its minor axis, and its eccentricity. The following may help to develop a better appreciation of the varying forms of an ellipse when (1) the eccentricity e remains constant and the semi-major axis a and semi-minor axis b vary; and (2) when the eccentricity e is the variable and the semi-major axis a remains constant.

. . . as a function of the semi-major axis

In Figure 11 we shall consider an ellipse with eccentricity $e = 0.75$ and length of the semi-major axis $a = 4$. On the same major axis line, three additional ellipses are constructed in such a manner that their eccentricity remains as 0.75 but their semi-major axis varies at a ratio 1:2:3:4.



ellipse	e	a	b
1	0.75	4	$\sqrt{7}$
2	0.75	8	$2\sqrt{7}$
3	0.75	12	$3\sqrt{7}$
4	0.75	16	$4\sqrt{7}$

Fig. 11

By using the formula for the ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \text{ and } b^2 = a^2(1 - e^2)$$

when $a = 4$ and $e = 0.75$ or $\frac{3}{4}$, we solve for b:

$$b^2 = 16\left(1 - \frac{9}{16}\right) \quad \text{or } b^2 = 7 \quad \text{and } b = \sqrt{7}$$

Other values for b when a changes to 8, 12, 16 are shown with Figure 11, which also shows the four resulting ellipses. It is conclusive that when the eccentricity e remains the same and the major axis varies, a series of ellipses similar in shape will result.

. . . as a function of eccentricity

Next let us consider the ellipse when the semi-major axis remains constant and the eccentricity varies in some specified ratio, for example 1:2:3. Figure 12 will demonstrate this series of ellipses. Again we use the formula for the ellipse:

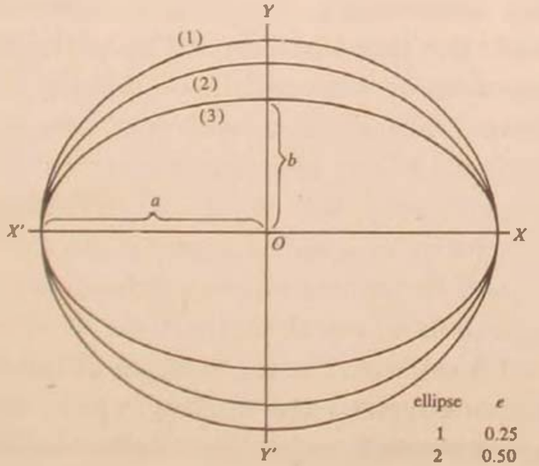
$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Now in $b^2 = a^2(1 - e^2)$ the eccentricity e changes from 0.25 to 0.50 to 0.75, but the semi-major axis a remains constant at 4:

$$b^2 = 16\left(1 - \frac{1}{16}\right) \quad \text{or } b^2 = 15 \quad \text{and } b = \sqrt{15}$$

The semi-minor axes of the other two ellipses are $\sqrt{12}$ and $\sqrt{7}$ respectively.

It will be noted from the figure that as the eccentricity increases, the



ellipse	e	a	b
1	0.25	4	$\sqrt{15}$
2	0.50	4	$\sqrt{12}$
3	0.75	4	$\sqrt{7}$

Fig. 12

semi-minor axis decreases. This particular relationship has significance to the missileman in the computation of elliptical orbits.

Paths of the Satellite

In Figure 13 a satellite or a mass *m* is considered to be in a position 100 miles from the surface of the earth. Further, for the purpose of this analysis the earth is assumed to be a perfect sphere and to possess no atmosphere, so that frictional air resistance may be discarded from the computation. If the satellite is free to move and if no additional velocity is imparted to it, it will move directly toward the earth.

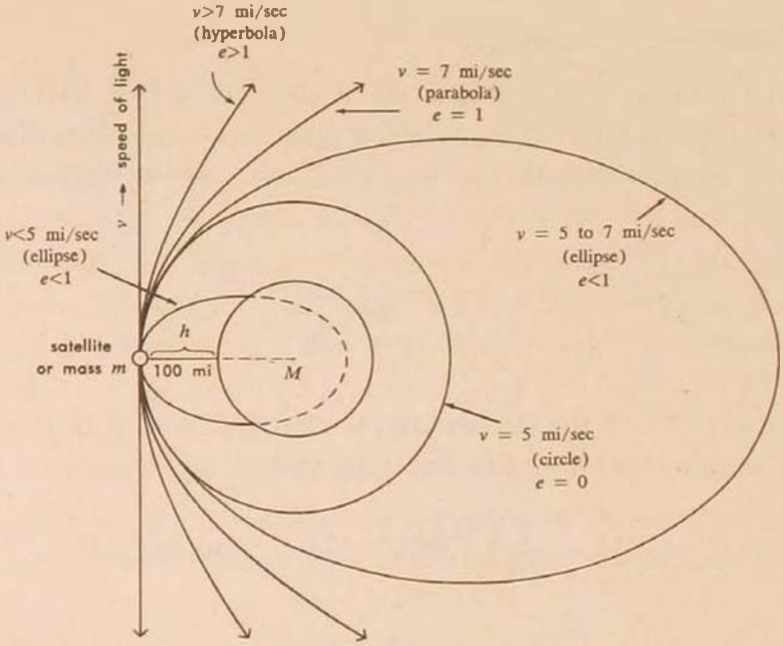


Fig. 13

Next the satellite is assumed to be given an extremely high lateral speed which would approach the speed of light. The path which the satellite will then take is a straight line, as indicated in the figure. If the satellite is given a velocity greater than 7 miles per second (mi/sec), it will follow a hyperbolic path, having a focus at the center of the earth. This conic section, as has been explained previously, will have an eccentricity *e* greater than 1. If the satellite has a velocity of approximately 7 mi/sec, it will follow a parabolic path, with focus at the center of the earth. It will be recalled that the eccentricity *e* of a parabola is equal to 1. If the satellite is given a velocity between 5 mi/sec and 7 mi/sec, it will follow an ellipse with the focus to the left of the origin, the one nearest the satellite, at the center of the earth. If the velocity imparted is about 5 mi/sec the satellite will move in a circle; the eccentricity *e* is then zero (0). And finally, an imparted speed less than 5 mi/sec will result in an ellipse, of which the farthest focus from the satellite will be at the center of the earth. It will be noted that the satellite is projected in all cases at an angle of 90 degrees with the line joining it to the center of the earth.

The Laws of Newton and Kepler

The theory and the mathematical derivations of conic sections are hundreds of years old, as these various curves are manifest in nature to be noticed by the mathematician and the scientist of any age. We may well improve our understanding of the orbital paths that missiles will follow in space by reviewing certain fundamental observations made by John Kepler (1571-1630). As the result of his avid interest in the orbit of Mars as it circumnavigated the sun, this German scientist has provided the missilemen of today with three very important conceptual tools. In fact the orbital laws he postulated are the basis for the science of celestial mechanics.

Kepler's Laws of Planetary Motion

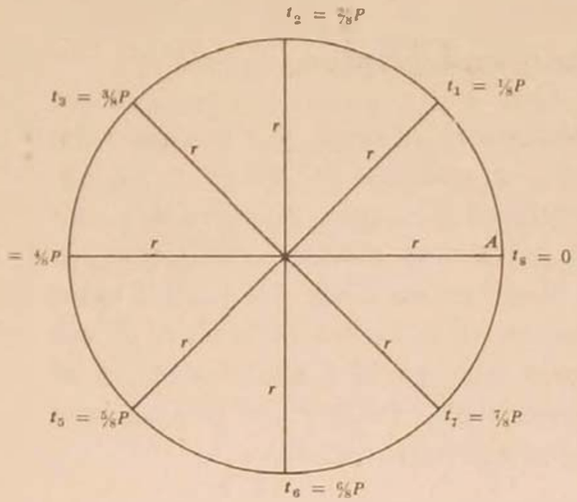
The laws of planetary motion that Kepler formulated from astronomical measurements are as follows:

1. The orbit of each planet is an ellipse with the sun at one of its foci.
2. Each planet revolves so that the line joining it to the sun sweeps over equal areas in equal intervals of time.
3. The square of the period of revolution of any planet is proportional to the cube of its mean distance from the sun.

. . . the Law of Areas

A more detailed look at Kepler's second law, often called the Law of Areas, is important. From this law we are able to ascertain the change in velocity of a satellite by its position at any point on an ellipse in which it circumnavigates the earth. Kepler drew his conclusions from observing the courses of the planets in their orbits around the sun. In his second law, the Law of Areas, he set forth the principle that as the radius vector of a circle or an ellipse makes a complete revolution, like a hand round the clock face, it will, if the time of revolution is divided into equal periods, sweep over equal areas of the conic during each period.

In Figures 14a and 14b, we have a circle with $e = 0$ and an ellipse with $e = 0.75$. The diameter of the circle is equal to the major axis of the ellipse. For the circle the radius vector is equal to the radius. Now in Figure 14a allow the radius vector to start at point A and to sweep counterclockwise around the circle. Note the eight separate areas formed by the radius vector during this revolution if it is drawn separately to the points t_1 through t_8. According to Kepler's second law all these segmented areas are equal, and, by observation, they are also symmetrical. Therefore all the eight arcs are equal. If we consider a mass m starting at A and making one revolution in a counterclockwise direction, the velocity of the mass *m* would be the same for each of the eight arcs.



$e = 0$

Fig. 14a

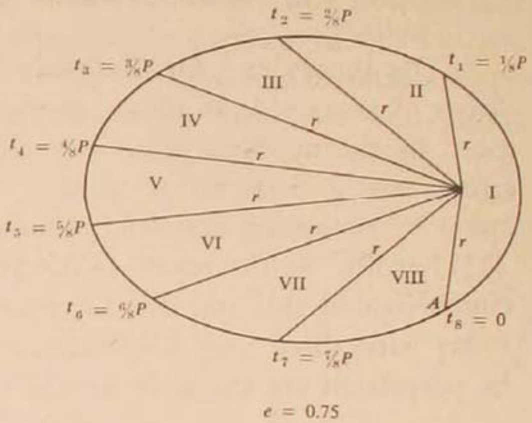


Fig. 14b

The ellipse in Figure 14b yields a different situation. Again applying the Law of Areas and allowing the radius vector to sweep over equal areas in equal intervals of time, it is noted that the areas are not symmetrical, since the radius vectors for the equal areas are not equal. The arc of Sector I is larger than the arc of Sector II, and the arc of Sector V is the smallest of all.

By applying Kepler's second law in astronautics we see that a satellite in an elliptical orbit about the earth will be in a constant state of acceleration or deceleration depending on its position with regard to the focus of its orbit. Since a satellite revolving around the earth in an elliptical orbit will have the earth at one of its foci, it must move at its fastest speed when it is nearest this focus (perigee) and slowest when it is most remote from it (apogee).

Newton's Laws of Motion

The laws of dynamics formulated by Sir Isaac Newton (1642-1727) form another set of principles pertinent for the missileman. These laws of force and motion may be stated as follows:

1. Every body persists in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by a force impressed on it by some other body. Stated another way, bodies at rest tend to remain at rest, and bodies in motion tend to remain in uniform motion unless acted on by other bodies. This latter statement is frequently referred to as the Law of Inertia.

2. The acceleration of a body is directly proportional to the net force applied to it by other bodies, and inversely to the mass of the body; it takes

place in the direction of the straight line in which the net force is acting. This law is expressed by the formula $F = ma$.

3. For every action there is always an equal and opposite reaction. In other words if a body A exerts a force on a body B, then body B exerts an equal and opposite force on body A. It is important to note that the action and reaction *never* act on the same body.

. . . *uniform motion in a circle*

Suppose that a body of mass m is moving with a constant speed v in a circle of radius r. According to Newton's first law of motion, an external force must be acting on this body; otherwise it would move uniformly in a straight line. Elementary considerations show that this force must be acting toward the center of the circle, as is perhaps obvious in the case of a stone whirled at the end of a string. The formula* for this force proves to be

$$F = \frac{mv^2}{r} \tag{1}$$

In other words if we see a body of mass m moving with the constant speed v in a circle of radius r, we can conclude at once that another body must be pulling it toward the center of the circle with the force mv^2/r.**

Newton's Law of Universal Gravitation

The genius of Newton was evidenced by the reasoning to show that the three laws of Kepler are deduced from a simple law of universal gravitation. He stated this law as follows: Every particle of matter in the universe attracts every other particle with a force that varies directly as the product of their masses and inversely as the square of the distance between them. By formula this law can be expressed in the following way:

$$F = G\,\frac{m_1 \times m_2}{d^2} \tag{2}$$

F = force of attraction

G = universal constant of gravitation

m_1 = mass of first body

m_2 = mass of second body

d = distance between masses

The constant of gravitation G is defined as the force of attraction between two unit masses at unit distance apart. If in Equation (2) m_1 and m_2 both equal 1 gram and d is 1 centimeter, then G equals F. The constant G is held

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*This equation and others discussed will be used in a series of problems on page 139. Each major equation is followed by a number in parentheses for later reference.

**If a body moves in a circle, the force pulling it toward the center of the circle is called the "centripetal" force. The reaction to this force (which acts on the body that causes the first body to move in a circle) is called the "centrifugal" force. For example, when a stone is whirled on a string, the string applies to the stone the centripetal (inward) force and the stone applies to the string the centrifugal (outward) force.

to be the same throughout the universe, whatever the physical properties of the attracting particles or their surrounding conditions. In the centimeter-gram-second system the value of G is 6.673×10^{-8} $dyne\ cm^2/gm^2$ and thus the attraction between 1-gram masses 1 centimeter apart is about one 15-millionth of a dyne. The gravitational force with which the earth pulls on a satellite can be written as

$$F = G\frac{Mm}{R^2} \tag{3}$$

where M is the mass of the earth, m the mass of the satellite, and R the distance from the center of the earth to the satellite.

A body of mass m located at the surface of the earth is pulled down with a force mg_0, where g_0 is the gravitational acceleration at the surface of the earth. The pull acting on this body is the gravitational pull of the earth, and is therefore equal to GMm/R_0^2 where R_0 is the radius of the earth. Consequently, $mg_0 = GMm/R_0^2$, and therefore

$$G = g_0R_0^2/M \tag{4}$$

The equation $F = GMm/R^2$ can therefore be written in the form

$$F = mg_0\frac{R_0^2}{R^2} \tag{5}$$

which is sometimes more convenient.

The reason for the law of gravitation is still not completely understood today, although the general theory of relativity provides good clues to it. In other words the law of gravitation tells *how* gravity acts but does not say *why*.

As opposed to other accepted scientific and mathematical phenomena, gravitation offers several notable differences. For example, light can be reflected or refracted, and its velocity is measurably reduced when it is directed through any transparent medium. But there is no evidence to indicate that gravitation can be either reflected or refracted, nor is there any noticeable reduction in its effect between two masses when they are separated either by a transparent or by an opaque substance.

Newton's Law of Gravitation, $F = Gm_1m_2/d^2$, refers to only two masses and suffices in this form for solution of the "two-body problem." In actual practice when applying Newton's "inverse-square law" to problems of astronautics, several bodies must be taken into account to embrace all the forces that would be reacting on a given body in space. We then have the "N-body problem," obviously much more complex than the two-body problem.

. . . *the two-body problem*

For our present discussion we shall deal with only the two-body, or two-point, problem. In Figure 15a, two masses, m_1 and m_2, are at a given distance d from each other. Assume that m_1 has 10 times the mass of m_2. Next consider the line joining their centers as a rod of zero weight with a length of 11 units. This two-point problem could be considered to balance at point *A* on the rod, which is one unit from the center of m_1 and 10 units from m_2. Point *A* is defined as the center of mass of the two-body problem and is often referred to as the center of gravity of the two-body system. Using Figure 15b, assume that m_1 is an extremely large mass such as the earth, and m_2 is a small mass like the satellite Vanguard. By the same analogy as before in determining the center of mass, it is obvious that here, for all practical purposes, it will be the center of mass of the earth. Yet though the center of the mass of the two separate masses may be considered at the center of the mass of the larger, there is still mutual attraction between the two masses.

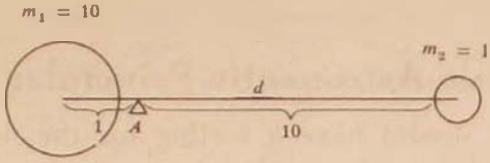


Fig. 15a

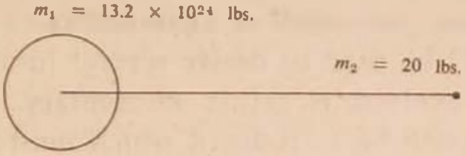


Fig. 15b

. . . the center of attraction

An important consequence of the law of gravitation is that the attraction of a sphere is always directed toward its center, as if the entire mass of the sphere was concentrated at that point.

In computation of missile trajectories one must remember that the earth is not a true sphere but an oblate spheroid. Consequently the force of attraction upon a given mass located on the surface of the earth is greater at the poles than if this same mass were positioned at the equator. This is readily seen from Newton's Law of Gravitation, since the force of attraction varies inversely as the square of the distance between two masses.

. . . acceleration of the attracted body

Another important fact of gravitational attraction is that if two bodies are attracted toward each other and are free to move, the acceleration of the *attracted body* is independent of its mass.

This fact can be readily demonstrated by considering Figure 15b. Assume m_1 to be the attracting body and m_2 the attracted body. The force of attraction between the two masses is $F = Gm_1m_2/d^2$. According to Newton's second law of motion, m_2 is accelerated toward the attracting body m_1 with an acceleration a_2, the force being $F_2 = m_2a_2$. Equating F and F_2, then $m_2a_2 = Gm_1m_2/d^2$ or $a_2 = Gm_1/d^2$.

This formula demonstrates that the acceleration a_2 of the attracted body is independent of its mass m_2, since its mass m_2 does not appear in the cleared equation.

Basic Astronautic Principles

By now the reader should have a feeling for the mathematics relating to conic sections, for the physical constants pertaining to missiles or satellites, and for certain fundamentals of physics considered in orbit computations. With such tools some basic principles of astronautics can be developed. A step-by-step procedure will be used to derive several formulas and equations when the mathematics involved is rather elementary. Some formulas or mathematical expressions will be introduced which must be accepted at face value, as their derivations are based upon principles and laws contained in celestial mechanics, all of which are beyond the scope of this paper. When notations of this category are cited, unfamiliar terms will be defined and particular reference will be made regarding the utility of the formula in demonstrating a principle of astronautics.

In this section a series of analyses will now be considered regarding a mass m in some type of orbit with respect to the earth. In these examples the mass m will not change as its velocity varies. The earth will be considered as a perfect sphere with its mass M at the center and without any surface irregularities, such as mountains. In addition the earth's atmosphere will be neglected in order that frictional air resistance losses may be discounted in the computations.

Circular Orbital Velocity

In this first analysis a formula will be developed for the circular orbital velocity of a mass m as it moves in a circular path at the earth's surface.

With reference to Figure 16, assume the mass m to be a few feet above the surface of the earth and a given force imparted to it which will cause the mass to remain in a fixed circular orbit. For all practicable purposes the distance of the mass m from the center of the earth M will be R_0, the radius of the earth. Since the mass moves uniformly in a circle, the arguments discussed earlier lead to the conclusion that the mass is pulled toward the center of the earth with a force equal to mv^2/R_0. This force is just the gravitational pull of the earth, which by Newton's law of gravitation can be written as $F = GMm/R_0^2$. Equating these two formulas, we have $mv^2/R_0 = GMm/R_0^2$ and therefore:

$$v^2 = GM/R_0 \tag{6}$$

Also we can numerically equate mv^2/R_0 to mg_0, the weight of the mass m. Solving for v^2:

$$v^2 = R_0 g_0 \quad (7)$$

This is known as the equation for the circular orbital velocity at the earth's surface.

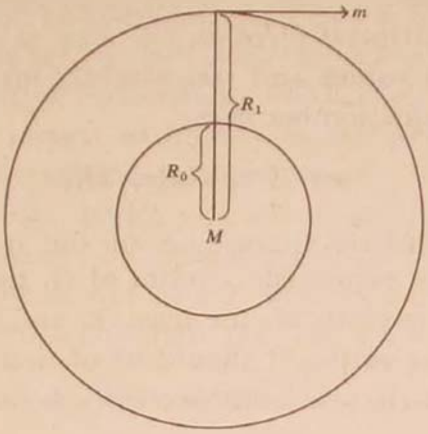


Fig. 16

Another interesting relationship is derived by equating $F = GMm/R_0^2$ and mg_0 and solving for GM:

$$\frac{GMm}{R_0^2} = mg_0$$

$$GM = R_0^2 g_0 \quad (8)$$

This equation proves useful in transforming equations containing the universal constant G to those of acceleration due to gravity g_0.

By using Equation (8) we can solve for M. This will provide a formula for which the mass M of the earth can be approximated:

$$M = \frac{R_0^2 g_0}{G}$$

Assume that the radius of the earth R_0 is 4000 miles, $g_0 = 32$ ft/sec^2, and $G = 1068 \times 10^{-12}$ poundal ft^2/lbs^2.

$$M = \frac{(4000 \times 5280)^2 \times 32}{1068 \times 10^{-12}}$$

$$M = 13.2 \times 10^{24} \text{ lbs}$$

Energy Relationships of a Mass in Various Orbits

When a mass m is in motion and moving in a straight line, circular, elliptical, parabolic, or hyperbolic path with respect to the earth, two different types of energy are in evidence, viz., potential energy (PE) $= mgh$, and kinetic energy (KE) $= mv^2/2$. The following discussion will show some of the relationships between these two energies when the mass m is following some prescribed conic-section path.

It has been stated that when a mass m is in circular orbit about the earth at some distance R_1 from the center of M, as in Figure 16, the force due to gravitation and the centripetal force on the mass m are equal in magnitude. If we equate these two values and concurrently multiply both sides of the equation by $R_1/2$, the equation becomes

$$mv^2/2 = GMm/2R_1 \tag{9}$$

This means that the kinetic energy KE of the mass m in circular orbit around the earth can be expressed in terms of G, the universal gravitational constant; the mass of the earth M; the mass m; and the distance R_1 the mass is from the center of the earth. It should be obvious that the KE needed to maintain the mass m in circular orbit decreases as its distance from the earth increases.

Another very valuable pair of formulas can be obtained from the next analysis. In Figure 17, M is the center of the earth, and R_0 its radius. The line A is perpendicular to the radius, and m is the mass of an object which will be under close scrutiny. A line is imagined from M through m and away from the earth toward infinity. The line A is called the surface reference line and the line B the infinity reference line.

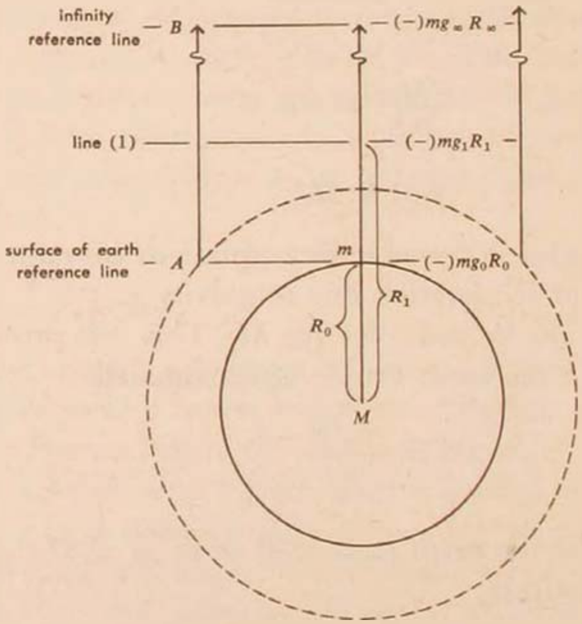


Fig. 17

First consider the mass m from the standpoint of the surface reference line A. The weight of mass m at the earth's surface is mg_0. As the mass m moves away from the earth, its weight (mg_0) is decreased and can be determined by the inverse-square law:

$$\frac{g_1}{g_0} = \frac{R_0^2}{R_1^2} \tag{10}$$

$$g_1 = g_0 \frac{R_0^2}{R_1^2} \tag{11}$$

The mass m at line (1) will have a weight of mg_1 with respect to the earth. At infinity the mass would be completely out of the earth's gravitational field and would therefore have zero weight with respect to the earth.

Now move the point of reference to the line B, or infinity. Any value regarding distance with respect to infinity in the direction of the center of the earth M would be negative (−); therefore the weight of the mass m at the line (1) would be $-mg_1$. Its PE would be $-mg_1R_1$. At the surface of the earth the PE of mass m would be $-mg_0R_0$. At infinity the PE would be zero (0), since the mass would be out of the earth's gravitational field. By substituting the value of g_1 from Equation (11), the PE of $-mg_1R_1$ becomes

$$PE = -mg_0R_0^2/R_1 \tag{12}$$

It has been stated that when a missile or satellite is moving along a conic-section path two types of energy, KE and PE, are evident. The total energy (TE) of the moving body is the sum of these two energies, as expressed by the equation $TE = KE + PE$. Accordingly the TE of a mass m in circular orbit could be determined from the following equation:

$$TE = \tfrac{1}{2}mv^2 - \frac{mg_0R_0^2}{R_1} \tag{13}$$

It is noted that the mass m has a $PE = -mg_0R_0$ at the surface of the earth, as is indicated on Figure 17. If the mass m were fired vertically, its KE would fall off from its maximum value at the earth's surface of $\tfrac{1}{2}mv^2$ to zero, at which point its vertical motion stops. Let this be at a height of R_1. The PE at this point would be $-mg_0R_0^2/R_1$. The maximum distance the vertically fired mass m would travel can be obtained from the equation $TE = KE + PE$:

$$KE + PE = 0 - \frac{mg_0R_0^2}{R_1} = \tfrac{1}{2}mv^2 - mg_0R_0$$

Solving for v^2 and reducing the equation of m:

$$v^2 = 2g_0R_0 - 2g_0\frac{R_0^2}{R_1}$$

$$v^2 = 2g_0R_0\left(1 - \frac{R_0^2}{R_1}\right) \tag{14}$$

As was previously stated, a number of formulas and principles are cited in this paper without benefit of derivation, because of the difficult mathematics involved. These formulas and principles can be verified in textbooks on advanced physics or celestial mechanics. With reference to Figure 18 the following statements are valid:

a. The total energies of a mass m moving in either circular or elliptical orbit are equal when the radius of the circle is equal to the semi-major axis of the ellipse.

b. The sum of the potential energy PE and the kinetic energy KE of a mass m in either circular or elliptical orbit is a constant.

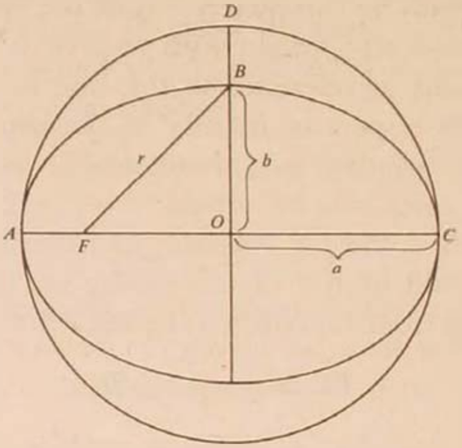


Fig. 18

The velocity of a mass m at any point in an elliptical orbit can be obtained from the following formula:

$$v^2 = GM\left(\frac{2}{r} - \frac{1}{a}\right) \tag{15}$$

This equation will determine the velocity of the mass m in elliptical orbit, in terms of the radius vector r and the semi-major axis a. As was mentioned previously, the semi-minor axis b of an ellipse only helps to fix the focus and does not enter into the energy equation. The values of constants G and M are listed on page 142.

The velocity for mass m when in hyperbolic motion is expressed by the equation

$$v^2 = GM\left(\frac{2}{r} + \frac{1}{a}\right) \tag{16}$$

The only difference between this equation and Equation (15) is that the sign of $1/a$ is positive.

Another useful equation clarified by Figure 19 gives the length of the radius vector r in terms of the angle θ, the semi-major axis a, and the eccentricity e. The angle θ is measured from the semi-major axis in a clockwise direction from the line AF to the radius vector r. The equation is

$$r = \frac{a\,(1 - e^2)}{1 + e \cos \theta} \tag{17}$$

By a different method than was used on page 118, the eccentricity e of an ellipse can also be defined as the ratio of the distance between the focus and the origin to the length of the semi-major axis. In Figure 19 the eccentricity $e = FO/AO$, or $e = FO/a$. It can also be proved that $FB = a$, the semi-major axis of the ellipse.

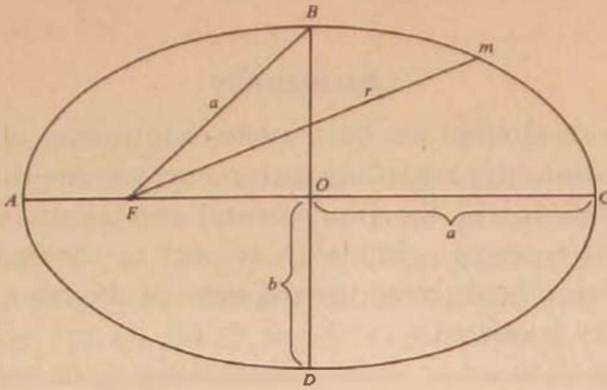


Fig. 19

Escape Velocity

In Equation (14) suppose the velocity imparted to the mass m to be such that the mass moves to infinity or $R_1 = \infty$. Then the fraction R_0^2/R_1 will become zero (0) and the equation would be reduced to

$$v^2 = 2g_0R_0 \tag{18}$$

This is the formula for the escape velocity, or the velocity that must be given to the mass m to cause it to follow a parabolic path and escape from the earth. Velocity of the mass m at infinity is considered zero. The velocity of escape, or parabolic velocity, can also be expressed as $v^2 = 2GM/R_0$. In Equation (8), $GM = R_0^2g_0$, or $GM/R_0 = R_0g_0$. Substituting in Equation (18):

$$v^2 = \frac{2GM}{R_0} \tag{19}$$

Imagine the mass m very near the surface of the earth and in circular orbit. Equation (7) stated that its orbital velocity was $v^2 = g_0R_0$. Equation (18) gives us the velocity of escape. A proportion can therefore be established between the two:

$$\frac{v^2 \text{ escape orbit}}{v^2 \text{ surface circular orbit}} = \frac{2g_0R_0}{g_0R_0}$$

Therefore

$$v \text{ escape} = v \text{ surface circular orbit} \times \sqrt{2} \tag{20}$$

Recalling Equation (7), i.e., $v^2 = g_0R_0$, and substituting the value of 32 ft/sec^2 for g_0 and 4000 miles for R_0, the circular orbital velocity of a mass m at the earth's surface is found to be approximately 5 mi/sec. Therefore from Equation (20), multiplying this value of 5 mi/sec by $\sqrt{2}$ gives the escape velocity of 7 mi/sec for the mass m.

Summary

In this paper an attempt has been made to introduce to the reader several mathematical relationships regarding astronomy, astronautics, and physics, all of which are significant in the fundamental computations of satellites and missiles in various types of orbits with respect to the earth. In order that further attention may be directed toward some of the more cogent points, the following summary is offered.

a. Satellites placed in orbits which circumnavigate the earth may follow one of two conic sections:

(1) circle (2) ellipse

b. A satellite in parabolic or hyperbolic orbit will have sufficient energy to leave the gravitational effect of the earth.

c. The following table summarizes the relationship of eccentricity e, satellite velocities, and types of orbits with respect to the earth:

Eccentricity (e)	*Velocity*	*Orbit*
zero	approx. 5 mi/sec	circle
less than 1	(a) varies 5 to 7 mi/sec	ellipse with center of the earth at the focus to the left of the origin O.
	(b) less than 5 mi/sec	ellipse with center of the earth at the focus to the right of the origin O.
equal to 1	approx. 7 mi/sec	parabola
greater than 1	greater than 7 mi/sec	hyperbola

d. Satellites in circular orbit revolve around the earth at a constant velocity.

e. Satellites in elliptical orbit around the earth accelerate when approaching the perigee and decelerate when approaching the apogee.

f. In computations of the gravitational effect of the earth upon a body, the mass of the body remains constant but its weight varies inversely as the square of its distance from the center of the earth.

g. The circular orbital velocity of a satellite, neglecting atmospheric and gravitational losses, is approximately 5 mi/sec.

h. The parabolic or escape velocity of a satellite with respect to the earth is approximately 7 mi/sec.

i. The total energy of a satellite in circular or elliptical orbit is equal to the sum of its potential energy and its kinetic energy.

j. In computation of velocities and energies of satellites care must be taken that the various values substituted in formulas are in the same units of measurement, i.e., either in the CGS (centimeter-gram-second) system or in the *FPS* (foot-pound-second) system.

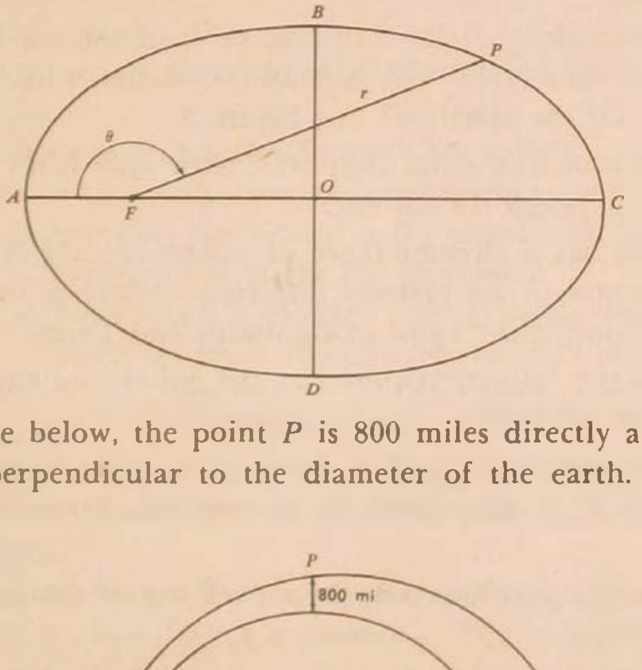
Problems

The reader is encouraged to try his hand at a few of the fundamental calculations relating to missile trajectories and satellite orbits. Armed by his perusal of the foregoing presentation of basic principles and formulas, he should find the play of the following problems an interesting and informative exercise. The figures and equations bearing on the solutions are referenced. Definitions on page 141 should be noted before solutions to the problems are attempted, as some of the terms used in the problems have not been previously defined. The answers are provided at the close of the list of problems.

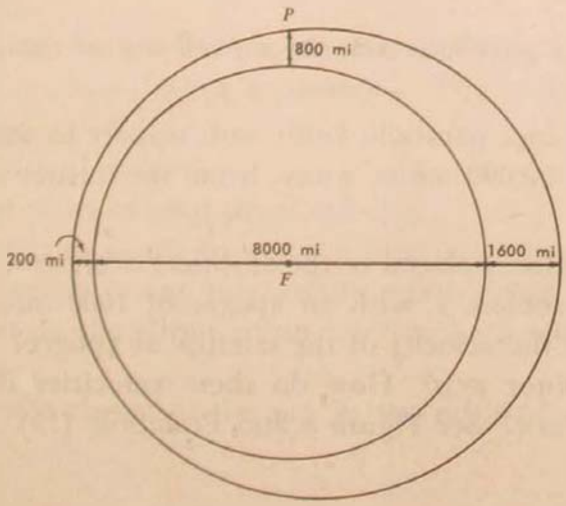
1. An ellipse has a major axis of 9800 miles and a semi-minor axis of 4400 miles. What is the numerical value of eccentricity e? See Figure 8.

2. In Problem 1, what is the length of the radius vector r from the focus F to the top of the semi-minor axis?

3. In the figure below, the ellipse has an $e = 0.20$ and a major axis of 20 units. What is the length of the radius vector r which makes angles of 0°, 90°, and 180° with the line AF? See Equation (17).



4. In the figure below, the point P is 800 miles directly above the earth. The line PF is perpendicular to the diameter of the earth. If the perigee



of the ellipse is 4200 miles and apogee 5600 miles, what is the eccentricity of the ellipse? What is the length of the radius vector r to the top of the semi-minor axis? See Figure 8 and Equation (17).

5. In Problem 4, what is the length of the minor axis? See Figure 8.

6. How much force is required to give a 200-gram mass an acceleration of 98 cm/sec^2? Express this force in dynes. In grams. See the following "Table of Definitions, Physical Constants, Terms, and Formulas."

7. A mass of 20 lbs is rotating in circular orbit near the earth's surface at 5 mi/sec. Compute the centripetal force on this mass. See "Table of Constants and Terms."

8. How much work is done when a 200-lb man walks to the top of a hill which is 555 ft high? See "Table of Constants and Terms."

9. What would a 200-lb pilot weigh at a height of 1000 miles above the earth's surface? (Newton's inverse-square law.) See "Table of Constants and Terms."

10. Where is the center of gravity of two particles (bodies) with respective masses of 20 and 30 units, if they are 10 feet apart? See Figure 15.

11. A pilot weighs 180 lbs at the surface of the earth. What would be his weight on the moon? (Newton's inverse-square law.) See "Table of Constants and Terms."

12. If the eccentricity of the elliptical orbit of the earth around the sun is 0.0167 and the semi-major axis is 93,000,000 miles, what is the distance of the perihelion? Of the aphelion? See Figure 8.

13. At a height of 2000 miles above the earth what is the value of acceleration of gravity in ft/sec^2? In cm/sec^2?

14. The earth has a circumference of approximately 25,000 miles at the equator and rotates in an easterly direction. What is the velocity of the earth at the equator? See "Table of Constants and Terms."

15. Compute the velocity required at the equator of the earth to place a satellite into a circular orbit. See Equation (7).

16. With the answer obtained in Problem 15, what would be the required take-off velocity if it were fired in an easterly direction? In a westerly direction?

17. Compute the parabolic velocity or velocity of escape for a 20-lb mass. See Equation (19).

18. A mass m is in a parabolic orbit with respect to the earth. What is its velocity when 10,000,000 miles away from the center of the earth? See Equation (18).

19. A 20-lb satellite is placed in the elliptical orbit around the earth shown in the figure for Problem 4, with an apogee of 1600 miles and a perigee of 200 miles. What is the velocity of the satellite at apogee? At perigee? At the top of the semi-minor axis? How do these velocities illustrate the theory of Kepler's second law? See Figure 8 and Equation (15).

20. In Problem 19, what is the kinetic energy of the mass at its apogee? See "Table of Constants and Terms" and Equation (15).

A Table of Definitions, Physical Constants, Terms, and Formulas

Definitions

acceleration due to gravity. The approximate value of the acceleration due to gravity, *g*, is measured at 32 ft/sec^2 or 980 cm/sec^2.

aphelion. That point farthest from the sun in the order of any member of the solar system.

apogee. That point on the ellipse of an orbiting body which is farthest from the earth. Also the highest point in the trajectory of a missile.

astronautics. The art and science of flying through space or sending vehicles or missiles through space.

astrophysics. A science which relates the more immediate applications of physics to astronomy.

atmosphere. The body of air which surrounds the earth.

celestial mechanics. The science that deals primarily with the effect of force as an agent in determining the orbital paths of celestial bodies. It is concerned largely with application of the law of gravity.

centrifugal force. A force which is directed away from the center of rotation.

centripetal force. A force which is directed toward the center of rotation.

conic section. The curves generated by the intersection of a plane with a cone of revolution.

ellipse. A conic section which has an eccentricity less than unity.

gravity. The force that makes a body, if free to move, accelerate toward the center of the earth.

hyperbola. A conic section made by a plane intersecting a cone of revolution at an angle smaller than that of a parabola. The value of its eccentricity is greater than one.

mass. Mass is quantity of matter.

momentum. The product of mass times velocity.

parabola. A conic section made by a plane intersecting a cone parallel to an element of the cone. It has an eccentricity equal to unity.

perigee. That point on the ellipse of an orbiting body which is closest to the earth.

perihelion. The point closest to the sun in the orbit of any member of the solar system.

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perigee. That point on the ellipse of an orbiting body which is closest to the earth.

perihelion. The point closest to the sun in the orbit of any member of the solar system.

revolution. The motion or the apparent motion of a body in orbit.

rotation. The turning of a body about its axis.

space. That which extends in all directions and has no outward bounds nor limits of divisibility and surrounds and encompasses all matter, as in "The earth travels through space as it revolves about the sun."

vector. An entity which has both magnitude and direction, such as a force or velocity.

velocity. Speed or rate of motion in a given direction and in a given frame of reference. Velocity is a vector quantity.

weight. The gravitational force or the pull exerted on a mass by the earth is the weight of the mass.

work. A measurement of the product of force exerted times the distance of displacement.

zenith. The point in the celestial sphere directly overhead.

Physical Constants

For the purpose of solving suggested problems contained in this paper, only approximate values for selected physical constants are given. It will be noted that many constants listed have been rounded off to the closest whole number. This is done primarily to facilitate solution of problems.

acceleration of gravity g	980 cm/sec^2
velocity of light	3×10^{10} cm/sec
	186,000 mi/sec
gravitation G	6.67×10^{-8} dyne cm^2/gm^2
	1068×10^{-12} poundal ft^2/lb^2
astronomical unit	93,000,000 miles
earth's radius	3964 miles (equatorial)
	3950 miles (polar)
	4000 miles (for use in problems suggested for solution in this paper)
earth's mass M	5.97×10^{27} gms
	6.6×10^{21} short tons
	13.2×10^{24} lbs
sun's mass	1.98×10^{33} gms or ($332,280 \times$ earth's mass)
moon's mass	$1/81.3 \times$ earth's mass
1 light year	9.46×10^{12} km
	5.878×10^{12} miles
1 day	86,400 sec.

Terms

. . . force

1 dyne	7.22×10^{-5} poundal (It is important that the dyne and poundal are understood. It is recommended that a physics textbook be reviewed for these units of force.)
1 poundal	13,825 dynes
1 gram–force	980 dynes
1 dyne–force	2.25×10^{-6} lb force
1 lb–force	4.45×10^{5} dynes
1 lb–force	32 poundals

. . . velocity

1 cm/sec	0.0328 ft/sec
1 ft/sec	30.5 cm/sec
1 mile/hr	44.7 cm/sec
1 mile/min	60 mi/hr 88 ft/sec

. . . mass

1 kg	2.2 pounds
1 lb	454 gm.
1 ton (short)	2000 lb

. . . length

1 foot	30.5 cm
1 mile	1.61 km
1 mile	5280 ft
1 meter	39.4 in

Formulas

distance	$D = vt$	D = distance	v = velocity	t = time
acceleration	$a = v/t$	a = acceleration		
velocity	$v = at$			
	$v = gt$	g = gravity		
Newton's second law	$F = ma$	m = mass	F = force	

momentum	$Mv = mV$	M and m are different masses
centripetal force	$F = mv^2/r$	r = radius of circle of rotating mass m
kinetic energy	$KE = mv^2/2$	
potential energy	$PE = mgh$	h = height mass is displaced against gravity
mass	$m = W/g$	W = weight
work	$W = Fd$	F = force d = distance

Air Command and Staff College

ANSWERS TO PROBLEMS

(derived by slide-rule calculation)

1. $e = 0.44$
2. $r = 4900$ miles This value can be determined by inspection. It can also be obtained by using Equation (17).
3. $r = 8$ when the angle $\theta = 0$ degrees
   $r = 9.6$ when angle $\theta = 90$ degrees
   $r = 12$ when angle $\theta = 180$ degrees
   The cosine of 0 degrees, 90 degrees, and 180 degrees equals respectively 1, 0, and —1. These cosine values can be obtained from any trigonometric table.
4. a. Eccentricity = 0.143
   b. Radius vector $r = 4900$
5. The minor axis = 9700 miles
6. a. 19,600 dynes.
   b. 20 grams
7. 20.6 lbs
8. 101,000 ft-lbs
9. 128 lbs
10. 4 ft from the 30-unit mass
11. 30 lbs
12. a. Perihelion = 91,500,000 miles
    b. Aphelion = 94,500,000 miles
13. a. 14.2 ft/sec^2
    b. 435 cm/sec^2
14. 0.29 mi/sec in an easterly direction
15. 4.93 mi/sec
16. a. 4.64 mi/sec in an easterly direction
    b. 5.22 mi/sec in a westerly direction
17. 7 mi/sec
18. 730 ft/sec
19. a. Velocity at apogee = 20,200 ft/sec
    b. Velocity at perigee = 27,200 ft/sec
    c. Velocity at top of semi-minor axis = 23,300 ft/sec
20. Kinetic energy = 4.08 x 10^9 ft/poundal

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