ICBM: A Step Toward Space Conquest
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I presume that the reason I have been invited to address you here tonight is because, as Commander of the Western Development Division, I am deeply engrossed in man's first concerted attempt to penetrate outer space. The compelling motive for the development of space technology is the requirement for national defense. For this reason, the Air Force Ballistic Missile Program was assigned highest national priority and is being pressed forward with utmost vigor.

Since 1954, the United States has come a long way in the development of space technology. The Western Development Division was given full authority and responsibility for all aspects of the Air Force's Ballistic Missile Program at that time. Since its inception, this Division has organized the strongest possible industrial team, selecting in all cases the best qualified segments of science and industry available. The program has already progressed through several important stages so that at this time we can identify a number of significant accomplishments toward the conquest of space. These include: (1) the evolvement of a development philosophy appropriate to the urgency and complexity of the task, (2) the establishment of a development team on an industrial base capable not only of development but of immediate production follow-up, (3) the construction of facilities for research, fabrication and testing, (4) the design, fabrication, and successful test of hardware components, and, finally, (5) a beginning of the flight test phase, including a substantial number of successful test flights that have confirmed theoretical design information.

1. Evolvement of a development philosophy
Our development philosophy includes two elements: a philosophy of testing and a dual approach. Stated simply, the test philosophy requires a great deal of component reliability testing at the earliest possible test level in order to insure reliability of components before proceeding to subsystem testing, captive system testing, and on to launch. A second element of our development philosophy is the multiple approach and back-up provision which calls for more than one contractor in the re-entry area, in guidance, in guidance, in airframe, and in propulsion. Backing up this system development is a comprehensive program of basic research in various fundamental areas, involving the participation of a large number of Air Force and civilian research centers. This approach, of course, provides insurance against failure and increases confidence in meeting schedules.

2. Establishment of a development team and an industrial base.
The complexity and urgency of the Ballistic Missile Program required the establishment of a unique development-management group. To meet this need an unusual arrangement was made involving two major commands of the Air Force and an industrial contractor. WDD, a division of Headquarters, Air Research and Development Command was organized to exercise overall

supervision over the management complex.

As Commander of WDD, I have full authority and control over all aspects of the Ballistic Missile Program. Serving also as Assistant to the Commander of ARDC, I am able to co-ordinate related activities of the various ARDC Centers, of which there are twelve. The Ballistic Missile Office of the Air Material Command is responsible to provide support in the areas of procurement and production, supply, maintenance engineering, and transportation. Brigadier General Ben I. Funk is in charge of the BMO office. Serving also as Assistant to the Commander, Air Material Command, he is able to secure cooperation from AMC and the Air Procurement Districts. The third member of the team is the Guided Missile Research Division of the Ramo-Wooldridge Corporation. This group of top flight scientists and engineers is responsible for systems engineering for the entire program and technical direction to our contractors. The management complex is supported by 16 major contractors representing the most competent elements of industry. Each was selected on the basis of a competition.

3. Construction of facilities.
Since the Ballistic Missile Program was accelerated in 1954, 470 million dollars has been made available for new test installations and plant expansion. A substantial percentage of this total, over 100 million, is privately financed by both prime and subcontractors. In airframe development, Convair, Douglas and Martin, have expanded present facilities or are building new ones. For example, at Convair here in San Diego, a vast plant area was created virtually overnight for pilot production of ATLAS airframes and within one year, cattle grazing land at nearby Sycamore Canyon was converted to a complex for captive testing of the ATLAS. Similar expansion has taken place in the engine development program at North American's Rocketdyne facility near Los Angeles, and the Aerojet-General Corporation which has expanded its complex of facilities at Sacramento, to develop and produce engines for the TITAN ICBM. And so it goes, with General Electric, Avco, Lockheed, Burroughs, Bell, Remington Rand, MIT, AC Spark Plug, Arma, and others.

Laboratory test equipment such as environmental test chambers, random noise vibration equipment, and data reduction equipment has been installed at contractors' plants to accomplish the extensive-environmental and reliability testing required. Major installations at Air Force Centers provide means for captive and launch tests of the complete system including thousands of miles of instrumented range whose scope and complexity far exceeds any previous missile effort.

These few examples make it demonstrably evident that the Air Force's Ballistic Missile Program represents a concerted effort of unprecedented magnitude jointly pursued by the most competent and widespread government, science and industry teams ever assembled on a single project.

4. The design, fabrication, and successful test of hardware component.
In addition to the industry-science-military team that has been established and the test and development facilities that have been constructed at ARDC Centers and at Contractors' plants, how else have the ICBM and IRBM programs contributed to the conquest of space? They have contributed in a very concrete sense from the standpoint of hardware that has been developed or is being developed for this program. A tremendous industrial capability is being built up and production know-how is being established in many new areas. Out of this tremendous effort will come a wealth of design information and hardware that will be useful for other things beyond that for which they were designed. These airframe, propulsion, and guidance and control subsystems, together with extensions of advance research presently underway and also

utilizing design information that will become available as ballistic missile test flights are made, will make it possible to achieve other goals with the subsystem than to carry the nose cone-warhead to a predetermined target. A whole gambit of follow-on projects immediately becomes feasible.

Take for example, the propulsive unit: the same propulsive unit that boosts a heavy nose cone-warhead to 25,000 ft/sec, could boost a somewhat lighter body to the escape velocity of 35,000 ft/sec or to an orbital path around the earth. Using the same number of stages, the ratio of thrust to weight would be greater by using a lighter payload, and higher accelerations and velocities could be reached before burnout. Or with our present state of knowledge, it would be relatively easy to add another stage. We have already done that successfully on our re-entry test vehicle, the X-17. The same guidance system that enables the warhead of a ballistic missile to reach its target within a permissible accuracy would also be sufficiently accurate to hit a target much smaller than the size of the Moon, even at that increased range. Or, if we are talking about circular orbits around the Earth, errors in guidance could be easily observed over a period of time and corrected, and the satellite kept on an accurate orbit. And, of course, these same propulsive and guidance components could also be used for surface-to-3surface transport vehicles of various sorts to experimentally carry mail or strategic military material to critical sites. The same applies to structural advances of the ICBM that have brought us to new heights in the ratio of total to structural weight. I would be willing to venture a guess that 90% of the unmanned follow-on projects that one could visualize for the future could be undertaken with propulsive guidance and structural techniques, presently under development in the AF Ballistic Missile program.

It is reasonable to expect that it will not be too difficult to extend these present developments to surface-to-surface transport of personnel by rocket propulsion, or space travel of personnel at some time in the future. However, before man can be committed to space vehicles, a tremendous amount of human factors research will be necessary. I am sure that these research problems have been discussed in great detail by the Human Factors Panel. The ICBM program may even be able to contribute some information in this area. Granted this research, there are other problems as well. As a specific example of the kind of advance development, not a part of an ICBM, probably necessary for manned space flight to distant planets, is sustained thrust through space. This, of course, to reach higher velocities and cut down the flight time which would otherwise be impractically long for a human passenger even to the closest planets. Such long sustained thrust, at a small enough magnitude level to be tolerable to a man, requires a type of propulsion technique that is not well suited to take-off thrust and general ICBM requirements. The successful achievement of the required propulsion system is clearly indicated by today's science, but it has to be developed as a program beyond the first ICBM program. Space technology, probably for some decades, will not revolve primarily around apparatus for controlled movement of vehicles from one point to another in empty space. Perhaps not only initially but for all time, space technology will include as its most characteristic problem the need for going from the surface of one celestial body to another with successful passage through the atmosphere of each. The first big problems then are how to bring a substantial mass up to empty space with velocity sufficient to continue inter-body space travel, with adequate precision in the velocity vector control, and how to bring it back through an atmosphere without disintegration. In each of these respects, if one by-passes human cargo ambitions for the moment, the ICBM is attaining the necessary capability and, in preparation for eventual manned flight, the ICBM test flying in substantial numbers could provide experimental data of direct interest.

Granted then that the ICBM program is a major, pioneering, and foundation step for space technology, what appears to be a logical future program? It is very difficult to make a firm prognosis on military need during a 20-year period for something as new and revolutionary as ballistic missiles, earth satellites, and space vehicles. We are somewhat in the same position today as were military planners at the close of the First World War when they were trying to anticipate the use of aircraft in the Second World War. Consequently my prognoses will go from those which are reasonably firm to those which might be considered visionary. Fortunately, there is a considerable overlap between the advances in the state-of-the-art which are required for firm and for visionary military needs.

First we should consider those changes in the operational and technical characteristics of ICBM's and IRBM's to make them superior, reliable weapons. Almost any military planner would agree that if we can increase the range, increase the payload, reduce the gross weight, increase the accuracy, reduce the cost, or simplify the operational procedures, we will have made a worthwhile contribution. Now, in order to achieve any or all of these objectives, it will be necessary to advance the state of the propulsion art, the structures art, or the guidance art, or perhaps all three. When these advances are made, they will be applicable also to the more visionary projects. The basic science underlying these engineering arts has been well surveyed in the past two years; it tells us that considerable advance is possible on all fronts. Thus, if on our first ICBM's we can attain controlled, precise velocity in the course of firing a large payload up to a speed close to satellite and escape velocity, it will be even easier to do so in the future and accordingly the extension to satellites and the space vehicles will represent an even smaller step.

A word is necessary on the relationship between military need and scientific feasibility in space technology. In the long haul our safety as a nation may depend upon our achieving 'space superiority'. Several decades from now the important battles may not be sea battles or air battles, but space battles, and we should be spending a certain fraction of our national resources to insure that we do not lag in obtaining space supremacy. Besides the direct military importance of space, our prestige as world leaders might well dictate that we undertake lunar expeditions and even interplanetary flight when the appropriate technological advances have been made and the time is ripe. Thus it is indeed fortunate that the technological advances required in support of military objectives can, in large part, directly support these more speculative space ventures even though in addition, it will be necessary to extend the navigational program and the space medicine program characteristic of this type of sustained flight.

Now, where does all this lead? My thought is that the evolution of space vehicles will be a gradual step-by-step process, with the first step beyond ballistic missiles being unmanned, artificial earth satellites and then perhaps unmanned exploratory flights to the Moon or Mars. These first flights would no doubt be research vehicles to gather scientific data and to accumulate information on space environmental conditions for future design use. The information gathered from these flights will supplement the information gathered from ballistic missile test flights. Many of the things that We can learn from satellites will lead not only to a better understanding of conditions to be encountered in space, but will lead to a better understanding of our own planet. Weather reconnaissance can be accomplished in a more effective manner. This will lead to a better understanding of the movements of polar air masses and the course of jet streams and will permit improved long range weather forecasts and improved aircraft and missile operations. A better understanding of the earth's magnetic field will lead to better radio communications, more reliable navigation instruments, and perhaps new ideas for propulsive devices. Refined data on the earth's gravitational effects will lead to improved guidance. Much remains to be known about cosmic rays. Unmanned satellites will be the means for obtaining this information.

I have described some of the benefits to be derived from our early ventures into space, and the contributions the ICBM program is making in this direction.

Payload capability of a future satellite could be in the order of hundreds or even a thousand pounds. Such payload would permit more instrumentation and many varied types of space experiments.

Vehicles with additional complications could be made to have the ability to return intact from space. But without fundamental extension the environment during flight would not be proper for a human passenger. Therefore, manned space flight cannot be attempted, with such apparatus, but many of the associated physiological questions can be answered by experiments with animals. We may, in fact, be able to fill nearly all of the gaps in our knowledge which are now holding back the design of manned spacecraft.

Given vehicles with these capabilities, still another avenue for a scientific achievement is immediately opened. With additional rocket thrust a lunar research vehicle may be possible. In view of the small additional cost of such an experiment, it seems certain that someday it will be tried.

In conclusion, we see that the ICBM program, through the technology it is fostering, the facilities that have been established, the industrial teams being developed and the vehicles themselves, is providing the key to the further development of space flight. Many fascinating new horizons are sure to open within the next decade as a direct result.