FLIGHT RESEARCH FOR SPACE CRAFT

presented by

Langley Aeronautical Laboratory

The success of ballistic missiles or of manned satellites depends very greatly upon the results obtained in an area of research generally spoken of as the re-entry problem. In conducting research into this difficult problem, the NACA has developed both theoretical solutions that indicate the general nature of the problem as well as experimental techniques that duplicate the high speed, high temperature environment which the structure of a re-entry vehicle must withstand.

A particular aspect of the general re-entry problem is the evaluation of the relative merits of a variety of promising materials. For this purpose the NACA has developed and has in operation several high-temperature air jets in which the test jet is of the order of 1/2-inch to 5-inches in diameter. These jets are basically of two types, the ceramic heated air jet and the electric-arc heated air jet. A photograph of a ceramic heated air jet facility is shown here and a close-up of one of these jets with a model in place is shown here. This is a photograph of an electric arc heated air jet in operation. Several of these small heated air jets are in operation at the various NACA laboratories.

This chart illustrates schematically the operation of the two types of jets. In the electric arc heated air jet, compressed air is supplied to the chamber and is heated by means of a high intensity electric arc generated between the electrodes and the nozzle block. The air heated by the arc then leaves the nozzle as a high-temperature supersonic jet with stagnation temperatures of the order of 11,000° F which roughly simulates the most severe aerodynamic environment encountered during re-entry of a long range ballistic missile. At present this type of facility is limited in size so that only small samples of the materials can be tested, such as the models shown here. At the present time larger pieces of material and parts of structures such as this portion of a fin leading edge can be tested in the ceramic heated air jets. The operation of this jet is as follows: Hot flue gases from an oil burner are used to heat the ceramic pebbles shown here. After the pebbles are heated, high-pressure air is then forced through the pebbles heating the air so that a jet having stagnation temperatures of the order of 4,000° F is then formed by the nozzle.

Some films showing the behavior of some typical materials tested in a small-scale ceramic heated air jet and in an electric arc heated air jet will now be shown.

FILM

TITLE: Three tests of 1/2-inch diameter samples of materials in a 3/4-inch diameter ceramic heated air jet at 4,000° F stagnation temperature will be shown first. The jet streams from the bottom toward the top of the picture.

<u>Zirconium Dioxide</u>

The behavior of the material shown here is typical of many ceramics. Ceramics in general have very high melting temperatures, but are relatively brittle and are subject to thermal shock. Small pieces can be observed flaking off the nose position during test and eventually the whole specimen breaks apart terminating the test.

<u>Crystalline Glass</u>

This is a new material recently available commercially. It has an interesting property in that although melting occurs on the nose, the nose remains rounded and very smooth during the entire test. Notice that time is indicated in tenths of seconds by this counter, and that in this test and all other tests you will be seeing the action in slow motion. The action in all of these films takes over five times as long as the original event. Typical tests run anywhere from several seconds to about a half a minute. Results obtained from this research indicate the relative durability of the materials tested.

<u>Graphite</u>

Graphite has an extremely high melting temperature and is comparatively strong at elevated temperatures. The test shown here demonstrated that graphite is quite durable in the environment of this jet and is capable of repeated tests without appreciable damage.

<u>TITLE</u>: Tests of 1/4-inch diameter samples of materials in a 1/2-inch diameter arc heated air jet at stagnation temperatures of about 11,000° F will be shown next. In this film the jet streams from left to right.

<u>Copper</u>

The behavior of the copper model in this jet demonstrates very vividly the intense heating ability of this jet. Melting occurs almost immediately at the nose and in a very short time the model has melted completely away (about 1 second).

<u>Fiberglas and Plastic</u>

As discussed in detail in the presentation at the Low Density and Heat Transfer Wind Tunnels the behavior of this material in the arc jet demonstrates a promising method of protection intended for satellites and missiles re-entering the atmosphere. Molten layers on the surface ablate away carrying most of the heated material with it. Therefore, as long as the material remains intact, the interior is prevented from overheating.

Graphite

Graphite is shown again for comparison with the test in the ceramic heated jet. The model is quickly raised to a white heat and failure eventually occurs at the attachment to the support.

These hot-air jets, however valuable, are after all only a supplement to flight testing in the natural atmosphere. In this field of research, the NACA has long made use of small, relatively inexpensive, solid-fuel rockets to provide propulsion for scaled models that are used to study the various problems associated with flight throughout the speed range. Research at hypersonic speeds was made possible by applying the multi-staging technique to the simple rocket motors used.

The advantages of employing rocket motors in stages are demonstrated graphically on this chart. Depicted here are a number of staging systems that have been used at our Pilotless Aircraft Research Station, Wallops Island, Virginia, to send aloft a thirty-pound payload. Here we see that by adding stages the maximum Mach number is increased. Only simple readily available motors were used in the staging. No effort was made to achieve optimum performance by using "tailor-made" motors. Such an effort would have, of course, increased the maximum Mach number, but would have greatly increased the time required to accomplish the required research.

In addition to making it possible to attain high velocities, multi-staging gives the user freedom in the choice of flight path and altitude. This means that it is possible to obtain research information at the same velocities and under the same atmospheric conditions "seen by" different types of aircraft or missiles. On this chart, we have indicated the wide range of altitude and velocity conditions that can be reproduced by the multi-stage systems currently being used by NACA. It is interesting to note that this area covers large portions of the velocity-altitude parameters associated with widely different vehicles such as ballistic missiles and hypersonic glide vehicles.

We are able to send our multi-stage systems along various flight paths without resorting to complicated and costly automatic guidance and control systems. Here we have three trajectories, altitude plotted against horizontal range, that have been obtained with a five-stage rocket system similar to the one overhead by simply varying the time delay between ignition of the second- and third-stage motors. The most complicated control that is used is a simple timer. To obtain the upward reaching trajectory the timer was set to ignite the third stage before the assembly reached the peak of the ballistic path. The nearly level trajectory was obtained by igniting the third stage near the peak of the ballistic path and the downward plunging, re-entry type trajectory, was obtained by igniting the third stage after the peak had been passed. Other variations in the trajectories can be obtained by simply changing the firing times still more and by changing the initial launch angle.

Above us is an actual five-stage rocket assembly, complete except for propellant. The take-off weight is about 7200 pounds and the over-all length from first to fifth stage is 55 feet. The fifth stage is a test model similar to the one displayed here. The telemeter compartment is here between the rocket and the test nose. Heat transfer, pressure distribution, stability, material behavior, and cooling schemes are some of the subjects studied with this system.

I have a short motion picture that will illustrate the innate simplicity of this five-stage assembly, the way it is handled at our Wallops Island Station, the firing, and what a telemeter record looks like.

MOVIE

The first stage has been placed into position on the launcher. This motor is used by the Army's Honest John ballistic missile.

The fins are easily attached to the second stage by a small team of men. Second and third stages are joined before they are rolled to the launching area and attached to the first stage. These motors are the booster rockets for the Nike Ajax antiaircraft missile.

Now the fourth stage is added to the assembly on the launcher.

Instrumentation and the telemeter receive a careful check before the fifth stage is "buttoned up" and attached to the fourth stage. This particular fifth stage was used in a heat-transfer investigation.

In keeping with the inherent simplicity of the system all stages are aerodynamically stabilized. The first three stages utilize fixed fins. The fourth and fifth stages are stabilized by means of the conical afterbody which has proved effective in the hypersonic, high heating portions of the flight. We are ready for the countdown.

Signals from the telemeter in the fifth stage are received and recorded in this room. Some of the records look like this one. In this case, the upper black line indicates the longitudinal acceleration and the lower line indicates the temperature of the nose. Note the scales at the right-hand side of the picture. The film is shown progressing right to left at normal recording speed of one foot/second. Some film that was recorded during the long coast to altitude has been omitted here. Accelerations from the third, fourth, and fifth stages are indicated by upward surges in the top line. The nose temperature remains low until the fifth stage reaches hypersonic speeds. Then the temperature climbs rapidly indicating considerable aerodynamic heating.

The previous discussions were concerned with research methods applicable to the take-off and re-entry into the sensible atmosphere of the earth. The Langley Laboratory of NACA is also conducting research on vehicles and structures for use in space where the main problem is no longer aerodynamic heating. One of the problems will be to place large but lightweight structures into space and one way of approaching this problem is to design and develop structures that can be carried in a compactly folded package and then can be remotely erected after being placed in orbit.

This chart illustrates several types of inflatable space structures which are currently being investigated at Langley - a large solar energy collector, 30 or more feet in diameter, for use as a basic source of energy for internal power supply for satellites - a radar corner reflector for use either by itself as an artificial star for navigation, or in conjunction with any other satellite as aid in tracking the satellite - parabolic reflectors for use with long range radar or communications systems that will be carried on satellites of the future - spherical satellites for many passive scientific experiments such as measurement of air density or the measurement of reflection and scattering of radio and radar signals.

This work on inflatable space structures began with the NACA proposal of an IGY satellite experiment to measure satellite lifetime and the air density. The proposal, which was accepted as IGY ESP-29 was to place in orbit a lightweight inflatable aluminum foil and polyester film sphere 30-inches in diameter, to be tracked by visual and optical means in order to determine the lifetime of artificial satellites of the earth and deduce from this lifetime the atmospheric density at the satellite altitudes.

This chart illustrates this experiment as it is presently designed for placement aboard the Vanguard launching system, along with another satellite designed by the Naval Research Laboratory, to measure the earth's magnetic field. After reaching orbital speed this satellite represented here by this sphere is ejected from the third-stage rocket. This releases the trigger on a small bottle of nitrogen gas which then inflates the 30-inch diameter subsatellite shown here. After inflation, the nitrogen gas is allowed to escape from the subsatellite since aluminum foil gives the sphere sufficient rigidity so that it remains spherical without internal pressure.

The total subsatellite experiment weighs only 2/3 pound including the plastic container, and the inflated sphere shown here weighs about 1/3 pound. The very lightweight of the subsatellite in comparison to its size makes it possible to determine experimentally satellite lifetime in 1/100 of the time that would be necessary with satellites having more conventional weight in proportion to their size.

The limited weight and space available for this experiment dictated the small size of the subsatellite which of course would make it appear as a very dim object barely visible to the naked eye at twilight. A much larger inflatable satellite, 12-feet in diameter, also constructed of aluminum foil and polyester film, has been developed. This large satellite when in orbit at 300 to 1000 miles would be readily visible to the naked eye at twilight. The satellite sphere which you see inflated here weighs only 9 to 10 pounds, and the total experiment including inflation bottle, ejection mechanism and satellite weighs about 14 pounds and fits into a package 7 inches in diameter and 24 inches long.

The following movie will show inflation tests of the 12-foot diameter satellite systems in a vacuum and inflation of a 12-foot diameter radar reflector at normal atmospheric pressure.

MOVIE

Inflation tests of a complete system, designed to eject and inflate the 12-foot diameter sphere from a spin stabilized launching vehicle such as the Explorer, were conducted in a 41-foot diameter vacuum chamber. The sphere was ejected from a cylinder spinning at 650 rpm. The movies being shown are at normal speed and indicated that the total time of ejection and inflation requires about 30 seconds. During inflation of the sphere the rpm decreases rapidly due to the conservation of angular momentum of the system. After about two minutes when the pressure in the system drops below a small predetermined value, the fully inflated satellite is automatically separated from the launching vehicle.

Erection tests of a 12-foot diameter corner reflector-type satellite were conducted at normal atmospheric pressure. The object of this test was to check the ability of this large radar reflector to be erected from the compactly folded package. In these tests the time involved was much longer than would be necessary under actual conditions since the amount of nitrogen gas required to inflate the structure against sea level air pressure is much larger than that needed to inflate the structure in the near vacuum of outer space. These films are being projected at about three times normal speed as can be noted when the man appears in the picture. Tests such as this indicate the feasibility of particular systems of folding and packaging of the basic structure.

This concludes the presentation at the Langley stop.

NACA
4000-9A

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY, MOFFETT FIELD, CALIF.

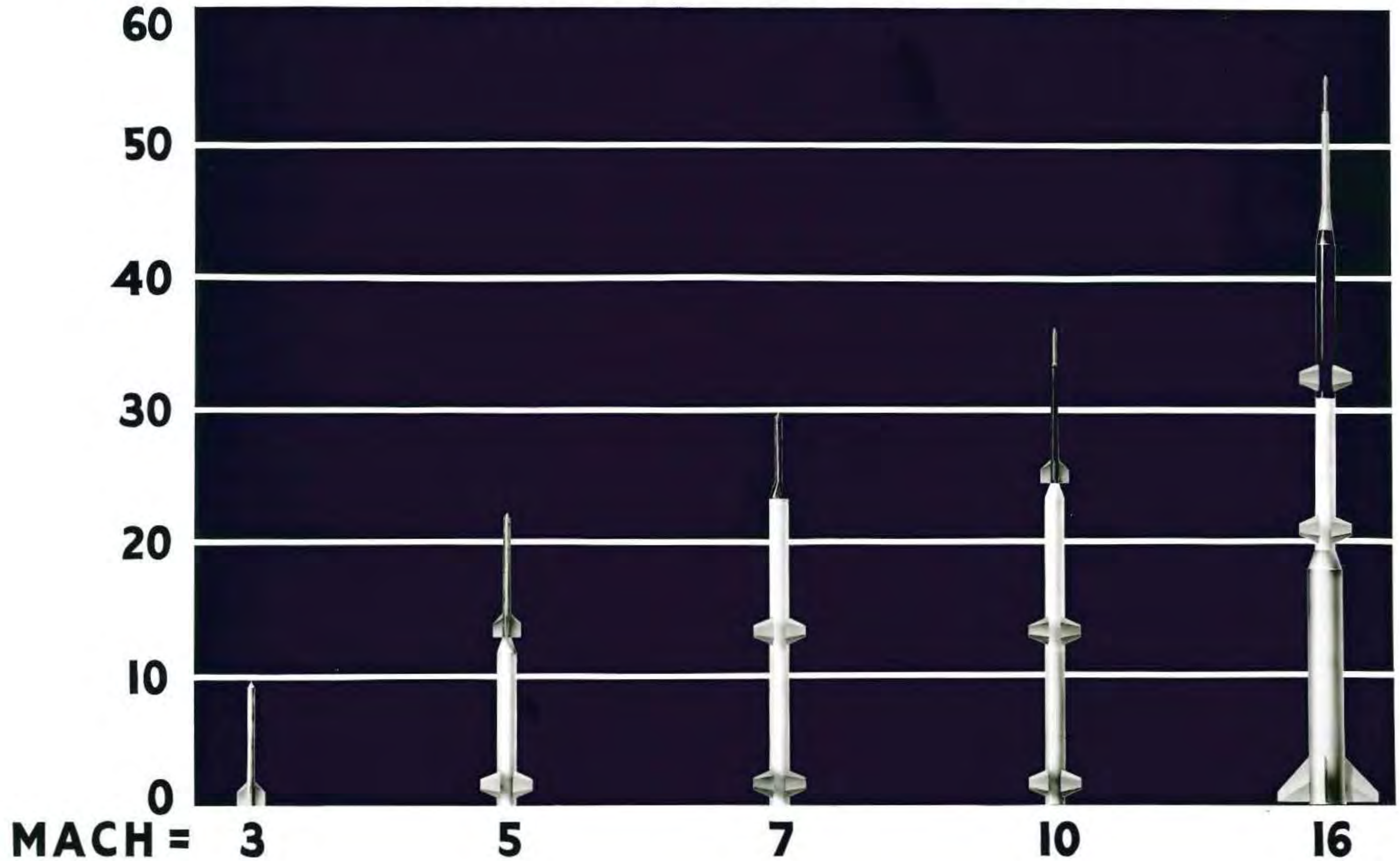
NACA
4000-9B

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
AMES AERONAUTICAL LABORATORY, MOFFETT FIELD, CALIF.

A-.000-9C

NACA MULTI-STAGE ROCKETS USED FOR HIGH-SPEED AERODYNAMIC RESEARCH

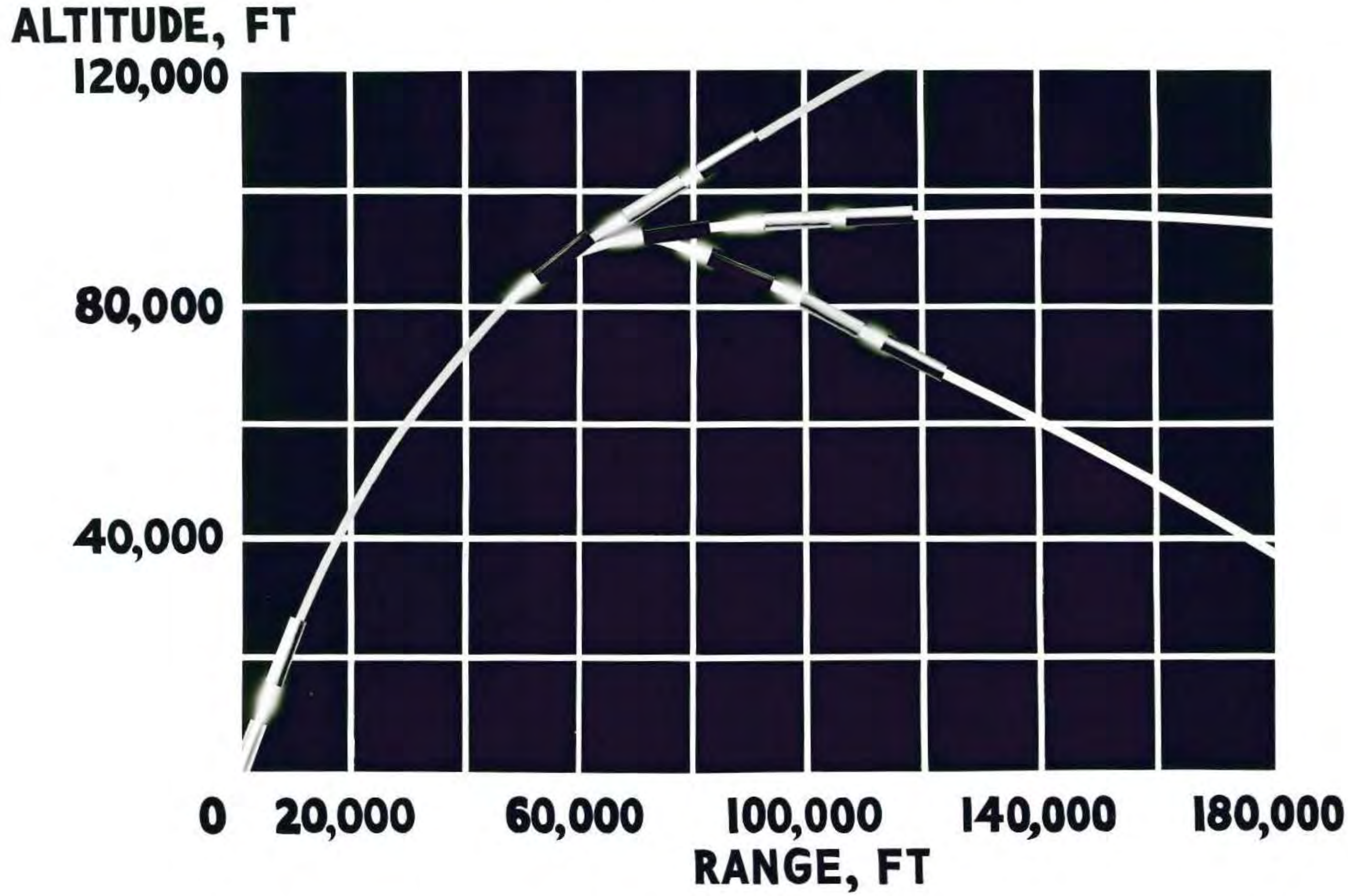
INSTRUMENT WEIGHT ≈ 30 LBS



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

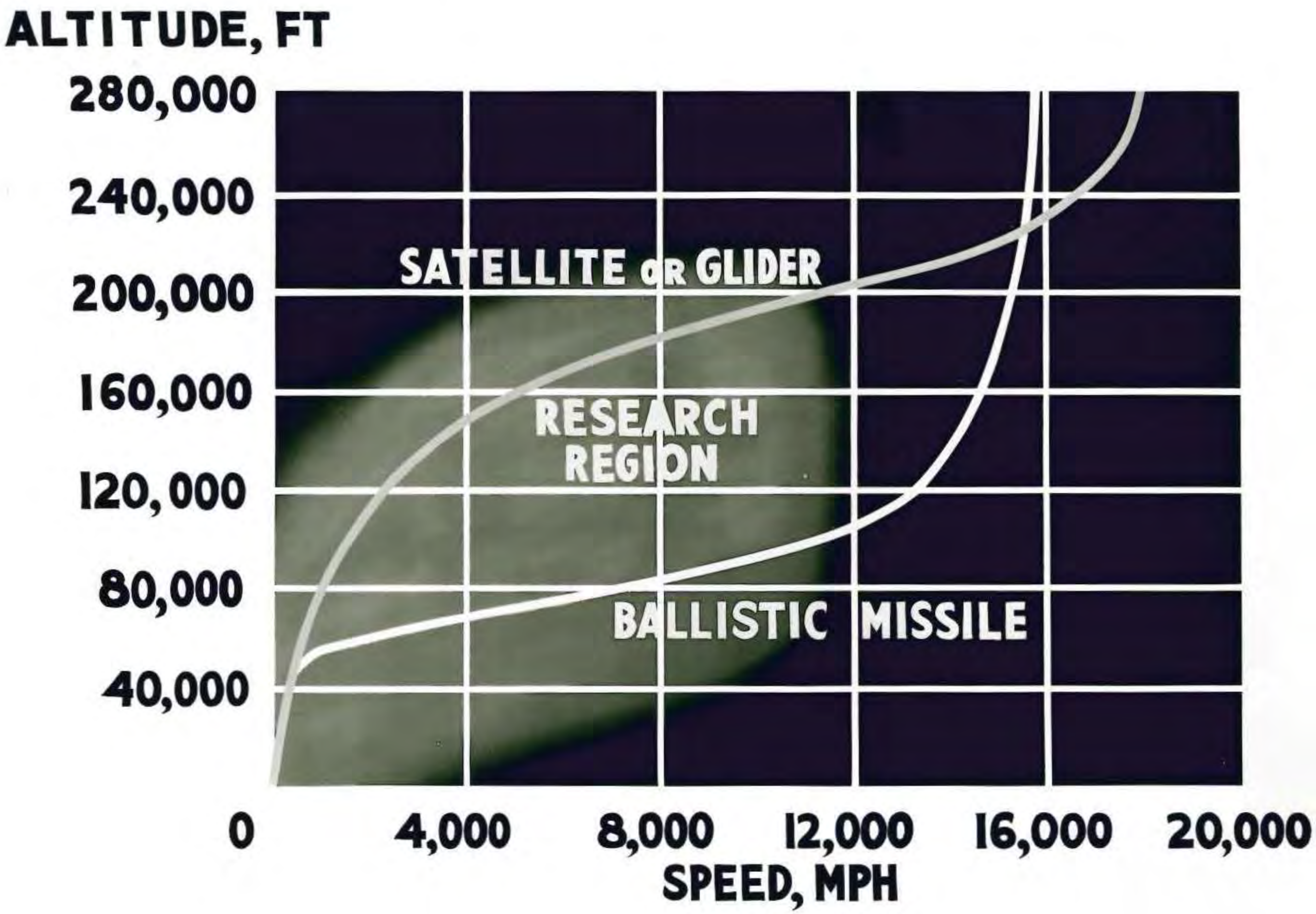
A 000-9D

FIVE-STAGE RESEARCH ROCKET TRAJECTORY VARIATIONS



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

MULTI-STAGE RESEARCH ROCKETS DUPLICATE REENTRY



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA