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N R L REPORT NO: R-3139

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DP 25

UPPER ATMOSPHERE RESEARCH
REPORT NO. III
PART II

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UPPER ATMOSPHERE RESEARCH REPORT NO. III PART II

Compiled and Edited

by

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April 1947

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FOREWORD

The material contained in this Upper Atmosphere Research Report originally formed part of a report to the Joint Research and Development Board concerning the Naval Research Laboratory's program in this field. It provides a comprehensive review of the work, from its inception to the present time, and includes proposals for both the immediate and the long range programs in Rocket-Sonde Research. Much of the subject matter presented here has appeared in the Upper Atmosphere Research Reports I and II, and the more recent information will be given in greater detail in future reports of this series. The present survey is published since it makes available in convenient form the essential features of the entire program.

CONTENTS

ABSTRACT

The proposed program of rocket-sonde research in the upper atmosphere is described. The rocket development programs are discussed and a detailed description is given of the Neptune, the Naval Research Laboratory's new high altitude research rocket. A review of the ionization experiments conducted with the V-2 is presented, and proposals for future research in this field are outlined.

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CHAPTER I

THE PROPOSED PROGRAM OF ROCKET-SONDE RESEARCH*

by

E. H. Krause

Proposed Immediate Program

The Naval Research Laboratory's presently scheduled program is based on an availability of four V-2's per year, and a total of five Aerobee and ten Neptune rockets. The past and proposed firing schedule is as follows:

Fiscal Year	V-2	Aerobee	Neptune
1946	1		
1947	6½		
1948	4	3	
1949	4	2	3 (See below)
1950	2-4 (See below)		3
1951			4

The three Neptune rockets scheduled under fiscal year 1949 will involve an unknown amount of instrumentation since these first rockets may all be required for flight check-out purposes. The first Neptune is definitely scheduled for only such instrumentation as is required to get rocket performance data. The number of V-2's available for 1950 will of course depend on the total available supply.

Proposed Long Range Program

The accomplishments to date clearly indicate that some of the initial objectives of this program have been met. But it is also clear that much remains to be done. On the basis of the work already done, the Naval Research Laboratory feels that the point of diminishing returns in this work will not be met for at least another five years, and that during this period the outlook of the program should broaden rather than contract. Because of the Naval Research Laboratory's long record of research in the upper atmosphere over the past two decades; because of its more specific experience in a well rounded, very active and very productive program of Rocket-Sonde Research during the past year; because

*The material contained in this chapter is classified Restricted.

of its sponsorship of the first truly high-altitude American-built rocket, the Neptune; because of its very successful development of two of the most important tools in this work, telemetering and remote control; and finally because of its determined faith in the long range contribution of this program to National Defense, the Naval Research Laboratory desires to continue its efforts in this field, and at this time feels that it will desire to participate in a program beyond the expenditure of presently available rockets. Such a future program obviously requires a broader base of financial support than the Naval Research Laboratory alone can provide, and must essentially be national in scope.

For such a national program, the Naval Research Laboratory presently believes that an additional quantity of Neptune rockets should be procured to be available during the fiscal year 1951 so that a continuing program can be maintained. However, since no real need for these additional rockets will develop until fiscal 1951, it is recommended that the letting of a contract for more Neptunes be held up pending the first Neptune trials in the summer or fall of 1948. This will still provide sufficient time for procurement to avoid gaps in the program. It is estimated that delivery can be made in eighteen months from date of contract.

The present price of Neptune rockets according to the Glenn L. Martin Company is roughly $85,000 each in quantities of 25, and $78,000 each in quantities of 50. The procurement of 25 more of these rockets including the necessary expendable radio control and telemetering equipment would require about $2,300,000. The Naval Research Laboratory at this time feels that plans for its program after 1951 should be based on the availability of six Neptune rockets per year for a minimum of three years. However, here again it is felt that the matter should be deferred for more serious consideration to the summer of 1948 by which time another year's work will have given a clearer picture of the program and the experience gained by firing several Neptune rockets can be applied to the new order.

In Conclusion

The estimates, schedules, and proposals contained herein are all based on the vast experience in this field which the Naval Research Laboratory has obtained during the past year. The proposal involves a continuation of the Naval Research Laboratory's efforts in this field at approximately the present rate. This program definitely does not involve any expansion of the present activities nor is it a paper program based on large extrapolations or guesses. It is the continuation of a research program which is now well established, the administrative features of which are well known and the technical aspects of which are based on extensive technical data obtained to date.

CHAPTER II

UPPER ATMOSPHERE RESEARCH VEHICLES*

A. The Rocket Development Programs

by

E. H. Krause

The Aerobee (XASR) Program

When, in the Spring of 1946, it appeared that only 25 V-2's would be available for upper atmosphere research, the Applied Physics Laboratory and the Naval Research Laboratory collaborated in the procurement of the Aerobee rocket from the Aerojet Corporation. This rocket was to be in part a "stop gap" affair for use until better rockets were available, as well as a small payload (150 pounds) rocket for research which could be satisfactorily performed below 120 Km. Twenty of these booster launched rockets were ordered, of which NRL contracted for five. Complete details about the Aerobee have been published by the Applied Physics Laboratory.

The Neptune (HASR) Program

The availability of V-2's for high altitude research allowed time for the development of a high performance American made rocket for use later on in the research program. Realizing that the development of such a rocket would require at least two years, the Naval Research Laboratory in the spring of 1946 began a study leading to the design of a new high altitude sounding rocket to be built in this country. On the basis of this study it was decided to develop a new rocket for high altitude research rather than to procure American made copies of the V-2. This decision was based on the following factors:

(a) The V-2 was designed as a long range high accuracy weapon rather than as a high altitude rocket.

(b) The form factor of the V-2 limits it to the performance for which it was designed, and makes any changes from this very difficult. Thus, because of stability problems which arise, it is very difficult to exceed an altitude of 180 Km in the V-2 by decreasing the 2,000 pound payload.

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*The material contained in this chapter is classified Restricted.

(c) Stabilization in the V-2 is obtained by means of very special carbon vanes which are already being pushed to their lifetime limit for the 65 seconds burning time of the V-2. The development of higher altitude rockets will involve longer burning times and hence, the elimination of vanes would be desirable. The Neptune rocket will utilize jet stabilization. It is felt that the development of these techniques is very important to the upper atmosphere program since it will be basic to the attainment of high altitudes.

(d) The total flight time of the V-2 is also limited by the conditions mentioned in (c) above. Thus, although for many experiments, altitudes higher than 150 Km are not necessary, it is important to remain above certain altitudes as long as possible. This is especially true for solar spectroscopy and cosmic ray experiments. The V-2 in a good flight (180 Km) will spend 325 seconds above 50 Km whereas the Neptune will, under 100 pound payload conditions, in a good flight (380 Km) spend 540 seconds above 60 Km. This almost doubling of the available time will in some cases mean the difference between data and no data.

(e) The Neptune is a convenient size rocket to fire from a ship. This is an important consideration in the upper atmosphere program in that work at lower latitudes is very desirable in the ionosphere, cosmic ray, atmospheric physics, and other programs.

(f) The development of a rocket such as Neptune allows the limited engineering staffs available in this country to gain experience in modern rocket techniques. This experience is essential not only to rocket development in general but also to the development of higher altitude rockets for research purposes, whereas the reproduction of V-2's would consume a tremendous amount of engineering on an antiquated design.

(g) The sad experiences and innumerable difficulties met with over a period of several years in the American built copies of the relatively simple German V-1's serve to bring into relief the tremendous difficulties which would be involved in making American copies of the vastly more complex V-2. On the basis of these experiences such American made V-2's must be considered as completely new and untried devices.

The initial study also led to a preliminary design and a set of specifications for a high altitude sounding rocket. These specifications were submitted to different manufacturers and resulted in various proposals. Among these proposals were several by Douglas Aircraft, one of which was for an improved Corporal E as a high altitude rocket. The use of the

Corporal E would, of course, have been desirable because the prototype was already under construction. The performance data showed that a 500 pound payload could be carried to a maximum altitude of 125 Km (78 miles) while a 100 pound payload could be carried to a maximum altitude of 150 Km (93 miles). It was felt that this was an insufficient payload-altitude increase over the Aerobee, which was already underway, to warrant manufacture.

A contract was let with the Glenn L. Martin Company in the summer of 1946 for the construction of ten HASR-2 (later called Neptune) rockets. The development and construction of a 20,000 pound thrust, liquid oxygen, alcohol motor was individually contracted for with Reaction Motors, Inc., through the Bureau of Aeronautics. The total cost of these 10 rockets including a launching platform, assembly, fueling, and engineering assistance in launching was $1,850,000.

The Neptune is a vertically launched, jet stabilized rocket which carried a somewhat lower payload than the V-2 (on an equal altitude basis) but is much more flexible in its payload-altitude variation. Calculations show that it should carry a 100 pound payload to an altitude of 380 Km (235 miles). Similarly it should carry a 2,000 pound payload to 135 Km (84 miles). Complete details on the Neptune rocket, including payload-altitude curves, are given in the next section.

CHAPTER II

UPPER ATMOSPHERE RESEARCH VEHICLES*

B. The Neptune(HASR-2), the Naval Research Laboratory's New High Altitude Research Rocket

by

C. H. Smith, Jr., M. W. Rosen,
and J. M. Bridger

Introduction

The Neptune is a high altitude sounding rocket destined to carry research instruments further into space than ever before attempted. The Neptune will be about the same length as the German V-2, but only about one-third the weight, and can easily be distinguished from the V-2 by its slender appearance. Its nosepiece will carry from 100 to 2000 pounds of various measuring instruments to altitudes of about 500,000 to over 1,000,000 feet. The Neptune will be launched from a vertical position and be automatically stabilized by mounting the thrust unit in gimbals which permit movement of the venturi relative to the main rocket structure. This design permits operation at longer burning times as jet vanes are not required.

A number of V-2 rockets brought to this country at the close of World War II are being fired currently at White Sands Proving Ground in New Mexico. In order to utilize these expensive vehicles most efficiently, the Naval Research Laboratory formulated a program of high altitude research. It was realized that such a program, if carried out to its logical conclusion, would require additional rocket vehicles over and above the limited number available from the V-2 program. Also, since the V-2 is now obsolescent it was realized that rockets of improved design and performance would be required. The Neptune was designed to fill this need and to permit continuation of this program which enters many fields of basic science. Some idea of the scope of these researches may be obtained from the chart of Fig. 1.

General Description

The Glenn L. Martin Company of Middle River, Maryland, under contract with the Naval Research Laboratory, is now constructing the Neptune. An artist's sketch of the rocket is shown in Fig. 2. A detailed drawing of the Neptune is given in Fig. 3. Design values

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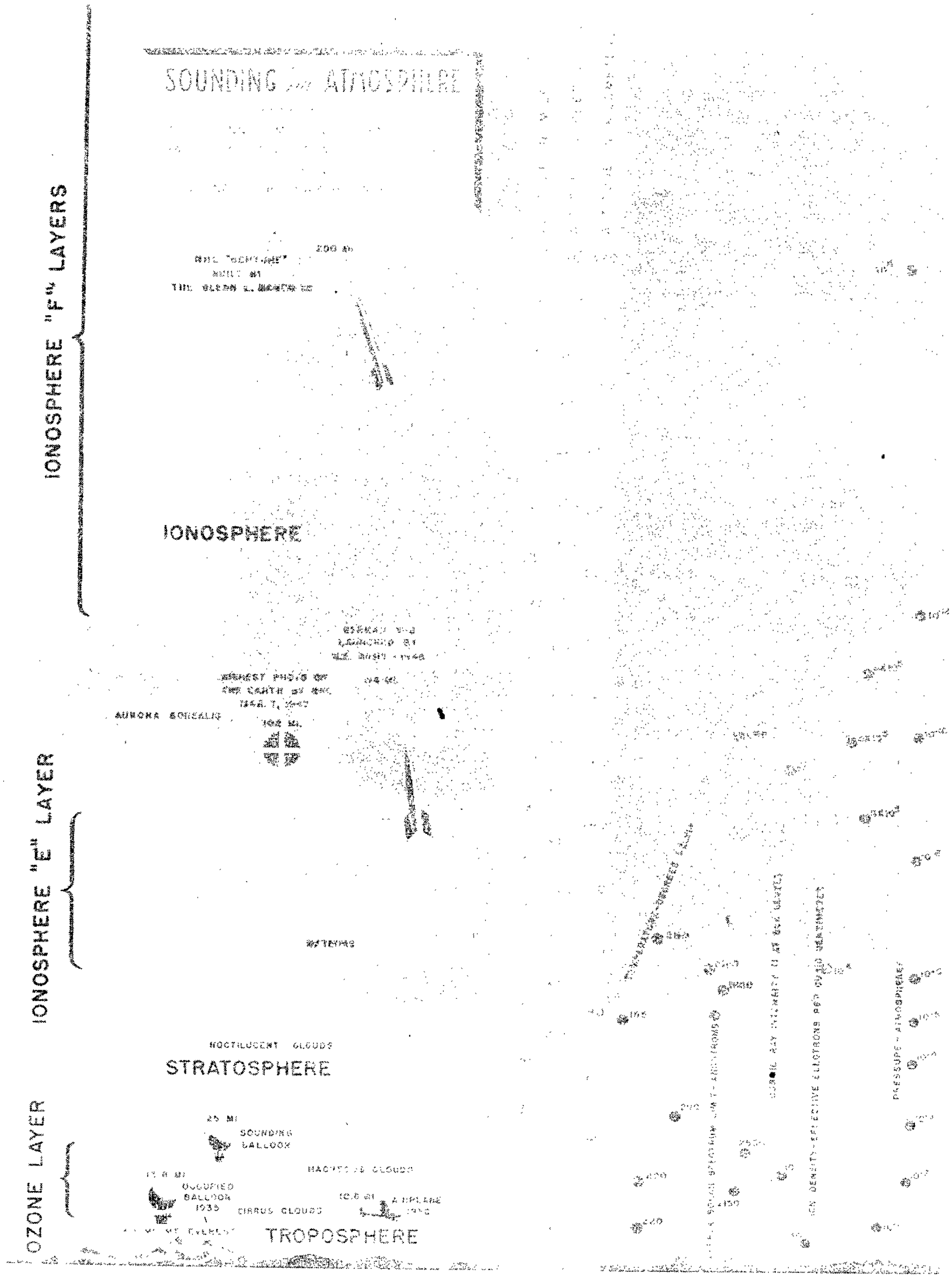
IONOSPHERE "F" LAYERS
IONOSPHERE
IONOSPHERE "E" LAYER
AURORA BOREALIS
METEORS
NOCTILUCENT CLOUDS
STRATOSPHERE
OZONE LAYER
SOUNDING BALLOON
CIRRUS CLOUDS
TROPOSPHERE

Figure 1

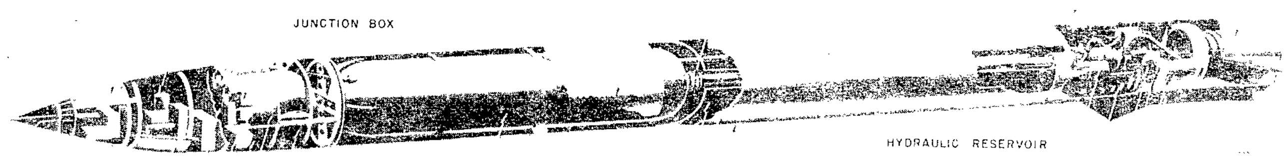

Figure 3. The Neptune

and performance given here must be considered as preliminary until the rocket is proven by flight tests. Completion of the first vehicle is scheduled for February 1948.

In the design of a rocket for high altitude soundings, it must be remembered that it is not to be used as a weapon, but as a research vehicle whose function is to serve as a platform from which measurements may be made. Such a vehicle should be constructed as simply and efficiently as possible, have a reasonably low acceleration and vibration, low overall weight, and high specific impulse (Specific Impulse as used herein refers to the ratio of thrust delivered in pounds to the weight rate of fuel combustion in pounds per second). A listing of the more important characteristics of the Neptune is given in Table I.

Propulsion System

A comparison of the various types of propulsion systems which could be used, in the light of the requirements enumerated above, led to the choice of a single cylinder, liquid-oxygen-alcohol rocket power plant with a turbo-pump propellant injection system for the Neptune. Calculations have indicated that, to meet the payload and maximum altitude requirements which have been imposed, it will be necessary for the rocket engine to deliver a thrust of 20,000 lbs. for a period of 75 seconds. That is approximately equivalent to saying that the specific impulse of the engine must be equal to 210 seconds, assuming propellant flow and burning rate to be constant for the entire burning time. Engineers of Reaction Motors, Inc., Dover, New Jersey, who were chosen to develop the propulsion equipment for the Neptune, have indicated that a system meeting the above requirements can be built.

It has been estimated that the power plant for the above system (less piping) will weigh 250 pounds, will have an overall length of about 44 inches and a nozzle exit outer diameter of approximately 19 1/2 inches. With a nozzle expansion area ratio of 4.3, a mean mixture ratio (alcohol/liquid oxygen, by weight) of 0.90 at sea level and average consumption of alcohol and liquid oxygen of 45.1 pounds/sec. and 50.1 pounds/sec. respectively, it should be possible to attain the desired specific impulse. The 4.3 nozzle expansion area ratio was selected after a comparison of disadvantages of larger ratios, such as: flickering of the jet, increased nozzle cooling problems and overall nozzle exit size, with the relatively small loss in altitude performance (approximately 1%) associated with less than optimum expansion at higher altitudes. A 4.3 ratio corresponds to an average back pressure of 0.8 atmospheres, as compared to a figure of 0.86 around which the V-2 motor is designed.

It was planned originally to use an alcohol-water mixture as fuel. As a result of tests performed by engineers engaged in the motor development, it has been decided tentatively to use straight alcohol. This change will be accompanied by a 15% change in optimum weight mixture ratio, and resultant decrease in overall weight, and increased specific impulse. Linde commercial liquid oxygen, or the equivalent, will be used.

A turbo-pump propellant injection system was chosen in preference to a pressure feed system despite its higher cost. A large saving in overall weight and the better performance of the system predicted for the turbo-pump were felt to outweigh the cost difference. Both alcohol and liquid oxygen pumps will be driven at about 10,000 RPM by the turbine rotor on an integral shaft. The turbo-pump uses the decomposition products of high concentration hydrogen peroxide to drive the turbine. The hydrogen peroxide, which is stable at high concentration, will be held in a tank shaped as a helical coil spiraling about the turbine chamber. A pressure of between 415 and 465 pounds per square inch absolute, derived from the gas pressurizing system to be discussed, will force the hydrogen peroxide into a gas generator where its decomposition is initiated upon contact with a special chemical agent (a compound of manganese). The resulting steam will drive the turbine. The product of this decomposition is also used to correct rocket roll as described later in the discussion of the overall problem of stabilization and control.

Adequate flow of all fluids, alcohol, oxygen and hydrogen peroxide, is assured by means of a pressurizing system using helium gas at pressures in excess of 3500 pounds per square inch. Through control valves and regulators suitable pressures or ranges of pressure are maintained on all tanks: alcohol range, 30 to 26 pounds per square inch absolute; oxygen range, 33 to 9 psia; and a hydrogen peroxide range of plus or minus 5 psia about a fixed value between 415 and 465 psia (to be determined). The pressurizing of all fluids was necessitated by the dangers of cavitation resulting from such rapid rates of consumption, and the requirement that fairly constant pump inlet pressures be maintained. Helium gas was chosen because of its low density and low affinity for any of the fluids being pressurized. (Sufficient helium for all requirements will weigh in the vicinity of 8 pounds.) By relocation of the oxygen tank forward, it has been possible to increase considerably the pressure head at the oxygen pump, thus reducing the problem of cavitation with the boiling oxygen. This relocation also shifts the center of gravity forward somewhat.

The rocket engine will be started by an electrical signal to a standard electric squib type igniter. Provision is made for this signal to be initiated externally, entering the rocket through a pullaway plug. Termination of the engine's operation will result from activation of either the turbine overspeed switch or the emergency cutoff relay which will receive its signal from the ground by means of radio, or internally from a timer, if desired.

Aerodynamic Considerations

One of the first decisions which had to be made was the selection of the general shape and contour of the rocket's body. On the basis of preliminary structural and fabrication studies, a design based on a simple ogival nose and a straight cylindrical body was chosen. Studies also indicated that no severe structural difficulties would arise from large length to diameter ratios, for example, 15:1 to 18:1. (Supersonic wind tunnel tests have indicated that for a given volume the drag variation with L/d ratio is very flat from 11:1 to 18:1). Fin weight penalties for required stability have indicated no real optimum. A diameter of 32 inches was chosen for the rocket on the basis of engine diameter, volumetric efficiency of components and on ease of construction from maximum width sheets of suitable aluminum alloys. With that diameter, the required volume can be housed in a vehicle 543 inches long, giving an L/d ratio of approximately 17 to 1. A conical nose of 25° included angle, ogive-faired into the main body, was chosen on the basis of drag considerations and other requirements based on the uses planned for the rocket.

The overall size and shape of the body having been selected, it was then necessary to determine the stability of the body used and to amplify that stability as required by the addition of exterior surfaces. The first problem was one of determining what stability was required.

The stability of a rocket such as this is a most difficult factor to determine. The rocket must be designed to fly at altitudes in which the density varies from atmospheric to practically zero and through all speed ranges from subsonic and transonic to supersonic. A realization of the importance of the stability problem led to the initiation of a comprehensive static and dynamic stability investigation using both mathematical and experimental wind tunnel methods.

Basically, two types of tumbling may be exhibited by missiles of this type. End-over-end tumbling, the simpler of the two, can be predicted fairly easily and is fairly well known. The rocket may exhibit this type of behavior early in its flight before appreciable speed is attained and again as the influence of the atmosphere is lost. The second kind of tumbling consists of motion in all three planes in which the rocket rotates about both its center of gravity and its longitudinal axis. The missile's nose describes a spiral about the flight path in this type of tumbling. The second type of tumbling presents a much more difficult stabilization problem, since large oscillations accompany the motion in all three planes.

Preliminary analysis of wind tunnel tests of models of the Neptune has indicated that the configuration described below will be stable to the extent required through the speed range expected, and that the proposed elevators have approximately the aerodynamic power required of them. Design of the first vehicle is proceeding based upon an L/d ratio of 16.85 to 1, and a tail structure composed of four fins having a total tail area per plane of 30 square feet, an aspect ratio of 1, a sweep angle of 60° and a tip chord of 3° (Aspect ratio as used herein refers to the square of the external fin span divided by the total fin area in a given plane). Aerodynamic trim tabs are planned for each fin. Tabs in the fins in one plane will be ground adjusted prior to flight to correct for minor misalignments in structure, tabs in the other plane will be coupled to the thrust deflection servo system in addition to being ground trimmed. The airfoil section for the fins was chosen as a double wedge plus flat sections having all plane surfaces. This selection meets aerodynamic requirements and will simplify manufacture. A 4% thickness ratio was selected.

A preliminary investigation of dynamic stability of the rocket, in which only its longitudinal oscillation about its center of gravity, c.g., restrained against lateral movement, has indicated the necessity for some form of automatic control to provide for the damping of oscillations, except for narrow altitude ranges.

Stabilization and Control

The preliminary design of the control system considers such items as: (1) accuracy of control, (2) reliability of control, (3) interaction of control axes, (4) gyro gimbal lock, and (5) the possibility of inadequate roll control. The stabilization and control system has been designed to provide for the correction of both steady state and transient errors about both pitch and yaw axes, and roll in either direction about the longitudinal axis. It is planned to launch the rocket vertically and introduce early in flight a tilt program of from 3° to 10° to the North. This will define the pitch axis as being horizontally East and West through the center of gravity, and the yaw axis as being horizontally North and South.

Past experience in rocket development has indicated that, to insure adequate control, provision must be made to alter the direction of thrust in addition to the production of moments by the aerodynamic surfaces. The direction of thrust may be altered either by the reorientation of the combustion cylinder or by the introduction of deflection surfaces into the jet stream. The Germans preferred the second method and utilized it on the V-2 rocket. Numerous design problems are encountered in the use of either system. Although the first method imposes more stringent demands on the control system, it has been chosen, tentatively, due to the improvement in performance anticipated from its use. Elimination of the loss of thrust due to the presence of the vanes in the jet is achieved, as well as an overall weight saving of approximately 275 pounds.

Since stabilization and control for this rocket is limited practically to vertical flight, its design should not be so difficult as radio command steering. Pitch and yaw gyro signal systems, whose function is to measure at every instant the deviation of the longitudinal axis of the rocket from the true vertical, are provided. These feed an appropriate signal, proportional in magnitude to the error deviation, to a correcting mechanism. Pitch and yaw systems may be practically identical. Each will consist of a sensing element: gyro, signal pickoff, lead circuit, amplifier and hydraulic servomotor. Through the use of double axis gyros having pickoffs and torquers on each axis, two units can be made to perform all position sensing required for pitch, yaw and roll control. If a control voltage proportional to the error were fed to the correcting mechanism, steering action would be delayed because of lag and inertia in various links of the system. Consequently, the phase of the correcting action must lead that of the error signal to accomplish stabilized operation of the system. A lead circuit is included to assure the correct phase relationship. The hydraulic servomotors are to be driven by a hydraulic motor pump combination using alcohol from the high pressure side of the main fuel pump. The exhausted alcohol is returned to the main fuel tank. It is not necessary that the pitch and yaw control systems be operated beyond fuel burnout, since by that time the rocket will have reached regions where aerodynamic trim tabs are ineffective and since reorientation of a dead motor is useless.

Certain research experiments planned for the Neptune are rendered more simple and effective if means are provided for roll correction. While roll correction is a problem with jet vanes, it is even more a problem when control is effected by altering the thrust line of the engine. Aerodynamic trim tabs are practically useless for this purpose on a missile which passes outside the influence of the atmosphere. The problem, of course, is not the sensing of the roll, but in bringing to bear a suitable counter moment about the longitudinal axis to correct the roll. Since considerable energy remains in the exhaust of the hydrogen peroxide turbine, it was decided to release this exhaust from roll jets at a distance from the longitudinal axis and in a direction so as to provide the necessary moment. Jets are so designed to release equal quantities of steam from each jet in opposite directions so as to produce no moment normally. The error correction signal from the roll control system operates valves in each jet which increases the steam exhaust on the side opposing the roll. Since it is possible that roll of the rocket may be induced after burnout by the deceleration of the turbine rotor (coaxial with longitudinal axis of rocket) or from other causes, it was decided to extend roll control beyond cutoff for 17 seconds. This is accomplished by inserting a changeover valve between the gas generator and the turbine which switches the gasses directly to the roll jets at fuel burnout. This requires that the hydrogen peroxide supply be increased by 30 pounds. The exact locations of the roll jets have not been finally determined.

Structure and Weight Distribution

The space contained in the forward 77 inches of the Neptune has been reserved for research instrumentation. The nose is a true cone of 25° included angle for the first 44 inches at which point it has a diameter of 19 1/2 inches. From this point the ogive begins and the rocket reaches its maximum diameter of 32 inches at the midpoint of the control compartment, 100 inches from the nose. The body of the rocket aft of the 100 inch station is cylindrical. The diameter at the base of the nose section, Station 77", is 30 inches, and is sealed by a magnesium casting. Access to the volume inside the nose is provided at two points by access doors and provision is made for pressurizing this whole section. Previous design has called for a skin of heat resistant steel, but this is being reconsidered in the light of recent temperature data obtained from V-2 experiments, possibly resulting in the substitution of aluminum.

The space between the stations 77" and 120" is reserved for the instruments necessary to flight control: gyros, batteries, cutoff receivers, control electronics, etc. The helium sphere will also be located in this volume.

Between stations 120" and 437" lie the fuel tanks. The forward tank will contain the liquid oxygen. Directly aft of the oxygen tank lies the alcohol tank. An interesting feature of the alcohol tank is the fact that it is an integral part of the rocket structure; that is, its surface forms the skin of the missile. Passing through its center is a tube through which passes the liquid oxygen feed line. Provision is also made for research and control cabling to pass through the alcohol tank.

All space aft of station 437" is occupied by the turbine, peroxide tank, combustion cylinder, hydraulic and valving equipment required for the missile's operation. Provisions are being made for ready access to the motor compartment through removable skin segments. The thrust force of the rocket engine is carried through a steel gimbal ring to aluminum fittings between the forward and center fin spar frames. These fittings effectively distribute both axial and normal components of thrust into the skin structure.

The calculated weight distribution throughout the rocket is given in Table II.

Little can be said of what research instruments or signal transmission or recording equipment will eventually be installed into late models of this rocket. Antenna structure, internal cabling, exact final weight and other factors will depend upon the installation planned. About all that can be said at this time is that this rocket is being built for a purpose and modifications necessary to fulfill that mission will be made, consistent with sound rocket engineering practice.

Performance Computations

Performance calculations made up to this time indicate that altitudes attained will exceed considerably those originally specified for the rocket. At best, preliminary calculations can give only approximations of the performance of this rocket, since many of its features have not been tried before. Data on drag at the velocities and pressures in the regions through which the Neptune will pass are very limited. Wind tunnel tests at Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, have established outside limits on drag at Mach number 1.72. Curves of drag coefficient versus Mach number were extrapolated from Mach number 1.72 on the basis of the general trend known from German Experiments on the V-2, and other data.

Performance data have been computed from the drag data mentioned above, and the latest design values of the rocket. The basic parameters for rocket performance in a vacuum are specific impulse (previously defined), the fuel weight ratio, and the initial velocity. For flight through a resistive medium the additional parameters of drag coefficient, maximum cross section or frontal area, dynamic pressure, and the initial weight must be considered. Remembering that the weight of a rocket is a function of time, an equation for the incremental velocity imparted during the nth interval of time Δt during burning may be written:

$$\Delta v \Bigg]_{n-1}^{n} = \frac{-\left(Ig \frac{dm}{dt} + D\right) \Delta t}{m_0 + \frac{dm}{dt} t_{n-1} + \frac{dm}{dt} \cdot \frac{\Delta t}{2}} - g \Delta t$$

and the incremental altitude during burning:

$$\Delta Z \Bigg]_{n-1}^{n} = \frac{-\left(Ig \frac{dm}{dt} + D\right) (\Delta t)^2}{2\left(m_0 + \frac{dm}{dt} t_{n-1}\right) + \frac{dm}{dt} \Delta t} - g \frac{(\Delta t)^2}{2} + v_{n-1} \Delta t$$

where I is specific impulse in seconds

g is acceleration of gravity (32.2 ft/sec^2 at sea level)
D is drag in lbs. equal $c_d qA$
c_d is drag coefficient
q is dynamic pressure in lbs./ft.^{2} equal $\frac{1}{2} \rho v^2$
ρ is density of medium in slugs/ft.^{3}
v is velocity in ft./sec.
A is cross section or frontal area in ft.^{2}
Δt is time increment in seconds
m_0 is initial mass of rocket in slugs
$\frac{dm}{dt}$ is mass rate of fuel combustion in slugs/sec. (taking $\frac{dm}{dt} \leqslant 0$) .
t_{n-1} is time at the end of interval (n-1)
v_{n-1} is velocity at the end of interval (n-1)

Δt was taken in 5 second intervals and the velocity and altitude obtained for vertical flight. After 75 seconds of burning, drag is no longer a factor and the height attained by coasting may be computed directly from:

$$z_{free\ flight} = \frac{(v_{final})^2}{2g}$$

To this altitude must, of course, be added the altitude reached at end of burning in order to obtain the peak altitude of the rocket trajectory.

Figures 4, 5, 6, and 7 give the calculated performance of the Neptune, during burning, with payloads of 100, 500, 1000 and 2000 pounds respectively under the following conditions:

1) Empty weight less payload at takeoff - 1992 lbs.
2) Fuel weight at takeoff - 7140 lbs.
3) Specific impulse at sea level - 210 seconds
4) Burning time - 75 secs.
5) Maximum cross section - 5.6 ft.^{2}
6) Launching assumed at sea level
7) Highest anticipated drag used on basis of wind tunnel data.

Table III is a comparison of the Neptune's performance with that of the German V-2.

For a payload of 500 lbs. a maximum altitude of approximately a million feet has been calculated for the Neptune. The variation of maximum altitude with increase in useful payload is shown in Figure 8. It should be pointed out that the Neptune is far less critical than the V-2 with regard to variation in total warhead weight as a function of rocket stability. While the V-2 is restricted to useful payload weights between approximately 1700-2600 lbs., the Neptune can tolerate a variation of 100 to 2000 lbs. This assumes that a warhead could be constructed for the V-2 weighing only 200 pounds.

Firing of the first Neptune is being planned for the summer of 1948. Following this, a series of flights will be made at about the rate of one missile each two month period.

TABLE I

NEPTUNE CHARACTERISTICS

Dimensions	
Length	543 in. (45 ft. 3 in.)
Diameter	32 in.
Span (across fins)	98 in.
Weight	
Total empty weight	1,992 lbs.
Fuels (alcohol, oxygen, H_2O_2 and H_e)	7,418 lbs.
Payload	100-2,000 lbs.
Total gross weight	9,510-11,410 lbs.
Performance (100 lbs. payload)	
Altitude (max)	1,255,000 ft.
Velocity (max)	8,200 ft/sec.
Time to max altitude	335 secs.
Thrust (max)	22,900 lbs.
Specific Impulse (max)	241 secs.
Duration of thrust	75 secs.
Fuel	
Alcohol	3,380 lbs.
Liquid Oxygen	3,760 lbs.
Hydrogen Peroxide	270 lbs.

TABLE II

WEIGHT DISTRIBUTION

Item	Weight (lbs.)		
Body Group		555	
Nose Cone and Instrument Compartment	61		
Control Compartment	33		
Oxygen Compartment	104		
Fuel Compartment	258		
Tail Section	99		
Fins		210	
Motor Mount		57	
Power Plant Group		871	
Motor (RMI 20,000C1)	250		
Alcohol Tank (included in body group)			
Oxygen Tank	95		
Peroxide Tank	50		
Main Pressurizing Tank	155		
Pump	140		
Gas Pressurizing Control System	40		
Piping, Valves, etc.	141		
Fixed Equipment		299	
Control System	241		
Electrical Equipment and Wiring	58		
TOTAL EMPTY WEIGHT			1,992
Useful Load			7,918
Payload	100-2,000		
Alcohol	3,380		
Oxygen	3,760		
Peroxide	270		
Helium	8		
TOTAL WEIGHT (GROSS)		9,510	11,410

TABLE III

COMPARISON OF NEPTUNE AND V-2 PERFORMANCE

	Neptune				V-2
	100 lbs. Payload	500 lbs. Payload	1000 lbs. Payload	2000 lbs. Payload	2200 lbs Payload
Max. Altitude (ft)	1,255,000	1,006,000	733,000	446,000	600,000
Altitude at Burnout (ft)	189,000	172,000	150,000	118,000	100,000
Burning Time (secs)	75	75	75	75	67
Max. Acceleration (g)	10.9	8.8	7.3	5.6	6
Max. Velocity (ft/sec)	8,200	7,260	6,070	4,570	5,200
Total Weight (lbs)	9,510	9,910	10,410	11,410	28,380
Fuel Weight (lbs)	7,140	7,140	7,140	7,140	19,613
Thrust (sea level) (lbs)	20,000	20,000	20,000	20,000	52,200
Useful Payload (lbs)	100	500	1,000	2,000	2,200

*Starred values have been observed at firings of the V-2 at the White Sands Proving Ground. Other values for the V-2 have been derived from the German literature on that rocket. It is of interest to note that the literature gives a maximum vertical altitude of 512,000 ft. for a 67 second burning period.

#Includes weight of V-2 warhead structure, approximately 1,000 lbs.; can be modified by redesign to about 200 lbs.

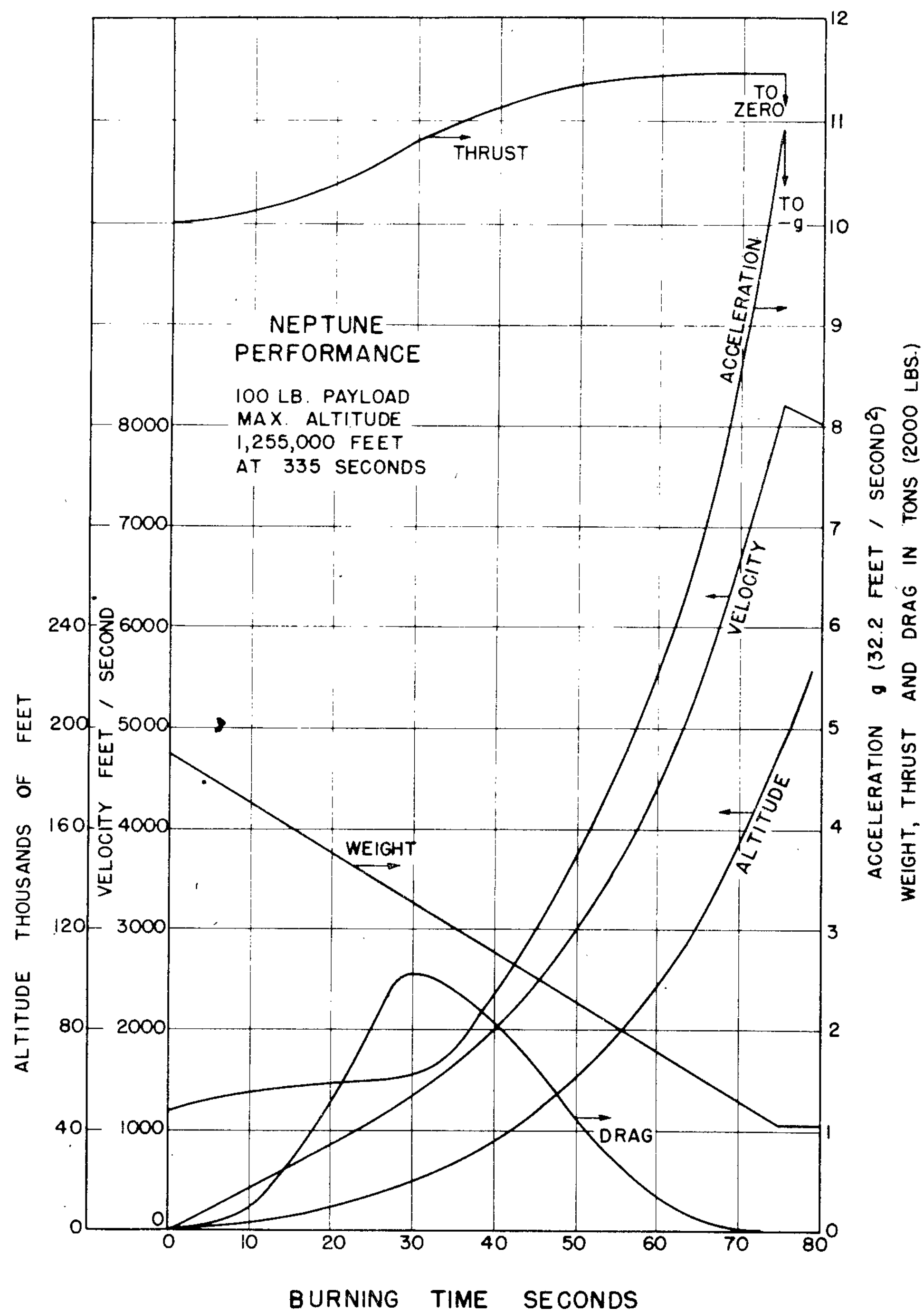
NEPTUNE
PERFORMANCE
100 LB. PAYLOAD
MAX. ALTITUDE
1,255,000 FEET
AT 335 SECONDS
THRUST
TO ZERO
TO -g
ACCELERATION
VELOCITY
ALTITUDE
WEIGHT
DRAG
ALTITUDE THOUSANDS OF FEET
VELOCITY FEET / SECOND
ACCELERATION g (32.2 FEET / SECOND²)
WEIGHT, THRUST AND DRAG IN TONS (2000 LBS.)
BURNING TIME SECONDS

Figure 4

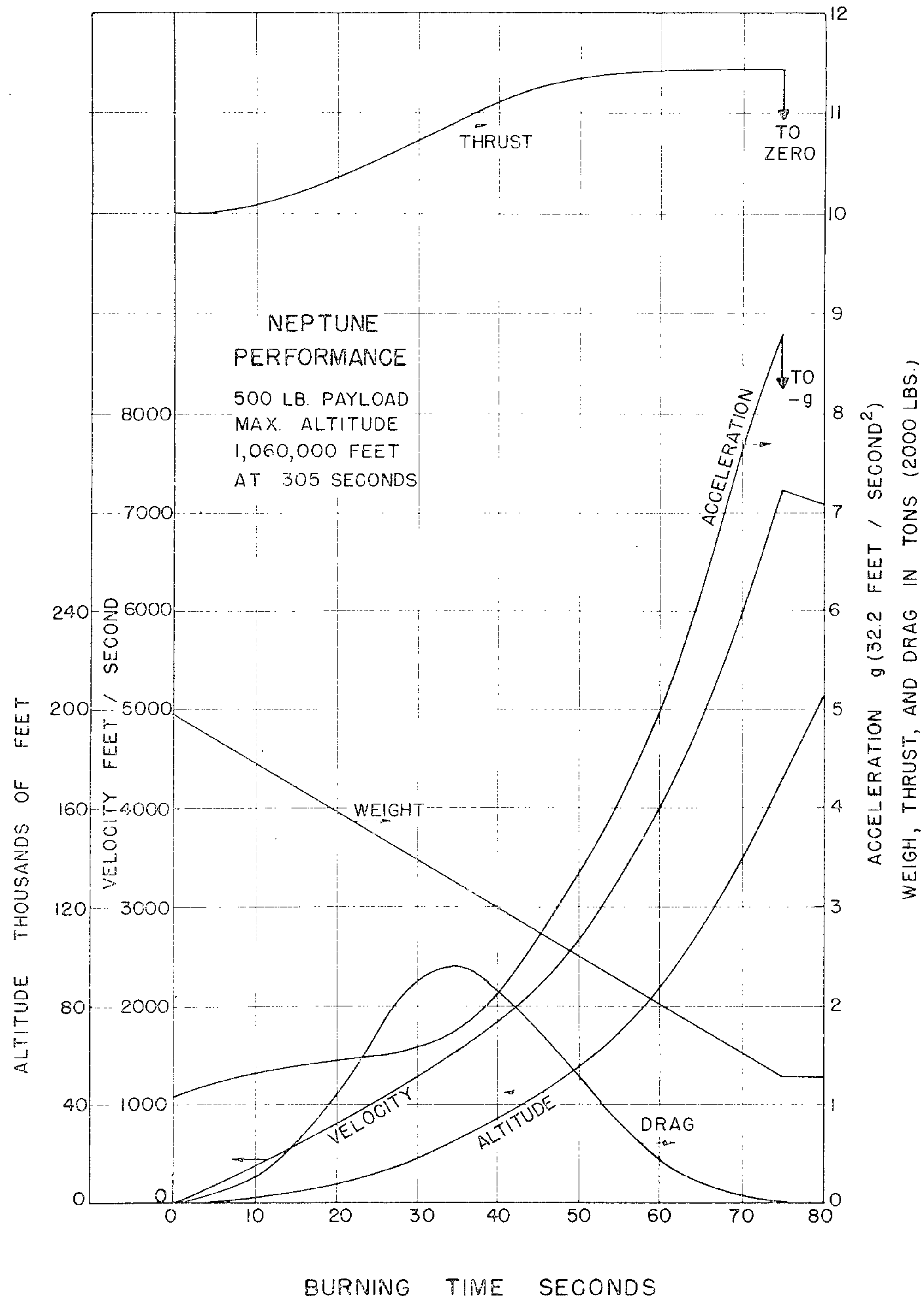
NEPTUNE PERFORMANCE
500 LB. PAYLOAD
MAX. ALTITUDE
1,060,000 FEET
AT 305 SECONDS
THRUST
TO ZERO
TO -g
ACCELERATION
WEIGHT
VELOCITY
ALTITUDE
DRAG
ALTITUDE THOUSANDS OF FEET
VELOCITY FEET / SECOND
ACCELERATION g (32.2 FEET / SECOND²)
WEIGH, THRUST, AND DRAG IN TONS (2000 LBS.)
BURNING TIME SECONDS
0
40
80
120
160
200
240
1000
2000
3000
4000
5000
6000
7000
8000
10
20
30
50
60
70
1
2
3
4
5
6
7
8
9
11
12

Figure 5

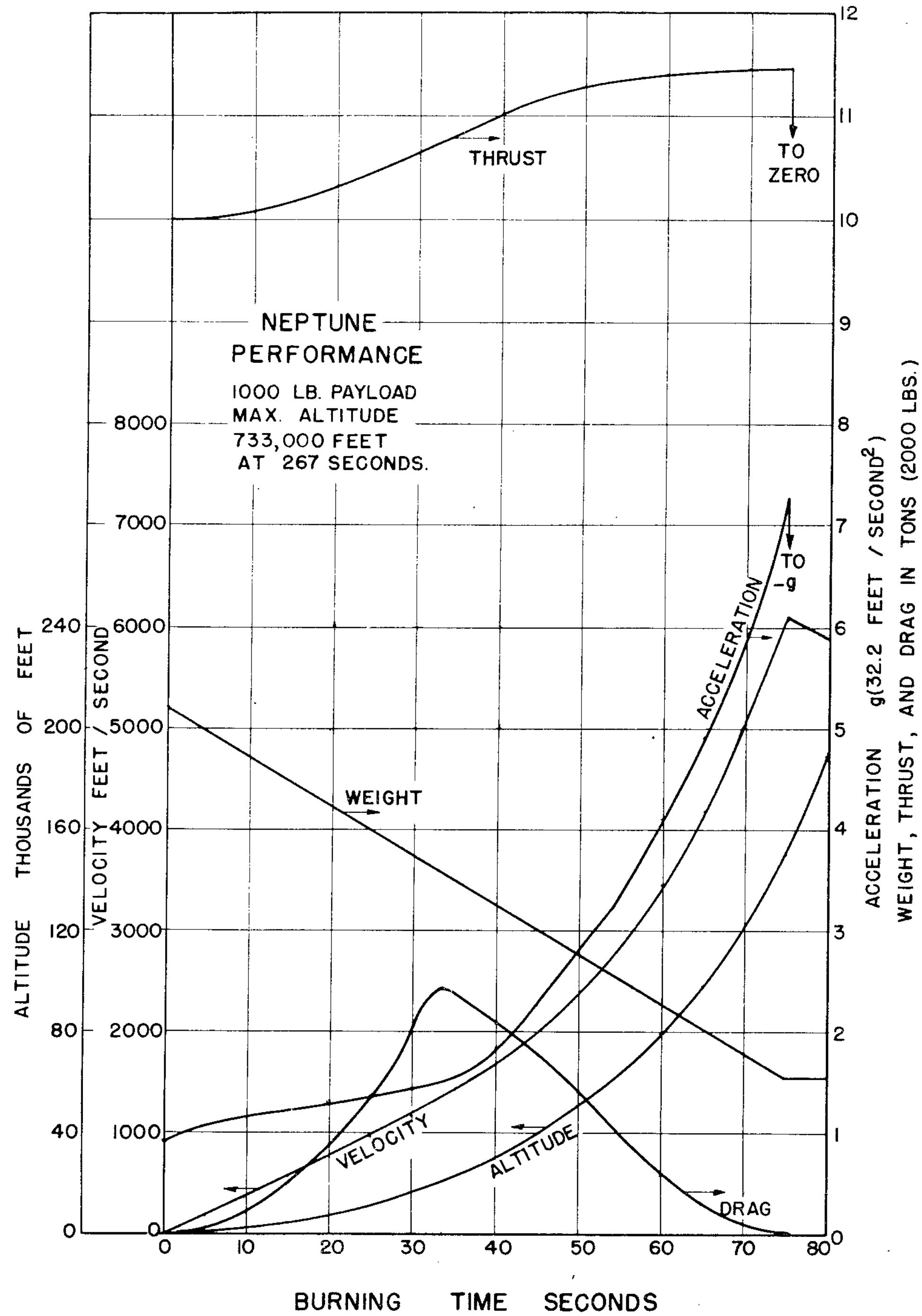
NEPTUNE
PERFORMANCE
1000 LB. PAYLOAD
MAX. ALTITUDE
733,000 FEET
AT 267 SECONDS.
THRUST
TO
ZERO
TO
-g
ACCELERATION
WEIGHT
VELOCITY
ALTITUDE
DRAG
ALTITUDE THOUSANDS OF FEET
VELOCITY FEET / SECOND
ACCELERATION g(32.2 FEET / SECOND^2)
WEIGHT, THRUST, AND DRAG IN TONS (2000 LBS.)
BURNING TIME SECONDS

Figure 6

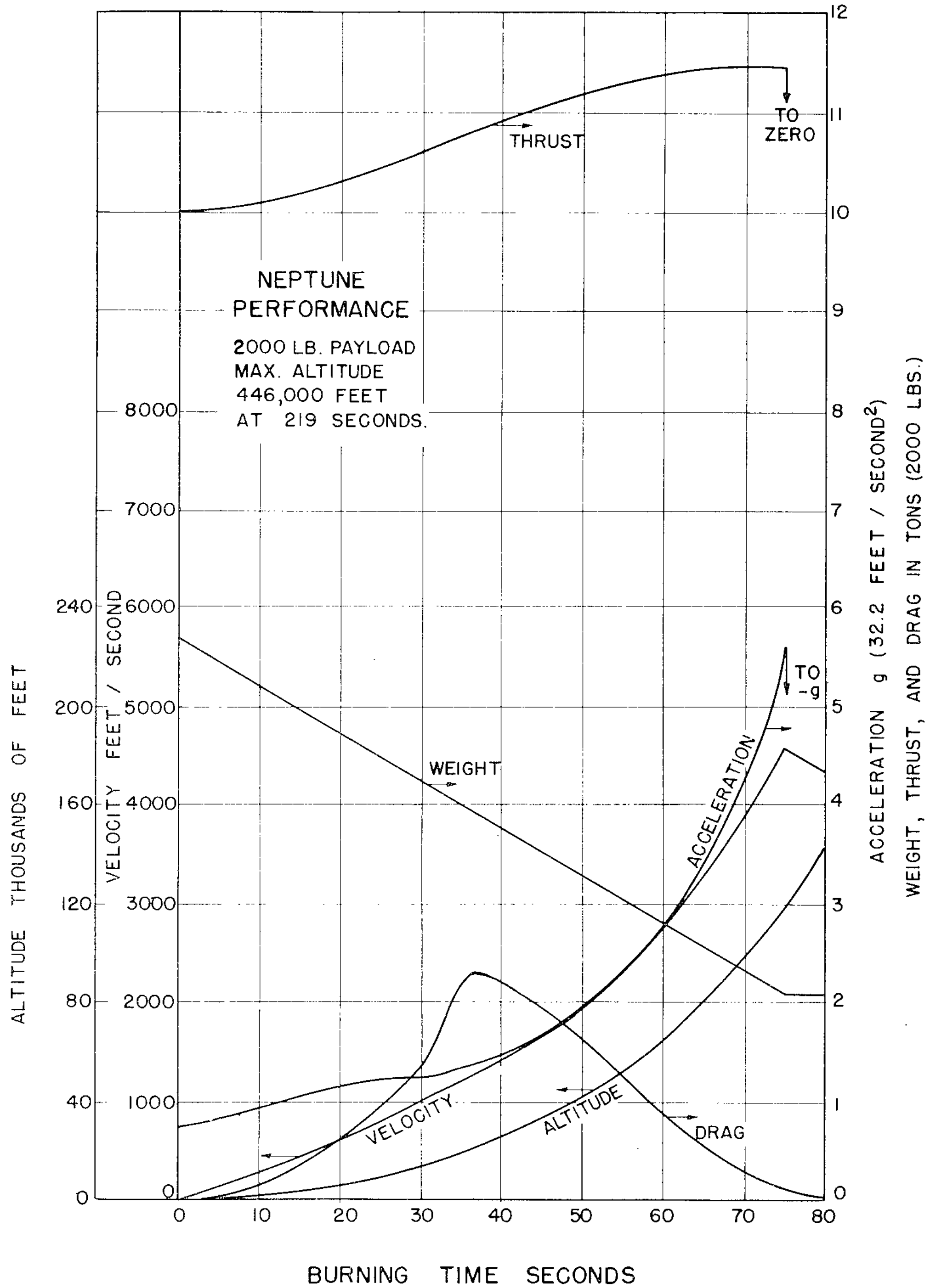
NEPTUNE
PERFORMANCE
2000 LB. PAYLOAD
MAX. ALTITUDE
446,000 FEET
AT 219 SECONDS.
THRUST
TO
ZERO
TO
-g
WEIGHT
ACCELERATION
VELOCITY
ALTITUDE
DRAG
ALTITUDE THOUSANDS OF FEET
VELOCITY FEET / SECOND
ACCELERATION g (32.2 FEET / SECOND²)
WEIGHT, THRUST, AND DRAG IN TONS (2000 LBS.)
BURNING TIME SECONDS

Figure 7

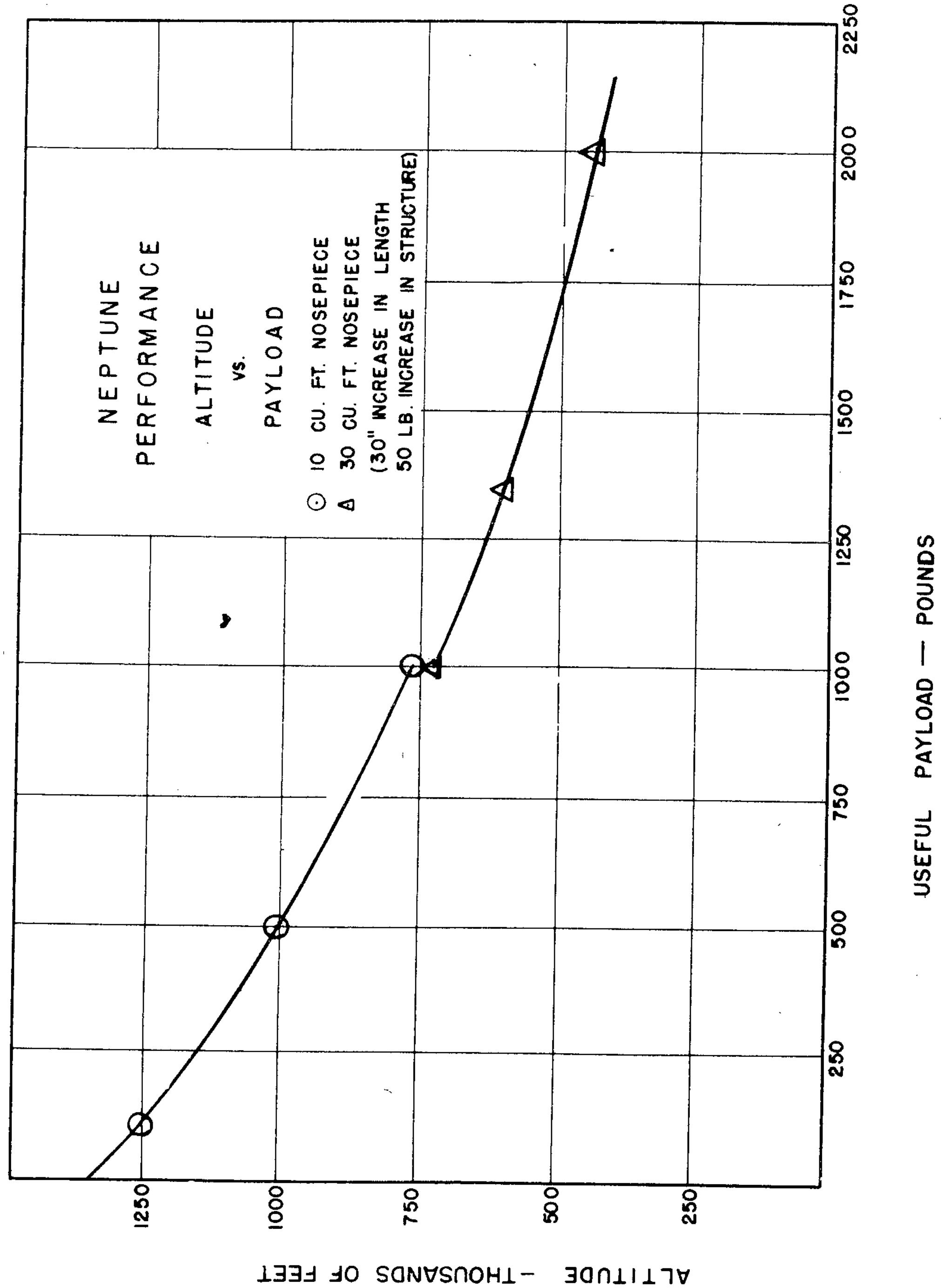
NEPTUNE
PERFORMANCE
ALTITUDE
vs.
PAYLOAD
⊙ 10 CU. FT. NOSEPIECE
Δ 30 CU. FT. NOSEPIECE
(30" INCREASE IN LENGTH
50 LB. INCREASE IN STRUCTURE)
ALTITUDE -THOUSANDS OF FEET
USEFUL PAYLOAD — POUNDS
1250
1000
750
500
250
250
500
750
1000
1250
1500
1750
2000
2250

Figure 8

CHAPTER III

OBJECTIVES, ACCOMPLISHMENTS, AND PROPOSED IMMEDIATE AND LONG RANGE PROGRAM IN THE MEASUREMENT OF ELECTROMAGNETIC PROPAGATION THROUGH JET GASES IN ROCKET FLIGHT

by

M. Becker, R. E. Bourdeau,
T. R. Burnight, and W. F. Fry

Objectives

The research on ionization being carried on by the Rocket-Sonde Research Section has as its purpose the study of ionization processes in the rocket jet, and ionization phenomena associated with rockets in flight. This study is of great importance because of the effects of the highly ionized region on electromagnetic propagation. Telemetering systems for obtaining data, and control systems for controlling the rocket or actuating devices involved in various experiments that rely on radio links, are adversely affected by the jet. The ionized jet may completely attenuate signals directed through it or the residually ionized region some distance behind the flame. At certain angles of incidence the flame may effectively shadow radio transmission paths by reflection from the interfaces at the flame boundary. Intelligence transmitted by radio from or to the rocket may have spurious modulation introduced due to the jet. The radiation patterns of antennas mounted on the rockets are greatly affected by the flame, especially for low frequencies and for microwave antennas which direct the energy near or through the flame.

The research carried on to date has led to the formulation of theories which have in most part been verified experimentally. These theoretical expressions permit the prediction of effects under conditions widely different than those of the experiments by which they were derived. Further effort will eventually be directed toward developing methods of avoiding or suppressing these difficulties in radio propagation due to the flame.

Accomplishments

The first experiments carried out on the V-2 consisted of a measurement of the attenuation of 3 cm radiation propagated directly across the jet between two antennas attached to the venturi ring. The transmitted power and the received signal were measured and this data telemetered to ground recorders. Several such experiments have been conducted which consistently show severe attenuation. A representative set of curves is given in Fig. 1. The source of a major portion of the attenuation in the flame is attributed to the presence of free electrons due to minute quantities of sodium in the alcohol-water fuel, namely 15 parts per million. A modified experiment was attempted using distilled water but no data was obtained due to failure of equipment not associated with the ionization equipment.

Immediate and Future Research Program

The research on this subject requires considerably more theoretical work and much laboratory experimentation to ascertain many of the parameters essential to a better understanding of the processes. The immediate experimental program will continue, with modifications and extensions of the present method. The following experiments are proposed for the near future.

(a) Studies of the jet effect on 1000 mcs radiation are being made in the May 15 Naval Research Laboratory V-2 in which a measurement across the jet similar to that described previously is being made simultaneously with recordings of the 1000 mcs signal received on the ground at two stations. These stations are so located that the signal path to one receiver is through the flame longitudinally and the other path does not go through the flame. Analysis of these records will give the gross attenuation and the frequencies of any modulation present.

(b) Simultaneous cross jet attenuation measurement on 10,000 mcs and 1000 mcs. By obtaining this data simultaneously the values of several parameters may be determined more closely.

(c) Cross jet experiments conducted with the fuel containing known amounts of given low ionization potential elements such as sodium.

(d) Measurements of the conditions in the jet at high altitudes by photographs of the flame shape and size and direct measurement of temperature and conductivity.

(e) Similar measurements on the Neptune in which the alcohol is not diluted and flame temperatures will be higher.

(f) A measurement of the effective index of refraction of the jet by a method similar to the phase beat experiment.

(g) Measurement of the collision cross section of the various components in the flame -- probably carried out in the laboratory.

(h) Determination of magnitude and sign of charging currents due to the jet for various fuels and added chemicals.

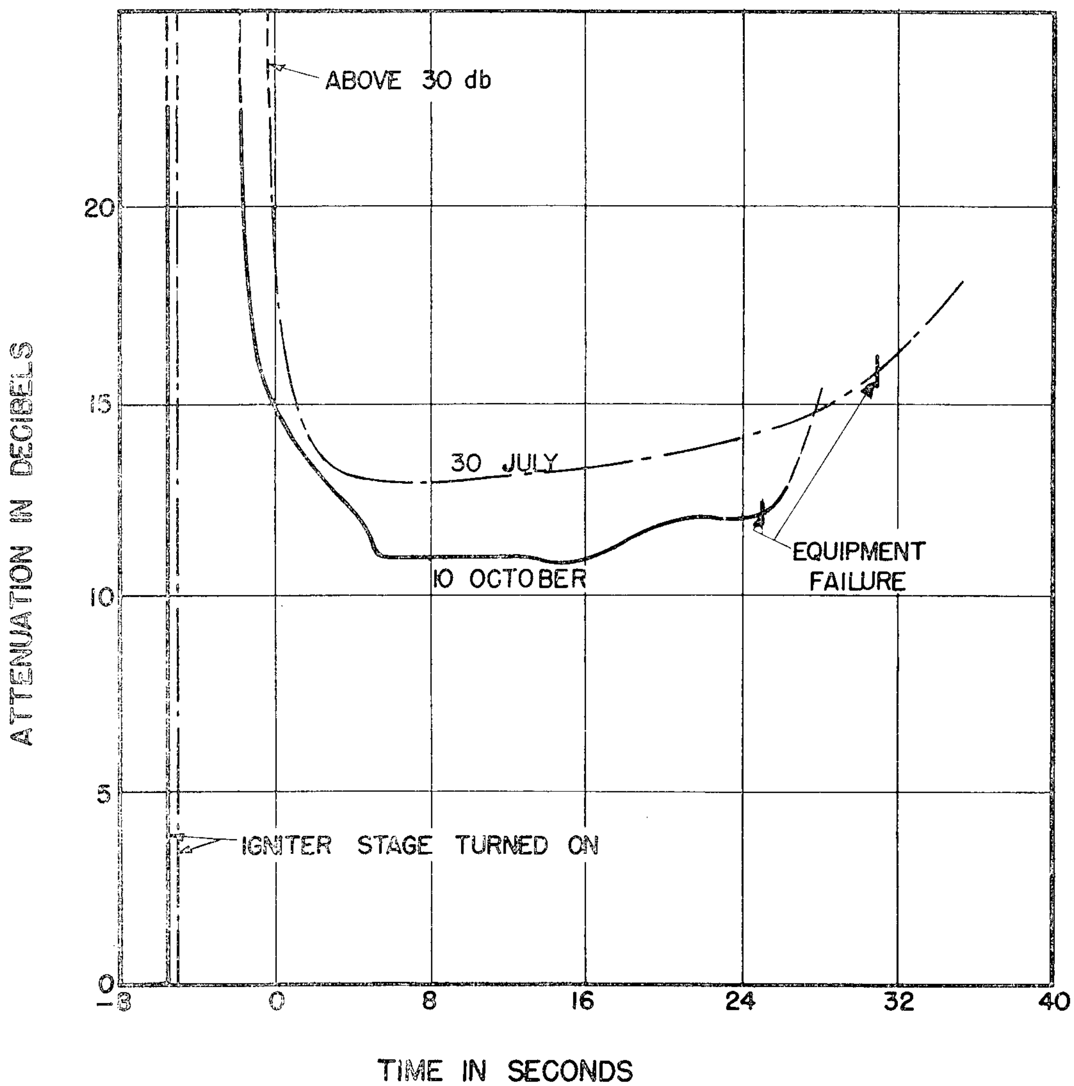

Figure 1 Attenuation of 10,000 mc. Radiation in the Exhaust of the V-2 as a Function of Time

APPENDIX I

CLASSIFIED REPORTS AND PUBLICATIONS BY NAVAL RESEARCH LABORATORY PERSONNEL ON UPPER ATMOSPHERE RESEARCH

"Upper Atmosphere Research with the V-2" by E. H. Krause, Naval Aviation Confidential Information Bulletin, July, 1946.

"V-2 Bomb Explores Upper Air" Written on the basis of an interview with Dr. E. H. Krause, Naval Aviation News July, 1946. Restricted.

"Upper Atmosphere Research with the V-2" by E. H. Krause, Guided Missiles Review, 1 July, 1946. Confidential.

"Miniature Labs Ride High Flying V-2", written on the basis of an interview wit h Naval Research Laboratory Personnel, Naval Aviation News October, 1946. Restricted.

"Upper Atmosphere Research Report No. I - Part II, by M. Becker, R. E. Bourdeau, T. R. Burnight, and W. F. Fry, Naval Research Laboratory Confidential Report No. R-2956, 1 October 1946.

"Upper Atmosphere Research Report No. II - Part II" by M. Becker, R. E. Bourdeau and T. R. Burnight, Naval Research Laboratory Confidential Report No. R-3031, 30 December 1946.

PRNC-2815-8-26-47-750