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58AA 5058

C7-16566

MAY 2 1958

(4) Cy #3

[redacted]

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ROBO presentation

AA 5058

C7-16566

BOEING AIRPLANE Co.~ SEATTLE DIVISION

D2-3101

[redacted]

INTRODUCTION

Boeing has studied boost-glide weapons for several years. This work has intensified in the past year. Both manned and unmanned rocket bombers have been examined. The first progress report was made to ARDC in December 1956 and this is the second report. As in the December report, Boeing interest is still primarily in the unmanned expendable boost-glide rocket field and this is the basic area to be covered in this report

This study has been accomplished in connection with the SR-126 "free study" program. It is pointed out that essentially all of the material has been developed with Boeing research funds. Expenditures on Boeing financed rocket bomber investigations and research will exceed $1,000,000 for the year 1957 not counting facilities or including overhead.

[redacted]

AGENDA

- OBJECTIVES
- SYSTEM FEASIBILITY
- DESCRIPTION OF REPRESENTATIVE SYSTEM
- BOEING INITIATED PROGRAMS
- REQUIRED SUPPORT PROGRAMS
- CONCLUSIONS

[redacted]

1-13 001- 208

[redacted]

SR-126 - OBJECTIVES

The basic objective of SR-126 is to determine the feasibility and practicability of a rocket-powered strategic bombardment system meeting the following requirements.

1. It must have intercontinental range capabilities at hypersonic speeds with 5500 n. miles as the minimum desired.

2. It should be available in the 1965-1970 time period.

As indicated in the SR-126 work statement, this aircraft could be either manned or unmanned and could be expendable or recoverable.

[redacted]

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SYSTEM REQUIREMENT No. 126

OBJECTIVES...

DETERMINE FEASIBILITY & PRACTICABILITY
OF ROCKET-POWERED BOMBER

REQUIREMENTS

- INTERCONTINENTAL RANGE (5500 Mi. MINIMUM)
- HYPERSONIC SPEED
- 1965-1970 TIME PERIOD

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BOEING AIRPLANE CO SEATTLE DIVISION

AD-159 001

TR-57-131

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ROBO PROGRESS REVIEW
Boeing Document D2-3101
(Unclassified)

ARDC System Requirements 126

The illustrations appearing in this book are reproduced from large presentation charts presented on June 18, 1957 at Wright Air Development Center

58AA 5058

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ARDC, RDZPS

7-25-57

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SYSTEM CHOICE

As outlined in SR-126 work statement, the system could be either manned or unmanned and either recovered or expendable.

Initial Boeing studies on rocket bombers indicated manned vehicles would be around 6 to 10 times heavier than if unmanned. This magnified the required rocket thrust development. It greatly increased the ground support problem and seriously jeopardized the mobility of the system.

Manned systems fly at much higher speeds and altitudes and thus involve more extensive airframe development.

To be useful the man must be able to communicate with the ground at Mach numbers of 16 or greater. Satisfactory solution of radar, radio or visual communication problems at hypersonic speeds has yet to be accomplished.

Severe limitations are imposed upon the vehicle design by the presence of man. Cabin conditioning and escape provisions are necessary. Throttled rockets, slower burning rockets or multiple stage development is required. The glide vehicle or a portion of it, must be landed in order to recover the crew.

None of the problems mentioned appear insurmountable. However, they are additional to the development required for an unmanned system and will result in a longer development time and increased cost.

The Boeing studies have indicated that the unmanned boost glide bomber can accomplish the strategic mission of deterrency and hard target destruction and at the same time provide the ground work which might logically develop into a manned system at a future date.

[redacted]

[redacted]

SYSTEM CHOICE

MANNED vs UNMANNED

PRESENT STUDIES INDICATE MANNED SYSTEMS:

- ARE LARGER BY AN ORDER OF MAGNITUDE
- REQUIRE MORE DIFFICULT & EXTENSIVE AIRFRAME DEVELOPMENT
- DEPEND UPON SOLUTION OF COMMUNICATION & OBSERVATION PROBLEMS
- IMPOSE MAJOR DESIGN LIMITATIONS
  - HUMAN FACTOR
  - ACCELERATION
  - RECOVERY

CONCLUSION: THE UNMANNED SYSTEM CAN BE OPERATIONAL MUCH EARLIER.

[redacted]

1-3300-1 191

FLIGHT PATH

Ballistic missiles fly beyond the earth's atmosphere and attain speeds in the order of M = 25. Target speeds are subsonic and are limited because of high temperatures reached during re-entry to the atmosphere. Ballistic missiles are guided during the boost phase only or about the initial 400 miles of flight. Accuracy of the ballistic system is influenced not only by the error due to guidance equipment but also by error introduced during re-entry to the atmosphere.

Boost-glide vehicles, on the other hand, utilize the atmosphere for wing lift and consequently can be guided over the entire mission by reasonably conventional aircraft type controls. The winged aircraft are boosted to 175,000 feet and glide from there to the target. Maximum speed is about M = 15. Target speed is higher than that for ballistic missiles, however, being around M = 2.

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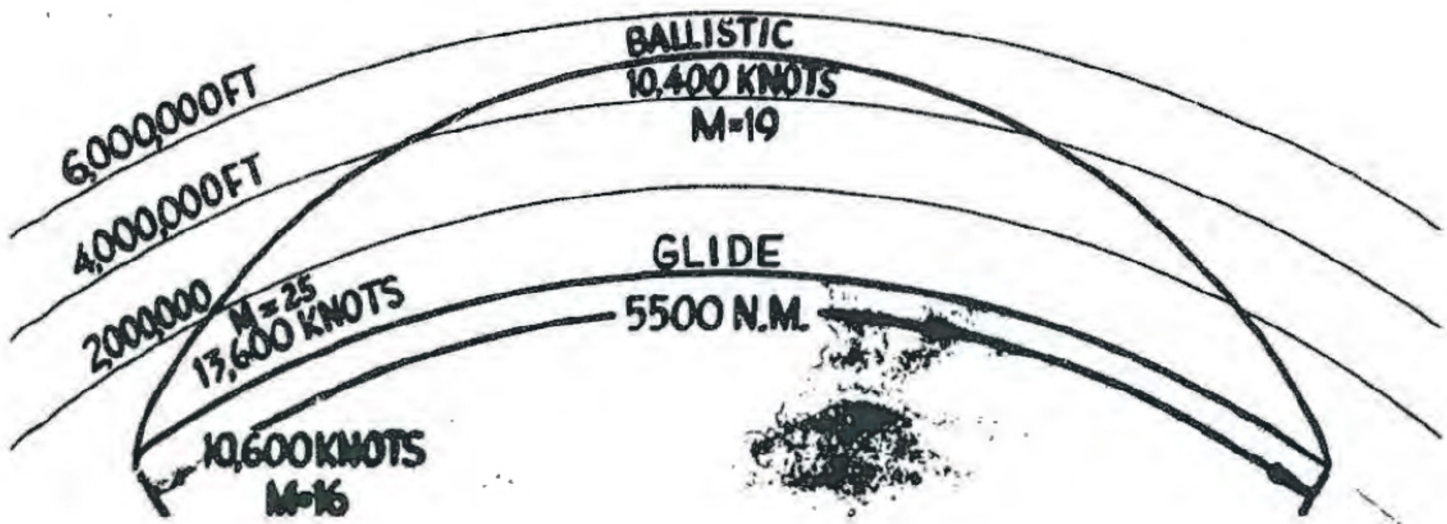
D2-3119
PAGE 133

Flight Path



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BOEING MODEL 728-113-200

Boeing Model 728-113-200 is presented as a representative expendable boost glide weapon system. It is [redacted]

This representative design is presented to illustrate the features of the boost-glide strategic weapon system in the prospective of an integrated design concept. This design is not intended as an "optimum" system. Further research and development is needed to completely detail such design and establish "optimum" design characteristics.

[redacted]

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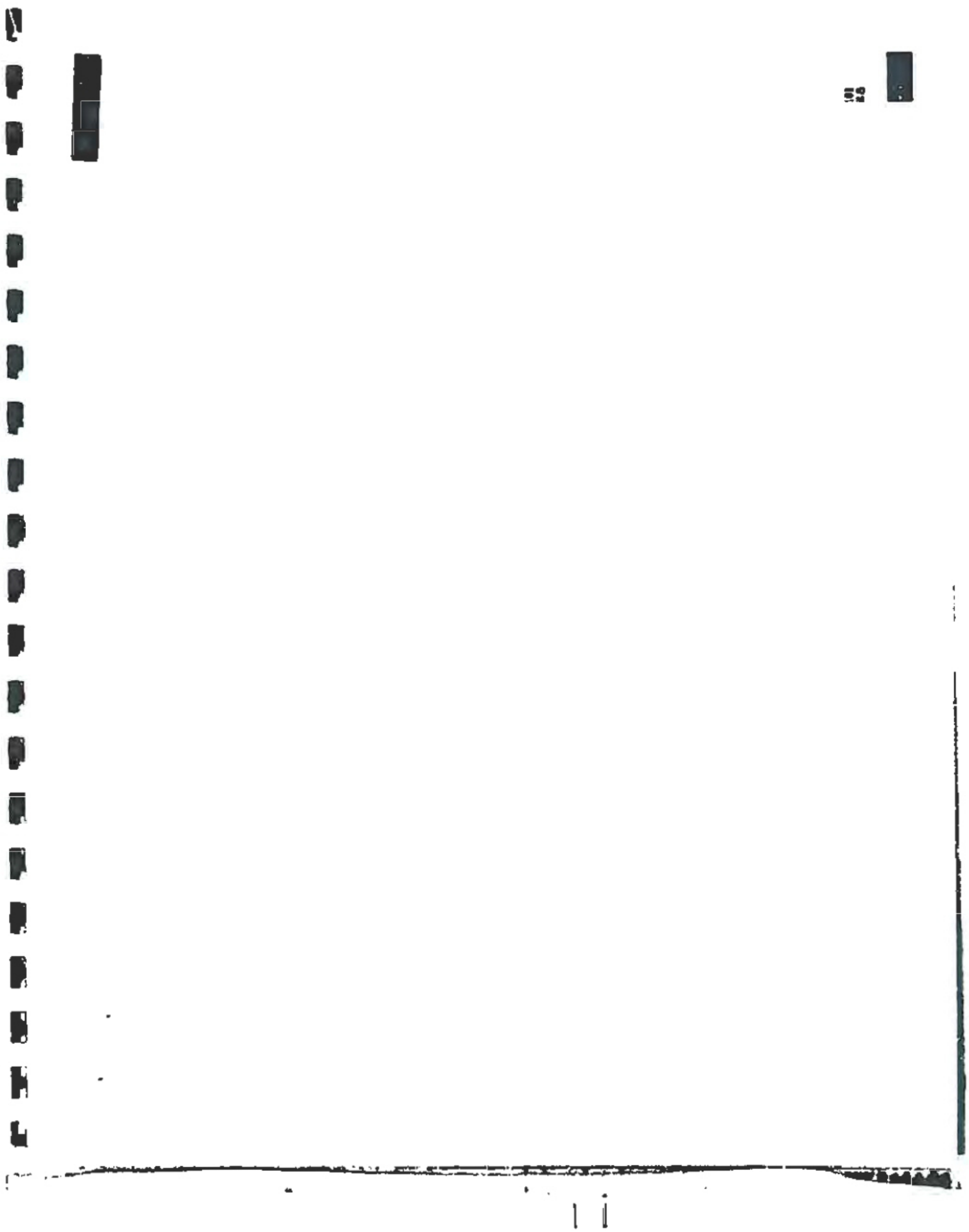

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PROPULSION SYSTEM

For the determination of suitable propulsion systems Boeing studies have covered both solid propellant systems and liquid propellant systems. A survey was made of the various propellants to establish specific impulses available, physical properties, and handling characteristics.

Methods of thrust vectoring and thrust termination are required and have been studied.

The development status of the various engines and propellants was considered in making the system choices.

It was required to have a propulsion system that would have a high reliability potential.

The effect of the propulsion system choice on the logistics was considered.

[redacted]

PROPELLANT AVAILABILITY

To summarize the rocket propellant availability we show the experimental specific impulse as a function of the calender time when these propellants will be available for large rocket engines. Both liquid and solid propellants are shown.

Two liquid propellants are available at the present time. [redacted]

Both the solid propellants shown have been fired in small experimental engines to date. [redacted]

[redacted]

VEHICLE SIZE

(Effect of Propulsion System)

To illustrate the effects of the propellant on the vehicle size we show on this chart a bar diagram with bars representing the launch gross weight. The glider in this comparison is the same for all bars. This comparison shows that the effects of the specific impulse differences (represented on the previous chart) are overshadowed by other design considerations such as the specific weight of the total propulsion system, the number of stages, the tank design factors, and the associated variations in the boost trajectory.

This points out that the launch weight is not a significant factor in the propulsion system choice. Such items as the logistics, handling problems, reliability and costs must be given careful consideration for establishing the propulsion system choice.

[redacted]

[redacted]

SUPPORT EQUIPMENT

The effect of the propulsion system choice on the support equipment requirement has been studied. Both the liquid propulsion system design and the solid propulsion system design in the size range of Model 728-113-200 or smaller can be equipped with a single vehicle to supply transportation erection and a launching stand. The major design problem for such a vehicle is weight for the solid propellant booster system. For the liquid booster system the major design problem is geometric size (primarily length).

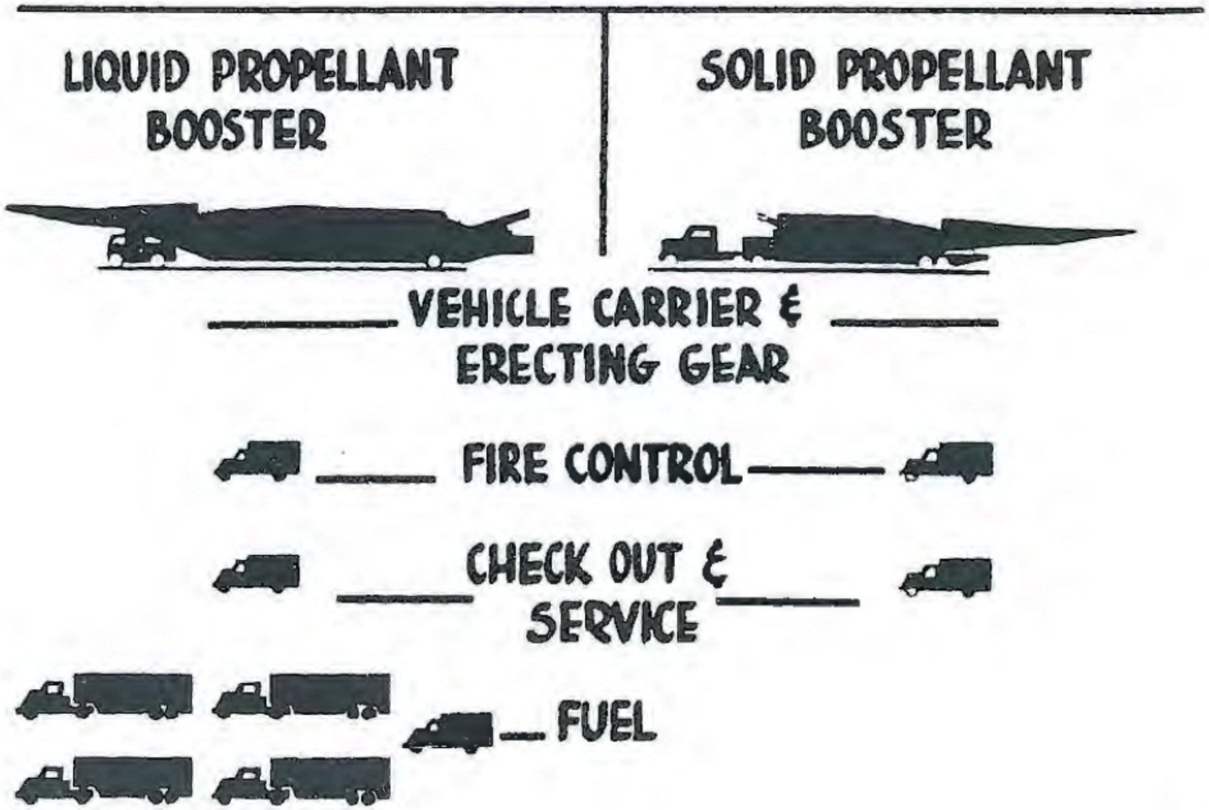
With either propulsion system, a fire control vehicle and a checkout and service vehicle are required.

In systems using a liquid propellant booster with a nonstorable propellant or where it is not desired to transport the booster prefueled, four propellant tank trucks would be required. If the oxidizer is liquid oxygen a fifth propellant vehicle, a liquid oxygen generator, is indicated to make up for the liquid oxygen boil-off.

[redacted]

SUPPORT EQUIPMENT

PER VEHICLE



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PAGE 13

1-33001-227

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ROCKET MOTOR COMPONENTS

This chart shows schematic diagrams of liquid and solid propulsion systems. In the liquid system the fuel and oxidizer must be delivered from their respective tanks to the combustion chamber by means of pump and regulators to ensure the proper mixture ratio. A typical liquid propellant engine system requires 28 valves (not all shown on the schematic diagram). In the solid propellant system the fuel is stored in the combustion chamber. The burning rate and mixture ratio are established by the chemistry of the propellant. The only valves required are those associated with the thrust termination. Satisfactory thrust termination and thrust vectoring can be achieved with either type of propellant system.

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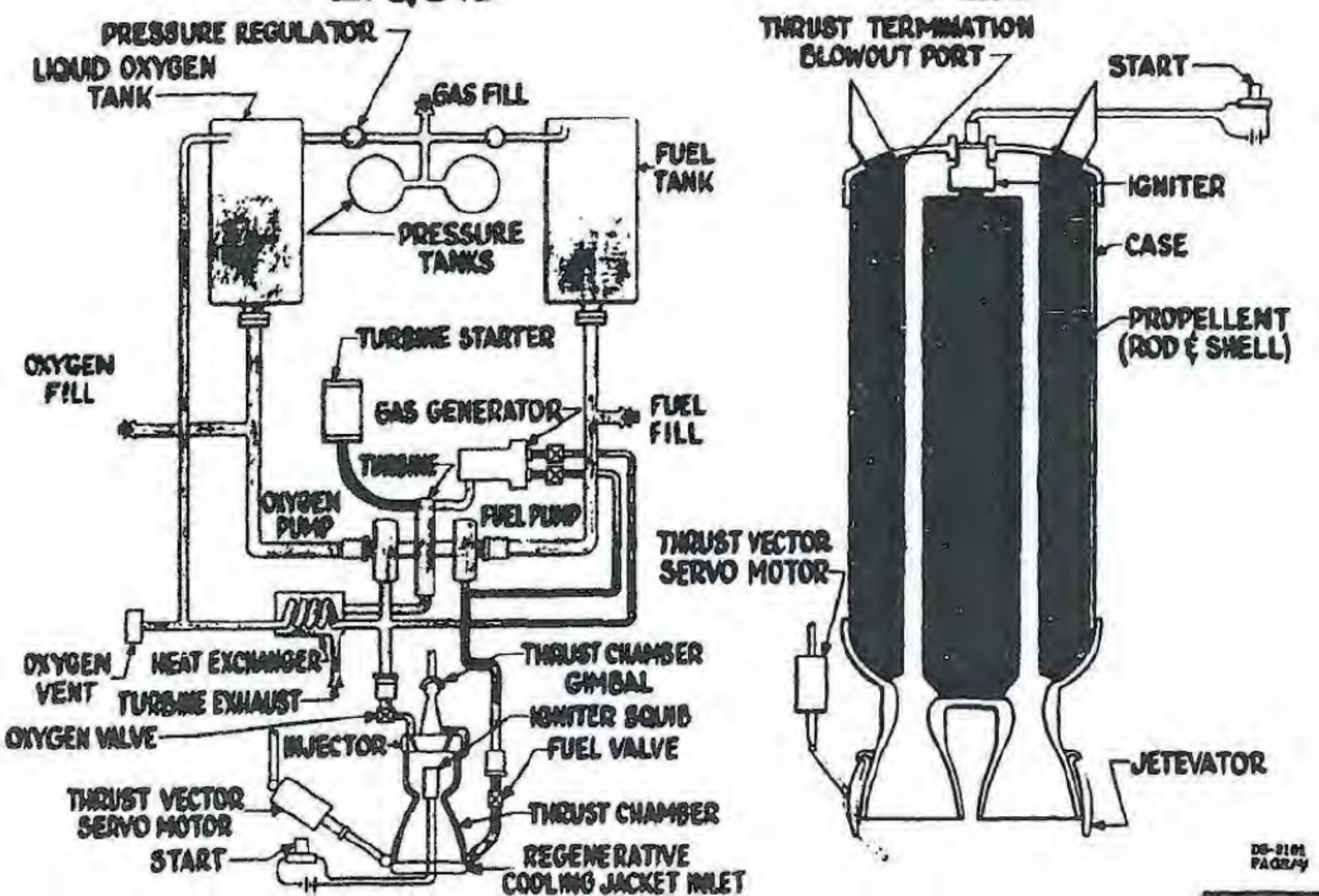
ROCKET MOTOR COMPONENTS

LIQUID   SOLID



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[redacted]

[redacted]

PROPULSION SYSTEM

- SYSTEM CONSIDERATIONS:
  - SOLID PROPELLANT
  - LIQUID PROPELLANT
  - SPECIFIC IMPULSE
  - THRUST VECTORING METHODS
  - THRUST TERMINATION
  - DEVELOPMENT STATUS
  - RELIABILITY
  - LOGISTICS

[redacted]

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SUPPORT EQUIPMENT

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[redacted]

[redacted]

PROPULSION SYSTEM

A two-stage solid propellant propulsion system has been chosen for the representative design for the following reasons:

1. The simplicity of the solid propellant system makes it particularly adaptable to military operation.
2. Solid propellant rockets have an excellent background record in smaller units such as those used in research programs—many firings have been made with multiple rocket clusters.
3. The base requirements are simplified by having preloaded propellants.
4. The solid propellant systems as well as the liquid systems are adaptable to the mobility requirements.
5. By eliminating the necessity to fuel the vehicle the ready time requirements are reduced.
6. Solid propellants can be stored in the rocket cases for three to five years with no deterioration of their performance.
7. The solid propellant rocket manufacturers are quoting less development time for new solid rockets than the development time being quoted for new liquid rockets.

[redacted]

[redacted]

PROPULSION SYSTEM
2 STAGE SOLID

- SIMPLICITY
- BACKGROUND RECORD
- BASE REQUIREMENTS
- MOBILITY
- READY TIME
- STORAGE
- DEVELOPMENT TIME

[redacted]

1-33001-229

[redacted]

DESIGN REGIONS

To introduce the structural design of the representative boost glide vehicle we show here the mission profile of altitude versus range.

During the first 100 seconds of flight the vehicle is boosted to a Mach number of 16.8 and 175,000 ft. altitude. The primary structural design conditions during this boost phase are associated with the thrust deflection for control and the internal pressure in the booster cases.

During the glide phase the vehicle travels unpowered to the vicinity of the target. The Mach number decreases from 16.8 to 4.0 and the altitude decreases from 175,000 ft. to 85,000 ft. The primary structural design condition during glide is the temperature of the structural materials.

For the last 42 miles of flight the vehicle experiences a minus one "g" dive into the target. The primary structu·al design condition during this dive in is a maneuver plus gust load.

[redacted]

[redacted]

ATRAN FIX-TAKING CAPABILITY

This tabulation shows the estimated fix-taking errors of an ATRAN system in the high altitude glide vehicle. It was assumed that the fix was taken during the last 300 nautical miles of flight when the missile is at an altitude of 80,000 - 100,000 feet and a speed of 4000 - 6000 ft.sec. The principle source of error is the azimuth stabilization of the antenna which is estimated to have a [redacted]

[redacted]

[redacted]

ATRAN CHARACTERISTICS

PAST SYSTEMS	FUTURE SYSTEMS
● CONTINUOUS RADAR OPERATION	● INERTIAL SYSTEM ELIMINATES CONTINUOUS OPERATION

● SPOT MATCHING

SMALL PORTION OF PICTURE USED FOR MATCHING

LOW SIGNAL/NOISE RATIO

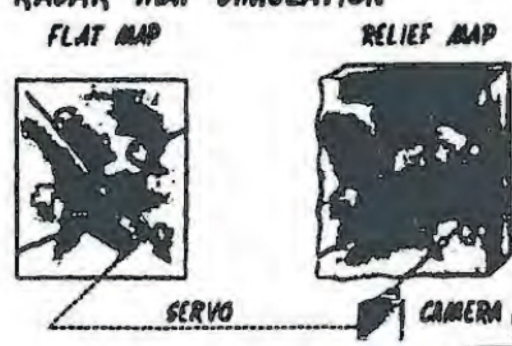
● AREA MATCHING

ENTIRE PICTURE USED FOR MATCHING

MAKES POSSIBLE AN AREA SEARCH FOR MAP-MATCH (10 N.M. SEARCH POSSIBLE)

● RECON FLIGHT REQUIRED

● RADAR MAP SIMULATION



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PAGE 34

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ATRAN CHARACTERISTICS

Past ATRAN systems have had some undesirable characteristics.

Use of an inertial system to dead-reckon over long distances eliminates the necessity of continuous radar operation and map-matching which has been characteristic of past ATRAN equipment.

In previous map-matching techniques, the radar picture was painted on the face of a short persistence cathode ray tube. Thus, at any one time, only a small portion of the picture was used in the mapping operation which resulted in a low signal-to-noise ratio for the match indication. A mis-match of up to only one nautical mile could be tolerated.

Recently a new matching technique called area matching has been developed. In this method, the radar picture is painted on the face of a storage tube in a few seconds and then the radar stops transmitting. The storage tube holds the picture while the matching operation occurs. Thus, the entire picture is used in the matching operation which results in a high signal-to-noise ratio. With this method, an area search for the matched condition is possible by moving the reference film with respect to the radar picture. An area search with a radius of 10 nautical miles will probably be possible.

Goodyear has recently developed a method of simulating radar pictures from topographical maps. This is accomplished by photographing the illuminated area on a relief map which has been fabricated from the flat topographical map. This technique should eliminate the necessity of radar reconnaissance flights.

These developments essentially eliminate the undesirable characteristics associated with ATRAN in the past.

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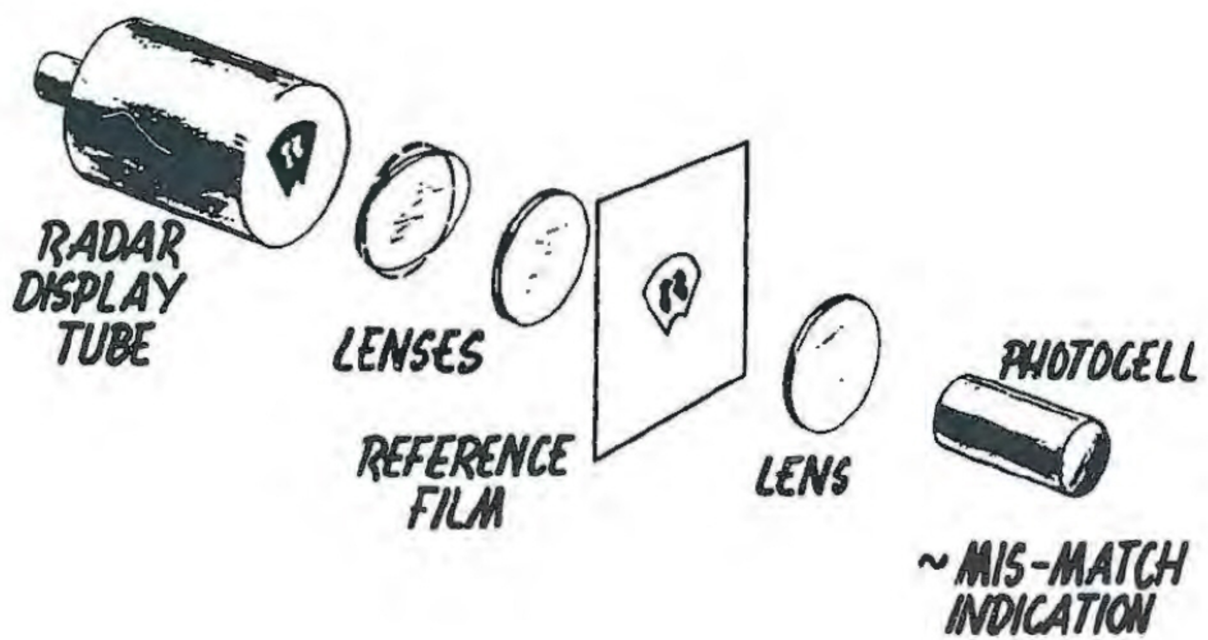
BASIC MAP-MATCHING EQUIPMENT



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[redacted]

BASIC MAP-MATCHING EQUIPMENT

An automatic checkpoint radar for use in the radar-inertial system has been developed by Goodyear Aircraft Corporation and is called the ATRAN system.

The ATRAN equipment compares the picture on a radar indicator with a reference picture which has been prepared prior to flight. The radar picture is imaged by a lens system on the reference film which is a negative transparency. If the aircraft is on course, the bright areas of the radar picture are imaged on the darkened areas of the reference picture and a minimum of light is transmitted to the phototube. If the aircraft is not on course, the bright spots of the radar indicator will be shifted somewhat into the transparent areas of the reference film and more light will be transmitted to the phototube. The amount of light received by the phototube is an indication of the distance the aircraft is off course. In order to determine the direction of mis-match, the image of the radar indicator is continuously moved through a small circle by cocking one lens and rotating it about the optical axis of the system.

In a radar-inertial system, the amount and direction of mis-match is used to correct the position information of the inertial equipment.

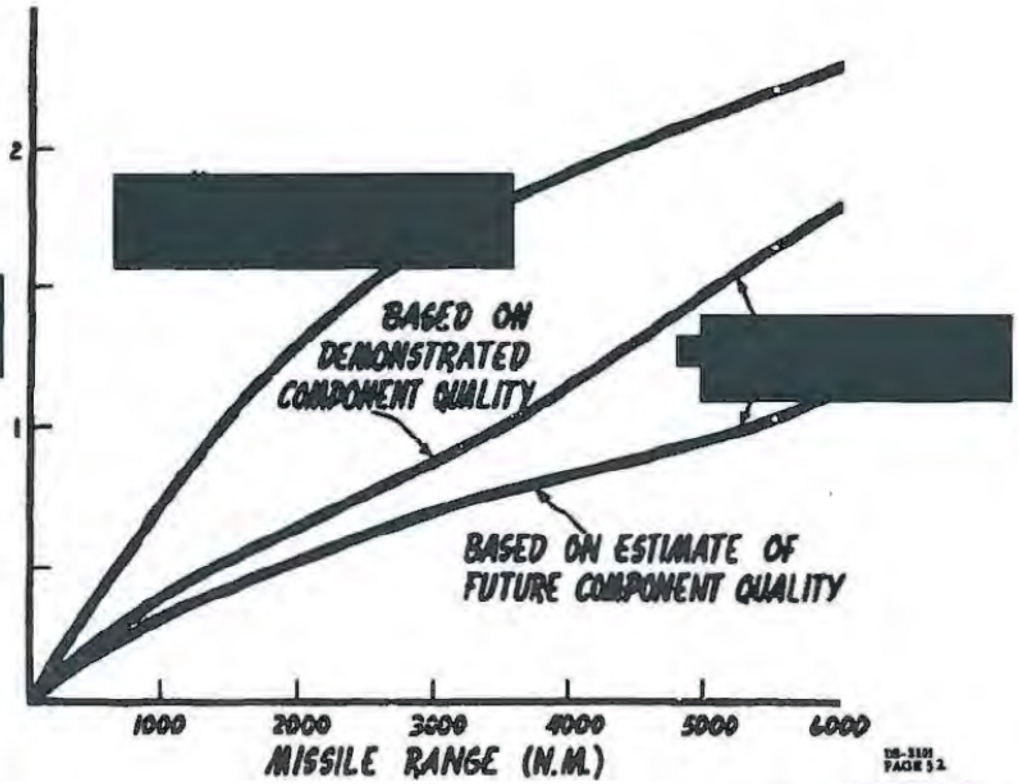
[redacted]

[redacted]

[redacted]

INERTIAL SYSTEM ACCURACY

[redacted]



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[redacted]

INERTIAL SYSTEM ACCURACY

The accuracy capabilities of all-inertial guidance systems are shown here. Both high and medium accuracy systems have been considered. Two approaches were used in evaluating the performance of the larger, higher accuracy system. The difference in predicted performance between the two approaches is probably indicative of the accuracy to which an error analysis can be made at this time.

[redacted]

[redacted]

[redacted]

GUIDANCE SYSTEM COMPARISON

SYSTEM TYPE	ADVANTAGES	DISADVANTAGES
INERTIAL	● ACCURATE FOR SHORT TIME OF FLIGHT ● NO RADOMES REQUIRED ● UNAFFECTED BY COUNTERMEASURES ● NO RADIATION FOR ENEMY TO DETECT	● PRODUCTION CAPABILITY UNTESTED ● PRE-FLIGHT WARMUP & ALIGNMENT REQ'D ● LAT-LONG OF TARGET AND LAUNCH POINT REQUIRED
RADAR	● ACCURATE IF LAST FIX IS TAKEN NEAR TARGET ● MINIMUM GROUND PREPARATION TIME ● PRODUCTION CAPABILITY SATISFACTORY	● TWO HIGH TEMP. RADOMES REQ'D ● AFFECTED BY ENEMY COUNTERMEASURES ● RADIATION FOR ENEMY TO DETECT ● LARGE LIBRARY OF REFERENCE MAPS REQ'D ● AFFECTED BY SHOCK WAVE IONIZATION
RADAR-INERTIAL	● VERY HIGH ACCURACY POSSIBLE IF FIX IS TAKEN NEAR TARGET ● RADAR CORRECTION CAN BE MADE AT RELATIVELY LOW SPEED ● MINIMUM RADIATION TIME	● SMALL LIBRARY OF REFERENCE MAPS REQ'D ● HIGH TEMP. RADOME REQ'D ● SYSTEM IS UNTESTED

[redacted]

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GUIDANCE SYSTEM COMPARISON

Listed on this page are the advantages and disadvantages of the three guidance system types considered. In comparing the disadvantages of the system it is apparent that the defects of the radar systems are more serious than those of the other two systems. Therefore, radar systems were eliminated as a possible choice and the capabilities of the other two systems will be discussed further.

[redacted]

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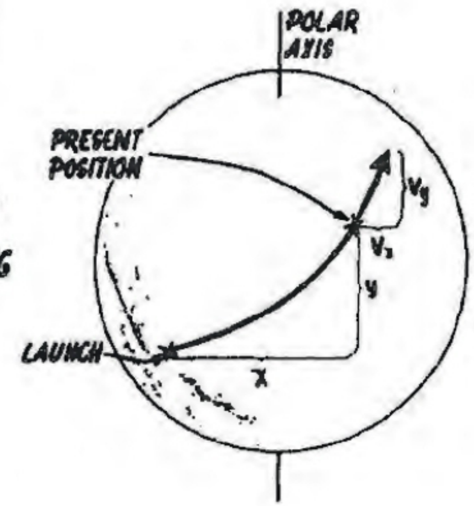
GUIDANCE



NAVIGATION REQUIREMENTS –

- CONTINUOUSLY FURNISH POSITION INFORMATION
- CONTINUOUSLY FURNISH THE CORRESPONDING VEHICLE VELOCITY INFORMATION

POSSIBLE SYSTEMS

- HIGH QUALITY INERTIAL AUTONAVIGATOR

  VEHICLE VELOCITY $= \int \left(\text{VEHICLE ACCLERATION} \right) dt$ DISTANCE TRAVELED $= \iint \left(\text{VEHICLE ACCELERATION} \right) dt\, dt$

- RADAR

  AUTOMATIC CHECKPOINT RADAR
  DOPPLER SPEED MEASURING RADAR
  HEADING REFERENCE

- RADAR-INERTIAL

  AUTOMATIC CHECKPOINT RADAR
  MEDIUM ACCURACY AUTONAVIGATOR

1-33003-377

[redacted]

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GUIDANCE

A boost-glide missile remains in the atmosphere throughout flight and is, therefore, subject to forces which are not completely predictable. Consequently, some form of guidance and control equipment is necessary throughout the entire flight. The navigation system must continuously furnish information on the missile position and velocity.

The three guidance system types listed appear to offer the most promise in this application and their capabilities have been seriously investigated.

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GUIDANCE

[redacted]

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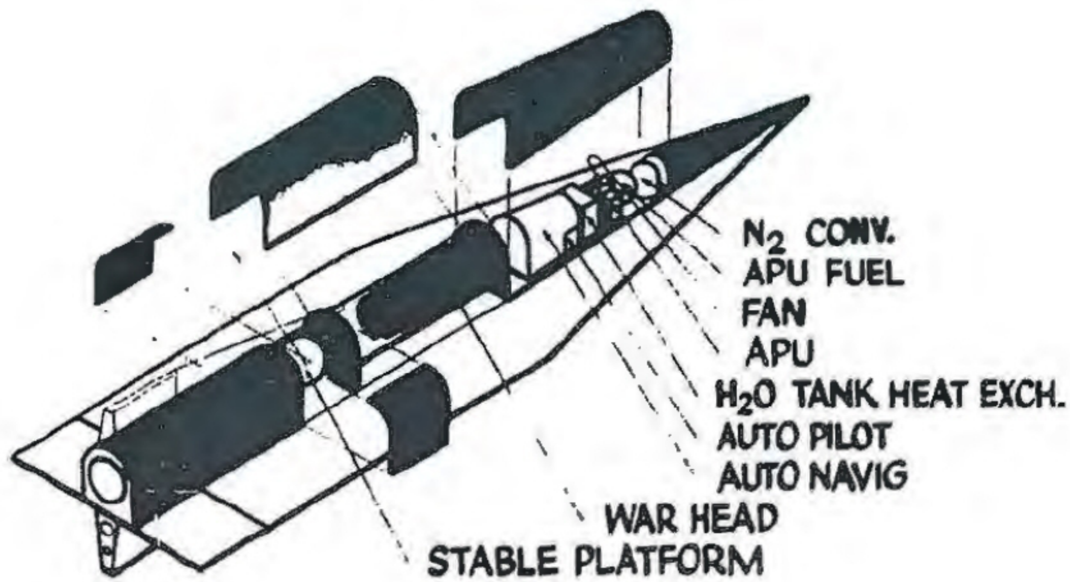
INBOARD ARRANGEMENT



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INBOARD ARRANGEMENT.

This inboard arrangement of the representative glider design shows the placement of the equipment and warhead and the access provision for servicing and maintenance.

[redacted]

[redacted]

SUBSYSTEMS REQUIREMENTS

AUXILIARY POWER

GLIDER ~ 25 H.P. - MONOPROPELLANT TURBINE

BOOST - 1ST STAGE 67 H.P. 2ND - 15 H.P.: SOLID PROPEL. TURBINE OR HOT GAS

HYDRAULICS

GLIDER - 15 H.P. FOR FLIGHT CONTROL

4000 PSI - 3.5 GPM PUMP - HI-TEMP. FLUID DESIREABLE

ELECTRICAL

GLIDER ~ 5.8 KW

3 PHASE 115/200 V A.C. ~ 7.5 KVA LIQUID COOLED ALTERNATOR

COOLING

GLIDER ~ 39,220 BTU

EXPENDABLE WATER - ALCOHOL COOLANT

PRESSURIZATION

GLIDER ~ 33 LB/HR. 10 PSI ΔP

LIQUID NITROGEN CONVERSION

D8-3101

[redacted]

[redacted]

SUBSYSTEMS & EQUIPMENT
DESIGN PHILOSOPHY

DESIGN SIMPLICITY
MINIMUM NUMBER OF COMPONENTS - MAX. SYSTEMS INTEGRATION

RELIABILITY
MINIMUM NEW DEVELO' 1ENTS - NO REDUNDANT COMPONENTS

CONFIDENCE
EXTENSIVE TEST, EVALUATION AND COMPONENT IMPROVEMENT

MOBILITY
MINIMUM GROUND SUPPORT - LONG STORAGE LIFE COMPONENTS

MAINTENANCE
MAXIMUM ACCESSIBILITY - BALANCED LIFE/ OPERATIONAL REQUIREMENTS

OPERATIONAL READINESS
MINIMUM PRE-FLIGHT SERVICING AND CHECKOUT

1-13001-120

[redacted]

[redacted]

SUBSYSTEMS AND EQUIPMENT DESIGN PHILOSOPHY

1. Design simplicity will be sought through critical analysis and careful integration of requirements of all subsystems.

2. Reliability will be achieved through good component and system design and application using well developed components rather than depending upon redundant systems.

3. The component design life requirement will be carefully balanced with the weapon system operational requirements.

4. The component development for extreme environment will be balanced with provisions for environmental control.

5. The glider subsystems will be separate from the boost stage systems whenever possible.

6. The supply and servicing will be simplified by minimization of the number of fluids, gases, and external power requirements.

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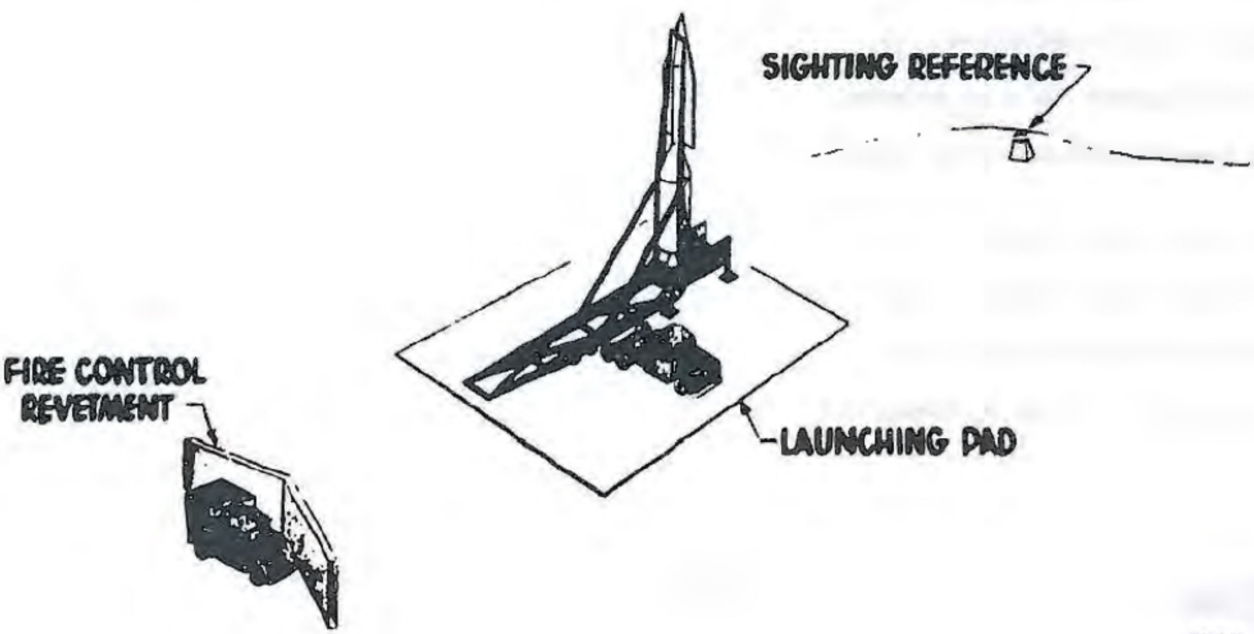
LAUNCH SITE REQUIREMENTS

MINIMUM BASE



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LAUNCH SITE REQUIREMENTS

The representative design system requires a minimum launch site. All that is required is a hard stand (stabilized soil or concrete) with a known location in earth coordinates and a remote sighting point to supply direction reference for guidance system alignment. For areas of very flat terrain it may be desirable to provide a fire control revetment.

The adaptability to a very minimum of base allows for a complete dispersion of the weapon system without tremendous costs and complication. To make effective use of the dispersed base potential the weapon system would have to be mobile or readily transportable. As mentioned earlier the transportation vehicle can be effectively combined with the erecting gear and firing stand. The vehicle would be carried in the inverted position so that service, maintenance and check-out can be performed without dismounting the vehicle.

[redacted]

[redacted]

STRUCTURAL DETAILS

The wing structure is composed of [redacted] upper surface sheet with full depth sandwich. A ceramic leading edge cap is provided to withstand the high leading edge temperatures.

All external skin surfaces are designed with sandwich panels. [redacted] wing surface, the body nose cone back to the first bulkhead and the ventral and dorsal fins. The rest of the body skins are designed for [redacted]

The body panels are attached to the wing surface by a continuous angle on either side of the body. Body frames and bulkheads are utilized at points of concentrated loads.

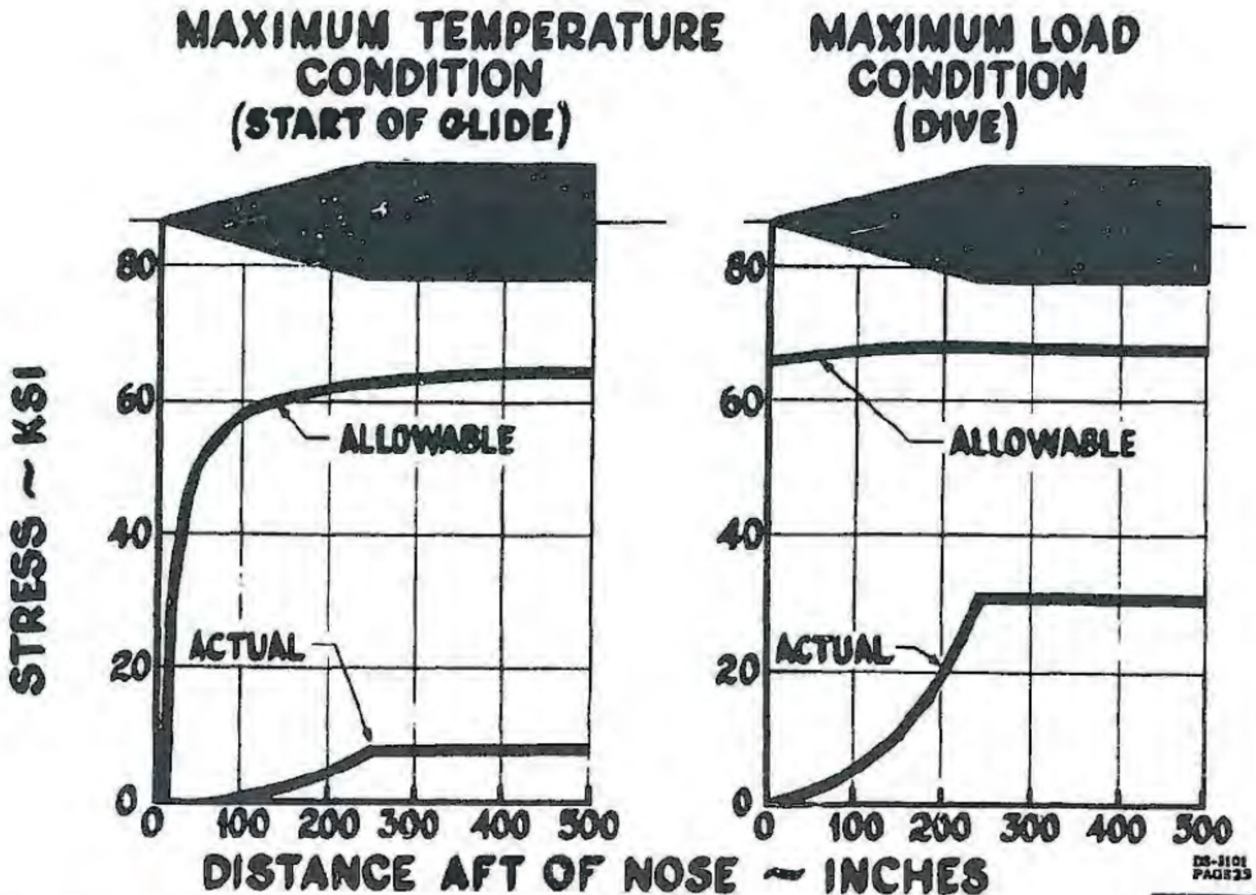
The dorsal fin is attached to the top of the body at two main body frames. The ventral fin is attached to the wing lower surface by a continuous angle running the length of the fin.

The molybdenum skins must be protected from oxidation by a suitable process of which several are currently under development.

[redacted]

[redacted]

WING STRESS

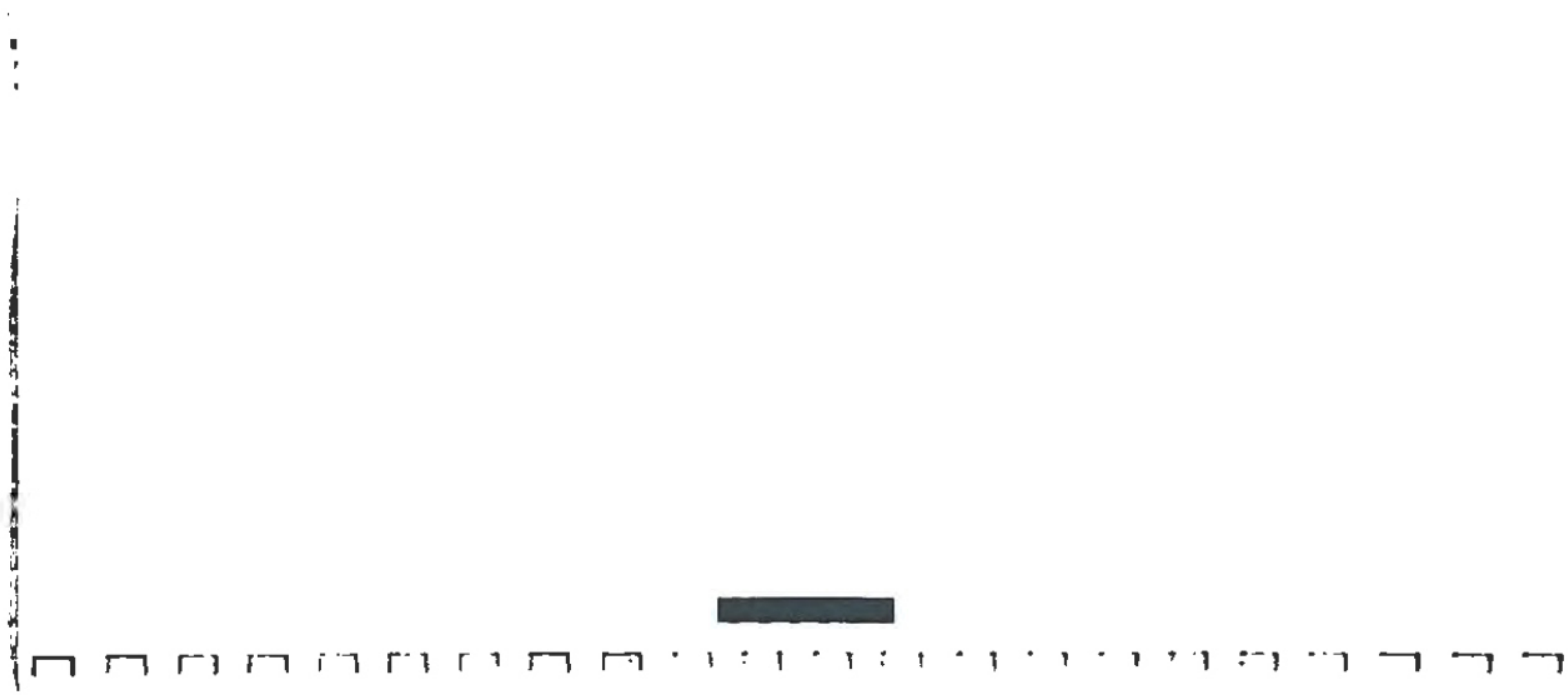


[redacted]

[redacted]

WING STRESS

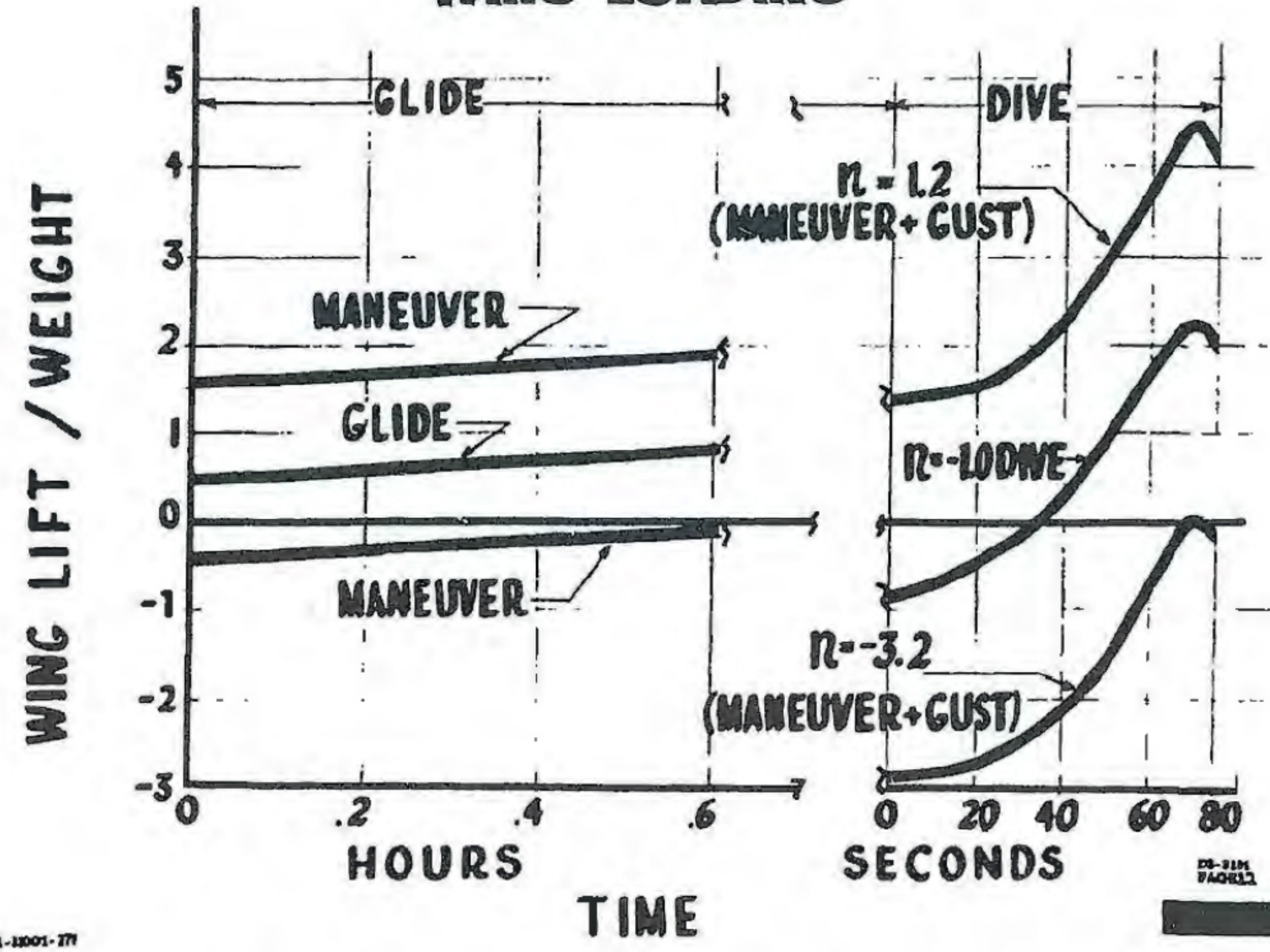
The tension stress at the root chord of the lower wing surface is shown here for the maximum temperature design condition and for the maximum load design condition. The allowable tension stress corresponding to the respective skin temperatures is also shown. These actual stresses [redacted] used as a minimum gage skin.



[redacted]

[redacted]

WING LOADING



[redacted]

[redacted]

WING LOADING

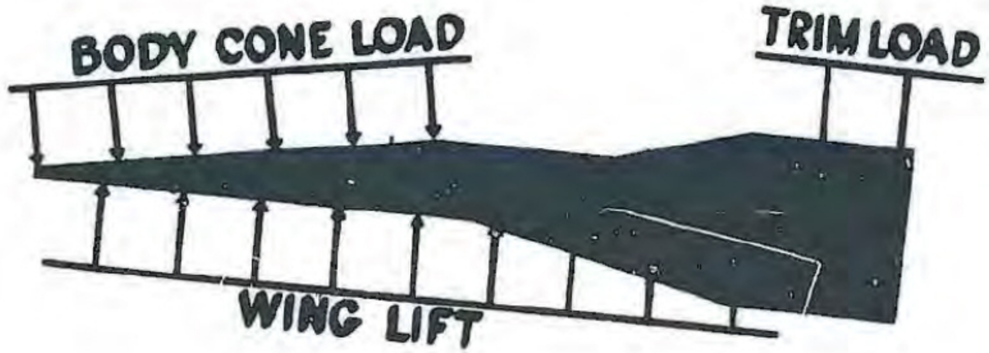
This chart shows the wing lift loading per unit of glider weight as a function of the mission time. The maximum lift during glide is that required for normal flight plus a one "g" maneuver factor. The maximum wing lift per weight factor of [redacted] is encountered during the terminal phase dive. This factor corresponds to a [redacted] This is the design load condition for the lower wing surface.

[redacted]

[redacted]

[redacted]

GLIDER AIRLOAD DISTRIBUTION



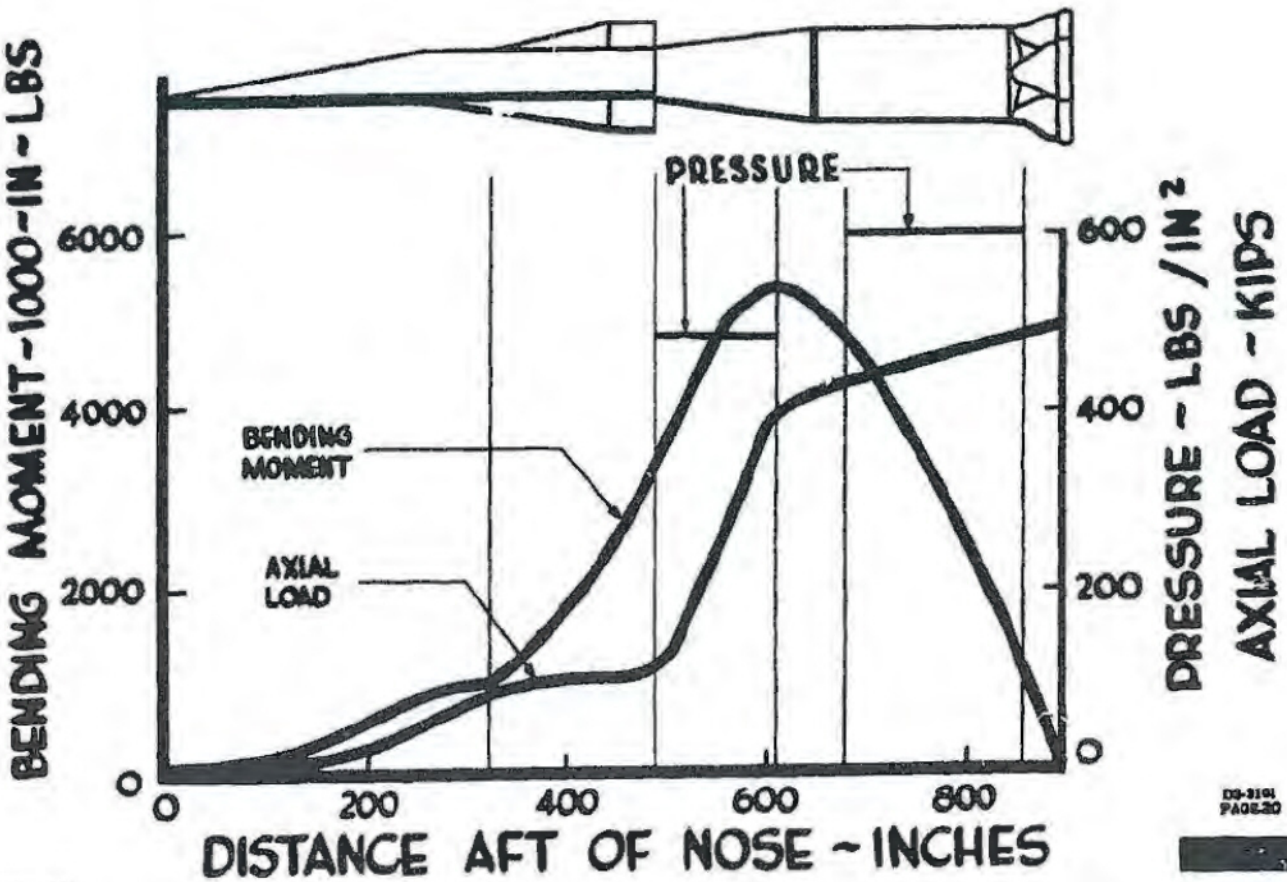
[redacted]

GLIDER AIRLOAD DISTRIBUTION

The glider weight during flight is supported by a combination of centrifugal force and aerodynamic lift. The wing lift load is greater than the net lift by an amount necessary to counter-balance the down load on the body nose cone and trim load of the longitudinal control surfaces. The time history of the wing lift for the representative design is presented on the next chart.

[redacted]

DESIGN LOADS ENVELOPE



1-18001-272

D3-3191 PAGE 20

[redacted]

[redacted]

DESIGN LOADS ENVELOPE

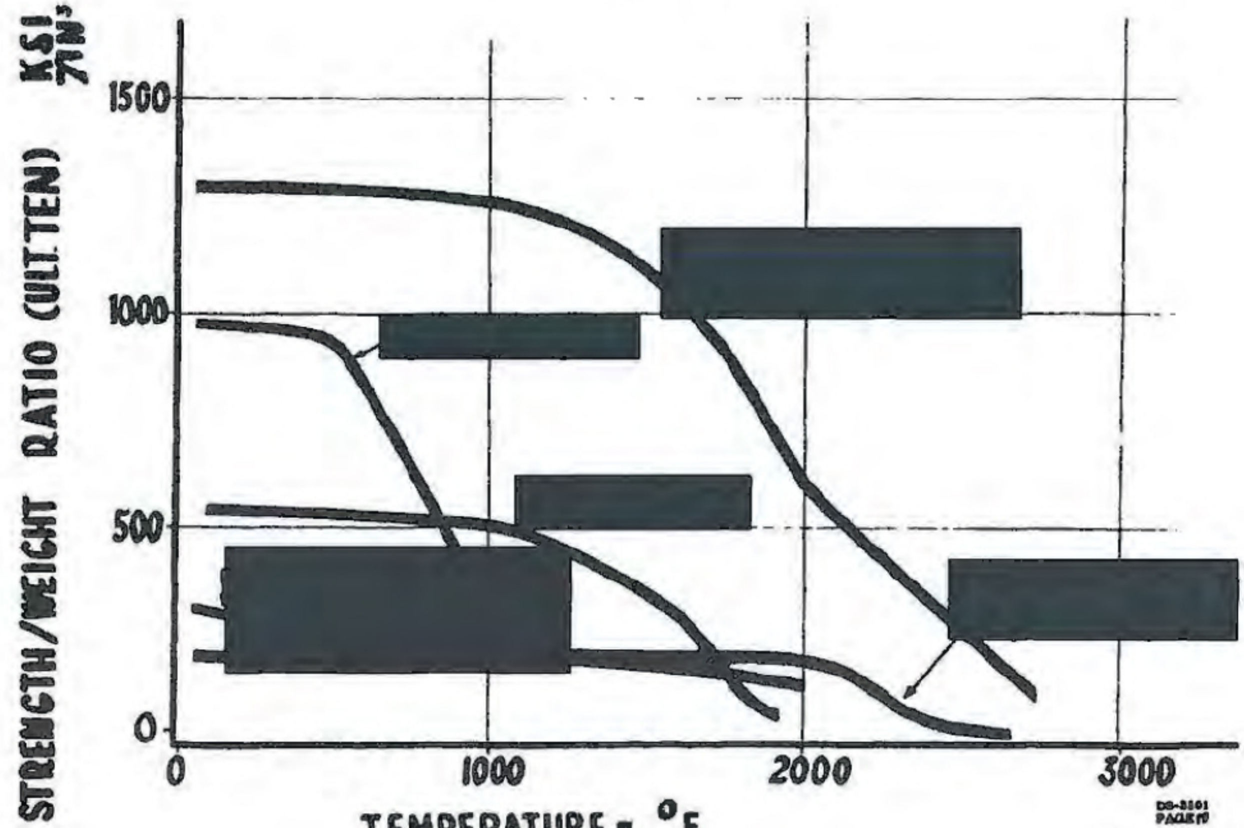
This chart presents the envelope of the maximum structural loads for the various portions of the representative boost-glide vehicle.

The pressure loads shown for the booster cases represent 120 % of the booster internal working pressure.

[redacted]

[redacted]

MATERIALS



[redacted]

[redacted]

MATERIALS

The materials used in the representative design are shown here in terms of the strength/weight ratio as a function of the temperature.

The leading edge of the wing and body nose [redacted] design temperature [redacted]

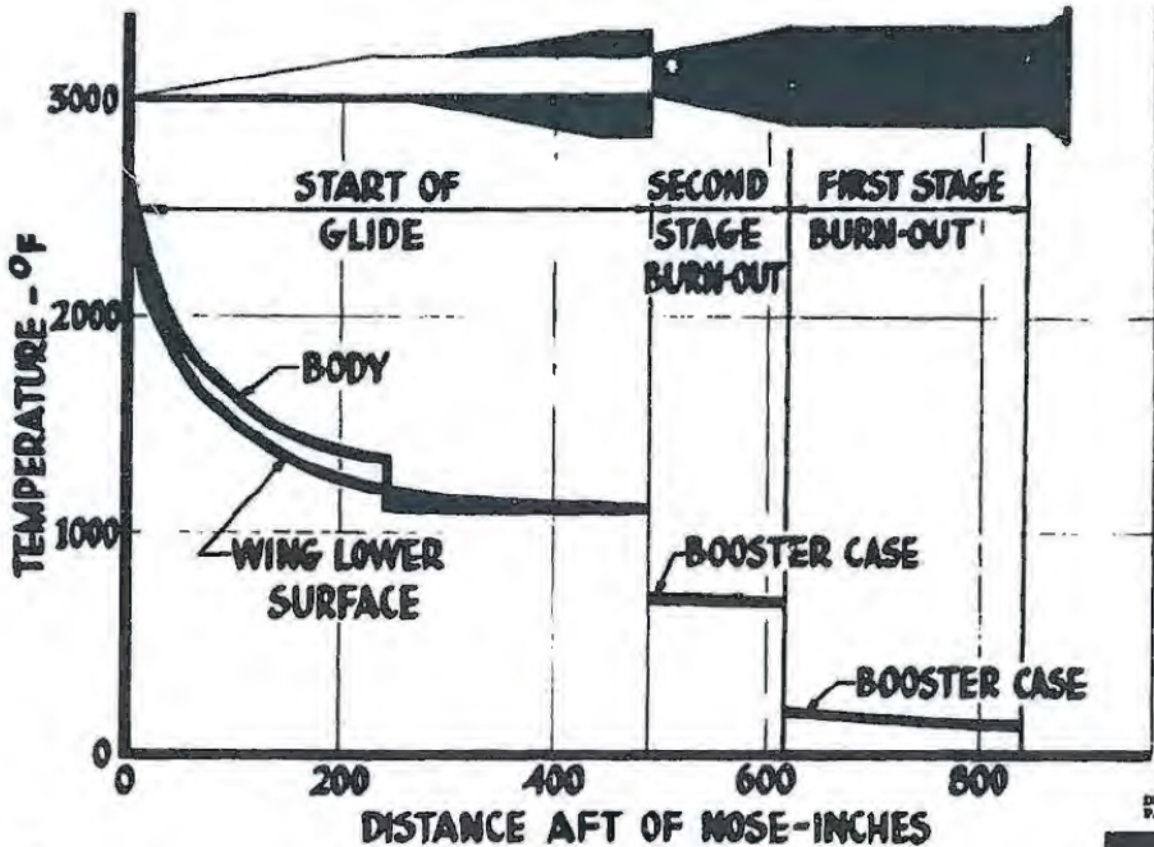
The lower wign skins, forward portion of the body nose, and the ventral and dorsal fin skins are [redacted] The remaining glider skins are designed [redacted]

The booster cases are designed [redacted]

[redacted]

[redacted]

DESIGN STRUCTURAL TEMPERATURES



[redacted]

[redacted]

DESIGN STRUCTURAL TEMPERATURES

The design structural temperatures for the various portions of the representative design are shown on this chart.

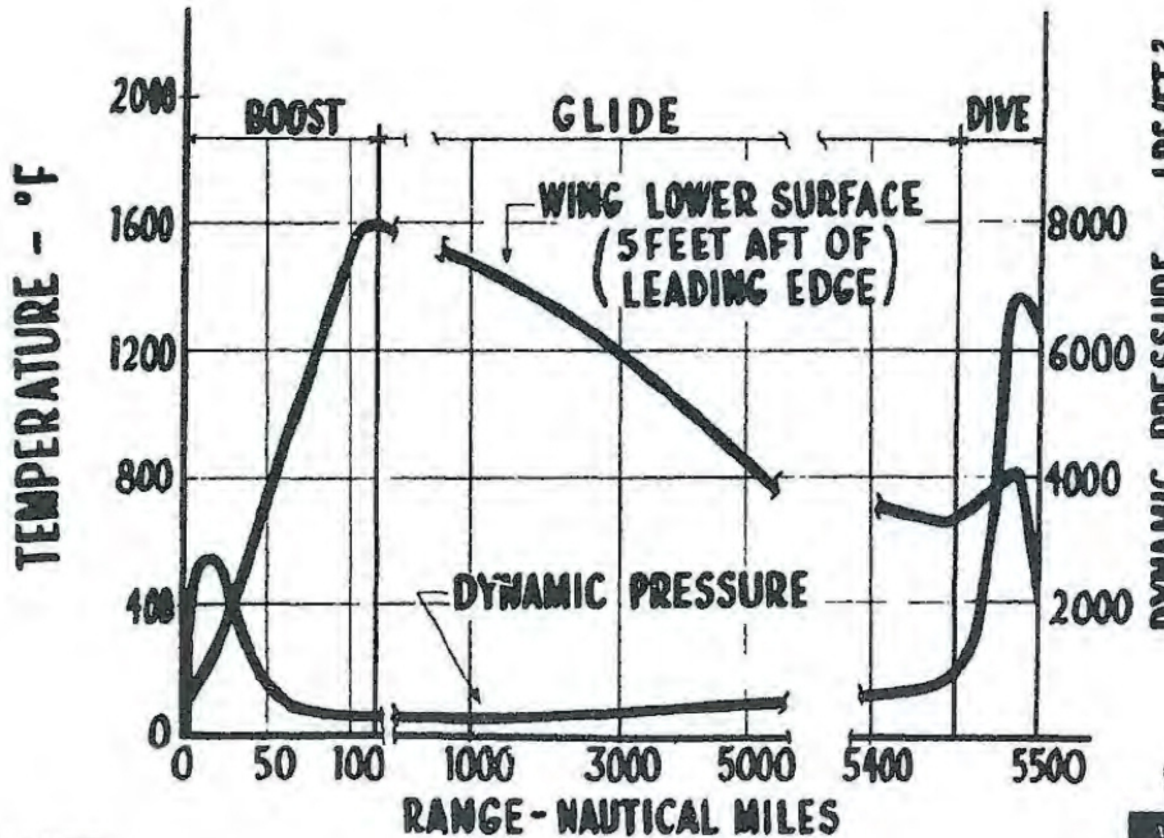
The maximum glider temperatures and maximum second stage booster temperatures occur at the end of the second stage boost or the start of the glide phase of flight.

The maximum temperature for the first stage booster case occurs at the end of first stage boost.

[redacted]

[redacted]

STRUCTURAL ENVIRONMENT



[redacted]

STRUCTURAL ENVIRONMENT

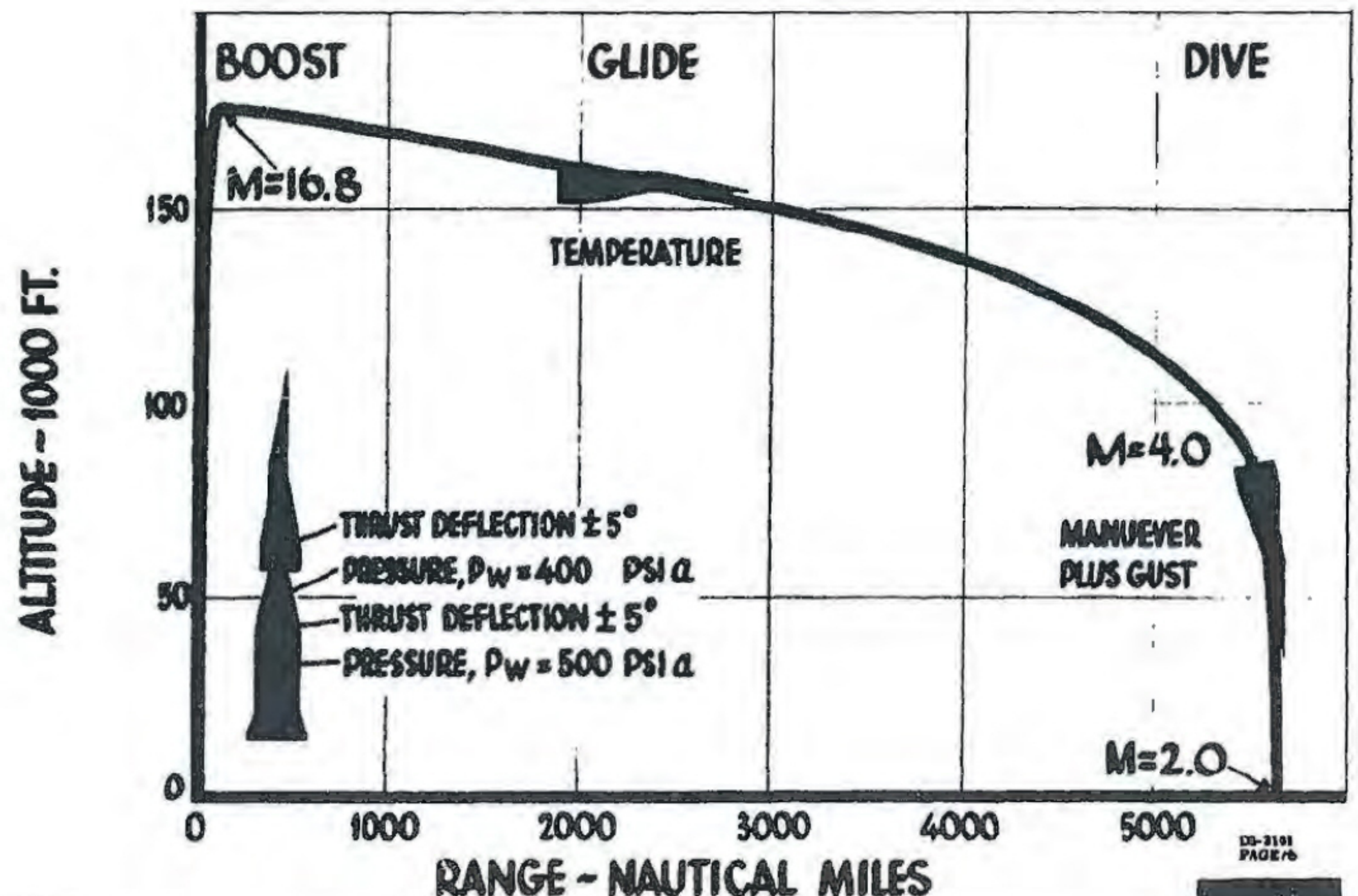
The structural environment associated with the mission profile of the previous chart is shown here in terms of a representative temperature variation and the dynamic pressure.

The maximum temperatures occur at the end of boost at start of glide. This is the temperature design condition and is the condition which in general determines the available structural materials.

The maximum dynamic pressure is encountered during the dive in or terminal phase. This is the design load condition and is the condition which determines in general the material gages to be used.

[redacted]

DESIGN REGIONS



[redacted]

1-30001-290

[redacted]

ATRAN FIX-TAKING CAPABILITY

ERROR SOURCE	LATERAL ERROR	LONGITUDINAL ERROR
STORAGE TUBE	185'	185'
VERTICAL STABILIZATION	370'	370'
AZIMUTH STABILIZATION	900'	—
VELOCITY CORRECTION	—	60'
ALTITUDE CORRECTION	—	400'
MAP SIMULATION	250'	250'
RADAR RESOLUTION	65'	20'
CEP	1000'	

[redacted]

[redacted]

ATRAN/INERTIAL SYSTEM ACCURACY

To the fix error must be added the error introduced by the inertial system in navigating from the fix point to the target. These curves show the CEP at the target for two different inertial systems when only one radar correction is made during flight. Also included in these curves is error due to the uncertainty in knowledge of the relative distance between target and checkpoint. This amounted to 500 feet at 100 nautical miles and increased slightly at the larger distances.

Since the difference in accuracy between the larger and smaller inertial systems is small in this application, it appears reasonable to select the [redacted] because of its lower weight and volume.

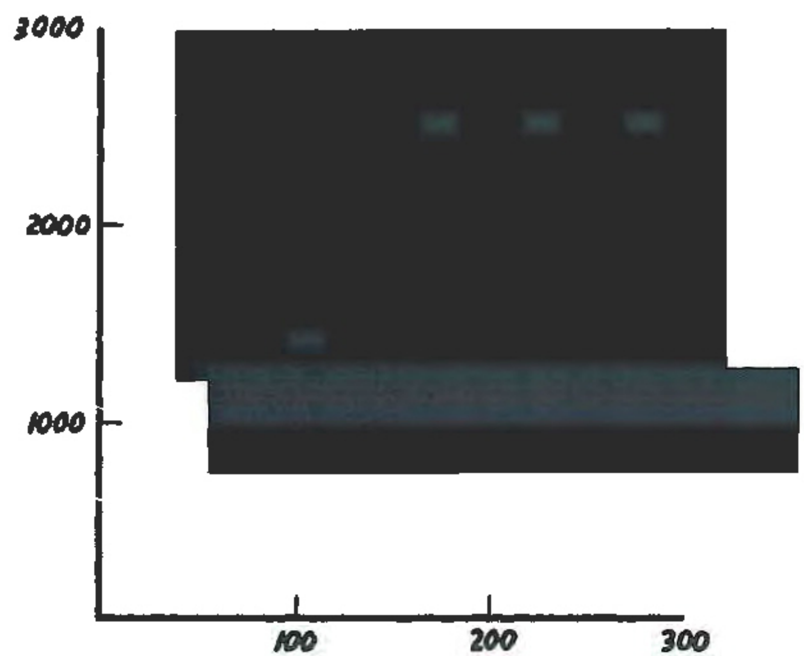
With the smaller system, the radar correction can be made with 97% certainty provided the ATRAN equipment can search through a 5 nautical mile radius. This is well within the capability of this equipment.

[redacted]

ATRAN-INERTIAL SYSTEM ACCURACY

MISSILE RANGE = 5500 N.M.

[redacted]



[redacted]

[redacted]

[redacted]

ACCURACY COMPARISON WITH INERTIAL SYSTEMS

This graph compares the accuracy of inertial guidance systems with the ATRAN/inertial system. The ATRAN/inertial system will give a [redacted] of whether or not the latitude and longitude of the target is accurately known. However, the relative distance between the target and checkpoint must be accurately known.

The larger inertial system will give a [redacted] the latitude and longitude of the target is accurately known. Otherwise, its accuracy is seriously degraded.

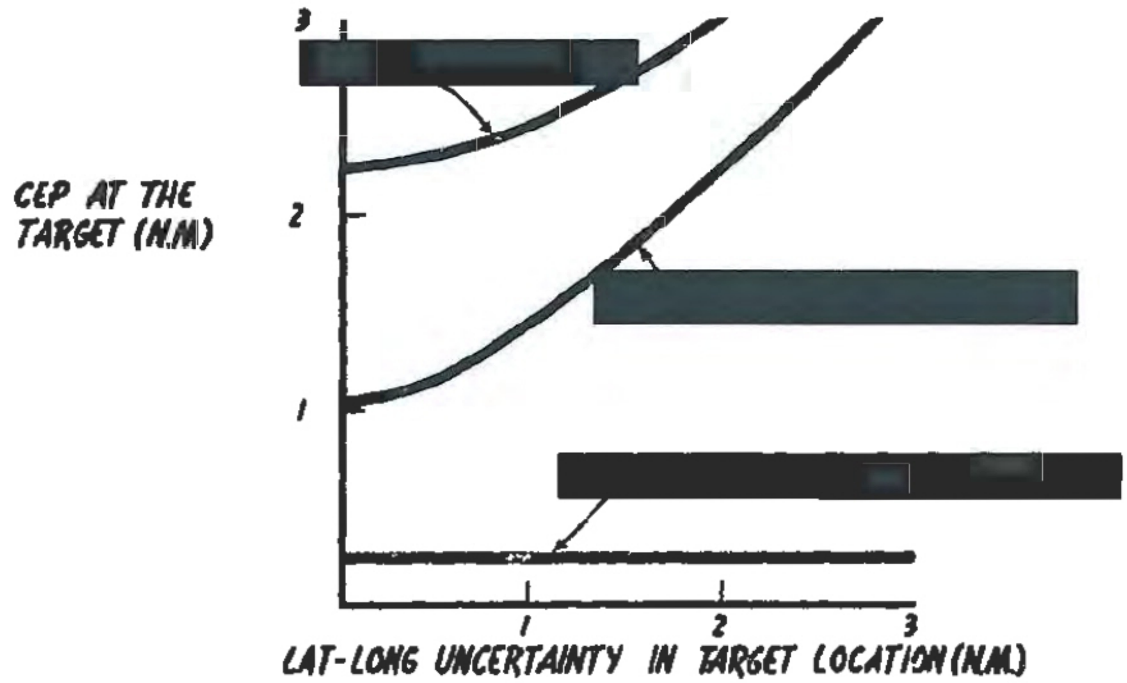
The high accuracy of the ATRAN/inertial system is an important feature [redacted]

[redacted]

[redacted]

ACCURACY COMPARISON WITH INERTIAL SYSTEMS

MISSILE RANGE = 5500 N.M.



[redacted]

[redacted]

[redacted]

FLIGHT TESTING

Shown here is the flight test experience accumulated with the various systems described.

The lack of flight testing on the area-matching ATRAN equipment is a significant disadvantage. As the altitude of flight is increased, a loss in radar contrast results. The seriousness of this effect can only be adequately evaluated by flight testing. Although there is no basic reason why radar operation in general will not be satisfactory at high altitude, there is some doubt about the optimum radar parameters for this application. A large, high power radar would not be compatible with the missile under consideration.

[redacted]

[redacted]

FLIGHT TESTING

HIGH ACCURACY INERTIAL SYSTEMS	~ 700 FLIGHTS
MEDIUM ACCURACY INERTIAL SYSTEMS	~ 300 FLIGHTS
SPOT MATCHING ATRAN SYSTEM (LOW ALTITUDE, LOW SPEED)	~ 1500 FLIGHTS
AREA MATCHING ATRAN	— NO TESTS

[redacted]

[redacted]

[redacted]

<u>SUMMARY</u>

The capabilities of inertial guidance systems have been demonstrated through numerous flight tests. They can be designed into a weapon system with a high degree of surety of obtaining the predicted performance.

However, since a much more effective weapon system will result in the ATRAN/inertial system is employed, it definitely merits additional development and testing so that the surety of its operation is guaranteed.

[redacted]

[redacted]

SUMMARY

- BOTH INERTIAL AND ATRAN-INERTIAL GUIDANCE SYSTEMS ARE TECHNICALLY FEASIBLE
- INERTIAL GUIDANCE SYSTEMS HAVE DEMONSTRATED CAPABILITY
- ATRAN-INERTIAL GUIDANCE DEFINITELY MERITS ADDITIONAL DEVELOPMENT & TESTING

[redacted]

[redacted]

<u>HYPERSONIC TESTING</u>

Boeing Airplane Company is doing extensive experimental work in direct support of the boost glide rocket bomber weapons system. One of the major experimental programs is in the field of hypersonic testing.

[redacted]

HYPERSONIC TESTING

BOEING
AIRPLANE
COMPANY

F33004-129

NEED FOR HYPERSONIC TESTING

The purpose of the hypersonic testing program is to establish, by means of scale model testing, the various aerodynamic parameters required for the design of a boost glide rocket bomber weapons system. To meet these objectives models and instrumentation have been designed and facilities have been obtained. Air Force support has been required for the use of some of the testing facilities.

[redacted]

Need for Hypersonic Testing

TO ESTABLISH

AERODYNAMIC FORCES
AERODYNAMIC LOADING
AERODYNAMIC HEATING

WITH THESE DESIGN REQUIREMENTS

HIGH LIFT TO DRAG RATIOS
OPERATING MACH NUMBERS TO 16
OPERATING ALTITUDES TO 180,000 FT.
OPERATING TEMPERATURES TO 2500 °F

[redacted]

FACILITIES AVAILABLE

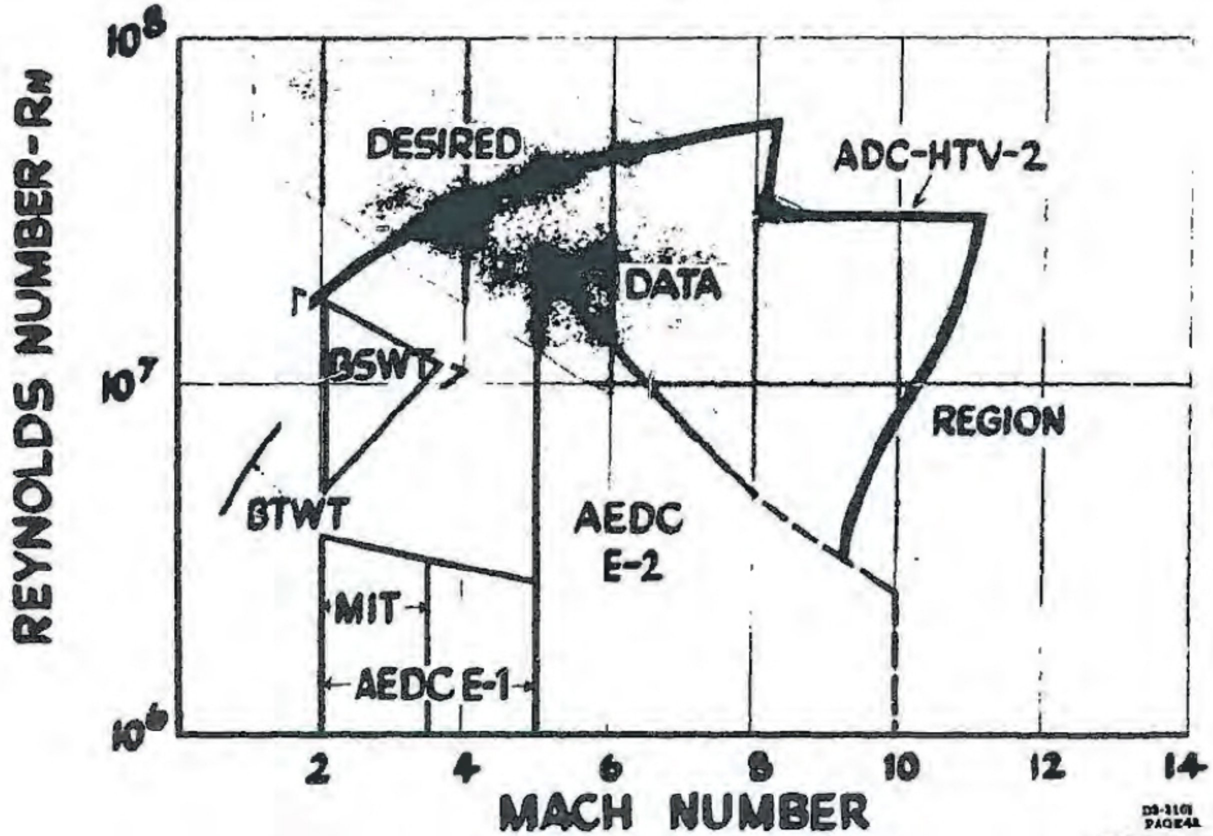
In determining suitable facilities, two of the primary correlating factors between model and full-scale are Reynolds number and Mach number. Good coverage of both of these correlating parameters will be achieved in the Boeing Program. For simplicity, the following abbreviations have been made on the chart:

ABBREVIATION	FACILITY
BTWT	Boeing Transonic Wind Tunnel Seattle, Washington
BSWT	Boeing Supersonic Wind Tunnel Seattle, Washington
MIT	Naval Supersonic Laboratory Massachusetts Institute of Technology Boston, Massachusetts
AEDC E-1	Arnold Engineering Development Center Gas Dynamics Facility E-1 Wind Tunnel Tullahoma, Tennessee
AEDC E-2	Arnold Engineering Development Center Gas Dynamics Facility E-2 Wind Tunnel Tullahoma, Tennessee
ADC HTV-2	Aerophysics Development Corporation Hypersonic Test Vehicle - 2 Free Flight Rocket Model Holloman Air Force Base

[redacted]

[redacted]

Facilities Available



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[redacted]

[redacted]

FACILITIES AVAILABLE

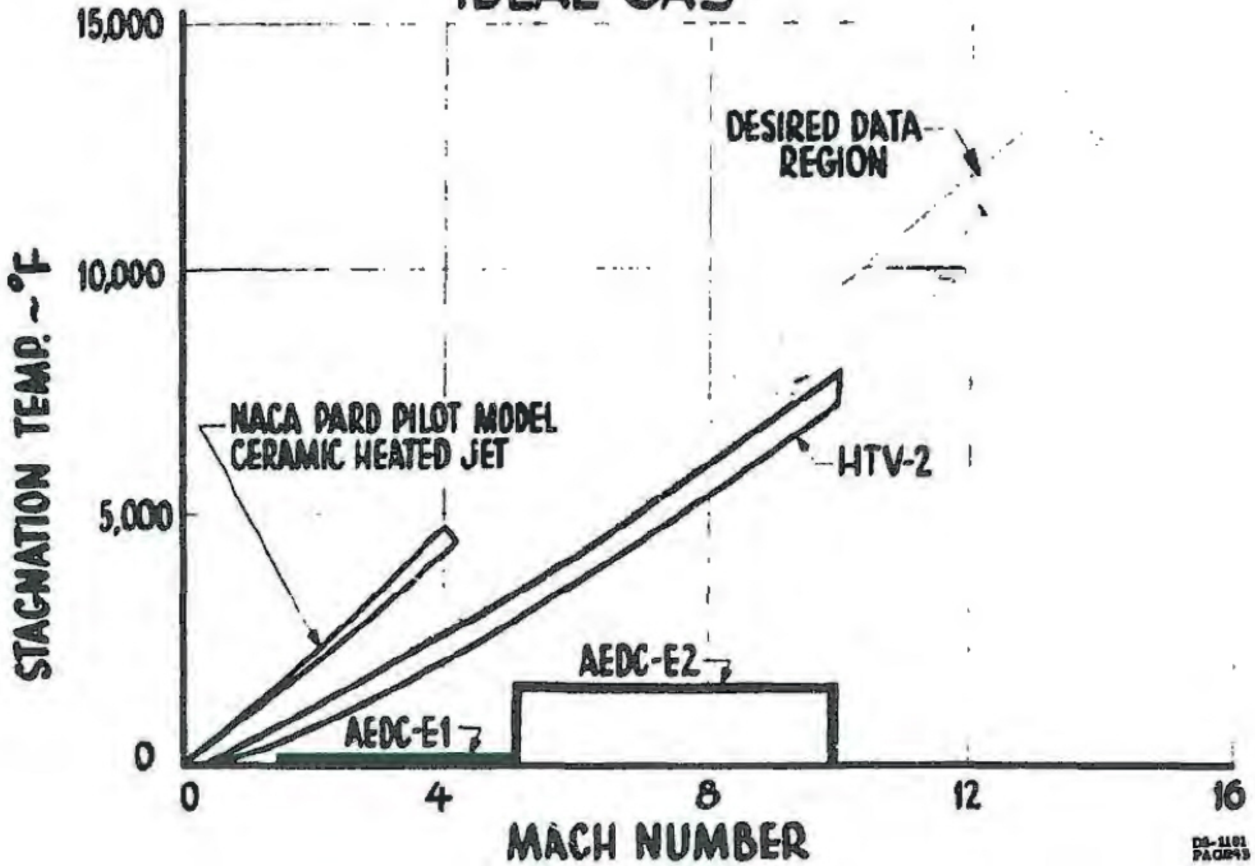
Of equal importance in the correlation of model and full-scale results is temperature. The wind tunnels do not provide sufficient temperature for aero-thermal evaluation. The HTV-2 facility will provide both Mach number and temperature for this correlation. In addition and with the cooperation of NACA, material evaluation is being done in the NACA PARD Pilot Model Ceramic Heated Jet at Langley Field, Virginia.

[redacted]

[redacted]

Facilities Available

IDEAL GAS



1-33001-132

[redacted]

[redacted]

HYPERSONIC TESTING PROGRAM

With the facilities obtained, the Boeing Airplane Company has established a schedule of testing for the next twelve month period which will lay the basic ground work from which the objectives of the hypersonic testing program can be achieved. The objectives of each test period are summarized as follows:

DATE	FACILITY	OBJECTIVES
April, 1957	MIT	Supersonic Wing-Body Investigation
June, 1957	MIT	Supersonic Planform Investigation
August, 1957	BTWT	Boost Drag and Stability
October, 1957	BSWT	Terminal Phase Stability and Control

The objectives of the other test programs are discussed in more detail in subsequent charts.

[redacted]

[redacted]

HYPERSONIC TESTING PROGRAM

		A	M	J	J	A	S	O	N	D	J	F	M	A
HYPERSONIC M=3.5-10	FREE FLIGHT ADC HTV-2							✓	✓					
	WIND TUNNEL AEDC E-1		✓											
	AEDC E-2							✓*						✓
	BHWT							✓						
	FREE JET NACA PARD			✓										
SUPERSONIC M=2.0-3.5	WIND TUNNEL MIT NSL	✓		✓										
	BSWT							✓						
SUBSONIC-TRANSONIC M=0.5-1.2	WIND TUNNEL BTWT					✓								

* STANDBY

1957

D2-1101 PAGE 91

1-10007-269

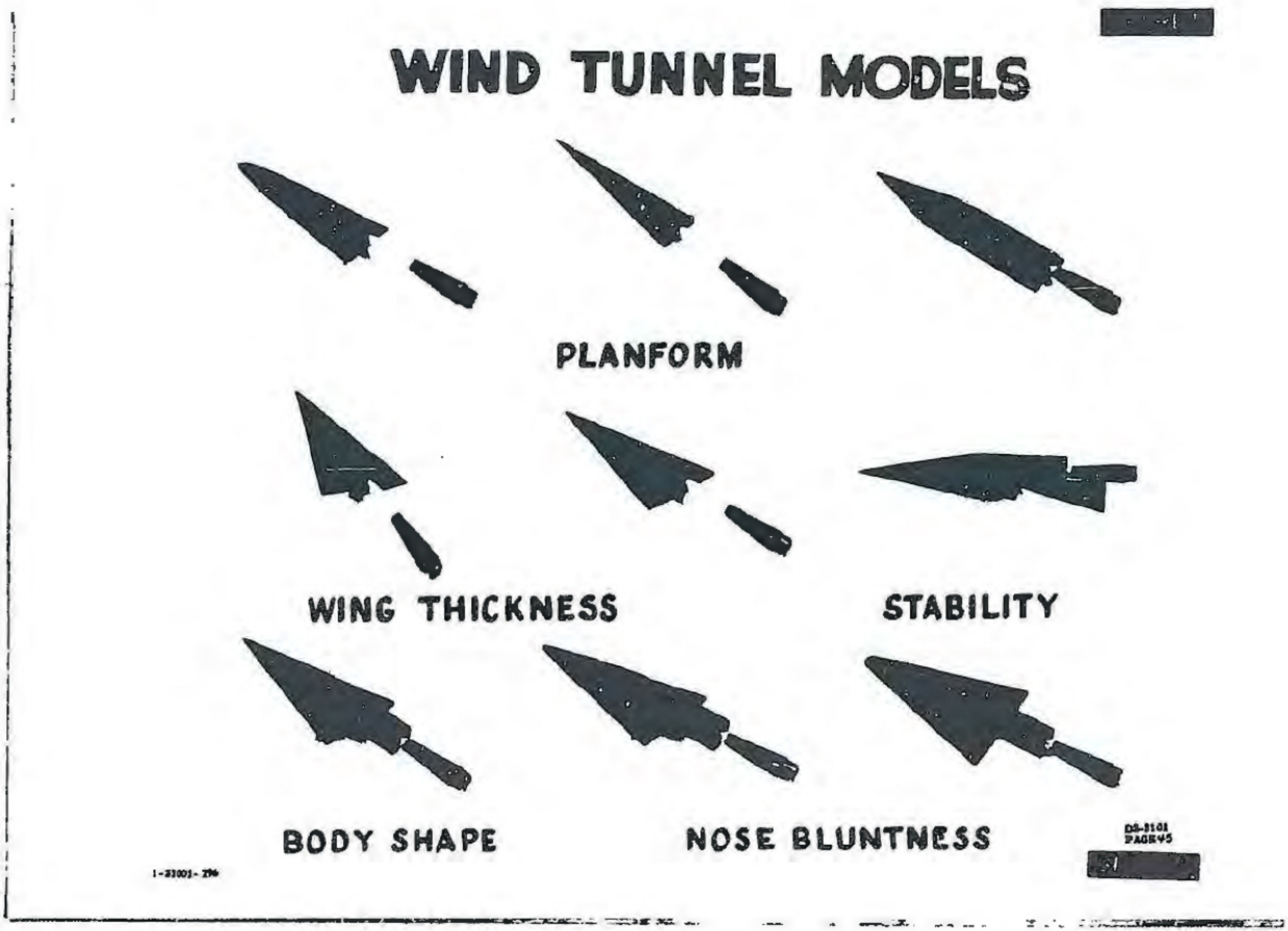
[redacted]

[redacted]

WIND TUNNEL MODELS

The AEDC E-1 test period in May, 1957, had the basic objectives of determining the effects of wing planform, wing thickness, and body shape on the aerodynamic forces. In addition, directional stability was also investigated. These parameters were investigated up to a Mach number of 5.

[redacted]


[redacted]
WIND TUNNEL MODELS
PLANFORM
WING THICKNESS
STABILITY
BODY SHAPE
NOSE BLUNTNESS
DS-3101
PAGE45
[redacted]
1-33001-296

[redacted]

WING PLANFORM (TEST)

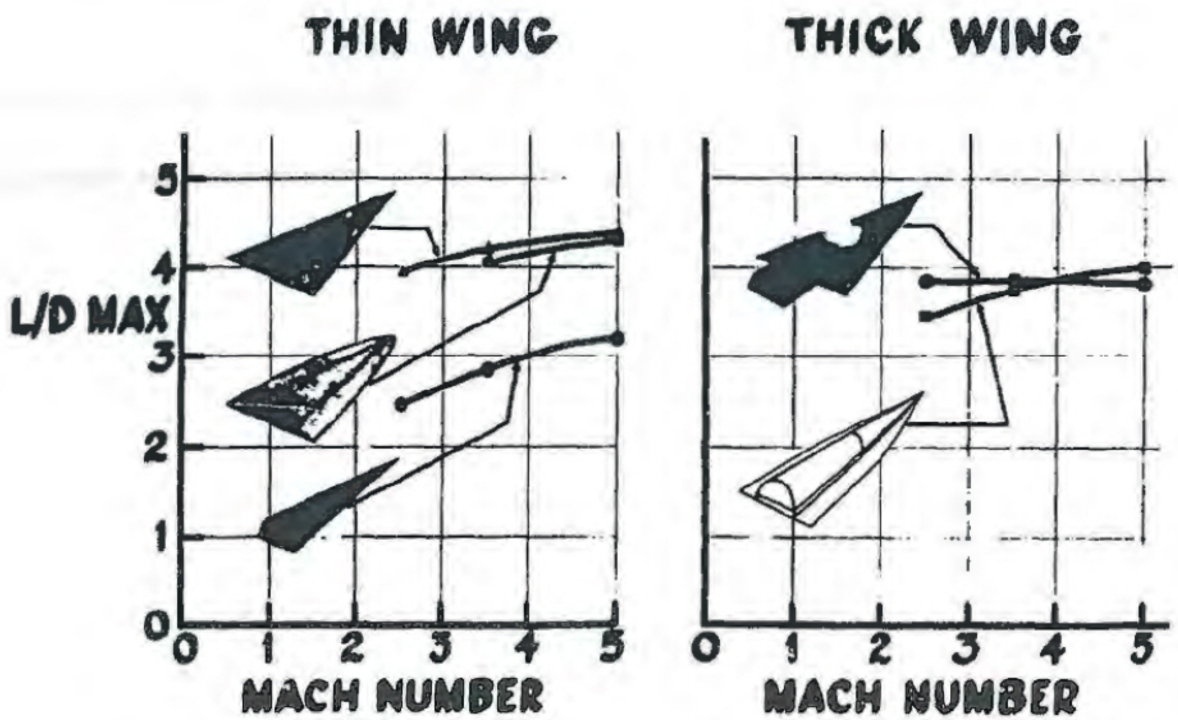
The range of a boost-glide rocket bomber is directly proportional to L/D. The preliminary results from the wind tunnel tests indicate that a triangular wing planform is superior to either a parabolic wing planform or a half cone planform. Clipping the tips of the triangular wing planform showed still further improvement in L/D at the higher Mach numbers.

It should be noted that the L/D's presented are at the test Reynolds number, and, hence, are lower than would be expected full-scale.

[redacted]

[redacted]

Wing Planform
TEST



1-33001-298

DS-8101
PAGE 90

[redacted]

[redacted]

BOUNDARY LAYER CONDITIONS

One of the primary purposes of the wind tunnel program is to establish the applicable aerodynamic theories to be used in the hypersonic regime. In the wind tunnel, transition was fixed at the leading edge of the triangular wing planform to obtain fully turbulent flow. A comparison of the test data with modified Newtonian theory would indicate that at the Mach number of 5, the theory is somewhat conservative.

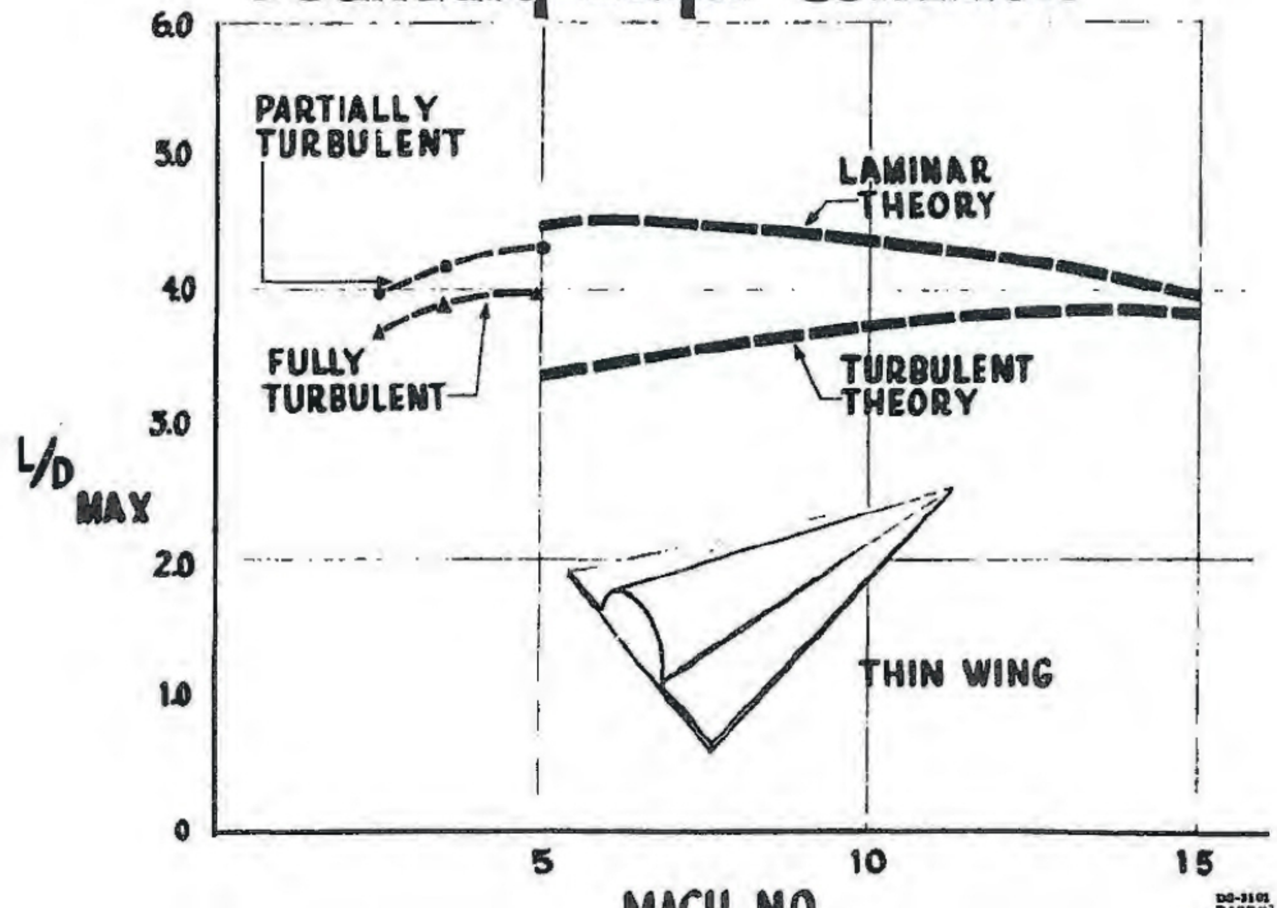
Without fixing transition, higher L/D's were obtained indicating some laminar flow over the model during test.

The results of the test program to date indicate that testing at higher Mach numbers is required before the applicable theories can be fully established.

[redacted]

[redacted]

Boundary Layer Condition



1-13001-299

[redacted]

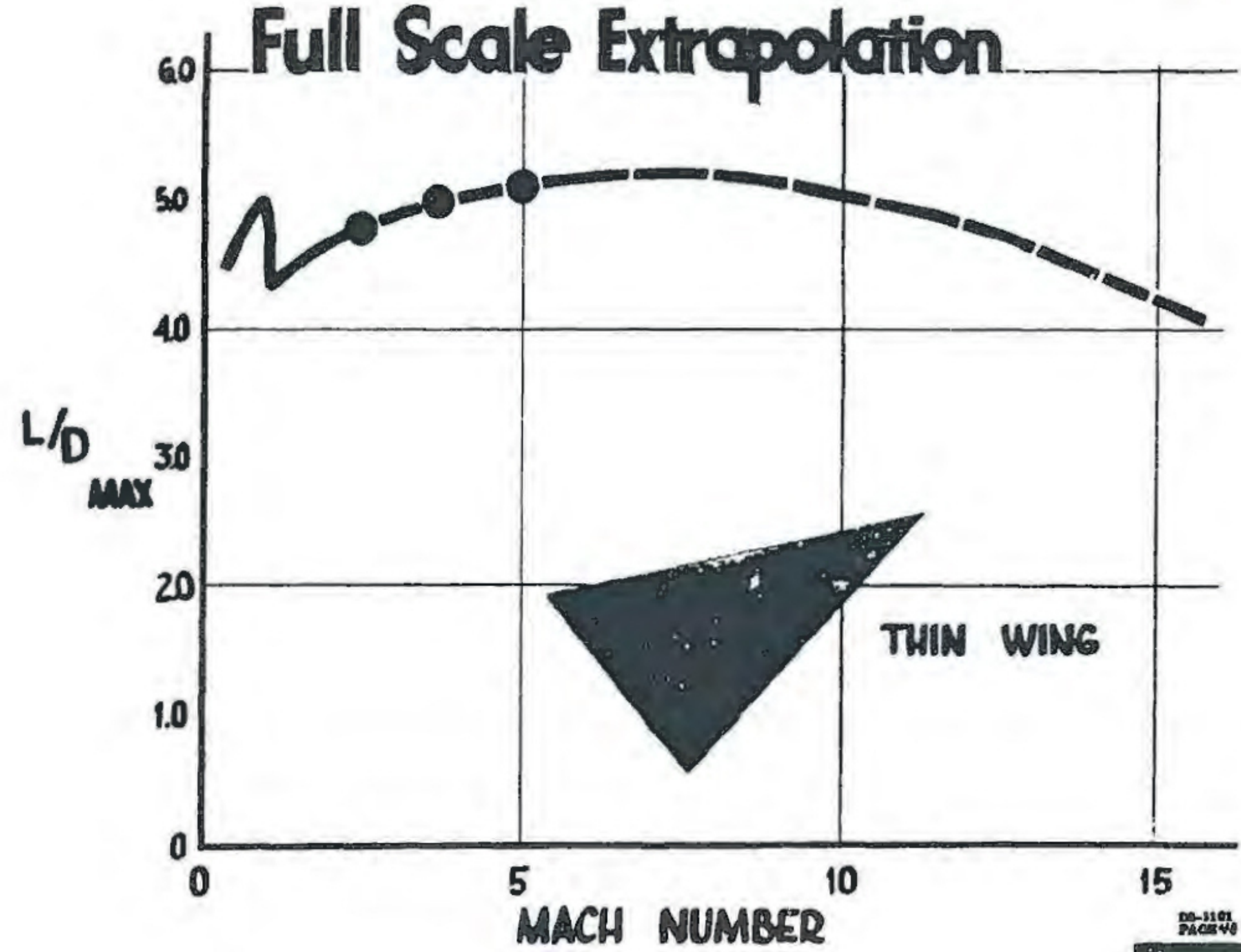
[redacted]

FULL-SCALE EXTRAPOLATION

The results obtained in the Wind Tunnel can be extrapolated to full-scale by assuming that the same amount of laminar flow would exist full-scale as was obtained in the Wind Tunnel. This full-scale extrapolation would indicate that L/D_{max}'s in the order of 4.5 to 5 could be obtained.

[redacted]

[redacted]



[redacted]

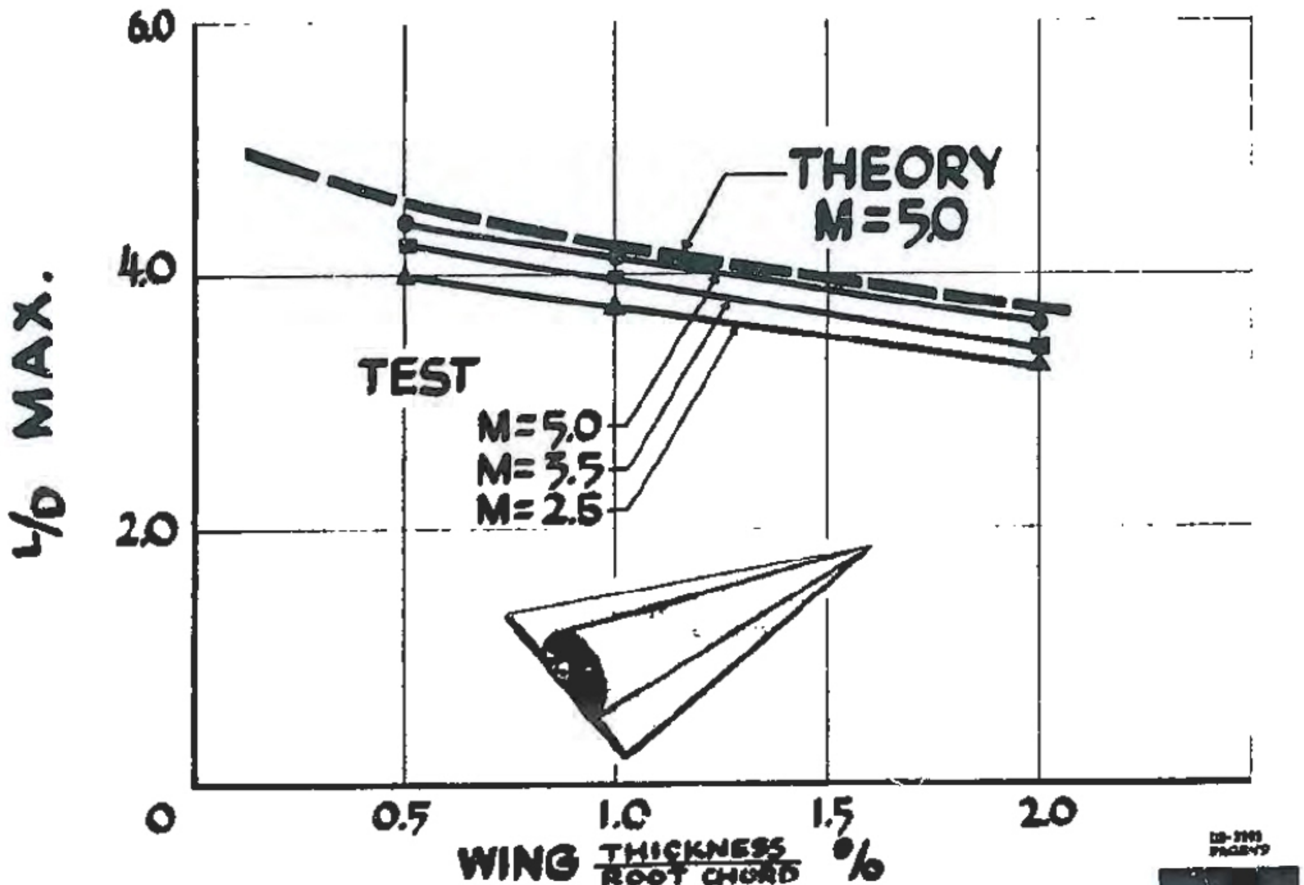
[redacted]

WING THICKNESS.

The effect of wing thickness upon L/D was investigated in the Wind Tunnel at test Reynolds numbers. The results obtained indicate that the penalty in performance obtained due to thickening the wing for aerodynamic heating reasons correlates reasonably well with theoretical predictions.

[redacted]

Wing Thickness



[redacted]

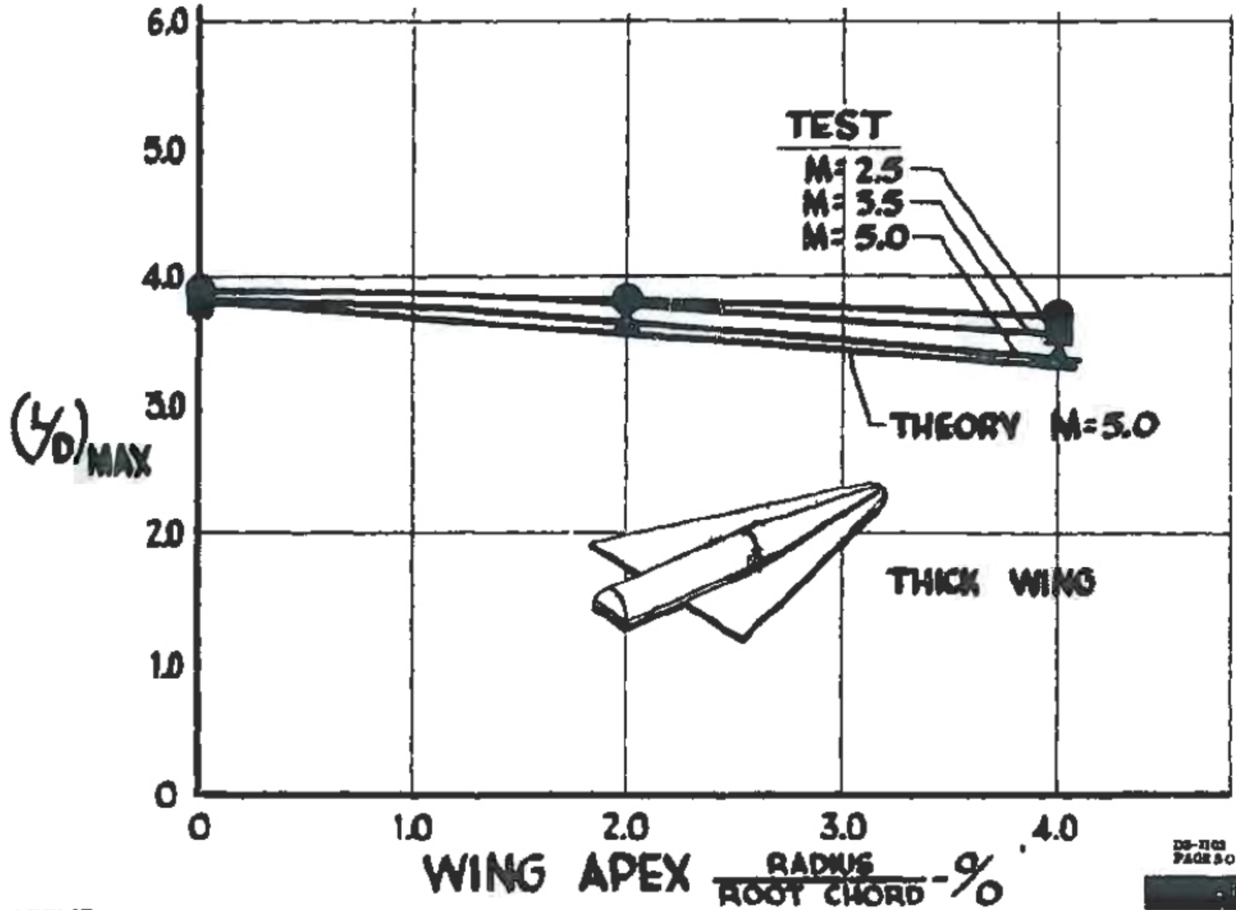
NOSE BLUNTNESS

The effect of blunting the nose upon L/D was investigated in the Wind Tunnel at test Reynolds numbers. The results obtained indicate that the penalty in performance obtained due to blunting for aerodynamic heating reasons correlates reasonably well with theoretical predictions.

[redacted]

[redacted]

Nose Bluntness



[redacted]

[redacted]

DIRECTIONAL STABILITY

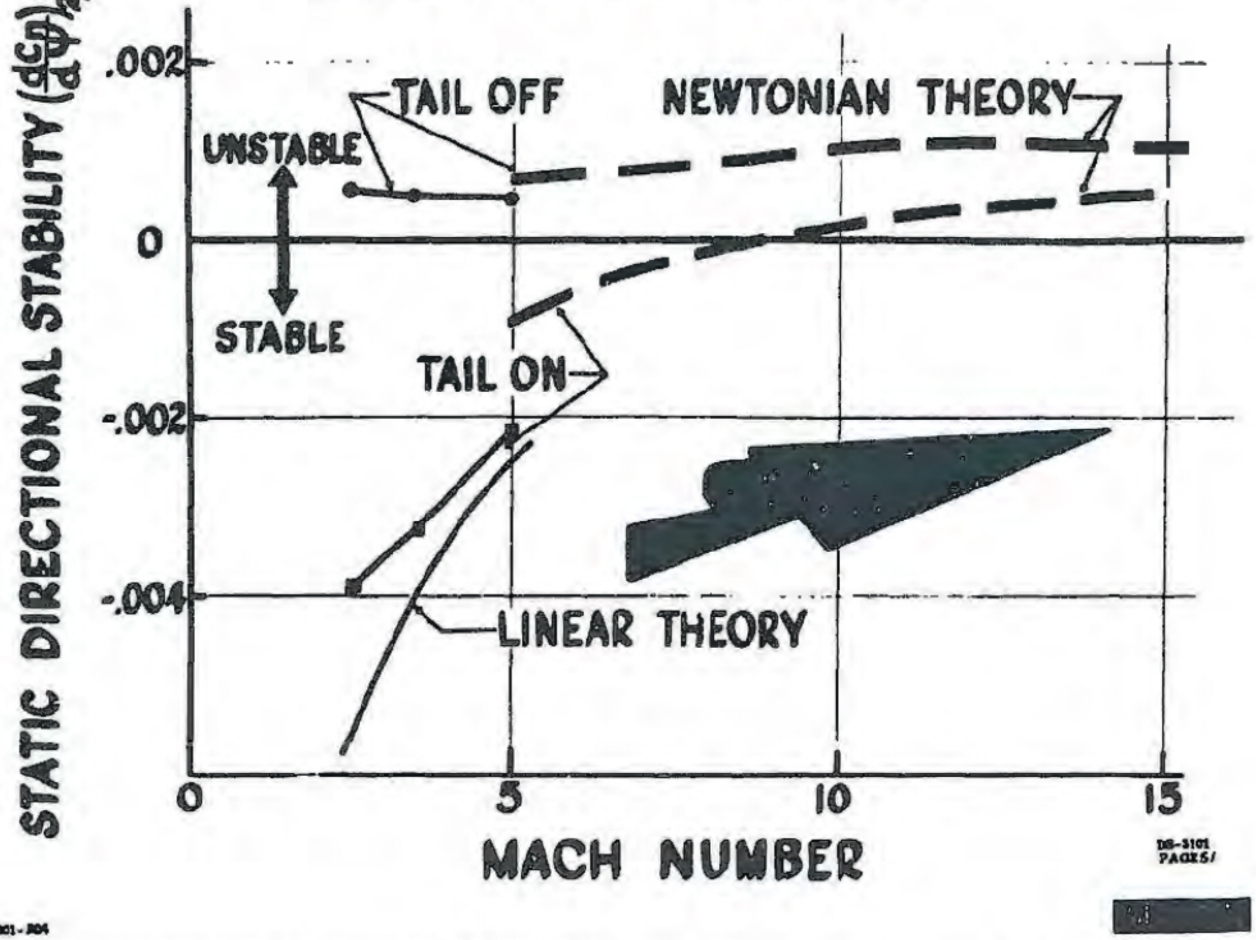
Directional stability of hypersonic vehicles was also investigated. A comparison of test and theory indicates that at a Mach number of 5, modified Newtonian theory compares reasonably well with test data for tail-off directional stability. For tail-on configurations, the test data at a Mach number of 5 compares more favorably with Linear theory than Newtonian theory.

Test data at higher Mach numbers is necessary before the applicable theories throughout the entire speed range can be determined.

[redacted]

[redacted]

DIRECTIONAL STABILITY



[redacted]

[redacted]

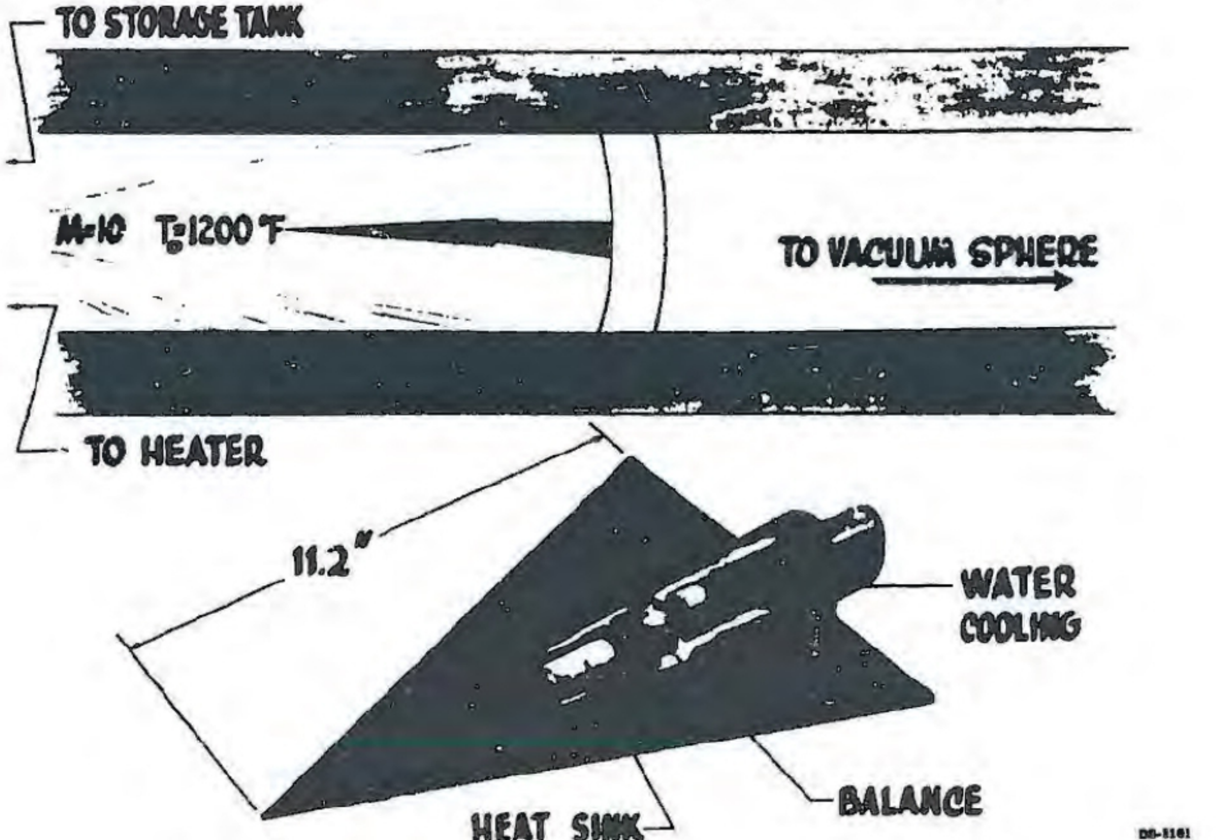
WIND TUNNEL TESTING TECHNIQUE

In October, 1957, the basic test program of AEDC E-1 will be extended to a Mach number of 6 in the AEDC Gas Dynamics Facility E-2 Wind Tunnel. The higher operating temperatures of the tunnel require that force balances be protected from these higher temperatures in order to obtain accurate data. Water cooled balances have been designed, built and calibrated for this test period.

[redacted]

[redacted]

Wind Tunnel Testing Technique



[redacted]

I-33001-133

[redacted]

BOEING HYPERSONIC WIND TUNNEL

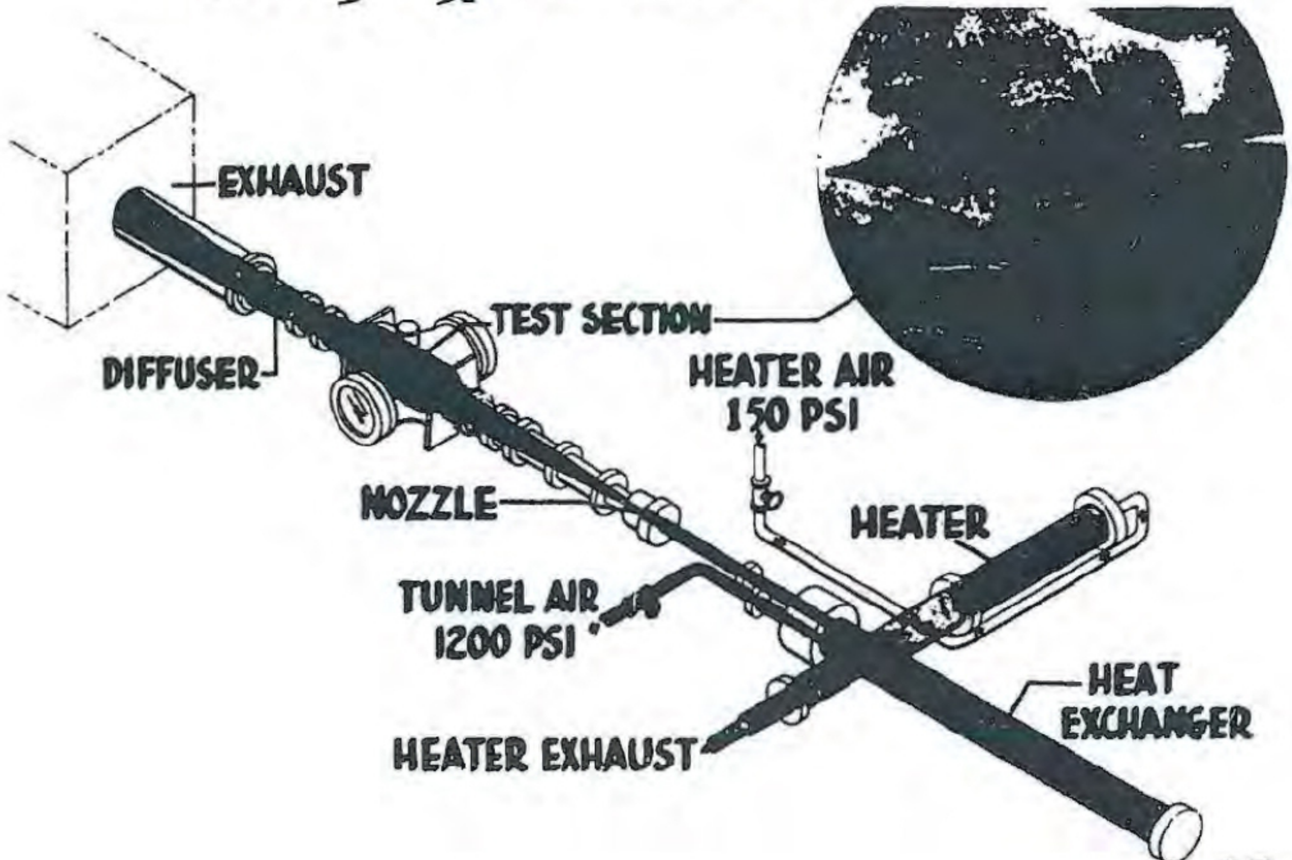
Early in 1957, it became evident that there were not enough hypersonic test facilities available in the near future to do development testing for the boost-glide rocket bomber weapons system. In order to improve this situation, Boeing constructed and is now operating a hypersonic wind tunnel. It has a Mach number range of 5.0 to 7.5 and test section size of 6 to 8 inches. The picture is a Schlieren photograph of a triangular wing-half cone configur-ation at a Mach number of 6.65.

Testing in this facility has indicated that with new nozzles and with test section and diffuser of larger size, it will be possible to test models of the same scale planned for the AEDC E-2 test program. The use of this facility will make it possible to more efficiently use the test time in the E-2 test facility.

[redacted]

[redacted]

Boeing Hypersonic Wind Tunnel



D2-3101
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[redacted]

1-55003-297

[redacted]

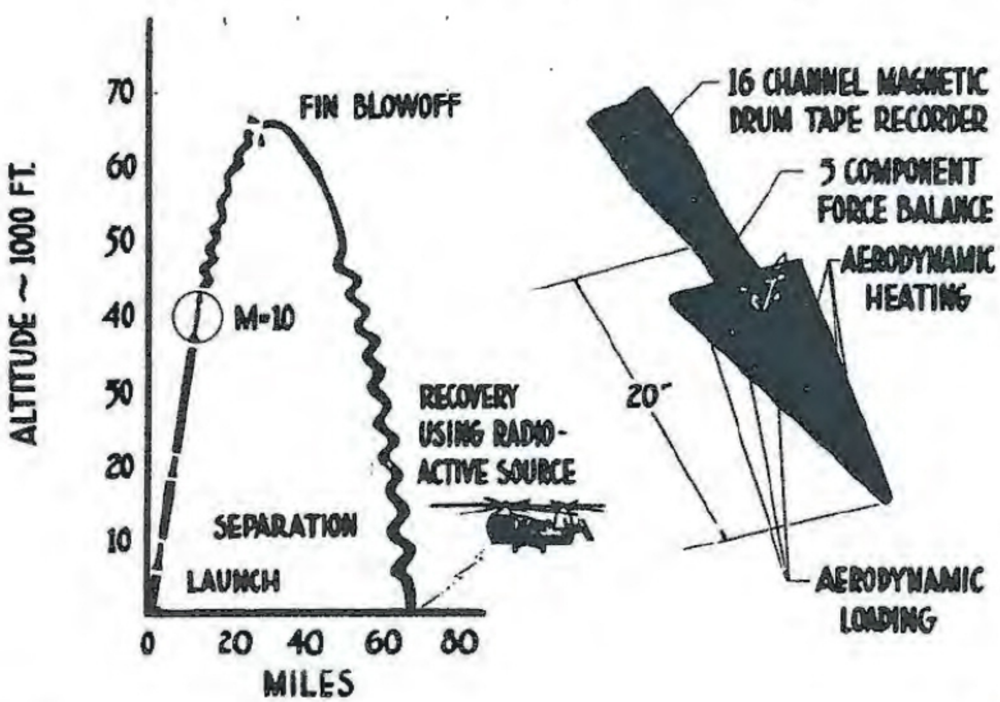
HTV-2 TESTING TECHNIQUE

In October, 1957, the first rocket-boosted free flight test program will be initiated. This will be done by using the hypersonic test vehicle No. 2 operating from Holloman Air Force Base. Aerodynamic load, heating, and force data will be recorded on tape throughout the entire flight of the test vehicle. From 0 to 40,000 feet and a Mach number of 10, data will be obtained at zero angle of attack. Above 40,000 feet, the model will be pitched to obtain data at varying angles of attack. At a higher altitude three of the four fins of the thrust stage are blown off and the model is destabilized and falls to the earth. The model and data type recorder are recovered and the data are processed for analysis.

[redacted]

[redacted]

HTV-2 Testing Technique



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[redacted]

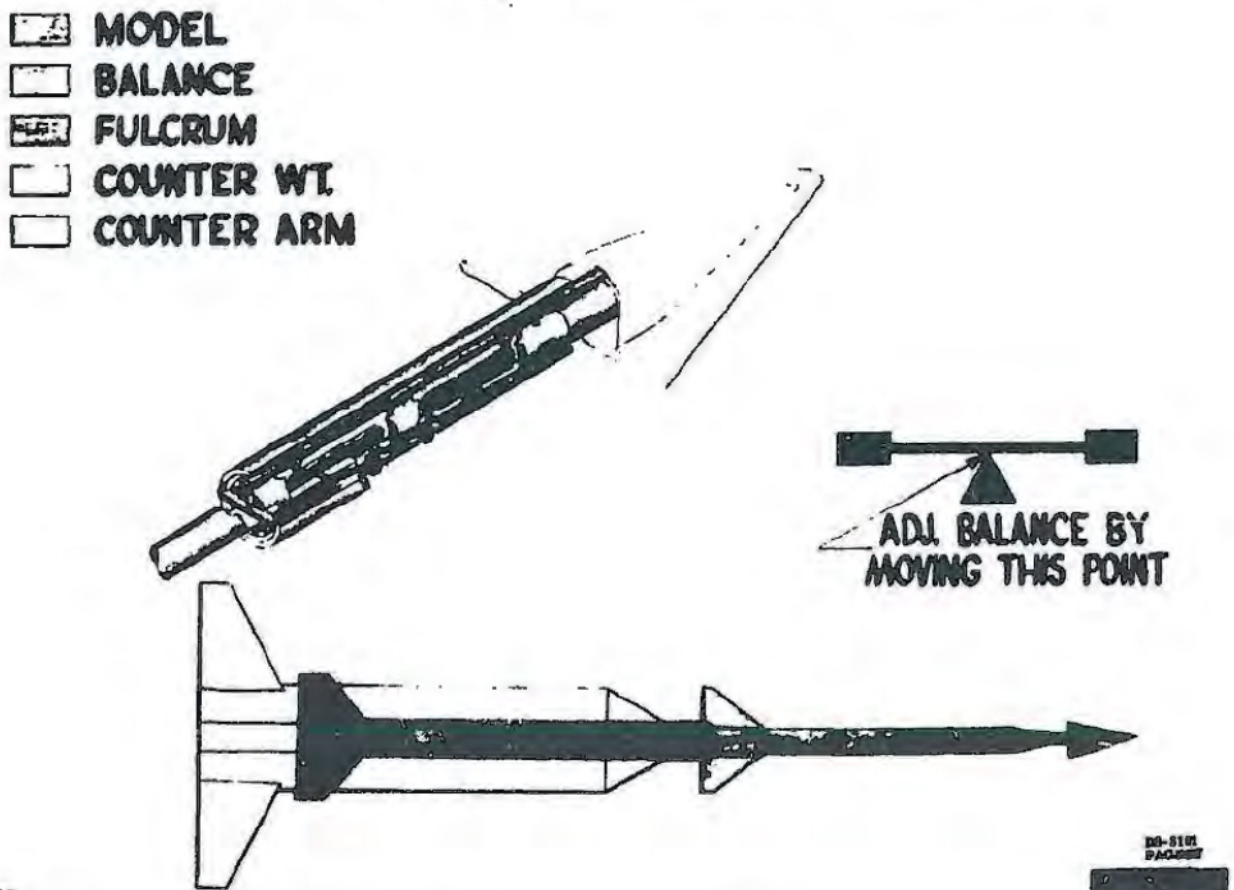
[redacted]

INERTIA COMPENSATED BALANCE

In order to obtain force data under the high accelerations encountered on the hypersonic test vehicle, an inertia compensated balance had to be developed. This balance is located between the third stage and the model. It operates upon the principle of counter balancing the model and balance mass loads by means of a counter weight supported on an arm and fulcrum. A test balance has been successfully calibrated and the final balance is 50% complete.

[redacted]

Inertia Compensated Balance



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[redacted]

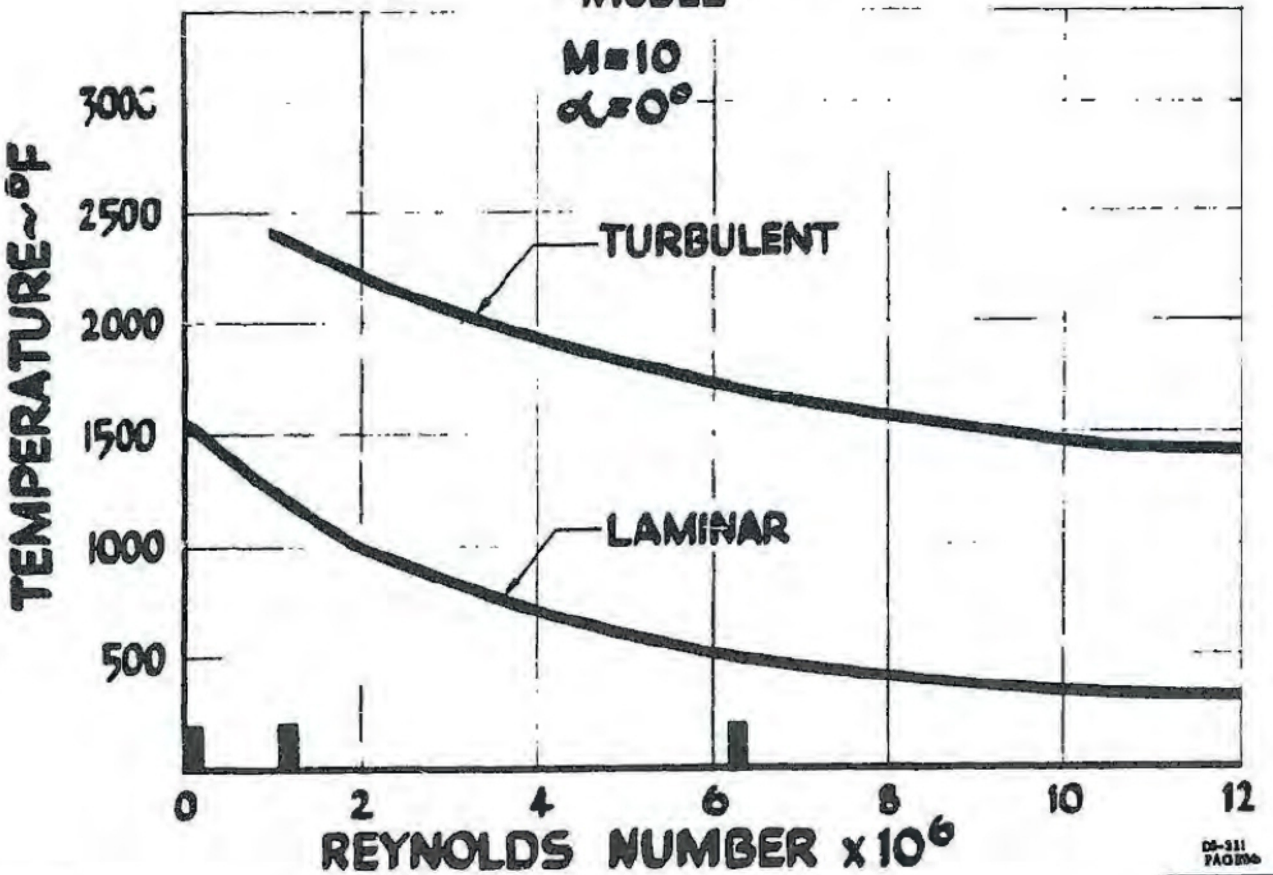
TRANSITION

The temperature measurements on the model will give some indication as to whether the flow is laminar or turbulent. At a given Mach number and altitude, the thermocouple locations on the chord of the wing represent various Reynolds numbers. The level of temperature at these thermocouple locations will then give an indication whether the flow is laminar or turbulent.

[redacted]

[redacted]

Transition
MODEL



DS-311
PAGE106

[redacted]

1-33001-149

[redacted]

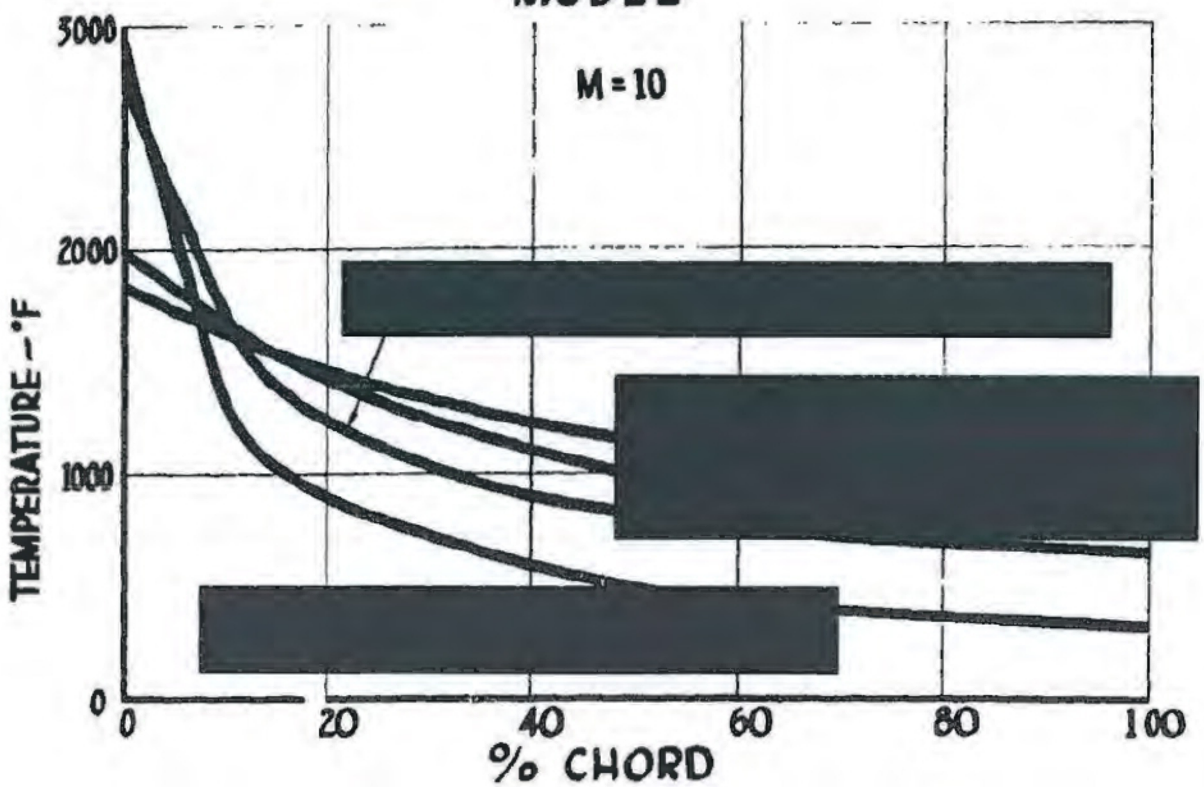
MATERIAL SELECTION

In order to withstand the temperatures anticipated for the model, a study was made of various model material combinations. From this study, a solid molybdenum wing was selected because of its strength-temperature capabilities and moderate chord wise temperature gradient.

[redacted]

[redacted]

Material Selection
MODEL



[redacted]

I-33001-151

[redacted]

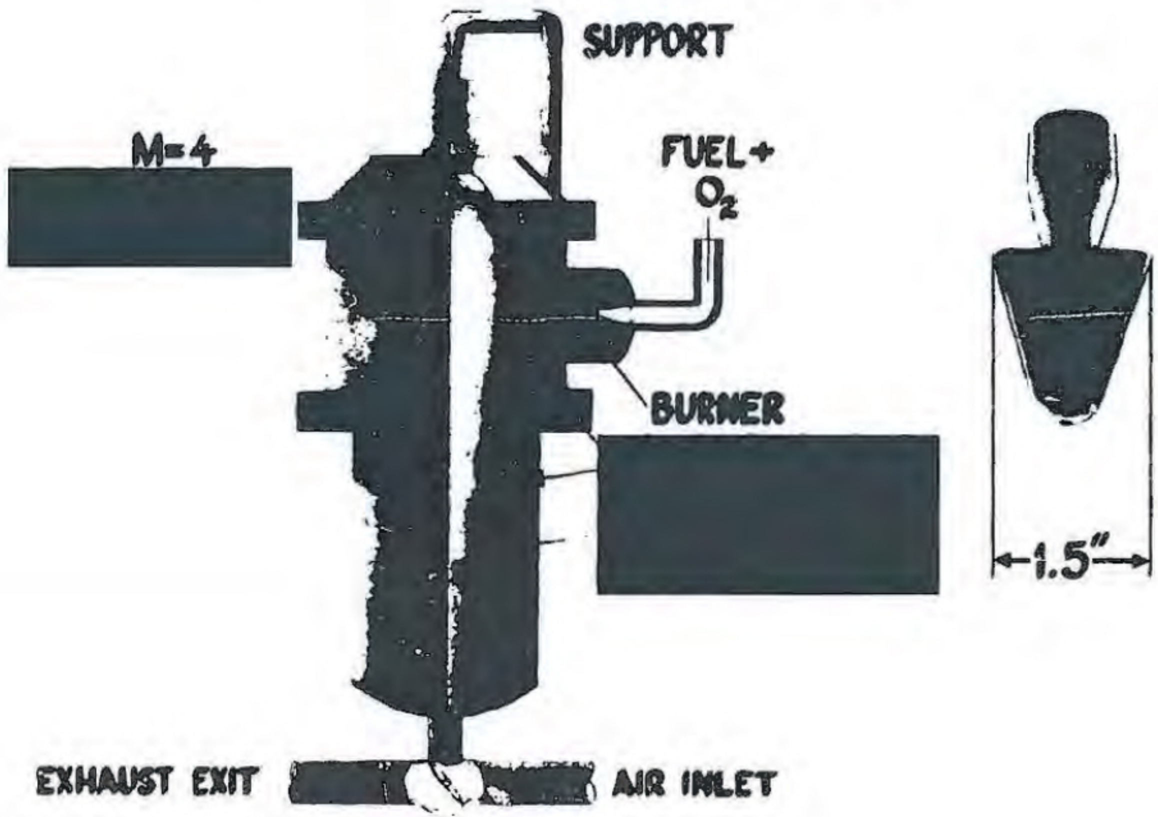
FREE JET TECHNIQUE

The nose of the free flight model will be subjected to extremely high temperatures. In order to determine the proper shape and finish for the nose of the model, a test program is being conducted with the cooperation of NACA PARD, Langley Field, Virginia. The facility for this program is the pilot model ceramic heated jet. Air is forced under pressure over [redacted]

[redacted]

[redacted]

Free Jet Technique



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[redacted]

[redacted]

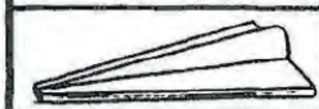
FREE JET TESTS

The program for this test involves testing various nose configurations at angle of attack with and without protective coatings.

[redacted]

[redacted]

Plan of Test

CONFIGURATION	ANGLE	COATING			
[redacted]					
	0° ± 10°	✓	✓	✓	✓
	0° +10°	✓	✓		
	-10°	✓			
	-10°	✓			

TEST RESULTS
1. VISUAL OBSERVATION
2. TEMPERATURE MEASUREMENT
3. PRESSURE MEASURMENT

1-35001-146

[redacted]

[redacted]

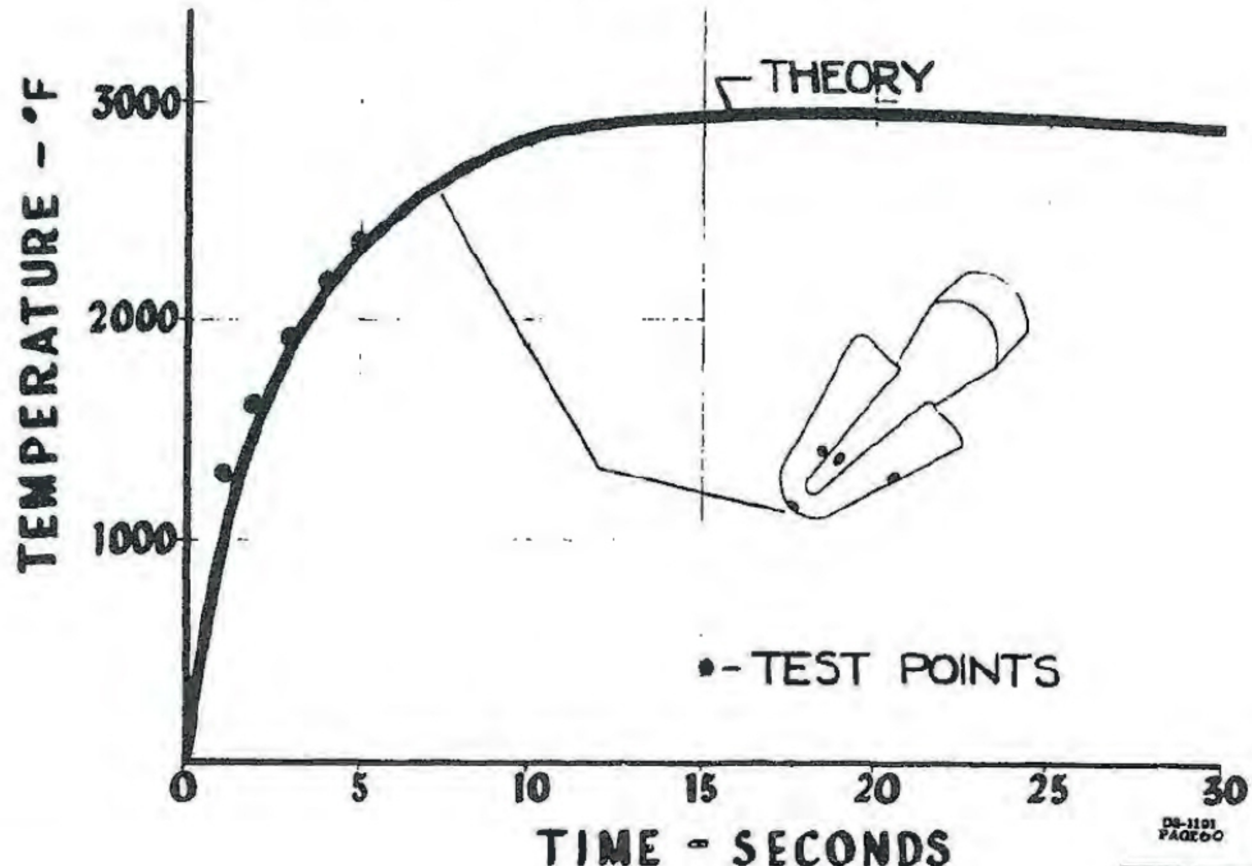
FREE JET TEST RESULTS

The theoretical temperature-time history [redacted] compared with test data. This comparison indicates the close correlation between theory and experiment.

[redacted]

[redacted]

Free Jet Test Results



[redacted]

[redacted]

THERMAL WARPAGE

In addition to the aero-thermal experimentation on materials for the free flight model, static temperature experiments were also conducted. An exact duplicate steel model wing was instrumented with thermocouple and strain gages to determine the thermal warpage characteristics of the model. High temperature quartz rods were placed around the leading edge of this model and temperature-time, deflection-time histories were measured.

[redacted]

[redacted]

Thermal Warpage

INSTRUMENTED MODEL

HEAT SOURCE

[redacted]

[redacted]

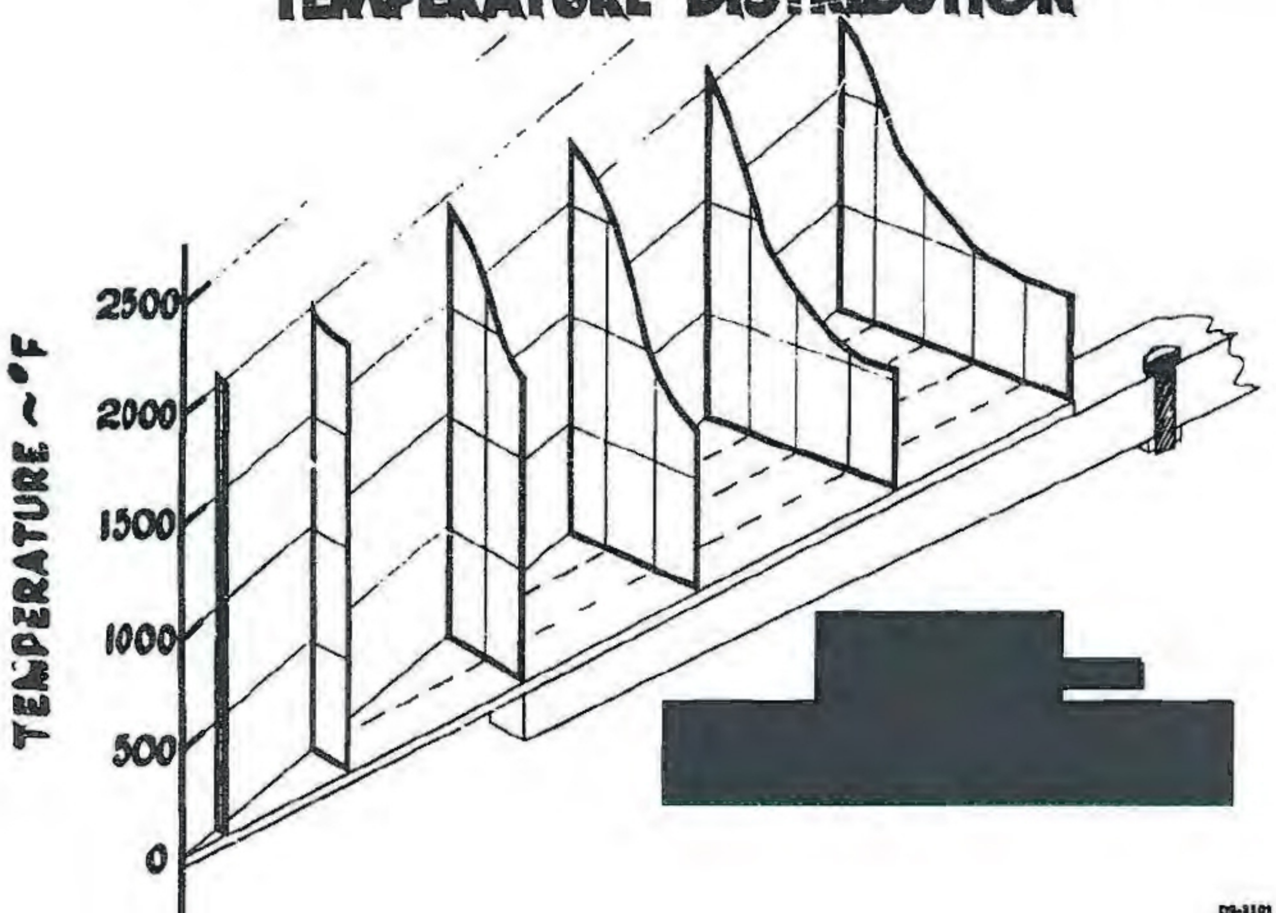
THERMAL WARPAGE TEST RESULTS

In the thermal warpage test, temperatures in excess of 2000° were reached on the leading edge after a period of 7 minutes. Temperatures at the root chord were less than 1000°. With this large temperature distribution across the span, no thermal deflection was measured. As a result it is anticipated that no thermal warpage will occur on the free flight model.

[redacted]

[redacted]

TEMPERATURE DISTRIBUTION



[redacted]

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[redacted]

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[redacted]

PROPOSED AIR FORCE PROGRAM

Contractor studies and experimentation alone are not sufficient to adequately develop the boost glide rocket bomber weapons system. Direct Air Force support of other areas is also required. In order to successfully use this Air Force supported development, the prime contractor must have close cognizance of all of this development.

[redacted]

[redacted]

Proposed Air-Force Program

- HYPERSONIC TESTING
- LARGE SOLID ROCKETS
- MATERIAL DEVELOPMENT
- UPPER ATMOSPHERE RESEARCH
- ACCESSORY POWER DEVELOPMENT
- ATRAN & INERTIAL GUIDANCE
- ★ CONTRACTOR COGNIZANCE

1-33001-174

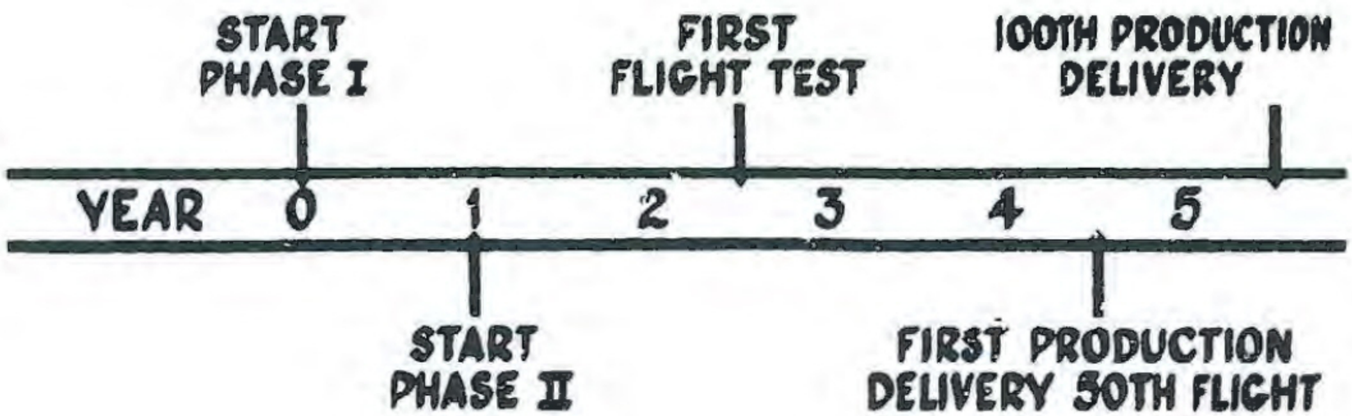
[redacted]

SCHEDULE

Research and development requirements for an unmanned expendable rocket bomber have been explored. Based upon the present rate of progress in the several problem areas, it is believed that the weapon could be in operation within five and one-half years from the start of Phase I and that the first production article could be delivered four and one-half years from Phase I "go-ahead".

[redacted]

DEVELOPEMENT SCHEDULE



[redacted]

[redacted]

CONCLUSIONS

Boeing has arrived at a number of conclusions as a result of the rocket-bomber studies and testing accomplished to date.

First, the company is definitely interested in pursuing the endeavor. Boeing financed studies and research testing on rocket bombers will exceed $1,000,000 for 1957.

[redacted]

plane, rail, or truck to the firing area.

Fourth, it will be practical to separate the vehicles, one from another, and thus to increase the enemy job of destroying our SAC capability. This becomes a powerful deterrent.

Fifth, solutions to the system technical problems are forseeable. The weapon operational availability is a function of getting started with a specific program.

Sixth, research and development will be required. Many of the problems will not be solved, however, if not tied to an active program.

It is believed Boeing is making significant progress in exploring boost-glide weapons. It is hoped this effort can continue.

[redacted]

[redacted]

CONCLUSIONS

EXPENDABLE BOOST GLIDE WEAPON :

- *is* FEASIBLE & PRACTICAL
- *can* DESTROY HARD TARGETS
- *is* MOBILE
- *will* OPERATE FROM DISPERSED BASES
- *can be* AVAILABLE BEFORE 1965
- *requires* MODEST DEVELOPMENT PROGRAM

[redacted]

1-33301 276

[redacted]

[redacted]