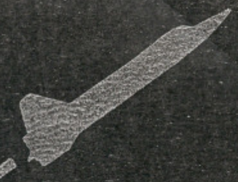
X-15



ADVANCED RESEARCH AIRPLANE

NORTH AMERICAN AVIATION, INC.

55WCS-9229-AA COPY 29

[redacted]

NA-55-221

CLASSIFICATION CANCELLED

(OR CHANGED TO Unclass

AUTHORITY: AFSC-AFCL Security Classification Guide

DATE 10 April 69

BY: Cynthia S. Parcell

[redacted]

[redacted]

Serial No. 29

CLASSIFICATION CANCELLED

(OR CHANGED TO Conf

AUTHORITY: DD 254 (16 Jan 61)

DATE [illegible] Dec 6[illegible]

BY: [illegible]

NOTICE: This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

This document contains proprietary information of North American Aviation, Inc., and is submitted in confidence. Information contained herein should not be disclosed to other than military organizations of the U. S. Government.

DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS.
DOD DIR 5200.10

PROPRIETARY INFORMATION

NORTH AMERICAN AVIATION, INC.

[redacted]

55-2423

[redacted] 54 45 WCS-9229-AA COPY 29

[redacted]

REPORT NO. NA-55-221
9 MAY, 1955
SERIAL NO.

[redacted]

X-15

ADVANCED RESEARCH AIRPLANE

DESIGN SUMMARY

[redacted]

NORTH AMERICAN AVIATION, INC.
INTERNATIONAL AIRPORT • LOS ANGELES 45, CALIFORNIA

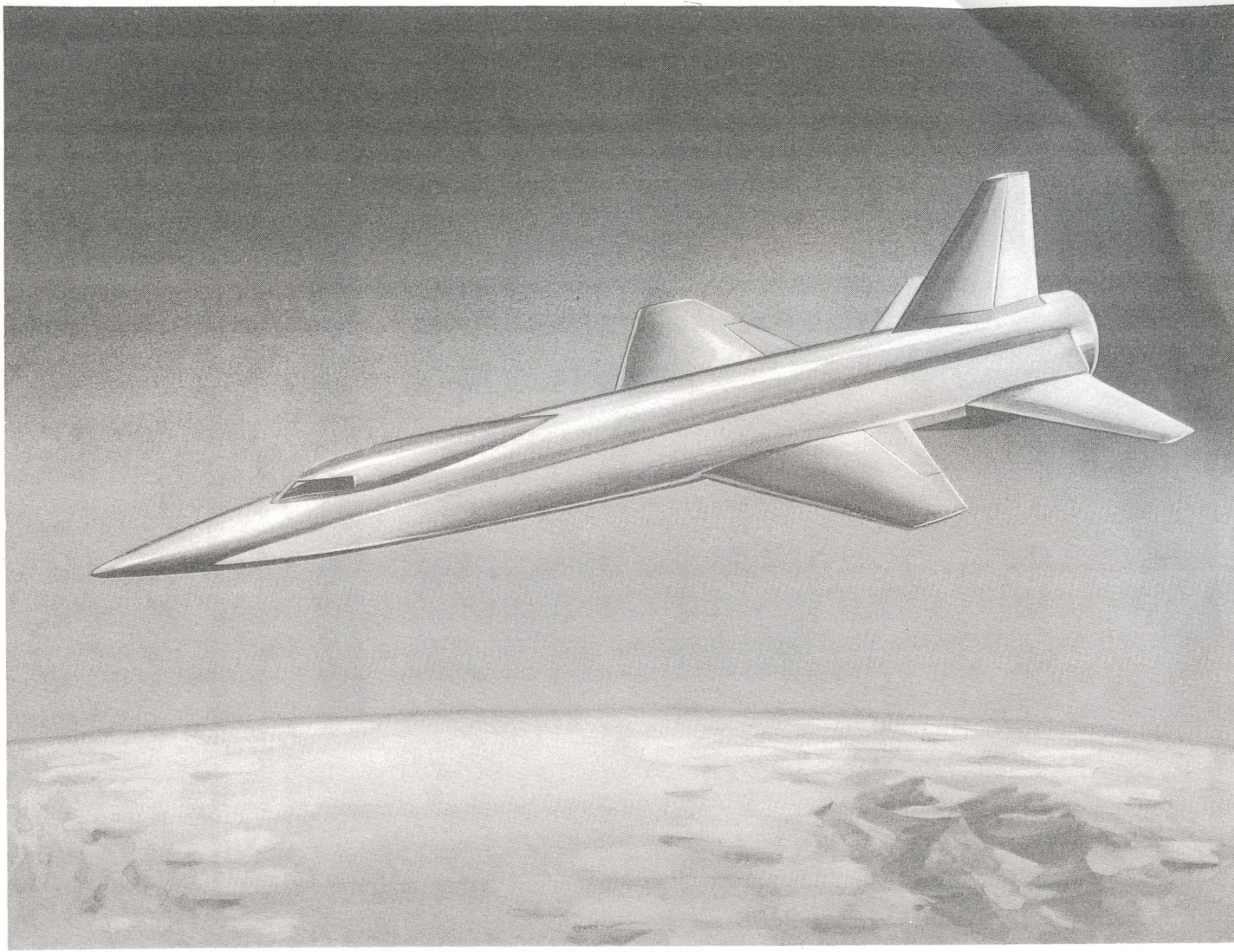
[redacted] 54WCS-9229-AA COPY 29

[redacted]

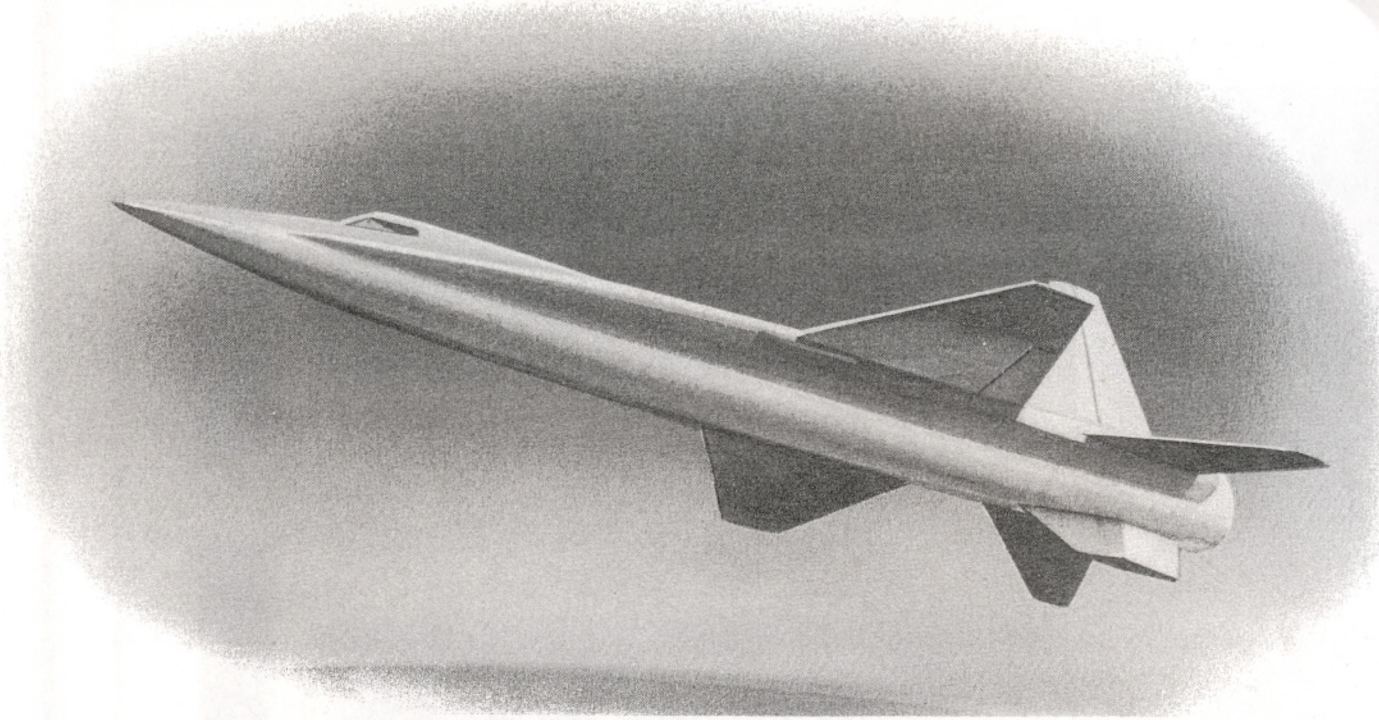
Introduction

In response to a request for proposals for a New Research Aircraft "Project 1226," North American Aviation presents in this brochure a summary of a proposed design. Additional detailed reports covering all phases of this proposal are listed under Supporting Data.

[redacted]



DESIGN CONCEPT



PROGRAM OBJECTIVE: The program objective is interpreted as exploration of the flight spectrum which will be traversed by a future generation of military aircraft. The regime of interest encompasses an altitude of 250,000 feet and speed of 6600 feet per second. The program, to be successful, must provide information which is useful in the design of aircraft in the near future. The element of time is therefore important, and the attainment of flight within 2-1/2 years, as specified, is vital.

DESIGN OBJECTIVE: It follows that the design objective must be to provide a minimum practical and reliable vehicle capable of thoroughly exploring this regime of flight. Limiting factors are time, safety, state of the art, and cost.

DESIGN SOLUTION: It has been determined that the specification performance can be obtained with very moderate structural temperatures; however, the airplane has been designed to tolerate much more severe heating in order to provide a practical temperature band within which exploration can be conducted, and to provide a safety margin for the unpredictable.

Available aerodynamic data indicates that the configuration presented is reasonable when the complete speed range is considered. The all-movable surfaces for pitch, roll, and directional control are known to be satisfactorily effective at the higher Mach numbers. Negative dihedral is incorporated on the horizontal tail to lessen abrupt trim changes due to shock impingement or wake immersion. Small variable thrust rocket motors arranged to provide moments about the three control axes comprise a separate space control system during periods of ineffectiveness of the aerodynamic controls due to reduced dynamic pressures.

The problem of providing a landing system compatible with a simple fixed lower vertical tail has been solved by simply allowing the airplane to touch down and ''rotate in'' about the tail bumper and providing adequate energy absorption in the main and nose gears.

The airplane presented is based upon a specific propulsion system; however, it appears feasible to use any engine or engines in the same performance category.

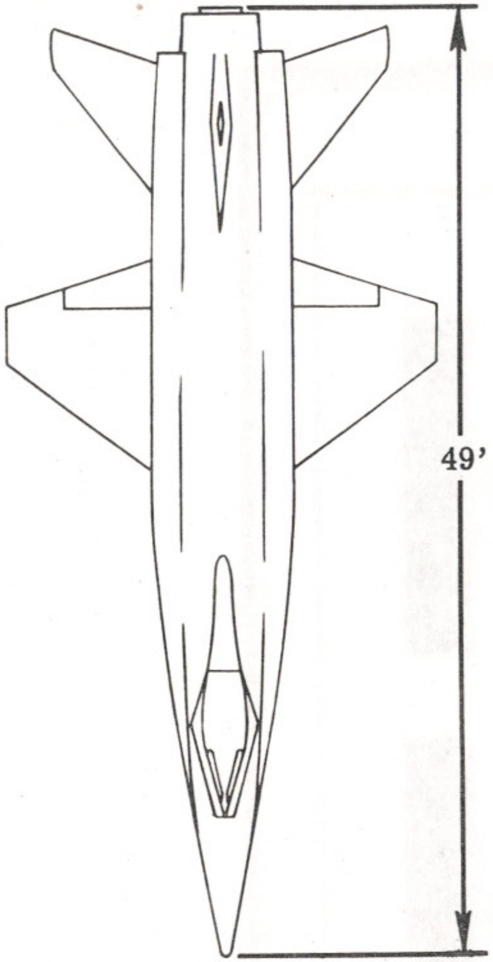
A secondary, but important, factor considered in preliminary design is the desirability of meshing with the present operational pattern for research aircraft. By following the established pattern of operations, a considerable saving in learning time should be achieved.

The basic philosophy regarding the thermal problems associated with bearings, lubricants, electrical insulation, seals, actuating fluids, etc, is to provide a controlled environment to suit present thermal capabilities rather than attempt to extend the thermal limits of these components by further development.

The basic concept of a specialized research aircraft, of which only several will be produced and which do not require being rapidly serviced as in a combat aircraft permits considerable compromise in favor of extreme simplicity in order to assure a high degree of ruggedness and reliability. NAA, through detailed study of current research aircraft and as a result of conferences with the operating personnel is acutely aware of and has incorporated this concept in the preliminary design of the proposed aircraft.

Detailed definition and solution of all problems which will be encountered in this program are believed impossible for a proposal of this scope; indeed, if this were possible, there would be little need for a research airplane. However, it has proved possible to design an airplane capable of successfully coping with these problems by allowing for easy modification of critical areas if the need arises.

CONCLUSION: North American Aviation has the technical ability, the facilities, and the desire to produce a successful research vehicle having the desired performance and operational flexibility required for a long-range research program.



DESIGN BRIEF

PERFORMANCE

MAX. VELOCITY AT BURNOUT (DESIGN MISSION)	6800 FT. PER. SEC.
MAX. ALTITUDE DURING COAST (DESIGN MISSION)	250,000 FT.
TOTAL FLIGHT TIME (DESIGN MISSION)	20 MIN.
MAX. ATTAINABLE ALTITUDE	800,000 FT.
MAX. TIME OF "WEIGHTLESS" FLIGHT	6.5 MIN.

WEIGHT

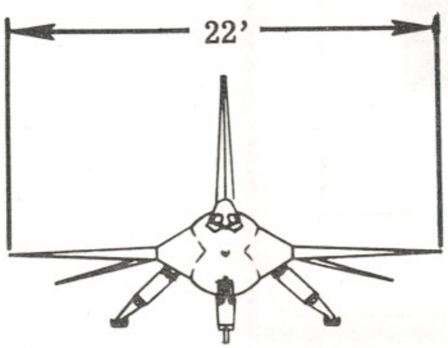
EMPTY	9,959 LB.
USEFUL LOAD	17,763 LB.
(PROPELLANT ONLY)	(16,410 LB.)
GROSS	27,722 LB.

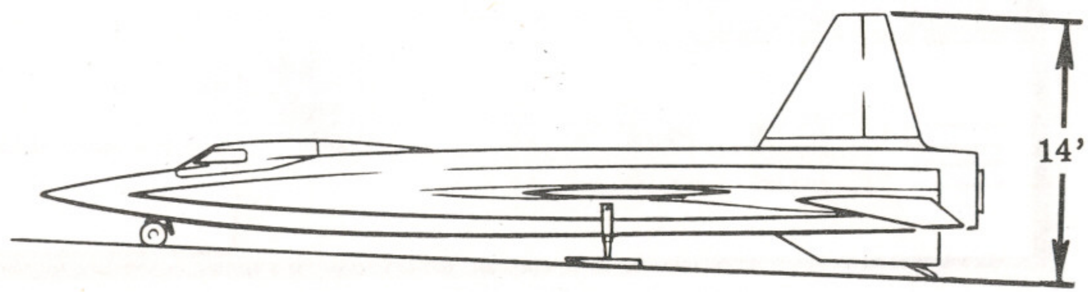
POWER PLANT

REACTION MOTORS INC.	XLR-30RM2
MAX. THRUST, 40,000 FT	57,000 LBS.

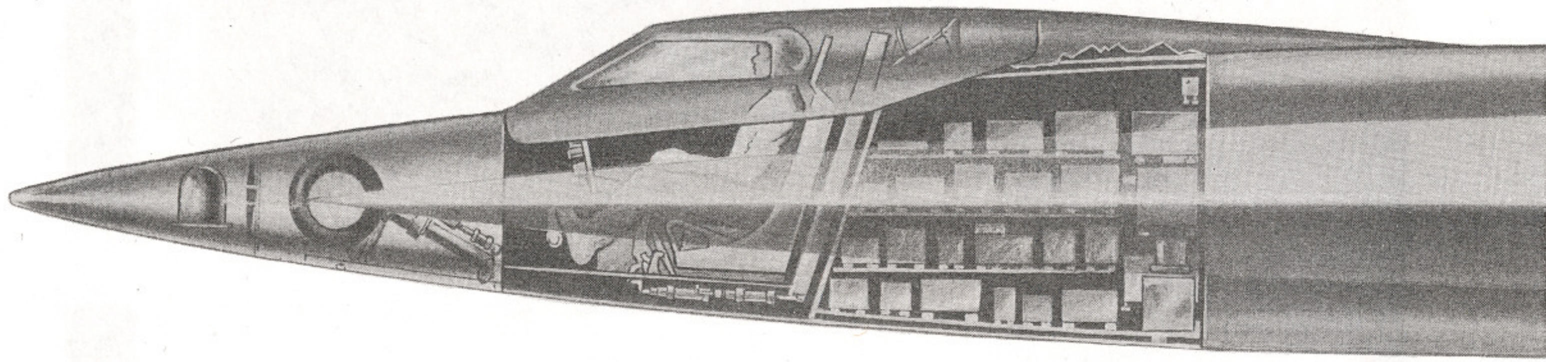
WING

AREA	200 SQ. FT
SWEEP	25 DEGREES
THICKNESS	5 PERCENT
ASPECT RATIO	2.5





GENERAL ARRANGEM



FLIGHT CONTROLS
Rolling tail; horizontal tail surfaces operate in unison for longitudinal control and differentially for lateral control.
All-movable vertical tail provides directional control.

SPACE CONTROLS
Hydrogen peroxide rocket motors for three-axis control

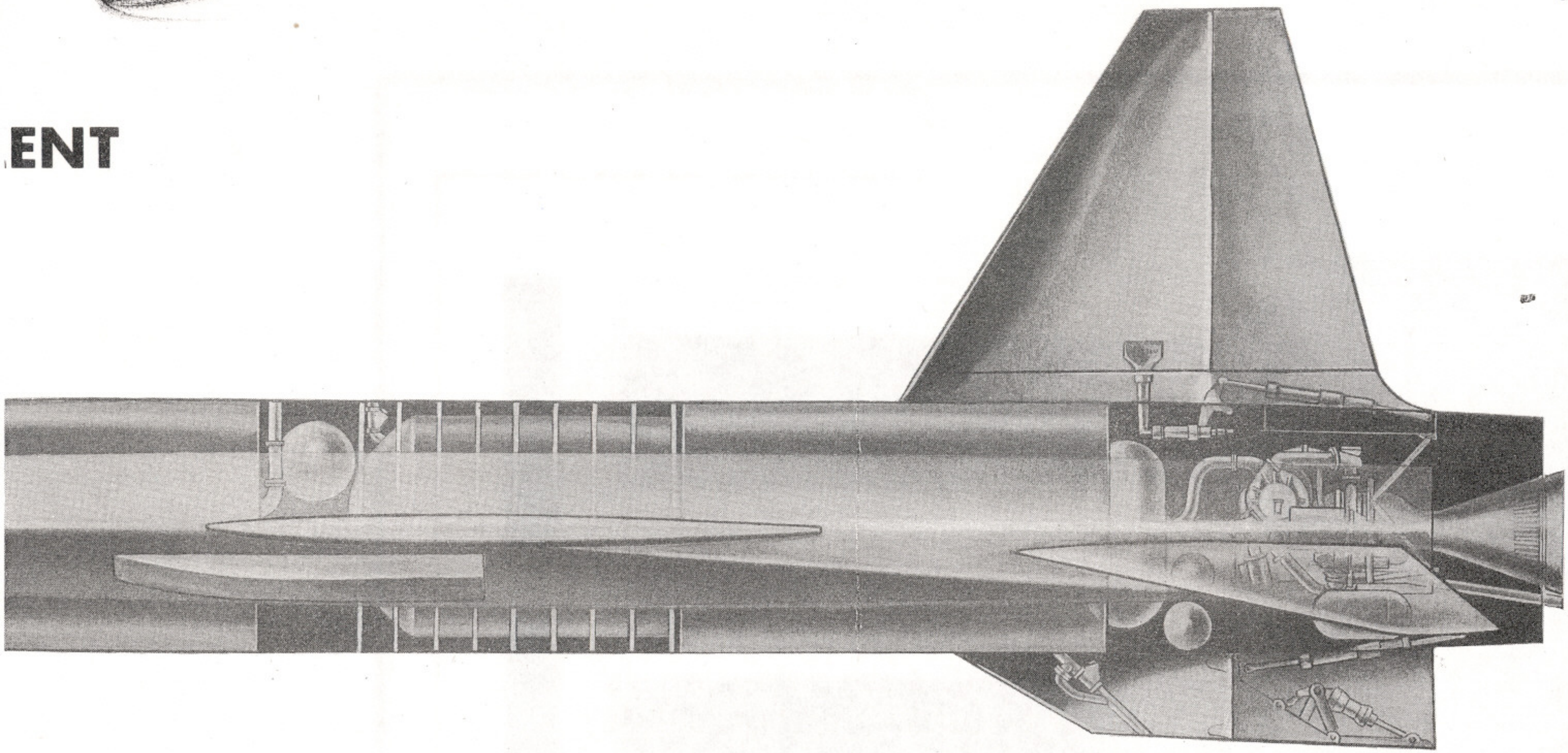
SPEED BRAKES
Independently operable split trailing edge surfaces on upper and lower vertical tail.

ELECTRONICS
UHF Command set AN/ARC-34.
Radio homing AN/ARA-22.
Voice recorder AN/ANH-3.

ELECTRICAL
Two 28-volt, 100-ampere generators.
750-volt-ampere, 115-volt, three-phase inver

FLIGHT TEST INSTRUMENTATION
40 cubic feet environment free.

ENT



ROCKET ENGINE
RMI XLR-30RM2 rated at 57,000 pounds of thrust at 40.000 feet altitude.

PROPELLANT
Forward integral tank contains 907.5 gallons of liquid oxygen.
Aft integral tank and center fuselage tank contains 1240 gallons of anhydrous ammonia.
Suppression pressure supplied by stored helium.

AUXILIARY POWER UNIT
Two RMI X50API. modified for hydrogen peroxide fuel,

·ter.

HYDRAULIC
Two 8 gpm 3000 psi pumps supply independent systems powering flight controls, speed brakes, and landing flaps.

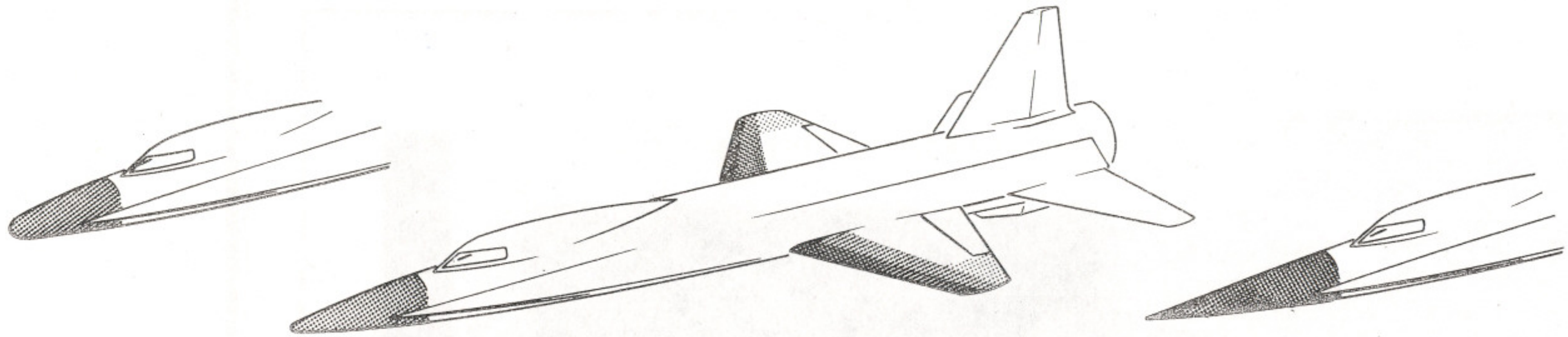
ALIGHTING GEAR
Manually released free-fall extension assisted by air drag and bungee springs.
Skid-type main gear; dual nose wheels

COCKPIT ENVIRONMENT
Liquid nitrogen provides refrigeration and pressure.
2-1/2 liter liquid oxygen breathing system.

WEIGHT SUMMARY

WEIGHT EMPTY			9,959 LB
USEFUL LOAD			17,763 LB
PROPELLANT		16,410 LB	
FUEL (AMMONIA)	7,240 LB		
OXIDIZER (LIQUID OXYGEN)	9,170 LB		
HYDROGEN PEROXIDE		835 LB	
PILOT		290 LB	
MISCELLANEOUS		228 LB	
LAUNCHING WEIGHT			27,722 LB
BURN-OUT WEIGHT			10,443 LB
STRUCTURAL DESIGN WEIGHT (7.33 G)			10,443 LB

RESEARCH SUITABILITY



The proposed airplane is considered to be a research tool, and as such has many outstanding features. The effectiveness of this tool can be measured by its performance, reliability, safety, and versatility.

The proposed airplane equals or exceeds the specified performance in all respects. This performance is attained without recourse to untested or complicated solutions to design problems. This should allow the major effort to be expended in obtaining the desired research information. Any unconventional solution would impose the risk of diverting a major portion of research effort to itself and thus seriously penalize the program performance.

Reliability is achieved by simplicity and convenient elimination of points where failure might occur. The proposed airplane is simple in concept and, with the benefit of the contractors experience and effort in detail design, will be a reliable airplane. North American Aviation has made an effort to acquire and use the experience already gained by the NACA on research aircraft and will continue to do so in the future.

Versatility is achieved by providing an inherent capability of flying a large variety of flight profiles, and by designing to allow convenient testing of a variety of shapes and structural configurations at the fuselage nose and wing leading edges. Removable wing tips can be easily provided to allow panel structures and aerodynamic shapes to be tested economically.

Stability and control problems, at the extreme high altitudes of the desired performance spectrum, may be studied through the control effectiveness afforded by special nonaerodynamic reaction-type attitude controls.

THERMAL PROBLEM

Major problems to be approached and solved by the use of the X-15 will be those material and structural problems caused by the high temperatures encountered in the very high speed portions of experimental flights. At a Mach number of 7, the boundary layer recovery temperature will be on the order of 4399°F and the skin equilibrium temperature, where heat input is balanced by radiation output, will exceed 1200°F even at altitudes above 100,000 feet. 1200°F approaches the upper limit for usage of Inconel X as a structural material.

The time rate of approach of equilibrium temperatures to boundary layer temperatures allow the use of the airplane at these high Mach numbers if flight duration is low and the skins are thick enough to form a heat sink of sufficient capacity.

High temperatures will affect not only the static properties of structural materials, but also the allowable stresses under repeated loads. Loss in stiffness, or Young's modulus, is detrimental from the flutter standpoint.

The unequal deflections, caused by dissimilar metals heated to the same temperatures or by unequal heating of a homogeneous structure, result in high order induced stresses built up between expanding and contracting portions of the structure. This effect is very important in considering the distortions set up by unequal heating between a hot skin, and cool inner structure, or between upper and lower skins on the wing during high-angle-of-attack flight. Widespread buckling of skins which are restrained by stringers or longerons, warping and curling of wing chord planes, large wing tip deflections, changes in wing camber, gross wing flutter, or localized panel flutter may be the symptoms of these thermal stresses.

The contractor's proposed design approach to these thermal stress problems includes:

1. Use of materials having different tension modulii where steep thermal gradients exist between adjacent attached members.

2. Use of corrugations of beads to provide a low effective tension modulus.

3. Use of thick skin structure with minimum internal framing where feasible.

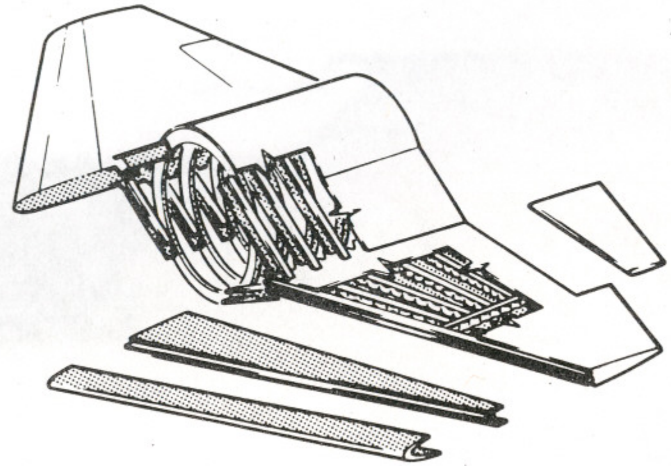
Wing and tail leading edges and the fuselage nose may experience temperatures approaching adiabatic stagnation maximums on the order of 4800°F during extreme test conditions. It is proposed to provide easily replaceable leading edges of laminated glass cloth which will be permitted to actually melt or burn locally during these extreme cases. The leading edges will be segmented for easy replacement. Tests indicate good dimensional stability, low thermal conductivity and stable decomposition for this type of material.

Thus it can be seen that the problems of high temperature will form a major field of research for the X-15 test program. The following pages describe a few design features based on present knowledge of these problems.

The high temperatures experienced during flight also pose the problem of furnishing a proper environment for the pilot and sensitive equipment whose temperature and pressure limits are relatively low. The range of ambient temperatures and near-vacuum pressures coupled with the design for a simple reliable conditioning system requiring little development work make the optimum design of the environmental control a difficult one. The lack of any convenient source of large quantities of either compressed air or ram cooling air such as is associated with the conventional jet aircraft, requires that a new and different approach be taken to the solution of pressurization and cooling. The uniquely simple conditioning system for the X-15 is comprised of a liquid nitrogen storage tank plus the required distribution plumbing, regulating valves etc. The cold nitrogen liquid plus the available heat absorption inherent in vaporization of the fluid, form the necessary heat sink for refrigeration. In addition the resulting gaseous nitrogen serves as atmosphere and a pressurizing agent for the cabin, equipment compartments, and other localized heat sensitive areas. The pilot's pressure altitude suit is also pressurized with nitrogen, his oxygen requirements being supplied 100 percent from a liquid oxygen source through an inner breathing mask. The nitrogen atmosphere in the equipment compartments also tends to lessen the possibility of fire or explosion. Another desirable asset resulting from proper environmental control is the ability to use presently available equipment instead of having to laboriously develop new high temperature and low pressure resistant instruments and equipment.

THERMAL SUITABILITY

. . . *wing*



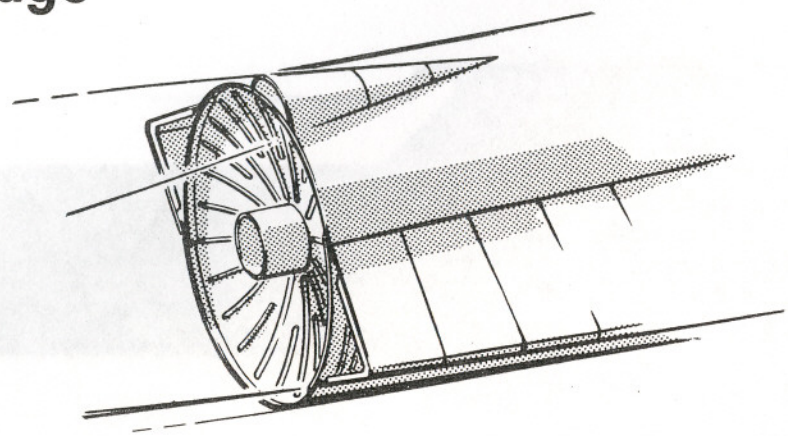
The basic wing is fabricated as a complete full-span assembly for best rigidity and lightness of structure. Wing skin loads are transferred into fuselage ring frames for transfer across the fuselage. The ring frames are of titanium alloy with numerous web beads to minimize thermal stresses. The wing structural box extends from the 25 percent to 75 percent chord lines. A spanwise series of shear beams, composed of corrugated 24S-T webs and titanium-manganese alloy attach angles, provide support for the taper milled Inconel X skins. The spar corrugations resist normal crushing loads and serve to relieve thermal stresses. The relatively lower modulus of elasticity of the titanium-manganese attach angles will reduce thermal stresses induced from the hot Inconel X skins. Thickness of the skins varies from 0.060 inch at the tip to 0.125 inch at the fuselage fairing intersection. Front and rear main spars are built up from titanium-manganese alloy with numerous beads for relief of thermal stresses. Panel stability will be investigated in tests conducted in environmental circumstances.

The airfoil shape has a rounded leading edge and a conventional cross section for low drag, reduced leading edge temperatures, and good subsonic characteristics. The leading edge section with a chord of 3-1/2 inches throughout, is made of laminated Fiberglas. The most severe flight profile will result in about 5/8 inch of material being burned away, but since the leading edge is separated into 24-inch lengths, the damaged sections may be cheaply and easily replaced. The Inconel X skin increases in thickness chordwise from the front spar to the leading edge to form a heat sink.

The square wing tip allows the tip rib to be at the same temperature as the skins. The rib at the fuselage juncture is titanium-manganese alloy, while the mid-span and nose ribs are corrugated 24S-T with titanium-manganese attach angles.

Tail surfaces, in general, are constructed in the same manner as described for the wing.

THERMAL SUITABILITY
. . . *fuselage*



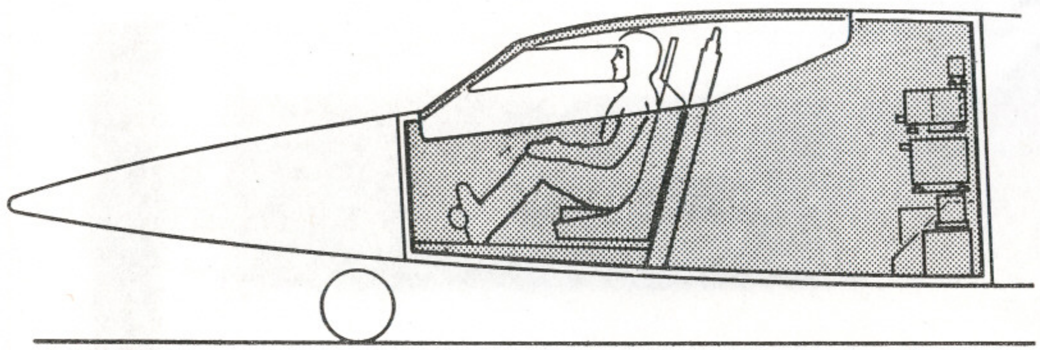
The necessity for use of moderately heavy skins for heat sink, use of a shape compatible with the pressures required within the integral tanks, and consideration of thermal stress problems has led to adoption of semi-monocoque fuselage with internal structure consisting only of rings or bulkheads except in local areas around the cockpit.and empennage. This method of construction allows the thermal deflections of the monocoque shell to take place without the crippling of conventional longerons and stringers which would result from temperature gradients. The shell is stabilized by bulkheads spaced approximately 25 inches apart. The bulkheads are stiffened with a series of radial beads to reduce thermal stresses. The monocoque shell is fabricated from Inconel X sheet metal for high-temperature strength. Internal pressures are considered to assist in stabilizing the monocoque shell.

Side fuselage fairings housing controls, hydraulic lines, etc, are made from Inconel X and segmented every 20 inches to reduce thermal deflections and stresses. Primary structure behind the fairings is beaded for relief of thermal stresses. Panel stability will be investigated through environmental tests.

The Inconel X nose cone forward of the cockpit is tapered in thickness from 0. 060 to 0. 100 inch at a point 8 inches from the tip. A replaceable laminated glass cloth fairing forms the foremost nose tip, which at the temperatures attained during the most severe flight profile, will partially burn away at the surface, thus protecting the remainder of the nose.

All bulkheads and frames, with the exception of tank bulkheads, are constructed from titanium-manganese alloy. The lower modulus of elasticity of this material reduces the magnitude of the induced thermal stresses, yet working allowable stresses are high. The use of service tunnels in the outer fairings minimizes the need for cutouts in the bulkheads for wire and plumbing routing.

THERMAL SUITABILITY
. . . cabin & equipment bay



The cabin and forward equipment bay utilize low-temperature, inner shells to retain compartment pressure. Conventional sealing techniques are used. Insulation between the inner shell and the structural skin comprises one inch of glass fiber plus aluminum foil radiation shielding.

The canopy seal is isolated, by distance, from the hot skins, permitting use of a conventional "blow-up" seal operated by stored nitrogen.

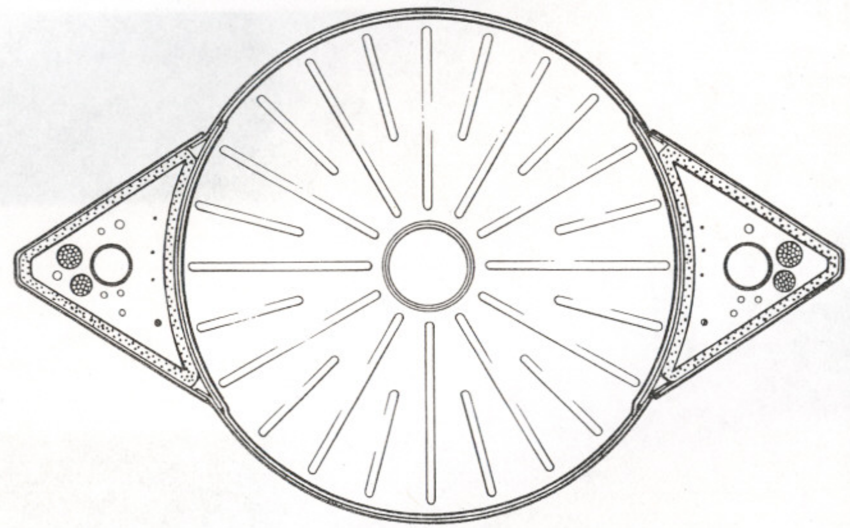
Liquid nitrogen storage systems provide a pressurized and refrigerated atmosphere.

The windshield consists of heavy fused silica or Pyrex outer panes and stretched acrylic inner panes. The inner low-temperature panes provide the normal pressure seal. All panes are geometrically flat to simplify fabrication.

A stabilized ejection seat and the pilot's full pressure suit combine to provide an escape system having minimum weight and complexity, environment control, and a probability of survival which is believed to exceed that of any capsule of acceptable weight which could be developed within the allowable time period. Since the design dynamic pressures are in the same range as those of present-day airplanes the seat should clear the airplane satisfactorily under all conditions.

THERMAL SUITABILITY
. . . remote equipment & routing

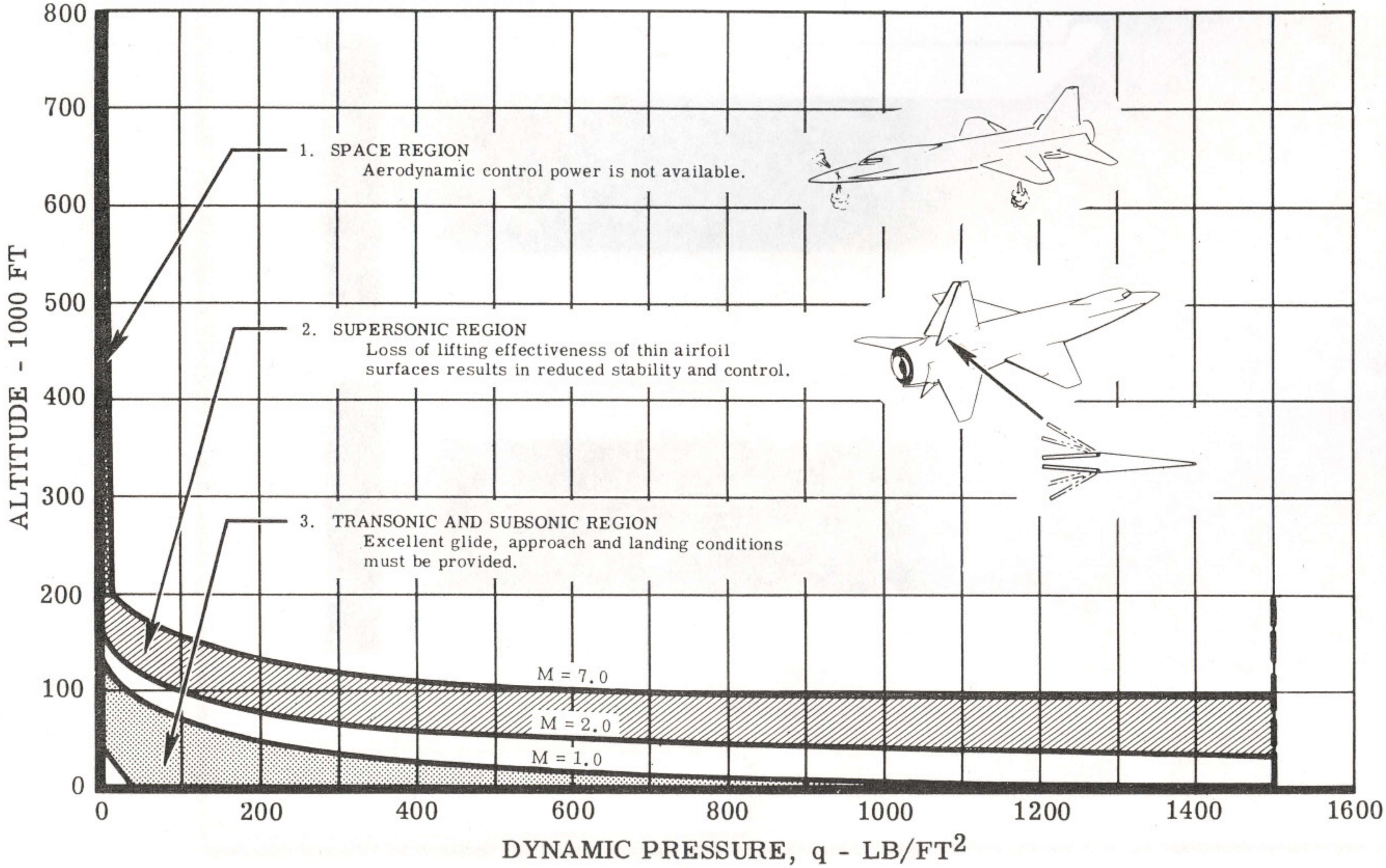
All fluid lines, controls, and wiring extending along the fuselage are routed outside of the monocoque fuselage structure and within the removable side tunnels. In the region of the integral tanks, insulation will be provided between the tank wall and the tunnel to afford protection from the extremely low temperature of the propellants. Insulation is provided adjacent to the inner surface of the tunnel walls subjected to aerodynamic heating. All propellant lines are provided with insulation to alleviate the low-temperature problem.



All wing routing, excepting terminal portions of the research instrumentation, is within a thermally insulated portion of the wing structural box, aft of the front beam. Access is obtained by removing lower surface access doors. Terminal portions of the research instrumentation will be serviced by suitably located access panels on the lower wing skin.

Remote equipment which is not capable of withstanding ambient conditions will be suitably protected. Items requiring pressurization and cooling will be installed in thermally insulated pressure cans and, if necessary, pressurized and cooled with the liquid nitrogen cabin pressurizing and refrigeration system. All bearings subjected to high temperatures will be provided with sufficient heat sink to allow use of dry lubricants such as molybdenum-sulfide, or be designed to operate without lubrication.

STABILITY & CONTROL PROBLEMS

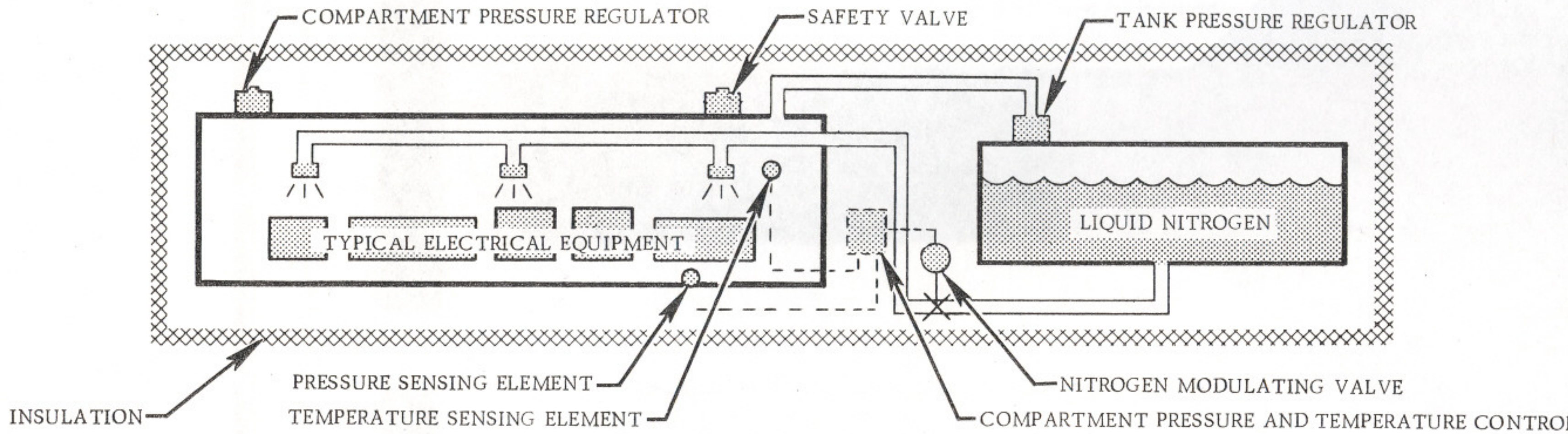


The stability and control of a vehicle moving at very high velocities in an atmosphere of low density will be one of the principal fields of investigation of the X-15. At the present time sufficient data is available from wind tunnel and model tests to indicate that the problems to be encountered will not be insurmountable. One major effect will be the reduction in stability at very high Mach numbers, and the total loss of stability and control effectiveness at altitudes where dynamic pressures fall to very low values. The proposed solution to the former problem will be provision of symmetrically split speed brakes which can transform the basic double-wedge vertical stabilizer airfoil trailing edge into a relatively obtuse blunt wedge. This configuration greatly increases the tail lift curve slope at high Mach numbers, and thus provides sufficient directional stability without actual increase of tail area. The relative location of airplane CG and supersonic aerodynamic center of the wing overcomes the trend to longitudinal instability so that a conventional horizontal tail airfoil, deflected through large angles, is sufficiently effective. The problem of control during space flight will be solved by the use of reaction jets arranged to provide control moments about the three aircraft principal axes. The primary use of this space control will be to orient the airplane attitude prior to re-entry into the atmosphere. Optimum control forces have been determined from an analog computer analysis.

The configuration of the X-15 will allow a wide flexibility in the types of re-entry trajectories that may be followed. The aircraft may re-enter on a zero lift curve, using the speed brakes for deceleration, and with subsequent pull up at reduced Mach numbers. Temperature differentials across the wing thickness will be at a minimum in this maneuver. At the opposite extreme a high lift coefficient and resultant high drag may be maintained for deceleration without the speed brakes, and yet excessively high load factors or bottom skin temperatures will not be encountered. This flexibility of flight path programming will permit a much wider range of conditions to be investigated during the test program, and provide a wide safety margin to cover unplanned deviations.

AIRFRAME SERVICE SYSTEMS

... cabin & equipment conditioning



EQUIPMENT CONDITIONING SCHEMATIC

A liquid nitrogen storage system is used for both pressurization and refrigeration of the cockpit, forward compartment, midship equipment, and left and right auxiliary power unit compartments.

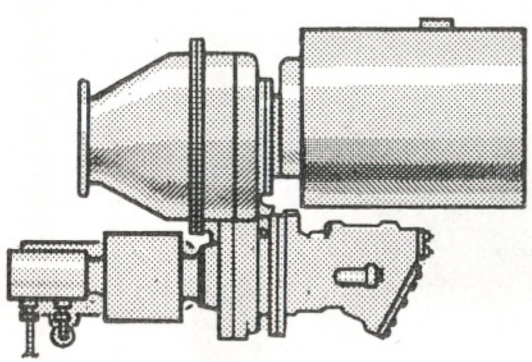
Four insulated tanks containing a total of 75 pounds of liquid nitrogen are self-pressurized. The nitrogen will be injected into the conditioned areas; cooling results from the rapid evaporation of the spray, and pressurization is automatically kept at the proper level by relief valves.

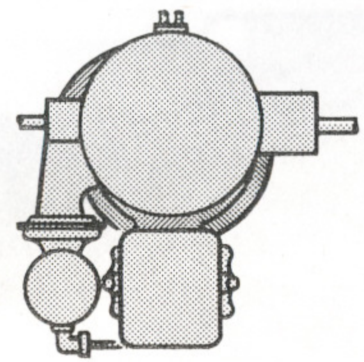
Tanks will be filled with liquid nitrogen on the ground prior to take-off.

The pilot is protected by a nitrogen pressurized altitude suit. A 100 percent oxygen supply system, with regulator attached to the suit, is supplied from a 2-1/2 liter liquid oxygen supply converter. In the event of failure of the cabin nitrogen pressurization, the oxygen system will serve to pressurize the pilot's altitude suit to ensure survival. A gaseous oxygen bail-out bottle is provided.

AIRFRAME SERVICE SYSTEMS

. . . auxiliary power units





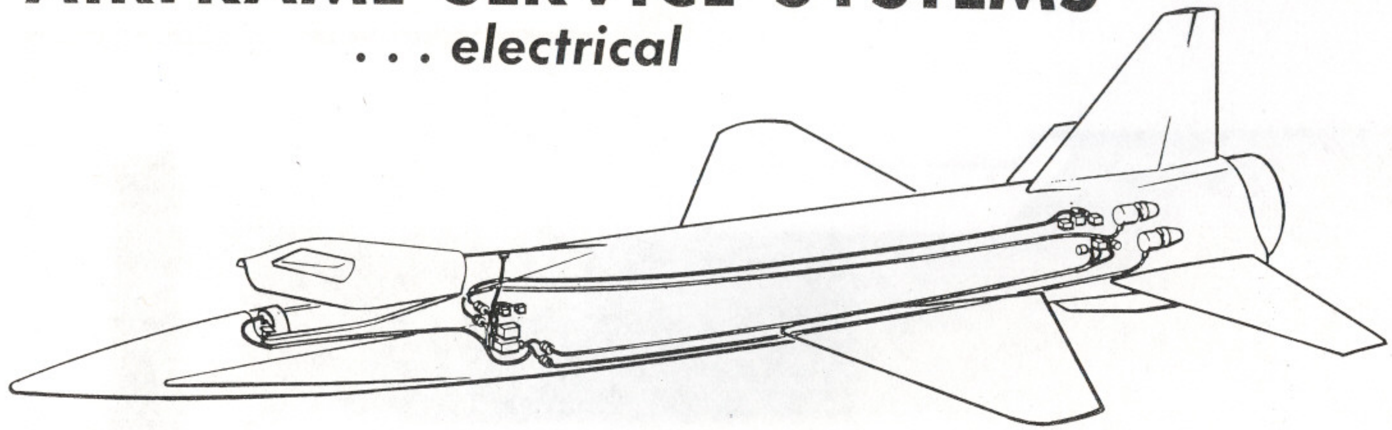
Power for operation of the airplane electrical and hydraulic systems is furnished by two RMI X50AP-1 gas turbine units modified to utilize hydrogen peroxide as a monopropellant. Each unit drives one 100-ampere 30-volt d-c generator through a 2:1 gear box on the 12,600 rpm pad and one 8 gpm, 3000 psi variable-displacement hydraulic pump mounted on the 3850 rpm pad. Each unit is completely automatic except for mechanically controlled propellant valves. The dual installation ensures system reliability in case of a power unit failure. The power units are located in the aft fuselage and are accessible through the engine cowlings. Hydraulic line runs are thus kept at a minimum length.

Propellant supply is from two pressurized bladder type tanks located in the aft fuselage. The space control system is also supplied from these tanks with 68.5 percent of the total capacity of 10 gallons being allocated to the auxiliary power units. Pressurization is at 400 psi through a regulator connected to a separate 3000 psi helium bottle. Propellant capacity is sufficient for a 5-minute prelaunch warm-up, plus continuous operation during a maximum duration flight.

A H_2O_2 propellant fill and return line and valve, with connections located in a common access port with the main engine turbo-pump peroxide filler, are provided for closed-circuit propellant servicing.

Propellant tanks, lines, valves, and catalyst chambers are insulated sufficiently to prevent freezing in -60°F ambient temperatures as well as to prevent boiling or decomposition during periods of high-speed, high-temperature flight.

AIRFRAME SERVICE SYSTEMS
. . . electrical



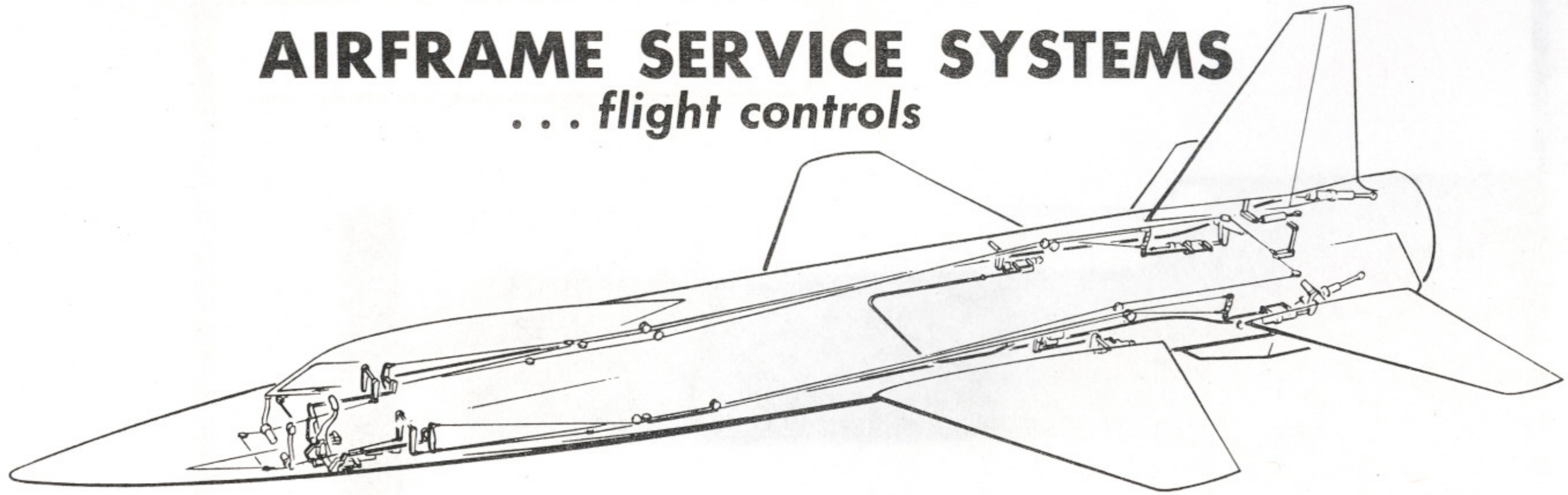
The electrical system is of the regulated 24-volt to 28-volt d-c type powered by two 100-ampere E-1601-1 (or equivalent) generators, each driven from one of the gas turbine auxiliary power units. The generators are installed in pressurized and refrigerated containers which provide the required environmental isolation. Each generator is equipped with a carbon-pile voltage regulator, reverse-current cutout, cockpit warning light, and on-off switch. Normal operation is in parallel, feeding both a primary and an essential bus system. In case of malfunction, the remaining unit will automatically continue to service the essential bus and will disconnect the primary bus. All equipment considered necessary for flight and landing is on the essential bus. Energization of both busses during captive flight is through an external receptacle connected to the mother airplane. Pilot's controls consist of generator warning lights, generator on-off switches, and an "internal-external" switch.

A secondary 115-volt, three-phase a-c system is powered by a 750-volt-ampere main inverter. Malfunction of this unit will activate a warning light, and the a-c load may be transferred to the research instrumentation inverter, with consequent dropping of the instrumentation load.

The use of two generators with environmental protection gives dual unit protection that is not duration-sensitive since the turbine fuel supply is based on the full system capacity demands.

The normal need for only a portion of the usable generator capacity permits flexibility and growth of equipment requirements, without electrical redesign, as the flight program progresses.

AIRFRAME SERVICE SYSTEMS
. . . *flight controls*



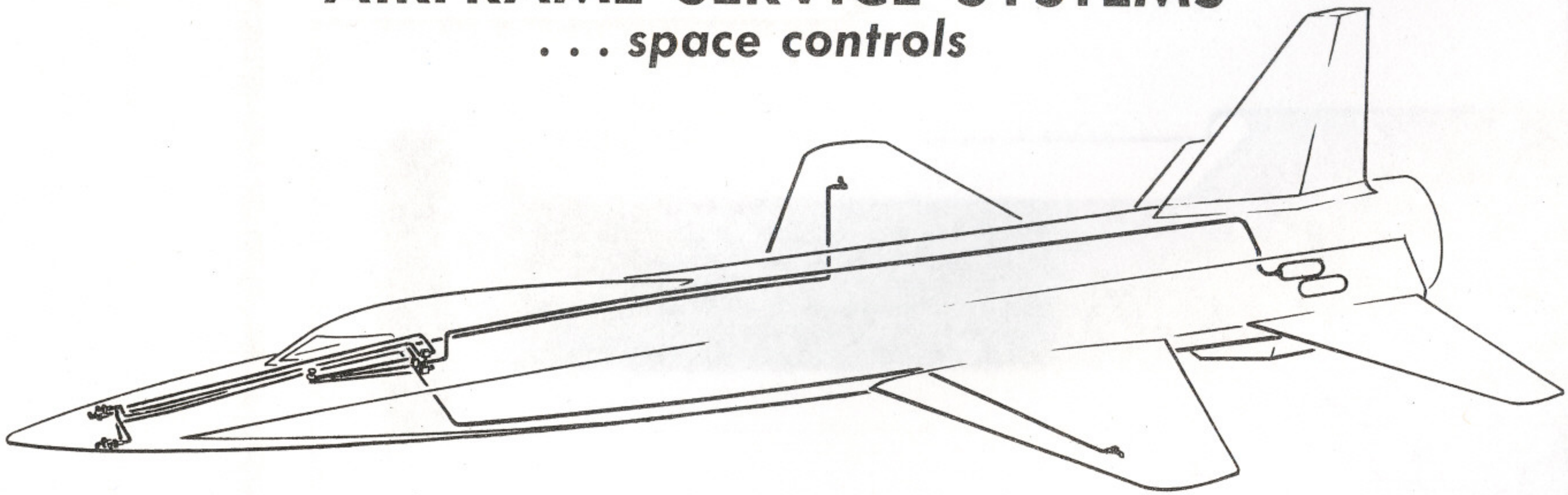
The aerodynamic control of airplane attitude is by means of all-movable horizontal tail surfaces operated symmetrically for pitch, and differentially for roll, plus an all-movable upper vertical surface for directional control. Dual tandem hydraulic actuators powered by twin independent hydraulic systems provide irreversible control actuation.

The conventional cockpit control stick is connected to the servo valves by cable runs down each side of the fuselage. A nonlinear pitching mechanical advantage increases stick travel per degree of stabilizer travel in the leading edge up range and reduces it in the leading edge down range. This reduces the variation of stick force per G produced by the feel bungee and any tendency for pilot-induced pitching oscillation. A trim button on the stick controls an electrically actuated bungee trimmer, and a small bobweight contributes to stick feel. Roll and directional feel is provided by manually trimmed bungee springs.

Split speed brakes on upper and lower vertical surfaces are individually controlled by separate cockpit levers which are cable-connected to the servo valves. A pre-select type control allows the brakes to follow up at rates proportional to the air loads.

Wing flaps of the plain type are operated hydraulically and are controlled by an electric switch in the cockpit and an electric servo actuator-synchronizer connected by flex shafting to the individual flap servo valves. A solenoid valve cuts off pump pressure to the servo valves when the flaps are up and locked.

AIRFRAME SERVICE SYSTEMS
. . . space controls



A separate space control system is provided for attitude control during periods of ineffectiveness of the normal aerodynamic controls due to reduced dynamic pressures. The system comprises a set of small variable-thrust hydrogen peroxide rocket motors arranged to provide variable moments about the three control axes. Four motors are located in a cruciform arrangement at the nose for pitch and yaw, and one motor at each wing tip for roll control.

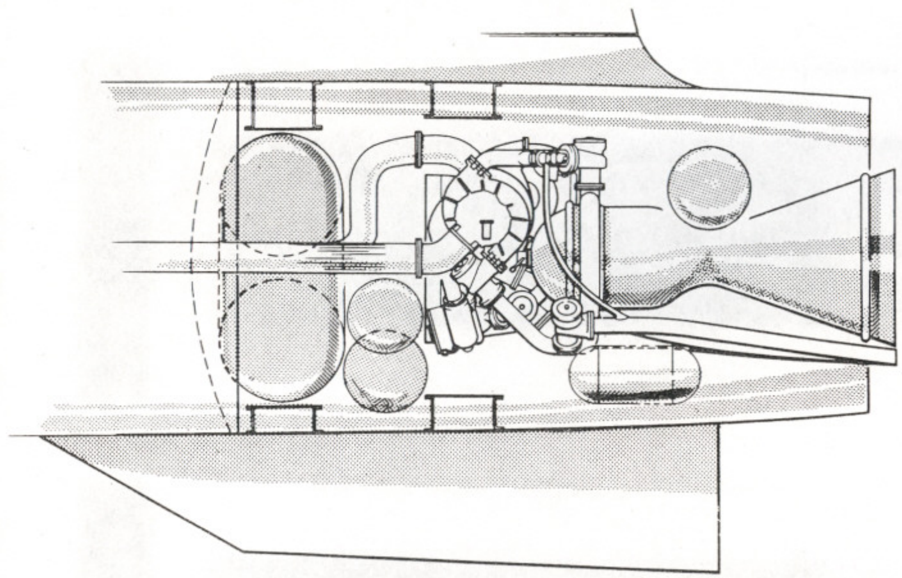
The rocket motors are similar to the RMI XLR-32-RM-2 type. Hydrogen peroxide is supplied to each pair of control motors by a two-way throttling valve connected by mechanical linkages to a three-mode maneuvering lever in the cockpit operated by the pilot. The lever is spring-loaded and normally neutral so that break-out forces and spring rates give a realistic feel, and resulting fuel flows and control moments are proportional to lever deflection.

Control operation is of the simple on-off no-feedback type, with the initial lever movement starting a certain acceleration about any axis, followed by a constant-velocity rotation with the lever in neutral, and ending with an opposite control application to damp out the rotational velocity to zero as the desired heading is reached.

The hydrogen peroxide monopropellant is supplied from two pressurized tanks, which also furnish fuel for the auxiliary power unit. The tanks, located in the aft fuselage, are of the positive-expulsion bladder type pressurized to 400 psi by a 3000 psi helium bottle through a pressure regulator. Total capacity is 10 gallons, with 3.15 gallons allocated to the control system. Automatic 50 psi check valves are located at each motor. A propellant quality gage is provided also. Sufficient thermal insulation is provided for the tanks, valves, lines, and catalyst chambers to prevent freezing during flight at -60°F and to prevent boiling or decomposition temperatures being reached during high-speed flight. A maximum rotational acceleration of 2.5 degrees per second per second about any axis may be attained. Normal duty cycles will ensure five gross attitude changes about each axis at approximately 6 degrees per second.

The flexibility inherent in using a common fuel supply for both space control and auxiliary power is consonant with the exploratory nature of the intended aircraft research program.

POWER PLANT
. . . rocket installation

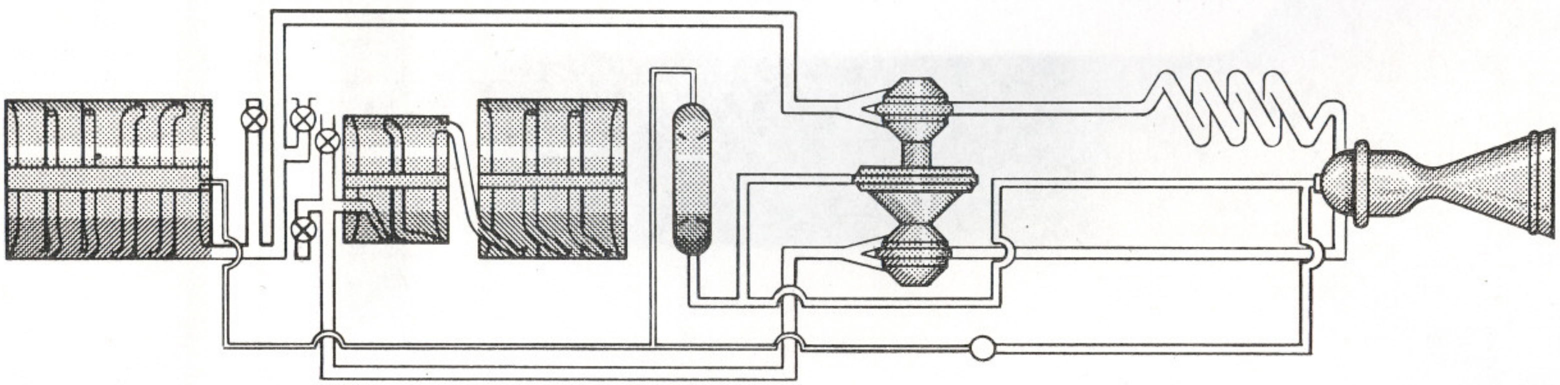


The research airplane is powered by a single-chamber liquid propellant variable-thrust rocket motor. The unit is a Reaction Motors, Inc. XLR30-RM-2 motor burning liquid oxygen and anhydrous ammonia. Maximum sea-level thrust is 50,000 pounds, and the thrust may be varied from 30% to full thrust by controlling power output of the propellant pump turbine. This turbine operates on superheated steam furnished by decomposition of 90 percent concentration hydrogen peroxide in a gas generator.

Throttling of the steam turbine input flow varies the propellant flow, and consequently the rocket thrust.

Starting is accomplished by utilizing the hypergolic reaction of hydrogen peroxide and ammonia in the rocket chamber prior to admittance of the main oxidizer. No electric ignition is required. The airplane helium pressurizing system is of sufficient capacity to allow three starts and shutdowns with full engine purging.

POWER PLANT
. . . propellant system

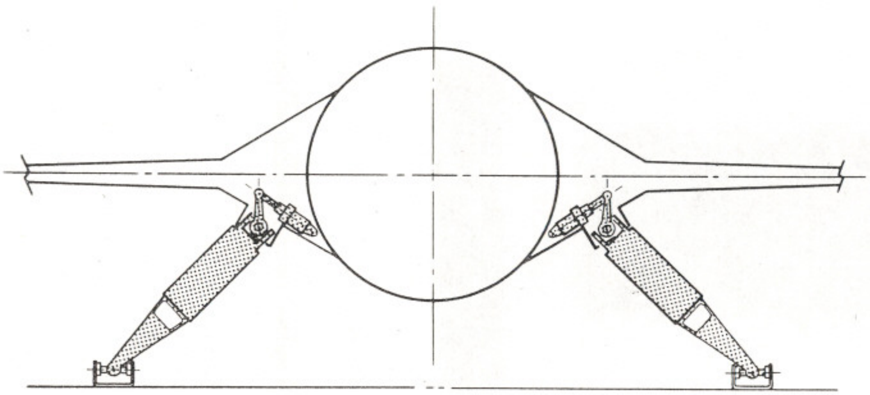


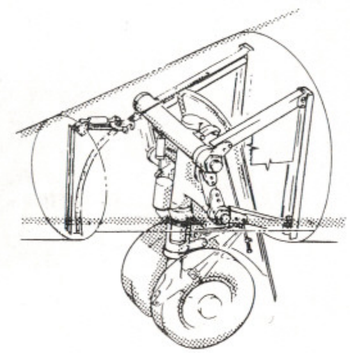
The main propellants are liquid oxygen and anhydrous ammonia, which are supplied under pressure to the suction side of the propellant pump. The propellant pump turbine is supplied with superheated steam formed from 90 percent hydrogen peroxide in a catalyst chamber.

Pump inlet pressure for the main propellant system is supplied by helium regulated at approximately 45 psi and stored at 3000 psi and approximately -300°F in a cylindrical tank on the centerline of the liquid oxygen tank. A similar tank supplies pressure for the propellant pump peroxide system, the engine, and system controls. The two pressurization systems are separated to reduce size and weight, since the main propellant system may operate to a much lower exhausted pressure than the engine and control system.

The liquid oxygen tank comprises a section of the forward fuselage structure and is constructed of seam-welded Inconel X. The aft tank, of similar construction, contains ammonia. A center section nonstructural tank provides the remaining ammonia capacity. All tanks comprise interconnected compartments arranged to provide automatic sequential propellant flow for CG control during normal or jettison operation.

ALIGHTING GEAR





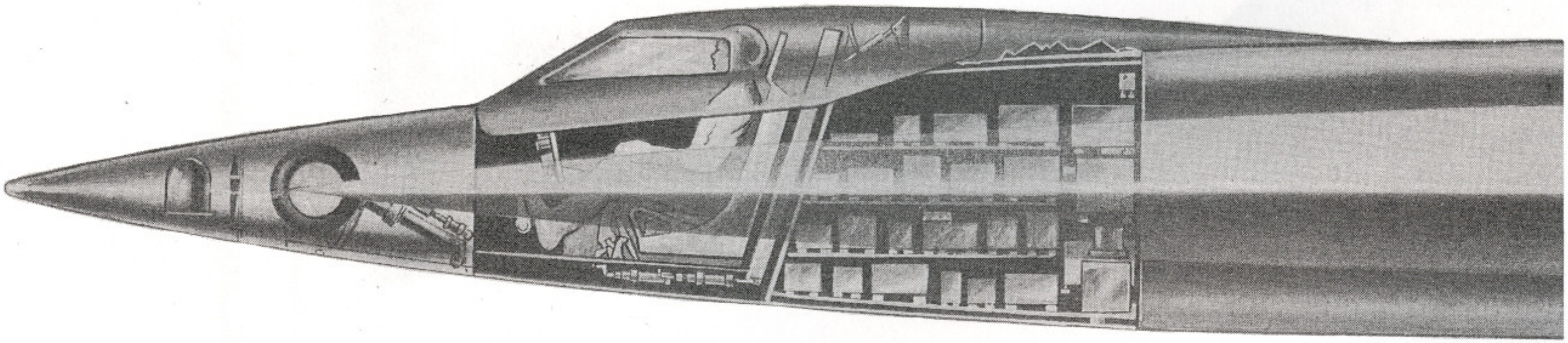
The main gear consists of two strut-mounted skids that fit flush to the fuselage when retracted. Gear extension is initiated by manual release of the uplock. Gravity and aerodynamic loads extend the gear and a bungee spring insures proper positioning of the drag linkage and actuation of the down lock. The skid is properly positioned for ground contact by a bungee system. The ground crew retracts the gear by manually unlocking the drag brace and rotating the strut and skid up against the fuselage.

The nose gear comprises dual wheels mounted on a retractable air-oil strut. Manual ground retraction of the gear is done by releasing the down-lock, collapsing the strut by means of an external air supply, and rotating the gear into the wheel well by hand. Extension is started by manual release of the uplock, followed by an initial rotation caused by the expanding air-oil strut operating against a cam, and then by gravity and air stream loads which bring the gear to the down-locked position. A fairing attached to the strut fully encloses the gear when retracted.

A manually retractable skid in the lower vertical tail is released by the pilot and is extended by gravity and a spring bungee.

The preferred method of landing will probably be to touch down tail-first, with a subsequent pitch-over onto the main skids and nose gear for ground deceleration and stopping. The wide tread of the skids and the castering ability of the nose wheel will minimize the tendency for directional oscillation while decelerating.

INSTRUMENTATION



Selection of this equipment has been guided by the basic principles of safety, ability to follow a programmed trajectory, and minimum need for development. All instrumentation is standard GFAE except the Air Data System, which is defined in NAA Report NA-55-231 included in this proposal.

A uhf AN/ARC-34 command transceiver will be used for voice communication. This unit provides more functions than are necessary, so the feasibility of using a smaller, more compact set of lower power (such as the AN/ARC-45) will be investigated.

Lateral steering during the initial portions of the flight will be principally aided by the use of a J-4 gyrocompass, while the later part of the mission, including the approach to the landing field, will be facilitated by the use of an AN/ARA-22 radio homing group. This unit time-shares a portion of the uhf command set circuits.

At altitudes above the limits of the air data unit, airplane attitude and orientation will be determined by a K-4B remote-indicating vertical gyro. This instrument does not tumble and has a very low rate of drift. The pilot will need this instrument while leveling the wings and adjusting pitch attitude prior to re-entry into the atmosphere. A panel-mounted accelerometer will aid in accurate determination of the desired climb paths subsequent to launching.

The pilot's immediate reactions and comments upon incidents during the course of a flight will be recorded on an AN/ANH-3 tape recorder for later playback and analysis.

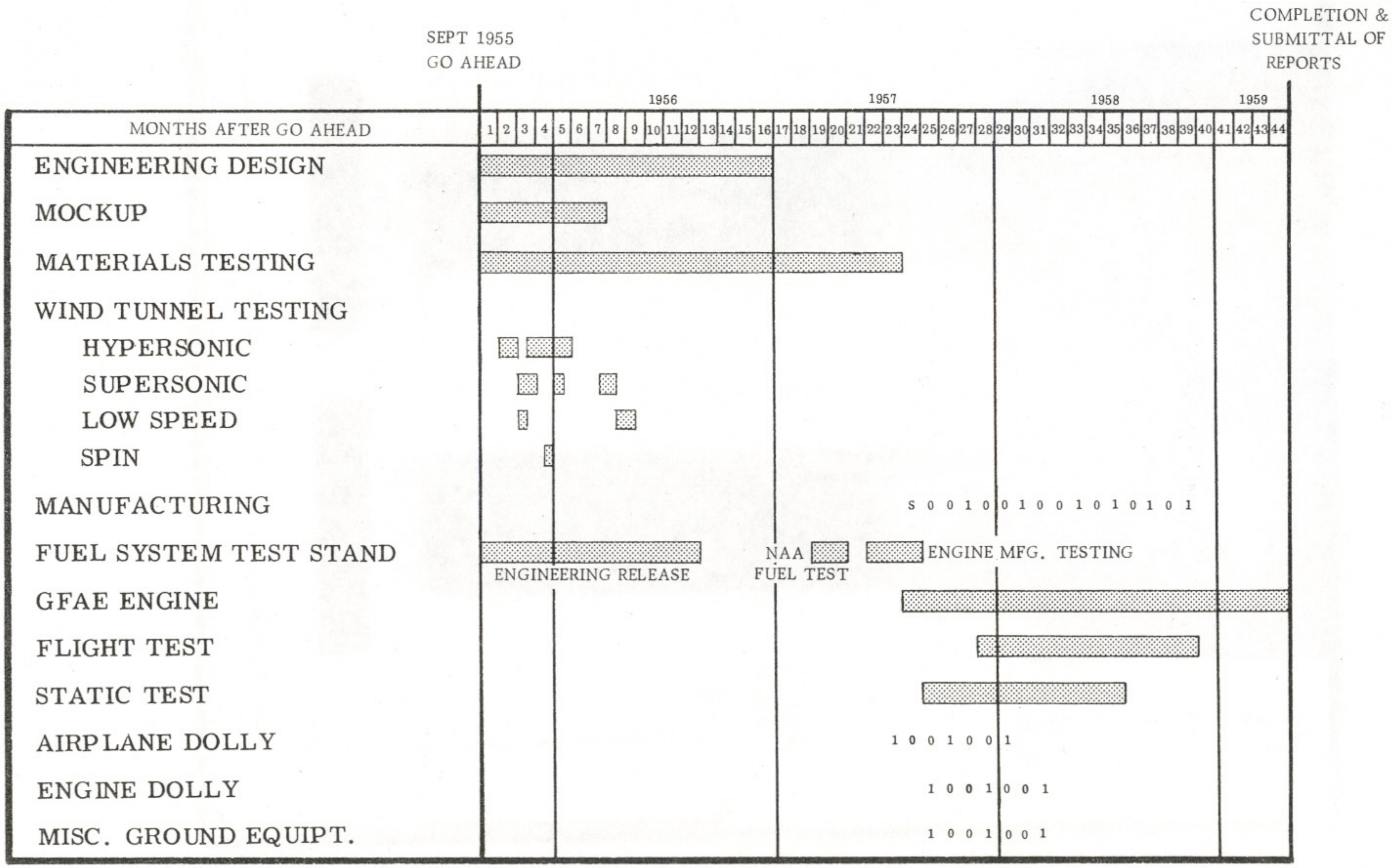
A multiple-purpose air data system, defined in NAA Report NA-55-231, will be designed to furnish certain information. Development time for this system will be minimized, since many of the components have already been successfully developed. Pitot-static pressures, differential dynamic pressures due to angle of attack and angle of skid, and air stream temperatures will be fed into a data computer, and outputs illustrating Mach number, indicated airspeed, rate of climb, barometric altitude, angles of attack, and skid will be presented to the pilot for his evaluation. Compensation for the total pressure errors at high Mach numbers will be applied to the observed pressure readings. The present-day NASEC (Static Error Compensation) device may be easily extended into the range of this test airplane. Conventional rate-of-climb instruments are too sluggish for a craft of this type, but a fast-acting sensitive instrument called NARODI (Rate of Descent Indicator), designed for missiles, may be adapted. A usable accuracy should still be available at a 100, 000-foot altitude. Accuracy is very good at low altitudes, and it will aid in determining the rate of descent during a landing. The Machmeter will have limits of 0. 7 and 7. 0 Mach number.

Re-entry into the atmosphere at very high speeds will result in great importance being placed on the knowledge of airplane angle of attack and skid. The sensitive differential pressure transducers will fortunately allow the detection of these angles about 30 seconds before the dynamic air pressures rise to significant values. Optimum boom shapes to maximize this sensitivity will be the subject of further research. Both angles will be presented on a single cross-pointer indicator for easy reading.

The specified research instrumentation equipment will be installed in the airplane in a compartment cooled and pressurized by means of a lightweight liquid nitrogen system. Components will include automatic recorders for airspeed, altitude, three-axis linear accelerations, angular velocities and accelerations, airplane attitude, airflow directions, control positions and forces, trim settings, hinge moments, structural temperatures and stresses, and stagnation temperature. Automatic cameras will record visual deformations of wing and tail surfaces. A multichannel telemeter will relay engine operational data and cosmic radiation information to the ground. An AN/APN-65 radar beacon transpondor will allow accurate ground tracking and ranging of the airplane during flight.

[redacted]

PROGRAM SCHEDULE



NOTE: 1. Contractor modified B-36 Carrier Airplane to be available for test program by Dec. 1957. Carrier to be flown and maintained by USAF personnel during Contractor's flight test program.

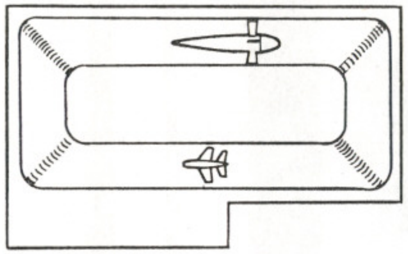
2. GFE engine thrust stand and loading ramps to be available by December 1957.

[redacted]

NORTH AMERICAN WIND TUNNELS

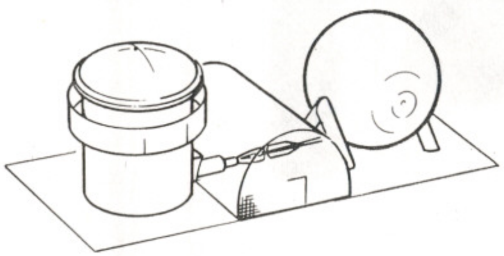
. . . type & availability

1. NORTH AMERICAN AERODYNAMICS LABORATORY



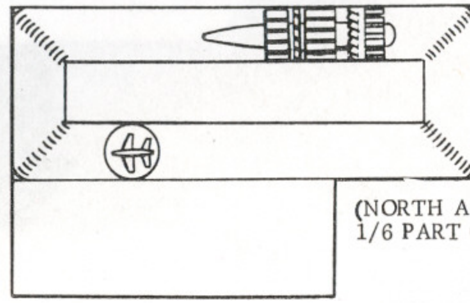
MACH RANGE:	.2
WIND TUNNEL SIZE:	7.75 FT x 11 FT
MODEL SIZE:	7 FT
AVAILABLE:	NOW

2. SUPERSONIC AEROPHYSICS LABORATORY



MACH RANGE:	.7, 1.22, 1.56, 1.87 2.48, 2.87, 3.24
WIND TUNNEL SIZE:	16 INCH x 16 INCH
MODEL SIZE:	10 INCH
AVAILABLE:	NOW

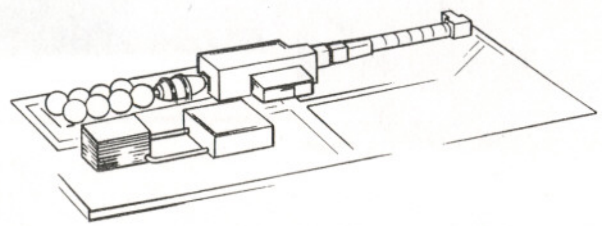
3. SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL



(NORTH AMERICAN HAS 1/6 PART OWNERSHIP)

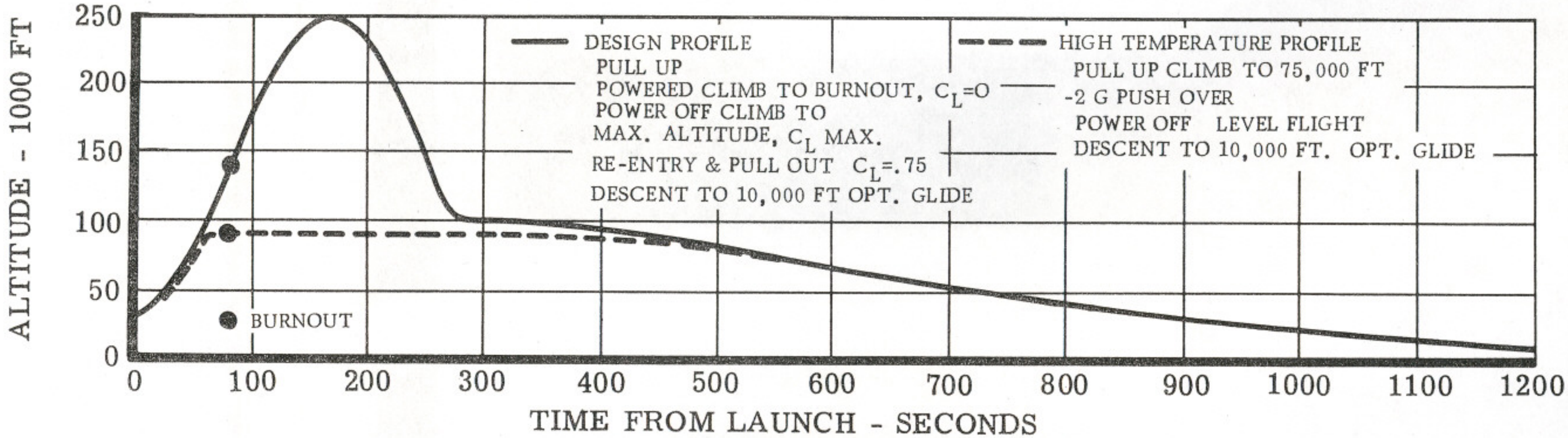
MACH RANGE:	.2 TO 1.80
WIND TUNNEL SIZE:	8.5 FT x 12 FT
MODEL SIZE:	5 FT
AVAILABLE:	SUBSONIC & TRANSONIC, NOV 55 SUPERSONIC , FEB 56

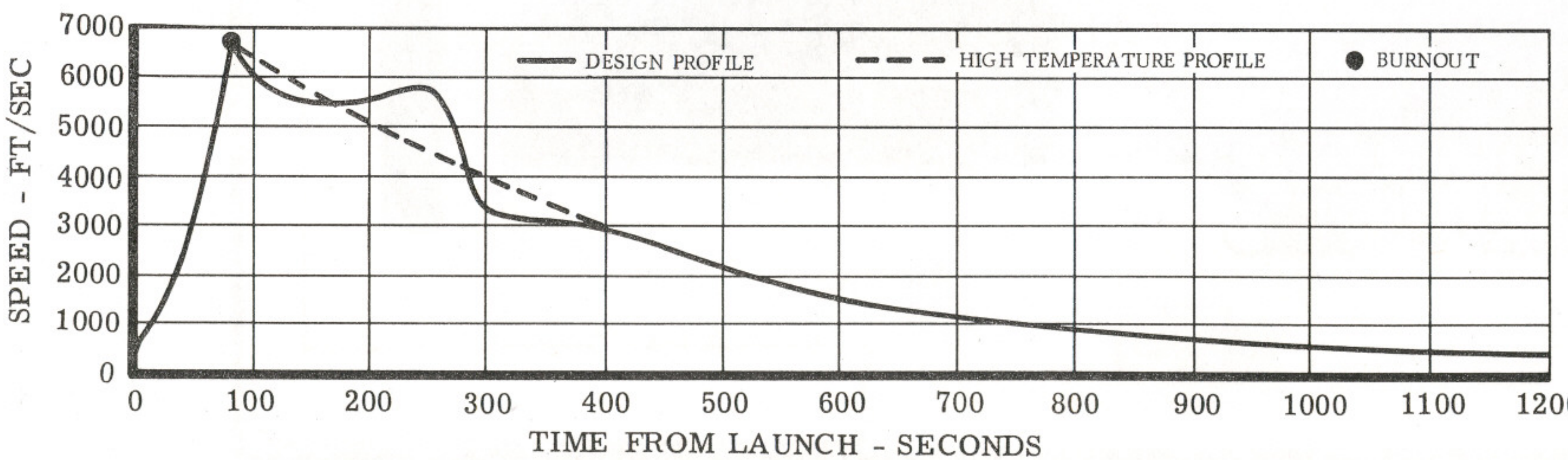
4. NORTH AMERICAN TRISONIC



MACH RANGE:	.2 - 3.50
WIND TUNNEL SIZE:	7 FT x 7 FT
MODEL SIZE:	5 FT
AVAILABLE:	MAY 1956

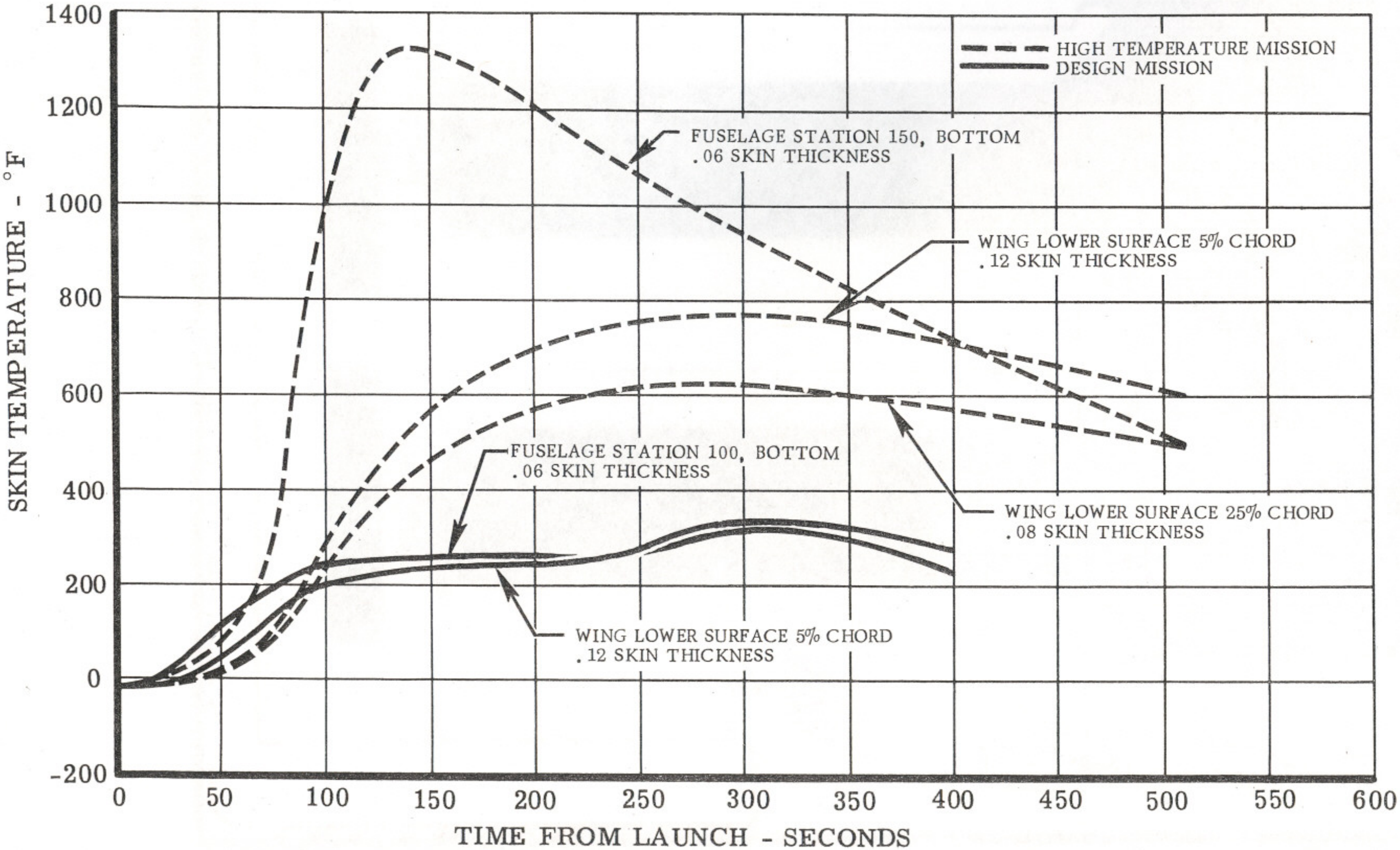
DESIGN MISSIONS
. . . altitude and speed vs. time



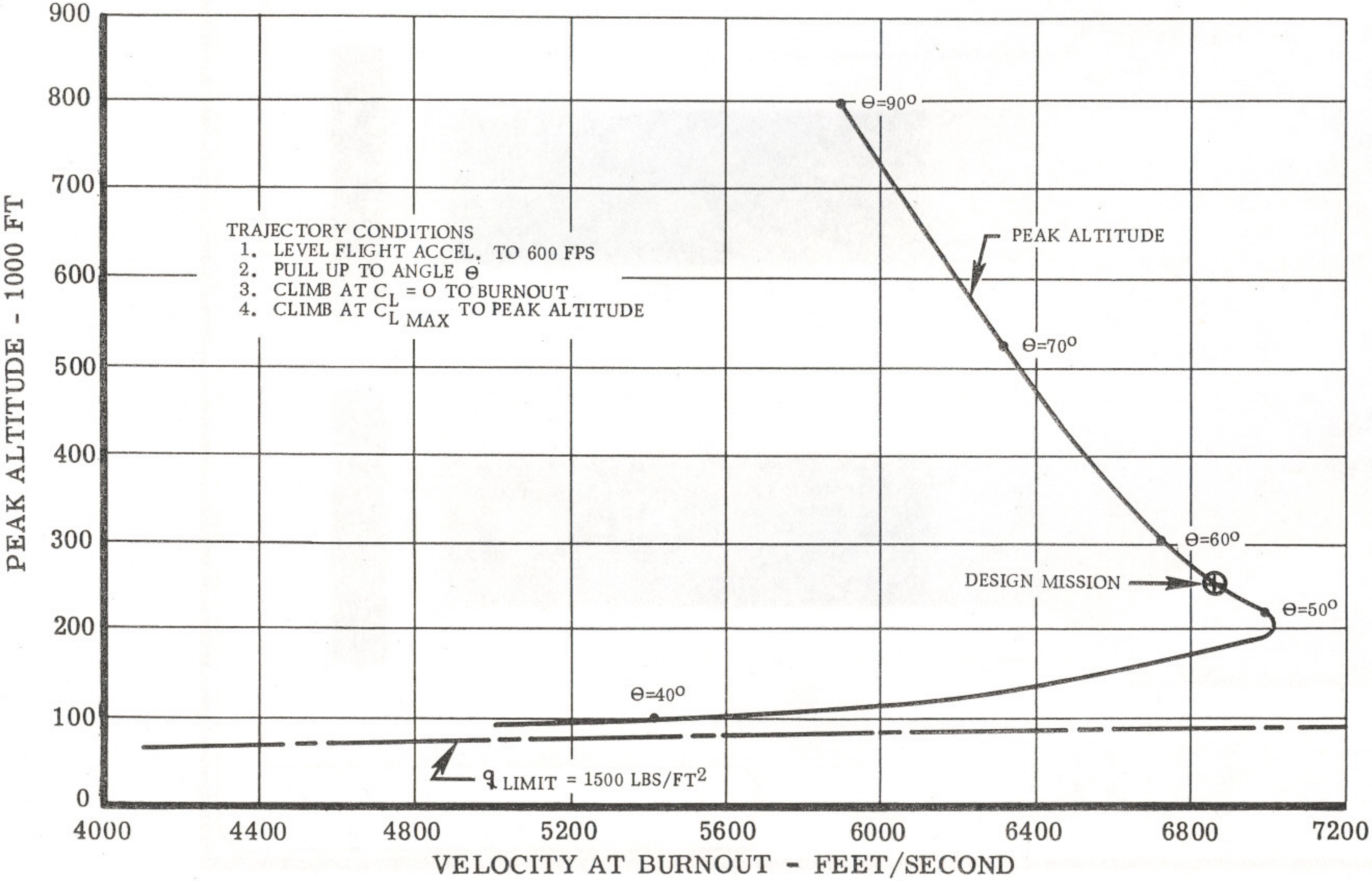


DESIGN MISSIONS

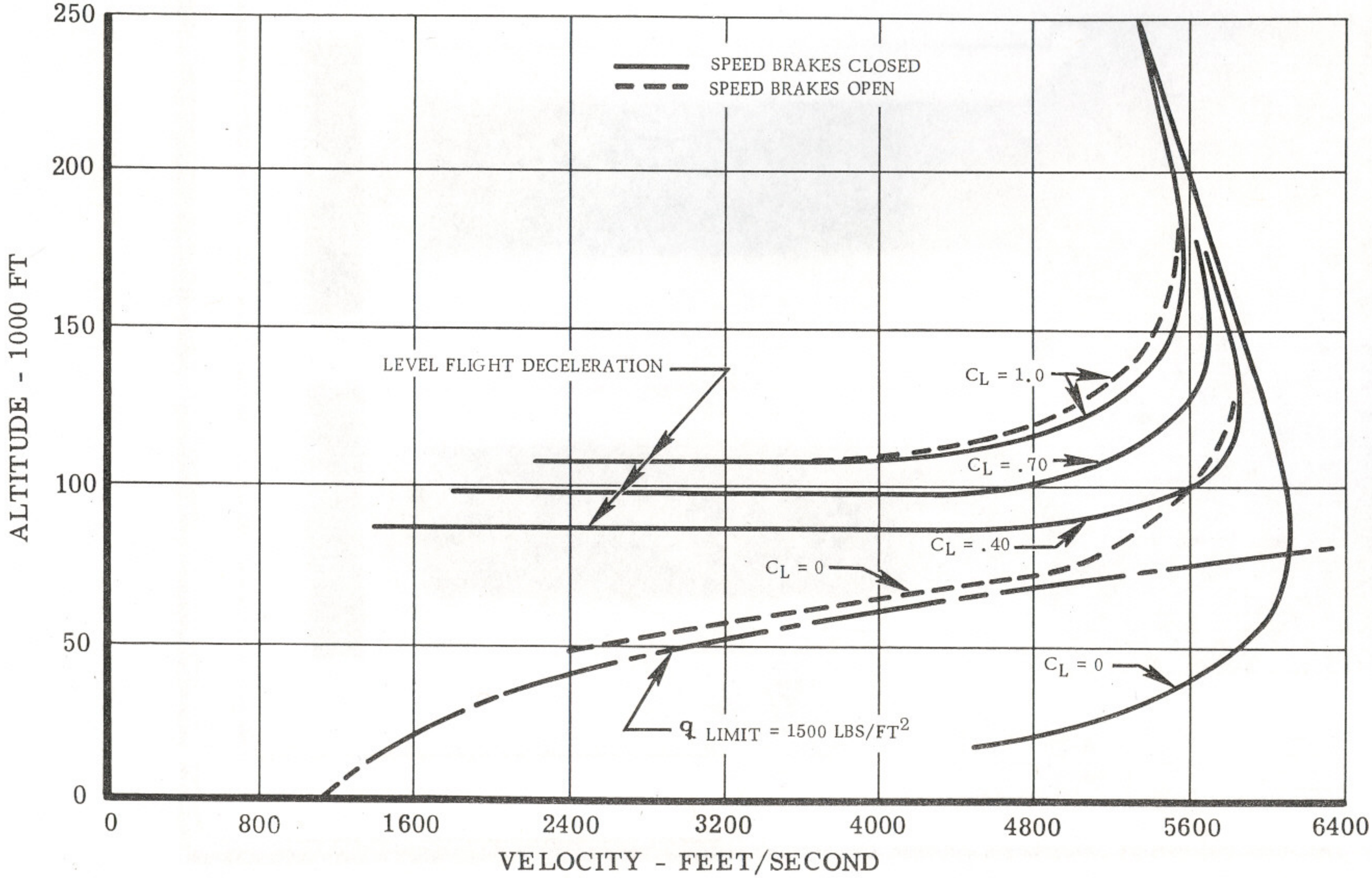
. . . temperature vs. time



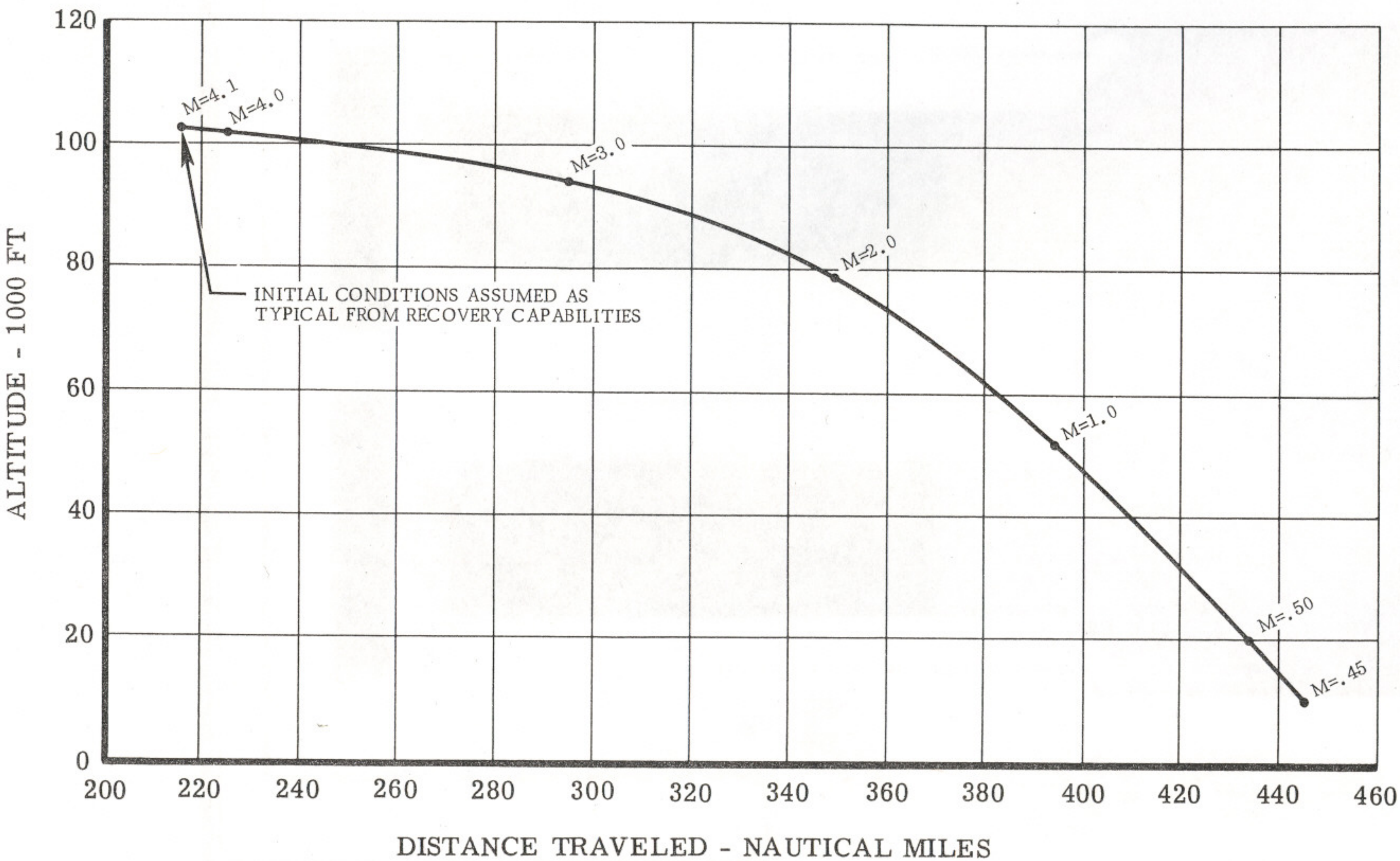
PERFORMANCE CAPABILITIES



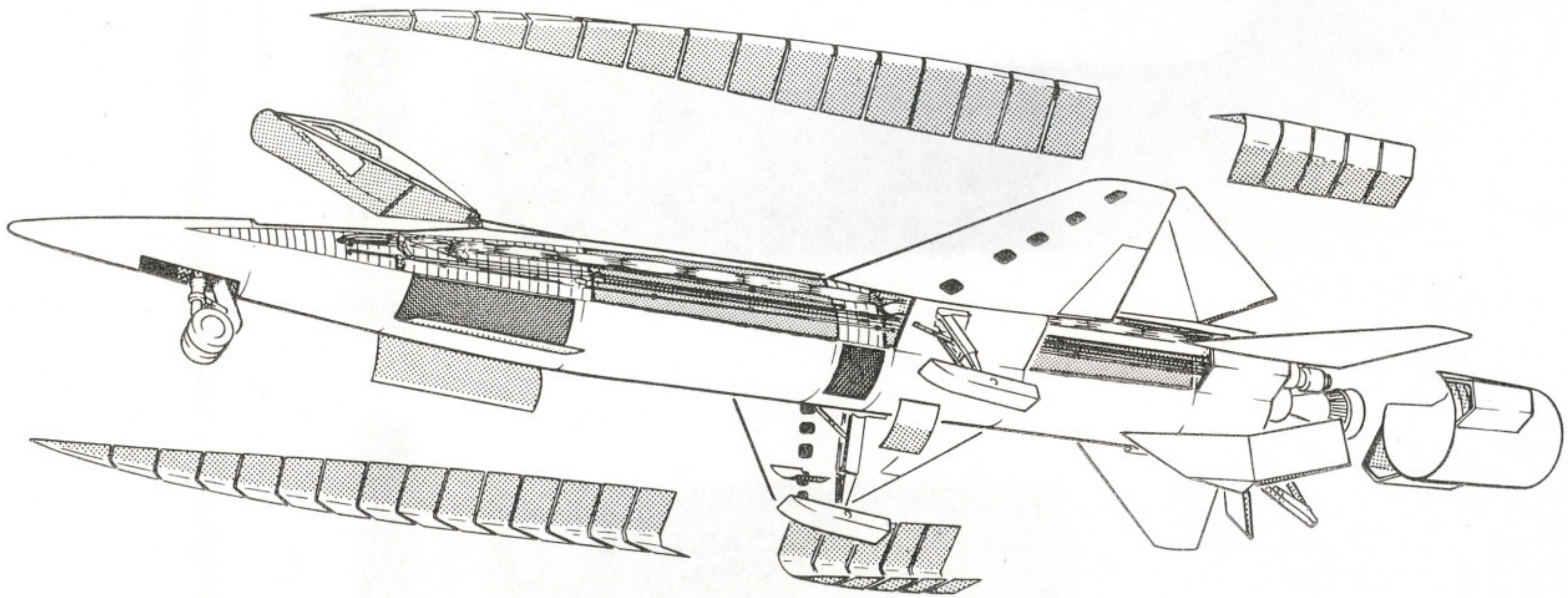
RECOVERY CAPABILITY



GLIDING CAPABILITY



ROUTINE MAINTENANCE



The most effective method of reducing routine maintenance is to incorporate the absolute minimum of systems and components which require servicing. This approach has been selected by North American and will be enhanced by detailed attention to the selected systems to insure that each requires a minimum amount of attention to guarantee reliable operation.

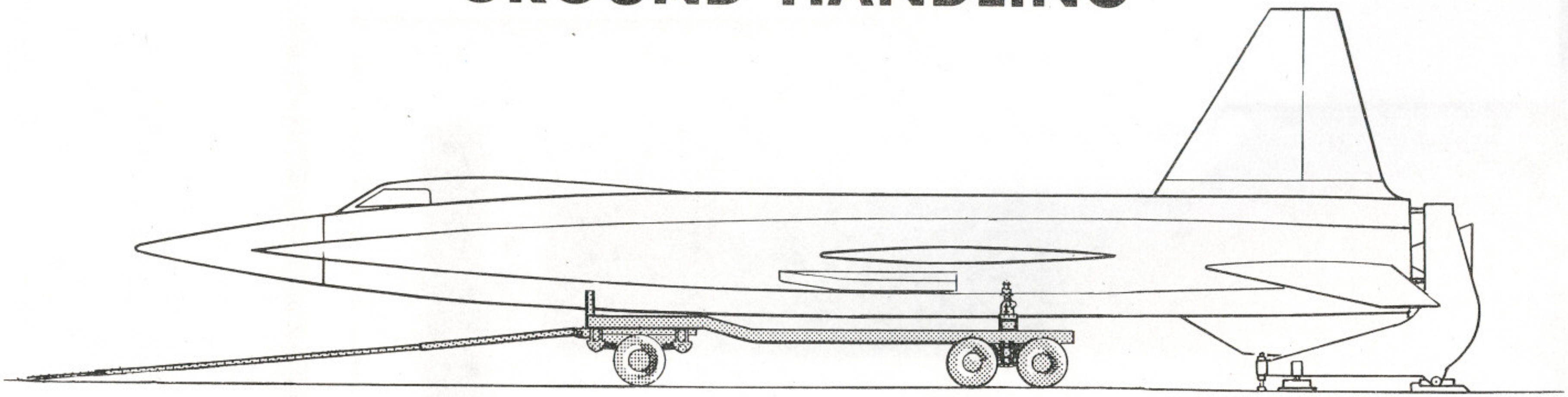
Access to wiring, hydraulic lines, etc, is facilitated by their location in removable, side fuselage fairings.

The fairings around the engine may be removed, and a special engine dolly may be directly attached to the engine for removal. Basic simplicity of the landing gear reduces maintenance in this department to a minimum. Access doors in the instrumentation compartment facilitate the long and extensive calibration procedures necessary on complex, multichanneled recorders. All hydraulic systems are located in the aft fuselage, and control system feel bungees and mixer linkages are in the cockpit.

Engine run-ups may be performed at full power after the airplane dolly is backed into position in line with a fixed engine thrust stand and the engine mount fittings are attached to the stand in readiness for starting. Engine thrust calibrations are possible by means of integral thrust recording devices in the stand.

Every attempt has been made to simplify and standardize the maintenance procedures for the X-15, consonant with the design of a practical and useful research airplane.

GROUND HANDLING



The two major pieces of handling equipment necessary for the care of this research airplane are the transportation dolly and engine run-up thrust stand. The dolly is a pneumatic-wheeled roadable unit, with provisions for easily mounting the airplane and leveling as required. A tow tug can quickly transport the fully loaded airplane between the shops, fueling pits, or the mother airplane. The fixed, thrust-recording, engine run-up stand provides a solid reaction support for the airplane engine during ground operation of the rocket motor. Hagen thrust units are arranged so that signals indicative of engine thrust are available for thrust calibrations.

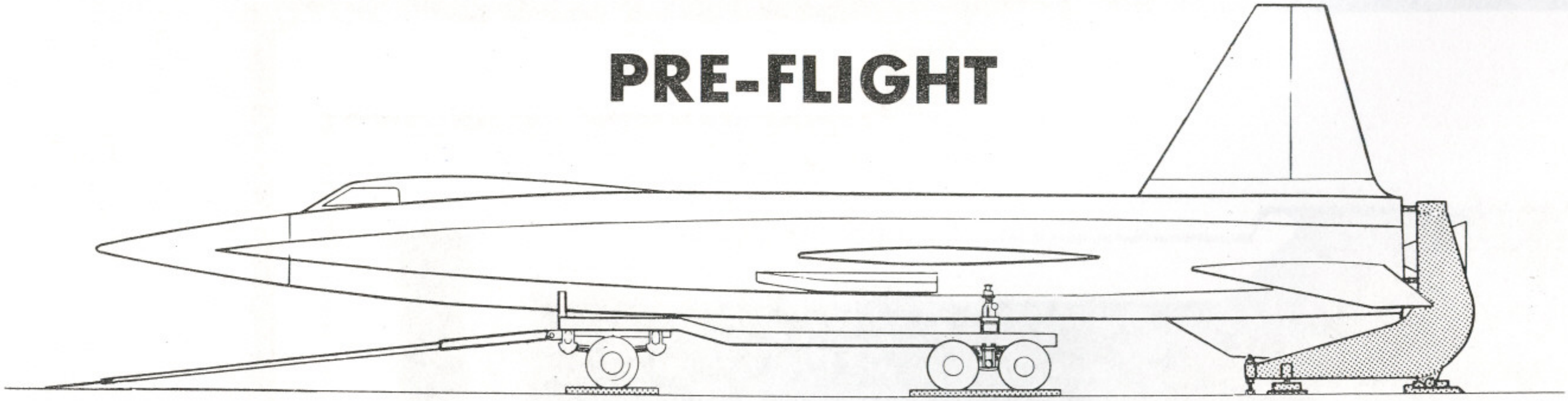
A small engine support dolly may be used for removal of the rocket motor from the airframe for repair.

A standard 15-ton motor crane is used to place the airplane upon its dolly. Standard ground power carts, propellant tank carts, etc, are used during maintenance and preflight preparation.

Loading of the X-15 into the mother airplane involves running the B-36 main landing gear bogies up on permanent concrete ramps by the use of commercially available electric cable hoists attached to the gear struts. This method of raising the mother airplane for loading does away with the need of expensive and dangerous loading pits.

Every attempt has been made to specify ground handling equipment for the X-15 that is simple, reliable, and as much "off-the-shelf" as possible.

PRE-FLIGHT



The X-15 research airplane, mounted on its transport trailer, will be easily accessible for preflight check-out and calibration. All operational checks of equipment and components, including run-up of the auxiliary power units, may be made on the trailer. External electrical and hydraulic power will be available from ground power supplies.

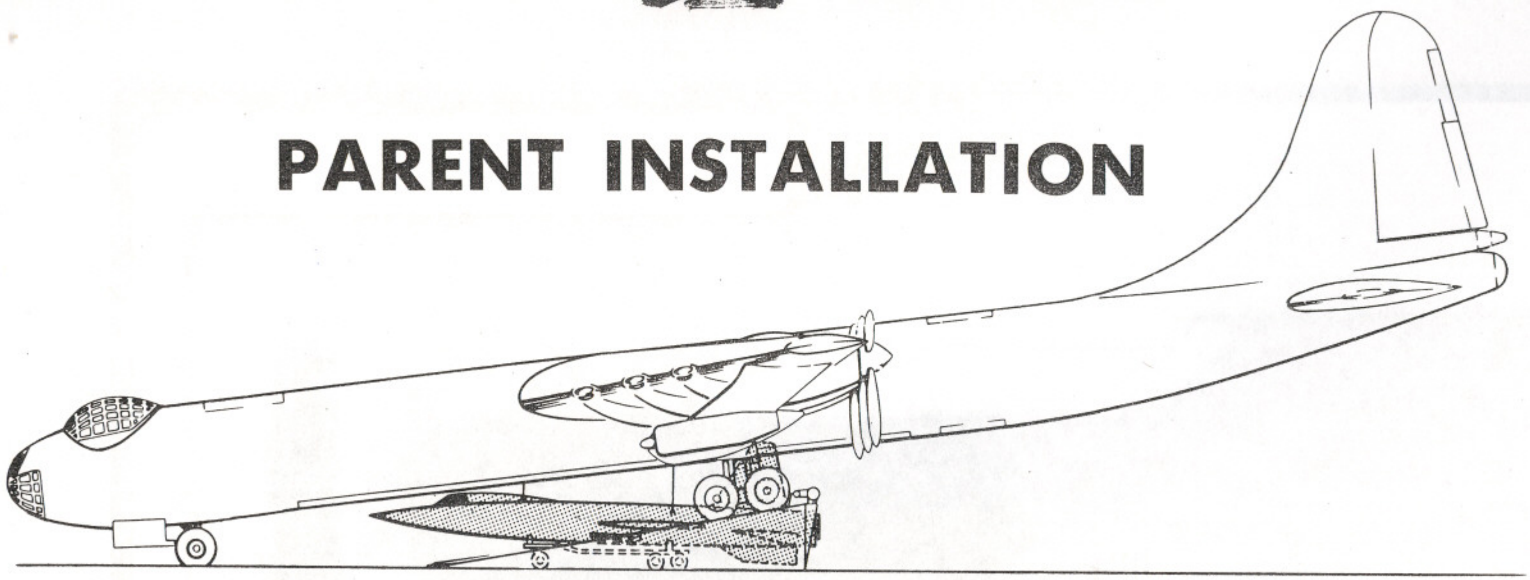
Electrical checks will include operation of each electric generator, test of "internal-external" power circuits, and operation of all electrically powered equipment. Calibration and final adjustment of all recording instrumentation will be made during this period. Operational checks of hydraulically powered control systems and control surfaces will be performed.

Ground operation of the rocket motor will be possible with the use of a solidly built engine test stand adapter. The X-15, on its trailer, may be positioned adjacent to the test stand, attachment made between the stand and the rocket motor support fittings, and the motor may be operated with its thrust being directly absorbed by the test stand. Provisions for Hagen thrust units and recording instruments will allow calibration of the rocket thrust forces. Blast deflectors will protect surrounding equipment from the jet efflux of the rocket.

The main preflight power plant activity, while the airplane is on the trailer, will involve leakage checks under both static and actual engine operation conditions, plus the final filling of propellant tanks and gas systems. The filling sequence will be: hydrogen peroxide tank, ammonia tank, liquid oxygen tank, and helium gas system charging. Upon completion of installation and mating of breakaway fluid fittings of the X-15 to the mother airplane, the liquid oxygen tank is topped off by opening the filler valve. The 1000-gallon carrier supply tank may be concurrently topped.

Upon the completion of the afore-mentioned procedures, the research airplane is receiving its power from the mother airplane, and all is in readiness for take-off.

PARENT INSTALLATION



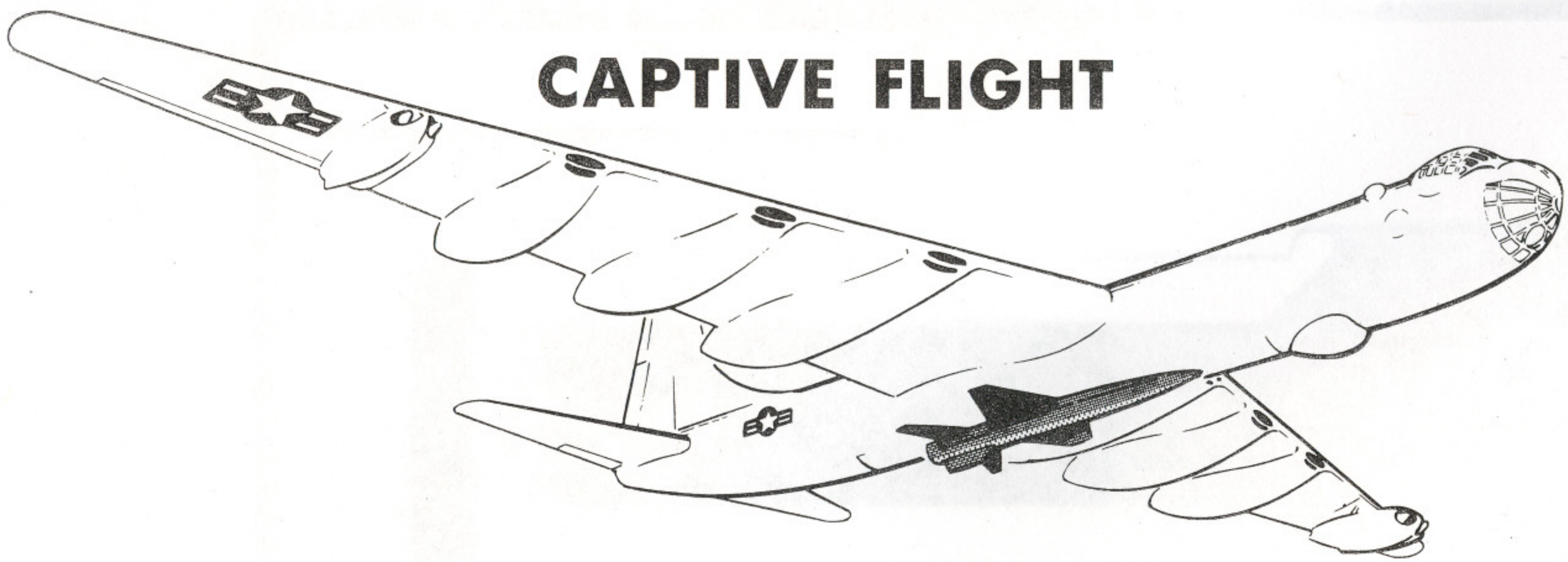
The basic method of operation for this research airplane is to air-launch at high altitudes from a mother airplane. With this in mind, the ease of installation of the X-15 is of great importance. A modified B-36 bomber will be used as the parent airplane.

Preparation of the B-36 parent will include filling a 1000-gallon liquid oxygen tank and a 60-gallon ammonia tank, to be used for topping off the X-15 tanks just prior to launching. The airplane is then taxied or towed into alignment with the loading ramps, and a pair of winches attached by cables to the airplane main gear struts will draw the B-36 up onto the ramps. External ground power is now connected, aft bomb bay doors opened, and the trailer carrying the fully loaded X-15 will be maneuvered into position under the bomb bay.

Three cable lifts, powered by commercial electric hoists, are used to raise the X-15 into position for engagement with the shackles. Hoist controls in the bomb bay allow the armorer to closely supervise this operation. Individual control of the three hoists allows accurate alignment of shackles and propellant breakaway fittings.

After shackles are locked and checked, the lift cables are removed, electrical connectors plugged in, and the X-15 canopy opened and secured to allow cockpit access during captive flight. (Using mother airplane electrical power and ground hydraulic power, checks may be run on the electrical and hydraulic systems, including full deflection of all control surfaces.) Aft bomb bay doors are closed, and the hydrogen peroxide discharge breakaway fitting to the X-15 is attached. Finally, the loaded B-36 is eased back down the ramps with the main gear winches, and the airplane is ready for take-off.

CAPTIVE FLIGHT



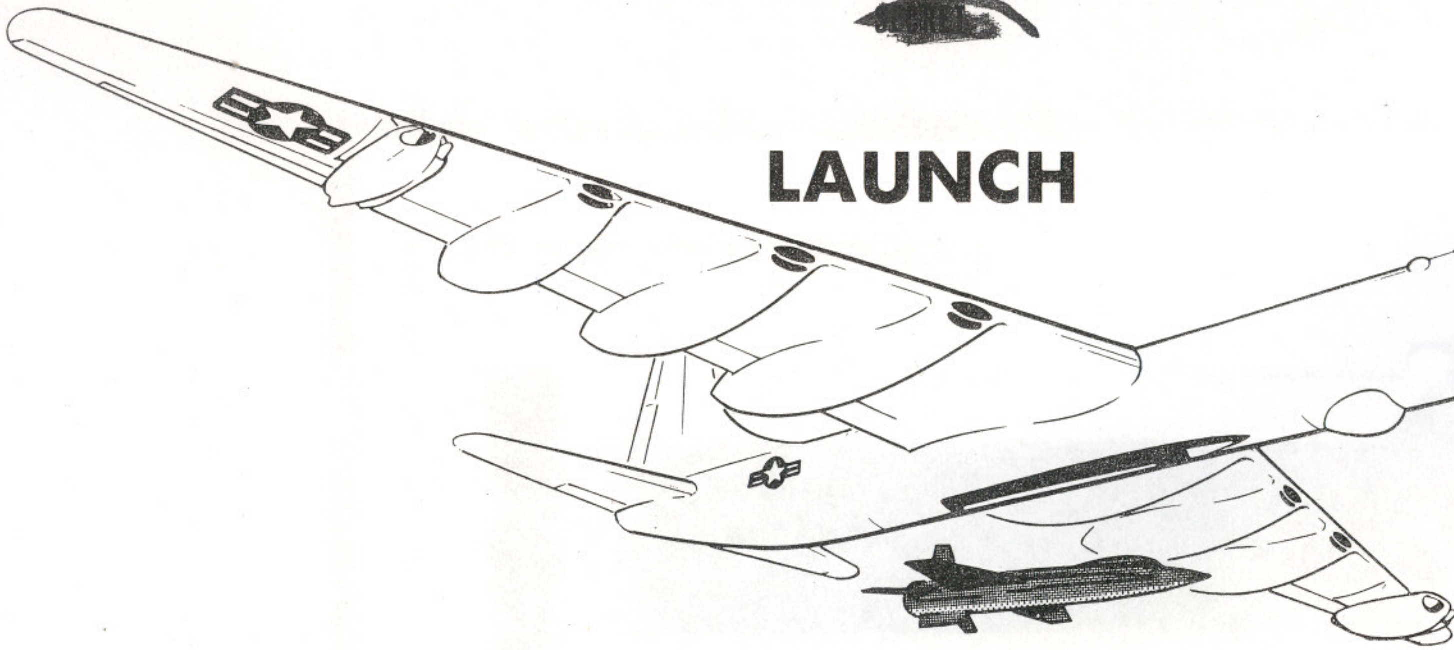
Provisions are made in the bomb bay of the mother airplane to allow easy access to the cockpit and other maintenance areas of the research airplane. The pilot may enter the cockpit, operate controls, check instruments, etc, and then leave with a minimum of effort. Wind buffeting within the bomb bay is minimized by the close-fitting fairings around the X-15 fuselage. Provisions will be incorporated in the mother airplane for access to pressurized areas from the bomb bay. All crew members will be connected into the intercom circuits. It is suggested that a bank of powerful lights be turned on several minutes prior to launching so that the pilot will not be blinded by the sudden glare of daylight during launching. Sufficient lighting for working will be installed throughout the bomb bay.

At a predetermined altitude, the liquid oxygen and ammonia filler valves will be opened, and the X-15 tanks will be continuously "topped off" from the mother airplane supply tanks. At the time of "arming" the X-15 engine, the filler valves will close automatically.

Vent lines from the mother airplane supply tanks will guide propellant vapors overboard.

In the event of an aborted launching, the airplane propellants may be rapidly jettisoned. The pilot may initiate this procedure with his "PRESSURIZE-JETTISON" control lever. Liquid oxygen and hydrogen peroxide are conducted through breakaway fittings to the jettison lines in the mother airplane and thence discarded at the tail of the mother airplane. Ammonia propellant will be jettisoned from the bottom of the X-15.

LAUNCH



The research pilot will maintain communication with the mother airplane pilot via command radio link during the period prior to launching. Time of launch will be at the discretion of the carrier pilot.

The auxiliary power units will be in operation for 5 minutes prior to launching.

The research pilot will turn on the "ARM" switch and then operate the "PRESSURIZE-JETTISON" lever to the PRESSURIZE position, which admits helium gas into the propellant tanks in readiness for rocket motor starting.

Operation of the "PRIME" switch will bleed the main propellant valves around the pumps to ensure against pump cavitation during starting. The hydrogen peroxide catalyst beds will be heated ready for operation. The "prime" period will last for about one minute, at the end of which time the mechanically synchronized suspension shackles will be actuated and the X-15 launched. Quick-disconnect fittings for the ammonia and oxygen fillers and the peroxide and oxygen jettison valves will separate easily, as will the electrical connectors. After the X-15 clears the mother airplane, the suspension links will retract cleanly into the research airplane mold line and the rocket motor may then be started.

The X-15 has been designed for a Mach 0.6 launch at 30,000 feet. The ability of the B-36 to attain this same Mach number at about 38,000 feet will give the research pilot an altitude margin that can be converted to additional speed in a short dive, if necessary, for satisfactory launching. It is expected that separation characteristics of the X-15 should be excellent.

EMERGENCY PROCEDURES

In the event that an emergency requires that the mission has to be aborted subsequent to launching, the propellants may be rapidly jettisoned within a period of 40 seconds and the X-15 may be glided to a landing. Assuming that a decision is made to abort immediately after launching at 38,000 feet, a gliding range approximately 30 miles is available before the X-15 sinks to 10,000 feet. Thus considering 10,000 feet to be a minimum altitude from which it will be possible to make the necessary turn into the wind and final approach, it is seen that an emergency landing strip must be available within approximately 30 miles of the point selected for normal launching of the X-15.

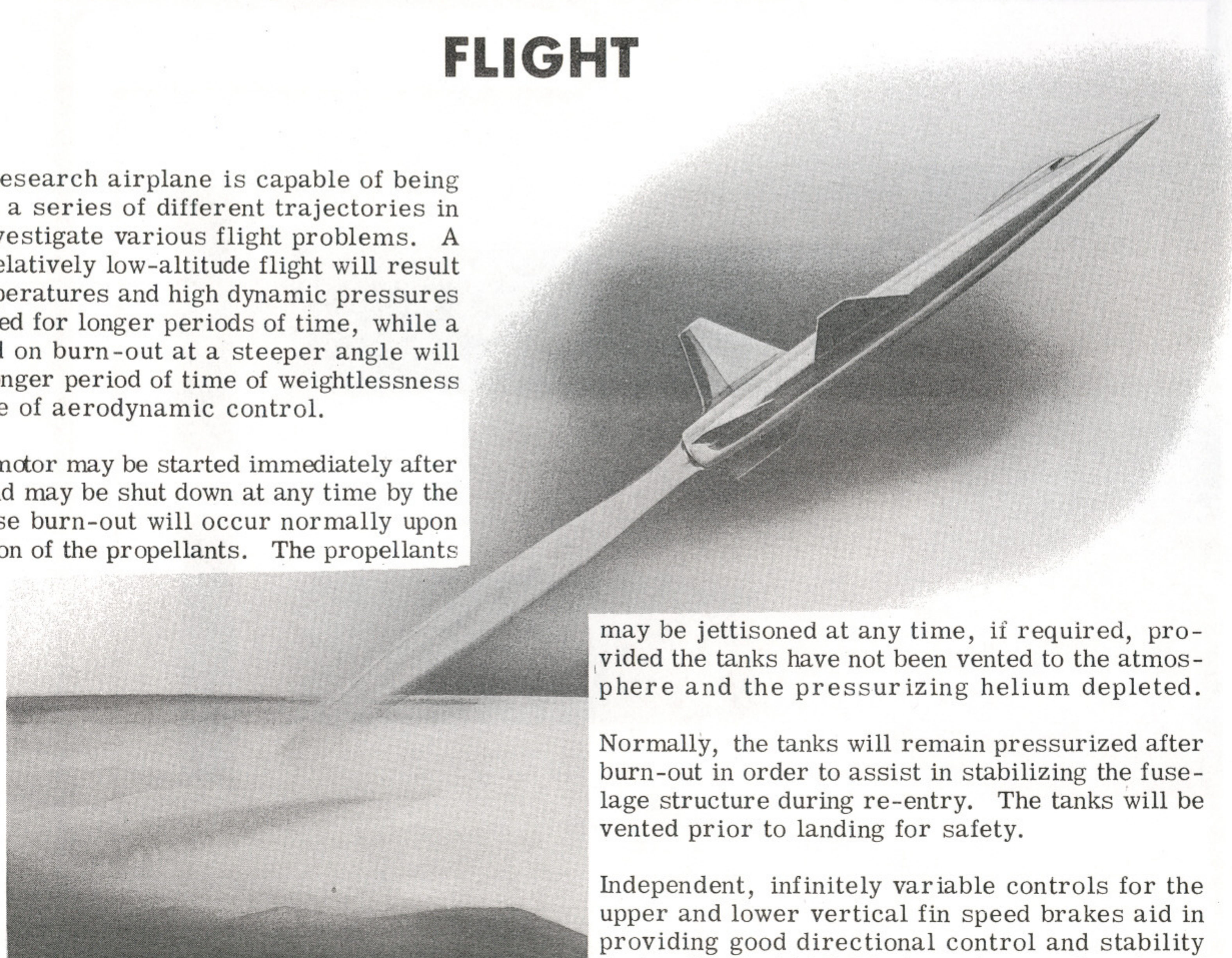
The time required to glide fully loaded, from 38,000 feet down to 10,000 feet is approximately 3.5 minutes. Three attempted engine restarts will extend over a period of 1 minute. At this time an altitude of 30,000 feet has been reached. If it is assumed that all propellants are jettisoned by the time the 10,000 foot limit is reached, then the jettisoning procedure must begin at 16,000 feet.

In the event the pilot is required to bail out, the normal procedure will be to use the ejection seat. The design dynamic pressures encountered are not higher than those assumed for present-day high performance aircraft, so the pilot in his seat should be able to clear the aircraft satisfactorily at any altitude. The protection afforded by the pressure suit will probably conserve body heat and provide sufficient oxygen for a free fall from very high altitudes. However, the two relatively unknown effects of high stagnation temperatures attained on the exterior of the suit upon entering the atmosphere after falling through space, and the possible high rates of angular rotation of the pilot's body during free fall will have to be studied in detail to determine the maximum altitudes at which it will be feasible to bail out. Current developments at NAA indicate that with the protection against the airstream afforded by a full pressure suit, a suitably stabilized ejection seat may be designed which will assure escape under extreme conditions.

FLIGHT

The X-15 research airplane is capable of being flown along a series of different trajectories in order to investigate various flight problems. A constant, relatively low-altitude flight will result in high temperatures and high dynamic pressures being attained for longer periods of time, while a flight based on burn-out at a steeper angle will provide a longer period of time of weightlessness and absence of aerodynamic control.

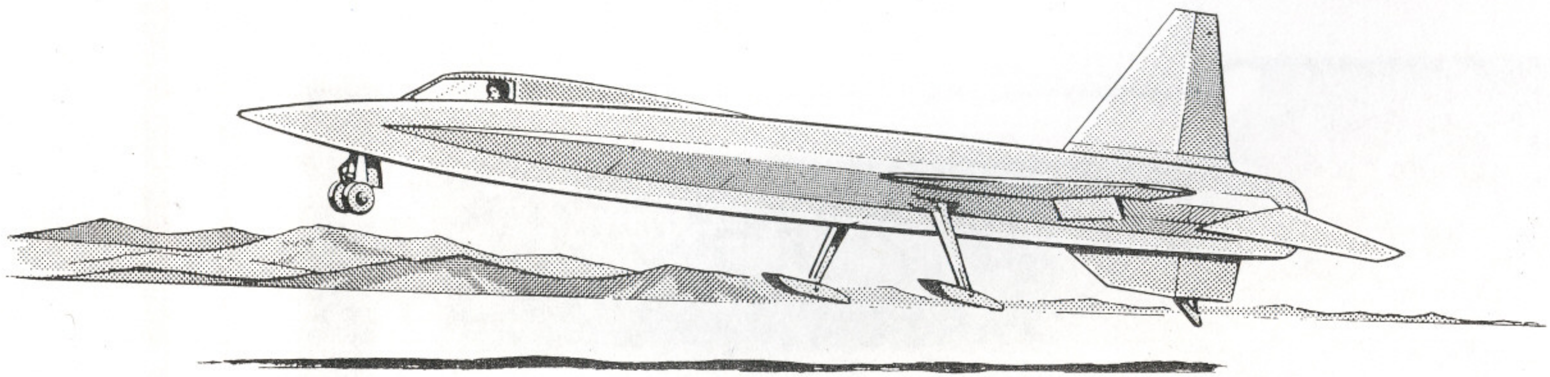
The rocket motor may be started immediately after launching and may be shut down at any time by the pilot, or else burn-out will occur normally upon the exhaustion of the propellants. The propellants may be jettisoned at any time, if required, provided the tanks have not been vented to the atmosphere and the pressurizing helium depleted.



Normally, the tanks will remain pressurized after burn-out in order to assist in stabilizing the fuselage structure during re-entry. The tanks will be vented prior to landing for safety.

Independent, infinitely variable controls for the upper and lower vertical fin speed brakes aid in providing good directional control and stability during flight at high Mach numbers and angles of attack.

LANDING

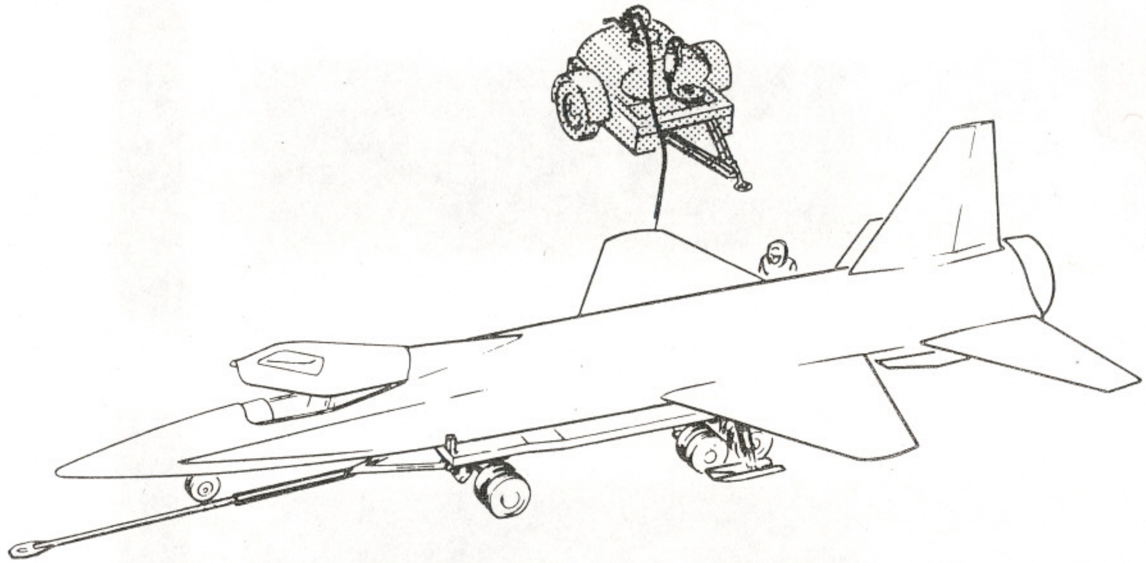


The approach and landing characteristics of the X-15 are considered to be excellent. The design landing attitude is 6 degrees. The pilot may select approach speeds ranging from 165 to 250 knots, which is the flaps-down limit speed. Based on a 6-degree attitude, minimum touchdown speed is 153 knots. The handling qualities of the airplane should be satisfactory, since only about 50 percent of the maximum available lift coefficient will be required. In addition to the conventional aerodynamic controls, the flaps and speed brakes are also easily manipulated to result in very good control characteristics for landings.

The main landing gear, of the skid type, has been selected to result in short landing runs and to minimize the stowage and cooling problems associated with conventional wheels and brakes. The wide-spread tread of the skids, plus the castering ability of the dual nose wheels, will prevent yawing and fishtailing during the short ground run. Normal landing technique will probably involve touching the tail skid down first and then pitching forward upon the main gear and nose gear.

The use of a protruding canopy enables the pilot to have superior landing vision limits, in comparison with a flush cockpit or periscopic installation.

POST FLIGHT

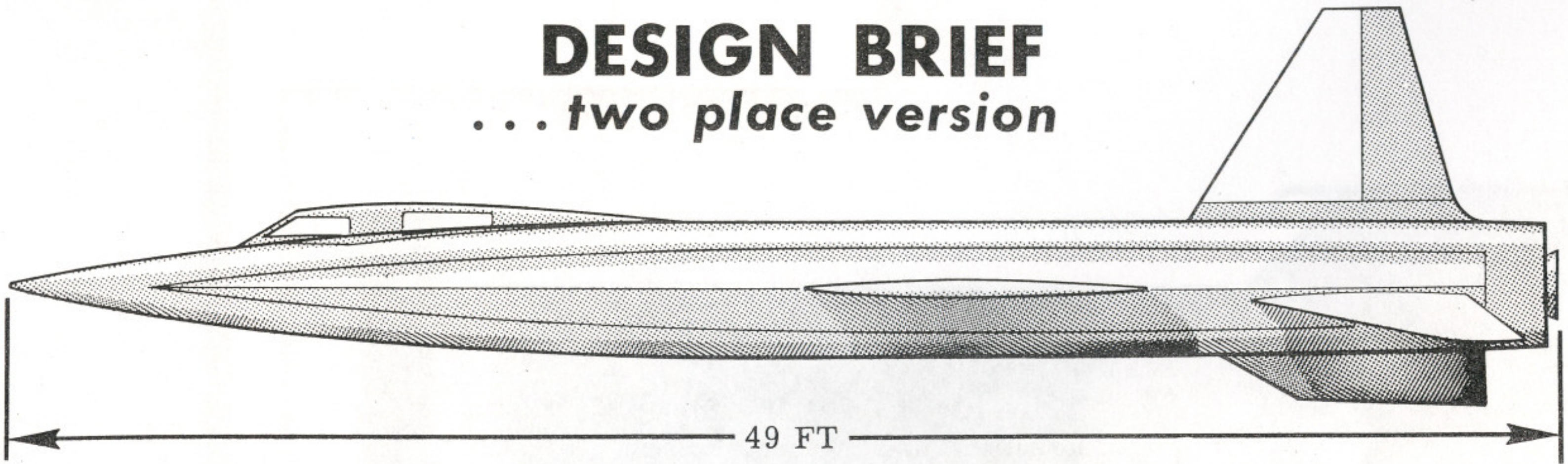


Subsequent to landing, the airplane will be placed upon its transportation dolly for return to base and preparation for the next flight. A 15-ton motor crane will pick up the airplane, using a three-cable sling, and lower it upon the dolly, which has been brought into position with a tractor tug. Once the airplane is mounted and locked on the dolly, its portability and accessibility make it very convenient to perform the necessary maintenance work.

Either before or immediately after the airplane is mounted on the dolly, the hydrogen peroxide tanks will be flushed clean with distilled water as a safety precaution. Recorded data from the research instrumentation compartment will be unloaded and rushed to the development labs.

ALTERNATE VERSION

DESIGN BRIEF
. . . two place version



PERFORMANCE

MAX. VELOCITY AT BURNOUT (DESIGN MISSION).	6800 FT. PER. SEC.
MAX. ALTITUDE DURING COAST (DESIGN MISSION).	250,000 FT.
TOTAL FLIGHT TIME (DESIGN MISSION).	20 MIN.
MAX. ATTAINABLE ALTITUDE	800,000 FT.
MAX. TIME OF "WEIGHTLESS" FLIGHT	6.5 MIN.

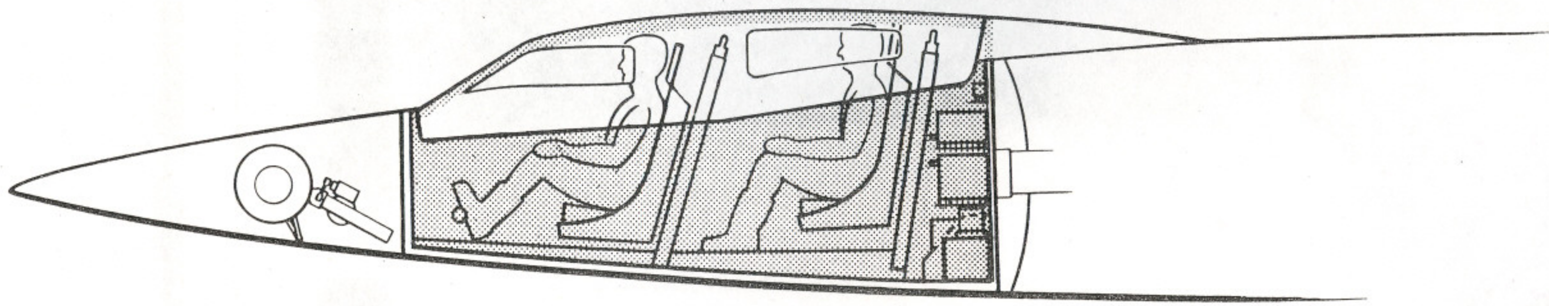
WEIGHT

EMPTY	9,631 LB.
USEFUL LOAD.	18,053 LB.
(PROPELLANT ONLY).	16,410 LB.
GROSS	27,684 LB.

POWER PLANT

REACTION MOTORS INC.	XLR-30RM2
MAX. THRUST, 40,000 FT.	57,000 LBS.

GENERAL ARRANGEMENT
. . . *two place version*



The proposed X-15 research airplane is well adapted for conversion to a two-place research vehicle.

Flight test instrumentation is removed from the airplane, and the instrumentation compartment and canopy are replaced by a rear cockpit and revised canopy. The forward or pilot's cockpit is unchanged.

The rear cockpit contains an ejection seat identical to the pilot's, flat-pane side-vision windows, and an abbreviated presentation of flight and research data. An intercommunication set is provided.

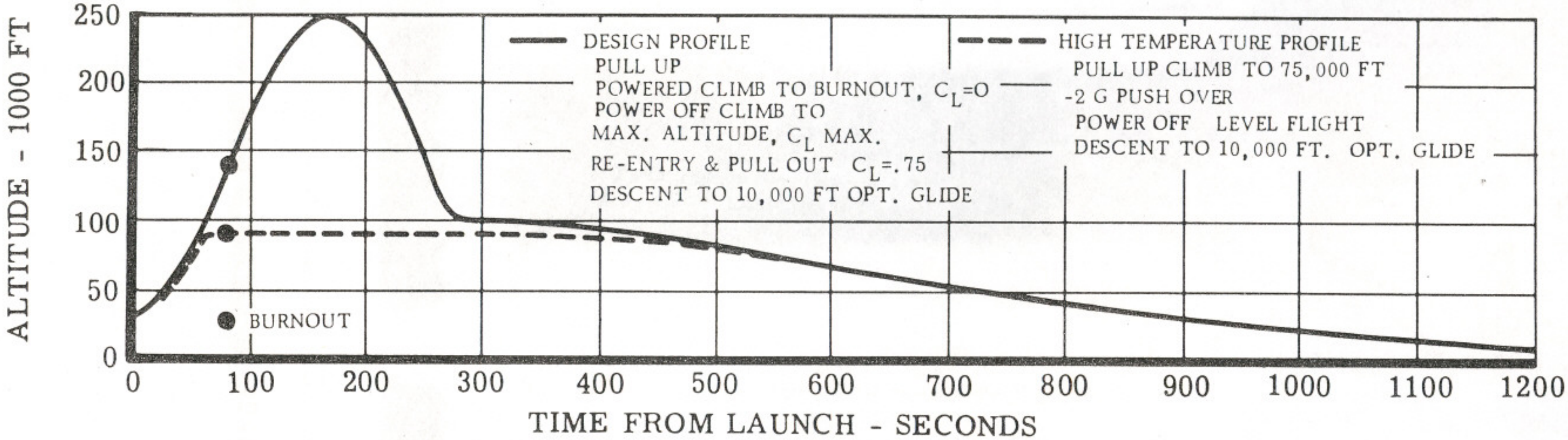
Inasmuch as the launch and burn-out weights and airplane drag are identical to those of the single-place version, no change in performance will result.

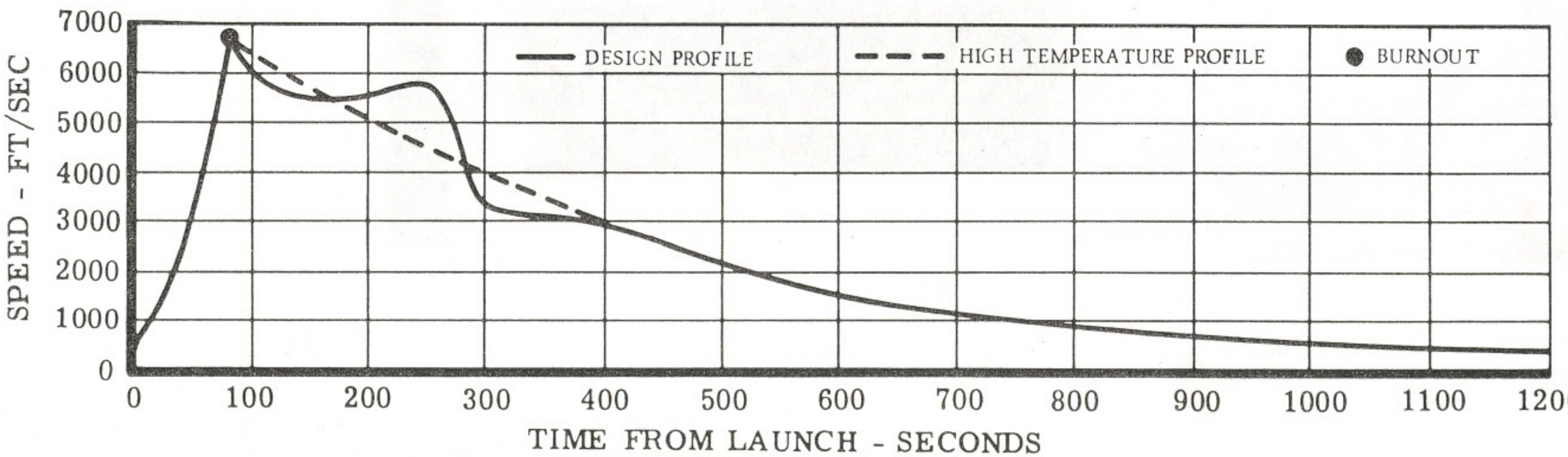
WEIGHT SUMMARY

. . . two place version

WEIGHT EMPTY			9,631 LB
USEFUL LOAD			18,053 LB
PROPELLANT		16,410 LB	
FUEL (AMMONIA)	7,240 LB		
OXIDIZER (LIQUID OXYGEN)	9,170 LB		
HYDROGEN PEROXIDE		835 LB	
CREW		580 LB	
MISCELLANEOUS		228 LB	
LAUNCHING WEIGHT			27,684 LB
BURN-OUT WEIGHT			10,405 LB
STRUCTURAL DESIGN WEIGHT (7.33 G)			10,443 LB

DESIGN MISSION
. . . *two place version*





SUPPORTING DATA LIST

NA-55-222	WEIGHT AND BALANCE REPORT
NA-55-223	PRELIMINARY STRUCTURAL DATA
NA-55-224	AERODYNAMICS CHARACTERISTICS REPORT
NA-55-225	DESIGN DRAWINGS
NA-55-226	GROUND HANDLING EQUIPMENT AND PROCEDURES
NA-55-227	CARRIER MODIFICATION DATA
NA-55-228	LANDING GEAR PROVISIONS
NA-55-229	SPACE CONTROL SYSTEM DATA
NA-55-230	THERMODYNAMIC STUDIES
NA-55-231	AIR DATA SYSTEM
NA-55-447	DETAIL SPECIFICATION
NA-55-448	COST & DELIVERY SCHEDULE
NA-55-449	PROCUREMENT SPECIFICATION-- MOCK-UP
NA-55-450	PROCUREMENT SPECIFICATION-- NON-FLYING STATIC TEST ARTICLE & STRUCTURAL TEST PROGRAM
NA-55-451	PROCUREMENT SPECIFICATION-- WIND TUNNEL TEST PROGRAM
NA-55-452	PROCUREMENT SPECIFICATION-- AIRPLANE GROUND HANDLING DOLLY
NA-55-453	PROCUREMENT SPECIFICATION-- CARRIER AIRPLANE MODIFICATION
NA-55-454	PROCUREMENT SPECIFICATION-- FUEL SYSTEM TEST STAND AND TEST PROGRAM
NA-55-557	FLUTTER DATA.
NA-55-574	PROPULSION SYSTEM OPERATION
NA-55-577	STRUCTURE THERMAL SUITABILITY DATA