December 10th 1958 Ref: 8826/01/J

Mr. J.C. Floyd

R.B. Cairns

VTOL DESIGN PROPOSAL

The attached brochure has been prepared to present what I feel is a logical and promising step in the VTOL approach of aircraft design.

I discussed the idea with Mr. J. Leyds and Mr. G. Sampson. Both felt that it merited consideration and were willing to devote some of their personal time in assisting in the preparation of the attached. Mr. Leyds cranked out sufficient numbers to provide us with a fair idea of its practibility, and Mr. Sampson provided what I am sure you will agree are some rather interesting lines. Both gentlemen were most helpful in discussing various phases of our effort in order to arrive at a logical presentation.

As a "spare time" job our resources of time and effort have, of necessity, been extremely limited. However, my personal opinion is that the idea is sufficiently promising to justify further study and on this basis I offer it for the Company's consideration.

R.B. Cairns

cc: Mr. R.N. Lindley
Mr. J.A. Chamberlin
Mr. M.A. Pesando

/cr

TL 115-58/12

A RAMJET VTOL AIRCRAFT

PREPARED BY
R.B. Cairns

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1.0 INTRODUCTION

The optimum power plant choice for aircraft capable of high supersonic speeds is the ramjet. However, the basic problem inherent to the ramjet is that thrust is relative to velocity, thus making a normal take-off possible only with the assistance of booster power plants.

Present design concepts of high speed aircraft are compromised to provide acceptable take-off and landing characteristics, and as the range of flight speeds increases so does the penalty paid for acceptable take-off and landing characteristics.

An aircraft configuration which employed ramjet power plants only, which had VTOL characteristics to carry the aircraft through a transition to normal flight at altitude, and which had a transition final break-out speed higher than normal take-off and landing speeds would appear desirable.

It is herein proposed that a configuration having these characteristics could be achieved by the use of ramjet power plants at the tips of wing surfaces which are in a fixed position during high speed flight and which rotate to maintain the ramjet combustion speed and provide lift in the low speed flight regime.

This proposal describes the configuration of such an aircraft for the purpose of evaluation of the basic concept. It does not attempt to provide a detailed description or justification of the many areas of a finalized configuration. These could only be determined after a much more comprehensive study of the project than has been undertaken up to the present.

2.0 GENERAL DESIGN CONSIDERATIONS

The aerodynamic characteristics of the aircraft are based on optimum efficiency in the high speed configuration. The basic principle employed is the use of two ramjet engines, each located at the tip of a variable incidence symmetrical airfoil wing. The wings are locked to, or rotate about, the fuselage structure as flight conditions require.

A fixed wing and vertical tail of delta configuration provide the major portion of the lift and stabilization in all but the initial stages of flight.

3.0 THE VTOL FLIGHT PATH

Engine start is accomplished by spin-up of the rotating wing at zero angle of attack up to the ramjet light-up speed, using an auxiliary power source. After light-up of the ramjets, take-off is accomplished by applying a positive increment of angle of attack to the freely rotating wing. Optimum tip speed is maintained by variation in angle of attack.

The transition to horizontal flight is commenced by upsetting the vertical axis in the desired direction by control jets and/or surface deflection in the rotating wing downwash. Consequently, a gradually increasing lifting force on the fixed wing is produced, sufficient to provide stability in a horizontal flight component. As the RPM decreases and the angle of incidence of the rotating wing blades increases during acceleration, an increasing forward thrust is obtained directly from the ramjet engines.

3.0 THE VTOL FLIGHT PATH (Cont'd)

The transition ends when the RPM reaches zero and the rotating wing is locked to the fuselage structure at 90 degrees incidence. Since the flight path during acceleration will be effectively normal to the rotating wing blade disc, the problem of retreating blade effect will not be presented to the airfoil and ramjets, and cyclic pitch control will not be required.

With the rotating wing locked to the fuselage, the aircraft effectively becomes a conventional high Mach number ramjet powered vehicle.

Control during take-off and transition is by auxiliary jets in combination with movement of aerodynamic surfaces. Control during horizontal flight at moderate altitudes is by surface deflection. At extreme altitudes control is effected by the auxiliary jets, possibly in combination with differential control of the ramjet thrust axes and/or movement of the aerodynamic surfaces.

The transition from horizontal flight to vertical flight for landing is the reverse of the take-off transition.

4.0 STRUCTURAL DESIGN

The airframe structure is designed to withstand the loads associated with sustained flight with moderate maneuvers at speeds in the order of 4.0 to 6.0 Mach. at altitudes of 100,000 to 150,000 feet.

4.0 STRUCTURAL DESIGN (Cont'd)

The low altitude maximum design speed is limited to the greater of the corresponding EAS for high altitude flight, or the maximum anticipated EAS for the climb to altitude.

5.0 INTERIOR ARRANGEMENT

A pressurized capsule accommodating one crew member, together with the required controls and instruments, is located at the rear section of the fuselage. In an emergency, the capsule is separated from the basic structure to provide a satisfactory means of crew escape. Provision is made for a weapon fire control system located in the fuselage nose and an armament bay located in the centre fuselage. The remainder of the interior of the centre fuselage, wing and fin houses fuel cells and aircraft services equipment.

6.0 AIRCRAFT SYSTEMS

6.1 Power Plants

Two ramjet power plants are employed, with one ramjet fixed to the tip of each blade of the rotating wing. Due to the high centrifugal loads encountered during rotating wing flight, a ramjet fuel distribution system employing pre-vapourization or variable direction nozzle spray may have to be developed.

6.2 Auxiliary Power Plant

A tri-purpose auxiliary power plant comprising an air-breathing gas turbine is housed in the fuselage. The turbine is utilized to provide power for all aircraft services during flight. Compressor bleed air is

6.2 Auxiliary Power Plant (Cont'd)

directed to the tips of the fixed wing and fuselage nose to provide "jet-blast" deflection control. With assistance from a ground unit, the turbine also provides the power required to spin the rotating wing up to the ramjet light-up speed.

6.3 Flight Controls

A combination of three types of flying controls may be employed. Aerodynamic controls comprising fully powered irreversible elevons and rudder are located on the fixed wing and the vertical tail. Compressor bleed air from the auxiliary power plant is ducted to movable nozzles located at the tips of the fixed wing and fuselage nose. During high speed high altitude flight, effective control is increased by variation of the ramjet power plant thrust axes.

Control is effected through the use of a conventional control stick and rudder pedal.

The landing gear fairings are designed to be utilized as speed brakes.

6.4 Landing Gear

To accommodate vertical take-off and landing from a "tail-sitting" attitude, a rectractable 4-point landing gear is located in the aft fuselage.

6.5 Aircraft Service Systems

The hydraulic, electrical air conditioning, and pneumatic systems required are powered by the auxiliary power plants.

In this presentation some performance data are suggested, i.e. Mach 4 to 6 at 100,000 to 150,000 ft. However, this type of aircraft will compare favourably with more conventional types of aircraft at lower supersonic speeds and altitudes, such as Mach 3 at 60,000 ft., as is discussed in later paragraphs.

Although the attached sketch illustrates the proposed concept as a fighter aircraft, this is not the only role for which it could be used. It would be very useful as a military or commercial long range, high speed transport. For a passenger configuration a satisfactory arrangement so that the passengers are comfortably seated in both the vertical and the horizontal attitude of the aircraft would need to be developed. It is believed that such an arrangement could be obtained without undue structural complexity.

Some of the more important advantages and disadvantages are outlined in the following.

(1) The VTOL Characteristics

It is generally recognized that it is desirable for an aircraft to be able to take-off and land vertically. The usefulness in conditions of poor visibility and the limited take-off area required are the arguments most quoted.

Some swivelling mechanism must be provided to maintain a relatively upright position of the pilot (and passengers) because of the necessary extremes of attitude. All systems equipment must also be selected or adapted to work satisfactorily throughout the range of attitudes.

(2) Rotating Wing

This device ensures that the most efficient powerplant, the ramjet, can be used for cruising without having to carry the deadweight of some type of conventional engine which is only useful during take-off. The combination of an aircraft with a separable booster stage for take-off is costly, time-consuming (installation before each flight) and does not provide for vertical landing.

(3) Powerplant

A ramjet engine at high speeds produces a larger thrust per unit of maximum frontal area than any other air-breathing engine. The resulting advantage of a reduction in drag will be partly absorbed by the extra drag of the rotating wing blades.

Ramjet engines can be operated with a higher maximum temperature in their thermodynamic cycle than other engines. This is the characteristic which makes the ramjet so much superior at the higher supersonic speeds.

The most striking characteristics in favour of the ramjet are its extreme simplicity and its very low weight. At supersonic speeds the net thrust to weight ratio is much higher than any other air-breathing engine. However, the weight saved is partly offset by the need for additional fuel because of the higher fuel consumption. While at low supersonic speeds the specific fuel consumption per pound net thrust is comparable to other air-breathing engines, at high supersonic speeds the ramjet is more economical.

(3) Powerplant (Cont'd)

The total weight of engine plus fuel for a given stage distance is less than for other air-breathing engines, provided that the cruise speed is Mach 2.0 or greater.

(4) Landing Gear

This can be of much lighter construction than the landing gear for conventional aircraft, because of the lower loads. Another advantage is that the landing legs and fairings, if constructed as suggested in the attached sketch, may be made to act as speed brakes in flight.

In the application of the aircraft as a passenger vehicle, the aircraft will have to be let down into the horizontal position for loading. This will add some structural complications to the landing gear and necessitate some other attachment points for support on the forward structure.

CONCLUSIONS

Rough calculations and a survey of the problems involved have shown that an aircraft designed on the principles outlined in this brief is feasible and should be superior to conventional aircraft in many respects. Therefore it is believed that a more elaborate study and a preliminary design are warranted.

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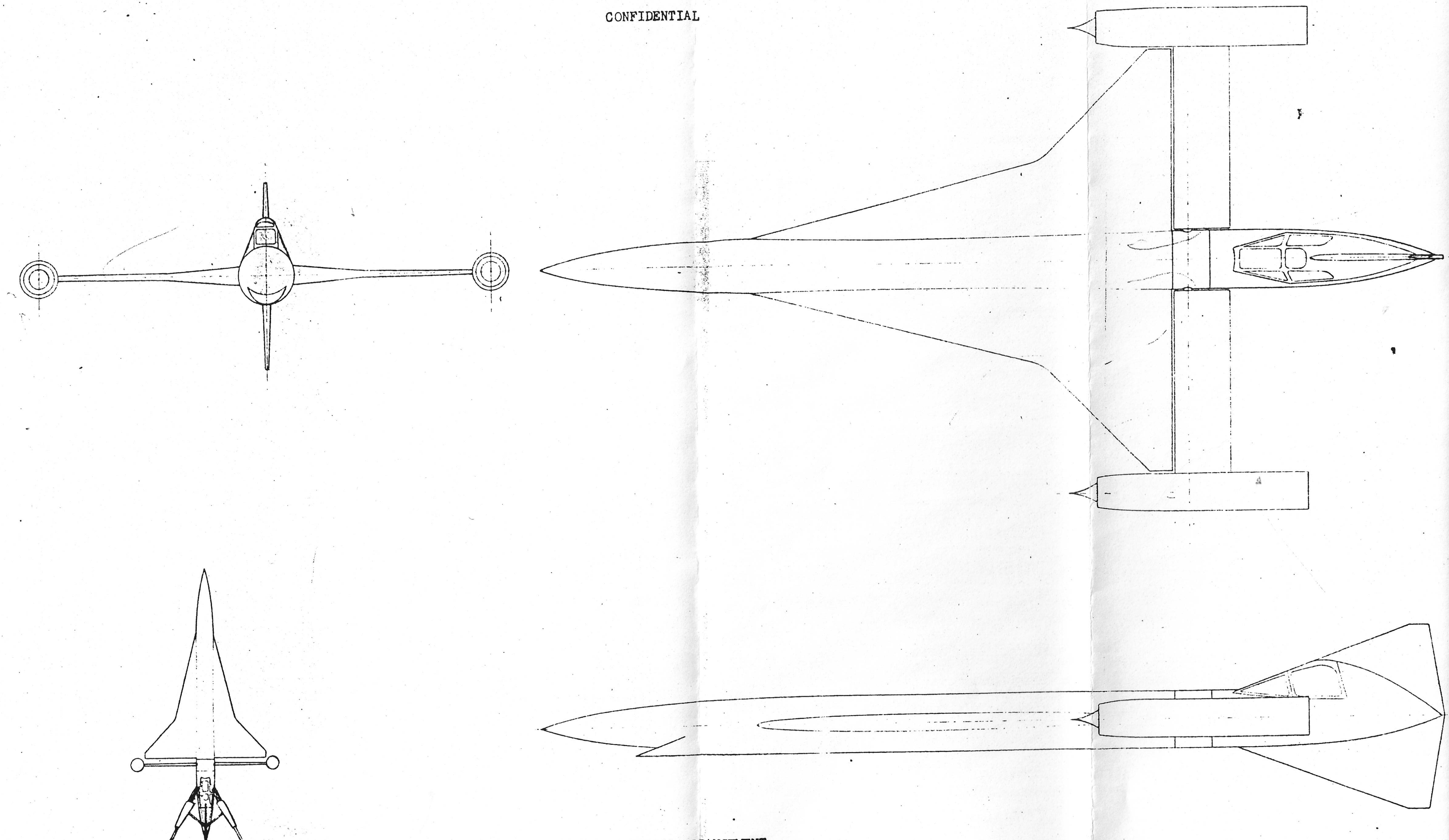

3-VIEW GENERAL ARRANGEMENT

FIGURE 1

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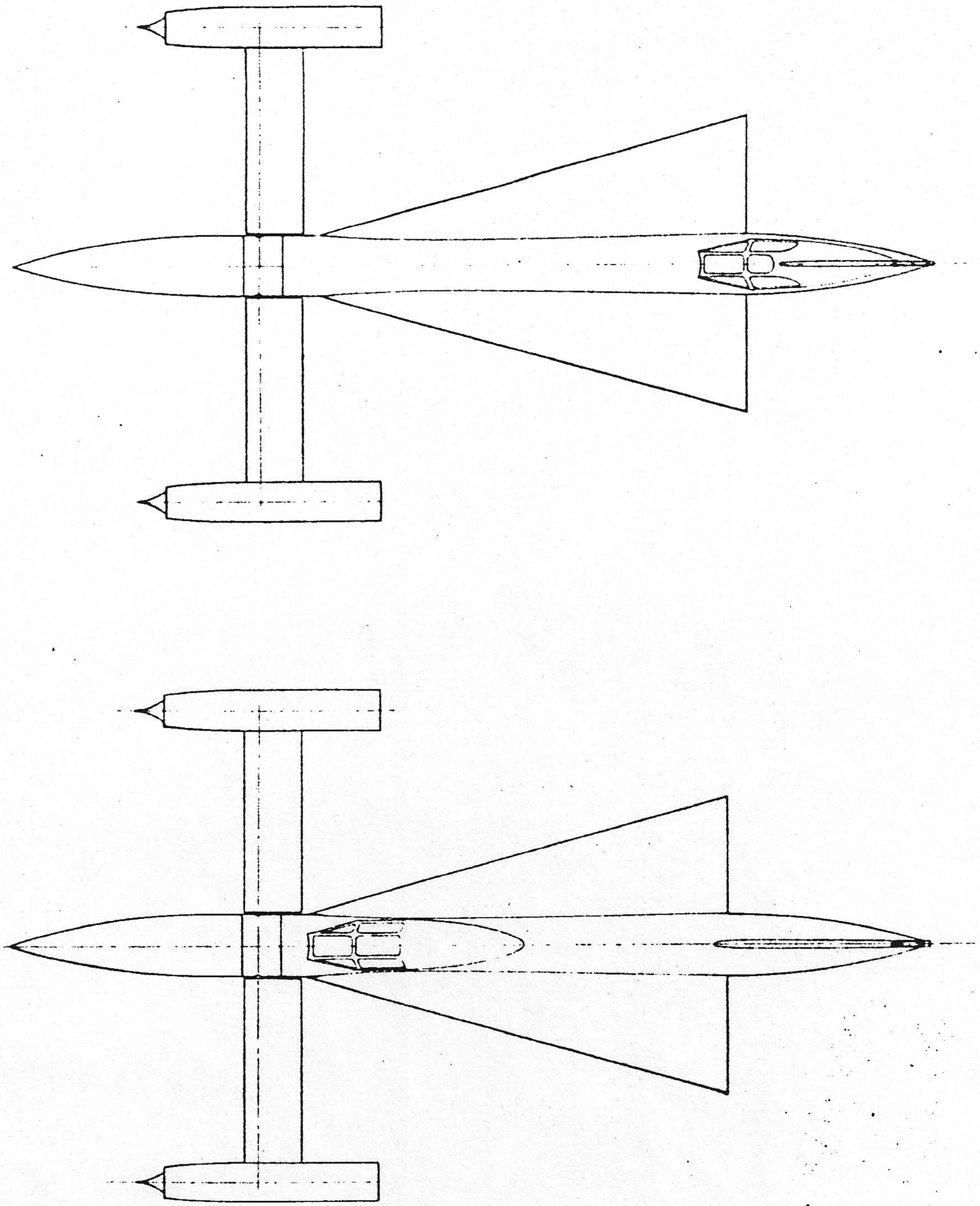

ALTERNATIVE CONFIGURATIONS

FIGURE 2