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AEROSPACE MEDICAL AND BIOENGINEERING CONSIDERATIONS

IN LIFTING-BODY AND RESEARCH-AIRCRAFT OPERATIONS

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35th Annual Meeting of Aerospace Medical Association
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## INTRODUCTION

The lifting-body vehicle we have flown at the Flight Research Center is the M-2 rather than the M-1, thus, it is this vehicle I shall discuss. For those who may not be familiar with the M-2 or the lifting-body concept, I shall describe it briefly. As the name implies, a lifting body is a vehicle with a body shape, rather than wings, which generates lift at an angle of attack. The only irregularities or protuberances in the body shape are the surfaces required for aerodynamic control. Figure 1 compares the advantages of the three configurations having reentry capability, that is, the ballistic or semiballistic, the lifting body, and the winged vehicle. The energy footprints of the vehicles, or landing areas available to each, can be estimated (fig. 2). For operational usage, a lifting reentry vehicle appears to be highly desirable because of its versatility for reentry from a number of orbit planes or the capability for recovery at a number of landing sites within the United States.

## LIFTING-BODY RESEARCH VEHICLE

An advanced vehicle is being procured by the Flight Research Center which will investigate supersonic, transonic, and subsonic flight regions. This vehicle (fig. 3) will be full scale in size and weight, will be launched from a B-52, and will require systems comparable to an operational fighter or X-15 research aircraft. The cockpit (fig. 4) is conventional in panel design and controls. The environmental control system provides a pressurized cockpit (3.5 psi air), temperature control, high-pressure breathing-oxygen system for unpowered flights, and X-15 pressure suit for powered flights with vent air and breathing oxygen. The escape system will use the modified T-37 seat and will allow subsonic ejection while in free flight or while mated to the B-52. No medical monitoring is planned for this program.

## BIOENGINEERING CONSIDERATIONS APPLICABLE TO LIFTING REENTRY VEHICLES

An area of interest, and to which we have devoted some effort, applicable to a mission vehicle is an indirect vision system. Such a system would be desirable on any reentry vehicle to eliminate all but the most necessary deviations from the basic shape. A canopy with windows is preferable from the pilot's viewpoint but would require additional structure, heating protection, and, if located in the nose for best visibility, could seriously affect vehicle stability. Optical or TV systems show some promise for use in maneuverable lifting vehicles and are readily adaptable to reentry vehicles. The Flight Research Center is studying the use of optical systems for approach, flare, and landing of low-lift-drag-ratio vehicles. A crude dual overlapping monocular system has been flown in an L-19 during power-off approaches and landings (fig. 5), and an advanced optical system (fig. 6) is being purchased for installation in an F-104B. This system will be used during approach, flare, and landings at lift-drag ratios as low as 2.5 and preflare velocities of 300 knots.

An actual mission vehicle will require approximately the same bio-engineering effort and considerations that were required for the Dyna Soar, since the environment and operating characteristics are similar. No unique problems are anticipated, inasmuch as the technology available from Gemini, and possibly Apollo, will be available before the first lifting-body mission and should be adequate for the planned missions of this type of vehicle.

## GENERAL COMMENTS

### Cockpit Design

Many improvements have been made in cockpit design in the manner of presenting information, such as, fixed vertical tapes, moving vertical tapes, and electroluminescent alpha-numerics. There has, however, been insufficient effort in the types of parameters presented for flight control or system monitoring (for example, total fuel and fuel flow when the pilot is really interested in the fuel time remaining at the present power setting). Systems gages are marked in terms of pressure, temperature, volts, and various other units of measure. Most of these quantities could be presented in percent values. When they are presented in terms of units, some reference must be known and remembered by the pilot, such as maximum and minimum and normal operating regions. He must mentally integrate all of this miscellaneous information to create a picture of his present situation, which requires concentration that could be used to greater advantage in other areas. The same is true of all the other situation information presented digitally, such as airspeed, altitude, and aircraft attitudes. The ANIP panel, or contact analog, is a step in the right direction, but it has not been utilized extensively because of an unwillingness to rely on electronics and because of the computer capacity and weight required. The reliability of electronics has been demonstrated thoroughly to the X-15 team by the MH-96 control system. No failures affecting system performance have occurred in 26 flights.

Another area requiring additional effort is the elimination of reflection or glare. An indication of the reflections in an F-104 cockpit at high-sun conditions is shown in the photograph of figure 7. In the X-15 at steep climb angles, the severe reflection problem is serious. The sun shines directly on the pilot's face and reflects into the suit visor. The only recourse is to shade the face with the hand.

## Protective Equipment

In the field of protective equipment there is also room for improvement. An example of the complex system now in use is the number of items requiring separate action by a pilot on entering or leaving an F-104 aircraft (table I). The integrated harness parachute system used in the X-15 and some other recent aircraft is definitely a step forward, since only three straps or connections are involved and only one fitting is required for pilot-suit systems. However, the connections are oriented in such a manner that the pilot cannot connect or disconnect without assistance.

Crash-protection provisions have not been improved in keeping with the increased operating velocities. It is almost certain death to ride a jet fighter down. A new concept of air-bag cushions could be an answer, inasmuch as the entire cockpit could be filled before impact.

## Escape System

Escape systems are still basically subsonic devices, since few, if any, have sufficient stability for high Mach number—high altitude ejection.

## Medical Monitoring

Medical monitoring systems used in the X-15 program are primarily flight-safety oriented. They serve only to assist the pilot in detecting an environmental system malfunction, since the parameters monitored and telemetered are available to the pilot also. The physiological instrumentation on the pilot has not been involved in a launch or mission abort and has not been considered mandatory for launch. Until some means of prediction can be incorporated into physiological or environmental monitoring and preventive action automatically initiated, the pilot will only reluctantly agree to biomedical instrumentation.

## Crew Selection and Evaluation

Crew selection and evaluation techniques at the Flight Research Center are informal in comparison to those used for astronaut selection. New pilots are normally obtained from the engineering groups at the Center. This practice has been in effect for the last 8 to 10 years. Interested applicants are informed of this selection procedure and, if sufficiently motivated, accept an engineering position with the hope of eventually flying.

Before the actual pilot assignment, a thorough physical examination at the Lovelace Clinic must be completed, followed by yearly reexaminations. After the original selection, experience and performance in assigned projects determine any further assignments.

## CONCLUDING REMARKS

There are no medical or bioengineering problems uniquc to the lifting-body vehicle. The flight environment will not approach any boundaries or limits of pilot endurance or performance, since the foreseeable missions are earth orbital, rendezvous, and return.

To properly utilize the hypersonic and subsonic lifting capability, the pilot must be a part of the primary control loop. Consideration of pilot control requirements in cockpit design and visibility will enable the pilot to accomplish the entire reentry, approach, and landing with consistent reliability.

## SYMBOLS

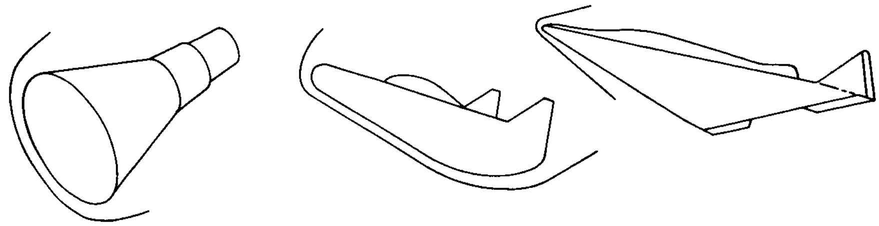
| | |
|---|---|
| $g$ | acceleration due to gravity, ft/sec$^2$ |
| $h$ | altitude |
| $\dot{h}$ | rate of climb |
| $L/D$ | lift-drag ratio |
| $V$ | velocity |
| $\alpha$ | angle of attack |
| $\theta$, $\psi$, $\varphi$ | angle of pitch, yaw, and roll, respectively |

TABLE I

INDIVIDUAL CONNECTIONS REQUIRED FOR NORMAL F-104 OPERATION

| | |
|---|---|
| Parachute buckles | 3 |
| Spurs to boots | 2 |
| Oxygen mask to helmet | 1 |
| Spurs to seat | 2 |
| Parachute to emergency kit | 2 |
| Seat belt | 1 |
| Shoulder straps to seat belt | 2 |
| Parachute lanyard to seat belt | 1 |
| Parachute lanyard to D-ring (zero delay) | 1 |
| Oxygen hose to T-block | 1 |
| Pilot's mask to T-block | 1 |
| Pilot's communication lead | 1 |
| "g" suit connection | 1 |
| TOTAL | 19 |

## REENTRY CONCEPTS



| BALLISTIC | LIFTING BODY | WINGED |
|---|---|---|
| SUPERORBITAL | SUPERORBITAL | ORBITAL |
| MAXIMUM VOLUME | HIGH VOLUME | LOW VOLUME |
| ABLATIVE HEAT SHIELD | ABLATIVE COOLING | RADIATION COOLING |
| MINIMUM HEAT LOAD | LOW HEAT LOAD | HIGH HEAT LOAD |
| MINIMUM WEIGHT | INTERMEDIATE WEIGHT | HEAVY STRUCTURE |
| EXTREME DECELERATION (9g) | INTERMEDIATE DECELERATION (2g) | MODERATE DECELERATION (<1g) |
| HYPERSONIC $L/D \approx 0$ TO 0.2 | HYPERSONIC $L/D \approx 1.3$ | HYPERSONIC $L/D \approx 2$ |
| SIMPLEST BOOST CONFIGURATION | READILY ADAPTED TO BOOSTER | POOR BOOSTER COMPATIBILITY |

Figure 1

## RANGE CAPABILITY IN RELATION TO HYPERSONIC L/D

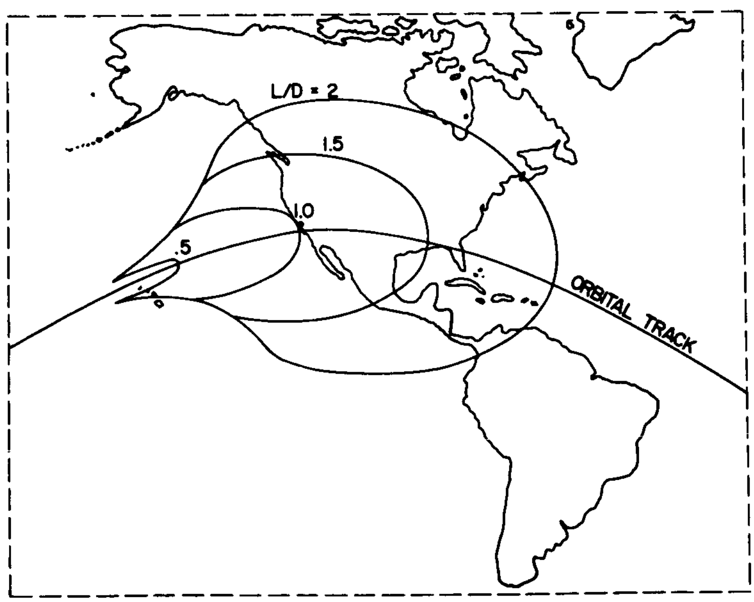



Figure 2

HEAVYWEIGHT M-2 VEHICLE


**Figure** 3

## COCKPIT ARRANGEMENT
### HEAVYWEIGHT M-2

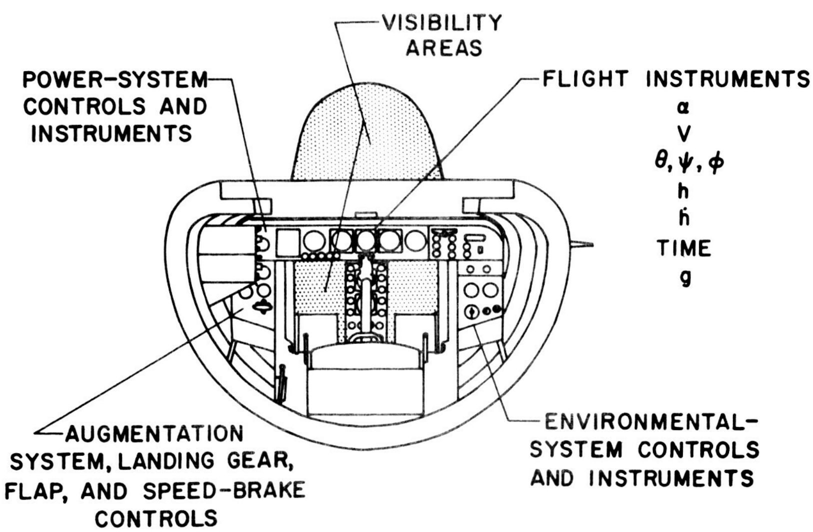



Figure 4

## MONOCULARS INSTALLED IN L-19


Figure 5

## OPTICAL SYSTEM FOR F-104B

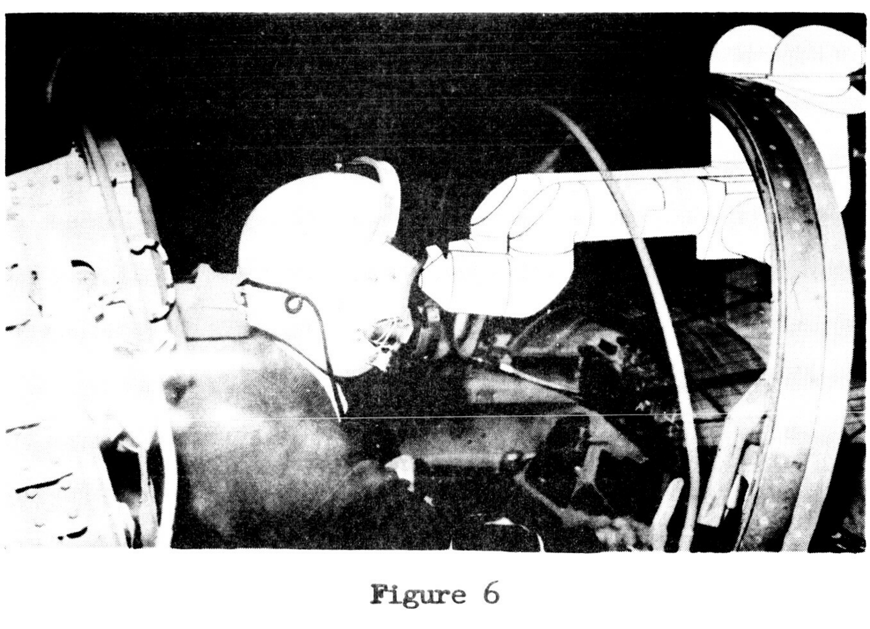


Figure 6

## REFLECTIONS IN F-104 COCKPIT

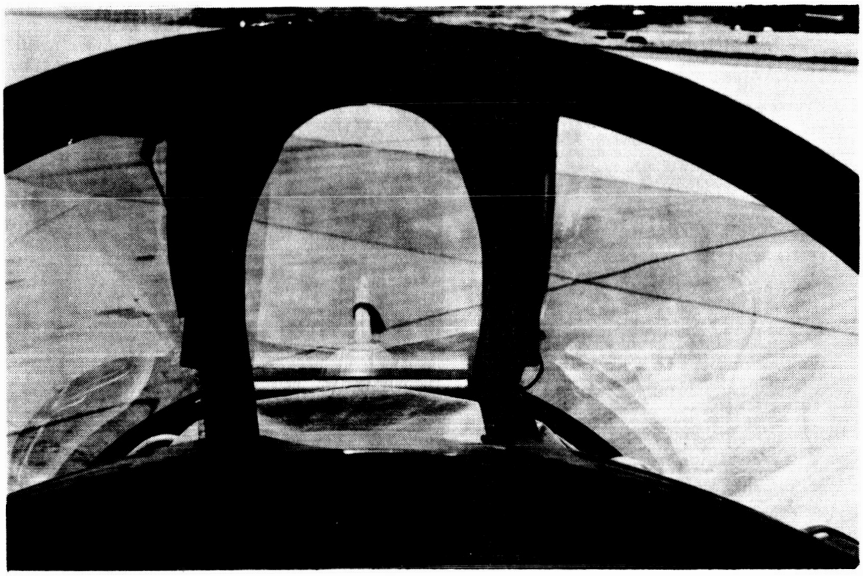


Figure 7