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# LIFTING-BODY PROGRESS REPORT

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I intend to give you a brief summary of the results to date of our lifting-body flight program which is being conducted at the NASA Flight Research Center. I have a film showing each of the vehicles in flight and some other interesting concepts we are testing.

Before discussing the flight program, however, I'd like to give you a little background. The lifting bodies which we are currently flying are not recent developments. The M2-F2 and HL-10 configurations were conceived in the late 50's for use as lifting-entry piloted spacecraft. They were, in fact, considered when the Mercury spacecraft configuration was being selected. They were designed at that time to be competitive with capsules in terms of volumetric efficiency and are thus characteristically rather thick blunt shapes. Although they could not quite equal the ballistic capsules in terms of volumetric efficiency, or weight, they offered the advantages of low entry "g" forces, hypersonic maneuverability, and a conventional horizontal landing on land, without landing propulsion. As you know, the ballistic capsule approach was selected, and our manned spacecraft have been recovered by parachute in the water.

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NASA has, however, always been interested in the concept of flying back from orbit. The X-15 was being flown into and back from space, and NASA was also actively participating in the Dyna-Soar program. The Flight Research Center's interest in lifting bodies was stimulated back in 1962 by the successful flights of some small-scale lifting-body models. We decided to construct, and attempt to fly, a manned lightweight lifting body of the basic M-2 configuration, a configuration which was developed at the NASA Ames Research Center. We made a successful flight from altitude in 1963 after being towed into the air by a C-47. We flew the lightweight M2-F1 for approximately 2½ years and made almost 100 flights from altitude.

The success of this flight program encouraged NASA to continue on with the investigation of the lifting-body concept. Money was authorized for the construction of two heavyweight lifting bodies, the M2-F2 (a modification of the M2-F1) and the HL-10 (a configuration developed at the NASA Langley Research Center).

The M2-F2 was the first vehicle to be delivered. We made the first flight in July 1966. A lateral control sensitivity problem was noted during that flight, and a severe roll oscillation was induced by the pilot. Recognizing the potentially serious nature of the problem, we still continued to fly the vehicle since we had developed positive recovery techniques.

On the sixteenth flight, however, the pilot again induced a severe roll oscillation and subsequently touched down before extending the landing gear due to disorientation and a number of other distractions. The vehicle was extensively damaged externally; however, the primary structure and vehicle subsystems survived. The vehicle was subsequently inspected and found to be repairable. We have since completed the repairs and made a flight last month. We have a number of modifications to the original configuration to improve its flight characteristics, the most noticeable of which is a center fin.

The HL-10 was flown for the first time in December of 1966. Flow separation problems were encountered on the first flight which were extensive enough to render the vehicle uncontrollable for brief periods during the flight. There were no violent vehicle motions involved, simply a lack of stability and control. The pilot was, however, able to make a successful landing. Following that flight, additional wind-tunnel tests were conducted to verify the nature of the problem and define a fix. It took over a year to do this and accomplish the modification on the vehicle. Since the modification was completed, we have made 35 more flights. We have flown the HL-10, using the rocket engine, to a maximum of 1.85 Mach number and to altitudes in excess of 90,000 feet. The HL-10 has so far been an extremely honest vehicle. The pilots are impressed by its handling characteristics and consider its handling qualities to be on a par with current operational jet fighter aircraft.

I'd like to show you a film now and after the movie I'll summarize our experience.

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In conclusion, then, we have made a total of 67 flights in the three lifting bodies. We have had problems with each vehicle even after exhaustive wind-tunnel tests of each configuration--a lateral PIO in the M2-F2, flow separation on the HL-10, and a less severe combination of both on the X-24A. We have found solutions to each of these problems either by analysis or additional wind-tunnel tests. We now have three good flying vehicles, but we and the wind-tunnel people had to work at it. These three lifting bodies are not candidate configurations for the space shuttle. They were optimized for a much smaller size than the current shuttle and for a simpler mission. The results obtained from the flight tests of these vehicles are, however, of significance to the shuttle program.

The flight test results validated the wind-tunnel data and indicated that the transonic and low speed flight characteristics of these unconventional configurations can be adequately predicted using existing facilities and current techniques.

The lifting-body flight results demonstrated that configurations designed for lifting entry can still have acceptable low speed flight characteristics and adequate maneuverability for approach and landing and are thus practical to consider for the shuttle mission.

The flight tests revealed a number of problems which had not been anticipated, and thus indicate the need for even more detailed wind-tunnel testing and analysis on these unconventional configurations, particularly in regard to low speed flow separation.