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INTRODUCTION TO BOEING PAPERS ON DYNA-SOAR PROJECT

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The preceding papers of this conference have been largely descriptions of research activities and results. The papers following the present paper will present discussions of the engineering applications of these data to specific problems of the Dyna-Soar. For example, the mission planned for Dyna-Soar is limited to earth-orbital flight or less. Therefore, data and trends presented in the paper by Thomas J. Wong, Glen Goodwin, and Robert Sly and in the paper by Frederick C. Grant do not apply directly to Dyna-Soar.

Papers by John F. Milton, G. E. Ledbetter, and Max T. Braun, which follow the present paper, will describe the results of Phase Alpha. One general question frequently asked about Phase Alpha is, "Why, of all possible reentry bodies, were only nine specific shapes chosen for detailed study?" Many additional concepts were examined at least briefly. It was believed vital that at least one configuration be examined in each of the four following prominent classes of reentry devices: modified ballistic, lifting bodies, winged bodies, and variable-geometry shapes. Within each of these classes, several shapes were considered to determine whether the results were common to all designs within that class. If so, the choice was rapidly narrowed. For example, two modified ballistic shapes were analyzed for several weeks to discover whether adding a variable-angle skirt or movable fins to a simple shape would provide better $(L/D)_{MAX}$ and lower weight than other ideas. When these shapes did not prove to be better, they were abandoned. In the lifting-body class, a shape similar to the Ames M-2a was examined and discarded for stability reasons. Two different structural concepts for the Ames M-2b were considered; one proved to be somewhat inferior and was dropped.

It was believed very desirable to have data on a spectrum of glider configurations having values of $(L/D)_{MAX}$ from 1 to 3 in order to determine the trends of weight and performance. Four different designs with low $(L/D)_{MAX}$ were investigated and the choice was narrowed to one. For variable-geometry configurations, a number of suggestions were eliminated with essentially no formal design work; an autogiro was one of these.

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It would have been very desirable to carry all these configurations through complete design and evaluation rather than narrowing from 21 configurations to 9 as was actually done. The effective design period of Phase Alpha was only eight weeks and the funds were limited. Attempting even as many as nine preliminary design studies in parallel was considered risky, but all of these were carried to conclusion. The final design of each is believed to be feasible although varying amounts of development time and risks are required.

Completion of even limited preliminary designs of this many bodies needed a great deal of help from other highly competent industrial organizations. In some cases, the idea for the reentry device originated with one of these companies and all the subsequent design was done by them. In other cases, the company provided necessary technical data and consultation. In every instance, Boeing Airplane Company supervised the work and must accept full responsibility for the final designs to be submitted at this conference.

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In order to enable rational comparisons between such different reentry techniques, a common set of ground rules, requirements, and objectives for Phase Alpha only was established. The significant requirements are shown in table I.

Piloted means the maximum use of the man to reduce subsystem complexity. A single crew member is used to reduce weight and cost. One thousand pounds of research-equipment payload does not include weight of structure, auxiliary power, and cooling to support the 1,000 pounds of payload. If those were included, the total would exceed 2,000 pounds. The 75-cubic-foot volume, combined with the large payload weight, allows flight tests of almost any military or scientific subsystem desired. "Once-around" operating capability means that the design shall be capable of Step IIA orbital operation although Step I reaches only about 19,000 ft/sec.

"Safe" boost means the boost trajectory shall not penetrate the recovery ceiling. The recovery ceiling is that altitude-velocity condition at $\gamma = 0$, from which the unpowered vehicle can just pull back into equilibrium glide without exceeding its temperature or load limits.

The requirement for landing within 10 square miles was established to avoid continued expensive marine recovery operations. This area was chosen to permit the use of military airports; thus trees and hills would not interfere with parachute landings. Consistent subsystems (and also consistent ground-support equipment) were used where logical to prevent differences in vehicle weight resulting only from different levels of refinement in subsystem design. Reusability for four flights (with refurbishment) was a contractual requirement.

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The requirement for at least neutral static stability during first-stage boost and reentry was established to provide better safety. During second-stage boost, the divergence rate is low enough to allow reasonable escape. Escape provisions were not required, but a requirement for safety approaching 100 percent led the designers to use escape systems. Ballistic reentry devices generally needed escape only during first-stage boost. The 6,000-foot margin above the critical heating limit requires that the vehicle not approach its structural limit too closely. This statement is only applicable for gliders; a similar rule was used for ballistic shapes.

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Certain other ground rules have been used both prior to and during Phase Alpha. These include structural factors of 1.4 on booster tanks and 1.5 on the remaining structure and a conservative heating assumption which requires the structure to withstand heating rates for either laminar, turbulent, or transition flow, whichever is worst.

None of the preceding ground rules are considered firm for the remainder of the Dyna-Soar program. Certain of these are being reevaluated now; the requirement for neutral static stability throughout the entire first-stage boost may be changed to require stability only at first-stage burnout. This will permit a coast period between stages one and two.

Certain items which were used as ground rules during earlier design efforts were abandoned as ground rules during Phase Alpha but were maintained as dependent variables, and the designs were compared with respect to these variables. Examples of these include the amount of lateral maneuverability, ability to land conventionally, ability to gather research data, and potential for eventual military use.

Certain terms have been used in this paper which need additional clarification. Figure 1 shows a typical variation of altitude h with velocity v for a glider. This plot can be used to define some of the less familiar terms of this paper and of subsequent papers.

The equilibrium glide lines for $C_{L,MAX}$ and $(L/D)_{MAX}$ are shown in figure 1. These lines bound the normal flight regime. Flight at a C_L less than that for $(L/D)_{MAX}$ is possible but not desirable. When the glider is banked to approximately 45° and flown at the C_L for $(L/D)_{MAX}$, the largest lateral range is attained. The glider seeks an equilibrium line at a somewhat lower altitude due to the bank angle.

The temperature limit line shown in the figure is actually a composite limit for either the nose, leading edge, or bottom surface

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depending upon the angle of attack. The q limit represents a dynamic pressure of 500 lb/sq ft during reentry. At this pressure the elevon surface actuator is load-limited. Under certain flight conditions, a load factor of 7.33 is limiting instead.

The distance shown as the flight corridor is a measure of the research ability of the glider. The 6,000-foot margin has been previously mentioned and is graphically described on the figure. The recovery ceiling is shown only in its approximate location. A glider inserted without power at that ceiling has insufficient velocity to maintain equilibrium flight at that altitude and hence falls. By pulling maximum lift, the aircraft can just barely arrest the fall before encountering the temperature or structural limit.

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In conclusion, the technical effort during and prior to Phase Alpha has formed a solid foundation for the remainder of the Dyna-Soar program.

TABLE I
GROUND RULES

- PILOTED (ONE CREWMAN)
- 1,000-POUNDS RESEARCH EQUIPMENT
- 75 CUBIC FEET VOLUME FOR EQUIPMENT
- ONCE-AROUND OPERATING CAPABILITY
- "SAFE" BOOST
- LAND WITHIN 10 SQUARE MILES
- CONSISTENT SUBSYSTEMS
- REUSABLE FOR FOUR FLIGHTS
- AT LEAST NEUTRAL STABILITY
- ESCAPE PROVISIONS
- 6,000-FOOT MARGIN WITH CRITICAL HEATING

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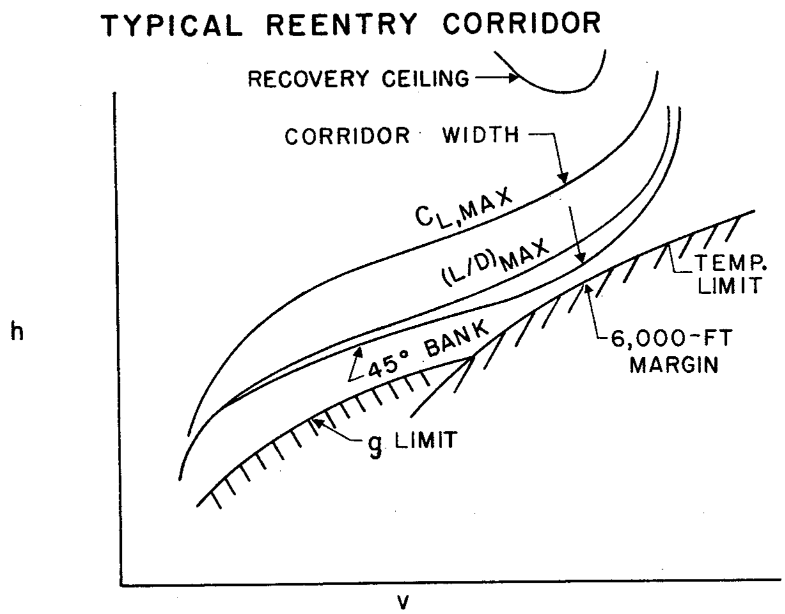

Figure 1

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