INTRODUCTION

Lifting hypersonic vehicles can be defined as vehicles which employ lift at hypersonic speeds in the accomplishment of their mission. In defining such vehicles, the hypersonic region is generally considered to be above Mach 5.0. Lifting hypersonic vehicles can encompass a wide range of operating modes and missions as shown in Figure 1. The block diagram in Figure 1 shows the interrelationship between the operating modes of hypersonic lifting vehicles. The space shuttle is in the category of recoverable launch vehicles; however, it does operate in a re-entry vehicle mode.

This discussion will be directed primarily at lifting entry vehicles since they encompass the complete hypersonic speed regime and many of the factors which will be discussed in relation to entry vehicles are applicable to other operating modes. At the end of the discussion those factors which are different between re-entry vehicles and other operating modes will be pointed out.

It is the intent of this discussion to treat 1) the subject of vehicle shape in relation to hypersonic lift to drag, L/D, level; 2) practical considerations of such shapes and 3) the critical aerodynamic problems of hypersonic shapes.

ENTRY VEHICLES

The first entry vehicles were the nose cones of ballistic missiles which were non lifting (ballistic) devices. The reasons for utilizing non-lifting entry vehicles included such things as 1) symmetry desired for launch considerations, 2) weight limitations precluded the use of an adequate control system and 3) the possibility of impact point dispersions. Our first manned re-entry vehicle, the Mercury capsule, was also a non lifting device. The initial question to be addressed is why lifting re-entry?

The answer to this question comes initially from a consideration of the load factor during entry. The sketch on the left in Figure 2 presents a schematic illustration of entry maneuvers for various entry flight path angles, γ_E. The sketch at the right on

Figure 2 shows the variation of maximum entry load factor with entry angle for non lifting entry which indicates that even at shallow entry angles the maximum load factor is quite high and increases rapidly with increasing entry angle. There are two limits on entry angle. The lower limit or overshoot limit is the entry angle at which the vehicle will skip back out of the atmosphere. This is illustrated by the upper entry trajectory on the sketch on the left in Figure 2. The upper limit or undershoot boundary on entry angle is a load factor limit established by human or vehicle system tolerances. The allowable range of entry angles which is equivalent to an altitude band is called the entry corridor.

Figure 3 shows the effect of lift on maximum entry load factor and corridor depth. The data is presented as a function of L/D since L/D is the basic aerodynamic parameter affecting these performance parameters. For this reason hypersonic L/D is one of the main parameters generally used to describe the types of lifting re-entry vehicles. It is seen that increasing L/D has significant effects on decreasing maximum entry load factor and increasing allowable corridor depth. These data of Figure 3 also indicate that most of the improvement in these performance parameters is obtained at an L/D of about 1.0. Increasing the L/D above 1.0 offers only modest improvement in these parameters.

There is however another performance parameter which is a function of L/D and which shows significant increase with increasing L/D. This is the cross range maneuver capability which is shown in Figure 4 as a function of L/D. The cross range performance increases non linearly with increasing L/D. It is this performance characteristic which generally leads to the consideration of lifting entry vehicles having maximum hypersonic L/D values much greater than 1.0.

Figure 5 defines vehicles as a function of their nominal maximum hypersonic L/D. It is noted that it has become customary in discussing nominal re-entry vehicle maximum hypersonic L/D to use the USAF Flight Dynamics Laboratory definition which is