22.3.1 Hypersonic Flight

The National Aero-Space Plane (NASP) was a special case of a hypersonic vehicle that was designed use air-breathing propulsion to take off from a regular runway and fly directly into orbit. The airplane would use turbojets up to about Mach 3, then scramjets up to orbital velocity.

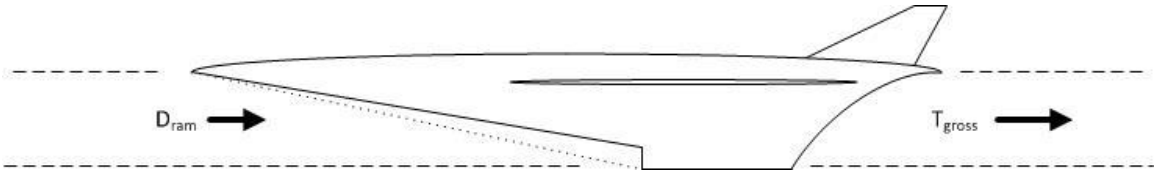

Fig. 21.3.1 Hypersonic Vehicle Gross Thrust and Ram Drag

For any air breathing vehicle, the net thrust is the difference between gross thrust (T_{gross}) and ram drag (D_{ram}). For NASP, ram drag could be as high as 90% of gross thrust. Thus a 1% change in nozzle efficiency (which is factored on gross thrust) would produce a 10% change in net thrust.

Raymer Eq. 19.8, which gives the ratio the final to initial mission weights, is:

$$\frac{W_i}{W_{i-1}} = \exp\left[\frac{-C\Delta h_e}{V\left(1-\frac{D}{T}\right)}\right]$$

The variable T in this equation is the net thrust, and if this is not much greater than the drag, the term $(1 - D/T)$ can become quite small. This in turn makes (W_i/W_{i-1}) quite large.

The annotation to section 3.6.5 Trade Studies indicated that for a vehicle with a small payload (as this vehicle had) small changes in the empty weight required line could have a large effect on gross weight. Thus a small change in nozzle efficiency could be leveraged by three factors to have a very large impact on takeoff gross weight. To reach orbital speed, the vehicle would have to accelerate up to about Mach 25. It was very difficult to calculate the nozzle efficiency at high Mach numbers, and impossible to determine through wind tunnel experiments or flight test.

Depending on assumptions for the values of nozzle efficiency and other factors, all of which were reasonable considering the state of knowledge of hypersonic technology, the TOGW to achieve the mission could vary between 100,000 lb and 1,000,000 lb.