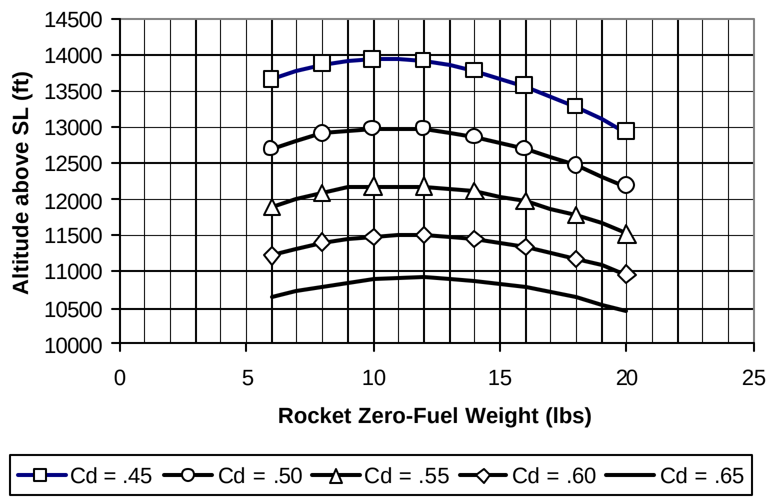
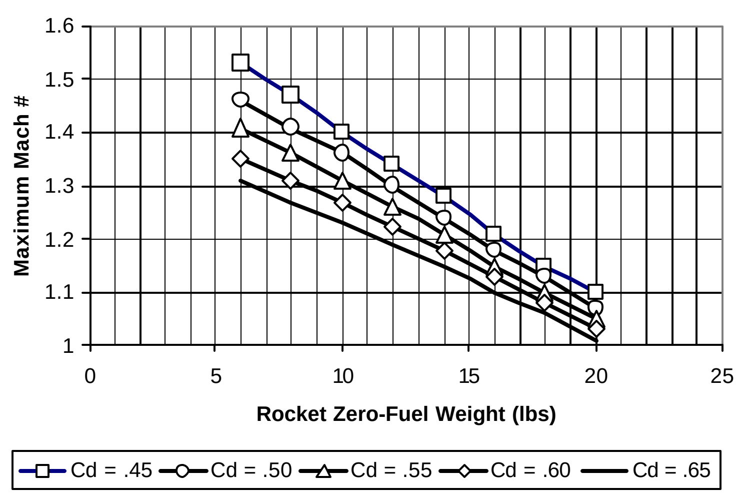
Design

Chapter 6

The drag and performance equations of the previous chapters are detailed enough to account for variations in geometry, mass, thrust and delay times. This capability provides the rocket designer the tools to conduct parametric and optimization analyses. As demonstrated in Chapter 3, we already saw how the equations could be used to optimize the coast time between first stage burnout and second stage ignition of a two- stage rocket. In this chapter, results from two parametric analyses will be presented in order to demonstrate the utility of the equations for rocket design and optimization.

For the first example, it was the objective to determine sensitivity of maximum altitude and maximum Mach Number to the rocket's zero-fuel weight. The analysis was conducted assuming a constant average drag coefficient for the rocket, rather than tracking its change with time. The analysis was repeated for several different values of average drag coefficient to determine if the drag coefficient has a significant influence on identifying the optimum zero-fuel weight for maximum altitude. A simple spreadsheet was written utilizing the equations of Chapter 3. This example is typical of one of many possible studies that could be quickly completed during the preliminary design phase. The results are presented in the following graphs.



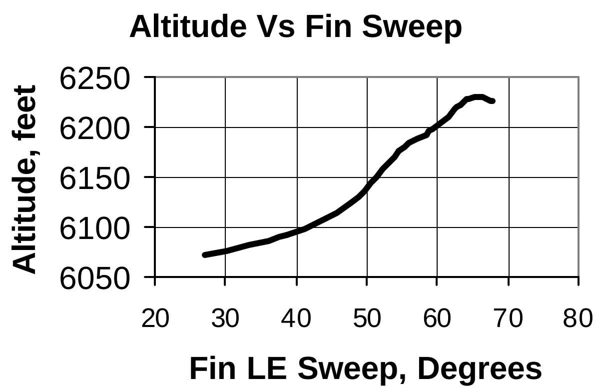


The plots of altitude versus zero-fuel weight indicate that an optimum zero-fuel weight does exist that maximizes altitude. The optimu m zero-fuel weight various slightly with assumed average drag coefficient, ranging from about 10-lbs for a C_d of 0.65 to about 12-lbs for a C_d of 0.45. If the objective was to maximize speed rather than altitude, then the plots of maximum Mach Number versus zero-fuel weight suggest that one design for minimum weight and drag.

For the second example, it was of interest to know what, if any, would be the optimum fin sweep angle to maximize altitude for a given rocket design. The constraint placed on this analysis was to maintain a liftoff Stability Margin (SM) of 1.0. A detailed rocket design spreadsheet was created to include accountability of drag coefficient change with Mach Number, as well as a continuous change of rocket weight with time. The results are presented in the following graphs.

Sweep Sensitivity for Xt/c = 0.6

Sweep	Altitude
27.150	6073
38.809	6093
47.855	6125
54.625	6176
59.530	6198
63.174	6222
64.608	6228
65.891	6231
67.979	6225



The table and plot suggest that a fin leading edge sweep angle of 65.9° is near optimum for maximizing altitude. This analysis was done for a maximum thickness-to-chord position equal to 60% ($X_{t/c}$ = 0.6) of the fin chord. Similar analyses can be conducted for other values of $X_{t/c}$ to determine what value of $X_{t/c}$ would contribute to a maximum altitude.