AE 440A Initial Sizing
Due Sept. 11, 2008

Consider a horizontal take-off, air-launch vehicle for the SpaceX Falcon 1 launcher (www.spacex.com). The Falcon 1, powered by LOX and kerosene is 21.3 m long and approximately 2m in diameter, with a launch mass of 27,670 kg. The vehicle will carry Falcon 1 rocket to a launch point, separate, and return to base with a two-person crew (assume each crew member weighs 90 kg). The design will take off from a runway in the United States. The launch point of the Falcon rocket from the aircraft is 800 km from take-off airport (e.g. Cape Canaveral). The vehicle would cruise at subsonic speeds (Mach 0.85) at an altitude of 30 km to the air-launch (rocket separation) point and the briefly accelerate to Mach 2 for launch for a distance of 200 km. Assume L/D=12 at subsonic cruise and an L/D=5 for supersonic conditions. For initial sizing purposes, the design must account for a launch abort, i.e. assume that payload is not released during mission. A 1000 km return to the same airport then occurs.

RECOMMENDATION: Use Excel for your plots and calculations as it will make it easier to change numbers if you make a mistake.

1) **10 points** Conduct a historical survey of at least four vehicles (built or in development) which are relevant to this Falcon-launch vehicle in terms of mission and capability and discuss the similarities and differences. Estimate (to the best extent possible) aspect ratio, engine type, maximum take-off weight, and empty weight fraction of each of these vehicles.

2) **10 points** Plot* the empty weight fractions (as symbol points) as a function of maximum take-off weight. On this same plot, include one or two relevant curves from Raymer's Table 3.1. Using the data points from the aircraft in part 1) that are most reasonable and representative, determine an empirical equation of the empty weight fraction as a function of take-off weight (i.e. find appropriate A and c values) and put a trend line based on these values on the same plot. Based on your research in part 1) determine what type of engine the Falcon-launch vehicle would probably use and the SFC for the subsonic and supersonic legs based on Fig. 3.3 of Raymer.

3) **10 points** Sketch a diagram showing the mission with leg numbers. Conduct an initial sizing of the Falcon-launch vehicle based on the above information to determine total aircraft take-off weight (in kg). Show all equations and all work . Don't forget units and use significant figures.

4) **10 points** a) Conduct a vehicle trade study of a single mission parameter (e.g. subsonic Mach number, launch Mach number, range, launch altitude, crew number, payload mass, etc.) and b) an empirical coefficient (e.g. engine SFC, empty weight fraction, $(L/D)_{max}$, etc.) to see their influence on total aircraft weight. Use a reasonable

range for your parameter or coefficient and plot* the impact of the parameter on the total aircraft weight. Comment on the trend.

*Plots should not be by hand. Use symbols for data points and use lines for trends or curve fits. Label axis with a symbol and put units in parentheses, e.g. L (Nt), then add a caption below (not a title above) that explains plot, e.g. “Lift as a function of aspect ratio for three different Mach numbers”. Do not use internal grid lines in plot; do not use color symbols, and do not place boxes around figure. Make sure all font size of axes and legend is at least 12 point.