Spaceport America Cup: Design and Simulation

March 2020

Introduction

This document summarises design constraints and provides some questions that should be used to inform initial designs of the launch vehicle. It will be continually updated.

Constraints

Independent

- (TBD) total budget

Rules and Requirements document

- **10'000 m** target altitude (Section 2.0)
- $\geq$ **4 kg** of payload (Section 2.2.1)
- $\leq \mathbf{40{,}960\,Ns}$ total impulse (Section 2.3)
- A non-functional payload must take the form of one or more CubeSats (each is **10cm** $\times$ **10cm** $\times$ **10cm**) (Section 2.2.5.1)
- The launch vehicle must:
  - carry a **GPS tracker** (Section 2.4)
  - carry a COTS **barometric pressure altimeter** with on-board data storage (Section 2.5)
  - be recovered in a state that would allow safe reflight after replenishing intended consumables (Section 2.7.1.4)

Design, Test, Evaluation guide

- Each independently recovered launch vehicle body anticipated to reach an apogee above **1,500 ft (457 m)** above ground level (AGL) shall follow a "dual-event" recovery operations concept (CONOPS), including an initial deployment event (eg a drogue parachute deployment; reefed main parachute deployment) and a main deployment event (eg a main parachute deployment; main parachute un-reefing).
  The **initial deployment event** shall occur at or near apogee, stabilize the vehicle's attitude (ie prevent or eliminate ballistic re-entry), and reduce its descent rate enough to permit a

successful main deployment event yet not so much as to exacerbate wind drift (eg **between 75 and 150 ft/s [23-46 m/s]**).
The **main deployment event** shall occur at an altitude no higher than 1,500 ft (457 m) AGL and reduce the vehicle's descent rate sufficiently to prevent excessive damage upon impact with ground (ie **less than 30 ft/s [9 m/s)]**). (Section 3.1)

- Aim to not set fire to the parachute(s) (Section 3.1.3)
- Aim to not tangle up the parachute(s) (Section 3.1.4)

Questions

> Ignoring aerodynamic drag, given a rocket motor with parameters P and a target altitude of A, what is the upper bound on the mass of the remainder of the rocket (excluding the motor)?

Treat the rocket as a point (of decreasing) mass moving in one dimension (along the Y axis) under gravity, and use P (thrust-vs-time, mass-vs-time, burn duration) to estimate the rocket's velocity at motor burnout numerically. Then apogee can then be determined analytically. Repeat the process above after starting with an estimate for remaining mass, and iteratively converge to a more precise result by comparing the simulated apogee with A and adjusting the estimate accordingly. This software will allow us to place a lower-bound on the motor power we will need to use and help narrow down the selection.
