EA204 Rocket Mission Requirement

The year is 2018. Due to increased demand for space launch vehicles from commercialization and globalization of space as well as increased tensions with China and North Korea, the Joint Requirements Oversight Committee recently reviewed and validated all Joint Capabilities Integration and Development System (JCIDS) documents for the Operationally Responsive Space (ORS) Capability. Operationally Responsive Space provides the capacity to respond to unexpected loss or degradation of selected capabilities, and/or to provide timely availability of tailored or new capabilities to support national security requirements. One key component of ORS is satellite launch capability that is both timely and affordable. As part of the JCIDS process, a Doctrine, Organization, Training, Material, Leadership, Personnel, and Facilities (DOTMLPF) study was conducted and determined that a new launch vehicle was necessary to meets the needs of ORS. Additionally, an Analysis of Alternatives concluded that an all solid fuel rocket was the only possible means to meet mission requirements due to their long term storage capability and mobility.

The Launch and Range Systems Wing, located at the Space and Missile Systems Center, Los Angeles Air Force Base, CA recently received industry responses to a Request for Proposal for a solid rocket launch system to launch small-medium satellites to low earth orbit. One response, from Boeing's Defense, Space & Security unit calls for a two-stage design using a new first stage motor developed by Alliant Techsystems Inc. and a second stage motor of the same type or an existing Aerojet Motor. A second response, from Lockheed Martin's Space Systems Company, proposes to use a new motor developed in a joint venture between Alliant Techsystems Inc. and Aerojet with the option of adding two additional existing Aerojet Motors.

Both Request for Proposal responses seem like they might satisfy the launch needs of Operational Responsive Space; however, they lack significant detail about size of the launch vehicle and control surfaces. As a result, the Air Force has asked the Space and Naval Warfare Systems Command's Program Executive Office for Space Systems to assist in the Joint evaluation of the designs through modeling and simulation to establish which launch system is the best value for the government. Luckily, the proposed designs can be closely modeled using Estes Rocket Kits.

The following describes the mission requirement and competitive performance criteria for the build, test and launch of an Estes Alpha derived Rocket. You will work in design teams of two.

1. Mission and Competitive Performance Criteria:

a. Mission Requirement (MR): *The rocket design team must develop a rocket that will reach 300 feet above ground level (AGL) and recover back to earth in tact including the avionics package. Successful recovery specifically means a successful parachute deployment and soft landing.*

b. Cost to Payload Mass Ratio (CMR) *The highest possible score is achieved by reaching the mission requirement at the lowest cost to payload ratio while ensuring the rocket does not get wet.*

   Note: *Teams must also clearly define all vehicle/propulsion system masses and mass fractions as described in paragraph two below.*

2. Rocket Design Constraints: The rocket design may vary from the "Alpha" kit design, but must utilize available stock tubing and balsa provided in the fluids laboratory.

a. The only motors allowed for use in this project are the Estes A8-3, B6-4, B6-0, C6-5 provided in the lab
b. Only one (1) nosecone per rocket is allowed.
c. The following engine configurations are acceptable as they model the proposals provided by Boeing and Lockheed Martin: A two (2) stage rocket using a B6-0 as the first stage with either an A8-3 or a B6-4 for the second stage. A single stage rocket using a single C6-5 or a single C6-5 with two strap-on A8-3

3. Definitions: The following definitions provide a reference for the mission requirements and competitive performance criteria described below:

a. Empty rocket mass: Mass of the rocket prior to adding the motor, propellant or payload mass - This mass includes the avionics (altimeter) and recovery system as well as the nosecone.
b. Initial propulsion system mass: Mass of the rocket motor before expelling propellant
c. Final propulsion system mass: Mass of the rocket motor after expelling all propellant
d. Propellant mass: Mass of expelled propellant, m_p
e. Structural mass: Mass of the empty rocket structure (a.) added to the final propulsion system mass (c.), m_s
f. Payload mass: This additional mass is the "useful" payload mass and cannot contribute to flight performance – it must be dead mass, m_{PL}. This is the rocket's throw weight to the height required in 1.a.
g. Initial rocket mass: The sum of the initial propulsion system mass (b.), structure mass (e.) and payload mass (f.).
h. Final (burn-out) mass: The sum of the structural mass (e.) and payload mass (f.).
i. Mass ratio: The ratio of the Initial to Final mass (g. divided by h.)
j. Payload Mass Fraction: Mass of the payload (f.) divided by the initial mass of the rocket (g.)
k. Cost to Payload Mass Ratio (CMR): The cost of the designed rocket divided by mass of the payload (f.)

4. Scoring of the Rocket Project:

10% - Propulsion system test, data reduction and analysis
10% - Wind-tunnel testing, data reduction and analysis
25% - Development of flight performance prediction
25% - Analysis of flight performance and comparison with prediction
10% - Appearance of rocket on Day of Launch (DOL) – in particular professionalism in construction
20% - Flight performance against other teams relative to the MR and the CMR including recovery

Note: You should design your own metric for performance. Keep track of all masses in a spreadsheet. You will be required to present your mass summary from paragraph 2 above on day of launch (DOL).

5. Critical Parameter for Estes Rocket Parts:

	Mass/Density	**Cd**	**Cost**
Avionics, Launch and Recovery Systems	40g		Included
Engine Adaptor System	5g		$5,000
Rocket Body Tube	.645g/in	.75	$1000/in
Balsa Wood (2mm thick)	.306g/in^2	.004	$100/in^2
Single C6-5			$2,964,000
C6-5 with two strap-on A8-3		.81	$3,995,000
B6-0 with A8-3 two stage			$1,000,000
B6-0 with B6-4 two stage			$2,535,710

	Initial Mass	**Prop Mass**	**Burn Time**	**Isp**	**Diameter**
A8-3	16.7g	3.3g	.73s	42.5	18mm
B6-0	15.6g	5.6g	.86s	78.8	18mm
B6-4	19.1g	5.6g	.86s	78.8	18mm
C6-5	24.0g	10.8	1.86s	83.3	18mm

6. Development of flight performance prediction.

Multiple methodologies can be used for max altitude prediction. Estes Rocket's provide a series of Technical Reports that can be useful to predict max altitude for a given rocket design. Additionally, several websites (such as http://my.execpc.com/~culp/rockets/rckt_eqn.html) offer simplified equations that can be used to predict the height. In order to obtain a more accurate estimate, a numerical integration technique must be used since there is not a closed form solution to the rocket equations. A simple numerical integration technique can quickly be programmed into excel; however, Matlab offers more accurate (although more complicated) numerical integration techniques. A simple example of Euler's method using excel will be presented in class.

As a minimum, you must submit an estimate for max altitude for a given payload using Euler Integration (Excel solution is fine) on day of launch. A numerical integration solution using MATLAB's ODE solver based on your current design must be submitted with the final report. It is okay to modify your design slightly based on data acquired during the thrust lab and the wind tunnel lab and flight data, but the estimate for max altitude using both the simplified equations and numerical integration technique based on your final design must be submitted with your final report.