Rocket Mission Requirement

The year is 2015. Due to increased demand for space launch vehicles from the initial deployment of the Galileo Constellation, accelerated commercialization and globalization of space and the requirement to rapidly supplement Galileo Constellation due to an on-orbit failure without sufficient on-orbit spares, the European Space Agency (ESA) in cooperation with the Centre National d'Études Spatiales (CNES) recently began an Operationally Responsive Spacen (ORS) initiative in Europe. 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. The ORS initiative identified a requirement for a new launch system that could rapidly deploy satellites based on rapidly changing needs of the ESA and European Union member nations.

The ORS initiative will utilize the ESA's Future Launcher Preparatory Program (FLPP) study that identified an ideal system to meet this requirement. The FLPP study 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.

One design, from Arianespace SA calls for a two-stage design using a new first stage motor developed by Avio and a second stage motor of the same type or an existing second stage from the VEGA rocket. A second design, from Starstem, proposes to use a new motor developed with the option of adding two additional existing VEGA Motors.

Both designs 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 European Space Agency asked you to assist in the evaluation of the designs through modeling and simulation to establish which launch system is the best value for the European Space Agency. 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. <u>Mission Requirement (MR)</u>: *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. <u>Cost to Payload Mass Ratio (CMR)</u> *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.*

   <u>Note</u>: *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 Arianespace SA and Starstem: 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.