1. Project Overview (1 page)

1.1. Overall goal or purpose

The purpose of this project is to add engineering rigor in a team based environment to a project that many students already have exposure to as a youth: launch of a model rocket. What sets this project apart from the work of hobbyist and similar projects in primary and secondary education is the addition of the structured conceive, design, implement and operate framework with iterative designs based on feedback from modeling/simulation (M&S), domain specific test methodologies and comparison of predicted and measured flight test results. Most importantly, this project, for the first time in an engineering student's education, requires the student to balance cost, performance, and risk (and to some extent schedule) in their design trade space.

1.2. Societal context and relevance

While many aerospace engineers often point to model rocketry from their youth as the spark that got them interested in engineering, this project attempts to bridge the gap between the work of hobbyist and detailed engineering design.

1.3. Integration (e.g., where project fits in a course, program, or curriculum)

This project is conducted in the Fundamentals of Astronautics course taught to Aerospace Engineering majors in the second year of study. It is conducted at the same time the propulsion block is taught in lecture. Additionally, students are also learning about Numerical Integration in a separate course, Engineering Analysis with MATLAB

While this project is aimed at Aerospace Engineering students, it could be utilized in any engineering program introductory course whose goal is to expose students to the engineering process using the CDIO construct. Minimal additional coverage of concepts such as coefficient of drag, subsonic flow over a streamline body, stability and control, rocket motor performance, and numerical integration may be necessary.

1.4. Description (e.g., complexity, duration, group size and number, budget)

This project is the primary design project for the course and spans approximately 1 month. Four (4) two hour lab periods are dedicated to the project and are broken down as follows:

Week 1: Project Introduction, distribution of material, numerical integration discussion
Week 2: Thrust Chamber Testing/Design/Begin Build
Week 3: Wind Tunnel Testing/Finish Build/Stability testing
Week 4: Flight Test day. An alternate day is scheduled if weather is poor.

Non-recurring expenses: $4690

Recurring expenses: $24 per student

1.5. Learning activities and tasks (brief summary)

Students conceive, design, and build (implement) Estes Model rockets and launch (operate) them with the goal of launching the most massive payload possible to 300ft at minimal cost. Students choose from several engine configuration and components each assigned a cost value. Their models (or similar designs) are placed in a Low Speed Wind Tunnel for accurate drag measurements. Additionally, several Estes engines are placed in a Thrust Chamber on a load cell to measure accurate thrust profile curves and examine the variability in engine performance from engines of the same type. Finally, the students, using all available data, conduct an altitude performance prediction using Numerical Integration and compare their prediction to Flight Test Data.

Learning Objectives (1 page)

1.6. Technical objectives (e.g., basic math, science and engineering knowledge, skills, processes and procedures)

Coefficient of drag calculation

Stability and control relating to Center of Mass and Center of Gravity locations

Rocket motor performance including total impulse, specific impulse,

Runga-Kutta Numerical Integration

1.7. CDIO outcomes (e.g., personal and professional skills and attributes teamwork, communication, conceiving, designing, implementing and operating skills)

2.1.1 Problem Identification and Formulation
2.1.2 Modeling
2.1.3 Estimation and Qualitative Analysis
2.1.5 Solution and Recommendation
2.3.4 Tradeoffs, Judgement and Balance in Resolution
2.4.3 Creative Thinking
2.4.4. Critical Thinking
3.1.1. Forming Effective Teams
3.1.2. Team Operation
3.1.3. Team Growth and Evolution
3.1.4. Leadership
3.1.5. Technical Teaming
3.2.4 Written Communication
4.4.3 Utilization of Knowledge in Design
4.4.5 Multi-disciplinary design
4.4.6. Multi-objective Design

2. Student Instructions

2.1. Project description (e.g., brief description of project purpose and context)

Please see Rocket Mission Attachment for details

2.2. Learning objectives

2.3. Learning activities including specific procedures, tasks, etc.

Please see Rocket Mission, Rocket Engine Test, and Rocket Wind Test attachments for details

2.4. Assessment criteria and standards

Please see Rocket Mission, Rocket Spec Sheet and Rocket Report Format

2.5. Equipment, tools, supplies and/or materials

Low-Speed Wind Tunnel with data acquisition system

Thrust Chamber and load cell with data acquisition system

Estes Launch System

Peak Altitude determination system

Electronic Altimeters or

Theodolite two-station altitude-azimuth altitude determination system

Reusables

1 ruler for each team in one given class

1 protractor for each team in one given class

Consumables

1 Estes Rocket kit per team

1 Extra Balsa wood sheet (6’’x36’’) per team

1 Extra Launch Rocket Body tubes per team

1 Extra Nose cone per team

1 bottle of wood glue for each team in one given class

1 bottle of super glue for each team in one given class

1 exacto knife for each team in one given class

2 extra parachutes per team

Spray paint in variety of colors (if desired)

2.6. Safety and risk mitigation procedures

While the launch of Estes Model rockets is considered a safe hobby activity, the National Association of Rocketry (NAR) provides general safety guidelines which can be found at www2.estesrockets.com/.../NAR%20Model%20Rocket%20Safety%20Code. pdf

2.7. Deliverables

One written report per team following the format specified in the Rocket Report Format. Be sure to answer all questions from Rocket Mission handout distributed on the first day of the project, the Rocket Engine Test handout, and the Rocket Wind Tunnel Test handout.

3. Instructor Guide

3.1. Commentary on conducting the project keyed to the Student Instructions

The Rocket Mission Handout provides an overall description of the project and a hypothetical purpose for the project. While some instructors might find the introductory material superfluous and try to remove it, the material provides significant context behind the project as well as motivation for the students. Recommend requiring students read aloud in class. This project was originally developed for Midshipmen at the United States Naval Academy and the introductory material was targeted towards potential engineering efforts they might undertake as Military Officers. To provide a broader context, two other versions of the introductory material were created that target civilian engineers in both the United States and in Europe.

3.2. Team Organization and Management suggestions (e.g., number of groups and group size, initial organization, and ongoing management)

The number of groups is based on the size of the class. Typically groups of 3 work best. Groups of 4 are acceptable and groups of 2 should be avoided due to workload requirements. Teams should be formed by the instructor based on knowledge of students. Since this project only spans a month, ongoing management of the teams is difficult and instructors should intercede only if they observe significant team dysfunction.

3.3. Assessment

3.3.1. Criteria (e.g., to judge the quality of student products, processes, or performances relative to the learning outcomes and activities)

The Rocket Mission handout, Rocket Engine Test handout, and the Rocket Wind Tunnel Test handout include questions that must be answered. The criteria to judge the quality of student's work for these questions should be no different than a standard engineering lab report. 20% of the grade is based on Flight performance against other teams relative to the Cost to Mass Ratio. If the rocket fails to reach 200 ft in three attempts, a significant deduction should be made (10%). Additionally, if the altimeter is not recovered due to stability and control issues resulting from a poor design or poor construction, a significant deduction (10%) should be made.

3.3.2. Methods and materials (e.g., rubrics for oral/written reflection methods, peer/team self-evaluation, assignments, lab reports, and standard quizzes embedded in the learning activities)

A lab report is the primary method for student assessment. Please see the Rocket Report Format. While not a complete rubric, the following breakdown provides weighting different sections of the report.

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 PMR <u>including recovery</u>

3.4. Resources

3.4.1. Budget (e.g., recurring and non-recurring expenses)

Non-recurring expenses (not including wind tunnel purchase): $4690/$3990

Thrust Chamber construction: $750.00

25 Pound Load Cell: $900

Computer for Thrust Chamber: $600

LABView Software: $315

National Instruments Data Acquisition System: $1875

Altimeter (10) initial purchase: $800 or Theotolite Construction: $100

Estes Launch System: $50

Recurring Costs:

$21 per student for consumables (see section 3.4.3 for list)

$80 per 30 students for loss of altimeter

3.4.2. Equipment and tools

Low-Speed Wind Tunnel with data acquisition system

Thrust Chamber and load cell with data acquisition system

Estes Launch System

Peak Altitude determination system

Electronic Altimeters or

Theodolite two-station altitude-azimuth altitude determination system

Please see Chapter 17 Handbook of Model Rocketry, 7th Edition, by Harry Stine for details on altimeters and theodolite construction

3.4.3. Materials and supplies (e.g., reusable and consumable including hazardous materials)

Reusables

1 ruler for each team in one given class

1 protractor for each team in one given class

Consumables

1 Estes Rocket kit per team

1 Extra Balsa wood sheet (6’’x36’’) per team

1 Extra Launch Rocket Body tubes per team

1 Extra Nose cone per team

1 bottle of wood glue for each team in one given class

1 bottle of super glue for each team in one given class

1 exacto knife for each team in one given class

2 extra parachutes per team

Spray paint in variety of colors (if desired)

3.4.4. Staffing (e.g., describe particular skills and scope of commitment of instructors, technical staff, and others with additional expertise or licensure)

No license is required to launch Estes Rockets

Minimal experience and outside classroom requirement on instructor

One (1) technician to operate wind tunnel one day

One (1) technician to operate thrust chamber one day

One (1) technician familiar with altimeter or Two (2) technicians familiar with theodolite two-station altitude-azimuth altitude determination system on day of launch.

While launch day theoretically could be accomplished using one instructor and one technician (if using an electronic altimeter system), recommendation is that you have at least two technicians and instructor

3.4.5. Spaces (e.g., minimum feasible space requirements per student or per student team, whether space is dedicated or used only during student activity, and use of space for design, build, operate, and storage)

Wind tunnel space should be large enough to produce adequate air flow and be viewable by students in groups of 3

Thrust chamber footprint can be small. Chamber, exhaust equipment and data collection equipment should be able to fit in a 400 sq ft space.

Student work space is based on the number of students in each class. We dedicated one student project workroom for the month the project spans. The room measures approximately 400 sq feet and supports 20 students at a time. One 5 foot folding table per team is sufficient for the design and build phase. This room allows the students to store their rockets and work on them outside of class time.

3.4.6. Other resources (e.g., computer hardware and software)
Standard word processing, spreadsheet, and presentation software. MATLAB for numerical integration. LABView is utilized for wind tunnel and thrust chamber operation and data collection; however, individual user software for this part of the project may vary.

3.5. Safety and Risk Mitigation

3.5.1. Operational safety

While the launch of Estes Model rockets is considered a safe hobby activity, the National Association of Rocketry (NAR) provides general safety guidelines which can be found at www2.estesrockets.com/.../NAR%20Model%20Rocket%20Safety%20Code. pdf

Additionally, while conducting thrust profile experimentation, one must ensure the chamber is capable of containing an explosive failure of the Estes Rocket and an exhaust evacuation system is installed. If conducting the thrust profile experiment outdoors, a blast wall capable of stopping fragment debris or an appropriate standoff distance between the burning rocket and personnel must be utilized (follow launch safety distances).

3.5.2. Governing policies and regulations (e.g., governmental and institutional)

While the launch of Estes Model rockets is routine even among primary education students, one should examine local regulations to determine if launching is permitted. In the United States, model rockets weighing less than one lb. (453 g) including propellant and rockets containing less than 4 oz. (113 g) of propellent do not require notification to the Federal Aviation Administration (FAA).

3.6. Other information, for example:

3.6.1. Possible variations in the project

This project has several variations depending on the capabilities and facilities of the program that is executing the project. For example, a wind tunnel may not be available. As a result, a modification to the project involving simply estimating the cross sectional area and researching a reasonable coefficient of drag would be sufficient. Additionally, if a thrust chamber with a load cell installed is not available, thrust profile curves are available from Estes. At a minimum, the altitude prediction using numerical integration and comparison to flight test data should be accomplished. Also, if the user wishes to alter the costs of the individual components based on observed flight test conditions, they may do so. However, the performance calculation of cost/payload mass ($/kg) should not be altered as the primary objective of the project.

3.6.2. Supplementary multi-media and other resources

Photos of sample thrust chamber

3.6.3. Sample student products from previous iterations of the project

See attached

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