FAMU/FSU College of Engineering

Department of Mechanical Engineering

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Needs Assessment

Team 24: Intercollegiate Rocket Competition

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Abstract

Team 24 of the 2016-2017 Senior design class has committed to designing and building a competitive rocket for the Experimental Sounding Rocket Association Intercollegiate Rocket Engineering Competition. This competition requires that a sounding rocket be created, flown to 10,000 feet above ground level, and safely recovered. As such, is imperative to accurately determine the pertinent requirements for this project. The purpose of this report is to dictate and clarify the goals, needs, constraints, and methodology that group 24 will be working with during the course of this venture.

Acknowledgements

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Firstly, this team would like to thank Dr. Rajan Kumar and John Hansel for their advisement and expertise. Additionally, Team 24 would like to express our appreciation of Dr. Nikhil Gupta and Dr. Chiang Shih for oversight and advisement of the senior design projects.

1. Introduction

The Experimental Sounding Rocket Association (ESRA) was founded in 2003 and aims to further the development of sounding rockets, which are rockets designed to carry a scientific payload. ESRA hosts a yearly intercollegiate rocket competition (IROC). This competition requires teams from Global Universities to design, build, and launch sounding rockets. Furthermore, these rockets must also contain a scientific or engineering payload. This year marks the first year that the FAMU-FSU College of Engineering will be participating in the basic category of the competition.

It is the aim and goal of Team 24 to create a competitive rocket capable of reaching apogee at 10,000 feet above ground level (AGL) whist simultaneously performing a scientific experiment or delivering an engineering related payload. Although limited by budget, there is ample opportunity for innovation and performance. Additionally it is of utmost importance to team 24 that all activities be performed and conducted as safely and professionally as possible.

2. Background and Literature Review

2.1 Early History

Experimental rocketry can be traced back to 1806 when Claude Ruggieri created rockets to carry animals into the atmosphere, however sounding rockets in their current use and configuration can be attributed to a Russian by the name of Tikhonoravov. In 1933 Tikhonoravov launched a liquid fueled rocket carrying scientific instrumentation [1]. Later in 1946, the V2 rocket, famous for causing devastation during the second World War, was used by both American and Russian scientists for atmospheric experimentation [2].

Use of sounding rockets exploded during the 1957 and 1958. During this period approximately 200 rockets were launched. Upper atmospheric and space experiments were being performed on a rapid rate. Some notable activities during this time frame include the launching of the first probes to the moon, discovery of the Van Allen belts and magnetosphere [1] [2].

2.2 Modern Sounding Rockets

Currently sounding rockets are used world wide for a vast expanse of disciplines and and studies. There are several reasons for this, but the most compelling reason is their large range of testing altitude. Weather balloons are primarily limited to altitudes below 120,000 feet and Satellites are limited to altitudes greater than 520,000 feet. Between this range there exist few delivery systems capable of experimentation.

2.3 Sounding Rocket Composition

A series of subsystems composes the typical sounding rocket: the payload, the recovery system, the flight control system, the propulsion system and the telemetry system. All of these systems possess unique hardware, however of most interest to this project is the payload which is typically housed inside of the nose cone; as such, the payload can be separated from the delivery vehicle, allowing for the rocket to be used multiple times for different experiments. Furthermore, the nose cone also houses a separate recovery system to ensure the sensors and the data collected from them survive the descent to Earth. [3].

2.4 Advantages and Disadvantages

Sounding rockets offer several distinct and compelling reasons for use. First and foremost, sounding rockets are simple in comparison to satellites. Satellites require a large development period and a sophisticated launch site. Rockets on the other hand, only require a small launch pad. Sounding rockets typically have only one or two experiments; this is primarily because these delivery systems are cheap enough to not require multiple agencies. As such, the general interest is limited to one or two goals.[1]

Unfortunately drawbacks also exist with this experimentation method. Sounding rockets are limited to small geographic regions during the course of one experiment. Since the rocket does not enter orbit, it lacks the ability to travel far lateral distances. In addition to this issue, experiments performed on sounding rockets are limited to a short duration since sounding rocket payloads only remain at high altitude for a small amount of time before gravity pulls it back towards the ground. Lastly, experiment size and type are limited to the geometry of the rocket; a rocket can only carry experiments that fit within it. [1]

3. Project Details

3.1 Needs Statement

This teams objective is to design and develop a recoverable rocket that safely delivers a payload to an apogee of 10,000 feet above ground level. The payload needs to have a scientific or engineering purpose, and every component must be recoverable. Additionally, the rocket and payload should conform to the rules of the Experimental Sounding Rocket Association's 2017 Intercollegiate Rocket Engineering Competition.

3.2 Goal Statement and Objectives

Successfully design, build, and fly a vertical take-off, single-stage, rocket powered launch vehicle to an apogee of 10,000 ft AGL, and deploy a scientifically useful payload as part of the Intercollegiate Rocket Engineering Competition sponsored by the Experimental Sounding Rocket Association.

In order to accomplish this goal, the following objectives are set by our team:

- Brainstorm concepts for the launch vehicle and for payloads that may be useful to the scientific or engineering community
- Conduct substantial background research into launch vehicle aerodynamics, materials, controls, and structural mechanics
- Benchmark the rocket-payload system using previous competition entries as case studies
- Develop a set of engineering characteristics using engineering parameters, design variables, and constraints
- Utilize engineering tools such as a house of quality chart to select parts and materials that best meet our goal
- Develop scale prototype to validate initial engineering design
- Reiterate on prototype to improve performance
- Design, fabricate, and assemble necessary parts for both test and flight articles
- Develop flight software and integrate into avionics sensors to control rocket functions
- Conduct flight testing of recovery system and flight controller
- Compete at the IREC

3.3 Constraints

The Basic category of the Intercollegiate Rocket Engineering Competition has a set of rules and requirements pertaining to the design of the vehicle and its payload. In addition there are numerous safety requirements imposed for the launch of the vehicle.

3.3.1 Vehicle & Payload Requirements

- The vehicle must attain an altitude of 10,000 ft AGL
- The payload must be at least 8.8 lb.
- The vehicle and payload must be recoverable
- The payload must not affect the stability of the rocket
- The vehicle must have an altimeter and record data using a fight computer
- A maximum of one propulsive stage is allowed
- Propulsion must use non-toxic fuels
- Payload may not contain hazardous materials or live animals

3.3.2 General Requirements

In addition to the rules regarding the design of the vehicle and payload, several other rules should be observed regarding the flight and launch preparation.

- The vehicle must be able to return to a “safe” mode after arming
- The vehicle should attain a speed of 100 ft/s before leaving the launch rail

- The vehicle and payload must have a recovery system
- Main parachute should slow rocket to at least 30 ft/s by 1,500 ft AGL

4. Methodology

To facilitate the successful operation and recovery of both the launch vehicle and payload during the rocket competition the design team will take the following approach:

4.1 Team Schedule

A consistent weekly schedule will be helpful conducive to the team achieving the stated goals and objectives. Below is a table of the planned weekly schedule for the team. Other meetings and events will be in addition to this

Type	**Day**	**Time**
¡¡¡¡¡¡¡ HEAD Team	Thursday	8:15 am - 8:50 am
Team	Saturday	10 am - 12 pm
Team + Mentor	Wednesday	1:00 pm - 2:00 pm
Team + Mentor	Friday	9:20 pm - 9:50 pm

Table 1: Table of team meeting times.

4.2 Pre-Design: Safety and Logistics

- Research the legal requirements associated with high power rocketry and the Intercollegiate Rocket Competition.
- Research design constraints imposed by the Intercollegiate Rocket Competition.

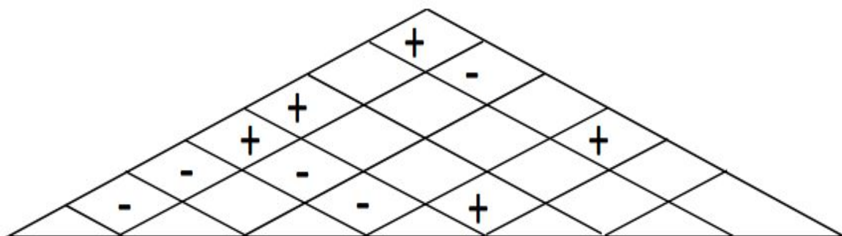
- Attend rocketry event to study launch and launch safety procedures.
- Develop a risk assessment and safety plan to ensure the safety of the design team, and reduce liability risks. Submit plan to Environmental, Health, & Safety department and advisors for review.
- Perform certification tests and attain rocketry organization membership to ensure launch site access and motor classification access.

4.3 Launch Vehicle Design

Before beginning the main launch vehicle design, it was important to determine what features would be most important to focus on. This was done by defining the characteristics of sounding rocket into the following categories.

- Stability : The ability of the rocket to maintain a stable and predictable flight path.
- Rocket Weight : The amount of mass that the rocket motor would be required to carry including the payload
- Total Impulse : The culmination of the burn time and force output of the motor selected. The higher the impuse, the more thrust the motor could provide.
- Reliability : The probability that the components will perform as designed.
- Scientific Value : The usefulness of the experiment being performed
- Material Strength : The ability of the material to withstand the the forces it will be subject to.
- Avionics : The sensor package included.

By weighting the correlation between these features and the competition requirements and constraints, the following table was produced.



Customer Requirements	Customer Importance	Stability	Rocket Weight	Total Impulse	Reliability	Scientific Value	Material Strength	Avionics
Accurate	7	8		8		7		9
Lightweight	1	6	10				4	4
Low cost	2		2	2			5	
Recoverable	8	10	7		9	9	7	8
Safe	10	9	3	6	10		8	9

Score	232	100	120	172	121	150	221
Relative Weight	0.208	0.090	0.108	0.154	0.108	0.134	0.198
Rank	**1**	**7**	**6**	**3**	**5**	**4**	**2**

Figure 1: House of Quality comparing Engineering Values with Requirements

With the ranking of characteristics performed, the actual design can be completed according to the following steps.

- General material selection and weight approximation.
- Determination of the necessary motor specifications based on preliminary calculations.
- Establish physical design scheme and parameters based on motor specifications.

- Research applicable components and develop a bill of materials including cost; submit to advisors for review.
- Arrange for procurement of components and stand

4.4 Payload Integration

- Establish payload preliminary design scheme based on rocket dimensions.
- Detailed design and analysis.
- Develop a bill of materials including cost; submit to advisors for review.

4.5 Verification and Validation

The proceedings for each of the following tests will be outlined in the safety plan and risk assessment. These tests will be scheduled and performed under the appropriate supervision at predetermined locations. All tests results will be documented and any discrepancies will reported to the advisory staff.

- Payload Test : The payload will be tested for functionality.
- Aerodynamic Drag test : A subscale wind test will be performed on a model of the launch vehicle to simulate flight conditions and provide data for tuning associated design parameters.
- Recovery Test : The parachute deployment systems will be tested for functionality.
- Flight Test : The final design will be tested for full functionality and recovery. The test results will inform final evaluation of the design.

5. Expected Results

At the end point of this project, it is expected that a competitive rocket capable of carrying an 8.8 payload will be created by Team 24. In addition to this Team 24 expects to launch this rocket at the ESRA IROC competition in 2017. For the purposes of Senior design, there are also other expectations.

For Senior Design, the results of this project will amount to a number of deliverables:

- All documentation pertaining to the Senior Design curriculum
- All documentation pertaining to the ESRA IREC rules and regulations
- All documentation pertaining to NAR and Tripoli rocket certification
- Final flight hardware to be flown in competition
- Final poster for Senior Design

6. Conclusion

Sounding rockets have been used for the majority of the last century to further scientific knowledge and engineering goals. It is the aim of Team 24 to continue this by creating a sounding rocket capable of reaching 10,000 feet AGL while performing a scientific or engineering experiment safely. To perform this goal it is imperative that we focus on the stability, reliability and avionics package of our rocket. These features will maximize the scientific usefulness of the final product as well as emphasize the importance of safety to this group. Design of the overall system will happen in 4 general steps. Pre-Design, Launch Vehicle Design, Payload Integration, and finally Verification and Validation. Each of these steps contain the most pertinent requirements to proceed to the next step. It is the goal of Team 24 that by completing the aforementioned steps, the final product created will be capable of competing at competition and provide useful scientific data.

7. Appendix A

References

[1] William R. Corliss "NASA Sounding Rockets, 1958-1968 A Historical Summary", Scientific Technical Information Office, 1971

[2] Gunther Seibert "The History of Sounding Rockets and Their Contribution to European Space Research", European Space Agency, 2006

[3] Steven Christe and Ben Zeiger and Rob Pfaff and Michael Garcia "Introduction to the Special Issue on Sounding Rockets and Instrumentations",Journey of Astronomical Instrumentation, 2016