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I) Summary of PDR Report

Team Summary

- Team Name and Mailing Address

  University of North Dakota Frozen Fury
  Witmer Hall, 101 Cornell Street Stop 7129
  Grand Forks, North Dakota 58202-7129

- Location

  Grand Forks, North Dakota 58202

- Team Mentor

  Dr. Timothy Young, NAR # 76791, Certification Level 2
  Brian Badders, NAR #94455, Certification Level 2

Launch Vehicle Summary

- Size and Mass

  Vehicle Dimensions

  Length: 114 in. / 9.5 ft.
  Diameter: 6.0 in.
  Span: 12.0 in.
  Unloaded mass: 900.9002 oz.
  CP: 77.6030 in.
  CG: 59.9158 in.
  Margin: 2.95

  Fin Dimensions

  Root: 20.0 in.
  Tip: 12.0 in.
  Sweep length: 0 in.
  Semi Span: 6.0 in.
• **Motor Choice**

_Aerotech L2200G_

Diameter: 75 mm  
Length: 665.0000 mm  
Burn: 2.40 sec.  
Thrust: 2104.9852 Newtons  
Impulse: 5051.9644 N*Sec

• **Recovery System**

Dual Deployment  
Drogue: 36 in. (5 sec after Apogee)  
Main: 72 in. (at 700 ft.)

• **Milestone Review Flysheet**

_Payload Summary_

• **Payload Title**

Hazard Detection Payload (3.1)  
Payload Faring/Deployment System (3.2.2.1)  
Liquid Sloshing Analysis Payload (3.2.1.2)

• **Summarize Experiment**

The Hazard Detection Payload will consist of a camera and the necessary electronics to scan the ground during decent and relay any landing hazards in real time to a ground station. This payload will require static ground tests to determine the abilities the camera and software in identifying potential landing hazards. One of the major challenges of this project will be creating a 2-way communications system for the rocket. Since the exact launch time is unknown and the video storage is limited, we need to be able to communicate with the cameras on board in order to tell them when to start recording. We also want to be able to view the video from cameras near real-time from a ground station. This will add an extra level of difficulty to the project.

The Hazard Detection Payload will be deployed by a faring deployment system, the payload fairing system will consist of an altered nose cone in two pieces that will be friction fitted together; each half will be attached to the body tube with hinges. Our faring system will consist of a mechanical cone separation system that will separate the two halves of the nose cone when the
drogue chute is deployed, upon the separation of the payload and engine mount sections. The mechanical system will consist of a tether with one end attached to the drogue chute and the other to a screw that will have levers with a gear on one end. Initially the levers will be orientated towards the base corners of the nose cone. When the drogue chute is deployed the tether will pull on the screw causing the levers to expand and separate the two halves of the nose cone. In order to prevent the halves of the nose cone from interfering with the hazard detection camera contained in the nose cone the hinges attaching the nose cone halves to the payload section will lock once the halves are out of the cameras viewing area. This mechanical system will require static ground tests to determine the force required to separate the nose cone. Problems with this system could arise if the drogue chute does not exert enough force on the levers, or another potential problem could occur if the cones do not separate enough to allow the hinges to lock.

The Liquid Sloshing Analysis payload will be designed to collect and analyze fluid flow patterns in microgravity. The purpose of this project is to research liquid sloshing in microgravity to support liquid propulsion system upgrades and development. Collection of this data will be done through a partitioned tank, mounted in the payload bay of our rocket, with the liquid in one half cylinder being allowed to move freely and the other half cylinder will be controlled by a low pressure piston. The data for this payload will be collected by four cameras and stored via the onboard electronics. Four (4) cameras will be used, positioned inside the rocket airframe, and each oriented to focus on one of the two partitions of the tank. If the space inside the body tube is insufficient, housings will be built alongside the rockets airframe to give the cameras the extra room, while minimally changing the geometry of the rocket. Two of the cameras will be positioned along the body tube 180 degrees from each other, to ensure the rocket remains balanced. The other two cameras will be positioned on the top of one tank and the bottom of the other. The data from the cameras used in the analysis of liquid sloshing will be stored onboard the rocket, to be analyzed post flight. We are still in the process of choosing our cameras. Currently, the GoPro HD Hero 960 helmet camera is at the top of the list. This camera is capable of obtaining 60 frames per second with 848x480 resolution. This project requires that we have at several dynamic ground tests to measure the liquid sloshing patterns, to determine liquid patterns in standard gravity. The data we collect in-flight can then be compared to this base data. One of the major challenges for this payload will be developing the appropriate software to analyze the video taken by the cameras in this payload bay.

- An image follows detailing the payload design.
Changes Made Since Proposal

- Changes Made to Vehicle Criteria

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<tr>
<th>Component</th>
<th>Proposal</th>
<th>PDR Changes</th>
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<tr>
<td>a. Rocket Length</td>
<td>108 in</td>
<td>114 in</td>
</tr>
<tr>
<td>b. Unloaded Mass</td>
<td>489.9834 oz</td>
<td>900.9002 oz</td>
</tr>
<tr>
<td>d. CP</td>
<td>82.2121 in</td>
<td>77.6030 in</td>
</tr>
<tr>
<td>e. CG</td>
<td>77.1725 in</td>
<td>59.9158 in</td>
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<tr>
<td>f. Safety Margin</td>
<td>1.34</td>
<td>2.4</td>
</tr>
<tr>
<td>i. Motor</td>
<td>L1500T</td>
<td>L2200G</td>
</tr>
</tbody>
</table>

The reason for the changes made to the rocket such as the length and mass, were due to the unknowns of how large are payload would be, along with the added need for extra room when working with the payload within the rocket. As for the change in mass, this was due to the increase in mass of the payload section and length of our model. The change in mass also caused changes in the CG and CP of the rocket. The motor being increased was also due to the fact that we need the extra thrust or impulse in order to reach an appropriate height to conduct our liquid payload experiment. Due to the larger rocket size and payload size the maximum altitude was significantly decreased so to attempt to regain some of the height we needed a more powerful motor.

- Changes Made to Payload Criteria

- Changes Made to Project

II) Vehicle Criteria

Selection, Design, and Verification of Launch Vehicle

- Mission Statement and Requirements/Success Criteria

Mission statement
The primary objective of the 2013-2014 University of North Dakota Frozen Fury rocket team is to design and construct a safe, stable rocket that will conduct research in liquid sloshing to assist in the understanding of liquid sloshing in microgravity. As well as develop a useful hazard detection system.

Rocket Launch Success Criteria
A successful rocket launch will consist of reaching an altitude at apogee within ± 3.00% of 5076.35 feet above ground level.

**Rocket Recovery Success Criteria**
A successful recovery of the rocket will consist of the recovery system ejecting at the appropriate time and altitude and recovering the rocket on the ground such that it is deemed reusable for future launches.

**Payload Success Criteria**
A successful payload system will consist of the Hazard Detection Payload, Payload Faring/Deployment System, and Liquid Sloshing Analysis Payload. The systems should operate successfully during and after the launch and be capable of determining the location of hazardous objects within the field of view of the rocket. The Liquid Sloshing Analysis Payload should provide detailed information of the flow patterns of liquids in microgravity. The Faring system should successfully deploy the hazard detection camera.

- **System Level Design Review**

  **Airframe Material**
  The 2013-2014 Rocket design is projected to have an airframe composed of a carbon fiber composite. Simulations have been conducted using RockSim for a 6 inch diameter and 114 inch length rocket. The simulations projected a peak altitude of 5076.35 ft. with both a carbon fiber and fiber-glass rocket (approximate dry weight 900.9002 oz.) using an Aerotech L2200G size motor.

  **Fin Material**
  Fins will be constructed out of the same material as the airframe (i.e. Carbon Fiber). The innate strength of the material will ensure that the fins will not break upon landing, which is something that the Frozen Fury Team has experienced in the past.

  **Bulk-Head/Centering-Ring Material**
  Internal bulkheads/centering-rings will be constructed out of 0.5 in. cabinet quality birch plywood purchased from a Grand Forks, ND local hardware retailer. The rationale behind choosing birch plywood is that it has a very clean face and very few knots. The use of higher grade wood ensures the bulkheads and fins will have uniform wood grain and will be structurally strong in order withstand the stress of flight. Bulkheads are cut from the plywood using a table saw, and then sanded to fit securely in the 5.75 in. diameter rocket body tube. The bulkheads are affixed inside the airframe with West Systems epoxy on both the superior and inferior edges for added strength. The plywood bulkheads make certain the rocket structure is rigid throughout its entire length.

  **Motor Type**
The current simulated motor type used for the 2013-2014 Frozen Fury Rocket is an Aerotech L2200G. This motor has a moderate impulse and projects the design’s max altitude at approximately 5076.35 ft. This motor type is still under discussion due to the payload component weights being unknown.

It was also verified that the AeroTech L2200G motor was not of the Skid mark/metal filing variety so there would be no additional fire hazard with its use.

*Workmanship*

The quality of work is very important to maintain a successful program. The team has plans to stay neat in the construction process and all tools and components will put away at the end of the day. This is propelling the team toward success by keeping our workspace clean day-to-day, which helps expedite work.

- **Subsystems**

  The subsystems that are required to accomplish our mission include: 36 in. drogue parachute which will deploy 5 seconds after apogee, and the 72 in. main parachute which will deploy at 700 ft. Both of these will be attached by nylon shock cords to the inside fuselage and will deploy based on altimeter readings.

- **Performance Characteristics for Systems and Subsystems**

- **Verification Plan and Status**

  *Purpose:*
  
  The primary purpose of the 2013-2014 University of North Dakota Frozen Fury rocket team is to design and construct a safe, stable rocket that will conduct research in liquid sloshing to assist in the understanding of liquid sloshing in microgravity. As well as develop a useful hazard detection system.

  *Scope of Work:*
  
  This describes roughly the work that must be done in detail and specifies the hardware and software involved and the exact nature of the work to be done.

  *Location of Work:*
  
  This describes where the work must be performed. This also specifies the location of hardware and software and where people will meet to perform the work.
Period of Performance:
This specifies the allowable time for projects, such as start and finish time, number of hours that can be billed per week or month, where work is to be performed and anything else that relates to scheduling.

Deliverables Schedule:
This part lists the specific deliverables, describing what is due and when.

Applicable Standards:
This describes any industry specific standards that need to be adhered to in fulfilling the contract.

Acceptance Criteria:
This specifies how the buyer or receiver of goods will determine if the product or service is acceptable, what objective criteria will be used to state the work is acceptable. See Acceptance testing

Special Requirements:
This specifies any special hardware or software, specialized workforce requirements, such as degrees or certifications for personnel, travel requirements, and anything else not covered in the contract specifics.

Type of Contract/Payment Schedule:
The project acceptance will depend on if the budget available will be enough to cover the work required. Therefore payments breakdown whether up front or phased will be negotiated very early at this stage.

Miscellaneous:
There are many items that do not form part of the main negotiations but are nonetheless very important to the project. They seem minor but being overlooked or forgotten could pose problems for the project.

- Risk Mitigation and Schedule
- Manufacturing, Verification, Integration, and Operations Plan

For the process of which we will be completing our rocket, we will be using equipment provided by the Physics and Engineering departments at the University of North Dakota to manufacture and assemble our rocket. To verify this process we will do functional testing’s, such as doing multiple practice charges on the ground, payload data taken from rooftops and verified against actual results, and practice flights throughout the assembly process to see what areas we can improve in or modify. The integration of our payload and subsystems (i.e. parachutes) will be done concurrently with the assembly process to assure that proper size is accommodated for each component.
Finally operations will be done once all tests assure us that we are ready to launch our finished product, and test its functionality.

- **Confidence and Design Maturity**

  The basis of our design is off of our 2012-2013 rocket that was done with the SMD payload. This gave us a good starting point in determining how large a diameter of rocket we wanted, as well as the overall length of the rocket. The reason why we’ve gone with our length is because we are unsure of how our payload will be incorporated, as in whether it will be more compact or lengthened out along our shaft which it will rotate about. We know from the 2012-2013 rocket that their design length was slightly smaller than needed, so from that, we determined that our finished rocket will be larger in length then that design.

- **Dimensional Drawings**

  The drawing for our assembled rocket, with a description of where each component will be placed, is located as **Figure 9** in the appendix.

- **Recovery System Electrical Schematics**

- **Mass Statement**

  The mass of the vehicle was estimated by Rocksim to be 900.9002 oz. with a margin of 2.4, Rocksim has projected that our rocket will hit a altitude of 5076.35 ft with our specified motor. A list of the weights for each component and subsystems are as followed:
  - Nose cone 11.6069 Oz.
  - Body tube 5.6923 Oz.
  - Transition 17.2926 Oz.
  - Body tube 9.5070 Oz.
  - Liquid Mass 529.1094 Oz.
  - Transition 17.2893 Oz.
  - Body tube 8.5357 Oz.
  - Tube coupler 5.6291 Oz.
  - Droge Parachute 1.2806 Oz.
  - Body tube 22.7690 Oz.
  - Fin set 58.2661 Oz.
  - Body tube 10.5152 Oz.
  - Centering ring 5.8017 Oz.
  - Centering ring 5.8017 Oz.
  - Main Parachute 5.5766 Oz
  - Bulkhead 5.4479 Oz
Recovery Subsystem

- **Mass, Attachment Scheme, Deployment Process, and Test Results/Plans**

  The rocket will utilize a drogue parachute deployment at apogee, and a main parachute deployment at 700 ft AGL. The drogue chute is a 36 in. nylon round parachute with a 7.0 in. spill hole. This allows the rocket and payload to descend at a velocity of 49.9 ft/s. This has been considered fast enough for recovery area purposes. The main parachute is a 72 in. PML chute with a 10.0 in. spill hole. The spill hole lets the rocket descend in a more stable fashion while maintaining a relatively safe descent rate of 23.4 ft/s.

- **Recovery System Components**

  The parachutes will be connected to a rip-stop nylon shock chord. They will have quick links attached at each end for ease of assembly and removal. The quick links will also be attached to eye bolts which are epoxied into place on the altimeter bay’s bulk head. The shock cord’s length will be large enough to ensure that none of the rocket’s structural components will collide during decent. Sheer pins will be used in conjunction with small amount of friction fitted tape at the separation points.
Mission Performance Predictions

- Mission Performance Criteria
- Flight Profile Simulations

Rocket Stability Relationships

Loaded Rocket

NASA SL-1
Length: 114.0000 In., Diameter: 10.0000 In., Span diameter: 18.0000 In.
CG: 59.8444 In., CP: 77.6030 In., Margin: 2.96 Overstable
Engines: [L2200G-None, ]
• Kinetic Energy Calculations

• Wind Drift Calculations

**Interfaces and Integration**

• Payload Integration Plan

• Launch Vehicle Internal Interfaces

• Launch Vehicle External Interfaces

• Launch Vehicle and Ground Launch System Interfaces

The launch rail is constructed of steel tubing, and the rail for use by the rocket with a bead system is 12 feet to the base platform. The length of the rail can be adjusted by moving a knuckle up and down on the rail so that the platform moves either up or down decreasing or increasing the length of the rail to adjust for conditions or for safety reasons. We plan to use 10 feet of the 12 foot rail, so we will have the knuckle two feet from the base, making the total distance traveled by the rocketed 10 feet total.

. Pro-E Launch Rail Schematic:
Launch Operation Procedures

- Final Assembly and Launch Procedure Checklists

Safety and Environment (Vehicle)

- Team Safety Officer
  Nicole Fitzgerald
- Preliminary Failure Modes Analysis
- Safety Hazards Analysis
- Environmental Concerns

III) Payload Criteria

Selection, Design, and Verification of Payload Experiment

- System Level Design Review
- Required Payload Subsystems
- System and Subsystem Performance Characteristics
- Verification Plan and Status
- Preliminary Integration Plan
- Instrument Precision, Measurement Repeatability, and Recovery System.
- Payload Drawings and Electrical Schematics
- Payload Component Integration
Payload Concept Features and Definition

- Creativity and Originality
- Uniqueness or Significance
- Suitable Level of Challenge

Scientific Value

- Payload Objectives
- Payload Success Criteria
- Experimental Logic, Approach, and Method of Investigation
- Tests, Measurements, Variables, and Controls
- Data Relevance and Accuracy/Error Analysis
- Preliminary Experiment Process Procedures

Safety and Environment (Payload)

- Safety Officer
- Preliminary Failure Modes Analysis
- Safety Hazards Analysis
- Environmental Concerns

IV) Project Plan

November
8 - Request for Proposal (RFP)
10 - Physics Day (outreach)
22 - Submit electronic copy of proposal
28 - Teams notified of selection

December
3 - Team teleconference
- Preliminary Design Review Question and Answer Session
6 - Web page completion

January
10 - PDR reports, presentation slides, and flysheet posted on the team Website
13-17 - PDR Presentation
18 - First Scale Test Launch (tentative)
23 - Critical Design Review (CDR) Question and Answer Session

February
10 - Full Scale Test Launch (tentative)
28 - CDR reports, presentation slides, and flysheet posted on the team Website

March
3-7 - CDR Presentations
12 - Full scale test launch
13 - Flight Readiness Review (FRR) Question and Answer Session

April
18 - FRR reports, presentation slides, and flysheet posted on the team Website
21-25 - Present FRR (tentative dates)

May
14 - Arrive in Salt Lake City, Utah
15-16 - Launch Readiness Reviews
- Flight Hardware and Safety Check (tentative)
17-18 - Launch Day

June
2 - Post the - Post Launch Assessment Review (PLAR) on website
13 - Winning USLI team will be announced

Schedule and Status of Activities

- Budget Plan

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- **Funding Plan**
- **Timeline**
- **Educational Engagement Plan**

V) Conclusion