Space Challenge

Phase 1 Preliminary Design Report

(Team Name/University)

This document must be uploaded to your Phase 1 Submission using the HeroX application portal. All supporting files must be uploaded to the 3DExperience platform and must be linked within the content of your submission.

Introduction

Provide an overview of your project and your approach to developing a vehicle capable of meeting the mission requirements. Describe your team structure, stakeholders and team management strategies, and discuss your overall systems engineering approach.

Description of Overall System Architecture

Provide a top-level overview of the complete integrated system, including diagrams and figures depicting the fully integrated vehicle and its major subsystems, as well as ground elements. Include subsections to provide a high-level description of each of the major vehicle subsystems. These should include at minimum:

- Propulsion
- Aerostructures
- Avionics & Telemetry
- Recovery
- Ground Support & Operations

Discuss your proposed approach to system integration. How will the overall system accommodate changes to individual subsystems or components?

Mission Concept of Operations Overview

A complete mission may be broken down into a series of phases, wherein specific things occur, involving specific subsystems. Definable events typically signify the beginning and end of the phase and the transition to the next phase. Such events could include operator actions (e.g. “FIRE button is pressed”), electrical signals (e.g. a timer triggering an event, a valve position switch closing, an altimeter sending a FIRE signal to an igniter, etc), or physical events (initial

acceleration of the vehicle, clearing the launch rail, reaching apogee, etc). Present an overview of your mission, broken down into phases, and describe the nominal operation of all relevant subsystems during each phase. Define the events that signify a transition from one phase to the next.

Your choice of phase definitions will be unique to your design and approach to achieving the mission objectives, but will serve as a useful organizing principle to systematically describe your mission.

Mission Analysis

Provide an overview of your complete mission, identifying the derived mission requirements specific to your vehicle (this could include high-level requirements for specific impulse, drag coefficients, mass fractions, etc.), and demonstrate how your vehicle design fulfills them. Present your mission analysis to demonstrate that your design is capable of reaching the target altitude, and list any underlying assumptions you have made.

Requirements

Your vehicle design will ultimately be governed by a set of requirements. The highest-level requirements were imposed on you by the System Requirements document, but these will be decomposed into more specific requirements that relate to your specific vehicle concept and its major subsystems. This could include requirements for engine specific impulse, burn duration, mass fractions, drag coefficients, pressures, flowrates, etc. Provide the specific set of requirements that will apply to your vehicle and its major subsystems.

Mass budget

Your mission analysis will be based on certain assumptions about the vehicle mass. Provide your vehicle mass budget, broken down by subsystem and decomposed into as much detail as possible. State any underlying assumptions behind your allowable weights, and specify the source of each weight number (actual measured hardware weight, preliminary calculation, scaling, etc.) in order to show your level of confidence in the number. Indicate how much weight margin is being included, discuss the areas that you believe contain the greatest risk of weight increases, and discuss your strategy for mitigating that risk.

Propellant Selection and Propulsion Design

Discuss your propellant choice and the rationale behind it, summarizing any trade studies that were done. Discuss the impact of your propellant selection on the design of your vehicle as a whole.

Broadly present the overall design of your propulsion system and its key parameters. Include calculations and/or analyses to support these.

Follow the high-level description with subsections for each of the major propulsion subsystems. Any supporting technical drawings, calculations and analyses may be included in an appendix.

- Chamber / Nozzle (including cooling approach)
- Injector
- Propellant valves and delivery
- Tank pressurization
- Engine instrumentation & controls
- Safety features

Engine test stand design and test plan

Engine design is highly iterative, and testing of components and the complete engine will be critical elements of the development process. Provide your test plan for engine testing, both at the component and subsystem level, and for complete engine hot firings. Discuss how you will address safety during these tests. Discuss your strategy and underlying assumptions with regard to the design of the engine test stand.

Range Safety Systems

The need to operate the vehicle within the constraints imposed by the launch requires that the design incorporate safety features as described in the System Requirements Document. Describe your intended implementation of these systems. Do they comply with the System Requirements?

Airframe Structure

Present the structural design of your vehicle, including the airframe, tankage (if part of the aerodynamic load path), nose cone and fins. Describe the load cases that you selected to drive the structural design, discuss the margin you are building in to the design, and discuss the

ability of your structure to accommodate any changes in engine design as development progresses.

Flight dynamics

Present your flight dynamic analysis, demonstrate the stability of your vehicle, and show that it will remain stable during transonic and supersonic flight. If any additional stability control measures will be taken, describe them. Also demonstrate that the rocket will be stable as it leaves the launch rail.

Electronics and altitude monitoring

Describe the electronic elements of your vehicle and ground support equipment. This should include

- Avionics, altitude and position monitoring
- Recovery system electronics
- Engine control and monitoring
- Instrumentation
- Telemetry

Software

Present the overall concept for any custom software you will be creating. This could include software for:

- Control or monitoring of functions on board the vehicle
- Launch control and ground support
- Data acquisition

Illustrate how the software will interface with other elements of the overall vehicle system, including electronics / hardware, and operators.

Recovery System

Present your recovery system design and include any calculations or analysis to support your sizing of the system and its components.

Ground Support equipment

A rocket system includes more than just the vehicle. The ground support equipment is equally important to ensuring a successful launch. This equipment can include the launch rail, fueling equipment, umbilicals, disconnects, ground-based control and telemetry systems, and any other equipment necessary to set up, fuel and launch the vehicle. Provide an overview of your anticipated ground support equipment and how they fit in to the overall operation.

Hazard Analysis

This section shall provide a comprehensive overview of any aspects of the design that could pose a hazard to personnel assembling, fueling, launching and recovering vehicle, as well as bystanders. This might include handling and loading of propellants, pyrotechnic devices, pressure systems, oxidizers, and any other potentially hazardous design elements. For each identified hazard, a mitigation approach - by process and/or design - shall be defined.

Risk Assessment

This section will focus on the reliability of the vehicle and ground elements. Failure modes posing a risk to mission success will be identified and discussed, and a mitigation approach - by process and/or design - shall be defined for each risk identified. Failure modes should be organized according to the mission phases defined in your Concept of Operations Overview.

Team development

In addition to the technical and engineering design work, teams will be judged for their plans to develop and maintain their teams – this is broken down into three components:

Succession Planning

Over the course of the challenge, team members will graduate or leave. Describe your plan to ensure that all major roles (CEO, Chief Engineer, Chief Safety Officer, and Business/Marketing Director) will be continuously occupied by individuals who are familiar with and knowledgeable of the respective responsibilities.

Knowledge Retention

As team members leave, they take away from the team their experience, expertise, and project-related knowledge. Describe your plan to ensure that such crucial information is conserved and accessible as the team composition shifts.

Outreach

To complete this multi-year challenge, teams will require regular influxes of new talent. Just like industry requires a talent development pipeline, so does your team -- and, in fact, your university. Describe your strategic plan for supporting the talent development pipeline in your community, including both the community college and K-12 level. Explain how you plan to implement the outreach program. Keep in mind that research shows innovation is higher when teams are diverse, so consider how you will target women and underrepresented minorities.

Business and Marketing

Rocketry is expensive. Provide a budget for your efforts to win this challenge. Specify how much money you project will be needed for successive phases and from where you expect to receive those funds. Rough estimates are acceptable at this Phase. Additionally, discuss your strategy towards fund-raising and budget management.