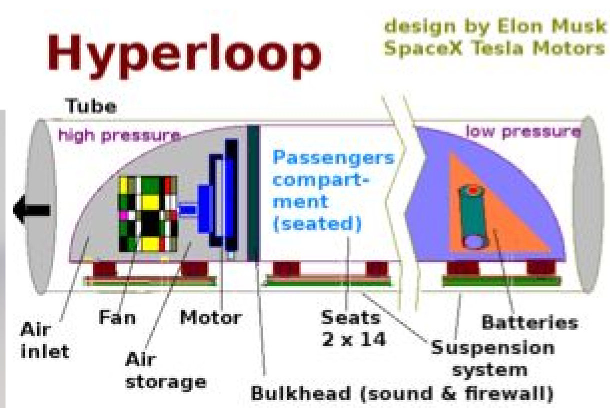
MAE 303 Fluid Mechanics & MAE 603 Fluid Dynamics and Aerodynamics

Project: Proposal to Solve a Fluid Mechanics Problem of Hyperloop Pod

PROBLEM DESCRIPTION

Elon Musk, CEO of SpaceX just announced an open call for competition (Appendix A.) to build and demonstrate Hyperloop Pod. ODU team Monarch-Loop plan to respond to the competition and propose to build a Hyperloop pod. Hyperloop pod is a prototype Hyperloop vehicle. ODU MonarchLoop that consists of teams from MAE, ECE, and CEE plan to submit a proposal to compete.

https://edpuzzle.com/join/celobir



ROLE

You are the team leader from the Department of Mechanical & Aerospace Engineering. Your team is responsible for propose a design of either the levitation system (air hockey), the propulsion system, or conduct an analysis of the aerodynamic coefficients of the pod.

AUDIENCE

The audience will be the proposal review panel that consists of the experts from SpaceX and representatives of the planning council of California state. Your job is to convince the audience that your proposed design and validation methods technical sound. In addition you need to show that the budget is reasonable.

TASKS

1. Select a specific research area and conduct literature survey. (W1)
2. Select an existing design and propose the validation methods. (W2-W5)

3. Estimate the project budget, including personnel, travel, materials and supplies, and other. (W4-8)
4. Write the whole proposal based on the template provided. (W8-12)

PROPOSAL TEMPLATE

Cover Page
Title:
Investigators:
Affiliation:
Project Period:
Budget:
Project Location:

Project Summary
Content: A brief summary of the proposal
Length: one-third to one-half page, never more than one page
Emphasis: highlighting of the proposed technical and management approach

Table of Contents

Statement of Problem: the "Why?"
Summary of the request by the sponsor (Space X) Background: Brief description of company and their business Relevance or importance of problem Background information to educate the reader Previous related work by others—literature review with credible sources Patent search, if applicable Detailed problem description, as you now understand it.

Objectives: the "What?"
In the Objectives section, you translate the customer's quantitative and qualitative needs into clear, objective design specifications. Define the scope of work and clearly state the project objectives, including the following: a. Design specifications in specific, quantitative terms. For example, "The plate must be rotated three times at a speed of between 1 and 3 rev/s" or "Control the temperature of a 1 liter non-insulated standard glass beaker of water to 37.5 ± 0.5oC for three hours without temperature deviation." b. Critical design issues, constraints, limitations.

Technical Approach: the "How?"
Although you may not know all the details of the problem solution, you should know a first design on how you will attack the problem, and you should have some design concepts. The purpose of this section is to present the process by which you will arrive at the final answer. This section answers the following questions: 3 1) What are the steps in the design process? (Describe and use the nine-step model from Chapter 1 of Hyman's text) 2) What are the benefits and advantages of employing a structured approach to design? 3) How will you generate

solution concepts? 4) How will you analyze the performance of your solution? 5) How will you decide on the best alternative?

Project Management

The Project Management section describes how the project will be managed, including a detailed timetable with milestones. Specific items to include in this section are as follows:
a. Description of task phases (typical development tasks: Planning, Concept Development, System-Level Design, Detailed Design, Testing and Refinement, Production)
b. Division of responsibilities and duties among team members
c. Timeline with milestones: Gantt chart .

Deliverables

The culmination of the proposal negotiation with your sponsor will be a completed “Deliverables Agreement.” In this section, provide a detailed description of what you are providing and when you will provide it. Be as specific as possible. Possible items include Detailed design drawings (specify Computer Aided Design format) Physical prototype Scale model Engineering analysis (Finite Element Analysis, MATLAB, etc.) Economic analysis (return on investment calculations) Detailed description of test procedures Data from experiments Computer program code, flowchart, documentation Circuit diagrams User-friendly instructions including training for personnel

Budget and Justification

Provide your best estimate of how project funds will be spent for your first design. The sponsor will allow for only this amount. At this time, you need to know the details for your initial design. Justify all the expenses.

Facilities and Resources

List all the facilities and resources that you can use to complete all the objectives.

APPENDIX A.

SpaceX Hyperloop Pod: Request for Proposal

August 31, 2016

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1 INTRODUCTION

On August 12, 2013, Elon Musk released a white paper on the Hyperloop, his concept of high-speed ground transport. In order to accelerate the development of a functional prototype and to encourage student innovation, SpaceX announced a Hyperloop Pod Competition in 2015 to design and build a half- scale Hyperloop Pod. For this competition, student teams from around the country and world came together for a Design Weekend in January 2016 to share their Pod designs. Top teams selected at Design Weekend advanced to the build phase and spent 2016 turning their designs into working Pods. These teams are currently preparing to take part in Competition Weekend on January 27–29, 2017, where they will race their Pods on a Hyperloop test track adjacent to SpaceX's Hawthorne, California, headquarters.

Based on the high-quality submissions and overwhelming enthusiasm surrounding the Hyperloop Pod Competition, SpaceX is moving forward with a second installment of the Competition: Hyperloop Pod Competition II.

This document outlines the competition logistics and rules. Competition Weekend II is open to new student teams interested in competing on the test track as well as to the existing student teams who have already built and tested Pods to further refine their designs. There will be some updates to the competition rules and track specifications for Competition Weekend II as outlined in this document.

Competition Weekend II will be judged solely on one criteria: maximum speed with successful deceleration (i.e. without crashing). This is different from Competition Weekend I, which featured multiple judging criteria. In addition, unlike first Competition Weekend, there will not be separate Pod classes (e.g. wheeled vehicles, micro-Pods, etc.); all Pods shall be judged in a single class with the single aforementioned maximum speed criterion.

2 DESIGN PACKAGE

The Final Design Package must consist of:

1. Description of team and updated list of all associated team members and advisors

2. Design description for Pod. At a minimum, this should include:

a. Pod top-level design summary b. Pod dimensions c. Pod mass by subsystem d. Pod payload capability e. Pod materials f. Pod power source and consumption g. Pod navigation mechanism h. Pod levitation mechanism (if any) i. Pod propulsion mechanism (if any) j. Pod braking mechanism k. Pod stability mechanisms (e.g. attitude and lateral motion) l. Pod aerodynamic coefficients m. Pod magnetic parameters (if applicable)

3. Predicted Pod thermal profile

4. Predicted Pod trajectory (speed versus distance)

5. Predicted vibration environments

6. Pod structural design cases: at a minimum, this shall include initial acceleration, nominal deceleration, and a reasonably foreseeable off-nominal crash

7. Pod production schedule

8. Pod cost breakdown

9. Sensor list and location map

10. Comments on scalability to an operational Hyperloop with respect to:

a. System size (increased tube length, tube diameter, and Pod size) b. Cost (both production and maintenance) c. Estimated Pod mass and cost if built full-scale d. Maintenance (e.g. not requiring specialized alignment tools, hot-swappable subsystems)

11. Loading and unloading plan

a. Full descriptions of all functional tests (see Sections 10 and 12) b. Full description of Ready-to-Launch checklist/state (e.g. Loop Computer in "Launch

Mode" and sending telemetry, Pod hovering at 0.25 inches). c. Full description of Ready-to-Remove checklist/state (e.g. Wheels locked, Power Off). d. Description of how Pod is moved from Staging Area to Hyperloop e. Description of how Pod is moved from Hyperloop to Exit Area

12. List and description of any stored energy on the Pod (i.e. pressure vessels, batteries).

13. List of any hazardous materials, if any

14. Description of safety features including:

f. Hardware and software inhibits on braking during the acceleration phase g. Mechanisms to mitigate a complete loss of Pod power h. Pod robustness to a tube breach resulting in rapid pressurization i. Fault tolerance of braking, levitation, and other subsystems j. Single point of failures within the Pod k. Recovery plan if Pod becomes immovable within tube l. Implementation of the Pod-Stop command 15. Component and system test program before the Pod arrives for Competition Weekend II 16. Vacuum Compatibility Analysis

7 FINAL DESIGN PRESENTATIONS

Based on the Final Design Packages, SpaceX will select certain teams to present their designs, via video conference, to a SpaceX judging panel. These presentations will be no more than 30 minutes, with a 15 minute Q&A session, and will take place in winter 2017. Following this, SpaceX will notify teams who are advancing to the build phase for Competition Weekend II.

Because it is possible that certain presenting teams are also taking part in Competition Weekend I and will be preparing simultaneously for that event, the presentation schedules will be kept flexible. There should be minimal additional work associated with the presentations – it is assumed that the Final Design Packages will be the basis for the presentation content.

8 SAFETY PACKAGE Before attending Competition Weekend II, competitors must submit a complete Safety Package, including the information below at minimum. Most of the information can be extracted from the previous submissions.

1. General:

a. Physical Pod configuration: pictures, drawings, mass, materials, and dimensions b. Acceleration

i. Method(s) for acceleration ii. Maximum speed at which your Pod can maintain control iii. Maximum acceleration at which your Pod can maintain control c. Deceleration

i. Criteria for Pod to initiate braking at the end of the run ii. Mechanisms for ensuring your Pod doesn't brake during the acceleration period 2. Magnets:

a. Provide strength of magnetic field at max power b. Provide a plot of magnetic fields / fringe lines for the entire vehicle when active. 3. Pressurized systems:

a. Provide Tank specifications and safety ratings, include MAWP, MEOP and BURST b. Provide proof that your vessel has been "proof tested" – this could be a video or photos

that show the test and pressure gages c. Provide a plan for transport of your components and how you will verify no overloads

during transport (i.e. accelerometers, temperature sensors) d. Provide Fluid schematics, Parts and Identifications list e. Provide proof that all components have been torqued to the appropriate value and

include in your procedures how this will be verified once onsite f. Provide a Quantity Distance Calculation and TNT equivalence to determine clear zone required. This is very important and SpaceX can assist you in the calculation. 4. Power systems:

a. Provide a power and grounding schematic showing voltages present and ground tie methods between chassis and power return

b. Provide details on harnessing and electronics mounting and prove they are robust to vibration c. Provide estimate of total energy stored in batteries, and battery data sheets showing battery chemistry type and technical specifications

d. Provide data/rationale for how batteries and power electronics will operate at vacuum pressures

e. Provide battery fire procedure

5. For control systems:

a. Provide an electrical block diagram for all components, showing all connectors and how any ground equipment interfaces to your Pod. b. Provide a software state machine diagram, howing how the Pod will behavior under all conditions, and how transitions between these states occur. This will be reviewed for safety and then:

i. Demonstrate every transition and behavior in each state before the run, ideally without changing software

6. Procedures: Procedures should be provided for all aspects of testing including:

a. Pod Loading and Unloading (higher fidelity than the Final Design Package submission)

b. Pod Intra-SpaceX transport

c. Pod Setup

d. Pod Testing (for every test case you plan to run)

e. Contingency (e.g. recovery in case of a failure)

7. Equipment:

a. Provide a list of equipment you will be bringing on site

b. Provide a list of hazardous materials will you be bringing on site and note if disposal will be required

c. Provide a list of any other stored energy or safety-critical components which have not been mentioned earlier

8. Team Member List: names and citizenship of all Team Members who will physically be attending

9. Rules of Conduct and Non-Disclosure Agreement: each Team Member who is physically attending should submit a signed version of this agreement, which will be provided to you in 2017

9 POD REQUIREMENTS

The Pod requirements for Competition Weekend II are intentionally broad in order to encourage diversity of design. Email any questions to Hyperloop@spacex.com.

1. Mass: Less than 5,500 lbm (2,500 kg)

2. Dimensions: Pods shall fit within the cross-section provided within the SpaceX Hyperloop Test Track Specification. Pod maximum length is 24 feet.

3. Service Propulsion System: The Pod shall be moveable at low speeds when not in operation, which may be accomplished by physically pushing it (wheels), physically lifting it (even with a dolly), or remotely controlling it.

4. Operational Propulsion System and Interface: See Test Track Specification for detail. If the Pod chooses to utilize the interface, the Pod will remain attached to the Operational Propulsion Interface during the entire acceleration phase.

5. Braking system: Each Pod must be able to reduce to zero speed in a controlled fashion (i.e. brake). Braking can be done in any reasonable manner, including, but not limited to, brake tabs, wheels, system drag, or onboard propulsion. Braking system actuation must be demonstrated, if feasible, in one of the pre-launch Functional Tests (see Section 10). The braking system, where feasible, shall be at least 1-fault tolerant.

6. Communications: Ability to send and receive data and commands (through a GUI created by the entrants) must be demonstrated during Functional Tests. See Test Track Specification for technical details on the provided WiFi system.

7. Telemetry: At a minimum, the telemetry stream must include the following data (at a minimum speed of 1 hz):

a. Position within tube (X, Y, and Z) b. Velocity within tube (X, Y, and Z) c. Acceleration within tube (X, Y, and Z) d. Vehicle attitude (roll, pitch, and yaw) e. Pod pressure (only applicable if Pod has any pressurized sections) f. Temperature from at least two points on the Pod g. Power consumption

8. Pod-Stop Command: Through a remote command, Pods must be able to be commanded to stop safely. The physical mechanism for stopping can, but does not have to be, the same as the Pod's standard braking mechanism.

9. Dummy Passenger: The Pod shall accommodate at least 1 life-sized dummy. The dummy does not have to be given a life support system nor a livable pressure, but should be physically in the Pod in a reasonable orientation for the duration of the test. The dimensions of the dummy are up to the entrants, who should be prepared to explain their choice of size.

10 POD LOADING

The conceptual Pod loading sequence for Competition Weekend II is as follows. Please note that, since every Pod will have unique features, all teams are required to submit a Pod loading and unloading plan as part of their Final Design Package:

1. Before loading, the Team Captain will give a Safety and Logistics briefing to the Hyperloop Test Director (a SpaceX or Tesla employee), which includes a description of their Pod Design, Pod- handling safety, and the loading/unloading process. The Hyperloop Test Director will also lead a safety and technical inspection of the physical Pod. The loading cannot proceed until the Hyperloop Test Director approves.

2. Pod will be transported via road to the Hyperloop Staging Area. Pods will be lifted, via a SpaceX- provided crane if necessary, onto the Staging Area, an open-air flat surface 20 feet in length.

3. On the Staging Area platform, Pods will perform Functional Test A, which will include a demonstration of power-up.

4. When Functional Test A is complete, Gate 1 will open and the Pod will be moved into the Hyperloop using the Pod's Service Propulsion System.

5. In the Hyperloop, the Pod will be physically connected to the Mechanical Propulsion Interface (if applicable) and to the Hyperloop Power Umbilical (if applicable). Once connected, Functional Test B will be performed, which may include vehicle hovering.

6. Gate 1 will then be closed and Functional Test C will be performed. This includes the demonstration of a continuous communications link.

7. The Hyperloop will be depressurized to operating pressure. 8. The Hyperloop Power

Umbilical shall be removed (if applicable).

9. At operating pressure, Functional Test D will be performed. Functional Test D must occur while the Pod is on internal power.

Functional Diagram of the Test Track (VP refers to Vacuum Pumps)

Summary of Conceptual Pre-Launch Functional Tests

Test ID Location Suggested

Duration (min)

Suggested Items

A Staging Area 5 Power-on, 2-way communications B Hyperloop (Gate 1 open) 5 Levitation C Hyperloop (Gate 1 closed) 2 Communications D Hyperloop (vacuum) 5 Levitation, Internal Power

11 POD LAUNCH

The conceptual Pod launch sequence for Competition Weekend II is as follows. Please note that, since every Pod will have unique features, variations are expected.

1. Once the Pod has passed Functional Test D, it is ready to Launch.

2. The Pod will go through its Pre-Launch procedures, which places it in "Ready-to-Launch" mode.

3. The entrant will then signal the Hyperloop Test Director that it is Ready-to-Launch.

4. The Hyperloop Test Director will activate the Operational Propulsion System. a. If the Pod is not using the Operational Propulsion System, Step 4 will be skipped.

5. Launch! 6. Upon launch, the Pod will undergo three phases of "flight":

a. Acceleration Phase: The Pod is accelerated through its mechanical interface to the Operational Propulsion Interface (if applicable). Once the Pod has been accelerated to speed, the Operational Propulsion Interface will stop, freeing the Pod. b. Coast Phase: The Pod coasts down the main Hyperloop section. c. Deceleration Phase: The Pod brakes itself, coming to rest within 50 feet from Gate 2 at the far end of the Hyperloop.

12 POD UNLOADING

The conceptual Pod unloading sequence for Competition Weekend II is as follows. Please note that, since every Pod will have unique features, all teams are required to submit a Pod loading and unloading plan as part of their Final Design Package:

1. The Pod is responsible for reaching the far end of the Hyperloop, defined as "within 50 feet from Gate 2."

2. The Hyperloop will then be pressurized.

3. Once at pressure, the Pod will perform a Functional Test E in order to verify that it is safe to open Gate 2. If the Pod requires manual movement from the Hyperloop to Exit Area, the test must also verify that the Pod is safe to approach.

4. When the Hyperloop Test Director deems the operation as safe, Gate 2 will be opened.

5. The Pod will then be moved onto the Exit Area, an open-air flat surface 20 feet in length.

6. The Pod will be placed into a safe powered-down "Ready-to-Remove" state.

7. The Pod will then be removed from the Exit Area via crane or other method.

Information provided in Sections 10 – 12 is conceptual and purely to provide initial information for potential applicants. The as-built loading, launch, and unloading interfaces are included in the separate SpaceX Hyperloop Pod Competition II Test Track Specification document that will be provided to competing teams following their submission of the Intent to Compete materials.