

# SpaceX Hyperloop Pod Competition Rules and Requirements

Revision 2.0

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## CONTENTS

1	Introduction.....	2
2	General Information.....	3
3	Preliminary Design Briefing .....	4
4	Final Design Package .....	5
5	Design Weekend .....	7
6	Pod Requirements.....	9
7	Pod Loading .....	10
8	Pod Launch .....	11
9	Pod Unloading.....	11
10	Notional Competition Weekend Judging Criteria.....	12

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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 is moving forward with a competition to design and build a half-scale Hyperloop Pod. In parallel with the competition, SpaceX will be constructing a sub-scale test track adjacent to its Hawthorne, California headquarters. During Design Weekend in January 2016, entrants will submit and present their Pod designs. On Competition Weekend, scheduled for Summer 2016, entrants will operate their Pods within the SpaceX test track.

This document outlines the competition logistics and rules and replaces the initial rules and requirements document released in August 2015. For test track specifications, please refer to the Working Test Track Specification released in October 2015.

For an updated competition schedule, visit [www.spacex.com/hyperloop](http://www.spacex.com/hyperloop).

Note: This competition is a SpaceX event. *SpaceX has no affiliation with any Hyperloop companies, including, but not limited to, those frequently referenced by the media.*

Any questions or comments should be submitted to [Hyperloop@spacex.com](mailto:Hyperloop@spacex.com) or can be posted on the Hyperloop Forum at <http://tx.ag/hyperloopforum> (click on “Enroll Now” to join).

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## 2 GENERAL INFORMATION

1. Any entity is welcome to enter the competition by September 30, 2015 and submit the Preliminary Design Briefing in November 2015. However, SpaceX, at its sole discretion, will select the teams that participate in the January 2016 Design Weekend. After submitting their Preliminary Design Briefing, teams will be notified within two weeks whether they have been chosen to participate in Design Weekend.
2. The team structure is flexible, with no minimum number of team members and no maximum number (within reason). If there is any question about eligibility, please email [Hyperloop@spacex.com](mailto:Hyperloop@spacex.com).
3. In addition to hosting the competition, SpaceX may enter a corporate team into the competition, but this team will not be eligible to win any prizes or awards.
4. Design Weekend. Design Weekend is an opportunity for entrants to present their Pod designs and will take place on January 29-30, 2016, at Texas A&M University, College Station. See Section 5 for further details on Design Weekend.
5. Design Weekend Prizes. The primary rewards for Design Weekend participation are access to corporate sponsorships. In addition, SpaceX, at its own discretion, may award multiple innovation awards (each of which includes a small cash prize). See Section 5 for further details.
6. Competition Weekend. Selected Pods will compete at the test track during Competition Weekend..
  - At SpaceX's discretion, Pod teams may be allowed to test their Pods on the test track before Competition Weekend.
  - SpaceX, at its sole discretion, may allow or disallow entrants from accessing the test track.
  - No human (or animal) shall ride in any Pod or other transportation device used within the test track during this competition or during any pre-competition access.
  - The Judging Panel will be composed primarily of SpaceX engineers, Tesla Motors engineers, and university professors.
  - Determinations of the Judging Panel are final, and entrants may not protest results.
7. Competition Weekend Prizes. The full prize package structure will be released later this year, but at a minimum:
  - The coolest trophy in history (seriously).
  - A SpaceX/Tesla experience prize to be named later.
  - People's Choice Award, where the attendees vote for the coolest feature/design. This will be accompanied by a small cash prize.
  - SpaceX, at its own discretion, may award prizes to teams (student and non-student) with any design features that SpaceX deems especially innovative with regards to design, safety, efficiency, and performance. SpaceX estimates it will award 5 to 10 of these innovation awards.

### 3 PRELIMINARY DESIGN BRIEFING

This Preliminary Design Briefing package shall consist of a PowerPoint slide deck (in PDF format) of no more than 30 slides, which will include:

1. Description of team and updated list of all associated team members and advisors
2. Indication of whether team intends to build a Pod, present at Design Weekend, or both.
3. Top-level design description for Pod (or subsystem). Teams are allowed to revise their design in subsequent submissions, so consider the Preliminary Design Briefing to be a “best initial guess.”

At a minimum, this should include, where applicable:

- a. Estimated Pod dimensions
  - b. Estimated Pod mass by subsystem
  - c. Estimated Pod power consumption by subsystem
  - d. Pod navigation mechanism
  - e. Pod levitation mechanism (if any)
  - f. Pod propulsion mechanism (if any)
  - g. Pod braking mechanism
  - h. Pod stability mechanisms (e.g. attitude and lateral motion)
4. List and description of any stored energy on the Pod (e.g. pressure vessels, batteries)
  5. List of hazardous materials, if any
  6. Top-level description of safety features
  7. Entrants are encouraged to attend Design Weekend in person. For those student teams who are unable to attend in person, we will likely have limited slots for virtual presentations by webcam. If your team is unable to attend Design Weekend and wishes to present virtually, please indicate this in your Preliminary Design Briefing along with a detailed explanation.

With their **Preliminary Design Briefing**, teams shall include a signed **Competitor Entry Agreement**, which was distributed to teams on October 20, 2015.

**Preliminary Design Briefings and signed Competitor Entry Agreement should be submitted to [Hyperloop@spacex.com](mailto:Hyperloop@spacex.com) by 5pm PT November 13, 2015.** In the subject line, write “Pod Competition Preliminary Briefing: TEAM NAME HERE”. Teams may submit only one Preliminary Design Briefing copy; any copies received after the initial submission will not be accepted. Please check your documents carefully before submission. SpaceX will respond to your submission within 48 hours to verify receipt. If you do not receive verification within 48 hours, please re-contact SpaceX at the same email.

The purpose of this briefing is for SpaceX to “sanity check” the design and ensure the entrant is heading in a viable direction. Following the submission, there may be a down-select decision in order to properly manage the number of entrants. SpaceX will notify teams as to whether they have advanced within two weeks of Preliminary Design Briefing submission.

## 4 FINAL DESIGN PACKAGE

All entrants who have successfully advanced to the Final Design Package phase must upload a completed version of the Final Design Package on the Hyperloop Forum at <http://tx.ag/hyperloopforum> by 5pm PT on January 13, 2015. This is to facilitate uploading any large files. To upload, click on “Submit Final Design Package” in the left-hand navigation. Name your package as “Pod Competition Final Design package: TEAM NAME HERE”. As with the Preliminary Design Briefing, teams may submit only one Final Design Package copy. Please check your documents carefully.

The Final Design Package must consist of:

1. Description of team and updated list of all associated team members and advisors
2. Re-iteration of whether team intends to build a Pod, present at Design Weekend, or both
3. If your team is unable to attend Design Weekend and wishes to present virtually, please indicate so, along with a detailed explanation
4. Design description for Pod (or subsystem). 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
  - 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)
5. Predicted Pod thermal profile
6. Predicted Pod trajectory (speed versus distance)
7. Predicted vibration environments
8. Pod structural design cases: at a minimum, this shall include initial acceleration, nominal deceleration, and end-of-tube off-nominal crash
9. Pod production schedule
10. Pod cost breakdown. If the team plans on building a Pod for Competition Weekend, an explicit singular construction cost should be quoted (and can be revised before Design Weekend), which will be helpful for potential Pod sponsors.
11. Sensor list and location map
12. 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)

Additionally, teams intending to build a Pod shall also submit:

1. Loading and unloading logistics plan (see Sections 7 and 9 for details)
  - a. Full descriptions of all functional tests (see Sections 7 and 9)
  - 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, etc.)
  - c. Full description of Ready-to-Remove checklist/state (e.g. Wheels locked, Power Off, etc.)
  - d. Description of how Pod is moved from Staging Area to Hyperloop
  - e. Description of how Pod is moved from Hyperloop to Exit Area
2. List and description of any stored energy on the Pod (i.e. pressure vessels, batteries, etc.)
3. List of any hazardous materials, if any
4. Preliminary bill of materials, with each line item categorized as “Commercial-Off-The-Shelf (COTS)” or “custom-built”
5. Description of safety features including:
  - a. Mechanisms to mitigate a complete loss of Pod power
  - b. Pod robustness to a tube breach resulting in rapid pressurization
  - c. Fault tolerance of braking, levitation, and other subsystems
  - d. Single point of failures within the Pod
  - e. Recovery plan if Pod becomes immovable within tube
  - f. Implementation of the Pod-Stop command
  - g. A top-down hazard analysis OR a bottom-up Failure Mode and Effects Analysis (FMEA).
6. Component and system test program before the Pod arrives for Competition Weekend
7. Vacuum Compatibility Analysis

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## 5 DESIGN WEEKEND

Design Weekend will take place on January 29 (Friday) and January 30 (Saturday) at Texas A&M University, College Station. The Design Weekend logistics will be released by Texas A&M this November. Some general notes:

1. Updates on Design Weekend details will be posted at: <http://engineering.tamu.edu/hyperloop>
2. The goals of Design Weekend are:
  - For entrants to present their Pod designs, which, after receiving feedback, vetting and approval to proceed, will be constructed for Competition Weekend.
  - For entrants to present innovative designs for the overall Hyperloop transportation system.
  - To connect student teams with potential sponsors.
3. Design Weekend applies to the full Hyperloop concept and is not limited to the specifications of the test track itself (as circulated in October 2015). Specifically, students can present designs that are innovative and address the full suite of technical challenges for future full-scale Hyperloop systems. However, teams that want to compete on the test track need to have a design (or version) that is compatible with the test track specification.
4. Entrants who are not interested in building a Pod may still present designs for a Pod, an individual subsystem, or an individual safety feature. As an example of an individual subsystem submission, a team could choose to optimize the Pod's aerodynamics or design the Pod's Service Propulsion System. The purpose of such submission is to receive design feedback and to participate in a fun educational event.
5. While teams are encouraged to begin finding sponsorships now, the primary awards for Design Weekend participation are access to corporate sponsorships. Select companies invited by SpaceX will be able to use Design Weekend as a platform for selecting teams to sponsor. At their discretion, such companies may contribute funds toward the construction of their sponsored team's Competition Weekend Pod. Entrants who are selected for sponsorship may elect not to be sponsored or receive funds, at their discretion.
6. Besides the corporate sponsorships, small cash prizes are available in two manners:
  - Entrants will present before a Judging Panel, which will be composed primarily of SpaceX engineers, Tesla Motors engineers, and university professors. The Judging Panel will award multiple awards. The criteria for said awards will be released to the teams selected to participate in Design Weekend.
  - SpaceX, at its own discretion, may award multiple innovation awards to teams with any design features which SpaceX feels are innovative with regards to safety, efficiency, and performance.
  - Prizes are available to all entrants, independently of their applicability to the SpaceX Hyperloop Test Track Specification.
7. While all teams are encouraged to attend Design Weekend, University Teams will be given priority by SpaceX when allocating presentation slots and for receiving Design Weekend sponsorships and awards, as defined by:

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- University Teams must be composed entirely of undergraduate or graduate students who are, were, or will be officially enrolled in the college or university with which the team is affiliated at any point between May 2015 and May 2016.
  - University Teams may {and should} have advisors, including Faculty Advisors. However, advisors should not design the vehicle, nor should they fabricate or assemble more than a minority of the components. Advisors may not directly participate in the development of any documentation or presentation.
  - SpaceX understands that this is a broad definition, so use your best judgment and contact [Hyperloop@spacex.com](mailto:Hyperloop@spacex.com) with any questions.

## 6 POD REQUIREMENTS

The Pod requirements for Competition Weekend are intentionally broad in order to encourage diversity of design. Email any questions to [Hyperloop@spacex.com](mailto:Hyperloop@spacex.com) or post them on the forum at <http://tx.ag/hyperloopforum>.

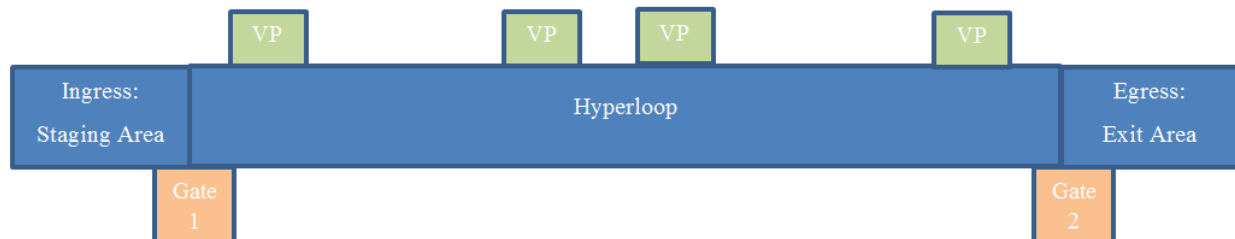
1. Mass: Less than 11,000 lbm (5,000 kg)
2. Dimensions: Pods shall fit within the cross-section provided within the SpaceX Hyperloop Test Track Specification.
3. Service Propulsion System: The Pod shall be moveable at low speeds when not in operation, which may be accomplished by physically pushing it (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 7). 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. Vibration Environments: SpaceX will provide a self-contained flight data recorder to monitor dynamic environments. After the flight, SpaceX engineers will use this data as part of the judging criteria. Pods must accommodate the unit, which will weigh less than one pound. The interface will be released in late 2015.
9. 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.
10. Dummy Passenger: See Section 10 for more details.

## 7 POD LOADING

The Pod loading sequence for Competition Weekend 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 15-minute Safety and Logistics briefing to the Judging Panel and 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 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

## 8 POD LAUNCH

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.

## 9 POD UNLOADING

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 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.

## 10 NOTIONAL COMPETITION WEEKEND JUDGING CRITERIA

The competition will be divided into 2 different classes:

- Vehicles in which wheels are the primary propulsion
- Vehicles in which wheels are not the primary propulsion

In each class, there will be two winners:

- The Pod which traverses the tube the fastest without crashing
- The Pod with the highest score per the table below

There will be an additional category of Micro-Pods, which are Pods which weigh less than 45 kg (~100 lbm). The purpose of these entrants is to allow teams to enter when full Pod construction is cost-prohibitive.

It is highly likely that bonus points will be added for accommodating at least 1 dummy (to be provided by SpaceX). The dummy would not have to be given a life support system nor a livable pressure, but would be physically on the Pod in a reasonable orientation for the duration of the test. The provided dummy would weigh less than 5 lbm and be approximately 5 feet in height. SpaceX is still evaluating the specifics of the dummy inclusion, and will make the final decision once teams have presented their designs at Design Weekend.

The overall Competition Weekend criteria will be finalized after Design Weekend:

<b>Category 1: Final Design and Construction</b>	<b>Points</b>
Overall Quality of Construction	100
Overall Cost of Materials (normalized per payload mass)	100
Levitation System	75
Braking System	75
Ability to Economically Scale	50
Power Consumption (normalized per payload mass)	50
Payload Capability (as % of overall mass)	50
<b>Category 1 Total</b>	<b>500</b>
<b>Category 2: Safety and Reliability</b>	
Structural margins of safety and design cases	100
Pod-Stop Command	100
Safety in Operations	50
Fault tolerance of braking system	50
Fault tolerance of levitation systems	50
Fault tolerance of other systems	50
Loss of power contingency	50
Tube breach contingency	50
<b>Category 2 Total</b>	<b>500</b>
<b>Category 3: Performance in Operations</b>	
Efficiency of transport from Staging Area to Hyperloop	100
Efficiency of Functional Tests	100
Efficiency of connection to the Operational Propulsion Interface	100
Efficiency of transport from Hyperloop to Exit Area	100
Pod is removed from the tube without requiring tube pressurization	100
<b>Category 3 Total</b>	<b>500</b>
<b>Category 4: Performance in Flight</b>	
Total distance Pod travels	200
Minimization of system drag	200
Functionality of Pod Braking/Deceleration System	200
Tightness of Lateral Control around Hyperloop center-line	100
Attitude Control System	100
Comfort of Ride (per measured vibration environment)	100
Reliability of Data Stream and DAQ Software	100
<b>Category 4 Total</b>	<b>1000</b>
<b>Total Points Possible</b>	<b>2500</b>