

CPLC Challenge Rules

Overview

The Collegiate Propulsive Lander Challenge (CPLC) is a 4-year challenge awarding prizes to university rocketry teams who hit major milestones in the development of self-landing rockets. The challenge is broken into 5 milestones, which may be pursued in any order. However, teams must be generally developing a self-landing vehicle to receive awards. The rules of the challenge are set forth in this document, and may be amended by CPLC at any time. Each of the 5 milestones listed below may be won by 3 different teams, meaning a total of 15 prizes are available – \$390k total.

Our goal is to enable and inspire ambitious young people to pursue reusable self-landing vehicles, and gain expertise in the related sub-fields. As such, one may notice you may not need a 500 lbf engine, or 7 degrees of TVC, to perform a 50 meter hop. We expect teams may use this challenge as a stepping stone towards all sorts of great projects – these requirements are not engineering requirements of the final hop, rather separate clear goals intended to enable ambitious accomplishments across the board. We expect some teams might even opt to skip a milestone; perhaps a team would rather not develop advanced throttling and skip to a hover test– that is fine.

We are aware this approach involves some degree of “solution constraining”, and therefore encourage feedback; we are always looking for ways to improve!

Baseline

- Vehicle must use a *Primary Propulsion Device* (described below)
- Vehicle, and specifically the *Primary Propulsion Device*, must be primarily student designed as decided by the judges. (ie, outsourcing some manufacturing is ok, but having a consulting company design the thrust structure is not ok)
- Vehicle must have been primarily designed, or heavily modified, in 2019 or later, as decided by the judges.
- Usage of other teams' major systems/hardware/design can result in dividing the prize, as determined by the judges & involved teams on a case-by-case basis.
- Prizes will not be given out retroactively for attempts made before the official launch of the challenge, or to re-demonstrations of those attempts.
- Teams are heavily encouraged to ask questions early and often & keep in contact with judges on their development to evaluate the legality of their approach. The rules may adapt as the challenge progresses.
- **For all attempts, Good Videos must be taken for judging. Teams unable to show Good Videos of one of their attempts will not be awarded a prize.**
- We advise teams to gather as much data as they can during attempts to avoid any ambiguity in success determination by the judges.
- All final decisions will be made by the judges, with consideration of the criteria below.

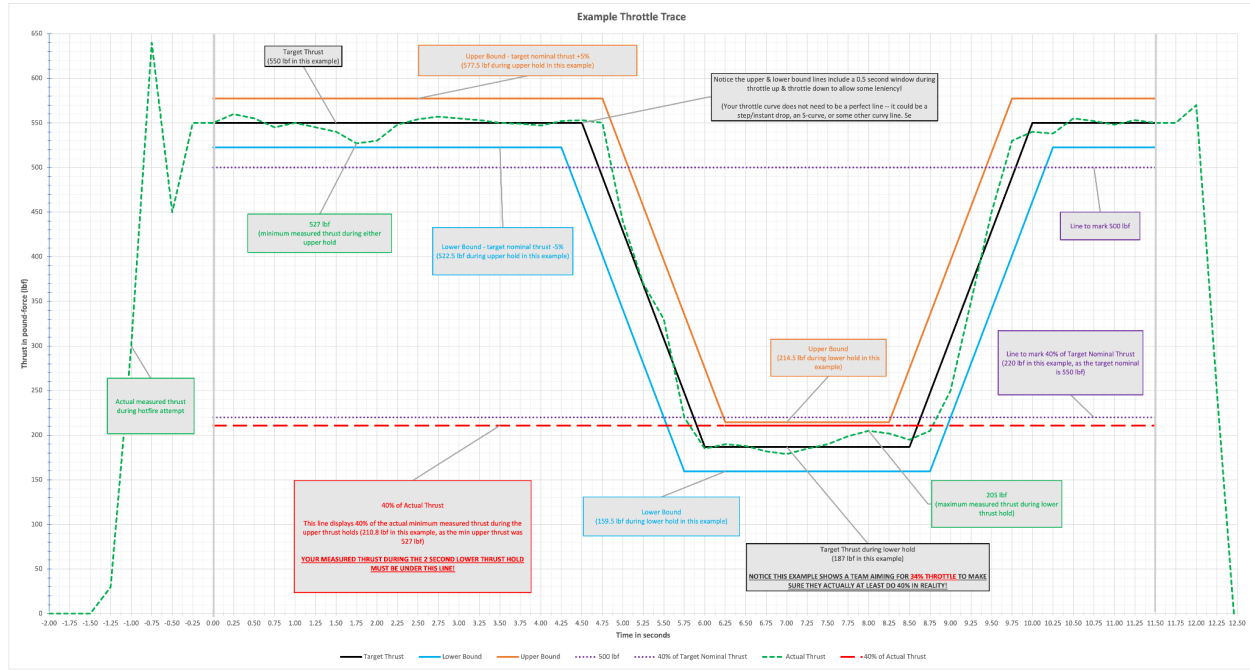
TVC Hotfire (\$15k)

- Hotfire *Primary Propulsion Device* above 500 lbf of thrust for at least 10 seconds.
- During hotfire, manipulate the thrust vector a minimum of 7 degrees in all directions, like a circle, in a controlled manner, as decided by the judges.
 - You must manipulate the *Primary Propulsion Device* (ie, you can't accomplish this milestone by adding gas thrusters to change the thrust vector), but other solutions like flow impingement are allowed. During the hover/drop/hop tests vehicles might rely much more heavily on gas thrusters/etc, and that's fine, just not for this award.
- Load cell & control system data, and any other relevant data, that clearly shows how the *Primary Propulsion Device* met all criteria laid out here, must be provided in reasonable & clear form for the judges to determine success.

Throttleable Hotfire (\$15k)

- Hotfire *Primary Propulsion Device* for at least 10 seconds of controlled thrust (ie, not including a transient startup period).
- During hotfire, demonstrate controlled & constant nominal thrust above 500 lbf for 4 seconds, smoothly throttle down to below 40% of that nominal thrust and hold constant for at least 2 seconds, then return to the same nominal thrust and hold constant for at least 1 second. "Controlled", "smooth" and "constant" as determined by the judges.
 - You must manipulate the *Primary Propulsion Device* (ie, you can't accomplish this milestone by adding gas thrusters to change the thrust level). During the hover/drop/hop tests vehicles might rely much more heavily on gas thrusters/etc, and that's fine, just not for this award.
- Teams will submit a planned thrust trace before their attempt. The thrust trace will have an upper 5% and lower 5% curve bounding it, and the actual measured thrust should be within that $\pm 5\%$ band centered around the planned thrust trace. This includes during throttle up and down, but note the 0.5s window mentioned below and shown in the example graph.
 - This refers to $\pm 5\%$ of the planned *nominal* thrust (not planned thrust at that point), meaning if your nominal 4 second hold was 600 lbf, your upper and lower bounds would be ± 30 lbf throughout the trace.
- The actual measured thrust during the 4s nominal thrust section must be above 500 lbf the entire time, and the 40% thrust boundary will be taken as the lowest point during this section. The actual measured thrust during the 2s lower thrust hold must be under 40% of the lowest point of the upper 4s thrust hold the entire time. This is shown by the red dashed line in the example graph below!
 - This means if you were planning for the worst case scenario, you would ensure the lower bound of your nominal thrust hold is above 500 lbf, and the upper bound of your lower thrust hold is below 40% of the lower bound of your nominal thrust hold. But, we will accept less conservative thrust profiles.

- Load cell & control system data, and any other relevant data, that clearly shows how the *Primary Propulsion Device* met all criteria laid out here, must be provided in reasonable & clear form for the judges to determine success.
- During the throttle down & throttle up periods, there is an additional 0.5 second window to allow for leniency on timing, as per the example graph below.



The Bess Touchdown Award (\$25k)

- Demonstrate a *Successful Landing* from a height of at least 10 meters, with a *Payload*.
- All parts of the vehicle must be above 10 meters, and at zero velocity, then must descend controllably to the ground using the *Primary Propulsion Device*, reaching zero vertical velocity within 1 meter of the ground before the *Successful Landing*. Vehicle may go past zero vertical velocity and ascend slightly (ie, doesn't need to perfectly hit the ground perfectly at zero absolute velocity).
- Vehicle may begin ignition, hover or ascend while above 10m before starting its 10m descent (ie, you don't have to release the vehicle and *then* start the engine). In fact, doing a 10 meter hop would also satisfy this milestone.
- Avionics & acceleration data, and any other relevant data, that clearly shows how the vehicle met all criteria laid out here, must be provided in reasonable & clear form for the judges to determine success. *Good Videos* are essential for the judging team to award this prize.
- Teams are reminded to follow safe practices and use a *Tether*.

Tethered Hover (\$25k)

- Hover in a controlled manner for 10 seconds with *Payload*. “Controlled” as decided by the judges. (For ex. the centroid of the vehicle should stay within a 1 meter cubic box during the test)
- The vehicle will use a *Tether* during the flight.
- Avionics & acceleration data, and any other relevant data, that clearly shows how the vehicle met all criteria laid out here, must be provided in reasonable & clear form for the judges to determine success. *Good Videos* are essential for the judging team to award this prize.

Hop (\$50k)

- Controllably ascend the vehicle, with *Payload*, using the *Primary Propulsion Device*, from the ground to 50 meters above ground level, then demonstrate a *Successful Landing* within the landing circle. “Controlled” as determined by the judges.
- The landing circle is a 10 meter diameter circle drawn/constructed on the ground at a place of the team’s choosing (ie. down range, or exactly where you took off, etc).
- To be considered a success, the entirety of the vehicle must be within the invisible vertical walls of the 10 meter circle, as determined by the judges. (This does not refer to negligible things like bits of thermal insulation, per judges discretion)
- Avionics, GNSS data, acceleration data, and any other relevant data, that clearly shows how the vehicle met all criteria laid out here, must be provided in reasonable & clear form for the judges to determine success. *Good Videos* are essential for the judging team to award this prize.
- Teams are reminded to follow safe practices and include a kill switch.

Definitions

- *Primary Propulsion Device*: A single, or multiple, liquid or hybrid engine(s) that provide the primary vertical lifting force of the vehicle. Monopropellants included. No aerodynamic or air-breathing methods are permitted (ie, jets or fans). However, thrusters, solid motors and other in-space-type propulsion systems are permitted for control other than the primary lifting force (ie, attitude, roll, etc), except for in the TVC or Throttle awards (these other thrust sources are not considered part of the *Primary Propulsion Device*). The *Primary Propulsion Device* must be capable of producing at least 500 lbf of thrust. The intent is that all milestones use a full-scale propulsion system, as opposed to a subscale one (ie, you shouldn’t make a smaller engine *just* for the purposes of meeting the TVC milestone). To be clear, we understand teams will iterate heavily, and possibly scrap, their engines as they progress – it is fine for the hop engine to perhaps be quite different from the engine used in the TVC award.
- *Good Videos*: In addition to the high-quality video requirements laid out in the Team Agreement, teams must at least provide two angles of video of all challenge attempts as part of the judging process. The video’s will be at least 1080p with 30fps, and begin at least 3 seconds before the *Primary Propulsion Device* fires/vehicle moves, and end at

least 5 seconds after firing and movement has stopped. The videos must clearly show the test— for example in the TVC & throttle milestones, the entire engine & plume should be pictured, and for the drop, hover & hop milestones, the vehicle & ground should both be visible in the same frame throughout the test, in at least one of the videos.

- **Successful Landing:** The vehicle must land gently VTVL style (ie, a vertical propulsive landing as opposed to a horizontal “airplane” landing), and afterwards be in good condition, such that one may reasonably consider reusing the vehicle again with minor repair. Designed-to-fail landing systems, like crush structure legs, are not permitted. The entire vehicle that took off must land (ie, no 2-stage vehicles). The judges will decide a successful landing, based on whether it was reasonably gentle, survivable and practical (ie, if it had tiny humans on board, would they have been pleased?).
- **Payload:** A single 15 kg mass that does not interact with the overall operation of the vehicle. The mass must be a single piece (ie, not distributed in small pieces around the vehicle) and cannot be dual purpose with respect to vehicle operation (ie, Ok to use for logos, sponsor names, etc, but cannot be a structural component).
- **Tether:** A physical restraint that prevents the vehicle from deviating substantially from a nominal flight area under the worst case scenario (i.e. throttle stuck open). The tether shall not assist the vehicle or substantially influence its flight during a nominal test (ie, while hovering).

A note on propellants & chemicals:

- By default, teams are banned from using toxic propellants or hypergolics. However, teams may reach out and make a case to the CPLC for use of these chemicals on a case-by-case basis.
 - We allow liquid oxygen (LOX), nitrous oxide, white fuming nitric acid, hydrogen peroxide and other non-toxic propellants like commercial ammonium perchlorate composite propellant (APCP), potassium nitrate and sugar (also known as “rocket candy”), kerosene, propane, alcohol and similar substances considered non-toxic.
 - Toxic propellants are defined as those requiring breathing apparatus, extensive personal protective equipment (PPE) such as chemical suits, breathing filters, or Self Contained Atmospheric Protective Ensemble (SCAPE) suits and posing significant public and/or environmental hazards in the event of a spill. Hydrazines, dinitrogen tetroxide (NTO), and red fuming nitric acid (RFNA) are examples.

Other Requirements

- Teams are expected to strongly collaborate with each other. This means, among other things, regularly sharing updates to and engaging heavily with the community, aggressively sharing CADs/test results/etc, and by default inviting and attending each others' design reviews. We also expect a culture of collaboration such that teams are generally open to sharing resources with each other.
- Teams are required to provide good updates on their progress & status at least every 2 weeks to the community and CPLC. We recommend teams consider sending a weekly email to their team-members, sponsors and other stakeholders!
- We strongly recommend teams obtain insurance to cover themselves and property damage for any rocketry activities, especially liquids & hybrids, or activities related to CPLC.
- **ITAR:** For both compliance with the ITAR and collaboration requirements for CPLC, teams must "publish" their work at least once every three months. This includes design documents, methodology, analysis, specifications, layout, simulation, software, CAD files, data, photos, videos, test results, procedures, manufacturing details, and more. Publication includes posting to the public internet. The CPLC plans to provide a forum through which to do this (as of Jan 9) shortly after launch.
 - The CPLC also heavily encourages teams to publish in an academic research journal at least every 6 months.
- **ITAR:** The CPLC prohibits teams from purchasing or using existing unpublished technical data or proprietary defense articles. Teams unsure about what this means must contact us for clarity.
- **ITAR:** University or other research is not fundamental research if the university or its researchers accept other restrictions, such as non-disclosure agreements, on publication of scientific and technical information resulting from the project or activity. It is essential that teams ensure they are not accepting such restrictions. Teams unsure about what this means must contact us for clarity.
- Teams are expected to engage with CPLC and the judges to ensure their approach is within scope as the challenge progresses.
- The CPLC may put on talks and events. Teams are expected to make strong efforts to attend, and have videos turned on for virtual meetings.
- All team members must complete the Base11/ESRA safety training as a minimum standard. We will ask for a confirmed list of members.

- Teams must designate a safety officer who primarily owns safety for that team, who will meet bi-monthly with the Safety Council for a check-in and update.
- Teams must at a minimum abide by the Safety Guide provided by the CPLC. This is intended simply as a good starting point for teams, not a comprehensive checklist.
- Teams must have at *least* one of the CPLC's Safety Council members in all final reviews before a major test, defined as involving high pressure gasses (>100 psi)— cold flows, hotfires & flight tests. The intent here is not to give approval, but to offer a chance to sound the alarm should there be major concerns. Teams should let the CPLC know about these reviews as far in advance as possible; at *least* a week.
- Teams should let the CPLC know as far in advance as possible about upcoming hotfires, launches and other tests (especially milestone attempts), as the CPLC will extend in-person invites to some of our sponsors and partners. Teams must ensure they're able to accommodate at least 10 people from the CPLC's partners & sponsors at hotfires, launches and other major tests. We understand sometimes these dates change; good communication is the important thing. Milestone attempts may be worked out as they come up.
- Teams must agree to host CPLC sponsors and partners for a meet & greet and tour of their facilities at CPLC request.
- Teams must provide all member emails and resumes for CPLC sponsors and partners.
- Teams must create sponsor "thank you" videos if requested.
- Teams must display CPLC sponsor & partner logos on their vehicles prominently as requested.
- Teams are required to share social media & email materials within reason as requested by CPLC. This might include sponsor events being passed on, CPLC social media posts promoting teams & the challenge, etc.
- Teams are generally required to take good photos and videos of their development as they progress to be shared, furthering the mission of the CPLC to inspire more young people to pursue ambitious projects.