

2025 DROP TOWER CHALLENGE

Paddle Wheel

<https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2025-drop-tower-challenge/>



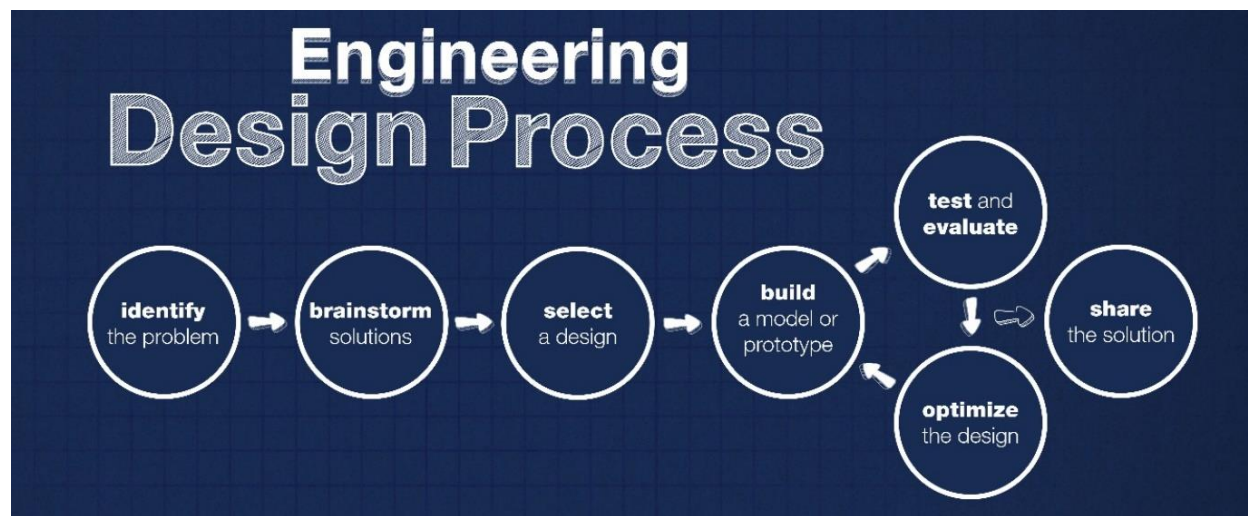
Guide with Instructions

Challenge overview

Why?

Future space exploration requires a better understanding of fluid behavior in microgravity because of the cooling, life support, propellant, and other spacecraft systems which include liquids. Especially in the apparent absence of gravity, the shape and nature of a surface can affect how liquids interact with it, for example within a channel or container. Furthermore, hydrophilic (water-loving) and hydrophobic (water-fearing) surfaces or coatings can have additional effects which are more pronounced in microgravity.

While it is hoped that you will learn about both fluid physics and microgravity research, you can more importantly learn about the engineering design process and scientific method, moving from a problem statement, to hypotheses, the design and preparation of your experiment, testing & analysis – ideally repeatedly with the refinement of your design – and finally reporting.



And while the challenge wasn't developed to specifically address any practical issues or applications, your approach to the challenge may inspire NASA to address microgravity fluid management in a new way.

Participation in a nationwide NASA design challenge might be worth noting in your applications for college, etc. Regardless, it is hoped that the challenge will inspire you to pursue a career in STEM (Science, Technology, Engineering, and Mathematics), perhaps even at NASA.

What?

Teams of grade 8-12 students are challenged to design and build paddle wheels that will turn in water because of the wetting properties of their surfaces when they experience apparent weightlessness, i.e., microgravity, in NASA's [2.2 Second Drop Tower](#) (shown below). To be clear, the rotation of each paddle wheel must result from the [hydrophilic and/or hydrophobic](#) ('water loving' and/or 'water fearing') surfaces of the paddle wheel and not because of mechanical means.

Teams are only responsible for their paddle wheels; NASA will provide the rest of the experimental hardware. After developing their concepts, the youth prepare their proposal, consisting of conceptual drawings and a short entry form, which is e-mailed to Ed-DropTower@lists.nasa.gov.

If selected, the youth prepare their paddle wheels based on provided guidance. The paddle wheels are then sent to NASA where they will fall 24 meters (79 feet). Video results of the microgravity testing are provided for student analysis and reporting.



Testing in the 2.2 Second Drop Tower.

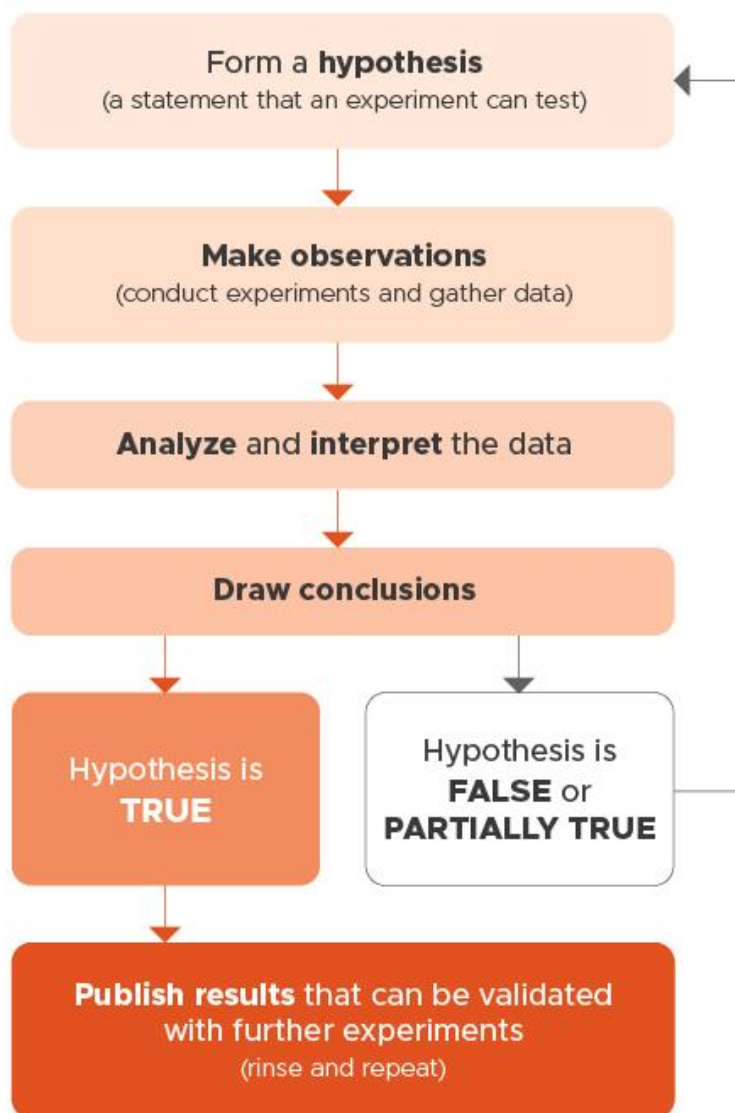
Who?

This design challenge is for students in grades 8-12 from U.S. schools, including the fifty states (and the Tribal Nations within them), District of Columbia, Puerto Rico, American Samoa, Guam, the Northern Mariana Islands, the U.S. Virgin Islands, and all [DoDEA](#) schools (which are for children of U.S. military personnel). Except for the DoDEA schools,

this challenge is not open to participants outside of the United States regardless of citizenship.

Teams will be favored over individuals in selection. Youth are expected to do most of the work, but may get help from adults, for example in building their paddle wheels. Furthermore:

1. Teams may be of any size, but a maximum of four students per team will be invited to the 2025 meeting of the American Society for Gravitational and Space Research ([ASGSR](#)).
2. Each student may belong to no more than one team.
3. Each team may submit no more than one proposal.
4. An organization (e.g., school, science center, 4-H club, Scout troop) may have many teams, but it may submit no more than two proposals to NASA. It is envisioned that no more than one proposal will be selected per organization.



Scientific Method.

Where?

Participation is remote, where participants do not travel to NASA for the testing. An exception is for those teams invited to present their results at the 2025 ASGSR meeting, but its location will not be announced until Dec. 2024.

Cost?

There is no cost to participate in the challenge other than for the (1) preparation of the paddle wheels, (2) shipment of the paddle wheels to NASA, and (3) travel costs for those invited to present their results at the ASGSR meeting. Regarding the latter, the ASGSR has typically provided travel support of \$500 each for invited non-local students who present their results at the conference.

Selection?

After proposal evaluation, NASA anticipates selecting up to 30 teams to build paddle wheels to be tested in the 2.2 Second Drop Tower at the NASA [Glenn Research Center](#) in Cleveland, Ohio. Only a few top-performing teams will be invited to participate in the ASGSR conference.

Table of Contents

A. THINGS TO KNOW	5
B. WHAT TO DO	8
1. Prepare your proposal	8
2. Build your paddle wheels	12
3. Analyze and document your results	14
4. Present at the 2025 ASGSR conference	16
Appendix A – FAQs: Frequently Asked Questions	18
Appendix B – Suggested Internet Links	20
Appendix C – 2025 Paddle Wheel Entry Form	23



A. THINGS TO KNOW

Calendar

2024	Now!!!	<i>Preparation of proposal</i>
	► Halloween Oct. 31, 11:59 PM	Deadline (in your time zone) to e-mail your team's proposal to NASA
	Early December	NASA announces teams selected for testing
2025	Jan.-February	Preparation of paddle wheels
	Jan. 15	Deadline to e-mail your team's updated and detailed materials list to NASA. You must also include updated dimensions and drawings if the size or shape of the paddle wheels has changed.
	► Valentine's Day Feb. 14	Deadline for the <u>arrival</u> of your paddle wheels at NASA
	Feb.-March	Testing in NASA's 2.2 Second Drop Tower
	Late March	NASA provides access to the drop test results
	April 7	Deadline for your team to e-mail confirmation of your successful download of the drop results
	April	Analysis and report writing
	► May 1, 11:59 PM	Deadline (in your time zone) to e-mail your team's written report to NASA
	Mid-May	NASA announces teams selected for ASGSR participation
	Fall (between late Oct. and early Dec.)	Annual ASGSR meeting

► **Failure to meet the key deadlines will disqualify a team from being selected for ASGSR participation, if not more!** This is a competition and each of these three deadlines have led to disqualifications of late teams in preceding challenges.

Key Rules

1. Eligibility

- The challenge is open to grades 8-12 in the United States including all fifty states (and the Tribal Nations within them), the District of Columbia, Puerto Rico, American Samoa, Guam, the Northern Mariana Islands, the U.S. Virgin Islands, and all [DoDEA](#) schools for the children of U.S. military personnel.
- Except for DoDEA schools, those outside of the United States are not eligible regardless of their citizenship.

2. Team

- Each team is required to have an adult advisor, who may advise more than one team.
- Teams may be of any size, but a maximum of four students per team will be invited to the 2025 meeting of the American Society for Gravitational and Space Research ([ASGSR](#)).

- c. Each student may belong to no more than one team.
 - d. Each team may submit no more than one proposal.
 - e. An organization (e.g., school, science center, 4-H club, Scout troop) may have many teams, but it may submit no more than two proposals to NASA.
- 3. Proposals**
- a. Each team may submit no more than one proposal.
 - b. An organization (e.g., school, science center, 4-H club, Scout troop) may have many teams, but it may submit no more than two proposals to NASA.
- 4. Paddle wheels**
- a. Each team may include up to 2 paddle wheels in their proposal and if selected for testing may send NASA up to 2 paddle wheels for testing.
- 5. Axle**
- a. For drop testing, NASA will mount each paddle wheel in a water vessel using a LEGO® Technic axle.
- 6. Size**
- a. Each paddle wheel must have a hole that can accommodate a LEGO® Technic axle that is 4.8 mm in diameter.
 - b. Each paddle wheel must fit within an imaginary cylinder that is 75 mm in diameter and 80 mm wide, where the NASA-provided axle passes through the cylinder's axis as seen in Figure 1 on page 9.
- 7. Prohibited materials, components, etc.**
- a. Hazardous materials that are corrosive, toxic, radioactive, etc.
 - b. Chemical reactions, compressed gases, sharp edges
 - c. Electrical components such as batteries, lasers, motors, etc.
 - d. Fragile materials such as glass, thin plastic, etc.
 - e. Materials or coatings that are liquid when shipped to NASA
 - f. Materials or coatings that dissolve in or react with water, e.g., antacid tablets
 - g. Parts, materials, or coatings that separate, intentionally or otherwise, from the paddle wheels and contaminate the water
 - h. Small creatures, whether dead or alive, and most biological materials other than cork, cotton, leather, wood, and wool
- 8. Deadlines**
- a. Late submission of the proposals, paddle wheels, and/or written reports will disqualify teams from the competition. In other words, teams that miss these deadlines will not be considered for invitation to the ASGSR meeting.
 - b. By Wed., Jan. 15, each team shall e-mail Ed-DropTower@lists.nasa.gov with an updated and detailed materials list. That e-mail must also include updated dimensions and drawings if the size and/or shape of the paddle wheels has changed.
 - c. By Monday, April 7, each team shall e-mail Ed-DropTower@lists.nasa.gov and confirm that they have successfully downloaded their drop results.

The use of LEGO® parts in the challenge is not meant to indicate an endorsement by NASA or the federal government.

Hints

Follow the rules and instructions!!!

Control and variables: You should ideally have two paddle wheels so that you can compare their performance in your report—and poster too if you are selected for ASGSR meeting participation. An added benefit is the increased probability of success with the challenge.

Conduct your own tests: To improve your odds of success, conduct your own tests to discover which designs work best.

Test as dropped, drop as tested: If you want to verify your designs, then you should conduct your own tests like they will be carried out in NASA's drop tower. Consider mounting your paddle wheels with water in a plastic jar (or similar) in a box with a video camera and dropping the box to get a glimpse of what happens in microgravity. Just a 4-foot fall provides a half second of microgravity. While that's not long, it can provide a hint of what will happen in the 79-foot fall in NASA's 2.2 Second Drop Tower. For inspiration on conducting your own drop research, check out the [Fire in Free Fall](#) video by Physics Girl [Dianna Cowern](#) (*who is now tragically suffering from a severe case of long COVID*). You may change the designs of your paddle wheels after your proposal is submitted, but the rules must still be followed.

Timing is critical: Late submissions to NASA of your proposal, paddle wheels, or written report will each disqualify your team from invitation to the ASGSR meeting. Don't wait until the deadlines to complete tasks!

Communication: When contacting the challenge staff, please e-mail Ed-DropTower@lists.nasa.gov rather than individual staff members to avoid the chance of e-mailing someone who is vacationing, sick, etc. and not checking their e-mail.

Selection Criteria for ASGSR Meeting Participation

Teams will be evaluated based on the following:

1. Performance during testing in the 2.2 Second Drop Tower
2. Team's approach to the challenge (as revealed in their proposal and especially their written report) including their application of:
 - a. engineering design process
 - b. scientific method
3. Team's analysis (as revealed in their final report)
4. Team's written report
5. Compliance with rules and instructions
6. On-time submission of the proposal, paddle wheels, and written report

B. WHAT TO DO

There are four phases of participation in the challenge:

1. Prepare your proposal – *open to all eligible*
2. Build your paddle wheels – *open to all teams selected by NASA for testing*
3. Analyze & document your results – *generally after the NASA microgravity testing, but some draft text can be written during the first two phases*
4. Present at the 2025 ASGSR conference – *open to those teams invited by NASA based on the selection criteria presented earlier*

Each phase is separated by a submission to NASA and subsequent phases rely on the earlier ones for continued participation. The proposal is used to determine whether a team will continue to phase 2 and build paddle wheels for microgravity testing at NASA. The paddle wheels must be submitted for testing to have results to analyze and write about in phase 3. Finally, invitation to present in the student poster session at the ASGSR meeting (phase 4) depends on the team's written report and performance in the preceding phases.

1. Prepare your proposal

1.1 Understand the challenge

The goal is to design and build paddle wheels that will rotate in water as far as possible during the apparent weightlessness, i.e., microgravity, that results from free fall in NASA's 2.2 Second Drop Tower. The wheel rotation must result from the wetting properties of the paddle wheels' surfaces and not because of mechanical means, such as released ballast. Example video clips showing paddle wheels mechanically moved in normal gravity can be seen at:

- <https://www.youtube.com/shorts/x6kvlNurDsc>
- <https://www.youtube.com/watch?v=5RuSfsmVWnc>
- <https://www.youtube.com/watch?v=0mjNQZtupoY>

Scoring: In testing, a paddle wheel's score is based on its maximum rotation, e.g., measured in degrees, during the 2.2 seconds of microgravity. Motion before release and after impact doesn't count. The team's test performance is based on the greatest motion of a paddle wheel during free fall. The rotation of two paddle wheels isn't averaged, nor is the rotation of the same paddle wheel in multiple drop tests. To be clear, only the greatest rotation is considered. But having two paddle wheels increases the odds of a high score and allows for the comparison of results in the report.

Adhesion & cohesion: The balance between the attraction of the liquid and a surface (adhesion) and the liquid's attraction to itself (cohesion) affects how liquids interact with a surface, including those on each paddle wheel. The adhesion/cohesion balance can cause a mobile object in a liquid to move when the force of gravity seems to disappear. The geometry of the surface(s), including both the shape and dimensions, can also influence the resulting motion.

Water loving & fearing: A surface's properties can affect liquid interactions, where their influence can be particularly strong in microgravity. Surfaces can be either hydrophilic or hydrophobic, that is 'water loving' or 'water fearing.' As an extreme example, the leaves of the Lotus flower have a superhydrophobic surface where researchers are working to mimic the 'Lotus effect.'

1.2 Become familiar with microgravity fluid physics

Before designing your paddle wheels, learn how liquids can behave in microgravity from the short video clips referenced in the Appendix B section on **Fluids in microgravity**. A suggested place to start is the [Science off the Sphere](#) demonstrations conducted on the International Space Station by NASA astronaut [Don Pettit](#).

Those who want to dig deeper may want to check the internet content listed in the appendix under **Capillary action, surfaces, etc.** or study [A Researcher's Guide to International Space Station Fluid Physics](#).

1.3 Develop your paddle wheel concepts

Based on your research, design your own paddle wheels that will rotate during free fall because of the wetting properties of their surfaces. NASA will provide the rest of the experiment hardware including the axles, two containers (each holding water and a paddle wheel), the video camera, and lighting.

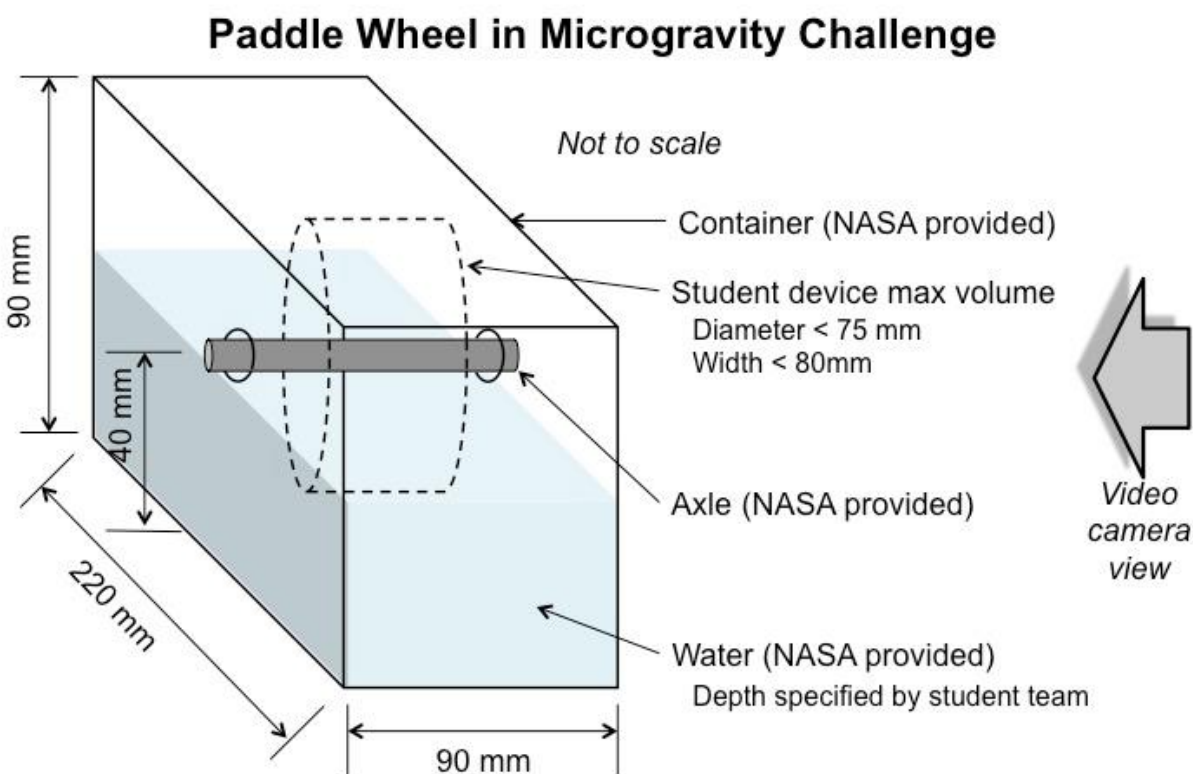


Figure 1. Sketch of a paddle wheel vessel (with axle) showing the maximum dimensions for the paddle wheel.

Number: Each selected team can propose and submit up to two paddle wheels for testing. Having two paddle wheels, which can be different, allows a team to compare test results, for example in the required report and—if invited—at the 2025 ASGSR conference. Of course, at least one paddle wheel must be proposed and assuming selection built and shipped to NASA for microgravity testing.

Containers: Each paddle wheel will be tested in its own container of water, where the interior is a rectangular prism which nominally has the internal dimensions shown on Figure 1. Two containers, and thus up to two paddle wheels, will be tested in a single drop test. Each drop test will only include paddle wheel(s) from a single team.

Axle: For drop testing, NASA will mount each paddle wheel in a water vessel using a LEGO® Technic axle.

Size: Each paddle wheel must have a hole that can accommodate a LEGO® Technic axle that is 4.8 mm in diameter. Each paddle wheel must fit within an imaginary cylinder that 80 mm wide and 75 mm in diameter as shown in Figure 1.

Shape: The paddle wheel doesn't need to be shaped like a one used for a ship or a boat, e.g., as seen in the sample video clips. But it must fit within the specified cylindrical volume. As extreme examples, a 40-mm sphere or cube with a hole through the middle for the axle would be acceptable, although those simple shapes may not result in the desired rotation.

Symmetry: The paddle wheel doesn't need to be symmetrically shaped, either axially, or along the axle (i.e., toward or away from the video camera).

Wetting: NASA will not advise your team on whether your paddle wheels should be hydrophilic (water-loving) and hydrophobic (water-fearing).

Water level: For each paddle wheel, the team must specify the height of the water in each vessel for the drop testing. This value, as measured vertically from the inner floor of the vessel to the top of the water in normal gravity, must be 10 to 40 mm. Given the variability, teams could plan for two identical paddle wheels where the only difference between testing them is the water level.

Orientation: When paddle wheels are shipped to NASA, teams can request an orientation for each paddle wheel relative to their water for the first drop (only), where that can be important for asymmetric paddle wheels. Given the variability, teams could plan for two identical paddle wheels where the only difference between testing them is the orientation. But jostling does occur during drop preparations, e.g., as the package is lifted to the top of the tower. As a result, NASA doesn't guarantee testing with your desired orientation.



Figure 2. Containers with objects from a past challenge being loaded into the drop rig. For the Paddle Wheel challenge, the containers will be vertically stacked instead of mounted side by side.

Materials: The paddle wheels must be fabricated from safe solid materials such as plastic or metal. Please avoid the use of fragile materials such as glass, thin plastic, etc. in your paddle wheels. Verify the ruggedness of your paddle wheels because they must survive shipping to and handling at NASA.

Safety: Corrosive, toxic, and radioactive materials are prohibited. Other hazards such as compressed gases and sharp edges are also not allowed.

Biology: Small creatures (such as insects) are not allowed, whether they are dead or alive. Other biological samples are generally not allowed, but materials such as cork, cotton, leather, wood, and wool are allowed exceptions.

Chemistry: Chemical reactions are prohibited, so avoid materials and coatings that react with water (such as antacid tablets).

Electricity: Electrical components such as batteries, lasers, motors, etc. are not allowed, but wire is an allowed exception.

Insoluble: Materials, including coatings, must not dissolve in water.

Liquids: While liquids can be used in creating your paddle wheels, they must be dry, not sticky, and contain no liquids when they are shipped to NASA.

Separation: The paddle wheels may not include parts, materials, or coatings that separate—intentionally or otherwise—in the water. As examples, (1) the separation of ballast is not allowed, (2) the water must not become cloudy or discolored, and (3) the wetting of the container must not be affected by contamination from the paddle wheel. **Paddle wheels causing such outcomes will receive zero in test performance scoring regardless of the motion of the paddle wheel.**

Drop testing: We envision dropping your paddle wheels twice. Your paddle wheels will typically be in the water for roughly 15 minutes prior to the first drop test and potentially for 30 minutes or more before the second drop test. That is just one reason why it is important that the materials, including any applied coatings, do not dissolve in water, etc.

1.4 Prepare and submit your proposal

Prepare your proposal using the entry form, shown in Appendix C, which is available online as a stand-alone file. The proposal shall include information about your team plus descriptions and depictions of your paddle wheels. It must be written in English and consist of a single file, in a pdf format, into which all figures must be ‘pasted.’ The file must be less than 9 MB in size or it will not be received by the challenge staff.

E-mail the proposal to Ed-DropTower@lists.nasa.gov by no later than Oct. 31, 2024. More precisely, your proposal must be e-mailed to NASA before midnight (i.e., by no later than 11:59 PM) in your local time zone. The proposals will be reviewed, and selections will be announced via e-mail to all proposers by at least mid-December. Teams are selected for testing may continue to the next phase.

2. Build your paddle wheels

Assuming that your team is selected for participation in the testing, build your paddle wheels following the rules in the design section (1.3) of this guide. Make sure to review the key rules and hints as you design your paddle wheels.

Changes: It is acceptable to change your designs, e.g., based on research conducted after your proposal submission, provided that the challenge rules are still met. As such, you encouraged to check with Ed-DropTower@lists.nasa.gov to ensure that the new designs are acceptable. Given the mid-February deadline for the arrival of your paddle wheels at NASA, you should strive to finalize your designs in January.

Materials, dimensions, and drawings update: Each team will be asked to e-mail our staff by Jan. 15 at ed-droptower@lists.nasa.gov with an updated list of all materials used in your paddle wheels. In that list, clearly identify any materials that were not listed in your initial proposal. In addition, if there are any changes to the dimensions or designs, updated drawings must be submitted. The update will be requested in early January to ensure that safety requirements will be met during drop testing at NASA.

Extra paddle wheels: You may want to make extra copies of your paddle wheels to keep because the ones sent to NASA won't be returned. For example, you could display them at your school or perhaps even at the ASGSR conference.

It is highly recommended that you conduct your own microgravity trials: Consider mounting trial paddle wheels with water within a plastic jar and dropping the jar with a video camera to get a glimpse of what happens in microgravity. Just a 4-foot fall provides a half second of microgravity, which can hint at what will happen in the 79-foot fall in NASA's 2.2 Second Drop Tower. For inspiration on conducting your own drop research, check out the [Fire in Free Fall](#) video by Physics Girl [Dianna Cowern](#). You can also contact Ed-DropTower@lists.nasa.gov for guidance on how to conduct your own drop tests.

Liquids: When shipped to NASA, all paddle wheels must be dry, not sticky, and not contain liquid. But your team can use liquids, including coatings, in preparing your paddle wheels. The devices, including any coatings, just need to be dry when they are shipped.

Coatings: Coatings must be applied by your teams before they are shipped to NASA. Coatings—and more generally all paddle wheel materials—must not (1) dissolve in water, (2) react with water, or (3) detach from your paddle wheels in water.

Packaging: Once your paddle wheels are ready, package them to prevent breakage during shipping and injury to challenge staff. Although a team's paddle wheels should be shipped together in one package, each one must be packaged individually in its own resealable plastic bag that is labeled with a permanent marker with the following:

1. Team identification:

PW25_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<TeamAbbrev>

2. Paddle wheel number or alternate identifier (e.g., 1 or 2, A or B)

3. Desired water level as measured vertically from the inner floor of the vessel to the top of the water in normal gravity. This value must be between 10 and 40 mm.

4. Paddle wheel orientation: For the orientation relative to the water (and/or camera) for the first drop, indicate either "no preferred orientation" or "preferred orientation enclosed." See the Orientation discussion below for more information.

An advisor with multiple teams may ship their paddle wheels together to NASA, making such labeling even more important.

Note that the shipment of more than two paddle wheels by a team is unacceptable even if more than two different paddle wheels were built. **Each team must choose no more than two paddle wheels to ship to NASA.**

Orientation: If you have a preferred orientation for a paddle wheel to the water (and/or camera) for the first drop, include sheet(s) of paper that indicate the desired orientation for each paddle wheel during its first drop. This may be best accomplished with drawings. Again, this information should be on paper identifying the paddle wheel (by its number, etc.) that is also labeled:

PW25_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<TeamAbbrev>

As an extreme example, if there are three uniformly spaced blades, do you want one or two in the water? Please note that jostling does occur during drop preparations, e.g., as the package is lifted to the top of the tower. As a result, NASA doesn't guarantee testing with your desired orientation relative to the water.

As stated earlier, if you have no preferred orientation for a paddle wheel, e.g., because of its symmetry, then label its resealable plastic bag with "no preferred orientation."

Shipping: Ship the paddle wheels and documentation referenced above to the following address, where they must **arrive at NASA by no later than February 14, 2025**.

Paddle Wheel c/o Tyler Hatch – DESK
NASA Glenn Research Center
21000 Brookpark Road, Bldg. 77, Rm. 110
Cleveland, OH 44135

Late paddle wheels will be disqualified from the competition!

Given the delivery requirement, we recommend that you use a shipper that will provide tracking information such as FedEx, UPS, or USPS (United States Postal Service), where those shippers are simply listed alphabetically. To be clear, these are suggestions and are not meant as endorsements. We cannot advise you on the time required for delivery from your location; that is your responsibility.

3. Analyze and document your results

3.1 Draft written report

Report writing can and ideally should begin after your team's proposal has been selected for testing. Even before your paddle wheels are completed and the drop tests are conducted, your team can begin writing an introduction based on what you've learned in preparing your proposal and from any preliminary tests performed by your team. References can also be documented. You can also draft the section describing your experiment (i.e., attempt at the challenge), once the design of your paddle wheels has been finalized. But of course, you'll need to wait until the tests at NASA have been conducted to write the results, discussion, and conclusions. Furthermore, the abstract should be the last section of your paper to be written.

Science: While Paddle Wheel is a design challenge in which you must apply engineering skills, the report should be prepared as a scientific paper that might be presented at a scientific conference or published in a journal. Such papers contribute to the advancement of science because they describe in detail what was both done and learned. The details allow readers to duplicate the described tests and verify or challenge the presented findings. Other researchers can't check your results if your paper doesn't sufficiently explain your paddle wheels to allow readers to make their own copies. Similarly, your paper should explain the testing, including that conducted at NASA, and how you made your measurements.

Format: There is no required format for the written report, but it should not be prepared like a school lab report. As two examples, it should not have a cover page and it should not have photos of team members, unless for example to show how at-home testing was conducted. As another example, your team's name (if any) shouldn't appear in your written report. Instead, it is suggested that teams generally follow the guidance found in "[A Guide to Writing a Scientific Paper: A Focus on High School Through Graduate Level Student Research](#)" by Renee A. Hesselbach et al.

Example papers: While the referenced paper provides guidelines, example papers can be seen, for example, in the [digital repository](#) for the meetings of the International Conference on Environmental Systems ([ICES](#)). Those papers aren't directly relevant to the design challenge but instead address life support and related spaceflight topics. You're encouraged to review a few scientific papers, whether from there or elsewhere, to get an idea of how you might prepare your report.

Authors: While student names should not be included in your proposal, they should be included in your written report and on the poster if your team is invited to present at the ASGSR meeting. Similarly, identify your team's organization if formal (e.g., school name) and where it is located, but just the city and state (for example) but not the full address. This is where you should be recognized for your work!

Audience: The paper should be written for readers don't know anything about the Paddle Wheel challenge, microgravity, and wetting phenomena (e.g., hydrophilic and hydrophobic surfaces).

Numbering: All images should be numbered, e.g., Figure 1, and have captions. Tables should similarly be numbered and have a title.

Plots: Graphs of results must have axes labeled and units identified in ways that are reasonably easy to read. Ideally results should be presented in ways that facilitate their comparison, for example between two paddle wheels or drop tests. That could be done with side-by-side graphs with axes with the same vertical ranges, although an even better option is to put the results to be compared on the same graph, for example using different symbols and/or colors to differentiate them.

Results & Conclusions: Through the text, figure(s), and/or table(s), your paper should share what you learned from your work, for example from a comparison of the results from your paddle wheels and/or drop tests.

It must be emphasized that the ranking and selection of the teams for invitation to present at the 2025 ASGSR meeting is not based on the performance in the drop tests alone. The analyses, written reports, etc. are also important factors. As a result, the team with the best test performance will not necessarily be the first-place winner or even necessarily invited to the conference.

3.2 Analyze results

NASA's goal is to electronically provide the test data to all teams by at least April 1, so if you don't receive access to your results by then, contact Ed-DropTower@lists.nasa.gov. For each test, the data will consist of a video filmed at 30 frames per second showing what happened during the drop tests, possibly supplemented by still images taken from the video.

[Tracker](#), which is shared by [Open Source Physics](#) as a tool for "physics teaching and student activities," is a suggested way to make measurements of motion in the tests. The Tracker software has notably been used by some participants in past drop tower challenges. As an alternate, many of NASA's microgravity researchers use [ImageJ](#) (from the National Institute of Health) or its 'batteries included' version called [Fiji](#), which are both freely available for making such measurements.

Position measurements can also be made with simple graphic software that continually reveals the position of the cursor. Simply load an image, move the cursor to each desired position and write down their values (i.e., by hand). Repeat with successive video frames to track positions as a function of time. Microsoft Paint is an example of such software, where it reveals the position of the crosshairs in the bottom left of the window (in pixels and relative to the image).

Measurements can also be made manually by taping a transparent overlay to your computer monitor and marking the positions using a permanent marker. You can make measurements for multiple images (i.e., times) using the same transparency, where it may be helpful to mark each position with the image number (or time).

Please understand that these are just suggestions and are not meant to indicate endorsements by NASA or the federal government.

3.3 Complete and submit written report

Using the results from the testing, complete your written report (e.g., as described in section 3.1) and e-mail it to Ed-DropTower@lists.nasa.gov by no later than May 1, 2025, more specifically by 11:59 PM in your local time zone. Note that the report must be no more 9 MB, written in English, and submitted in a pdf format.

Please name the pdf of your report in a similar format as the proposal, specifically as PW25_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<TeamAbbrev>_paper; an acceptable example is PW25_WV_GWHS_Smith_Team1_paper.

4. Present at the 2025 ASGSR Conference

Based on their performance in the drop testing, application of the engineering design process and scientific method, analysis, and written reports, some teams will be invited in mid-May to present their results in a student poster session at this annual meeting. All participating teams will be contacted by e-mail about the selections.

When and where? The meeting dates and location have not yet been announced, but it is expected that the conference will be held in late October, November, or early December with the student day on a Saturday (other than on Thanksgiving weekend).

Cost: It is expected that there will be a nominal registration fee, such as \$25/each, for the invited students presenting at the conference as well as accompanying advisors, parents, and/or chaperones. Except for continental breakfast(s), the admission does not include meals, but tickets may be purchased for the Saturday evening banquet. The special admission includes participation in the student day and tentatively the preceding day, but probably not the full conference.

Travel support: It is expected that financial support will be provided to help invited non-local teams travel to the conference. The expected travel support is \$500 per invited student presenting at the conference. Given that the travel expenses could exceed that value, teams coming to the conference will need to take action to address the likely shortfall. Furthermore, the financial travel support will not be provided in advance. Instead, it will probably be provided as a check to the advisor at the conference.

Poster: The posters are pinned up on vertical boards and are typically no more than 48" wide and 48" tall, but the size specifications for the 2025 meeting are not yet known. The posters are almost always printed in a single piece (where software such as PowerPoint allows for custom sizes) and brought rolled up in a tube. To be clear, there will not be tables for the poster session so you should not have a tri-fold display board as might be used at a school science fair. There are many online resources with recommendations for creating and presenting scientific posters, where these are a few examples:

- [10 simple rules for designing a scientific poster](#)
- [Conference presentations: Lead the poster parade](#)
- [Creating Anthropology Conference Posters: A Guide for Beginners](#)
- [Designing conference posters](#)
- [How to Create a Research Poster](#)
- [How to make an academic poster](#)
- [Poster Perfect](#)
- [Ten Simple Rules for a Good Poster Presentation](#)

ASGSR awards will be presented based on the poster presentations, where other students will be presenting on projects other than the drop tower challenge. So, this is another opportunity to do your best!

Activities: The conference will include opportunities for students to tour the exhibit hall, attend research presentations, and interact with other students, the challenge staff, and various microgravity researchers.

APPENDIX A – FAQs: Frequently Asked Questions

Q: How are microgravity conditions created?

A: During its fall in NASA's 2.2 Second Drop Tower, each object behaves as if there is no gravity, just as if it were in orbit on the International Space Station (ISS). Our sensation of gravity and weight comes from a resistance to its pull, for example because of the floor preventing us from falling. If we are freely falling (e.g., after jumping off a diving board), we feel weightless, and free-fall is the basis for many amusement-park rides. This occurs because all objects fall at the same acceleration unless acted upon by another force. As one result, the astronauts and the ISS fall together (around the Earth) such that the astronauts float within the space station. This happens even though the space station is so close to the Earth that the gravity is only about 10% less than that at the Earth's surface.

Q: Can students be on more than one team?

A: No.

Q: Can a team submit more than one proposal?

A: No. Your organization (e.g., school, club, Scout troop, etc.), however, can have multiple teams but it may submit at most 2 proposals to NASA. A school, for example, could select the top 2 proposals to submit to NASA for evaluation.

Q: Can home schools participate?

A: Yes; teams don't need to be affiliated with a school and can be formed from any group of youth in grades 8-12 including siblings, neighbors, and friends as a few examples.

Q: Can teams from countries other than the United States participate?

A: No, unless your team is from a [DoDEA](#) school for the children of U.S. military personnel. All other students from outside of the USA are not eligible, even if they are U.S. citizens.

Q: Where do we get the entry form?

A: Online, at the [2025 Drop Tower Challenge](#) webpage.

Q: Can proposals, reports, etc. be submitted in a language other than English?

A: No! They will be rejected, where the challenge staff doesn't have the language skills or resources to appropriately address the challenge in other languages.

Q: Are drawings required for the proposals?

A: Yes; your proposal must include descriptions and drawing(s) of each paddle wheel, although duplicate drawings are not necessary if the size and shape of your paddle wheels are identical. The maximum diameter and width of the paddle wheels must be identified with dimensions on the drawings. They can be drawn by hand, with standard software (e.g., PowerPoint), or using Computer Aided Design (CAD). The drawing(s) must be 'pasted' into the proposal, so that the proposal consists of a single file.

Q: What file formats are acceptable for the proposals and written reports?

A: Your proposal and written report must each be submitted as a pdf file. Teams submitting those documents in another file format risk rejection.

Q: What is the maximum file size for the proposals and written reports?

A: Each proposal's file must be less than 9 MB or it will not be deliverable to the challenge staff.

Q: Does the number of paddle wheels proposed affect the odds of selection?

A: Yes; preference will be given to plans with two paddle wheels because their results can be compared in the report. But each team is limited to a maximum of two paddle wheels.

Q: Can we build paddle wheels using a 3-D printer?

A: Yes.

Q: Can we simply buy paddle wheels?

A: Yes.

Q: Will we get our paddle wheels back?

A: No.

Q: Will NASA help us with ideas for our proposal?

A: No.

Q: Will NASA provide guidance for our paddle wheels if we are selected to participate in the microgravity testing?

A: No, except for reminders, clarifications, etc. about the rules and instructions. Otherwise, the challenge staff won't help teams succeed. The competition isn't over until the winners are invited to present their results at the ASGSR meeting.

Q: Will NASA provide guidance on conducting our own preliminary drop tests?

A: Yes.

Questions?

If you can't find the information you need in this guide or at the challenge website, then e-mail Ed-DropTower@lists.nasa.gov.

APPENDIX B – Suggested Internet Links

2025 Paddle Wheel challenge

<https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2025-drop-tower-challenge/>

Paddle Wheels (*video clips*)

- <https://www.youtube.com/shorts/x6kvlnurDsc>
- <https://www.youtube.com/watch?v=5RuSfsmVWnc>
- <https://www.youtube.com/watch?v=0mjNQZttpoY>

Microgravity & drop testing

2.2 Second Drop tower

<https://www1.grc.nasa.gov/facilities/drop/>

Brian Cox visits the world's biggest vacuum (*video*)

<https://www.youtube.com/watch?v=E43-CfukEgs>

Fire in Free Fall (*video*)

https://www.youtube.com/watch?v=VAA_dNq_-8c

Microgravity (*video*)

<https://www.youtube.com/watch?v=GSLwvtF4Zo0>

What is Microgravity?

<https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-microgravity-58.html>

Zero Gravity Research Facility

<https://www1.grc.nasa.gov/facilities/zero-g/>

Zero Gravity [Research] Facility (*virtual tour*)

<https://www3.nasa.gov/specials/zero-g/>

Fluids in microgravity (*all videos unless otherwise noted*)

4K Camera Captures Riveting Footage of Unique Fluid Behavior in Space Laboratory

<https://www.youtube.com/watch?v=Vx0kvxqgC1c>

4K Video of Colorful Liquid in Space

https://www.youtube.com/watch?v=bKk_7NIKY3Y

A Cup of Joe in Space

<https://www.youtube.com/watch?v=8sDc00IK7mA>

A Researcher's Guide to International Space Station Fluid Physics (*booklet*)

https://www.nasa.gov/wp-content/uploads/2019/10/iss-fluid_physics_tagged.pdf

Behaviour of water in microgravity

https://www.youtube.com/watch?v=HjBU_4if_CE

Boiling Fluids Behave Quite Differently in Space

<https://www.youtube.com/watch?v=kdt20h0ZaDw>

Capillary Flow Experiments on Space Station

<https://www.youtube.com/watch?v=3lwy8xxJxKo>

Christa's Lost Lessons: Liquids in Microgravity

<https://www.youtube.com/watch?v=HGf4Uka5hac>

Honey in space

<https://www.youtube.com/watch?v=Say3pUblISA>

ISS Update: Capillary Flow Experiments-2

<https://www.youtube.com/watch?v=K-PQE-VEdhc>

Liquid Ping Pong in Space - RED 4K

https://www.youtube.com/watch?v=TLbhrMCM4_0

Moving Water in Space - 8K Ultra HD

https://www.youtube.com/watch?v=H_qPWZbxFl8

Open Science: Space Coffee Cup

https://www.youtube.com/watch?v=Kr3OPNjsx_M

Playing with water in space!

<https://www.youtube.com/watch?v=Z2Jh9KyvJgg>

Science off the Sphere: Astro Puffs

<https://www.youtube.com/watch?v=e6Faq1AmISI&t=8s>

Science off the Sphere: Fun with Antibubbles

<https://www.youtube.com/watch?v=U9VFwGYRZQg&t=69s>

Science off the Sphere: Bistronauts

<https://www.youtube.com/watch?v=q1k9njdSVE0>

Science off the Sphere: Goo!

<https://www.youtube.com/watch?v=Ohs8TQxDuX8&t=117s>

Science off the Sphere: Knitting Needle Experiment

https://www.youtube.com/watch?v=gHrBhgwq_Q&t=101s

Science off the Sphere: Lenses and Vortices

<https://www.youtube.com/watch?v=CrTUpTDyGpl&t=103s>

Science off the Sphere: Space Balloonacy

<https://www.youtube.com/watch?v=Wlsydeu7ZTo&t=78s>

Science off the Sphere: Space Soundwaves

https://www.youtube.com/watch?v=U0rl_-z1YwQ&t=175s

Science off the Sphere: Thin Film Physics

https://www.youtube.com/watch?v=Uddz-3RwA_Y&t=1s

ScienceCasts: Space Coffee

<https://www.youtube.com/watch?v=dWuEVSCw8B8>

Sciencetasia (*also addresses plants and flames in microgravity*)

https://www.youtube.com/watch?v=dZpTaC_SP_4

Scientists popping water balloons in weightlessness (microgravity)

<https://www.youtube.com/watch?v=u7TQM9z2IJA>

Space Station Live: A Cup of Coffee Beats a Bagful

https://www.youtube.com/watch?v=Fttaf_rhpm4

Space Station Live: ISS: Space Cup Full of Science

<https://www.youtube.com/watch?v=0Lmsvr8VVwM>

SpeedyTime 5 – Water in Space

<https://www.youtube.com/watch?v=NmnnBvYFOIs>

STEMonstrations: Properties of Water

https://www.youtube.com/watch?v=4A_dMWsw2oA

STEMonstrations: Surface Tension

<https://www.youtube.com/watch?v=34bFgA3H3hQ>

Tears in Space (Don't Fall)

<https://www.youtube.com/watch?v=P36xhtpw0Lg>

Water and Ping Pong Ball - Microgravity Experiment

https://www.youtube.com/watch?v=hl8fg_d67fU

Water Glove in Space

https://www.youtube.com/watch?v=aD1D9E_tdS8

Why Is NASA Boiling Fluids in Space?

<https://www.youtube.com/shorts/O1gj-MMjtgc>

Wringing out Water on the ISS - for Science!

<https://www.youtube.com/watch?v=o8TssbmY-GM>

Capillary action, surfaces, etc.

Capillarity – Measuring Surface Tension

https://www.teachengineering.org/lessons/view/duk_surfacetensionunit_less2

Capillary Action and Water

<https://www.usgs.gov/special-topics/water-science-school/science/capillary-action-and-water>

Explained: Hydrophobic and Hydrophilic

<https://news.mit.edu/2013/hydrophobic-and-hydrophilic-explained-0716>

Fundamentals of Surface Tension/Wettability

<http://web.mit.edu/nnf/education/wettability/index1.html>

Superhydrophobic surfaces

www.lawrencehallofscience.org/sites/default/files/pdfs/college_resources/modules/Superhydrophobic/Superhydrophobic_Surfaces.pdf

Superhydrophobicity – The Lotus Effect

https://www.teachengineering.org/lessons/view/duk_surfacetensionunit_less4

Surface Tension Basics

https://www.teachengineering.org/lessons/view/duk_surfacetensionunit_less1

Wetting and Contact Angle

https://www.teachengineering.org/lessons/view/duk_surfacetensionunit_less3

Analysis software

Fiji

<https://fiji.sc/>

ImageJ

<https://imagej.nih.gov/ij/>

Tracker

<http://physlets.org/tracker/>

A Guide to Writing a Scientific Research Paper

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3528086/pdf/zeb.2012.0743.pdf>

Microgravity on aircraft (*selected videos for related fun & enlightenment*)

OK Go - Upside Down & Inside Out

<https://www.youtube.com/watch?v=LWGJA9i18Co>

OK Go - Upside Down & Inside Out BTS - How Parabolas Work

<https://www.youtube.com/watch?v=bMrX014HTqU>

OK Go - Upside Down & Inside Out BTS - How We Did It

<https://www.youtube.com/watch?v=pnTqZ68fI7Q&t=2s>

Please understand that these are just suggestions and are not meant to indicate endorsements by NASA or the federal government.

APPENDIX C – Entry Form

The form can be downloaded from the [2025 Drop Tower Challenge](#) webpage.

This entry form must be completed in English; the use of other languages is unacceptable.

PARTICIPANT INFORMATION		
A	Adult advisor name	
B	Adult advisor e-mail address	
C	Team type (choose one) Formal: [school, club, troop, etc.] Informal: [friends, family, solo]	
D	Team organization name (<i>only for formal teams</i>)	
E	School(s) of the team members	
F	City (or township, etc.)	
G	State or territory (etc.)	
H	Student grade level(s) [8 9 10 11 12]	
I	Number of students on the team	
J	Team name (<i>if any</i>)	
K	How did you learn of the drop tower challenge?	

Notes

- A-B All teams are required to have an adult advisor, such as a teacher, group leader, parent, or guardian.
- C Formal teams are typically advised by a teacher, staff member, or volunteer leader of the organization. In contrast, informal teams are typically advised by a parent or guardian of one of the team members. Appropriate entries include school, club, troop, science center, friends, family, solo, etc.
- D Name of the team's organization, e.g., the school (whether public, private, or home), club (whether school or otherwise), Scout troop, science center, etc. This only applies to formal teams, which are typically advised by a teacher, staff member, or volunteer leader of the named organization.
- E Name of the school(s) which the team members attend.
- F-G For formal teams, specify the city and state (or territory, etc.) of the organization. For informal teams, use the advisor's city and state (etc.).
- H The Paddle Wheel challenge is open to team members in grades 8-12, where selection preference will go to teams over individuals. Multi-grade teams, as might be found in a club or family, are acceptable.
- J The optional team name can, but doesn't need to, match that of your school mascot, etc. This is an opportunity to be creative.

EXPERIMENT INFORMATION		
1	Experiment name	
2	Research question	
3	Hypothesis (optional)	
4	Number of paddle wheels (max 2)	
5	Materials from which the paddle wheel(s) will be fabricated, incl. any coatings, adhesives, etc.	
6	Paddle wheel 1 dimensions (in mm)	
7	Paddle wheel 2 dimensions (in mm)	
8	Water level for each paddle wheel (between 10-40 mm)	
9	Will the orientation of the paddle wheels (if two) to the water be a variable in testing? If so, how?	
10	How will the paddle wheels (if two) differ in NASA testing?	
11	How will the paddle wheels (if two) be the same in NASA testing?	
12	Analysis plan (optional)	

Notes

- 2 The research question should be specific to the testing of the paddle wheel(s), for example the differences between them (if there are two). Generic research questions, such as “which paddle wheel will rotate the furthest?” are inappropriately vague.
- 3 The hypothesis should address the research question.
- 4 The experiment should include two paddle wheels to allow the comparison of results.
- 5 To the best of your ability, clearly identify all materials from which the envisioned paddle wheels will be made including any coatings, adhesives, fasteners, etc.
- 6 Identify the maximum dimensions, e.g., diameter and width, in millimeters (mm). These and your design can be changed later provided that the rules are still met.
- 7 *Skip if only 1 paddle wheel.*
- 8 The water level(s), like your paddle wheel design and dimensions, can be altered later.
- 10-11 Besides the paddle wheels themselves, please address differences and similarities in the water level and the orientation of paddle wheels relative to the water.
- 12 A brief description of an analysis plan is optional and will not be used in the selection process.

DRAWINGS

Drawing(s) of the paddle wheel(s) are required. They must be pasted into this entry form (below and/or on subsequent blank pages), where attaching them as separate file(s) is unacceptable.

The maximum dimensions, e.g., diameter and width, of each paddle wheel must be labeled in millimeters on the drawing. Orthographic (e.g., front, side, top) drawings, explained for example at <https://www.youtube.com/watch?v=SdLegfoMXNA>, can be helpful for identifying dimensions. Note that only two views (i.e., [orthographic projections](#)) are required for cylindrically symmetric objects, where an example of such a drawing (without dimensions) can be seen in Figures 1 and 2 of an [1862 patent drawing of a paddle wheel](#).

The drawings can be (1) drawn by hand and scanned or photographed, or (2) they can be created on the computer, e.g., using a drawing program such as MS PowerPoint. Computer-Aided Design (CAD) drawings are acceptable but are not required. But again, it must be emphasized that the drawing(s) must be embedded in this entry form file.

Note that there is no limit to the number of drawings and pages that may be included in the entry, but the resulting entry form file must be less than 9 MB and must be submitted by email. Some servers will not send emails larger than 9 MB.

KEY RULES CHECKLIST (See pages 5-6 of the guide for many more rules.)

- ☐ Participants must be grade 8-12 students in the United States (incl. territories) or [DoDEA](#) schools.
- ☐ A student may only be on 1 team.
- ☐ Teams can be of any size, but a maximum of four students per team will be invited to the ASGSR meeting.
- ☐ A team may only submit 1 entry.
- ☐ An organization (e.g., school) may submit no more than 2 entries.
- ☐ Each team may include up to 2 paddle wheels in their proposal.

SUBMISSION CHECKLIST**This entry form must ...**

- ☐ be in English, where use of other languages is unacceptable
- ☐ include drawing(s) of each paddle wheel in which:
 - ☐ each paddle wheel is identified by number, name, etc.
 - ☐ maximum dimensions (e.g., diameter and width) of each paddle wheel are clearly labeled in millimeters
- ☐ be submitted in a .pdf format (where all other formats are unacceptable) named PW25_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<TeamAbbrev>_entry, where an acceptable example file name is PW25_WV_GWHS_Smith_Sailors_entry.pdf
The abbreviations for eligible states, territories, etc. are provided on the next page for reference. The team abbreviation can be the team's name (if short) or initials or some other short designator. If an organization submits two entries (the maximum allowed), the team abbreviations must be different.
- ☐ be less than 9 MB in size (where, in contrast, there is no limit to the number of pages)
- ☐ be e-mailed to Ed-DropTower@lists.nasa.gov no later than Oct. 31, 2024, 11:59 pm (your local time)
The adult advisor should either be cc'd with the submission e-mail or personally submit it on behalf of the team. If two entries are submitted by the same advisor, they must be e-mailed separately.

QUESTIONS

If you still have questions after checking the following:

- (1) entry form
- (2) guide
- (3) [website](#)

then e-mail the Paddle Wheel challenge staff at Ed-DropTower@lists.nasa.gov.

STATE, ETC. ABBREVIATIONS

US State	Abbrv	US State	Abbrv	US State	Abbrv	US Territory	Abbrv
Alabama	AL	Louisiana	LA	Ohio	OH	American Samoa	AS
Alaska	AK	Maine	ME	Oklahoma	OK	District of Columbia	DC
Arizona	AZ	Maryland	MD	Oregon	OR	Guam	GU
Arkansas	AR	Massachusetts	MA	Pennsylvania	PA	Northern Mariana Islands	MP
California	CA	Michigan	MI	Rhode Island	RI	Puerto Rico	PR
Colorado	CO	Minnesota	MN	South Carolina	SC	U.S. Virgin Islands	VI
Connecticut	CT	Mississippi	MS	South Dakota	SD	DODEA schools	DOD
Delaware	DE	Missouri	MO	Tennessee	TN		
Florida	FL	Montana	MT	Texas	TX		
Georgia	GA	Nebraska	NE	Utah	UT		
Hawaii	HI	Nevada	NV	Vermont	VT		
Idaho	ID	New Hampshire	NH	Virginia	VA		
Illinois	IL	New Jersey	NJ	Washington	WA		
Indiana	IN	New Mexico	NM	West Virginia	WV		
Iowa	IA	New York	NY	Wisconsin	WI		
Kansas	KS	North Carolina	NC	Wyoming	WY		
Kentucky	KY	North Dakota	ND				