2019 DROP TOWER CHALLENGE

Plant Watering in Microgravity

https://spaceflightsystems.grc.nasa.gov/education-outreach/drop-tower-challenge/

UPDATES:11/14/18

- **Water height has been updated to be 40mm (1.6 in). See section 1.3.**
- **New FAQ clarifying what is meant by "test objects must sink"**

Instructions

Challenge overview

Why? Future long-duration space missions will require crew members to grow their own food, so, understanding how to water plants in microgravity is an important step toward that goal – and for understanding how plants behave in such an environment. A key factor in this design challenge is that plant roots need both water and air for the plant to grow and delivering sufficient quantities of both in the apparent absence of gravity is challenging because water and air don't mix well together.

What? Teams of grade 9-12 students are challenged to design and build objects that will allow air to penetrate towards the bottom of a water-filled container on at least one side/surface while the water climbs along a different side/surface during free fall. Objects from the selected teams will experience microgravity in NASA's 2.2 Second Drop Tower. NASA will invite the top-performing teams to present their results in a student poster session at the 2019 meeting of the American Society for Gravitational and Space Research (ASGSR) for which the location has yet to be announced.

Who? The design challenge is for students in grades 9-12, where teams will be favored over individuals in selection. The program is limited to students from the United States, but citizenship is not required. It is open to all fifty states, 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. Students are free to get help from adults, for example, in building their test objects. An organization (e.g., school, science center, 4-H club, Scout troop) may submit no more than five proposals, where it is envisioned that no more than two will be selected from a single organization.

Selection?

After proposal evaluation, NASA anticipates selecting up to 20 teams to build objects to be tested in the 2.2 Second Drop Tower at the NASA Glenn Research Center in Cleveland, Ohio. Some preference will be given to teams local to the fall 2019 ASGSR conference site (e.g., within 150 miles), although its location has yet to be announced. Only a small number of top-performing teams will be invited to participate in the

conference.

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A. Things to Know

Calendar

Now	open for proposals
Nov. 20, 2018	deadline for e-mail submission of proposals to NASA
Mid-December	teams selected for testing announced by NASA
Feb. 15, 2019	deadline for object(s) to arrive at NASA
Feb.-March	objects tested in NASA's 2.2 Second Drop Tower
May 1, 2019	written report due to NASA
Mid-May	teams selected for ASGSR participation announced by NASA
Fall 2019	annual ASGSR meeting

Key Rules

- **Proposals:** No more than 5 proposals will be accepted per organization (e.g., school, science center, 4-H club, Scout troop), and no more than one proposal. will be accepted from one team.
- **Team:** Teams can be of any size, but each student can only be on one team. Each team is required to have an adult advisor, who may advise multiple teams.
- **Number:** Each team may include up to 3 objects in their proposal and if selected for testing may submit up to 3 objects for that purpose.
- **Size:** An object's longest dimension (e.g., length or diameter) may be no more than 60 mm and no less than 5 mm
- **Prohibited materials:** fragile materials (e.g., glass), hazardous materials (e.g., that are corrosive, toxic, radioactive), materials or coatings that dissolve in or react with water, small creatures (whether dead or alive), most biological materials

Hints

Conduct your own microgravity trials: Consider putting trial objects with water in a plastic jar mounted 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, which 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**.**

Control and Variables: You should ideally have two or three different objects for testing so that you can compare the performance of each object 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.

Timing is important: Late submissions to NASA of the test objects will disqualify teams from the competition. Late final reports will disqualify teams from being selected to participate in the ASGSR conference, so don't wait until the deadlines to complete tasks.

Selection Criteria for ASGSR Meeting Participation

Teams will be graded for each object dropped based on the following:

1. ~~1.~~ Performance during testing in the 2.2 Second Drop Tower
2. ~~2.~~ Team's Analysis
3. Team's Final report

Failure to submit a final report as well as late reports will disqualify a team from being selected to go to ASGSR.

B. What To Do

There are four phases to participating in the challenge:

1. prepare your proposal – *open to all eligible*
2. develop & self-test your test object(s) – *if the team's proposed project is selected for testing*
3. analyze & document the results – *generally after the NASA microgravity testing*
4. present at the 2019 ASGSR conference – *if invited to participate based on the challenge performance and submitted report*

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 the objects must be submitted for testing to enable phase 3. Finally, the test performance and written report will both be used to determine which teams are invited to present their results in the student poster session at the 2019 ASGSR conference (phase 4).

1. Prepare your proposal **now to Nov. 20**

1.1 Understand the challenge

The goal for Plant Watering in Microgravity is to design and build an object that will cause air to penetrate downward into water on at least one side/surface while the water climbs along a different side/surface in microgravity. Surfaces can be either hydrophobic or hydrophilic, that is "water fearing" or "water loving." As an extreme example, the leaves of the Lotus flower have a superhydrophobic surface where researchers are working to mimic the Lotus effect. For example, during free fall, objects with "water fearing" surfaces can be pushed from the water. That was the goal of the previous Drop Tower challenge called *Microgravity Expulsion from Water* where students were asked to use hydrophobic properties to push objects out of the water under microgravity conditions.

When an object is floating on water in normal gravity, an upward force is exerted by

water that opposes the weight of the less dense object. However, in microgravity, there is effectively no "weight" and the interaction between the object and the water is governed by the contact angle or wettability of the object by the water. Thus, to submerge the object, it was necessary to increase the wettability of the object which was the goal of the Drop Tower challenge from 2 years ago called DIVing into Experimental Research (DIVER). For the Plant Watering in Microgravity challenge, you must use these two basic wettability behaviors to design and build your object.

Scoring: An object's score is the maximum vertical distance (i.e., delta) between the air's downward penetration and the water's rise – in both cases along on the object's surfaces. In case of a tie, the following are the tiebreakers:

- 1st: volumetric amount of gas dive
- 2nd: height of the water rise from its pre-drop position

1.2 Watch videos of hydrophobic and hydrophilic objects

The expulsion of an object floating in microgravity can be seen in a video at www.facebook.com/NASA.celere. The video is courtesy of researchers at Oregon's Portland State University (PSU). As can be seen, the ball 'jumps' out of the water in microgravity. It must be emphasized that the present challenge's test objects must sink in the water in normal gravity, while the object in the video instead floats. Please know that the challenge staff will **not** share the hydrophobic treatment of the ball in this video, as we are looking for participating teams to research and find their own approaches to the challenge rather than copy what was done in the video.

The video at Ping Pong Ball On Water shows the response of a floating hydrophilic object to free fall, where it can be seen to dive into the water. It was from an experiment created by a middle school team for a previous drop tower competition.

1.3 Develop your test object(s)

Design – Based on your research, design your test object(s) using the guidelines below to achieve the highest score as described in the previous section. Note that NASA will provide the rest of the experiment hardware including the water (which will tentatively be colored), the three water containers in which your objects will be tested (with one object per container), the video camera, and lighting.

Number – Each selected team can submit up to three different objects for testing. This allows a team to compare test results, e.g., in the required report and - if invited - at the 2019 ASGSR conference. Of course, at least one test object must be proposed and - assuming selection - built and shipped to NASA for testing.

Materials – The objects must be fabricated from see-through or transparent material such as plastic. Glass and similarly fragile materials are unacceptable. Coatings must also be transparent. Water-soluble materials and coatings are prohibited, as are materials and coatings which chemically react with water. For safety, corrosive, toxic, and radioactive materials are prohibited. Other hazards such as sharp edges, compressed gases, batteries, and lasers are not allowed.

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

Containers – Each of the team's objects will be tested in its own container of water. The vessel's interior is a rectangular prism which s 210 mm (8.25 in) tall and 63 mm (2.4 in) across from left to right and front to back (i.e., where the cross-section is square). Each of the team's objects will be placed alone inside a container which will then be filled with water to a height of 40 mm (1.6 in). The team may specify if a certain orientation is required, e.g., in a drawing. Three objects, each in a separate container, are typically tested during a single drop operation.

Size – The longest dimension of each object shall be no more than 60 mm (2.36 in) and no less than 5 mm (0.2 in).

Air Penetration – The air must penetrate into the water during the drop because of the object's hydrophobic surface characteristics and must not move because of other reasons, e.g., mechanical fans initiated during free fall.

Water Rise – In microgravity conditions, the water must rise because of the object's hydrophilic surface and must not rise because of other reasons, for example, mechanical pumps initiated during free fall.

1.4 Prepare and submit your proposal

Prepare your proposal using the entry form, in Appendix A, sand which will is also available on the Plant Watering in Microgravity website. The proposal shall include information about your team plus descriptions and depictions of your test object(s). Each proposal shall consist of a single file, in either doc or pdf formats, into which all figures must be 'pasted.' The file must be less than 10 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 Nov. 20, 2018.** The proposals will be reviewed and selections will be announced via e-mail to all proposers by mid-December. Teams who've been selected for testing will continue to the next phase.

2. Build your test object(s) mid-December to Feb. 10

Assuming that your team's proposal is selected, build your test object(s) following the rules in the design section (1.3) of this guide. Also review the key rules and hints as you design your test object. It is acceptable to change your design(s), e.g., based on research conducted after your proposal submission. But you are strongly encouraged to check with Ed-DropTower@lists.nasa.gov to ensure that the new design(s) are acceptable. Note that you may want to make extra copies of your test objects to keep because the objects sent to NASA won't be returned,

It is highly recommended that you conduct your own microgravity trials: Consider putting trial objects with water in a plastic jar or container and dropping the jar in front of a video camera to get a glimpse of what happens in microgravity. Just a 4-foot fall provides 0.5 seconds of microgravity, which 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**.**

Once your object(s) are ready, ship your test object(s), with appropriate care in packing, to the following address. The object(s) must **arrive at NASA by no later than February 15, 2019**.

Plant Watering c/o Nancy R. Hall
NASA Glenn Research Center
21000 Brookpark Road, MS 77-7
Cleveland, OH 44135

Late objects will be disqualified from the competition!

3. Analyze & document the results mid-December to May 1

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 test object(s) are completed and the microgravity test 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 test object(s) has been finalized. But of course, you'll need to wait until the tests have been conducted to write the results, discussion, and conclusions. Furthermore, the abstract should be the last section of your paper to be written.

There is no required format for the written report, but 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.

3.2 Analyze results

NASA's goal is to electronically provide the test data to each team within two weeks of their tests and by at least April 1, with objects tested in the order received at NASA. For each test, the data will consist of a video filmed at 30 frames per second showing the objects' motion during the drop tests, tentatively supplemented by still images taken from the video.

One option for analyzing the video results is through NASA's Spotlight software.

For Macintosh computers, use Spotlight-8. For Windows computers, use Spotlight-16. Many NASA researchers are now instead using ImageJ, which is freely available from the National Institute of Health (NIH). Meanwhile, the free Tracker software is shared by Open Source Physics as a tool for "physics teaching and student activities." The Tracker software has notably been used by some participants in past drop tower challenges.

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 cross-hairs 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, 2018.

4.0 Presentation at ASGSR Conference

4.1 present at the 2018 ASGSR conference *mid-May to fall 2018*

Based on their scores and written reports, some teams will be invited in mid-May to present their results in a student session at this annual meeting. All participating teams will be contacted by e-mail about the selections.

The meeting dates and location have not yet been announced, but it is expected that the conference will be held in October or November with the student day on a Saturday. Admission will be free on that day for a limited number of students who present their posters at the conference, as well as accompanying advisors and chaperones. The free admission does not include meals or participation in the evening

banquet, although tickets may be purchased for the latter.

It is tentatively expected that financial support will be made available to help invited non-local teams travel to the conference for this purpose. That anticipated travel support is unlikely to cover the full cost of the trip, so teams will need to take action to address the likely shortfall. The travel support will likely be up to $500 per student presenting at the conference.

Awards will be presented to teams on the student day based on their posters and success with the challenge. The conference will also include opportunities for students to participate tour the exhibit hall, attend research presentations, and interact with microgravity researchers and other students.

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 home schools participate?
A: Yes, where teams don't need to be affiliated with a school at all and can be formed from any group of youth in grades 9-12 including siblings, neighbors, and friends as a few examples. But note that preference in proposal selection will be given to teams over individual participants.

Q: Does the number of objects proposed affect the odds of selection?
A: Preference will be given to plans with two or more objects because their results can be compared. Keep in mind that each team is limited to a maximum of three test objects.

Q: Where do we get the entry form?
A: An entry form can be found in Appendix or on the Plant Watering in Microgravity website

Q: What file formats are acceptable for the proposals?
A: The proposals must be submitted as either doc or pdf files. Teams submitting their proposals in other file formats risk rejection.

Q: Are drawings required for the proposals?
A: Yes; each proposals must include both descriptions and drawing(s) of each test object(s). The drawing(s) must be 'pasted' into the proposal, so the proposal will consist of a single file.

Q: What is the maximum file size for the proposals?
A: Each proposal's file must be less than 10 MB or it will not be deliverable to the challenge staff.

Q: Can we build test object(s) using a 3-D printer?
A: Yes.

Q: Can we simply buy test object(s)?
A: Yes.

Q: Do we get our test object(s) back?
A: No

Q: Is the water used in the drop tests distilled, de-ionized, etc.?
A: It is simply tap water at room temperature that will tentatively be dyed with food coloring to allow us to better see the fluid behavior.

Q: Can a team submit more than one proposal?
A: No, because a student cannot be part of more than one team. However, your organization (e.g.,

school, Scout troop, club, etc.) can submit up to five proposals.

Q: **When you say "test objects must sink", does that mean the object must be totally submerged?**
A: No, it needs to be partially submerged.

Questions?

If you can't find the information you need at the challenge website, or www.facebook.com/NASA.celere, then e-mail Ed-DropTower@lists.nasa.gov.

APPENDIX A – PLANT WATERING ENTRY FORM

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	**School/organization/group**	
D	**City (or township, etc.)**	
E	**State or territory (etc.)**	
F	**Student grade level(s) [9 10 11 12]**	
G	**Number of students on the team**	
H	**Team name (if any)**	

Notes

A All teams are required to have an adult advisor, such as a teacher, group leader, parent, or guardian.

D-E The city and state (etc.) should be that of the school/organization/group rather than that of the advisor or student participants.

F The Plant Watering in Microgravity challenge is open to teams in grades 9-12, where selection preference will go to teams over individuals. Multi-grade teams, e.g., as might be found in a science club, are acceptable.

EXPERIMENT INFORMATION		
1	**Experiment name**	
2	**Research question**	
3	**Hypothesis (optional)**	
4	**Number of test objects (max 3)**	
5	**Materials from which the object(s) will be fabricated, including any coatings**	
6	**Test object dimensions**	
7	**How do the objects differ?**	
8	**How are the objects the same?**	
9	**Analysis plan (optional)**	

Notes

2 The research question should be specific to the object(s). Generic research questions, such as “which object will rise the furthest?” are inappropriately vague.

4 The experiment should include two or three objects to allow comparison of results.

5 To the best of your ability, list the materials from which the objects are planned to be made including any coatings.

7 A brief description of an analysis plan is requested, but it is optional and will not be used in the selection process.

DRAWINGS

Drawing(s) of the test object(s) are required. They must be pasted into this entry form (e.g., below), where attaching them as separate files is unacceptable. The drawings must show the planned dimensions of each test object and should also show the orientation in which they should sit in the water vessel prior to free fall. **Please note that that some jostling will occur as the drop package is transported to the top of the drop tower, so this should be considered in the design of your objects.**

The drawings can be (1) drawn by hand and scanned or photographed, or (2) they can be created on the computer, e.g., using 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 the 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 file must be less than 10 MB.

SUBMISSION

This entry form must …

1. be completed in English,
2. include drawing(s) of the test object(s) with dimensions labeled as described above,
3. be submitted in either a .doc or .pdf format,
4. be named Plant_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<EntryAbbreviation>, where an example is Plant_OH_JGHS_Smith_Team1,
   The abbreviations for eligible states, territories, etc. is provided below for reference. The entry abbreviation can be the team name (if short) or initials or some other short designator which will distinguish between multiple entries from the same advisor.
5. be less than 10 MB in size (where, in contrast, there is no limit to the number of pages),
6. be e-mailed to Ed-DropTower@lists.nasa.gov by no later than November 15, 2018.

The adult advisor should either be cc'd with the submission e-mail or personally submit it on behalf of the team. As a reminder, an organization (e.g., school) may submit no more than 5 entries. Each entry should be e-mailed individually.

QUESTIONS

If you still have questions after checking …

(1) this instructions guide,
(2) the entry form, and
(3) the website, i.e., https://spaceflightsystems.grc.nasa.gov/education-outreach/drop-tower-challenge/,

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

STATE 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**				

APPENDIX B – Suggested Internet Links

Plant Science

For an introduction to the research to enable farming in space, check out these videos:
www.youtube.com/watch?v=y9aR2-7sOjg
www.youtube.com/watch?v=M7LslyCX7Jg
Educator resources with relevant classroom activities can be found at:
www.nasa.gov/audience/foreducators/spacelife/topics/plants/index.html
A social-media option for following the ongoing research includes:
www.facebook.com/spacebiology.
A Researcher's Guide to International Space Station Plant Science:
www.nasa.gov/sites/default/files/atoms/files/np-2016-06-016-jsc_plant_research_mini_book508c.pdf

Microgravity

What is Microgravity?:
www.nasa.gov/centers/glenn/shuttlestation/station/microgex.html
2.2 Second Drop tower:
www1.grc.nasa.gov/facilities/zero-g/

This YouTube video shows a middle-school student team's ping pong ball in water during microgravity in the 2.2 Second Drop Tower.
www.youtube.com/watch?v=wOqYCt-n2ts

How to conduct your own microgravity tests

Fire in Free Fall with tests conducted in a dropped box with a camera by Physics Girl, Dianna Cowern (http://physicsgirl.org/, www.pbs.org/show/physics-girl/):

Different types of surfaces

Hydrophobic Surfaces:
http://soft-matter.seas.harvard.edu/index.php/Hydrophobic_Surfaces
Video of hydrophilic object (Ping Pong Ball on Water)
www.youtube.com/watch?v=wOqYCt-n2ts
Video of hydrophilic object (Ping Pong Ball on Water)
www.facebook.com/NASA.celere/videos/1602830553111832/
Hydrophobic and Hydrophilic Surfaces:
http://news.mit.edu/2013/hydrophobic-and-hydrophilic-explained-0716
Superhydrophobic surfaces
www.lawrencehallofscience.org/sites/default/files/pdfs/college_resources/modules/Superhydrophobic/Superhydrophobic_Surfaces.pdf
Lotus Effect
www.hk-phy.org/atomic_world/lotus/lotus01_e.html
Hydrophobic and Hydrophilic
https://news.mit.edu/2013/hydrophobic-and-hydrophilic-explained-0716

Analysis software

ImageJ

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

Mac – use Spotlight-8. Windows – use Spotlight-16.

https://spaceflightsystems.grc.nasa.gov/spotlight/

Tracker

http://physlets.org/tracker/

A Guide to Writing a Scientific Research Paper

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3528086/