

2021 DROP TOWER CHALLENGE

Droplet Ejection



<https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2021-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, a surface's shape can affect how liquids behave on it, for example within a channel or container. Furthermore, hydrophobic (water-fearing) and hydrophilic (water-loving) surfaces or coatings can have additional effects which are more pronounced in microgravity.

What? Teams of 9-12 students are challenged to design and build simple devices which use capillary flow (only) to eject water droplets as far as possible [while they fall](#) down 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 2021 meeting of the American Society for Gravitational and Space Research ([ASGSR](#)).

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. **To be clear, this challenge is not open to participants outside of the United States, with the exception of the DODEA schools, regardless of citizenship!** 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. Only a few top-performing teams will be invited to participate in the ASGSR conference.

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A. THINGS TO KNOW

Calendar

Now	open for proposals
Nov. 10, 2020	deadline for e-mail submission of proposals to NASA
Mid-December	teams selected for testing announced by NASA
Dec.-February	preparation of test objects
Feb. 15, 2021	deadline for objects to arrive at NASA
Feb.-March	objects tested in NASA’s 2.2 Second Drop Tower
May 1, 2021	written report due to NASA
Mid-May	teams selected for ASGSR participation announced by NASA
Fall 2021	annual ASGSR meeting (<i>presumably in Oct. or Nov.</i>)

It is possible that the COVID-19 pandemic may delay testing and subsequent activities, where the challenge staff will notify selected teams of any schedule changes.

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 no more than 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 40 mm
- **Prohibited materials:** 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. If you choose to construct an object using a fragile material (e.g., glass), it must be packaged carefully to prevent

it from breaking during shipping and keep the challenge staff safe.

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 evaluated based on the following:

1. Performance during testing in the 2.2 Second Drop Tower
2. Team's analysis
3. Team's final report

Failure to submit a final report by the deadline will disqualify a team from being selected for ASGSR participation regardless of their test performance!

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, but some draft text can be written during the second phase*
4. present at the 2021 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 in order to have results to analyze and write about in 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 2021 ASGSR conference (phase 4).

1. Prepare your proposal

1.1 Understand the challenge

The goal is to design and build an object which will cause water droplets, to be spontaneously ejected upward as far as possible due to capillary forces (only) when they enter microgravity conditions.

Scoring: An object's score will be calculated based on the vertical distance travelled by the ejected droplet(s). If water is not ejected from the nozzle, the vertical distance travelled inside the nozzle will be used (although there will be a point penalty for no ejection). For this reason, we recommend making your nozzles out of a clear or translucent material so that the water rise can be observed. If your nozzle is opaque, you won't earn any points if the water isn't ejected. In case of a tie, the winner will be the team with the largest droplet ejected. If there is still a tie, the team with the most droplets ejected will be the winner.

[Capillary action](#) occurs when the attraction between the liquid and the surface (adhesion) is stronger than the the liquid's attraction to itself (cohesion). The adhesion/cohesion balance affects how liquids interact with a surface and can cause the liquid to move, for example when the force of gravity seems to disappear. [Recall, that motion (or a change in motion) occurs when forces are not balanced.] The geometry of the surface, including both the shape and dimensions, can influence the resulting motion.

A surface's properties can also affect liquid interactions, where their influence can be particularly strong 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](#).

1.2 Watch video of droplet ejection

Droplet ejection in microgravity can be seen in the video clip at www.youtube.com/watch?v=JXKM6D9rPis. Please know that the challenge staff will **not** share additional details of how the spontaneous capillarity-driven droplet ejection was achieved, 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. Note that the referenced video used silicone oil, while this challenge uses water. These fluids have different properties that determine how each rises up a nozzle.

1.3 Develop your test object concepts

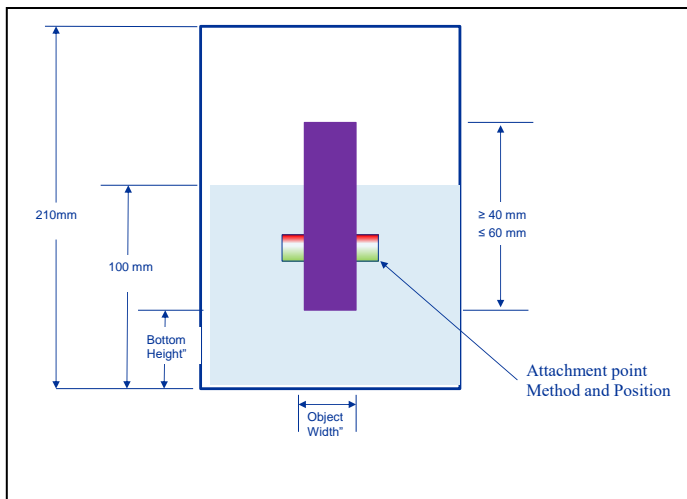
Design – Based on your research, design your test object(s) using the guidelines below to achieve the highest score as described in the previous section. Note that NASA will provide the rest of the experiment hardware including the water (which will tentatively be colored), the three water containers 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. Using multiple objects allows a team to compare test results, for example in the

required report and - if invited - at the 2021 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 should be fabricated from transparent material such as plastic or you risk a scoring loss as discussed in section 1.1. Glass and similarly fragile materials are acceptable with proper packaging. Coatings, if any, must also be transparent or you similarly risk a scoring loss. 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 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 is 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 100 mm (4.0 in). The team may specify if a certain orientation is required for their object, 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 40 mm (0.241.575 in).

Water Rise – In microgravity conditions, the water must rise

because of the object’s capillary action associated with the objects’ shape and surface properties 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, shown in Appendix B which will be available online as a stand-alone document. The proposal shall include information about your team plus descriptions and depictions of your test object(s). It must be written in English and 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. 10, 2020. More precisely, your proposal must be e-mailed to NASA by no later than midnight 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 who've been selected for testing may continue to the next phase.

2. Build your test object(s)

Assuming that your team is selected for participation in the testing, build your test object(s) 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 test object. It is acceptable to change your designs, e.g., based on research conducted after your proposal submission. However you are strongly encouraged to check with Ed-DropTower@lists.nasa.gov to ensure that any new designs 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. For example, you could display them at your school or perhaps even the ASGSR conference.

It is highly recommended that you conduct your own microgravity trials: Consider putting trial objects with water in a plastic jar 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 objects are ready, package them to prevent breakage during shipping and injury to challenge staff. Although a team's objects should be shipped together in one box, each object should be packaged individually. An object's individual package can be as simple as a resealable plastic bag, but the package must be labeled (e.g., with a permanent marker) with the organization name, team or experiment name, and the nozzle number or other identifier. An advisor with multiple teams may ship their objects together to NASA, making such labeling even more important. But note that the shipment of more than three objects by a team is unacceptable even if more than three different nozzles were built. Three is the 'magic' number and **each team must chose no more than three objects to ship to NASA.**

Ship the objects to the following address, where they must **arrive at NASA by no later than February 15, 2021.**

Droplet Ejection 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 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 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.

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

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. However, please recognize that it is possible that testing and subsequent activities could be delayed as a result of the COVID-19 pandemic. The challenge team will contact participating teams if this happens.

For each test, the data will consist of a video filmed at 30 frames per second showing the water motion during the drop tests, tentatively 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 the droplet motion. 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 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 2021, more specifically by midnight in your time zone. Note that the report must be written in English.

4. Present at the 2021 ASGSR Conference

Based on their performance in the drop testing 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.

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. It is expected that 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 student-day 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 invited student presenting at the conference.

Additional awards will be presented to teams on the student day based on their poster presentation. The conference will also include opportunities for students to 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; 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: 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. Students from other schools outside of the USA are not eligible, even if they are U.S. citizens.

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: <https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2021-drop-tower-challenge/>

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: Can proposals or reports be submitted in a language other than English?

A: No.

Q: Are drawings required for the proposals?

A: Yes; your proposal must include descriptions and drawing(s) of each test object(s). The drawing(s) must be 'pasted' into the proposal, so that the proposal consists 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: Will 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, and a student can only be a member of one team so a student cannot be part of more than one proposal. However, your organization (e.g., school, Scout troop, club, etc.) can have as many as 5 teams submit proposals.

Questions?

If you can't find the information you need in this guide (for example in the FAQs section) or at the challenge [website](#), then e-mail Ed-DropTower@lists.nasa.gov.

APPENDIX A – Suggested Internet Links

Droplet Ejection Challenge

<https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2021-drop-tower-challenge/>

Microgravity

What is Microgravity?

www.nasa.gov/centers/glenn/shuttlestation/station/microgex.html

2.2 Second Drop tower

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

How to conduct your own microgravity tests

with tests conducted in a dropped box with a camera by Physics Girl, Dianna Cowern

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

<http://physicsgirl.org/>, www.pbs.org/show/physics-girl/

Capillary Action

Capillary Action and Water

www.usgs.gov/special-topic/water-science-school/science/capillary-action-and-water

Spontaneous Capillarity-Driven Droplet Ejection

www.youtube.com/watch?v=JXKM6D9rPis

Different types of surfaces

Hydrophobic and Hydrophilic

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

Hydrophobic Surfaces

http://soft-matter.seas.harvard.edu/index.php/Hydrophobic_Surfaces

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-physics.org/atomic_world/lotus/lotus01_e.html

Video of hydrophilic object (Ping Pong Ball on Water)

www.youtube.com/watch?v=wOqYCt-n2ts

www.facebook.com/NASA.celere/videos/1602830553111832/

Analysis software

ImageJ

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

Tracker

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

A Guide to Writing a Scientific Research Paper

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

APPENDIX B 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 Droplet Ejection challenge is open to team members 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 or family, 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 differences among the objects. 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 objects 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 the each test object and should also show the orientation in which they should sit at the bottom of their 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 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 10 MB.

SUBMISSION

This entry form must ...

1. be completed in English,
2. include drawing(s) of the test objects with dimensions labeled as described above,
3. be submitted in either a .doc or .pdf format,
4. be named Droplet_<StateAbbrev>_<OrgAbbrev>_<AdvisorLastName>_<EntryAbbreviation>, where an example is Droplet_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), and
6. be e-mailed to Ed-DropTower@lists.nasa.gov by no later than November 10, 2020.

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 the ...

- (1) entry form,
- (2) Droplet Ejection guide, and
- (3) website, i.e., <https://www1.grc.nasa.gov/space/education-outreach/drop-tower-competition/current-drop-tower-challenges/2021-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				