Folding for Launch - Origami in Space
折り紙

Objectives
Students will:

- Discover why the Japanese Space Agency, JAXA, uses the principles of origami as a part of their astronaut selection process
- Explore the engineering marvel that is NASA's Webb Space Telescope
- Use origami principles to learn how many satellites are constructed and compacted to meet launch requirements
- Follow the Miura Folding Procedure.

Suggested Grade Level
6^{th} - 8^{th}

Subject Areas
Engineering

Timeline
60 minutes

Standards
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

21^{st} Century Essential Skills
- **Learning Skills**
  - Critical Thinking, Creativity, Collaboration, Communication
- **Literacy Skills**
  - Information, Media, Technology, Environmental

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- **Life Skills**
  - Social, Global Awareness, Listening

Background

NASA's Webb Telescope will use its superb angular resolution and near-infrared instruments to discover and study planetary systems similar to our own, analyze the molecular composition of extrasolar planets' atmospheres and directly image Jupiter-size planets orbiting nearby stars.

The Webb Space Telescope will make observations once thought to be impossible; multiple new technologies had to be invented simply to build it. The groundbreaking mirror and powerful instruments will discover and study distant planetary systems, analyzing the molecular composition of extrasolar planets' atmospheres and directly imaging Jupiter-size planets orbiting nearby stars. It will also look deep into the past, to a time when the earliest stars and galaxies were born. By extending our knowledge of the cosmos, the telescope will help us answer the compelling questions, "How did we get here?" and "Are we alone?"

Northrop Grumman is focused on ensuring that this once unthinkable achievement becomes a reality. Identified as a top priority for astronomy and astrophysics by the National Research Council, the Webb Telescope is a key program for NASA and the scientific community and is central to the nation's ground- and space-based astrophysics program. The Northrop Grumman engineers behind the program have no easy task. It has taken one hundred million hours of people's lives to build the telescope, the largest, most complex and powerful space telescope ever built. Hear from the engineers who take pride in what they're accomplishing – writing the next chapters of space exploration history. https://www.youtube.com/watch?v=rErBbFiLbVc

This lesson will focus on three areas:

1) The Japanese Space Agency, JAXA, uses the principles of origami as a part of their astronaut selection process. Candidates must fold one thousand paper cranes during a week-long observation session. Observers use this task to analyze candidates in a repetitive task under time constraints.
2) Discover the different jobs, as well as the cultural diversity, of the people involved in the development of the Webb Space Telescope.
3) The role that the principles of origami play in space exploration:
   a) Many parts of satellites and deep-space telescopes, like the JWST, unfold while in space. Scientists must figure out how to design each component to unfold properly after launch.

b) Students will discover how many satellites and telescopes are constructed and compacted to meet launch requirements, learning some of the principles of origami along the way!

Vocabulary
Hubble Telescope, NASA's Webb Space Telescope, Miura Folding Procedure, Origami, Solar Panels, Sun Shield

Materials
- Origami Paper (white, copy paper would work as well) - several pieces per student
- Pencils - 1 per student
- Ruler - 1 per student
- Scissors - 1 per student
- Paper towel tubes – 1 per student/group
- Toilet paper tubes – 1 per student/group
- Clear tape

Lesson
1. Ask students, "What IS origami?"
   a. *Origami is the Japanese art of folding paper.*
2. Discuss with students the following question: "Why would JAXA use origami as a part of their astronaut selection process?" Allow 5 - 10 minutes for a class discussion before revealing the answer.
   a. *During a week-long continuous observation session, candidates have to fold a thousand origami cranes. These cranes are then analyzed by a team of psychologists to see how the person deals with boring, repetitive tasks and time constraints. The psychologists check whether the folds get less precise at the end of the task and see how they compare with the first ones.* (see Image One - Origami Paper Crane)
3. Show students the following video, "Master of Folds." This video highlights the work of NASA physicist, and origami legend, Robert Lang. His groundbreaking work has helped pioneer new ways of applying origami principles to complex real-world engineering problems, including the development of airbags and solar panels that unfold after being launched into space.
   https://www.youtube.com/watch?v=DJ4hDppP_SQ

4. Show students the following video, “An Introduction to the Webb Space Telescope Mission” This video provides students with a visual image of the telescope, as well as providing insight into its mission and capabilities. https://www.youtube.com/watch?v=YF22Ba-xrk8
5. Explain to students that it will be the largest telescope ever placed in space; 100 times more powerful than the Hubble Telescope. So big it has to fold origami-style to fit into a rocket. Slowly unfolding, over the course of 3 weeks, after it has been launched into space.
6. Show students the following short videos, which all provide a look at just how it will be, “folded for launch”.
    a. “Social Media Short: How Will Webb Fit into a Rocket?” https://www.youtube.com/watch?v=noEwEAw5oCU
    b. Show students the following video, “Social Media Short: The Webb Space Telescope's Folding Mirrors.” https://www.youtube.com/watch?v=cO-zo5z7oxQ
    c. Show students the following video, “NASA’s Webb Space Telescope is Folded and Ready for its Final Suite of Testing.” https://www.youtube.com/watch?v=gNeuXhfhHc4
7. Finally, show students the following video, “Webb: Through the Eyes of Engineers.” Ask students to look for the different jobs, as well as the cultural diversity, of the people involved in the development of the telescope. Allow 5 minutes to discuss what students noticed after the completion of the video. https://www.youtube.com/watch?v=rErBbFiLbVc
8. Hand out the materials, listed in the material list above, to students.
9. Explain to students that they will be using the principles of origami to fold their own Webb Space Telescope piece, utilizing the Miura Folding Procedure.
10. Display the Miura Folding Procedure for students as a reference throughout the folding process. (see Images Two - Four below, Miura Folding Procedure).
11. Provide the students with one paper towel tube and one toilet paper tube. These objects simulate the Ariane 5 Rocket, which will launch the Webb Space Telescope into orbit in late 2021.
12. Students will have to fit their folded paper into their simulated rocket without bending it at all (they’ll find that it won’t fit into the paper towel roll). They will need to modify their toilet paper tube using scissors and tape in order to fit their folded paper into the payload (top) part of their “rocket”. They will need to attach the payload area

(modified toilet paper tube) onto the rocket body (paper towel tube) with their folded paper inside.

13. If time allows, or for students who finish early, allow them to fold their own origami paper crane. (see Image One - Origami Paper Crane)

Extensions

1. To make the activity more challenging, increase the size of paper. This could include an old poster or poster board. NOTE: Students will have to fold the paper several more times than the instructions indicate; omit the 5x7 grid. They must use the techniques they learned with the smaller paper to make their larger one a success. Teachers can decide on the size of their simulated rocket (like a 2L bottle, 1L bottle) and size of paper, depending on the level and abilities of their students.
2. For the Webb Space Telescope to fit into a rocket, it must fold up. Whether it is the primary mirror or the sunshield, many parts of Webb are designed to deploy or unfold once in space. This origami pattern of the Webb primary mirror highlights the elegant engineering and artistic inspiration behind the telescope. Click on the following link to download this origami pattern to make your own artistic version of the telescope's primary mirror. (The dark blue are mountain folds, magenta dashed are valley folds. For best results, please use at least a 16" image.)
   https://www.jwst.nasa.gov/content/features/origami.html
3. For the JWST to fit into a rocket, it must be folded up. After launch, Webb will deploy during its roughly 30-day, million-mile journey out to the second Lagrange point (L2). This 48-frame flipbook highlights how Webb deploys or unfolds like a transformer once in space. It can be made at home using paper and a binder clip. As you quickly flip through the frames, you can see an animation of how Webb will deploy in space! Click on the following link to download your own James Webb Deployment Flipbook. Piece the images together, flip them quickly, and watch Webb blossom!
   https://www.jwst.nasa.gov/content/features/flipBook.html
4. In 2021, the Webb Space Telescope will join the Hubble Telescope in the sky. Show students the following video, "Social Media Short: Hubble and Webb: Friends in the Sky," and discover the distinct features that make these missions good partners in science, working together to answer fundamental questions about the cosmos. Then, have students create a Venn Diagram, in order to support their claims as to the differences, and similarities, between the Webb Space Telescope and the Hubble Telescope.
   https://www.youtube.com/watch?v=rIChTeKmyGw

The following website is another excellent resource for students to use as they create their Venn Diagram.
https://www.jwst.nasa.gov/content/about/comparisonWebbVsHubble.html

Resources

An Introduction to the James Webb Space Telescope Mission ... (n.d.). Retrieved from https://www.youtube.com/watch?v=YF22Ba-xrk8

Comparison: Webb vs Hubble Telescope - Webb/NASA. (n.d.). Retrieved from https://www.jwst.nasa.gov/content/about/comparisonWebbVsHubble.html

Flipbook Webb Deployment - Webb Telescope/NASA. (n.d.). Retrieved from https://www.jwst.nasa.gov/content/features/flipBook.html

James Webb Space Telescope - Northrop Grumman. (n.d.). Retrieved from https://www.northropgrumman.com/wp-content/uploads/JWST_datasheet.pdf

NASA's James Webb Space Telescope is folded and ready for ... (n.d.). Retrieved from https://www.youtube.com/watch?v=gNeuXhfhHc4

Nishiyama, Yutaka. (2012). Miura folding: Applying origami to space exploration. International Journal of Pure and Applied Mathematics. 79. 269-279.

See a NASA Physicists Incredible Origami - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=DJ4hDppP_SQ

Social Media Short: How Will Webb Fit Into a Rocket? - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=noEwEAw5oCU

Social Media Short: Hubble and Webb: Friends in the Sky ... (n.d.). Retrieved from https://www.youtube.com/watch?v=rlChTeKmyGw

Social Media Short: The James Webb Space Telescopes ... (n.d.). Retrieved from https://www.youtube.com/watch?v=cO-zo5z7oxQ

Webb and Origami - Webb Telescope/NASA. (n.d.). Retrieved from https://www.jwst.nasa.gov/content/features/origami.html

Webb: Through the Eyes of Engineers - YouTube. (n.d.). Retrieved from https://www.youtube.com/watch?v=rErBbFiLbVc

www.ngst.nasa.gov. (n.d.). Retrieved from https://www.ngst.nasa.gov/education/jwst_lego_assembly_instructions.pdf

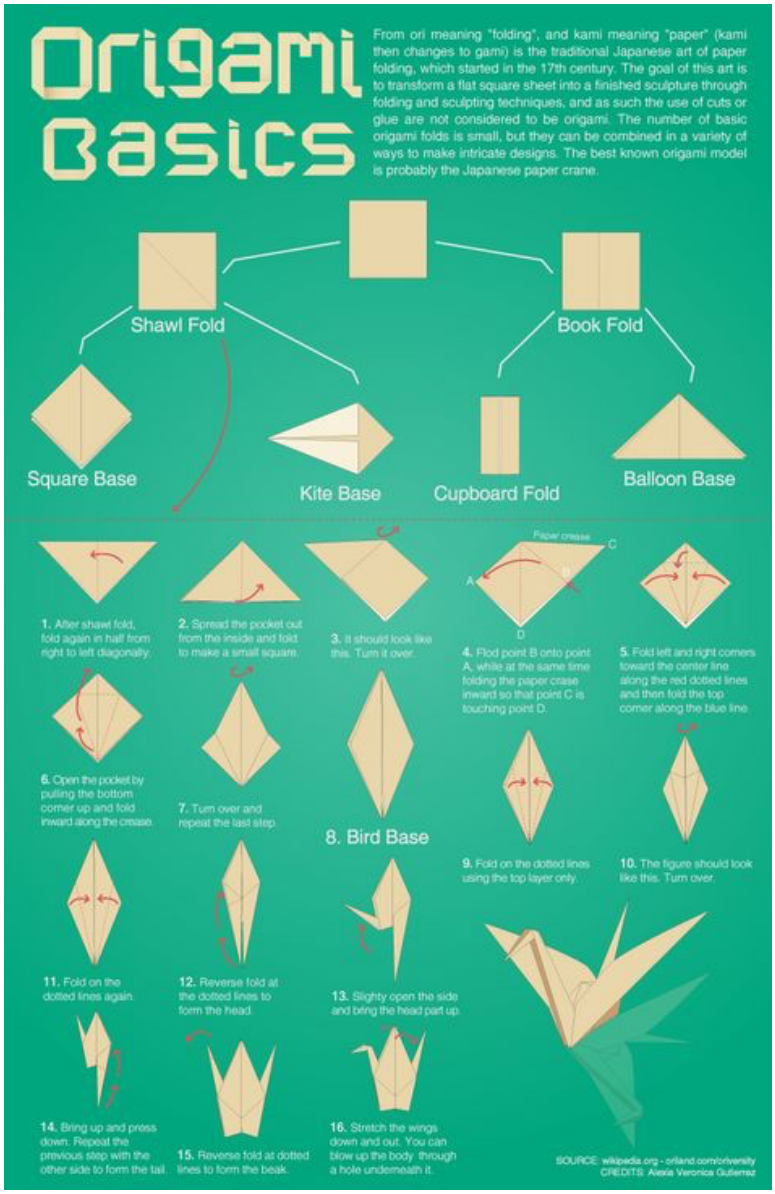
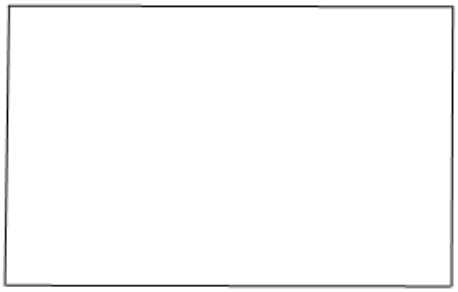
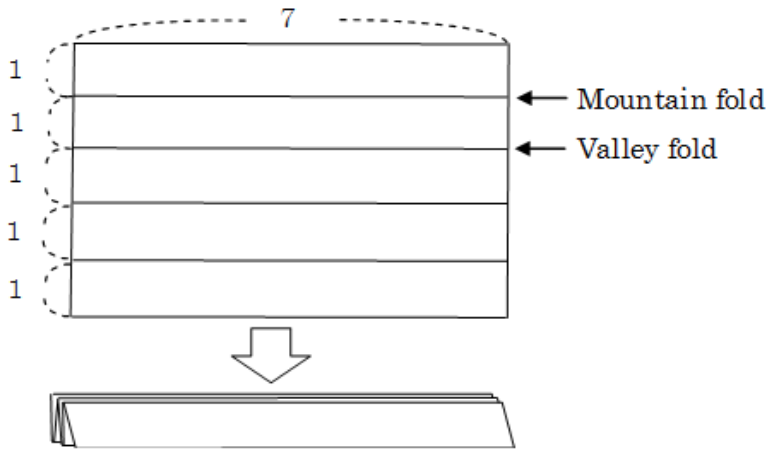


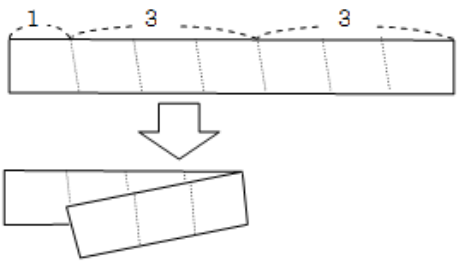
Image One - Origami Paper Crane



(1) Prepare a sheet of A3 or B4.

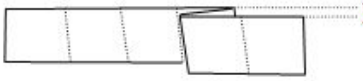


(2) Fold it into five sections vertically.

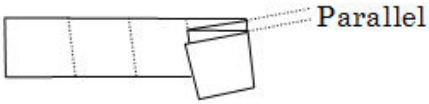


(3) Fold the length of the 3rd layer diagonally.

Image Two - Miura Folding Procedure (Steps 1 - 3)



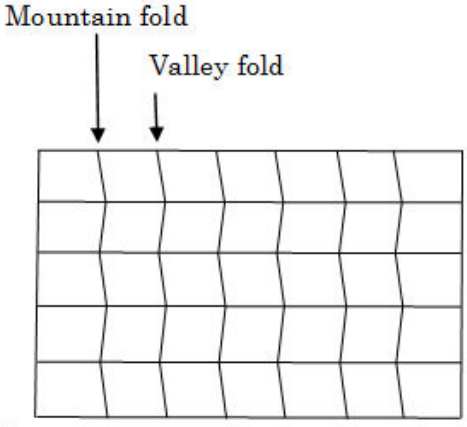
(4) Fold back the length of the 1st layer parallel to the initial line.



(5) Make a repeated zig-zag.

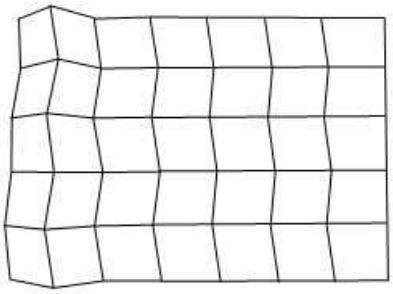
(6) Flip it vertically and fold the reverse side in the same way.

(7) At this point half of the Miura folding is now finished

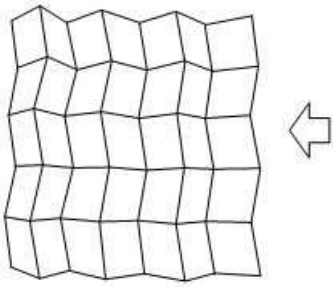


(8) Spread the paper out on a desk.

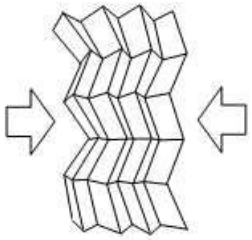
Image Three - Miura Folding Procedure (Steps 4 - 8)



(9) Fold the leftmost column with a mountain fold, and then the next column with a valley fold.



(10) Keep repeating the sequence mountain fold, valley fold, mountain fold, valley fold.



(11) Fold down the left and right.

(12) Fold down the top and bottom at the same time.

(13) The completed Miura folding

Image Four - Miura Folding Procedure (Steps 9 - 13)