National Aeronautics and Space Administration

STEM LEARNING:

Explore Flight: Supersonic Aircraft Recommendations Peformance Assessment (Grades 6-8)

www.nasa.gov

OVERVIEW

In this performance assessment, students will be asked to analyze pressure wave data from different aircraft capable of flying at supersonic speeds. Through group and individual work, students will graph data, make claims about noise levels, and present their claims and evidence to the class. Individually, students will have a chance to revise their claims, explain their reasoning, and apply their knowledge as they make a recommendation about where each aircraft should be allowed to fly.

OBJECTIVES/PERFORMANCE OUTCOMES

Students will be able to:

- Analyze and interpret pressure data by using a digital spreadsheet to graph the data.
- Construct an argument about the relative noise level of various aircraft based on evidence.
- Communicate recommendations about where each aircraft should fly based on evidence and reasoning.

STUDENT PREREQUISITE KNOWLEDGE

Students before beginning this performance assessment students should know:

- How to use a spreadsheet program to create a line or scatter plot.
- How to interpret the slope of a curve.
- Properties of waves such as amplitude, wavelength, and frequency.
- The basics of sound (pressure waves) and how sonic booms are formed.
- How to craft an argument with a claim, evidence, and reasoning.

STANDARDS

Next Generation Science Standards

Disciplinary Core Ideas

MS-PS4-1

Waves and their Applications in Technologies for Information Transfer

Crosscutting Concepts

Patterns
Energy

Science & Engineering Practices

- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

MATERIALS

- Supersonic Reader Handout (one for each student, or online access)
- Superonic Flight Recommendations Student Handout (one for each student)
- Graph or scratch paper (optional)
- Individual white boards (optional)
- One laptop or device for each student with graphic software installed or online access to an online program
- Supersonic aircraft data file

PREPARATION

- ☐ Print one copy of the student assessment for each student.
- ☐ Print one copy of the “Supersonic Reader” for each student, or use a class set, or digital access.
- ☐ Download the data file and make sure it is accessible to students on a Cloud service drive, class website, or learning management system.
- ☐ Ensure each student has access to a digital device (laptop or other internet connected device).

OTHER CONSIDERATIONS

- This activity can be completed digitally with an internet connected device, if desired.
- Consider putting the supersonic reader into sheet protectors and using dry erase markers to mark the text instead of printing a copy for each student; or use the online version and a PDF markup tool.

- Group of five work well for this assessment, as each student is then responsible for graphing one aircraft's data. Alternatively, you can have groups of four, and have one of the aircraft data sets be a "team" activity to show students to how to properly graph the data.
- Ideally, each student group should be working within a single copy of the data file per group to make analysis and revision easier. This is easy with Cloud services, but if that's not an option, make sure that each student makes their own copy of the data file from your original, or do this for them before class.
- In part B, students are asked to make a quick sketch of each of the graphs. If you have individual white boards, consider having each student make their sketch on the white board, using the same scale. During part C, where students share their claims about the aircraft, you can have students line up with their graphs in the correct order while they explain their evidence and reasoning.

OPTIONS FOR DIFFERENTIATION

- Depending on the length and of your class periods, and the level of students, this activity can be broken into two or more days. Introduce the assignment and do part A on one day, and the rest on the next class peiod(s).
- You can also choose to have "Supersonic: The History of NASA's Sonic Boom Research" be a stand-alone assignment during the unit. Simply revisit the reader during this assessment.
- If your students have studied slope, consider using line regression features in a graphing program to find the slope of parts of the graphs.
- Part E can be used as an extension activity or as evidence of a higher level of proficiency.

STEPS

1. Divide students into groups for the assessment.
2. Introduce the assessment. Read the Background, Challenge, and What is Being Assessed sections together, in small groups, or individually.
3. Ask students if they have questions and answer them as a class.
4. Pass out the Supersonic Reader (if using paper copies). Have students complete part A individually.
5. (Optional) If you choose, have a class discussion about the answers.
6. (Optional) Stop here for the day if splitting this activity between two or more class periods.
7. Part B: Hand out internet conneccted devices and direct students to the data file and the graphing program that they will use in this activity.
8. Either assign or have students decide wich aircraft's data they will graph.
9. Have students complete part B as a group.
10. Once all students have completed part B, have a group discussion where each group presents their claims, evidence, and reasoning to the class and records any additional useful information in part C.
11. Students should complete part D individually, using the information they have learned to write an argument consisting of their predicted ranking of the aircraft from quietest to loudest (the claim) supported by evidence and reasoning.
12. Students should also complete part I individually, applying new information in tables 1 and 2 to make recommendations about what land use types the aircraft should be allowed to fly, and again supporting their claim with evidence and reasoning.

TEACHER BACKGROUND

The X-59 QueSST

For decades, NASA has been researching ways to make aircraft quieter—including reducing the noise associated with sonic booms. This body of research has led to NASA's newest X-plane—the X-59 Quiet Supersonic Transport, or QueSST. This aircraft is an engineering marvel (with innovative features that have been tested in wind tunnels and through computer modeling) that will reduce the sound of disruptive sonic booms to quieter sonic "thumps."

Starting in 2023, after rigorous flight testing, the X-59 will fly over communities in the United States to collect public opinion on the quieter sonic thumps. NASA hopes that sound data from the airplane's flights along with public survey data will help the FAA change the existing regulations that prohibit supersonic flight over land and will usher in a new era of commercial supersonic flight.

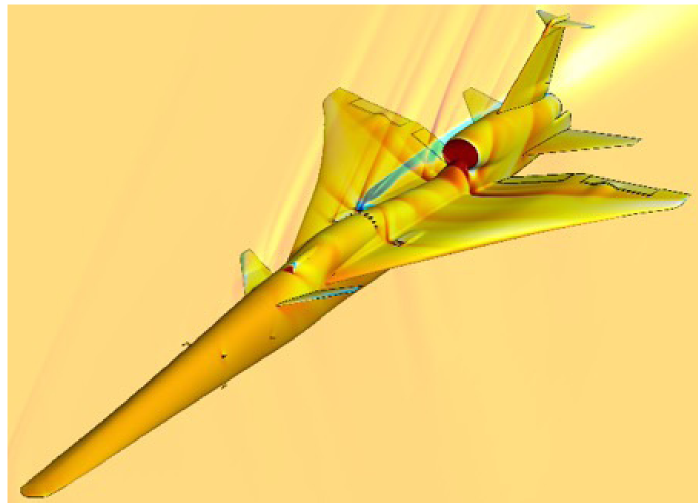

Figure 1. Air flow simulation for the X-59 QueSST.

The Sound Barrier and Sonic Booms

You may have heard the phrase "breaking the sound barrier," but what does that really mean? The sound barrier is "broken" when an aircraft exceeds the speed of sound. More accurately, it is the point at which the aircraft's speed increases from the transonic range (slower than the speed of sound) to the supersonic range (faster than the speed of sound). In rare instances, you can actually see the sound barrier being broken. The image below is an F/A-18 Hornet with a white cloud enveloping the rear of the aircraft. At the precise moment the aicraft broke the sound barrier, a large drop in air pressure behind the wing reated the cloud. Notice the smaller cloud that also formed near the rear of the cockpit, which is another sonic boom.

Pilots of jet aircraft often refer to their speed in relation to the speed of sound, using the term "Mach number," which is the ratio of the aircraft's speed compared to that of the speed of sound. Mach 1, for example, is the speed of sound. At cruising altitude, most airliners today fly at approximately Mach .80 (M .80), or 80% of the speed of sound. A sonic boom is formed once a plane begins flying faster than the speed of sound. As the plane flies, air flows from the nose around the plane and past the tail. As the plane travels faster and faster, air molecules collide and build a high level of pressure around the plane. When the plane exceeds Mach 1, the airpressure becomes a shock wave and is quickly and constantly released as long as the plane continues to fly above the speed of sound.

This shock wave is actually the comination of two shockwaves, one originating from the aircraft's nose and one from its tail, that combine and release. To a person standing on the ground, this quick release of built-up pressure produces a sonic boom, a very loud, low frequency sound that lasts less than one second. Some sonic booms are powerful enough to cause structural damage to buildings, but these are rare. The biggest concern with most sonic booms resulting from supersonic flight is that they are very loud and may annoy people if heard regularly, particularly people in the flight path. The higher the altitude of the plane and the farther the observer is from the flight path, the quieter the boom. However, even at normal cruising altitude for planes the noise is still too loud for people living near airports or along the flight path of a supersonic plane. There are a variety of ways to mitigate this unwanted noise. The answer to how the X-plane's design makes a quiet sonic boom is in the way its quniquely shaped hull generates supersonic shock waves.

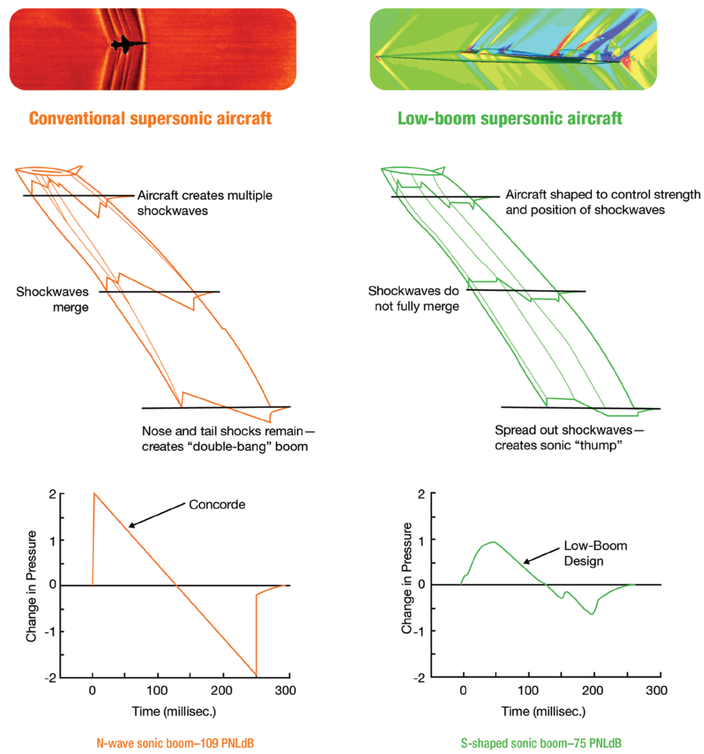

Figure 2. The relative loudness of a sonic boom can be predicted from graphing the change in pressure over time caused by the passing shock wave. The slope of the pressure spikes and the higher the amplitude of the change both contribute to the perceived loudness of the observer.

Shockwaves from a conventional aircraft design combine as they expand away from the airplane's nose and tail, resulting in two distinct and thunderous sonic booms. The X-plane's shape sends those shock waves away from the aircraft in a way that prevents them from coming together in two loud booms. Instead, the much weaker shock waves reach the ground still separated and are heard as a quick series of soft thumps, if anyone standing outside notices them at all.

Other Resources

NASA has several free, online eBooks which cover the topics in this assessment.

Quieting the Boom: The Shaped Sonic Boom Demonstrator and the Quest for Quiet Supersonic Flight

Sonic Boom: Six Decades of Research

All NASA Aeronautics eBooks

For other X-59 related curriculum:
https://www.nasa.gov/aeroresearch/X59

All about the X-59: A Digital Experience. An online introudction to the X-59 QueSST, the science of sound, and the tools and people behind the aircraft.

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NP-2019-10-2777-HQ