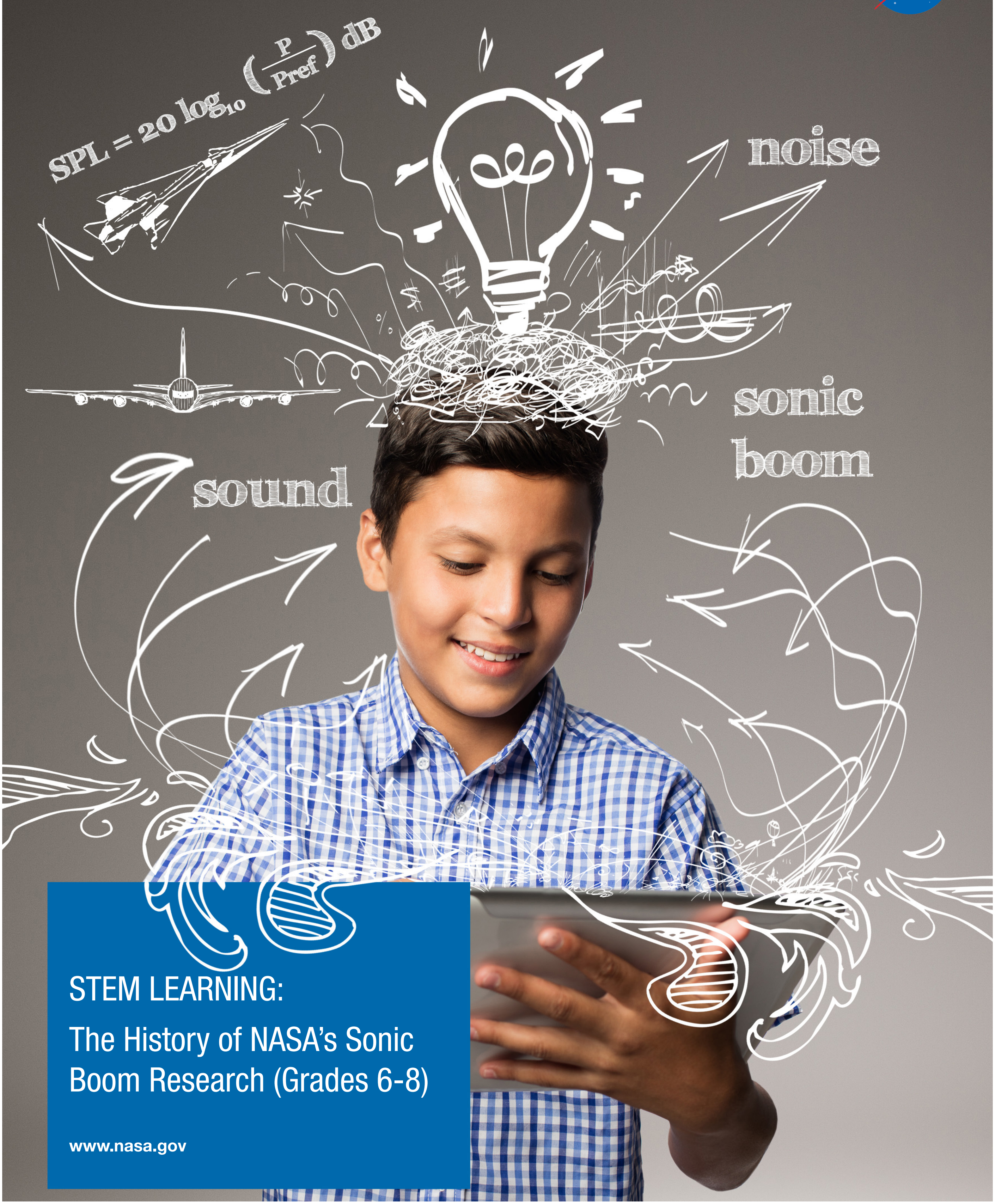
National Aeronautics and Space Administration



STEM LEARNING:

The History of NASA’s Sonic Boom Research (Grades 6-8)

www.nasa.gov

SUPERSONIC: THE HISTORY OF NASA'S SONIC BOOM RESEARCH (6-8)

WHAT ARE SONIC BOOMS?

Sound is caused by the vibration or movement of objects in a **medium** such as a solid, liquid, or gas. The vibrating object causes the particles of the medium to vibrate, too, causing a **longitudinal wave** (also called a pressure wave). Longitudinal waves have areas of higher pressure (more particles in an area or **compressions**) and lower pressure (less particles in an area or **rarefactions**). When a sound travels through the air, the pressure waves quickly reach our ears, and our brains translate them into sounds of different **amplitude** (or loudness) and **frequency** (or pitch).

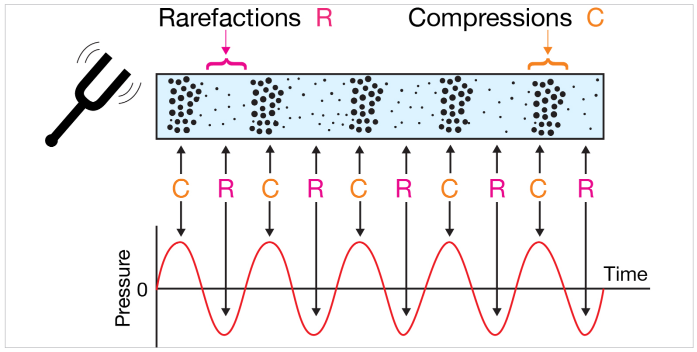


Figure 1. As an object vibrates in a medium such as air it creates a longitudinal wave (also called a pressure wave). The movement of the air particles causes areas of high pressure (compressions) and areas of low pressure (rarefactions). We can graph the changes in pressure to see how they change over time.

As an airplane moves through the air it also creates pressure waves, much like a boat moving through water creates a wake. When the airplane is moving at or faster than the speed of sound, these pressure waves join together to form a large **shockwave** behind the aircraft. This shockwave is called a **sonic boom**, because it sounds like a loud "boom" or "crack" when it reaches our ear. The shockwave caused by supersonic flight can slo cause buildings or structures to vibrate.

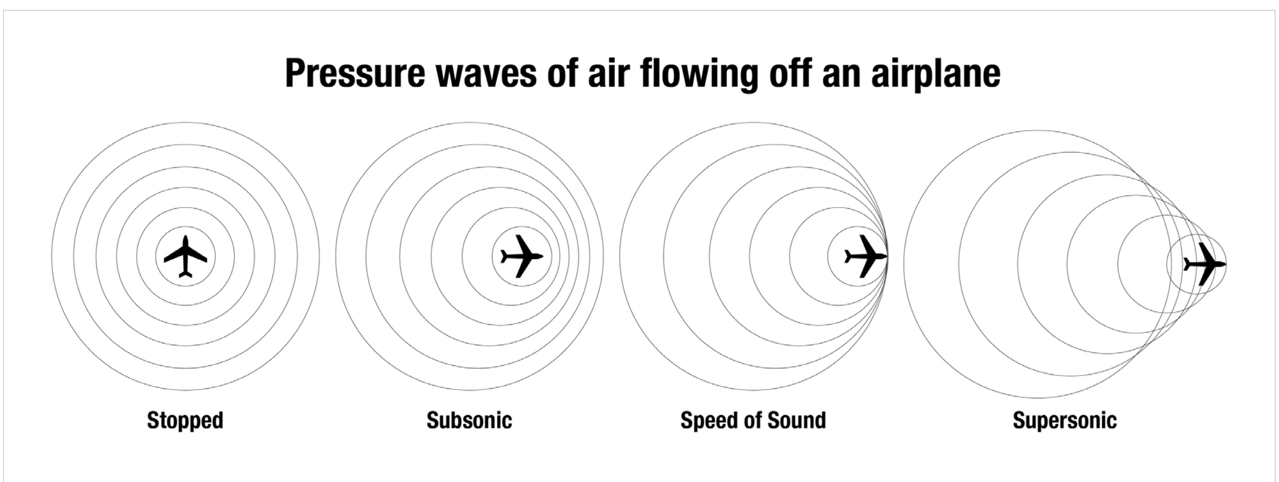


Figure 2. When an object moves faster than the speed of sound, or "supersoic," air pressure waves combine to form a continuous shockwave behind the aircraft.

NASA's SONIC BOOM RESEARCH

Believe it or not, sound travels through the air at about 767 miles per hour at sea level (1,236 km/h)! Airplanes have been able to fly faster than the speed of sound, or **supersonic**, for a long time. The X-1, piloted by Captain Chuck Yeager, was the first plane to fly faster than the speed of sound on October 14th, 1947.

Figure 3. Chuck Yeager stands in front of the X-1 airplane which he named after his wife, Glennis.

Since 1958, one of NASA's missions has been to develop commercial supersonic aircraft. In the 1960's, NASA started collecting data on the effects of sonic booms on people and structures. Between 1961–1962 in St. Louis, Missouri, NASA talked with 1,000 people that experienced a sonic boom caused by an airplane flying overhead. Ninety percent of people said that they heard the sonic boom and about 3 percent were annoyed by it.

In 1964, NASA did another sonic boom experiment in Oklahoma City, Oklahoma. This time, NASA talked to 3,000 people. Seventy-three perccent of people they talked to said they could live with sonic booms, but 40 percent said that they thought the booms caused damage to buildings and 27 percent said that they wouldn't be okay with the constant sonic booms. In the next few year, more experiments showed that people were not happy with the loudness of sonic booms. Some of the words people used to describe sonic booms were "disturbing," "annoying," "irritating," and "startling.

Other experiments on the effects of sonic booms on buildings found that sonic booms sometimes caused buildings to shake and every once in a while caused cracks in plaster, tile, and other easily broken building materials in spots where they were already weakened. People also complained about rattling windows or worried about future problems with buildings because of repeated vibrations from too many sonic booms. During all of these experiments, NASA scientists also collected sound and air pressure data. When

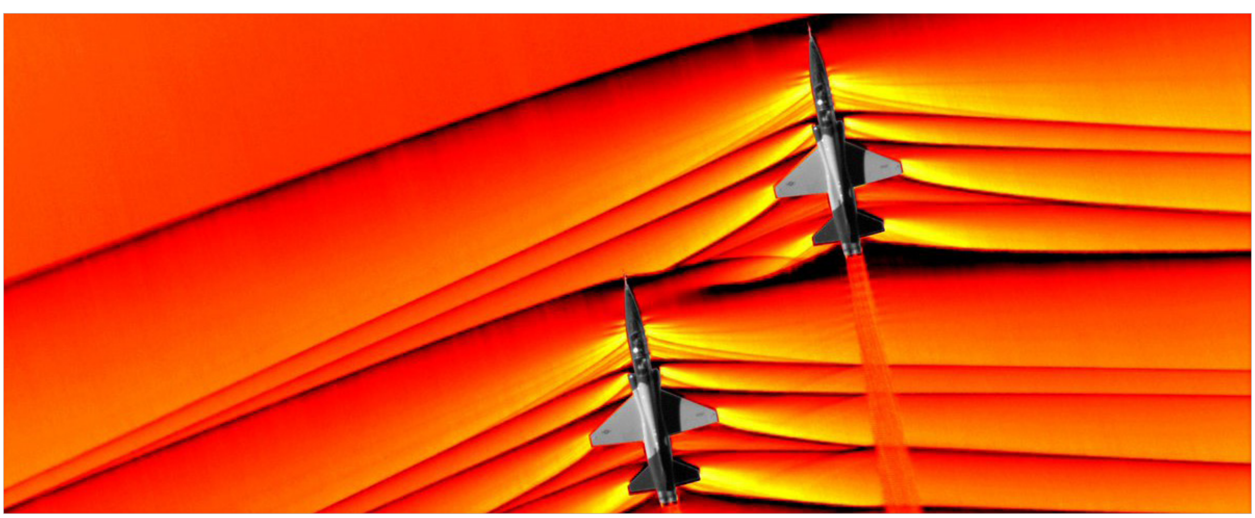


Figure 4. Schlieren photography that shows shockwaves from two T-38 airplanes flying at supersonic speeds.

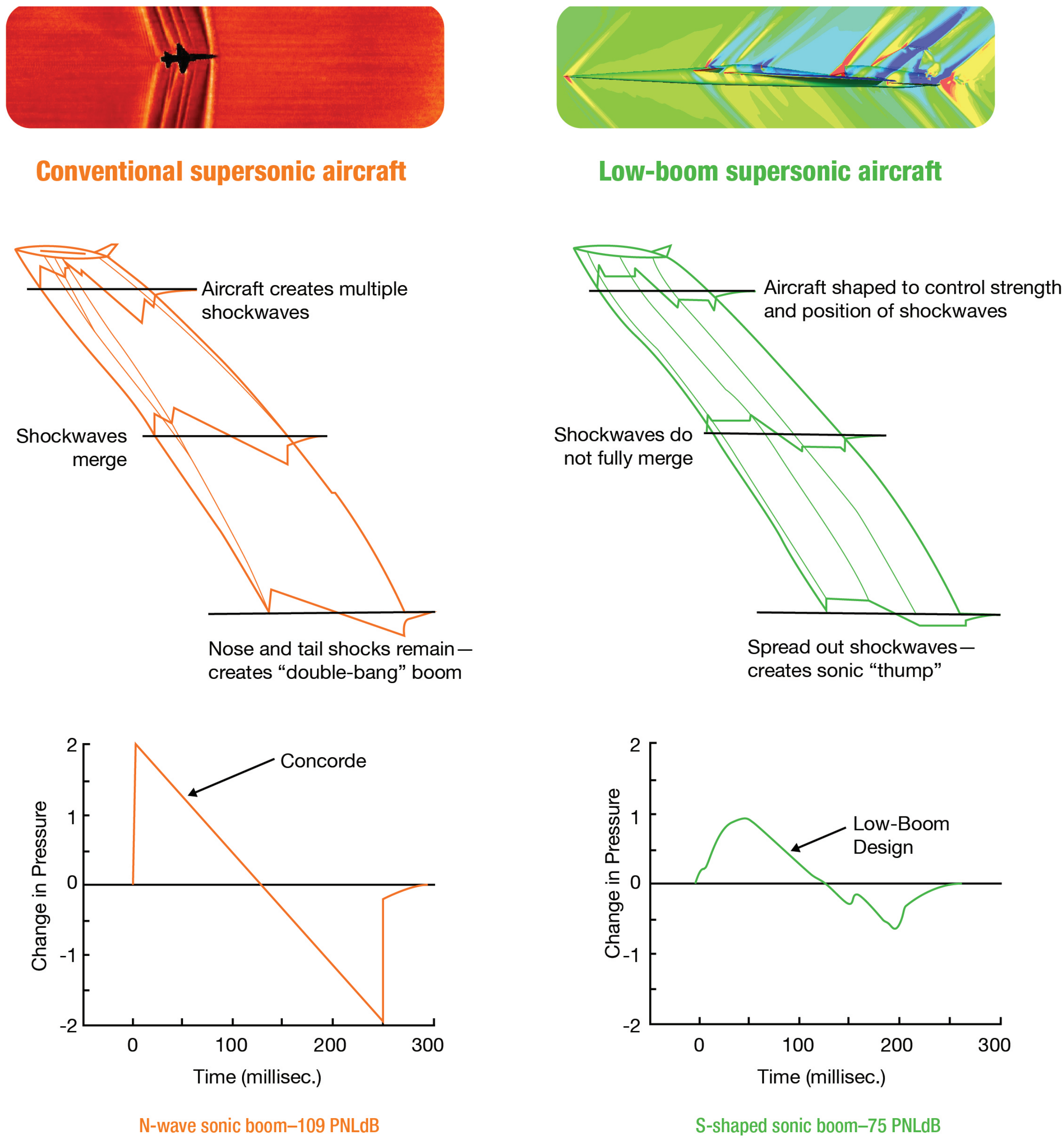


Figure 5. The shockwaves formed by a plane flying at supersonic speeds merge as they travel towards the ground. The low-boom aircraft changes the way the shockwaves merge and causes a quiet "thump" instead of a "boom."

scientists graphed the air pressure data from a sonic boom, they noticed it looks like the letter "N" (see figure 5). When they compared what people said about sonic booms to the graphs of air pressure data, they noticed that people thought the noise was more annoying when the change in pressure happened quicker. They also noticed that the more the pressure changed, the more annoyed people were. In other words, as the "N-shaped" graph of pressure change gets higher and steeper, more people complain.

After 1970, most of NASA's sonic boom research was done inside at NASA centers. NASA uses large wind tunnels that can move air at supersonic speeds over a model of an airplane instead of flying planes over cities. Also, computers became faster and new computer programs can model the flow of air around an airplane. This new type of coputer modeling is called **Computational Fluid Dynamics**, or **CFD**, and lets scientists predict where the loudest parts of an airplane will be.

Finally, NASA uses a technique called **Schlieren photography** to "see" sound waves. When research planes fly at supersonic speeds, NASA can use the images to see how the air pressure waves form around the aircraft. All of these tools help NASA understand sonic booms.

SUPERSONIC FLIGHT

In 1973, the Federal Aviation Administration, or FAA, made a new rule that commercial airplanes couldn't fly at supersonic speeds over land in the United States because of sonic booms. Some companies still designed and built supersonic jets, but these planes could only fly at supersonic speeds over the ocean.

After the rule was passed, NASA continued its supersonic research and focused on ways to reduce the loudness of the sonic boom. After decades of research, NASA introduced its newest X-plane: the X-59 QueSST, or Quiet Supersonic Technology. This experimental airplane has a special design that will reduce the sound of the sonic boom to a quiet sonic "thump." The X-59 will hold a single pilot and will fly at speeds of Mach 1.4, or 1.4 times the speed of sound.

Starting in 2023, NASA will fly the X-59 QueSST over communities in the United States. During these flights, NASA scientists will collect sound and pressure data and ask people questions about the noise from the airplane. After the experiments, NASA will share the information with the FAA, and the FAA will decide whether to change the rules to let commercial supersonic planes fly over land again. This means that you might someday be able to fly from New York to Los Angeles in half the time! Thanks, NASA!

Figure 6. The Concorde was a supersonic jet that flew between the United States and Europe from 1976–2003. Photo by Eduard Marmet.

Figure 7. NASA's newest X-plane, the X-59 QueSST, will fly over communities to measure sound levels and how people react to quieter sonic thumps.

READING COMPREHENSION QUESTIONS

1. What kind of a wave is a sound wave?

2. How do compressions and rarefactions relate to pressure?

3. What is a sonic boom?

4. What are some of the problems with sonic booms?

5. What did people say about sonic booms during NASA experiments?

6. Look at Figure 5. What are the differences between the conventional supersonic aircraft and the low-boom supersonic aircraft?

7. PNLDb stands for "Perceived Noise Level in Decibels." Do some research on the decibel scale. About how much quieter will the low-boom supersonic aircraft be that the conventional supersonic aircraft?

8. What are three tools that NASA uses in sonic boom research?

9. What is the X-59 QueSST?

10. What does NASA hope that the X-59 QueSST will do?

GOING FURTHER

1. The speed of sound changes depending on several factors. Do some research and find out what affects the speed of sound. How will the speed of sound change as an aircraft flies at higher elevations (or distance above the earth)?

2. Different types of aircraft travel at different speeds. Do some research to find out the speeds of different types of aircraft such as military jets, commercial jet aircraft, and smaller turboprop aircraft. Why do different planes have different maximum speeds?

3. On June 28, 2019, the FAA released a fact sheet about Supersonic Flight (https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22754). Skim this fact sheet and summarize key points to share with your classmates.

GLOSSARY

Medium: A substance such as air or water, which a longitudinal (or pressure) wave travels through.

Longitudinal wave: A wave where the disturbance (or source) of the wave moves in the same direction as the wave. Sound waves are longitudinal waves that travel through a medium like air or water. Also called pressure waves.

Compressions: Areas of a longitudinal wave where particles are closer together.

Rarefactions: Areas of a longitudinal wave where particles are further apart.

Amplitude: The distance between particles of the medium where it is compressed by the wave. The closer together the particles are, the greater the amplitude of the wave. The higher the amplitude of a sound wave, the louder it is.

Frequency: In a sound wave, the number of rarefactions or compressions that pass a fixed point in a certain amount of time, usually a second. Also called pitch. The higher the frequency, the higher the pitch of the sound.

Mach: A ratio of the speed of an object to the speed of sound in the fluid or other medium through which the object travels. Usually used to describe supersonic speeds; the Mach number. For example: The jet traveled at Mach 3, or three times the speed of sound (767 miles per hour, or 1,236 km/h, at sea level.

Shockwave: A quick change of pressure caused by pressure waves joining together when a plane is flying at supersonic speed.

Sonic boom: A loud noise caused by the shockwave generated by an object moving at or above the speed of sound (767 miles per hour, or 1,236 km/h, at sea level).

Supersonic: Greater than the speed of sound waves through the air.

Computational fluid dynamics: A computer program prediction of how air flows around objects.

Schlieren photography: A special way of taking pictures that shows shockwaves in the air.

MORE RESOURCES

Want to learn more about some of the things mentioned in this article? Check out the videos below.

The X-59/X-Planes
Low-Boom Flight Demonstration
History of X-Planes

Supersonic Flight
NASA Edge: The Future of Commercial Supersonic Travel

Sonic Booms
Sonic Booms and the X-59

Sound
What is sound?
What are the parts of a sound wave?

Schlieren Photography
NASA captures shockwave interaction in flight

Computational Fluid Dynamics (CFD)
Videos that shows CFD in action

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