



# What are Hypersonic Vehicles? What Are Reentry Vehicles?

## Grades 5-8

**Objective:** Upon completing this lesson, the student will be able to identify hypersonic flight vehicles and describe how they fly. The student will also be able to identify reentry vehicles and how they re-enter the earth atmosphere.

### **National Science Standards:**

- Standard A: Science as inquiry - Abilities necessary to do scientific inquiry
- Standard B: Physical Science - Position and motion of objects

### **Vocabulary:**

- [Aerodynamics](#) – forces on a vehicle caused by moving through atmosphere
- Atmosphere – the layer of gases surrounding a planet
- Attitude – the direction a vehicle points into the wind
- Deceleration – slowing down
- Dynamics – the study of how objects move
- Engineer – a person trained to use science, experiment, and math to improve our lives
- Entry – entering the atmosphere of a planet from space
- Gravity – the attraction between two objects because of their masses
- Heat Shield – a protective cover designed to survive very high heating
- Mach number – the speed of a vehicle relative to the speed-of-sound.
- Mechanics – the study of how objects respond to forces
- MSL – Mars Science Laboratory
- Orbit – the path an object follows around another object due to gravity
- Re-entry – returning to Earth from space; entering the atmosphere of Earth from space
- Scramjet – Supersonic Combustion Ramjet: an engine where the airflow through the engine always exceeds the speed-of-sound
- Shock wave – a wave that occurs in air when a plane is flying faster than the speed-of-sound
- Spacecraft – a vehicle designed for space travel
- Trajectory – the path of an object as it moves

- Vehicle – a machine made to carry people, supplies, or other things

### **Activity Websites:**

- [http://www.ehow.com/how\\_2247750\\_explain-bernoullis-theorem-experiment-kids.html#ixzz1PIpjwHo6](http://www.ehow.com/how_2247750_explain-bernoullis-theorem-experiment-kids.html#ixzz1PIpjwHo6)  
How to Explain Bernoulli's Theorem Experiment to Kids | eHow.com
- <http://www.nasa.gov/audience/foreducators/nasaclips/toolbox/guides.html>  
Educator Guides – NASA eClips
- <http://www.grc.nasa.gov/WWW/K-12/rocket/topics.htm>  
PowerPoint Slides for Educators
- <http://www.grc.nasa.gov/WWW/K-12/rocket/TRCRocket/RocketActivitiesHome2.html>  
Rocket Classroom Activities
- <http://www.grc.nasa.gov/WWW/K-12/rocket/TRCRocket/Intro.html>  
Rocket Teacher's Guide with Activities
- <http://quest.nasa.gov/space/teachers/rockets/>  
Rocket Lessons for Teachers
- <http://www2.jpl.nasa.gov/basics/index.php>  
Basics of Spaceflight
- <http://www.aero.org/education/primers/space/index.html>  
Space Primer
- <http://women.nasa.gov/a2i/>  
Women in Science, Technology, Engineering & Math Careers Info
- <http://www.geaviation.com/education/engines101/>  
How jet engines work.
- <http://science.howstuffworks.com/transport/flight/modern/hypersonic-plane1.htm>  
How Stuff Works: Hypersonic Planes

## What is a Hypersonic Vehicle?

A Hypersonic Vehicle is a vehicle that travels at least 4 times faster than the speed-of-sound, or greater than Mach 4. A hypersonic vehicle can be an airplane, missile, or spacecraft. Some hypersonic vehicles have a special type of jet engine called a Supersonic Combustion Ramjet or scramjet to fly through the atmosphere. Sometimes, a hypersonic plane uses a rocket engine. A Re-entry Vehicle is another type of Hypersonic Vehicle. A Re-entry Vehicle is a spacecraft that travels through space and re-enters the atmosphere of a planet, and most of the time, does not have an engine.



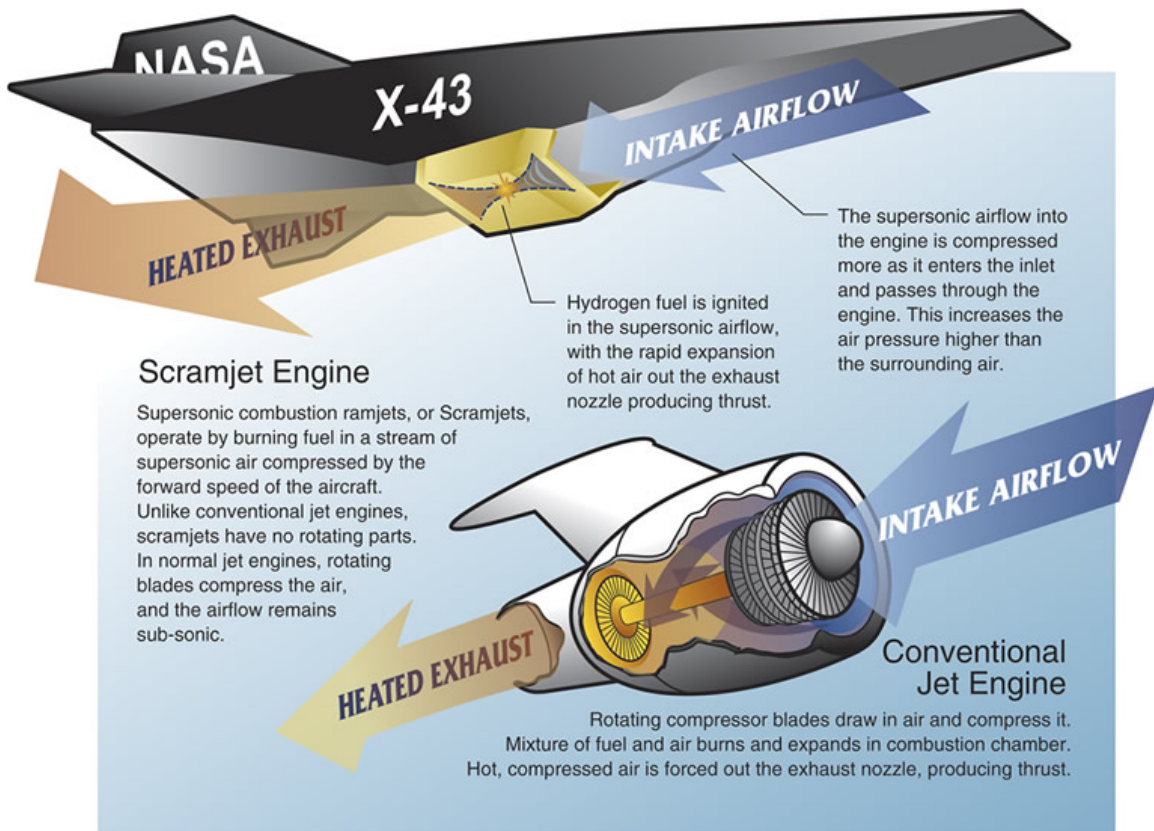
NASA Orion Re-entry Vehicle



U.S. Air Force X-51 Scramjet Engine Demonstrator

## How do Scramjet-powered Hypersonic Vehicles Work?

What is special about a scramjet engine is that the air moving through the engine never goes slower than the speed-of-sound, or Mach 1! Have you ever seen a jet engine on an airliner or fighter plane? These jet engines have spinning parts to move air through the engine. A scramjet engine does not have any moving parts and only works when the airplane is going very fast! What makes designing a scramjet engine hard is making sure that the fuel will burn in the very fast air to produce thrust. Think about what happens when you blow on the candles on your birthday cake. Figure 1 shows how the X-43 scramjet engine works. Look closely at the shape of the X-43. The entire bottom of the airplane is actually the engine! The area under the nose is used to compress, or squeeze, the air using shock waves.



NASA Dryden Flight Research Center Graphics Collection  
<http://www.dfrc.nasa.gov/gallery/graphics/index.html>  
 created March 23, 2004 by Dave Faust

X-43A engine comparison

Figure 1. How a Scramjet works (Source: NASA)

## What Is a Reentry Vehicle?

A Re-entry Vehicle could be a rocket, [satellite](#), or a manned capsule. When returning to Earth or when landing on another planet, a safe reentry through the atmosphere is needed. Safe [re-entry](#) can be difficult, because the very high speed of the spacecraft creates very high temperatures, when entering through the atmosphere. Engineers need to find ways for the spacecraft to survive these very high temperatures.

## How Do You Re-enter the Atmosphere?

The United States has been sending astronauts into space since the 1960s. To come home, the astronauts have to safely travel through the atmosphere and slow down to make a safe landing. Engineers design the vehicles to survive this entry and are called re-entry or entry vehicles.

To design a re-entry vehicle, engineers must study the aerodynamics, deceleration, and trajectory dynamics of the re-entry vehicle. Aerodynamics involves the prediction of forces produced on the vehicle by the atmosphere. Deceleration involves safely reducing the very high speed required for space flight. Trajectory dynamics involves the prediction of the vehicle's motion and steering as it flies through the atmosphere.

NASA is sending the Mars Science Laboratory from Earth to Mars. It will then land on Mars and deploy a robot to explore the planet. Figure xx below shows how the Mars Science Laboratory will [safely enter the atmosphere](#) of Mars. While still in space, the MSL points its heat shield towards the atmosphere of Mars. The heat shield is designed to survive very high temperatures. As the MSL travels through the atmosphere, it reaches a point where the temperature is highest – this is called peak heating. A short time later, it reaches a point where the rate of slowing down is highest – this is called peak deceleration. After the MSL continues to slow down, it is safe to open a parachute, to slow it even more for landing. There are different ways to land. Figure 2 shows just one way how the MSL can land.

Engineers that work in the area of “Hypersonic and Re-entry Vehicles” use their knowledge and education to design spacecraft, satellites, and rockets for spaceflight and atmospheric reentry. The design can involve hand calculations, computers, and tests.

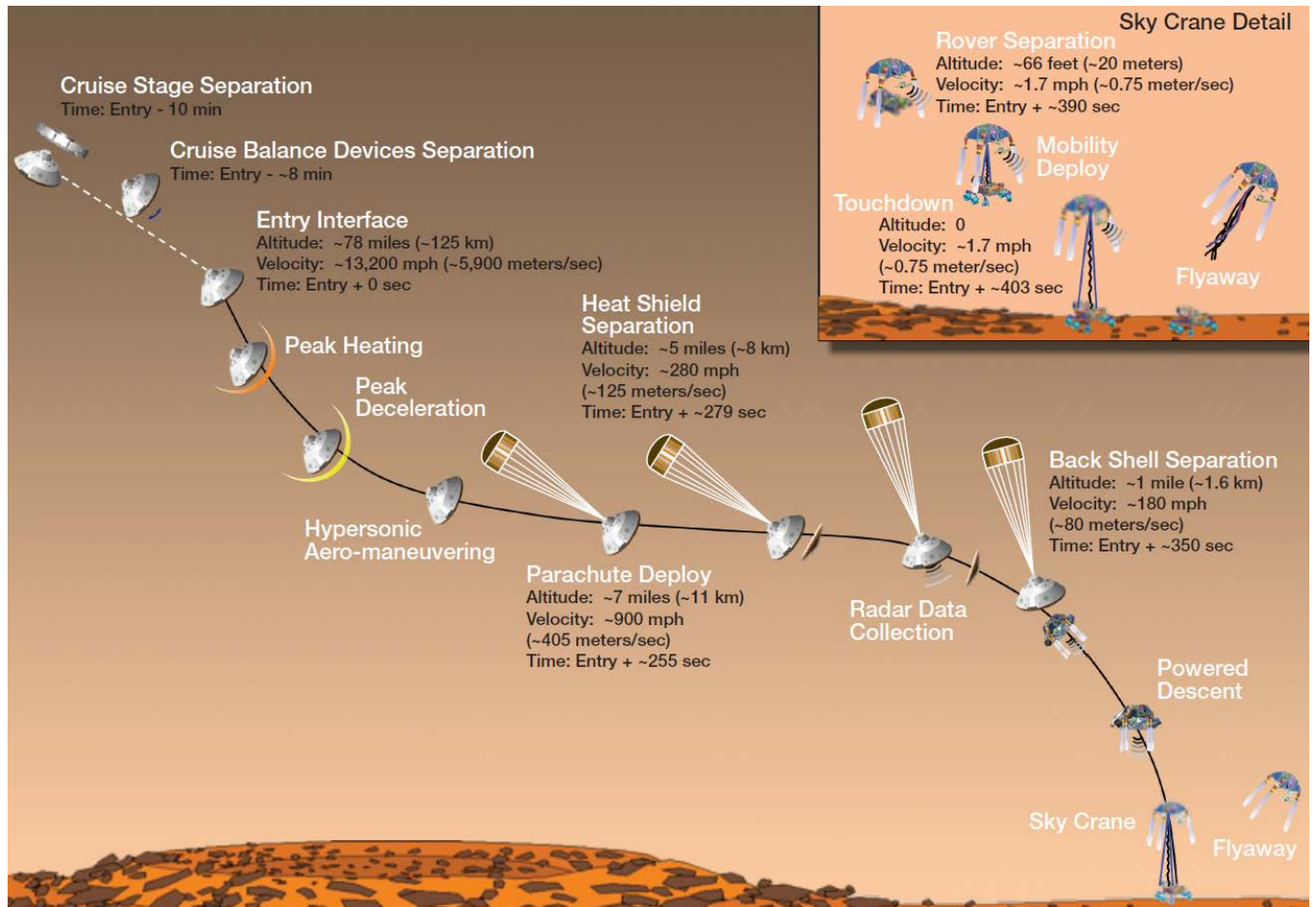


Figure 2. Mars Science Laboratory entry into atmosphere of Mars (Source: NASA)



# Fact Sheet

## Scramjet-powered Hypersonic Vehicles and Re-entry Vehicles

### Four Forces of Flight

Lift, thrust, weight, drag

### Sir Isaac Newton (1642 - 1727)

First presented his three laws of motion in the "Principia Mathematica Philosophiae Naturalis" in 1686.

### Newton's Laws of Motion

Newton's First Law of Motion states that a body at rest will remain at rest unless an outside force acts on it, and a body in motion at a constant velocity will remain in motion in a straight line unless acted upon by an outside force.

The Second Law of Motion states that if an unbalanced force acts on a body, that body will experience acceleration ( or deceleration), that is, a change of speed.

The Third Law of Motion states that for every action force there is always an equal and opposite reaction force.

### Bernoulli's Principle

States that an increase in the speed of moving air or a flowing fluid is accompanied by a decrease in the air or fluid's pressure.



# Reentry Vehicles

## K-W-L

**K** - What do I know about reentry vehicles?

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**W** - What do I want to know about reentry vehicles?

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**L** - What did I learn about reentry vehicles?

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# Scramjet-Powered Hypersonic Vehicles K-W-L

**K** - What do I know about scramjet-powered hypersonic vehicles?

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**W** - What do I want to know about scramjet-powered hypersonic vehicles?

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**L** - What did I learn about scramjet-powered hypersonic vehicles?

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