Space Shuttle

The Space Shuttle was a reusable spacecraft used from 1981 to 2011. It consisted of the Orbiter, two solid rocket boosters (SRBs), and an external fuel tank (EFT). During launch, the SRBs and the Orbiter’s engines accelerate the craft from rest to 4800 KPH in just 2 minutes. At this point, the SRBs are jettisoned and the Orbiter uses its engines along with fuel from the EFT to move it into orbit around the Earth. Once in orbit, the EFT is jettisoned. While in orbit, the crew can run experiments, dock with the International Space Station, or even repair the Hubble Space Telescope.

De-Orbit

To re-enter the Earth’s atmosphere, the Orbiter must reduce its velocity and drop down to a lower orbit in which the atmosphere is significant enough to further slow the Orbiter down through friction. To land safely on the ground, the Orbiter must lose all its energy before it lands. The amount of energy it needs to lose can be calculated using the energy equation:

\[ \Delta E = \frac{1}{2}mv_i^2 + mgh \]

Where,
- \( m \) = mass of Orbiter
- \( g \) = acceleration from Earth’s gravity
- \( h \) = height of orbiter above Earth’s surface

To solve for velocity, \( v \), we use the Vis-Viva Equation:

\[ v = \sqrt{GM\left(\frac{2}{r} - \frac{1}{a}\right)} \]

Where,
- \( G \) = the gravitational constant
- \( M_E \) = mass of the Earth
- \( r \) = radius of orbit + radius of Earth
- \( a \) = length of semi-major axis

Re-entry Physics

During re-entry, the Orbiter is travelling at over Mach 25. At these speeds, the air in front of the Orbiter becomes compressed to super high temperatures, creating plasma. This plasma can reach temperatures of over 1600 °C, hot enough to melt the Orbiter’s aluminum structure. Because of this, the Orbiter needs to be able to reduce the amount of heat that it interacts with. One of the ways it accomplishes this is by designing the nose cone such that the shockwave is pushed away from the vehicle.

Heat Shields

The Thermal Protection System (TPS), more commonly known as “heat shields,” protect the spacecraft during atmospheric entry. There are several types of heat shields including ablative and reusable. The Space Shuttle used reusable heat shields. Because the program used a reusable orbiter, the Thermal Protection System needed to be reusable as well, so ablative methods (which lose energy through the removal of material) could not be used. Instead, the Shuttle used several materials including Reinforced Carbon-Carbon (RCC) coating on the nose cone and leading edge of the wings as well as Reusable Surface Insulation Tiles (RSIT) along the nose cone and the base of the Orbiter. The RCC and RSIT absorbed, reflected, and dissipated the energy to the surrounding atmosphere. There were over 32,000 tiles on the Space Shuttle Columbia, each of which had a unique identification number corresponding to its unique placement on the Orbiter.

Space Shuttle Columbia

On February 1, 2003, the Space Shuttle Columbia was destroyed during re-entry because of the failure of its TPS. Roughly 80 seconds into launch, a briefcase sized chunk of foam and ice smashed into the Shuttle’s left wing, creating a large hole in the RCC. While the damaged RCC did not pose a threat while in space, its failure was catastrophic when Columbia re-entered the atmosphere. The hole in the RCC allowed hot gas and plasma to enter the wing, melting its aluminum structure. Moments later, the wing separated from the Orbiter, ripping the Orbiter apart, and killing all 7 astronauts.

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