6. Background

The Ares Launch Vehicles

On July 20, 1969, Neil Armstrong and Buzz Aldrin became the first humans to set foot on the Moon. They arrived there in a lunar lander, which had been propelled into orbit around the Moon as part of the Apollo 11 space flight. NASA now has plans to return humans to the Moon and eventually to Mars. NASA is designing new spacecraft to carry them there. These spacecraft are known as the Ares launch vehicles.

NASA Engineers at Marshall Space Flight Center are currently developing the launch vehicles for the next generation of space travel. The Ares I crew launch vehicle will deliver the Orion crew exploration vehicle into Earth orbit. Astronauts in Orion can then dock with the International Space Station, or rendezvous with the Altair lunar lander, put into orbit by the Ares V launch vehicle for transport to the Moon.

Ares I is a two-stage rocket. (See Figure 6.1.) The first stage is a reusable solid rocket booster (RSRB) similar to the boosters of the Space Shuttle. Its second stage is a liquid oxygen-liquid hydrogen engine similar to the upper stage engine of the Saturn V rocket, which propelled the Apollo missions to the Moon. Ares I will weigh 2 million pounds (907 metric tons) at liftoff, will stand about 325 feet tall (100 meters), more than a football field, and will deliver the Orion crew exploration vehicle to low Earth orbit (LEO).

Ares I will produce roughly 3.5 million pounds-force (15.6 meganewtons) of thrust at liftoff. The RSRB booster will burn for about 126 seconds. At the end of this burn, the rocket will be about 36 miles (58 kilometers) above Earth, traveling at a speed of 4,445 miles per hour (2,000 m/sec). The vehicle will have lost 69% of its weight by having burned up 1.4 million pounds (630 metric tons) of solid rocket fuel. The RSRB, no longer needed, will be jettisoned and will fall back to Earth, where it will be recovered to be used again. The liquid fuel J-2X engine of the Ares I upper stage will burn for about 464 seconds, producing 294,000 pounds (1.3 meganewtons) of thrust, to lift the crew module to a higher orbit at 185 miles (298 kilometers) above the Earth. In this orbit, the vehicle will be traveling at about 17,500 miles per hour (7,800 m/sec).

Figure 6.1.
Ares I.

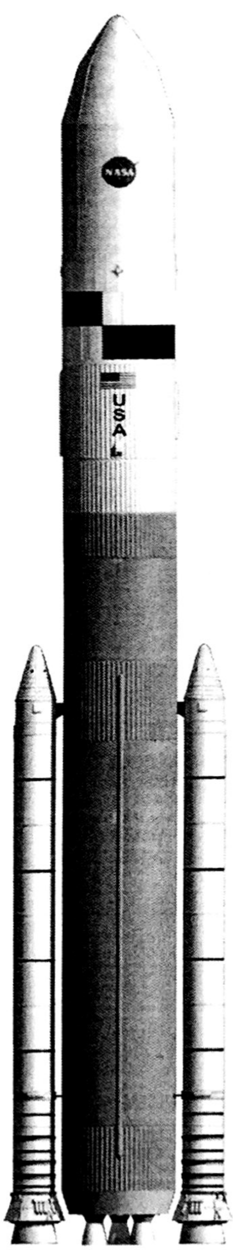

Figure 6.2.
Ares V.

Ares V, shown in Figure 6.2, is NASA's heavy-lift cargo vehicle that will enable NASA to send more crew and more cargo to the Moon than the Apollo-era Saturn V. Ares V will weigh 7.4 million pounds (3,357 metric tons) at liftoff, will stand 360 feet (110 meters) tall, and can carry 287,000 pounds (130 metric tons) to LEO. The Saturn V was 4 feet (1.2 meters) taller but weighed nearly 1 million pounds (453,600 kilograms) less than Ares V and carried approximately 39,000 pounds (17,690 kilograms) less to the Moon. Ares V has a payload shroud more than 32 feet (10 meters) in diameter for carrying more massive payloads. It is this unmatched lift capability that will not only support extended exploration of most of the lunar surface, but will also support numerous human and robotic missions of exploration beyond the Moon.

Ares V has two stages. The first stage is powered by two solid rocket boosters similar to the Ares I first stage and a core stage powered by five commercial RS-68 liquid fuel engines working together. After the boosters burn out, they fall to Earth, and the core stage continues operating to an altitude of roughly 87 miles (140 kilometers). The stage falls to Earth, and the second stage, called the Earth departure stage (EDS), ignites to place the lunar lander, Altair, in Earth orbit. The EDS is powered by the same J-2X engine as the Ares I upper stage. After the astronauts in Orion rendezvous and dock with Altair, the EDS ignites again to send the Orion, Altair, and the crew to the Moon.

Spacecraft Structures

Every pound that is carried to space requires fuel to do so, regardless of whether that pound is cargo, crew, fuel, or part of the spacecraft itself. The more the vehicle and fuel weigh, the fewer passengers and smaller payload the vehicle can carry. Designers try to keep all the parts of the vehicle, including the skeleton (or structure), as light as possible. To design a lightweight structure is very difficult, because it must be strong enough to withstand the tremendous thrust (or force) of the engines during liftoff. Throughout the history of space vehicles, engineers have used various strategies for the structure.

Students can calculate the "payload" to total weight ratios for (a) the family car and (b) a student riding a bicycle.

In order to make the Ares spacecraft as light as possible, NASA engineers are constructing them of lightweight, strong materials, such as Al-Li 2195, an aluminum-lithium alloy, which is less dense and stiffer than pure aluminum. NASA engineers also design structures that use as little material as possible to achieve the strength and rigidity they need. So, for example, they make use of a network of hollow tubular struts (called a truss) rather than use more compact, but heavier solid beams.

This engineering design challenge focuses on the Ares V thrust structure, which attaches the five liquid fuel engines of the Ares V to the body of the spacecraft. The thrust structure is an essential part of the spacecraft, which must be kept lightweight. As they burn, the five RS-68 engines of the Ares V produce about 3,510,275 pounds (1,592 metric tons) of thrust. This means that the thrust structure must bear a load equivalent to 3,510,275 pounds (1,592 metric tons) of weight pushing on it. The thrust structure must not only withstand this terrific force, it must transfer it to the vehicle in a balanced way, without damaging the vehicle.

Students may be familiar with design strategies used to make lightweight bicycles.

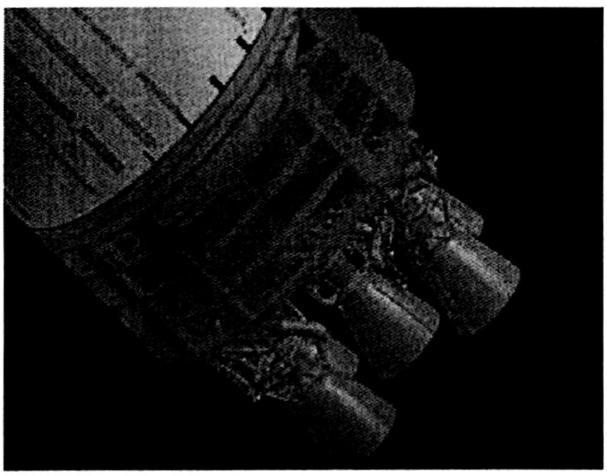

Figure 6.3. View of Ares V engines and thrust structure. This image appears in a larger version in the "Masters" section.

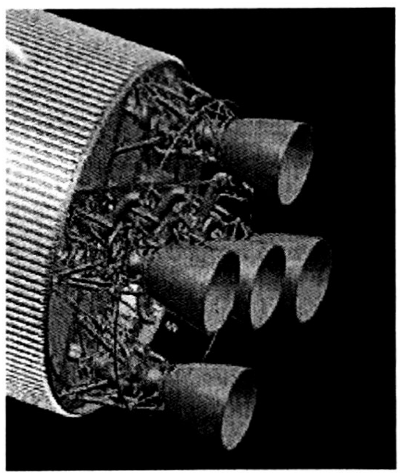

Figure 6.4. Ares V engines attached to thrust structure. This image appears in a larger version in the "Masters" section.

Figure 6.5. Ares I.

Ares I

Length: 325 feet (100 meters)

Width: 18 feet (5.5 meters)

Takeoff weight: 2 million pounds (907 metric tons)

Propellant fuel weight: 1.7 million pounds (764 metric tons)

Main propulsion: single RSRB

Take-off thrust: 3.5 million pounds-force (15.6 meganewtons)

Maximum speed: 17,500 miles/hr (7,800 m/sec)

Maximum speeds at end of staging:

Ares I First Stage: 6250 ft/sec (1,904 m/sec)

Ares I Upper Stage Orbit Injection: 25,582 ft/sec (7,798 m/sec)

Largest payload it can carry into orbit: 56,512 pounds (25.6 metric tons)

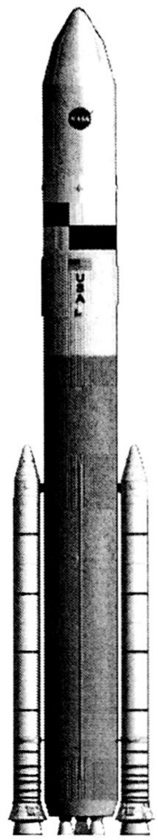

Figure 6.6. Ares V.

Ares V

Length: 360 feet (110 meters)

Core stage diameter: 33 feet (10 meters)

Takeoff weight: 7.4 million pounds (3,357 metric tons)

Core stage fuel weight: 3.16 million lbs (1,435.5 metric tons)

Main propulsion: 2 RSRBs plus 5 RS-68 liquid fuel engines

Take-off thrust: 10.65 million pounds (47.4 meganewtons)

Maximum speed: 24,462 mi/hr (10,935 m/sec)*

Maximum speeds at end of staging:

Ares V SRB separation: 3,958 ft/sec (1,206 m/sec)

Ares V Core stage cutoff: 16,227 ft/sec (14,946 m/sec)

Ares V Earth Departure Stage (orbital burn): 25,460 ft/sec (7,760 m/sec)

Largest payload it can carry into orbit: 287,000 pounds (130 metric tons)

**Trans-Lunar Injection (TLI)*

NOTE: The Ares vehicles are a very preliminary configuration and will be subject to change as the design progresses.

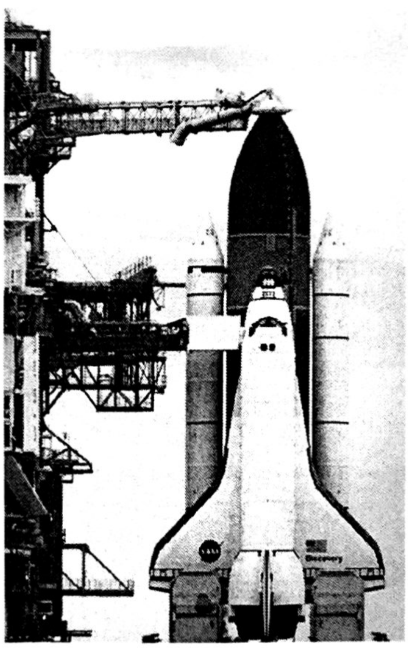

Figure 6.7. Space Shuttle.

Space Shuttle

Length Orbiter: 122 feet (37 meters),
Overall: 184 feet (56 meters).

Width Orbiter: 56.67 feet (17.3 meters),
Overall: 76.6 feet (23 meters)

Takeoff weight: 4.5 million pounds (2,041 metric tons)

Fuel weight: 4.3 million pounds, including Solid Rocket Boosters and external fuel tank (1,937 metric tons)

Main propulsion: 3 Main Engines, 2 Solid Rocket Boosters

Take-off thrust: 3.3 million pounds or (1,497 metric tons)

Maximum speed: 17,500 miles/hr (7,800 m/sec)

Largest payload it can carry into orbit: 50,000 pounds (22.7 metric tons)