technology today

Alan Pierce
pierceaj@techtoday.us

The *Curiosity* Martian Landing

On August 6th, *Curiosity*, the Mars rover, made its spectacular landing on Mars. I am writing this story a mere four days after *Curiosity*'s perfect landing, but because of lag time between the deadline for the column and the mailing of the finished magazine you won't get to read it until October. From liftoff to landing, *Curiosity* flew 352 million miles in 245 days.

Lockheed Martin

Photo 1—*Curiosity*'s aeroshell capsule has a back shell and a heat shield. Both parts have the needed thermal protection to survive the heat generated as the rover plummeted through the Martian atmosphere.

When it comes to landing a capsule or shuttle on Earth, our planet's atmosphere is thick enough to help mission control and pilots orchestrate a parachute capsule landing or winged shuttle landing. However, the Martian atmosphere is 100 times thinner than our own, making it insufficient to support a winged landing. Use of a heat shield with a parachute landing would be extremely difficult to orchestrate because Mars is too far away for earthbound controllers to handle the event. Because of the distance between planets, NASA Mission Control didn't even know if the landing worked until *Curiosity* had been on the ground for seven minutes.

A parachute landing on Mars wouldn't be simple, even if you could have people back on Earth controlling the capsule's descent. Even though the Martian atmosphere is too thin to effectively slow down a capsule, it is definitely thick enough to burn up objects from space that pass through it.

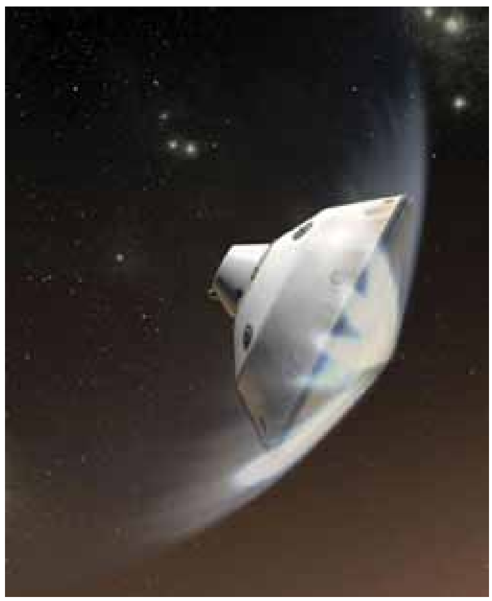
Curiosity's entry capsule, aeroshell, was designed and built by Lockheed Martin. (See Photo 1.) This capsule was designed to carry out very complex maneuvers without human assistance from controllers back on earth. The computer-controlled landing depended on a computer program that contained half a million lines of code. All tests before the landing were simulations and many things could go wrong if *Curiosity* encountered an unforeseen variable during the actual landing.

When *Curiosity*'s aeroshell capsule entered the Martian atmosphere, it was traveling at 13,200 miles per hour. During deceleration, the heat shield on the capsule reached 2,912° F. (See Photo 2.) The shield and the rest of the aeroshell capsule are covered with a cork/silicone heat shielding that burns away, keeping internal structures reasonably cool. The burning away (erosion) of an outer protective layer without transmitting heat to the inner layers is called ablation, and the tiles on the aeroshell capsule were built to withstand much higher temperatures than the capsule actually reached.

The best shape for a heat shield is a partial sphere with the rest of the capsule designed to keep the full weight of the vehicle, including its contents, behind the center of the shield. To help analyze how well the shield would function, Lockheed Martin built in sensors that collect data about the heat shield's performance. With sensors located at different depths in the tiles, sensor failures tell how much of the heat shield burned away during the descent through the Martian atmosphere.

During the intense heating of the descent, the capsule also experienced 10 g's of force created by its rapid deceleration. If the tiles and the structure of the capsule failed to handle the heat and g-forces of the landing, the engineers back on earth probably would never have found out why the mission failed.

To get to its landing location, the



NASA

Photo 2—During deceleration, the heat shield reached 2,912° F. The heat-shielding tiles slowly burn away in a process called ablation. The inside of the capsule stays cool as the outside shield takes the heat.

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NASA

Photo 3—The heat shield's shape provides the aerodynamic characteristics necessary for the aeroshell to catch Mars's thin air and fly to its landing location.

aeroshell capsule used thrusters. The computer system used the aerodynamic characteristics of the heat shield's spherical shape to catch the thin Martian air and allow the aeroshell to control its descent by flying a curved trajectory. (See Photo 3.) The slowing-down process was furthered by the release of a parachute.

Onboard computers running 500,000 lines of code piloted *Curiosity*'s landing. From the entry into the Martian atmosphere, the computer controlled every aspect of the landing. It fired the thrusters to produce the correct angle of attack to enter and fly through the atmosphere. It controlled the release of the parachute, gave the order to jettison the heat shield, directed a rocket-powered sky crane in lowering the *Curiosity* rover to the planet, and then flew itself off to a safe distance for its final landing.

What NASA accomplished with *Curiosity*'s landing is truly amazing. A NASA video entitled "Seven Minutes of Terror," found at www.youtube.com/watch?v=Ki_Af_o9Q9s&feature=player_embedded, will give you a good sense of the orchestration of the aeroshell landing. You will find links to other NASA videos online at www.technologytoday.us/page13.html.

Recalling the Facts

1. Why was the entire aeroshell capsule covered with heat-shielding tiles even though the heat shield would be on the side of the capsule taking most of the heat?
2. Define ablation and describe how NASA will determine the effectiveness of the aeroshell ablation system.
3. Why didn't NASA control each step of the landing from earth? ⓣ

Alan Pierce, Ed.D., CSIT, is a technology education consultant. Visit www.technologytoday.us for past columns and teacher resources.

More Than Fun Answers

1 – C. Wattage measures only the amount of electric energy the bulbs will use. Light output is measured in lumens, which isn't given. Compare the wattage and lumen output of a florescent bulb and an incandescent bulb.

2 – C. If the bird had a wingspan to reach both conductors, it would be electrocuted. This does occur with large birds!

3 – A. Because of the high internal resistance of the man's body and the low voltage of the battery, only a small amount of the 700 A pass through him.

4 – B. Space is a vacuum with nothing to block the signal except the earth's own atmosphere, so a low-watt transmitter can be used for less power draw on the limited supply of the probe.

5 – A. Electricity needs significant energy to jump through open air, but since it's at very low current, the person feels only a slight shock.

6 – B. Lightning exhibits properties of high ac frequencies. (That's why your radio and TV pick it up during a storm.) Such frequencies behave in a way known as the "skin effect," in which the electron flow is on the surface of the car. Note: Please don't think that 6" of rubber Insulation in your tires would stop the current flow!

7 – A. The first computers contained vacuum tubes and relays, and a bug prevented the closing of a set of relays.

8 – A. Wattage, not voltage, is the measure of electricity used.

9 – B. The third prong is a safety feature. Anything that prevents it from connecting to earth ground increases the risk of electrocution.

10 – B. Microwaves make water molecules vibrate. This movement is transferred as heat.

