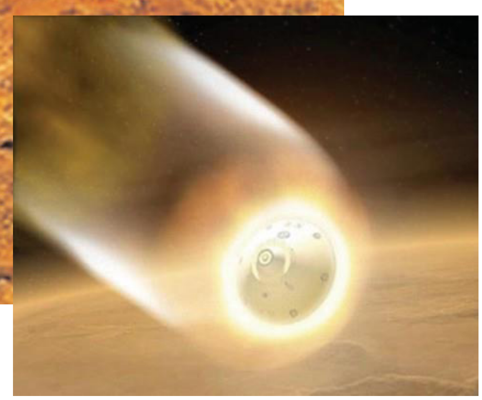
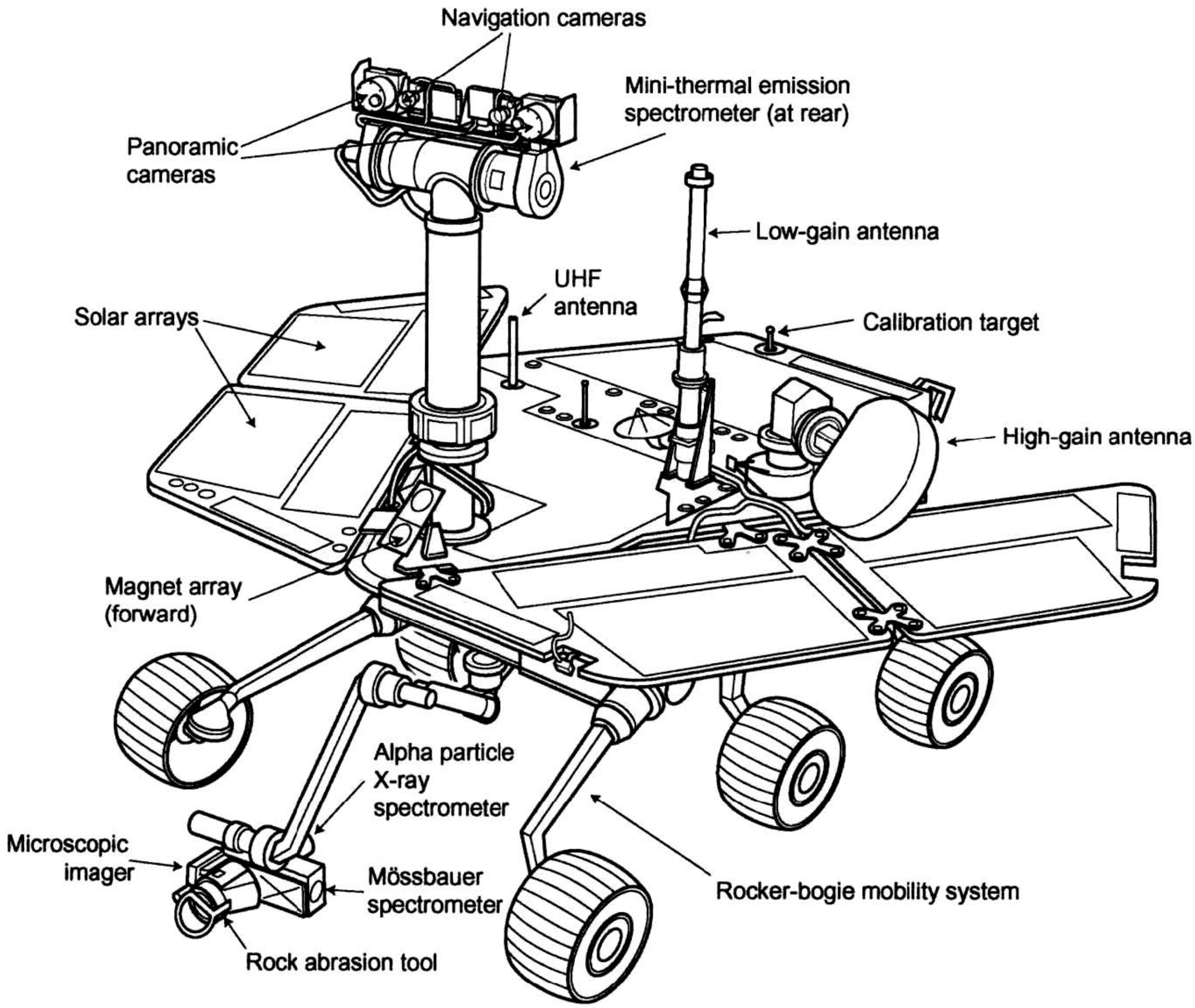
BUILD A RADIO CONTROLLED MARS SPIRIT ROVER

OBJECTIVE – This is a project that can be used at conferences, workshops, recruiting sessions, air shows and other events. It is a "standoff-scale" replica of the Mars Spirit Rover and it is powered using the running chassis of a radio controlled model race car.

The incredibly powerful Delta II rocket carried the Martian craft to its destination in space. According to NASA "Quick Facts," Spirit was launched on June 10, 2003 and landed on January 4, 2004. The distance flown, including orbits, was 303 million miles.



After a blazing entry into the Martian atmosphere, the craft was lowered to the surface of Mars.



Mars Exploration Rover

SPACECRAFT

Each of the two Mars Exploration Rover spacecraft resembles a nested set of Russian dolls. The rover traveled to Mars tucked inside a folded-up lander wrapped in airbags. The lander in turn was encased in a protective aeroshell. Finally, a disc-shaped cruise stage was attached to the aeroshell on one side and to the Delta II launch vehicle on the other.

(The following description was written prior to the launching of the Rovers).

Cruise stage

The cruise stage provides capabilities needed during the seven-month passage to Mars but not later in the mission, such as a propulsion system for trajectory correction maneuvers. Approximately 2.6 meters (8.5 feet) in diameter and 1.6 meters (5.2 feet) tall, the disc-shaped cruise stage is outfitted with solar panels and antennas on one face, and with fuel tanks and the aeroshell on the other. Around the rim sit thrusters, a star scanner, and a Sun sensor.

The propulsion system uses hydrazine propellant stored in two titanium tanks. Since the entire spacecraft spins at about two rotations per minute, fuel in the tanks is pushed outward toward outlets and through fuel lines to two clusters of thrusters. Each cluster has four thrusters pointing in different directions. The star scanner and Sun sensor help the spacecraft determine its orientation. Since the rover's solar arrays are tucked away inside the aeroshell for the trip, the cruise stage needs its own for electrical energy. The arrays could generate more than 600 watts when the spacecraft was about as far from the Sun as Earth is, and generate about half that much as it nears Mars.

The cruise stage also carries a system for carrying excess heat away from the rover's computer with a pumped Freon loop and rim-mounted radiators.

Entry, Descent and Landing System

The system for getting each rover safely through Mars' atmosphere and onto the surface relies on an aeroshell, a parachute, and airbags. The aeroshell has two parts: a heat shield that faces forward and a backshell. Both are based on designs used successfully by NASA's Viking Mars landers in 1976 and Mars Pathfinder in 1997.

The parachute is attached to the backshell and opens to about 15 meters (49 feet) in diameter. The parachute design was tested under simulated Martian conditions in a large wind tunnel at NASA's Ames Research Center near Sunnyvale, California.

The backshell carries a deceleration meter used to determine the right moment for deploying the parachute. Solid-fuel rockets mounted on the underside of the shell reduce vertical velocity and any excessive horizontal velocity just before landing.

The airbags, based on Pathfinder's design, cushion the impact of the lander on the surface. Each of the four faces of the folded-up lander is equipped with an envelope of six airbags stitched together. Explosive gas generators rapidly inflate the airbags to a pressure of about 6900 Pascal (one pound per square inch). Each airbag has double bladders to support impact pressure and, to protect the bladders from sharp rocks, six layers of a special cloth woven from polymer fiber that is five times stronger than steel, are attached. The fiber material, Vectran, is used in the strings of archery bows and tennis racquets.

Lander

The lander, besides deploying the airbags, can set the rover right-side-up, if necessary, and provides an adjustable platform from which the rover can roll onto Mars' surface. It also carries a radar altimeter used for timing some descent events, as well as two antennas.

The lander's basic structure is four triangular petals made of graphite-epoxy composite material. Three petals are each attached with a hinge to an edge of the central base petal. The rover stays fastened to the base petal during the flight and landing. When folded up, the lander's petals form a tetrahedral box around the stowed rover. Any of the petals could end up on the bottom when the airbag-cushioned bundle rolls to a stop after landing. Electric motors at the hinges have enough torque to push the lander open, righting the rover, if it lands on one of the side petals.

Other motors retract the deflated airbags. An apron made out of the same type of tough fabric as the airbags stretches over ribs and cables connected to the petals, providing a surface that the rover can drive over to get off of the lander. The side petals can also be adjusted up or down from the plane of the base petal to accommodate uneven terrain and improve the rover's path for driving off of the lander.

Nearly four million people have a special connection to the Mars Exploration Rover project by having their names recorded on each mission's lander. Each of the two landers carries a DVD containing millions of names of people around the world collected during a "Send Your Name to Mars" campaign, which ended in November 2002.

Rover

At the heart of each Mars Exploration Rover spacecraft is the rover. This is the mobile geological laboratory that will study the landing site and travel to examine selected rocks up close.

The Mars Exploration Rovers differ in many ways from their only predecessor, Mars Pathfinder's Sojourner rover. Sojourner was about 65 centimeters (2 feet) long and weighed 10 kilograms (22 pounds).

Each Mars Exploration Rover is 1.6 meters (5.2 feet) long and weighs 174 kilograms (384 pounds). Sojourner traveled a total distance equal to the length of about one football field during its 12 weeks of activity on Mars. Each Mars Exploration Rover is expected to travel six to ten times that distance during its three-month prime mission. Pathfinder's lander, not Sojourner, housed that mission's main telecommunications, camera and computer functions. The Mars Exploration Rovers carry equipment for those functions onboard and do not interact with their landers any further once they roll off.

On each Mars Exploration Rover, the core structure is made of composite honeycomb material insulated with a high-tech material called aerogel. This core body, called the warm electronics box, is topped with a triangular surface called the rover equipment deck. The deck is populated with three antennas, a camera mast, and a panel of solar cells. Additional solar panels are connected by hinges to the edges of the triangle. The solar panels fold up to fit inside the lander for the trip to Mars, and deploy to form a total area of 1.3 square meters (14 square feet) of three-layer photovoltaic cells. Each layer is of different materials: gallium indium phosphorus, gallium arsenide, and germanium. The array can produce nearly 900 watt-hours of energy per Martian day, or sol. However, by the end of the 90-sol mission, the energy generating capability is reduced to about 600 watt-hours per sol because of accumulating dust and the change in season. The solar array repeatedly recharges two lithium-ion batteries inside the warm electronics box.

Doing sport utility vehicles one better, each rover is equipped with six-wheel drive. A rocker-bogie suspension system, which bends at its joints rather than using any springs, allows rolling over rocks bigger than the wheel diameter of 26 centimeters (10 inches). The distribution of mass on the vehicle is arranged so that the center of mass is near the pivot point of the rocker-bogie system. That enables the rover to tolerate a tilt of up to 45 degrees in any direction without overturning, although onboard computers are programmed to prevent tilts of more than 30 degrees. Independent steering of the front and rear wheels allows the rover to turn in place or drive in gradual arcs.

The rover has navigation software and hazard-avoiding capabilities it can use to make its own way toward a destination identified to it in a daily set of commands. It can move at up to 5 centimeters (2 inches) per second on flat hard ground, but under automated control with hazard avoidance, it travels at an average speed about one-fifth of that.

Two stereo pairs of hazard-identification cameras are mounted below the deck, one pair at the front of the rover and the other at the rear. Besides supporting automated navigation, the one on the front also provides imaging of what the rover's arm is doing. Two other stereo camera pairs sit high on a mast rising from the deck: the panoramic camera included as one of the science instruments, and a wider-angle, lower-resolution navigation camera pair. The mast also doubles as a periscope for another one of the science instruments, the miniature thermal emission spectrometer.

The rest of the science instruments are at the end of an arm, called the "instrument deployment device," which tucks under the front of the rover while the vehicle is traveling. The arm extends forward when the rover is in position to examine a particular rock or patch of soil.

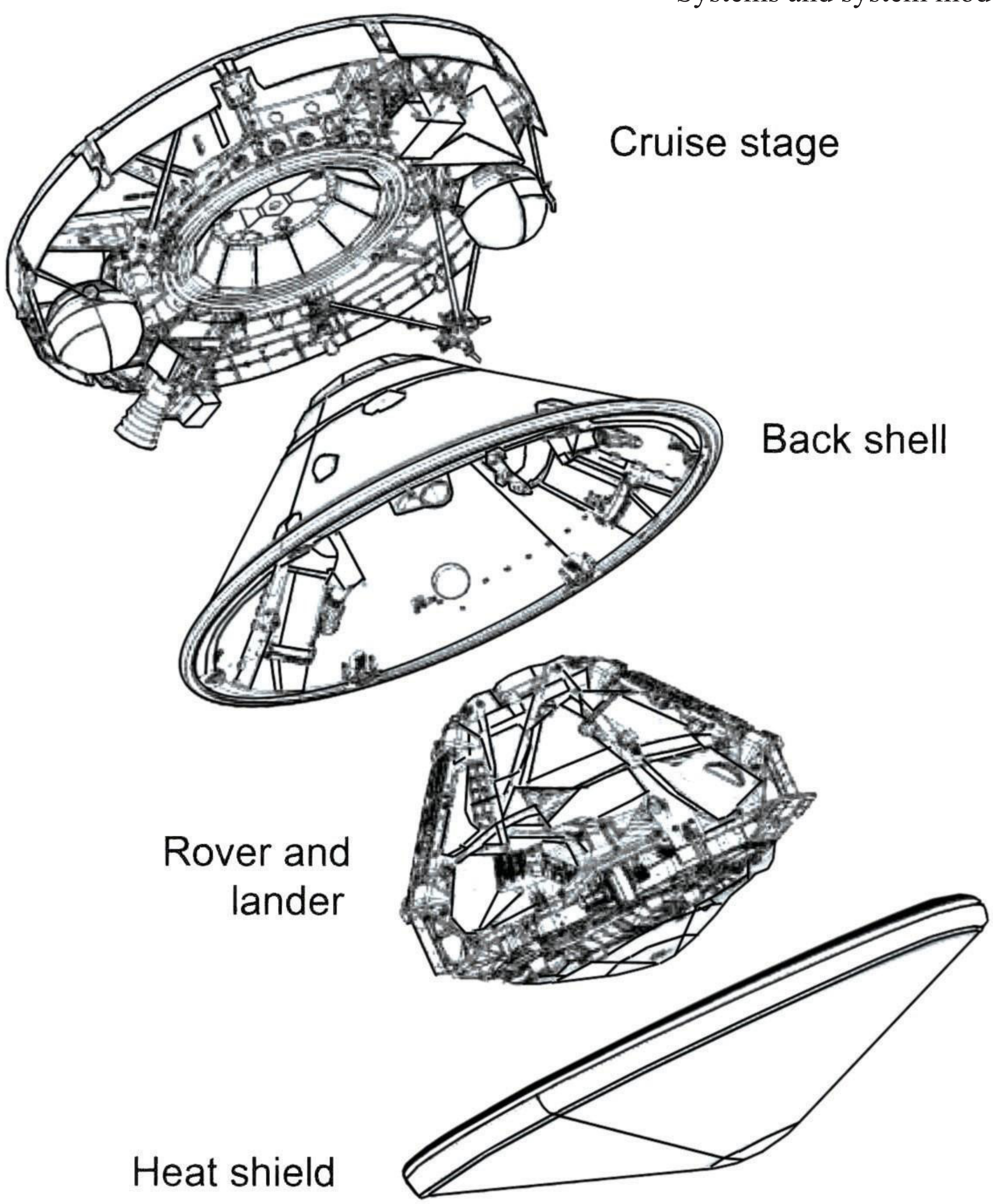
Batteries and other components that are not designed to survive cold Martian nights reside in the warm electronics box. Nighttime temperatures may fall as low as -105° C (-157° F). The batteries need to be kept above -20° C (-4° F) for when they are supplying power, and above 0° C (32° F) when being recharged. Heat inside the warm electronics box comes from a combination of electrical heaters, eight radioisotope heater units and heat given off by electronics components.

Each radioisotope heater unit produces about one watt of heat and contains about 2.7 grams (0.1 ounce) of plutonium dioxide as a pellet about the size and shape of the eraser on the end of a standard pencil. Each pellet is encapsulated in a metal cladding of platinum-rhodium alloy and surrounded by multiple layers of carbon-graphite composite material, making the complete unit about the size and shape of a C-cell battery. This design of multiple protective layers has been tested extensively, and the heater units are expected to contain their plutonium dioxide under a wide range of launch and orbital-reentry accident conditions. Other spacecraft, including Mars Pathfinder's Sojourner rover, have used radioisotope heater units to keep electronic systems warm and working.

The computer in each Mars Exploration Rover runs with a 32-bit Rad 6000 microprocessor, a radiation-hardened version of the PowerPC chip used in some models of Macintosh computers, operating at a speed of 20 million instructions per second. Onboard memory includes 128 megabytes of random access memory, augmented by 256 megabytes of flash memory and smaller amounts of other non-volatile memory, which allows the system to retain data even without power.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
Earth Space Science Progression
- ESS2.A: Earth materials and systems
- ESS2.D: Weather and climate
- ESS3.B: Natural hazards

Cross-cutting Concepts
- Systems and system models

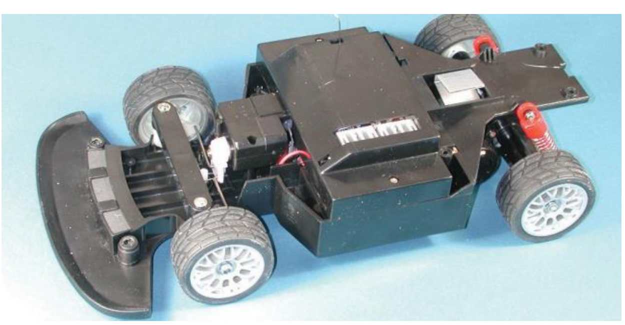


Flight System stages.

Activity Thirteen: Radio Controlled Mars Rover

Retro-firing rockets and a parachute were used to slow the aeroshell down after it entered the atmosphere; then a series of inflated spheres allowed it to bounce to a stop. The mechanism opened up and the rover was given a signal from Earth to start its exploration.

This 1/12 scale model Corvette is an inexpensive model car that would work for this lesson.



After the body is removed, the running chassis will look like this.

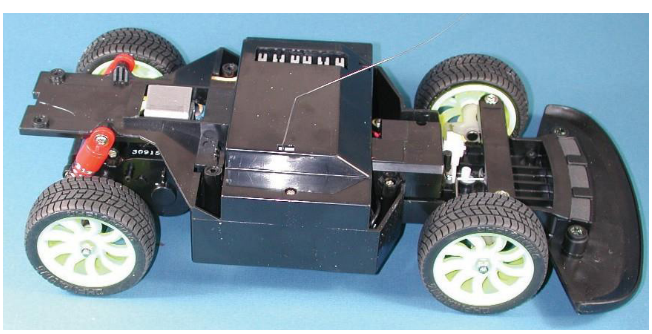
MATERIALS –

- **a.** Remote Controlled 1/12 scale model car (body removed)
- **b.** Set of 6 wheels and tires
- **c.** Two frame braces
- **d.** 1/4 inch foam board
- **e.** Epoxy or Hot glue and glue gun
- **f.** Toilet overflow tube
- **g.** Plastic "T"
- **h.** Dremel Tool
- **i.** Optional items: Gold foil, blue and yellow paint

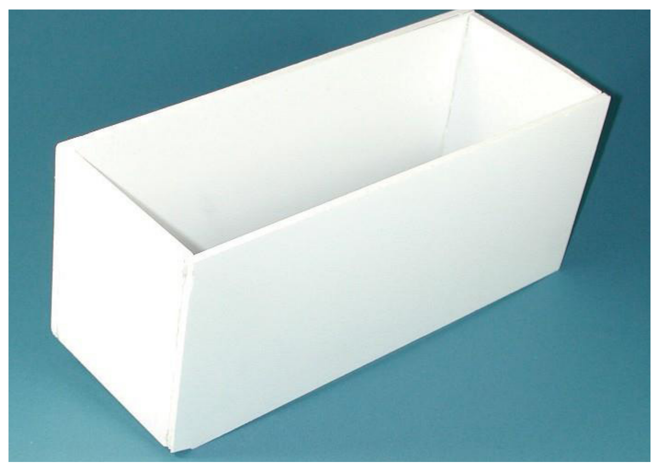
PROCEDURE – Let's build a Mars Spirit here on planet Earth. This is a relatively inexpensive model.

1. One of the first items to change is the wheel set. The frame braces will carry the two front wheels as you will see later in the activity.

*It should be noted that our model is not an exact replica, however, the more you make it look like the real thing, the better. Look at the "Mars Exploration Rover" diagram and you will see that we did not include a low-gain antenna, a high-gain antenna and a carrier for the front arm. These can be added, but be aware, they can also be broken easily. Study the illustration and then get as creative as you can to make it even more fun... and, radio controlled.



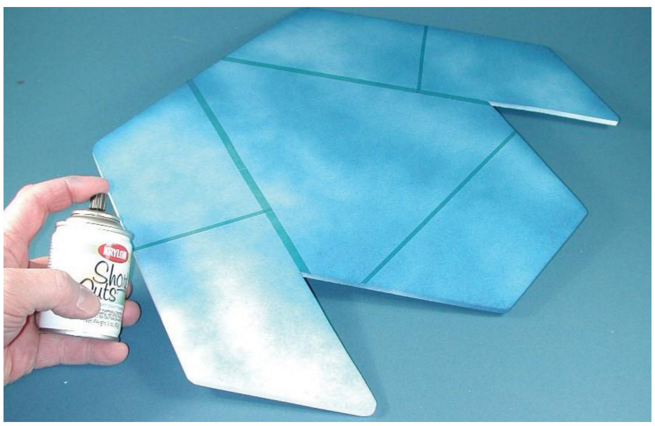
2. The wheels and tires were mounted according to instructions and this is what your Mars Spirit will have to negotiate the "Red Planet." Remove the tires from the R/C and mount four of these new wheels and tires to the R/C chassis.



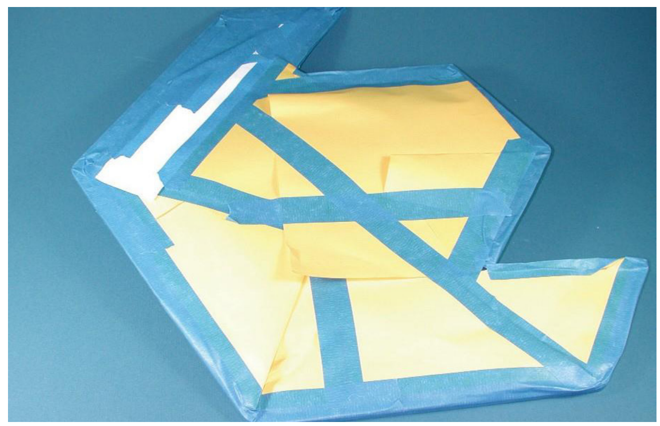
3. Use ¼ inch foam board to make the "box" or main body of the Mars Spirit. These are cut so that they fit the powered chassis as shown. The reason specific numbers were not given is because not everyone will be using this exact R/C car. A certain amount of "eyeball" engineering will have to be used to make it work with other cars. Just remember the goal is to make a rectangular foam board box.

4. Five minute epoxy or hot glue can be used to bond the box parts together.

5. The solar panels should look like this and if the builder wants to really make it look “right,” tape off the lines and spray the surface medium blue.

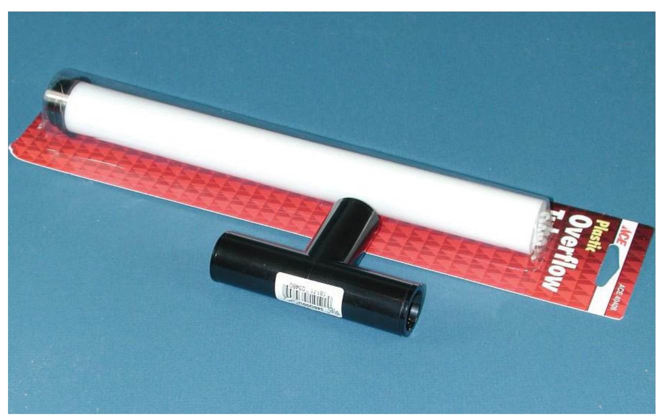


6. The first coat should be a mist followed, in about 15 minutes, with two color coats.



7. Once thoroughly dry, the solar panel is masked off on the upper side and the lower side is painted yellow.

...like this!

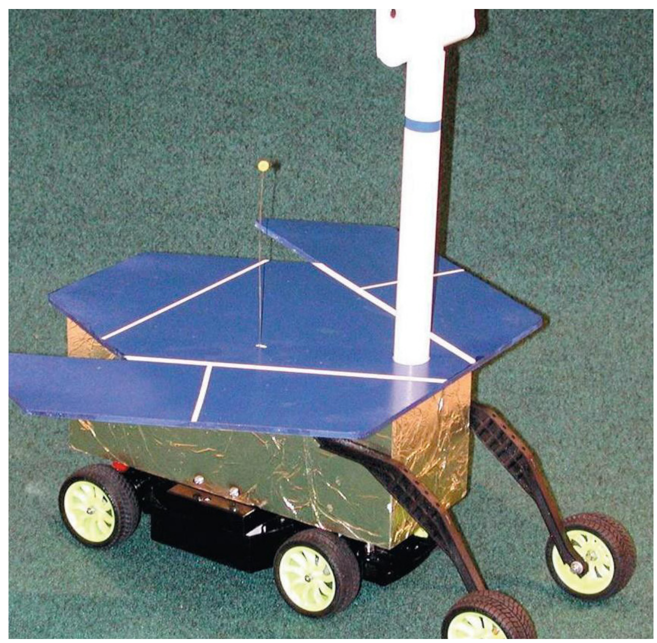


8. The toilet overflow tube and a plastic “T” will make the post that carries the “navigation cameras and the mini-thermal emission spectrometer.”

9. A Dremel Moto Tool was used to make a hole in the Solar Array panels so we could mount the camera post. The post is then fitted and bonded with epoxy.

10. This image shows how the box was glued together-- how the foil was glued to the box---and how the frame braces were mounted to the box. Again the frame braces will carry the front wheel assembly.

11. Our "cameras" were made from a couple of buttons purchased at a fabric store. They add a bit of humor to the little Spirit Rover.



Ideally, the carpet or background should be red to represent the Martian surface. Here's your fully powered, six-wheeled Mars Spirit Rover.
A good additional purchase to ensure power for this rover would be a battery charger that works on a small radio control craft like this. Get ready for the fun!