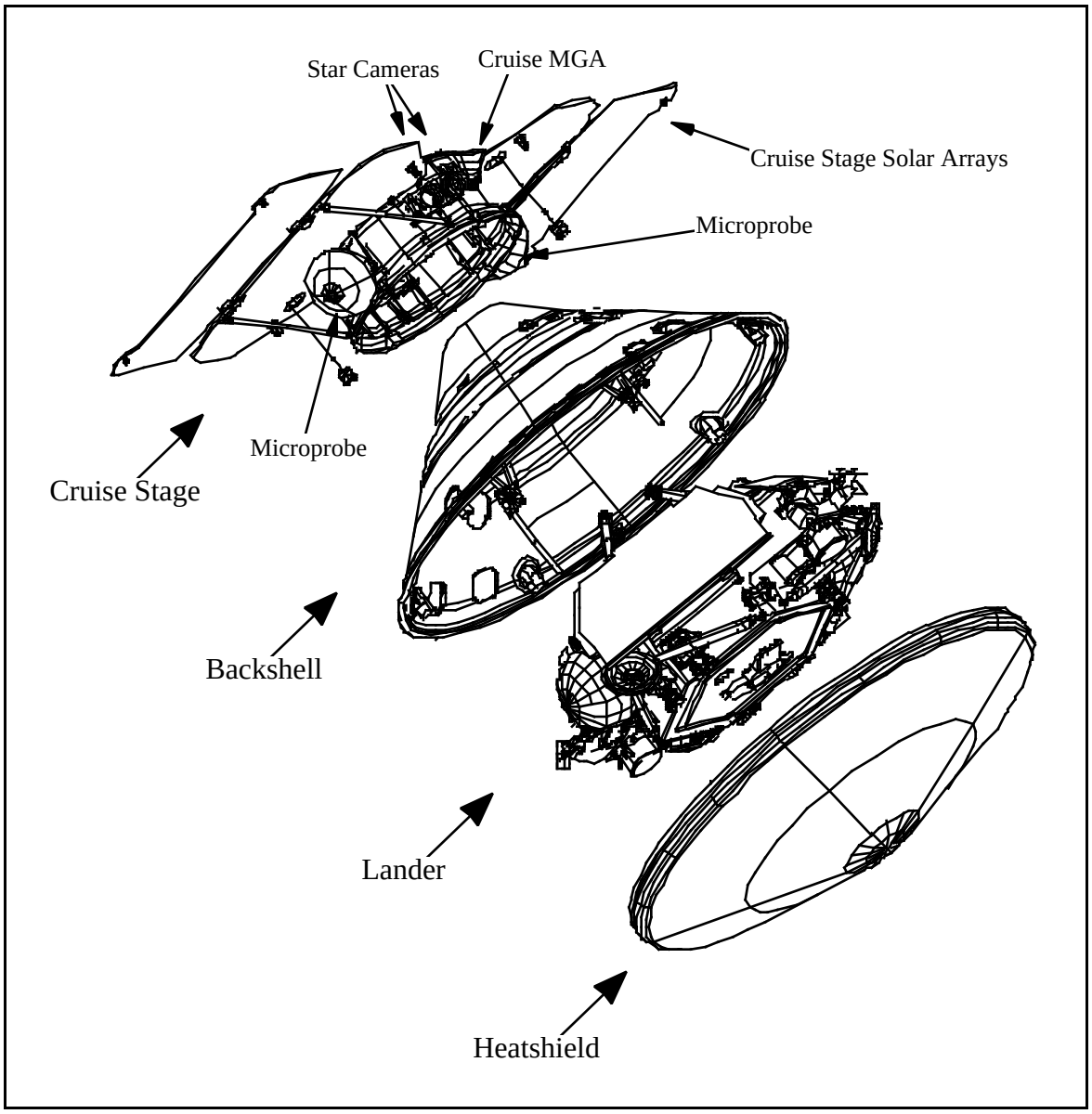
Mars Polar Lander, Cruise Configuration
1/24 Scale Model Assembly Instructions

This scale model of the Mars Polar Lander spacecraft is designed for anyone interested, although assembly might be inappropriate for children younger than about ten years of age. Children should have adult supervision to assemble the model.



1 SETUP

1.1 DOWNLOAD AND PRINT

- You'll need Adobe Acrobat Reader software to read the Parts Sheet file. You'll find instructions for downloading the software free of charge from Adobe on the web page where you found this model.
- Download the Parts file from the web page to your computer. It contains paper model parts on several pages of annotated graphics.
- Print the Parts file with a black & white printer; a laser printer gives best results. It is highly recommended to print onto card stock (such as 110 lb cover paper). If you can't print onto card stock, regular paper will do, but assembly will be more difficult, and the model will be much more fragile. In any case, the card stock or paper should be white. The Parts file is designed for either 8.5x11-inch or A4 sheet sizes.
- Check the "PRINTING CALIBRATION" on each Parts Sheet with a ruler, to be sure the cm or inch scale is full size. If it isn't, adjust the printout size in your printing software.
- Print out these instructions, too.

1.2 YOU WILL NEED THE FOLLOWING TOOLS

- A good pair or scissors.
- An art knife, such as X-ACTO #11, with a sharp new blade. Children must have adult supervision, of course, to use an art knife. You'll also need a cutting surface such as a linoleum pad, or thick chipboard, when using the art knife. Use caution: one can hurt oneself, or the furniture, with an art knife.
- Glue. Use regular white glue (Elmer’s Glue-All® or equivalent). You might also try a thick white glue, sold in art and fabric stores, called “TACKY GLUE” (Aleen’s or equivalent).
- Low Moisture Glue, such as a glue stick.
- A round pencil or dowel to wrap curvature into some parts.
- A metal ruler to use as a straight edge.
- A BLACK wide tip marker to use for coloring some parts.
- A YELLOW wide tip highlighter to use for coloring some parts.
- A BLUE wide tip highlighter to use for coloring some parts.
- Space. Set up a well lighted, comfortable work area, with room to set glued parts to dry.

- Time. Don't hurry. Plan to spend several hours for assembly. About 4 hours would probably be minimum if you concentrate solely on assembly. It can easily be done in shorter steps, however, over a period of several days.

- Patience. There may be trying times. But remember that extra care, and time, will pay off with a surprisingly accurate representation of the spacecraft.

1.3 BEFORE BEGINNING ASSEMBLY

- **Read all of these instructions**. Compare model parts with images. Examine the Parts Sheets and read the names of all the parts.

- Get your bearings: During assembly, you'll notice that the spacecraft's axes are indicated. These three imaginary lines pass through the center of mass of the spacecraft, and are labeled X, Y, and Z. The Z axis goes up and down. The general directions for the X and Y axes are indicated on the parts. The axis directions can also be used to point to a side of the spacecraft. INBOARD means toward the center, OUTBOARD means outward from center.

1.4 OTHER NOTES

- Sections marked with a • may be accomplished at the same time if two or more people are working on assembly, or if you wish to work on one section while glue dries on another. In fact these steps were performed separately while building the actual spacecraft.

- What to cut out? Each part is drawn against a shaded background. This shading appears gray when printed on a black & white printer. Each part should be completely cut away from its shaded back-ground. Some parts have areas within them of shaded gray. These areas should be cut out of the part. Spacecraft details are printed on most of the parts. Don’t confuse these with background shading. If there's any question, look at it on a color computer monitor: all the background shading appears blue: if it isn't blue, don't cut it away.

- When you finish cutting out a part, flatten it.

- If an instruction doesn't say which way to fold something, then fold with the printed side on the inside of the part.

- When instructed to fold a part, consider scoring it first. To do this, line up a metal ruler or straight edge along the line to be folded, and very lightly scratch it with an art knife, only breaking the surface of the card stock. You have to be very careful not to cut through if you do this. While this is more time consuming, it will result in much neater folds, and will help the parts fit together properly.

- If you cannot print the model parts onto card stock (such as 110 pound cover paper), then skip over the steps which indicate to “VERY lightly score using a modeling knife.” It is highly recommended to print onto card stock.

- When instructed to roll a part, wrap the part around a dowel or round pencil. This will make a more even curvature in the part. Alternatively, try “drawing” the part between your finger and the sharp edge of a table of desk to warp curvature into the part.

• 2 ASSEMBLE THE LANDER CRUISE CONFIGURATION

• 2.1 ASSEMBLE THE HEATSHIELD AND BACKSHELL

a. Assemble the Parachute Mortar

1) Cut out the two PARACHUTE MORTAR pieces from Parts Sheet 1. Roll the square shaped piece into a small cylinder, allowing the sides to overlap along the edge marked GLUE. Roll the piece around a pencil or dowel to make a smooth cylinder. Smear some glue along the tab of this piece marked GLUE, overlap the opposite end onto the glue, press together, and let the glue dry.

2) Apply glue to the edges on one end of the cylinder, and glue the cylinder to the back side of the round piece (the cylinder should be centered on the side opposite of the printed side) , and let the glue dry.

b. Use a yellow highlighter to color the dark portions of the HEATSHIELD and HEATSHIELD SIDES. The actual color of the Heatshield is tan-beige (see color in PDF viewer).

c. Cut out the large circular HEATSHIELD from Parts Sheet 1. Using a pencil or dowel, form the circle into cone by rolling the part to impart a curved shape with the printed shading on the outside. For this step, use a low-moisture glue such as a glue stick. Smear a thin film of glue on the tab marked GLUE, from the center to the outer edge. Overlap the opposite edge onto the glue, bringing the circle up into a cone. Adjust so the edge aligns with the line which separates the glue tab from the Heatshield.

d. Cut out the large circular BACKSHELL from Parts Sheet 1. DO NOT cut out the thrusters (four dark shaded boxes). Using a pencil or dowel, form the circle into cone by rolling the part to impart a curved shape with the printed circles on the outside. For this step, use a low-moisture glue such as a glue stick. Smear a thin film of glue on the tab marked GLUE, from the center to the outer edge. Overlap the opposite edge onto the glue, bringing the circle up into a cone, with the printed circles on the outside. Adjust so the edge aligns with, and just overlaps the line which separates the glue tab from the Backshell.

e. While holding the cylinder portion of the Parachute Mortar, bend the four tabs down (away from the printed side) about 45 degrees. Apply glue to the top of the four tabs (the printed side), and insert the part inside the Backshell. Adjust as necessary to make the round flat portion even with the hole in the Parachute Cone on the Backshell.

f. On Parts Sheet 1, VERY lightly score the HEATSHIELD SIDES between the tabs and long shaded sides using a modeling knife along the edge of a ruler (do not cut through the paper). Make a total of four different scores. Do this before cutting out the two HEATSHIELD SIDES from the parts sheet. This will allow easier bending of the tabs.

g. Cut out the two HEATSHIELD SIDES from Parts Sheet 1. The Heatshield Sides have a top and bottom, where the white tabs on the "top" will attach to the inside of the Backshell, and the dark tabs on the "bottom" will attach to the inside of the Heatshield. Make small "V" cuts between each of the 62 glue tabs along the sides of the parts. Make small cuts near the end of each piece marked GLUE (between the glue tabs and the colored portion of the Heatshield Side) to allow the glue tabs A and B to overlap. This is a time consuming step and will require a bit of patience.

h. Smear some glue along the tabs marked GLUE, overlap the tab with the tab on the other Heatshield Side piece (Tab A with the other Tab A). The tabs should overlap, gluing each tab on the non-printed side of the other piece. Repeat with other set of tabs to form one ring (Tab B with the other Tab B), and let the glue dry. Bend all the "top" tabs (along the score marks) about 45 degrees away from the printed side of the ring.

i. Apply glue to all the white tabs along the "top" of the Heatshield Sides and glue the tabs to the inside of the Backshell. Adjust the ring so all of the tabs are inside the edge of the Backshell. None of the white tabs along the "top" of the Heatshield Sides should visible. This is a difficult step and will require a bit of patience.

j. Bend all the "bottom" tabs of the Heatshield Sides (along the score marks) about 70 degrees away from the printed side of the ring. Apply glue to all the dark tabs along the "Bottom" of the Heatshield Sides and glue the tabs to the inside of the Heatshield. Adjust the tabs so they are all inside the edge of the Heatshield. This is a difficult step and will require a bit of patience.

• 2.2 ASSEMBLE THE CRUISE STAGE

a. Cut out the CRUISE STAGE RING from Parts Sheet 2. Note the two "Alignment Marks" on the top and bottom of the Cruise Stage Ring. Roll the piece into a cylinder, allowing the sides to overlap along the edge marked GLUE. Roll the piece around a pencil or dowel to make a smooth cylinder. Smear some glue along the tab of this piece marked GLUE, overlap the opposite end onto the glue, press together, and let the glue dry.

b. Cut out the CRUISE STAGE RING INNER STIFFNER from Parts Sheet 2. Cut out the light shaded circular portion on the inside of the ring before cutting the part from the parts sheet. Note the "Alignment Mark" on the stiffener near the Low Gain Antenna (called LGA). Dry fit the stiffener inside the top edge of the Cruise Stage Ring - it should be a tight fit, cut and adjust as necessary. Apply glue along the outside edge of the Stiffener Ring and place the Stiffener Ring inside the top edge of the Cruise Stage Ring with the alignment marks as close as possible. Using a toothpick, apply several small drops of glue between the Cruise Stage Ring and the Stiffener on the inside of the Cruise Stage Ring.

c. Cut out the AEROSHELL SEPARATION RING from Parts Sheet 2. Using a pencil or dowel, form the circle into shallow cone by rolling the part to impart a curved shape. The conic shape of the ring should match the shape of the Parachute Cone on the Backshell, with the outside edge of the ring just inside the Parachute Cone. Smear some glue along the tab of this piece marked GLUE, overlap the opposite end onto the glue, press together, and let the glue dry.

d. Apply glue along the bottom edge of the CRUISE STAGE RING. The bottom edge has 4 small rectangles where the Solar Panel Support Struts will attach. Attach the CRUISE STAGE RING to the bottom edge of the AEROSHELL SEPARATION RING, centering the Cruise Stage Ring over the conic shaped Separation Ring, and let the glue dry.

e. Use a blue highlighter to color the four large rectangles on the CRUISE STAGE SOLAR ARRAYS. The actual color of the flight solar array elements is bright blue.

f. Cut out the two CRUISE STAGE SOLAR ARRAYS from Parts Sheet 2. Apply glue along the inside circular edge of one Solar Array Panel and attach the Solar Array Panel along the dotted line on the CRUISE STAGE RING. The Solar Array Panel should be centered above the circle marked "P1" or "P2", and parallel to the top of the Cruise Stage Ring. Repeat with the other Solar Array Panel, aligning the panel opposite of the previous panel. Allow the glue to dry.

g. Cut out the four SOLAR PANEL SUPPORT STRUTS from Parts Sheet 2. Note the struts are a matched pair of two struts. Use a black marker to color the opposite sides of the struts to match the printed side. Apply glue to both ends of one of the struts, and attach the dark shaded end to one of the small rectangles at the bottom edge of the CRUISE STAGE RING. Attach the "pointed" end of the strut to the backside of the Solar Array Panel, directly opposite a similar shaped small rectangle. Repeat with the other three support struts, and allow the glue to dry.

• h. Assemble the Cruise Stage Medium Gain Antenna (MGA)

1) Cut out the two MGA pieces from Parts Sheet 2. Cut out the round hole in the middle of the MGA Bracket before cutting the part from the parts sheet. The MGA Bracket will fold away from the printed side; the side with the hole will fold about 45 degrees and the pointed sides will fold 90 degrees to match the pointed sides. Score along the three fold lines on the printed side of the MGA Bracket before folding. Apply glue to the pointed side edges near the side with the hole and mate the edges together, and let the glue dry.

2) Roll the MGA Feed Horn into a cone, with the GLUE marking on the inside of the cone. Smear some glue along the tab of this piece marked GLUE, overlap the opposite end onto the glue, press together, and let the glue dry. The MGA Feed Horn will mount inside the MGA Bracket (when holding the bracket with the side marked “M” vertical and the arrow pointing up, the pointed end of the MGA Feed Horn will point down and the opening will be about 45 degrees from vertical). Apply some glue to the edges of the hole on the MGA Bracket, insert the MGA Feed Horn into the bracket, and let the glue dry.

• i. Assemble the Microprobes

1) Cut out the two MICROPROBE HEATSHIELD parts from Parts Sheet 2. Form the dark shaded Heatshield into cone by rolling the part to impart a curved shape with the printed shading on the outside. Smear a thin film of glue on the unshaded glue tab, from the center to the outer edge. Overlap the opposite edge onto the glue, bringing the circle up into a cone. Adjust so the edge aligns with the line which separates the glue tab from the Heatshield. Repeat with the other Heatshield part.

2) Cut out the two MICROPROBE BACKSHELL parts from Parts Sheet 2. Be sure to cut out the center slots in the Backshell. Form the Microprobe Backshell into cone by rolling the part to impart a curved shape with the printed line on the inside. Smear a thin film of glue on the glue tab, from the center to the outer edge. Overlap the opposite edge onto the glue, bringing the circle up into a cone. Adjust so the edge aligns with the line which separates the glue tab from the Backshell. Repeat with the other Backshell part.

3) Once the glue is thoroughly dry, set the Backshell on the work surface with the point facing down, and crush the point by pressing the cone down onto the work surface. As you crush it, the central hole will become smaller, and the central slots will overlap. Apply some glue to the overlapping slots to hold their shape. Try to adjust the cone's shape so it is even. Repeat with the other Backshell part.

4) Apply glue along the circular edge of the Microprobe Heatshield, and align the circular edge of the Microprobe Backshell onto the Heatshield, and let the glue dry. Repeat with the other Microprobe Heatshield and Backshell parts.

5) Cut out the four MICROPROBE SUPPORT SPYDER parts from Parts Sheet 2. Cut along the inside circular edge of the Microprobe Support Spyder before cutting the remaining portion of the part from the parts sheet. The “top” of the support bracket is the long straight portion, nearest the “e” in the word “glue”. Bend the lower portion of the support bracket approximately 120 degrees. Bend the glue tab of the support bracket 90 degrees away from the printed side (the word “glue” should be opposite of the support bracket ends). Apply two small drops of glue to the inside tips of the two bracket ends and attach the Microprobe Backshell into the bracket. The inside tips of the two bracket ends should be in contact with the outside edges of the Microprobe Backshell.

6) Apply glue to the ends of the (very) small bracket arm and attach one end to the larger Microprobe Support Spyder near the crushed point of the Microprobe Backshell. The other end of the small bracket arm should attach to the outside edges of the Microprobe Backshell, approximately 120 degrees from the other two arms.

7) Repeat the previous two steps with the other Microprobe and Support Spyder parts.

• j. Assemble the Star Cameras

1) On Parts Sheet 2, VERY lightly score the two STAR CAMERAs between the tabs and sides using a modeling knife along the edge of a ruler (do not cut through the paper). Make a total of eight different scores on each Star Camera Body. This will allow easier bending of the tabs. Cut out the four STAR CAMERA parts from Parts Sheet 2 (two camera bodies and two lens hoods).

2) Fold the 6 tabs away from the printed sides of the Star Camera Body, and fold along the two lines between the top and bottom of the camera body. Apply a small drop of glue to the three tabs marked GLUE and overlap the other opposing three tabs onto the glue tabs. This should make a small box with a dark circle on one side and an “S” on the other side. Repeat with the other Star Camera Body.

3) Roll the square shaped piece into a small cylinder with the dark printing on the inside, allowing the sides to overlap along the edge marked GLUE. Roll the piece around a pencil or dowel to make a smooth cylinder. Smear some glue along the tab of this piece marked GLUE, overlap the opposite end onto the glue, press together, and allow the glue to dry.

4) Apply glue to the edges on one end of the small cylinder, and glue the cylinder to the side of the camera body with the round dark spot, and let the glue dry. Repeat with the other small cylinder and camera body.

5) Cut out the two small donut shaped lens hood objects from Parts Sheet 2. Cut out the inside hole of the lens hood before cutting the remaining portion of the part from the parts sheet. Apply glue to the edges of the small lens hood cylinder, and glue the donut shaped lens hood to the cylinder, and let the glue dry. Repeat with the other small cylinder and camera body.

2.3 FINAL ASSEMBLY

a. Smear some glue along the glue tab of one of the Microprobe Support Spyders, attach the glue tab to the rectangle marked “g” on the Cruise Stage Ring, centering the probe over “P1”, and let the glue dry. The Microprobe Heatshield should point down, away from the backside of the Solar Panel. Repeat with the other Microprobe Support Spyder, centering the probe over “P2”.

b. Smear some glue on the “S” of one of the Star Camera Bodies, and attach the camera to one of the squares marked “S” on the Cruise Stage Ring. Each Star Camera should be tilted down about 22 degrees (away from the Solar Array). Repeat with the other Star Camera Body, attaching the camera to the other square marked “S”, and allow the glue to dry. Star Cameras A and B are marked “SC-A” and “SC-B”, respectively.

c. Smear some glue on the “M” of the MGA Mount, attach the MGA to the Cruise Stage Ring with both arrows pointing up, and allow the glue to dry. The MGA Feed Horn should be aligned between the alignment marks on the Cruise Stage Ring, and open upward, away from the bottom of the Cruise Stage Ring.

d. Assemble the Cruise Stage to the Lander Backshell. Apply several small drops of glue to the inside edge of the Aeroshell Separation Ring, at the bottom of the Cruise Stage Ring. Attach the Cruise Stage Ring to the Backshell, aligning the Cruise Stage Ring alignment marks over the Backshell alignment marks, and allow the glue to dry.

THIS COMPLETES YOUR MODEL

3 ABOUT YOUR MODEL

The Mars Polar Lander is 3-axis stabilized during cruise mission phases following separation from the launch vehicle. The primary attitude determination is via star camera and ring laser gyro inertial measurement unit, and is backed up by analog sun sensors. The RCS thrusters provide attitude control during Trajectory Correction Maneuvers, Mars Entry Descent and Landing, and safe mode. The eight cruise thrusters are part of the Lander spacecraft, and scarfed through the Backshell. The cruise thrusters are used for Trajectory Correction Maneuvers and pitch/yaw/roll control. The Spacecraft Computer (C&DH) uses the RAD6000 processor (a predecessor to the PowerPC). The X-band link with Earth employs Cassini Deep Space Transponders, 15 W RF solid state power amplifiers (SSPA's), one transmit/receive medium gain antenna (MGA) on the cruise stage, one receive-only low gain antenna on the cruise stage, and one transmit/receive medium gain antenna (MGA) on the Lander body. A 10 Watt RF UHF system supports the 2-way link with the Mars Climate Orbiter. The cruise stage solar arrays and landed solar arrays use GaAs/Ge solar cells. The batteries are NiH2 CPV batteries, while the electrical power electronics are based on the SSTI spacecraft electronics. The thermal control subsystem includes control of the Lander electronics, batteries, and SSPA's. Both thermostatically controlled and computer controlled heater circuits are used. Most subsystem components are redundant, with critical items cross strapped.

The Mars Polar Lander will enter the Martian atmosphere directly from the hyperbolic transfer orbit at 7 km/s. The Lander spacecraft will decelerate to a soft landing using a heat shield to aerobrake, a parachute, and actively guided propulsion to reduce vertical velocity to less than 2.4 m/s and horizontal velocity to less than 1 m/s at surface touchdown. The Lander will be targeted to the northernmost boundary of the polar layered deposits at a high southern latitude site, between 75 degrees and 80 degrees south latitude. The surface science mission will be conducted over the course of a 3 month primary mission. The landing will occur during late spring in the southern hemisphere and extend through the early summer season. The timing of the landing is optimal for a high southern latitude site because the sun is always above the horizon during the course of the primary mission providing maximum solar insulation and a relatively benign thermal environment.

Mars Polar Lander Spacecraft Science

The "Volatiles and Climate History" theme for the 1998 Mars Surveyor missions was recommended by the Mars Science Working Group and is aligned directly with NASA's Mars exploration strategy for the next decade focusing on: Evidence of past or present life, Climate, and Resources. The Lander will carry the Mars Volatiles and Climate Surveyor (MVACS) instrument suite, which will perform in situ investigations to address the science theme "Volatiles and Climate History", the Mars Descent Imager (MARDI), and a LIDAR instrument supplied by the Russian Space Agency. The Lander will search for near-surface ice and possible surface records of cyclic climate change, and characterize physical processes key to the seasonal cycles of water, carbon dioxide and dust on Mars. The duration of the landed science phase is expected to last no more than approximately 90 days. Piggybacking on the Mars Polar Lander are two small microprobes. Separating from the Lander just prior to entry into the Martian atmosphere, the two microprobes will slam into the surface of Mars at a velocity of 200 meters per second. The aeroshell on each probe will shatter to release the science package which will penetrate up to 2 meters into the soil. The microprobes will determine if water ice is present in the Martian subsurface, and will also measure the temperature and monitor the local Martian weather. The science complement for the 1998 Lander includes: the Mars Volatile and Climate Surveyor (MVACS) integrated Lander payload with Dr. David Paige of UCLA as Principal Investigator, the Mars Descent Imager (MARDI) with Dr. Michael Malin of Malin Space Science Systems as Principal Investigator, and an atmospheric LIDAR experiment provided by the Russian Space Agency Institute for Space Science. Dr. Paige's integrated Lander payload includes a Surface Stereo Imager (SSI) with Mars Pathfinder heritage; a meteorology package (MET); an instrumented robotic arm (RA) for sample acquisition, soil manipulation, and close up imaging of the surface and subsurface; and the Thermal and Evolved Gas Analysis (TEGA) experiment for determining the nature and abundance of volatile material in the Martian soil. The descent images obtained by MARDI while the Lander spacecraft descends to the surface will establish the geological and physical context of the landing site. The atmospheric LIDAR experiment will determine the dust content of the Martian atmosphere above the landing site.

The Mars Surveyor Spacecraft was designed and manufactured at Lockheed Martin Astronautics, Denver, Colorado, under contract with the Jet Propulsion Laboratory.

Model design completed 03 May 1998 by G. Bollendonk, Mars Surveyor Program, Lockheed Martin Astronautics, Denver, Colorado. An after-hours project.