Instructions for Making Mars Rover with Space Frame Wheel Support System (Super-Size Version and Smaller Version)

Design Notes

The Mars Rover design is an “adaptation” which uses a space frame wheel support instead of the tubular supports found on the original Mars Rover fielded by NASA. NASA’s Mars Rover is approximately the same size as an automobile or pickup truck. The original design effort for the Mars Rover found in the Science Fest 2021 Discovery Box utilized something the size of a shoe box for the main body of the Mars Rover. The kind folks who provided the materials for the Discovery Boxes needed a large package to contain everything for the fabrication effort (that is, an 18” long x 14” wide x 6” high box). As a result, some of the components in the Discovery-Box design are somewhat smaller than desired. For example, the large Discovery Box required a design change for the Radar unit located on the back of the Mars Rover. It was decided to designate the design which uses the Discovery Box as the Super-Size Mars Rover design. If the builder (that is, you) decides to construct a slightly smaller Mars Rover which is closer to the design utilizing a shoe box, consider providing your own cardboard box (approximate dimensions of 14” long x 9” wide x 4-1/2” high) instead of the Discovery Box. A smaller Radar Unit is provided to construct the smaller Mars Rover. It may also be necessary to move the space frame / box supports (that is, the two supports located near the end the space frame) closer together on the smaller box. Otherwise, the two Mars Rover designs are basically the same.

Credits

1. Carl Sagan, COSMOS Series (Note: Carl Sagan was fascinated with Mars and stars. The COSMOS Series gave me an appreciation for science and history.)
2. Images of Mars Rover (Note: If desired, do a search on the internet for “Images of the Mars Rover, that is, the MARS 2020 Perseverance Rover.” For design purposes, various images and the names of components on the Mars Rover were obtained from the images found on the internet. Some of the components for the Mars Rover found in the ScienceFest 2021 are similar to the images found on the internet. Other components were developed to make the Rover fabrication effort both instructive, challenging and fun. The Rover design provided here is not an exact replica or model of the actual Mars Rover.)

List of Systems

Housing for Navacam / Mastcam-Z / Supercam (laser microimager) (Note: Not included)

PIXL (x-ray spectrometer) / Drill System / SHERLOC (ultraviolet spectrometer) / WATSON (camera)

RIMFAX (subsurface radar) / RTG (radioisotope generator) (Note: Not included)

Robotic Arm

MEDA (weather station) (Note: Not included)

MOXIE (produces oxygen from Martian carbon dioxide) (Note: Not included)

1. Curiosity Rover Presentation on U-Tube (Note: If desired, do a search on the internet for “Images of the Mars Rover” to find an image of the “Curiosity Rover.” The basic concept for making the Rover wheels and the use of the SciencFest Discovery Box to construct the body of the Mars Rover were developed from the Curiosity Rover.)

Construction Hint: It will take some time and effort to construct the Mars Rover. Work on the effort some every day. If you become tired or impatient, take a break. Keep trying!

\*\*Caution: Before attempting to make and assemble the Mars Rover, please read the “Caution” statements located throughout the instructions. It will help to keep you safe and prevent damage. Remember: Not looking at or following the instructions is like wearing sunglasses and looking for a black cat in a dark room.\*\*

\*\*Caution: The box-making project will create small pieces of paperboard and other waste materials (for example, pieces of paperboard scrap and masking tape) which could be a **choking hazard to small children or pets.** Consider keeping small pieces of paperboard scrap and bits of masking tape in an envelope or small container. Discard or recycle small scrap pieces of paperboard as needed. Discard any small pieces of masking tape. If a single-edge razor blade is used, it can also be a **choking hazard to small children and pets**. In addition, single-edge razor blades are sharp. When a single-edge razor blade is not in use, use a piece of clear tape to attach the razor blade on to a piece of cardboard which is larger than the razor blade. Then store the protected razor blade in a safe location. Alternately, a pill bottle (with the prescription label removed) may be used to store a razor blade. This practice will prevent a skin laceration or cut if you are fishing around in a drawer looking for the razor blade at some later time.\*\*

Mars Rover Supplies Contained in the Discovery Box

The folks who prepared the Discovery Box included a supply of paperboard, 2-layer flexible cardboard, and other materials to help construct the Mars Rover.)

A General Note on Discarded Paperboard Boxes

When a box is empty, it may be discarded or recycled. However, it takes trucks, truck drivers, and hydrocarbon fuel to transport material for recycling. Additional equipment and effort is required to turn the recycled material into recycled products. A better idea is to make the box into something which can be used again (that is, reusing the box material). So with that said, let’s see how an empty box can be used again.

An original box (made of paperboard which is about 1/32-inch thick) requires careful disassembly to make a flat sheet of paperboard which can be reused. (Note: Consider using a paperboard wrapper for soda pop cans to make the space frame for the Rover. The paperboard is printed on the outside and brown on the inside. (Note: Some paperboard, such as that found on the interior of cereal boxes, is gray in color.) Be aware that soda pop wrappers contain areas which have been punched through and weakened. Weakened locations may require reinforcing with small sections of brown Kraft paper grocery bags and glue.) Disassembly of a box may be accomplished with a small screwdriver or an unsharpened dining table knife. Most paperboard boxes (for example, a soda pop can wrapper or a cereal box) have a seam on one of the corners. A small screwdriver or unsharpened knife can be inserted into the seam and the overlapping paperboard can be separated. Any glue on the surface of the paperboard can be scrapped away to provide a flat sheet of paperboard.

\*\*Caution: The Mars Rover project is provided with a series of paper templates printed on 8-1/2 inch x 11 inch sheets of paper. **There is only one set of paper templates.** Some of the templates are provided with notes and dimensions. It is required that the paper templates be cut out with a pair of scissors and the shape information transferred on to paperboard or cardboard. **Consider saving the sheets of paper with the template notes and dimensions. Also consider saving the paper templates which are cut out and attaching them to the original paper sheets using pieces of masking tape.** If anything goes wrong (for example, a paper template is damaged or a paperboard part is damaged), it will be possible to recover the original sheet of paper where the template was cut out and removed and / or recover the paper template itself. This will assist in fabricating a new replacement part.\*\*

\*\*Caution: The Wheels for the Mars Rover Wheels utilize both 1/8-inch thick 3-layer cardboard (stiff cardboard) and 1/8-inch thick 2-layer cardboard (flexible cardboard). It will be necessary to obtain an 8-inch wide x 10-inch long piece of 3-layer cardboard (or two pieces of 4-inch wide x 10 inch long 3-layer cardboard) to fabricate the Wheel Disks. The Wheel Rings are fabricated from a sheet of 2-layer cardboard found in the Discovery Box.\*\*

\*\*Caution: Consider using a paperboard wrapper for soda pop cans to make the space frame for the Rover. The paperboard is printed on the outside and brown on the inside. Be aware that soda pop wrappers contain areas which have been punched through and weakened. Weakened locations may require reinforcing with small sections of brown Kraft paper bag and glue.\*\*

\*\*Caution: If sections of paperboard boxes are repaired with glue, be sure to put down a piece of cardboard or other hard sheet material to protect underlying counter surfaces, floor surfaces, table surfaces, etc. The cardboard, etc. will prevent the glue from damaging surfaces.\*\*

\*\*Caution: The use of tape is not recommended to repair or splice sections of paperboard together – particularly for the space frame. Tape has a tendency to peel away from paperboard surfaces. The surface area for tape bonds on the space frame is limited, and may result in the space frame falling apart.\*\* The adhesive on the back of tape may also deteriorate over time due to heat and aging.\*\*

Paperboard Repair

If a section of paperboard has been punched through or is damaged somehow, the damaged area may be repaired with pieces of heavy paper from a brown Kraft paper bag (for example, an 8-inch x 12-inch x 16-inch grocery bag). Cut out a piece of paper bag of the appropriate size. The Kraft paper may be coated with a “thin” layer of Elmer’s School Glue (glue) on one side and then applied to either the printed or brown side of the paperboard. Alternately, the printed or brown surface of the paperboard may be covered with a thin layer of glue and a piece of paper bag applied to the paperboard. (Note 1: If glue is not spread in a thin / even layer over the surface of the Kraft paper or paperboard, the paper may tend to peel. To achieve even spreading of the glue, consider using your finger to spread the glue on the paper or paperboard. Wash your fingers / hands as needed to remove the glue.) (Note 2: It may be desired to place brown Kraft paper pieces on both sides of the paperboard to reinforce a particular area.)

**Space Frame / Axle and Wheel Support / Wheel Subassembly**

(Note: The space frame is a large component containing triangular and rectangular cut-outs. The space frame is too large to fit on a single 8-1/2” x 11” sheet of paper. Therefore, two templates are provided with a “match line.” Cut out the two templates. Tape the templates together at the match-line location using 1/4-inch wide pieces of masking tape.)

1. One side of a discarded box usually has printing on it and the opposite side shows either gray, tan, or white paperboard. A decision must be made about whether the printed side will be used for the outside of the space frame or the paperboard side will be used for the outside of the space frame.
2. Inside the Discovery Box, you will find a variety of paper templates. Select the template for the space frame. An important decision must be made about whether the space frame will be constructed with cut-outs or the space frame will be made as a simple tube with a triangular cross-section. (Note: It is time-consuming to make all the cutouts in a space frame. If you feel that the effort is too complex, consider making a simple triangular tube with no cut-outs. Alternately, making a few cut-outs will give you some practice in how to make a space frame. (Note: Consider providing cut-outs in the areas where the axles / wheels are attached to the space frame using the axle supports. It will help with locating the axle support pieces.) It is not recommended to make any cut-outs after the space frame has been assembled into the triangular tube configuration. The Discovery Box effort is provided to be both challenging and fun. Decide which combination challenge and fun is best for you.)
3. \*\*Caution: If a single-edge razor blade is used to make cut-outs in the paper template (and the paperboard space frame), be sure to put down a piece of cardboard or other hard sheet material to protect counter surfaces, floor surfaces, table surfaces, etc. The cardboard, etc. will prevent the razor blade from damaging surfaces.\*\* \*\*Caution: Razor blades are sharp, and particular attention must be given to making cuts in the paperboard when your finger tips are nearby.\*\* There are two ways to make the cut-outs in the space frame template (and the paperboard space frame). One method is to use a single-edge razor blade to make the cut-outs. The other method requires making a short cut with a razor blade or sharp knife somewhere within middle of the cut-out area, inserting one blade on a pair of scissors into the small cut, and carefully making cut-outs with the scissors. It is helpful to make a curved cut followed by a straight cut toward the vertices (or angled points) of the triangular cut-outs or the corners of the rectangular cut-outs. Some additional trimming to make straight edges on the cut-outs may be required. (Note 1: It will not damage the space frame template or the paperboard space frame to bend or twist them slightly when trimming to make the edges straight.) (Note 2: Consider using a practice piece of paper and then paperboard in order to learn how to make the triangular and rectangular cut-outs. Choose the cutting method with a razor blade or scissors which works best for you. You can always splice a damaged section of the paperboard space frame with 1/4-inch wide by 1/2-inch long strips of brown Kraft paper and glue.) Remember: This is not a beauty contest, it is an effort to build skills.
4. \*\*Caution: The space frame with cut-outs is rather flimsy and it may tear. Consider using four or six small pieces of masking tape to hold the template in place on the paperboard. When tracing the template information on to the paperboard with a sharp pencil or pen, attempt to keep the template flat. Keeping the template flat can be accomplished by holding the template flat with your fingers and lightly pressing on the edge of the template and paperboard with a pencil. However, try to press on the pencil hard enough so that the marks can be seen for cutting. Technique is important, so work slowly and be patient. If your pencil slips, do not worry about erasing any stray pencil marks.\*\* (Note 1: The portion of the space frame with the rectangular cut-outs will be attached to the bottom of the Discovery Box or Small Box.) (Note 2: It is necessary to make two space frame supports – one for each side of the Rover. The **Space Frame / Axle and Wheel Support / Wheel Subassemblies** are the same on both sides of the Rover. There is no concern about reversing the two.)
5. Prepare a piece of paperboard which is large enough to accommodate the space frame template. It may be necessary to splice two pieces of paperboard together with a ½-inch to ¾-inch wide strip of brown Kraft paper bag and glue. Place the paperboard on a sheet of corrugated cardboard to prevent damage to underlying surfaces. Using four or six pieces of 3/4-inch x 3/4-inch pieces of masking tape, attach a large piece of paperboard to a piece of cardboard other protective sheet material. Using four or six pieces of 3/4-inch x 3/4-inch pieces of masking tape, attach the space frame template to the large piece of flattened paperboard (or spliced paperboard). Using a sharp pencil or pen, carefully trace the outline entire space frame and cut-outs on to the paperboard. (Note 1: It may be necessary to relocate the pieces of masking tape on the paper template as cutting proceeds.) (Note 2: Masking tape is desirable because it can be removed along with the paper template from the paperboard space frame in order to make the second space frame.)
6. Remove the space frame template along with the pieces of masking tape and place it on a second sheet of paperboard. Repeat the process for making the space frame in Step 5. (Note: Two space frames are required to make the Rover. Each space frame may be made individually or both at the same time. There is no problem with completing one of the Space Frame / Axle and Wheel Support / Wheel Subassemblies and then coming back to make another paperboard space frame and the second subassembly.)
7. \*\*Caution: Find a safe place to store the space frame with all the cut-outs. The flat shape of the space frame could easily get torn or damaged. If you have a pet(s) in the house, the pet may find it enjoyable to use the space frame as a toy for chewing. Similarly, a young child might have fun ripping it apart.\*\* Once the shapes on the template have been traced on to the paperboard, cut out the perimeter of the template. Then, carefully make the triangular and rectangular cut-outs. Review Step 3. Discard or recycle the scrap paperboard which is left over after cutting out the template.
8. \*\*Caution: Single-edge razor blades are very sharp.\*\* (Note 1: Consider using an alternate tool for scribing / punching the long dashed lines on the space frame to permit folding. A small screwdriver, point of a compass, dinner fork, or pattern-making wheel might be used instead.) (Note 2: A ruler or straight-edge may be used as a guide when lightly scribing or making a shallow cut in the paperboard. Avoid cutting all the way through the paperboard. The goal / objective is to weaken the paperboard, not cut completely through it which may cause the paperboard to separate.) (Note: Prior to scribing recycled / reused paperboard, determine whether the brown / gray paper side of the paperboard or the printed side of the paperboard will be scribed.)
9. \*\*Caution: When lightly scribing or punching the space frame, avoid damaging the table surface or other surface underneath the work piece.\*\* Place the space frame on a sheet of corrugated cardboard or other protective sheet material underneath the space frame requiring scribing or punching of depressions which permit folding. Consider using some small pieces of masking tape to hold the space frame in place for the scribing or punching operation.
10. \*\*Caution: If a ruler is used for scribing along with a single-edge razor blade, make sure to keep the tips of your fingers away from the edge of the ruler. This will help to prevent a skin laceration (cut) if the razor blade slips.\*\* Scribe or punch the areas shown by dashed lines on the space frame template (that is, between the row of rectangular cut-outs / adjacent row of triangular cut-outs and the row of triangular cut-outs / adjacent row of triangular cut-outs).
11. Remove the pieces of masking tape and safely store the paperboard space frame or proceed with additional work.
12. Using brown Kraft paper grocery bag stock, make a 1/2-inch wide x 16-inch long strip of brown Kraft paper (that is, a long tab) to hold the length of the space frame together. (Note 1: A long brown Kraft paper tab was selected because it is easier to bend than a paperboard tab.) (Note 2: For convenience, shorter lengths of brown Kraft paper may also be used.) Apply glue to an area approximately ¼-inch wide and 16-inches long on the space frame section with the rectangular cut-outs. Attach the brown Kraft paper strip to the edge of the space frame with the rectangular cut-outs. Orient the paper strip so the section without glue extends ¼-inch beyond the side of the space frame with the rectangular cut-outs. (Note: This creates a tab for gluing the space frame together.)
13. Using the edge of a counter top or table, bend the space frame along the scribe lines or punched lines. Fold the space frame to form a tube with a triangular cross-section. Also pre-fold the brown Kraft paper tab on the side of the space frame with the rectangular cut-outs.
14. Apply glue to the brown Kraft paper tab on the side of the space frame with the rectangular cut-outs or apply glue to the edge of the space frame with the triangular cut-outs.
15. Assemble the tab to the side of the space frame with triangular cut-outs. Trim off any brown Kraft paper which extends beyond the space frame. (Note: The space frame goes from being rather flimsy to being less flexible at this point.)
16. Locate the “diamond-shaped” **Wheel / Axle Support** template which allows for attachment of the Rover axles to the Space Frame. Decide if you want the printed side or paperboard side to show. Cut out the template, trace the shape of the template on to a piece of paperboard. Make 6 each Wheel / Axle Support pieces.
17. \*\*Caution: Use a sheet of cardboard or protective sheeting for scribing / punching.\*\* Lightly scribe or punch the dashed line locations shown on the Wheel / Axle Support template (that is, the locations of the tabs for gluing and the middle of the diamond shape where the axle will be located.)
18. Fold the tabs on the Wheel / Axle Support template. Also fold the locations in the middle of the diamond shape where the axles will be attached.
19. Locate the black dots (axle locations) on the space frame. Cut off 1/2-inch x 3/4-inch pieces of masking tape to hold the axle support pieces on the space frame. Apply glue to the tabs and attach an axle support to the triangular cut-out area with the black dot on the space frame. Install pieces of masking tape to hold the Wheel / Axle Support pieces on the space frame while the glue dries. Repeat the process for the other two Wheel / Axle Supports on the Space Frame / Axle and Wheel Support / Wheel Subassembly. (Note: It is important to properly align the Wheel / Axle Support pieces with the triangular cut-outs in the Space Frame. It is also important that the “1/4-inch wide flat area” in the middle of the diamond-shaped Wheel / Axle Support is parallel with the Space Frame surface, that is, the Space Frame section with the rectangular cut-outs. If the surfaces are not parallel, the wheels on the Rover will not be located at the correct angle. Take your time to see how the each axle support fits on to the space frame and work carefully.)
20. Once the glue has dried, remove the pieces of masking tape.
21. Locate the template for the triangular **Wheel Support Cover** (with tabs) which fits into the Wheel / Axle Support piece. Decide if you want the printed side or paperboard side to show. Cut out the template, trace the shape on to a piece of paperboard, and cut out 6 each Wheel Cover Support pieces. Scribe / punch the dashed lines as shown on the template. The top tab is scribed on the top of the paperboard. The two side tabs are scribed on the top of the paperboard. Fold all three tabs over on the triangular Wheel Support Cover. The top tab which is installed near the top of the Space Frame (that is, near the rectangular cut-outs) is almost bent back on itself.
22. Apply glue to the tab locations, insert the Wheel Support Cover into the Wheel / Axle Support, and apply small pieces of masking tape to hold the Wheel Support Cover in place. Repeat the process for the other two Wheel Support Covers. (Note 1: Some trimming and fitting may be necessary to make the Wheel Support Covers fit into the Wheel / Axle Supports.) (Note 2: The top Wheel Support Cover tab may have a tendency to pull the Space Frame out of position. If the space frame is distorted, push the top of the Space Frame back into the proper position. If necessary, a small piece of brown Kraft paper strip may be glued on the Space Frame to prevent distortion. The strip will form a mini-triangle in cross-section.)
23. Once the glue has dried, remove the pieces of masking tape. Consider filling in any gaps around the Wheel / Axle Supports and Wheel Support Covers with glue. Allow the glue to dry. (Note 1: The additional glue will help to maintain the strength of the Space Frame / Wheel and Axle Support / Wheel Subassembly as additional components are added to the Rover.)
24. \*\*Caution: Cutting pencils may create graphite dust which can create black marks in the work area or on the Rover components.\*\* Put down a sheet of paper to collect any graphite and wood cuttings. Prepare three 3-3/8-inch long Axles using pencils as stock material. The pencil pieces may be cut using an X-acto razor saw, a hack saw blade, or sharp knife. Dispose of the graphite and wood cuttings in the trash before it gets all over everything.
25. Attach a pencil piece (Axle) to the 1/4-inch wide flat area on the bottom of the Wheel / Axle Support using glue. The Axle needs to be perpendicular to the side of the Space Frame and parallel to the surface on the top of the Space Frame where the rectangular cut-outs are located. (Note: If the axle support area is not quite flat, a slight taper can be cut on the Axle using a razor blade. Alternately, the Axles can be shimmed with small pieces of paperboard and glue to provide the proper alignment.) Apply glue to one side of the pencil (Axle). Allow the glue to dry. Repeat the process for the other two Axles. (Note: Sight down the space frame and work to ensure that all three Axles are in alignment. A ruler may also be placed on the top of the Axles to see if they are all in alignment. )
26. To rigidly hold the Axle in place, cut out a 1-inch wide x 1-1/2 inch long piece of brown Kraft paper from a paper bag. Fold the piece of paper over the Axle and Wheel / Axle Support so that it forms a “U” or “V” shape. Coat the surface of the piece of paper with glue and attach it to the Axle and each side of the Wheel / Axle Support. Allow the glue to dry. Repeat the process for the other two Axles.
27. If desired, do a search on the internet for “Images of the Mars Rover” to find an image of the “Curiosity Rover.” “Making a Curiosity Rover” is a U-Tube presentation. The basic concept for making the Rover wheels was developed from the Curiosity Rover.
28. Obtain an 8-inch x 10-inch x 1/8-inch thick piece of corrugated cardboard. Alternately obtain two each 4-inch wide x 10-inch x 1/8-inch thick pieces of corrugated cardboard. (Note: Use pieces of cardboard which do not have any creases or punched cut lines.)
29. Prepare to make the middle of the Rover wheel or **Wheel Disk**. Obtain a 16-ounce food pack can to use as a template (approximately 3-inches in diameter). Use a pencil and trace the outline of the can on a piece of corrugated cardboard. Use a pair of scissors or small tin snips to cut out the Wheel Disk. Locate the center of the Wheel Disk (that is, the 1-1/2 inch radius). Use a Straight Pin and punch a hole through the cardboard at the center of the disk. Remove the Straight Pin and store it in a safe location. Mark the center of the disk with two 1/2-inch long lines located at 90-degrees to each other (that is, similar to a “+” sign). Mark both sides of the disk using the hole created by the Straight Pin as a guide. Position a new pencil (which has not been sharpened) or a short section of cut-off pencil from the Axle fabrication effort so that it is in line with the crossed lines in the center of the disk. Use a sharp pencil and trace a line around the perimeter of the new pencil or cut-off Axle piece.
30. \*\*Caution: Attempt to keep the hole in the Wheel Disk as small as possible or the finished wheel may wobble.\*\* Use a single-edge razor blade to cut out the outer pieces where the pattern was traced around the pencil. Also cut out the center corrugated piece of cardboard where the pattern was traced around the pencil. (Note 1: The hole in the disk will receive the Axle on the Space Frame / Wheel and Axle Support / Wheel Subassembly.) (Note 2: If the hole in the disk ends up being too large, one or two washers with the proper inner diameter can be made from brown Kraft paper and glued to the Wheel Disk.) Repeat these steps five more times to provide a total of six disks to fabricate three Wheels. A total of 12 disks will be needed for all six Wheels on the Rover.
31. Prepare to make the outer section of a Rover Wheel. Find the drawing of the Wheel Ring. Cut out a 2-inch wide x 10-1/4-inch long strip of 1/8-inch thick 2-layer flexible corrugated cardboard. (Note: The corrugations in the cardboard must be in line with the 2-inch width – not lengthwise.) (Note: A supply of “flexible” or two-layer cardboard sheet consisting of a flat cardboard layer and corrugated cardboard layer may be found in the Discovery Box contents.) It is also possible to make your own flexible cardboard sheet (as follows). Begin by locating a 12-inch wide x 10-1/4-inch long x 1/8-inch thick piece of three-layer cardboard. Cut the sheet into 2-inch wide x 10-1/4-inch long strips. Using a small screwdriver, carefully pry up and separate one side of the outer cardboard sheath from the corrugated center section in the cardboard strip. Carefully remove any fuzzy pieces of cardboard which remain on the surface of the corrugated strip. (Note: The remaining 2-layer piece of cardboard piece is flexible.) Locate the end of the strip and remove a 2-inch wide x 3/8-inch long wide section of corrugated cardboard (that is, only the middle section of the 2-layer cardboard sheet). Locate the opposite end of the cardboard sheet (that is, the smooth side of the cardboard sheet) and mark off one each 2-1/8-inch long increment followed by 3 each 2-1/4-inch increments. Cut out 4 each 1/4-inch wide x 1-1/4-inch long pieces of 1/8-inch thick 3-layer cardboard (or 2-layer cardboard). Apply glue and center the 1/4-inch wide cardboard pieces on the smooth side of the cardboard at each 2-1/4-inch increment line. (Note: The strips of cardboard will help to position the 3-inch diameter disks prepared in Steps 29 and 30.)
32. (Note: Provide a 1-inch long x 3/4-inch wide piece of masking tape or a large diameter / thin rubber band to help with the Wheel assembly effort.) Select one of the 3-inch diameter Wheel Disks. Apply glue to the end of the 10-1/4-inch long cardboard strip. Wrap the Wheel Ring cardboard strip (corrugated section outward) over the Wheel Disk. Overlap the ends of the Wheel Ring cardboard strip and hold the ends together until the glue begins to set. Use a piece of masking tape or a large / thin rubber band to hold the Wheel Ring cardboard strip together. Before the glue dries, insert a second Wheel Disk on the side opposite to the first Wheel Disk. Adjust the position of the Wheel Disks so that each disk is inset from the edge of the Wheel Ring cardboard strip by approximately 1/4 inch. Once both Wheel Disks are in place, apply glue between the disk and the inner diameter of the cardboard strip. Let the glue dry. Turn the wheel over and apply glue in the same manner. Repeat the Steps 31 and 32 five more times to create six Rover Wheels.
33. \*\*Caution: There must be some clearance between the Wheel Disk and the Wheel Retaining Washer or the Rover Wheel may bind.\*\* Prepare to make a **Wheel Retaining Washer** to hold the Wheel on the Space Frame / Axle and Wheel Support / Wheel Subassembly. Select a small piece of paperboard. Mark a pair of 1-inch long lines approximately 90 degrees to each other (that is, like a “+” sign). Position a new pencil (which has not been sharpened) or a short section of cut-off pencil from the Axle fabrication effort so that it is in line with the crossed lines. Trace the outline of a pencil perimeter on the paperboard using a sharp pencil. Cut out the template for the Wheel Retaining Washer. Center the template on the crossed lines. Then trace the perimeter template on to paperboard. Use a razor blade and pair of scissors to cut out a paperboard washer. Fabricate a total of six Wheel Retaining Washers. (Note: The Washer must fit tightly on to the Axle.) Place the Wheel on the Axle of the Space Frame /Axle and Wheel Support / Wheel Subassembly. Stack up a couple of pieces of scrap paperboard next to the Axle (that is, on the surface of the Wheel Disk) to serve as clearance spacers. Install the Wheel Retaining Washer on the Axle of the Space Frame / Axle and Wheel Support / Wheel Subassembly. Carefully glue the washer to the Axle. Allow the glue to dry and remove the clearance spacers next to the Wheel Disk. Check that the Wheel will spin. Repeat the step for the other Wheels. This completes the Space Frame / Axle and Wheel Support / Wheel Subassembly for the Rover. (Note: If only one Subassembly was completed, then fabricate a duplicate Subassembly using the previous fabrication steps.)
34. Optional Step: It may be desirable to create a **Spinner** for each wheel. Fabricate a **Spinner Ring**. Cut out a 3/16-inch wide x 2-5/16-inch long strip from paperboard. Roll the strip up into a ring and glue the ends together using a short piece of brown Kraft paper grocery bag. Apply glue to the edge of the Spinner Ring and attach the ring to the wheel area located around the Wheel Retaining Washer which holds the Wheel in place. Allow the glue to dry. (Note: The Spinner Ring must not rub against the Wheel Retaining Washer and glue must be kept away from the Washer to ensure that the Wheel will spin freely.) Cut out the paper template for the Spinner. Trace the outline of the template on to a piece of paperboard. Cut out the Spinner using a single-edge razor blade and a pair of scissors. Apply a thin bead of glue to the Spinner Ring, attach the Spinner to the Ring, and ensure that the Spinner is centered on the Wheel. Allow the glue to dry. Check that the Wheel still turns freely. Repeat the step for the other Wheels.

Assemble Space Frame / Axle and Wheel Support / Wheel Subassembly on to Discovery Box (Mars Rover Which Utilizes the Discovery Box)

(Note: If it is desired to construct the Mars Rover which utilizes the Small Box, see the assembly instructions in the following section.)

1. \*\*Caution: The Discovery Box needs be sealed so that attached components will not fall off the Discovery Box.\*\* Cut off several 1-inch wide strips of brown Kraft paper from a grocery bag. Apply glue to the strips of paper as needed. Use the pieces of paper to seal any seams which could open on the Discovery Box.
2. The top of the Space Frame Subassembly with the rectangular cut-outs is 2-1/4-inches wide. Measure 5/8-inch over from the top outer edge (Wheel side) of the Space Frame Subassembly. Make a pencil mark on the Space Frame Subassembly. A 1-5/8-inch wide portion the space frame must be attached to underside of the empty Discovery Box. The other portion of the Space Frame Subassembly will extend 5/8-inch beyond the sides of the Discovery Box. Align the Axle for the middle wheel on the Space Frame / Axle and Wheel Support / Wheel Subassembly with the middle (that is, the 9-inch center) of the 18-inch long empty Discovery Box. The ends of the Space Frame Subassembly will extend approximately 1/4 inch beyond each end of the empty Discovery Box.
3. \*\* Caution: Install one Space Frame / Axle and Wheel Support / Wheel Subassembly at a time. Considerable effort was put in to fabricating the Space frame / Axle and Wheel Support / Wheel Subassemblies. It is suggested that the entire space frame be installed on the Discovery Box using paperboard strips (instead of gluing the entire Space Frame Subassembly to the Discovery Box). If a mistake is made while aligning and gluing the Space Frame / Axle and Wheel Support / Wheel Subassemblies in place, it is possible to cut and re-align the space frame without damaging it.\*\* Cut out three pieces of 1/2-inch wide x 1-1/2-inch long strips of pasteboard. Draw a 1-1/2-inch long line in the middle of the each strip (that is, subdivide it into two 1/4-inch wide sections). Use a razor blade to scribe the middle of the strip. Fold the strip lengthwise into a V-shape. Apply glue to the strip. Turn the Discovery Box with the top in the downward position. Using glue, attach the strip in the middle of the space frame (on the railing with the triangular cut-outs) and the Discovery Box. Allow the glue to dry. Using glue, attach the second strip between the side of the space frame and the Discovery Box toward one end of the Space Frame Subassembly. Using glue, attach a third strip between the side of the Space Frame Subassembly and the Discovery Box toward the opposite end of the Space Frame Subassembly. Allow the glue to dry.
4. \*\*Caution: The Space Frame / Axle and Wheel Support / Wheel Subassemblies are loose and may flip downward while changing the position of the Discovery Box. To avoid damaging the Space Frame Subassembly, exercise caution when removing any temporary masking tape supports from the Space Frame Subassembly.\*\* Apply a couple of 1-inch long pieces of masking tape between the outside of the top outer portion of the Space Frame Subassembly (that is, the portion with the rectangular cut-outs). The pieces of masking tape need to be positioned on the Space Frame Subassembly between the Wheel locations.
5. \*\*Caution: The Discovery Box and Space Frame / Axle and Wheel Support / Wheel Subassemblies may try to flip off a table, countertop, or work surface. This can result in damage to the partially assembled Rover.\*\* Prepare four to six 3-inch long pieces of masking tape. Carefully position turn the Discovery Box with the side of the box in the downward position on the side of a table, countertop, or work surface. The wheels need to extend below the table, countertop, or work surface and face outward toward you. While holding the Discovery Box, tape the both ends of the Discovery Box to the table, countertop, or work surface using several strips of masking tape.
6. Caution: The scribe line near the top of the **Space Frame-Box Support** needs to be on the back side of the Support. The scribe line on the bottom of the Space Frame-Box Support needs to be on the front (top) side of the support.\*\* Cut out the template for the **Space Frame – Box Support**. Using a sharp pencil, trace the pattern of the Space Frame – Box Support on to a piece of paperboard. Cut out the pattern with a pair of scissors. Using a single-edge razor blade, scribe the fold tabs as described in the preceding Caution note. Fold the top tab so that it is bent upward. Fold the bottom tab so that it is bent downward. Apply glue to the tabs. Assemble the first Space Frame Box-Support above the middle Wheel Support Cover on the Space Frame Subassembly (Note: The Wheel Support Cover is a triangular shaped piece of pasteboard located on the Space Frame Subassembly behind of each Wheel.) If desired, use a couple of 3/4-inch x 3/4-inch pieces of masking tape to hold the Space Frame-Box Support in place while the glue dries. Install the other two Space Frame-Box Supports above the other two Wheel Support Covers. Once the glue has dried, remove the pieces of masking tape. Apply additional glue to hold the Space Frame-Box Supports in place and allow the glue to dry.
7. \*\*Caution\*\* The Space Frame / Axle and Wheel Support / Wheel Subassemblies are loose and may flip downward while changing the position of the Discovery Box. To avoid damaging the space frame, exercise caution when removing any temporary masking tape supports from the Space Frame Subassembly.\*\* Apply a couple of 1-inch long pieces of masking tape between the outside of the top outer portion of the Space Frame Subassembly (that is, the portion with the rectangular cut-outs). The pieces of masking tape need to be positioned on the Space Frame Subassembly between the Wheel locations.
8. \*\*Caution: Exercise care when removing the masking tape strips which hold the partially assembled Rover to the table, countertop, or work surface.\*\* Prepare four to six 3-inch long pieces of masking tape. Carefully remove the pieces of masking tape which hold the Discovery Box to the table, countertop, or work surface. Carefully reposition the Discovery Box (that is, turn the Discovery Box on to the opposite side so that the Wheels are facing outward toward you). The wheels need to extend below the table, countertop, or work surface. While holding the Discovery Box, tape the both ends of the Discovery Box to the table, countertop, or work surface using several strips of masking tape.
9. Repeat the Steps 1 through 8 for installing the Space Frame / Axle and Wheel Support / Wheel Subassembly on the opposite side of the partially-completed Rover.
10. Carefully remove the pieces of masking tape which hold the Discovery Box to the table, countertop, or work surface.
11. Reposition the Rover with wheels on the table, countertop, or work surface. Check the alignment of the wheels and determine if all of the wheels will turn.

Assemble Space Frame / Axle and Wheel Support / Wheel Subassembly on to Small Box (Mars Rover Which Utilizes the Small Box)

1. \*\*Caution: The Small Box needs be sealed so that attached components will not fall off the Small Box.\*\* Cut off several 1-inch wide strips of brown Kraft paper from a grocery bag. Apply glue to the strips of paper as needed. Use the pieces of paper to seal any seams which could open on the Small Box.
2. \*\*Caution: Use pieces of masking tape to hold the partially completed Rover on to the table, countertop, or work surface.\*\* With the exception of installing the **Space Frame-Box Supports** on the ends of the Space Frame, follow the previous steps in the Assembling the Space Frame / Axle and Wheel Support / Wheel Subassembly on to Discovery Box. The installation of the middle Space Frame-Box Support on the Small Box is the same as the installation of the middle Space Frame-Box Support on the Discovery Box.
3. (Note: The Small Box is shorter than the Discovery Box. This requires that the Space Frame-Box Supports located on the ends of the Space Frame Subassembly be moved inward toward the Space Frame-Box Support located in the middle of the Space Frame Subassembly.) Locate the fourth triangular cut-out (or offset location) which is located inward from the end of the Space Frame Subassembly (that is, inward and adjacent to the triangular cut-out where the Axle and Wheel Supports and Wheels are located). Install the Space Frame-Box Support above the offset location. Other than the location of the Space Frame-Box Support, follow the guidance provided in Step 6 in the previous section (Assemble Space Frame / Axle and Wheel Support / Wheel Subassembly on to the Discovery Box).
4. Install another Space Frame-Box Support in the offset location on the opposite end of the Space Frame Subassembly.
5. \*\*Caution: Use pieces of masking tape to hold the partially completed Rover on to the table, countertop, or work surface.\*\* Turn the partially-completed Rover over and complete the installation of the Space Frame-Box Supports.
6. Complete Steps 10 and 11 in the previous section (Assemble Space Frame / Axle and Wheel Support / Wheel Subassembly on to the Discovery Box).

Installing Instrumentation and Components on Upper Portion of Mars Rover

1. Place a 2-inch or 3-inch high box or some blocks of wood or books underneath the bottom of the Discovery Box or the Small Box (that is, between the Space Frame Subassemblies). (Note: The box / blocks / books will prevent wear and tear on the space frame subassemblies while the Rover is completed.)
2. Cut out the template for the **Boom**. (Note: The horizontal Boom is attached to the front of the Rover directly or with 1/2” x 1” Gussets or Attachment Tabs). Using a sharp pencil, trace the pattern of the Boom on to a piece of paperboard. Cut out the pattern with a pair of scissors. Use a single-edge razor blade to scribe the fold lines and fold tabs. Fold as needed. Using glue, assemble the Boom. Use short pieces of masking tape to temporarily hold the Boom together if desired. Allow the glue to dry and remove the pieces of masking tape. Draw a horizontal line on the front of either the Discovery Box or the Small Box. The line needs to be 1/2-inch below the top of the box. The horizontal boom needs to be centered on the front of either the Discovery Box or Small Box. The top of the Boom needs to be aligned about 1/2-inch below the top of either the Discovery Box or the Small Box. Apply glue to the back of the Boom. Alternately, the Boom may be attached with glue and 1/2” x 1” Gussets or Attachment Tabs. Allow the glue to dry. (Note 1: The folded Boom section may be attached to the front of the Discovery Box or Small Box directly as discussed previously. Alternately, the boom may be extended out in front of the Rover. See Optional Step 14 for guidance on installing the Drill / SHERLOC / WATSON on an extended Boom.)
3. Cut out the template for the **Super CAM**. (Note: The Super CAM is attached to the top of the vertical Super CAM Support). Using a sharp pencil, trace the pattern of the Super CAM on to a piece of paperboard. Cut out the pattern with a pair of scissors. Use a single-edge razor blade to scribe the fold lines and fold tabs. Fold as needed. Apply glue to the tabs and use small pieces of masking tape to hold the Super CAM together if desired. Allow the glue to dry and remove the pieces of masking tape. If necessary, trim off any excess pieces of paperboard with a pair of scissors. (Note: If desired, a paperboard ring may be fabricated and attached with glue to simulate the lens on the Super CAM. Make a ring which is about 1/2” longer than the Spinner Ring attached to the Rover Wheel. (Note: The Spinner Ring is discussed in Step 34 in the Assembly Instructions for the Space Frame / Axle and Wheel Support / Wheel Subassembly. Alternately, the Spinner Ring may be drawn on the front of the Super Cam.)
4. Cut out the template for the **Super CAM** Support. (Note: The Super CAM is attached to the top of the vertical Super CAM Support). Using a sharp pencil, trace the pattern of the Super CAM on to a piece of paperboard. Cut out the pattern with a pair of scissors. Use a single-edge razor blade to scribe the fold lines and fold tabs. Fold as needed. Apply glue to the tabs and use small pieces of masking tape to hold the Super CAM Support together if desired. Allow the glue to dry and remove the pieces of masking tape. If necessary, trim off any excess pieces of paperboard with a pair of scissors.
5. The bottom of the Super CAM has dimensions of 3” wide x 2” long. Locate the middle of the Super CAM (that is, 1-1/2” x 1”). Using glue, attach the Super CAM support to the bottom of the Super CAM at the middle position. Provide 4 each scribed and folded Gussets or Attachment Tabs to hold the Super CAM Support to the bottom of the Super CAM. Cut out the template for the **Gussets** or Attachment Tabs. Using a sharp pencil, trace the pattern of the Gusset on to a piece of paperboard. Cut out the pattern with a pair scissors. Using a single-edge razor blade, scribe the fold lines. Fold as needed. (Note: The installed Gussets will look like a cross once they are installed.) Glue the gussets in place and allow the glue to dry. Using glue, attach the Super CAM Support (supporting the Super CAM) to the top of the Discovery Box or Small Box. The Super CAM Support needs to be installed near the front of the box and approximately 1 or 2 inches from the side of the box. Use 3 or 4 Gussets on the sides of the Super CAM Support to hold the Support on the top of the Box. (Note: The gussets will prevent the Super CAM from sagging or being accidentally knocked off the Box.)
6. Cut out the templates for the **Drill (hexagonal shape)**. (Note: The Drill is attached to the top of the vertical **SHERLOC Support**.) Using a sharp pencil, trace the pattern of the Drill on to a piece of paperboard. Cut out the pattern with a pair of scissors. Use a single-edge razor blade to scribe the fold lines and fold tabs. Fold as needed. Apply glue to the tabs and use small pieces of masking tape to hold the Drill together if desired. Allow the glue to dry and remove the masking tape. If necessary, trim off any excess pieces of paperboard with a pair of scissors.
7. \*\*Caution: Scribe lines need to be located on the top and underside of the **PIXL and WATSON Support**.\*\* Cut out the template for the PIXL and WATSON Support. Using a sharp pencil, trace the pattern of the PIXL and WATSON Support on to a piece of paperboard. Cut out the pattern with a pair of scissors. Repeat the process and make a second support. Using a single-edge razor blade to scribe the fold lines and fold tabs. (Note: Two scribe lines are needed on the top of the PIXL and WATSON Support and two scribe lines are needed on the underside of the Support.) Fold as needed. Locate the drawing which shows the PIXL and WATSON Supports installed on the sides of the hexagonal Drill.) The drill is 4-inches high, and the PIXL and WATSON Supports need to be installed in the middle of the Drill (that is, 2” from the top or bottom of the Drill). Orient the PIXL and WATSON Support so that middle of the support fits above the peak on the hexagonal Drill. (Note 1: The fold lines and fold tabs will be parallel with the 4-inch long vertical lines on the hexagonal Drill surface.) (Note 2: The flat surfaces created by attaching the PIXL and WATSON Supports, which are attached to the sides of the hexagonal Drill, need to be in line with or parallel with the flat side of the Discovery Box or Small Box. The flat surface on the Drill will also be in line with and parallel to the front of the Discovery Box or Small Box.) (Note 3: If it is desired, it is also acceptable to have the entire Drill / PIXL / WATSON subassembly rotated at an angle, that is, not parallel to the side of the Discovery Box or Small Box.)
8. Cut out the template for the vertical **SHERLOC Support** (3” long tube with a 1/2” square cross-section). Using a sharp pencil, trace the pattern of the support on to a piece of paperboard. Cut out the pattern with scissors. Using a single-edge razor blade, scribe the fold lines and fold tabs. Fold as needed. Using glue, assemble the SHERLOC Support. Use short pieces of masking tape pieces to temporarily hold the Support together if desired. Allow the glue to dry and remove the pieces of masking tape.
9. Using glue, attach the SHERLOC Support to the flat side of the hexagonal Drill. Position the Support so that it is in line with the PIXL and WATSON Supports (that is, in the middle of the drill or 2” from the top of the Drill). Provide 2 each scribed and folded Gussets or Attachment Tabs made from paperboard to hold the hexagonal Drill on to the SHERLOC Support. Cut out the template for the **Gussets** or Attachment Tabs. Using a sharp pencil, trace the pattern of the Gusset on to a piece of paperboard. Cut out the pattern with a pair scissors. Using a single-edge razor blade, scribe the fold lines. Fold as needed. Using glue, assemble the gussets on either side of the SHERLOC Support and the flat surface on the hexagonal Drill (that is, the Gussets are 180 degrees apart). An additional pair of Gussets may also be made from brown Kraft Paper. The brown Kraft paper Gussets may be installed on the side of the Drill in the area of the hexagonal peaks. (Note 1: The paperboard and brown Kraft paper Gussets will form a cross on the side of the hexagonal Drill. (Note 2: The Gussets will prevent the Drill / PIXL / WATSON from sagging or being accidentally knocked off the box.).
10. Cut out the template for the **PIXL**. Using a sharp pencil, trace the pattern of the PIXL on to a piece of paperboard. Cut out the pattern with a pair of scissors. Using a single-edge razor blade, scribe the fold lines and fold tabs. Fold as needed. Using glue, assemble the PIXL. Use short pieces of masking tape pieces to temporarily hold the PIXL together if desired. Allow the glue to dry and remove any pieces of masking tape. Once the glue has dried, apply some additional glue to the middle of the PIXL. Attach the PIXL to the PIXL Support located on the side of the hexagonal Drill. Allow the glue to dry.
11. Cut out the template for the **WATSON**. Using a sharp pencil, trace the pattern of the WATSON on to a piece of paperboard. Cut out the pattern with pair of scissors. Using a single-edge razor blade, scribe the fold lines and fold tabs. Fold as needed. Using glue, assemble the WATSON. Use short pieces of masking tape pieces to temporarily hold the WATSON together if desired. Allow the glue to dry and remove the pieces of masking tape. Once the glue has dried, apply some additional glue to the middle of the WATSON. Attach the WATSON to the WATSON Support located on the side of the hexagonal Drill. Allow the glue to dry.
12. Using glue, attach the vertical **SHERLOC Support** (with the hexagonal Drill, PIXL, and WATSON) to the end of the horizontal boom located on the front of the Discovery Box or Small Box. Glue may be applied to both the top end of the Boom and the front side of the Discovery Box or Small Box. Install the SHERLOX Support (holding related components) on the end of the horizontal Boom. To prevent sagging, a 1./2” x 1” Gusset or Attachment Tab may be applied to the front of the Boom and the SHERLOC Support using glue. A Gusset may also be glued on to the SHERLOC Support and the top of the Discovery Box or Small Box. Allow the glue to dry.
13. Option for installing the Drill / SHERLOC / WATSON on the end of an extended Boom / SHERLOC Support: (Note 1: The folded boom section may be attached to the front of the Discovery Box directly. Alternately, the Boom may be extended out in front of the Rover. Images of the extended Boom on the Mars Rover may be found on the internet. If the Boom is attached in the extended position, it may sag. Consider making some gussets – paperboard strips folded at a right angle to hold the Boom in place and prevent it from sagging. Overlap about a 3/4-inch long area on each section of the extended Boom. Glue the Boom and SHERLOC Support pieces together.) (Note 2: The Boom on the Rover has swivel joints. If desired, a mock-up of the swivel joints can be made from a section of paper towel tube. See the Step 15 – located below - related to fabricating the Antenna from a paper towel tube.) (Note 3: Due to excessive weight, it is not recommended to install the hexagonal Drill (middle component) / PIXL (x-ray spectrometer) / SHERLOC (ultraviolet spectrometer) / WATSON (camera) on the end of the extended boom. If the builder of the Rover is up to the challenge, consider making the Boom section longer, cutting a square hole in the each end of the Discovery Box or Small Box, and attaching the extended boom section inside the Discovery Box or Small Box. Use paperboard gussets to reinforce the boom structure as needed. If the boom is extended too far or the SHERLOC components are too heavy, it may be necessary to provide a counterweight or some ballast weight inside the opposite end of the Discovery Box or Small Box or the Radar Unit.)
14. Cut out the template for the **Antenna Support**. Using a sharp pencil, trace the pattern of the Antenna Support on to a piece of paperboard. Cut out the pattern with scissors. Using a single-edge razor blade, scribe the fold lines and fold tabs. Fold as needed. Using glue, assemble the Antenna Support. Small pieces of masking tape may be used to hold the Antenna Support together if desired. Allow the glue to dry and remove any pieces of masking tape. Once the glue has dried, apply glue to the 2” wide x 1” high surface of the Antenna Support. Attach the Antenna Support near the back corner of the Rover Discovery Box (that is, the right rear side of the Discovery Box or Small Box). (Note: Position the flat upper side of the Antenna Support so that it is flush with the flat top surface of the box.) Use a small piece of masking tape to hold the Antenna Support in place if desired. Allow the glue to dry and remove the piece of masking tape.
15. Obtain a 2” diameter paper towel tube. Measure off a 2”-long section on the paper towel tube. Wrap a piece of paper around the paper towel tube as a guide. Use a piece of masking tape to hold the guide in place. Mark the circumference of the tube using the guide. Using a single edge razor blade, cut off a 2”-long section of the tube. (Note: The tube is made from spiral-wound paperboard. Cutting may be a little more difficult where the spiral windings overlap. Make numerous cuts, and gradually cut through the spiral windings.) Apply glue to the bottom of the tube section and install it on the middle of the Antenna Support. Using the remaining section of the paper towel tube, place the end of the tube on a piece of paperboard. Trace around the end of the paper towel tube to create the shape of a disk. Cut out the disk. Apply glue to the edges of the disk. Attach the disk to the top of the Antenna (located on the Antenna Support). Allow the glue to dry.
16. Option 1: The RIMFAX (subsurface radar) **Radar Unit for the Super-Size Rover** consists of four templates (that is, Top / Back Template, Bottom / Front Template, and Side Templates). Cut out all of the templates for the Radar Unit. Using a sharp pencil, trace the pattern of the Radar Unit on to pieces of paperboard. Cut out the patterns with a pair of scissors. Using a single-edge razor blade, scribe all of the fold lines and fold tabs. Fold as needed. Using glue, assemble Top / Back and the Bottom / Front pieces. Use small pieces of masking tape to hold the Radar Unit pieces together if desired. Allow the glue to dry. Using glue, assemble the side pieces of the Radar Unit on the Top / Back and the Bottom / Front pieces. Again, use small pieces of masking tape to hold the Radar Unit pieces together if desired. Allow the glue to dry and remove the pieces of masking tape. Trial fit the Radar Unit on the back of the Rover (that is, center the Radar Unit on the back of the Rover.) If desired, mark a horizontal line on the back side (1-1/2” below the top) of the Rover Box to help align the Radar Unit. Apply glue to the front (angled) section of the Radar Unit and attach it to the back of the Rover. Alternately, the Radar Unit may be attached to the Discovery Box with four each Gussets located near the front corners of the Radar Unit.
17. Option 2: The **Radar Unit for Small Rover** consists of two templates connected by match lines. Cut out all both templates for the Radar Unit. Cut off a few pieces of masking tape and connect the template pieces at the match line. Using a sharp pencil, trace the pattern of the Radar Unit on to a piece of paperboard. Cut out the pattern with a pair of scissors. Using a single-edge razor blade, scribe all of the fold lines and fold tabs. Fold as needed. Using glue, assemble the Radar Unit. Use small pieces of masking tape to hold the Radar Unit pieces together if desired. Allow the glue to dry and remove the pieces of masking tape. Trial fit the Radar Unit on the back of the Rover (that is, center the Radar Unit on the back of the Rover.) If desired, mark a horizontal line on the back side (approximately 3/4” to 1” below the top) of the Small Box to help align the Radar Unit. Apply glue to the front (angled) section of the Radar Unit and attach it to the back of the Small Box. Alternately, the Radar Unit may be attached to the Small Box with four each gussets located near the front corners of the Radar Unit.
18. More detail can be added to the Rover if desired. The work done so far should allow you to fabricate additional components as needed. Study photos available for the Mars Rover on the Internet. Use your best judgement about fabricating and attaching additional components.

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