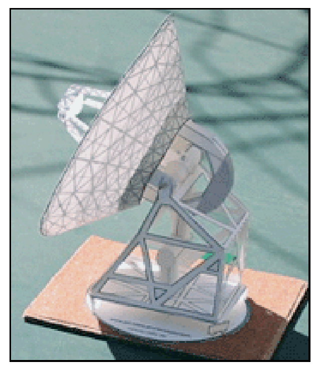
FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
Children
Middle & High School
Other Programs
GAVRT
Image Tutorial
Build Your Own DSN Station
GALLERY
LINKS

Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

NOTE: An online instruction manual is available at:
http://deepspace.jpl.nasa.gov/dsn/educ/model.html



COMPLETED 1/250 SCALE MODEL

The scale model has enough fidelity to demonstrate how most of its major mechanical components, and its larger microwave components actually work, as they track and communicate with interplanetary spacecraft in flight. It illustrates waveguide articulation as it rotates in azimuth and elevation.

This scale model may not be appropriate for people younger than about 14 years, depending largely upon motivation.

The scale model replicates a station like the 34m BWG DSS-55 at Madrid, Spain, and its counterparts in Australia and the U.S. While you're building your scale model, you can view extensive photography, video clips, and descriptions of building the real DSS-55 in Spain: each step in model assembly offers links to appropriate photos and narrative.

Bigger and Better

Parts and assembly instructions on this site provide a simplified, relatively easy-to-construct scale model. However, by studying this website and its links, an experienced model builder will see how easy it would be to improve on this version, using materials obtained locally. Scale model and hobby shops have I-beams and other components available in plastic and metal which would greatly improve on fidelity. This may be of interest for a school, a science museum, or a planetarium wishing to build a 34m BWG DSS model of any scale.

//// CAUTION ////

Assembling this scale model requires using, and changing blades of, a razor-sharp art knife. It is not intended for children except under strict adult supervision.

The 34m BWG DSS was selected for this scale model because it is DSN's newest design. It offers a new concept in tracking antennas that are easily replicated in a small model, as well as being remarkable and of great interest to a builder who has some technical interest. It is fortunate that so many photographs of constuction an actual 34m BWG DSS (DSS 55 at Madrid), as well as narrative, have been made available.

Click below to build your 34m BWG DSS 1/250 Scale Model.

(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Curator: Shirley Wolff
Webmaster: David Martin
Last Updated: 28-May-2003
Clearance No. **CL 03-1214**

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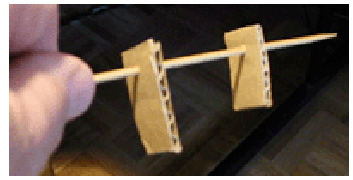
What You'll Need to Build Your 34m BWG DSS Scale Model

- Some experience. If you've never built a scale model before, you might not wish to tackle this as your first. Also, it may help to have previously worked on some other technically complex scale model made of paper (see http://www.jpl.nasa.gov/scalemodels for ideas).
- A dictionary. What's an "alidade?" A dictionary may help make this project an enjoyable learning experience.
- Pencil, preferably with round, rather than hexagonal cross section. This will be used to curl some small parts into ring shape, and to make a reference mark.
- White Glue, such as Elmer's Glue-all® or equivalent.
- Spray Glue, such as 3M Super77®, or equivalent low-moisture, permanent, rubbery spray adhesive.
- Art knife, X-Acto® #11 or equivalent, and a good supply of fresh new blades. While working, you'll need to change blades in your art knife a few times, to ensure smooth, accurate cuts. This project probably requires more than two blades.
- An appropriate cutting surface, such as X-Acto® Self-Healing Mat.
- A couple of small plastic drinking cups that can fit inside the main reflector, to help while gluing. Their base has to be less than 7 cm in diameter. Ideally, the mouth of the cups should be around 9 cm diameter.
- A flat, well-illuminated work surface.
- Scissors, small.
- Card stock, white, of a size that will fit your computer's printer. Generally called "cover stock" or "card stock", it should be stiffer than regular copy paper, but not too stiff to roll a small piece around a pencil. You might wish to experiment.
- Base of wood, foamcore, cardboard, or any other flat surface, at least large enough to support the circular AZIMUTH TRACK on Parts Sheet A, which is 9.3 cm in diameter.
- Two short lengths of thick solder (about 3mm diameter, each about a cm in length) to make soft metal rivets. These will be used in the Elevation Bearing assembly. Solder of the thickness needed is usually sold in

hardware stores for plumbing work. (Caution: some solder contains lead, which is harmful if ingested.)

- Diagonal cutters to snip the solder



LOW-MASS CLAMP

- Metal ruler to guide your art knife for cutting and scoring, and to press against when making a crease in paper parts. It should be graduated in SI units, mm and cm. If you prefer inches, use an appropriate metal ruler to convert the callouts on this website.
- Small alligator clips are useful for clamping sometimes. A larger clamp, good for assembling the alidade, can be made by skewering a couple pieces of scrap cardboard on a bamboo stick.
- If you have a very small hole punch, it would be helpful for making the four holes required when assembling the elevation bearing. 3 mm would be an ideal size, but a little larger might also work. If you don't have such a punch, you'll probably be able to cut good enough holes with your art knife.
- Long-nose pliers, small.
- Bamboo skewers for reaching through trusses to apply white glue.
- Time: 24 hours nominally. But that's a guess. Click here to tell us how long it actually took you, and we'll update this based on results.
- Patience. Resist the occasional urge to crumple and throw things. Careful work is required. The result will be a technically accurate scale model of the newest of NASA's Deep Space Network front-end machines, that can be used to demonstrate the major mechanical and microwave concepts they employ.
- Feedback. Please send some notes telling about your experiences with this project, how long it took you to assemble it, how you're using it, what mistakes you uncovered, and so on. Click here.
- Here's where you can obtain the Adobe Acrobat Reader® software, free of charge, for reading and printing .pdf files such as the parts sheets for this scale model project.

Click below to build your 34m BWG DSS 1/250 Scale Model.

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Curator: Shirley Wolff
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Last Updated: 28-May-2003
Clearance No. **CL 03-1214**

Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Download the Paper Parts for Your 34m BWG DSS Scale Model

There are twenty-seven intricate parts on five sheets. Notes on what kind of paper to use can be found here. Click each link below to download.

Note that if your browser has selectable options for either displaying .pdf files within the browser, or downloading them separately. You will want to download them separately.

- **Parts Sheet A** (16 Kbytes) Print on card stock
- **Parts Sheet B** (12 Kbytes) Print on card stock
- **Parts Sheet C** (16 Kbytes) Print on card stock
- **Parts Sheet D** (20 Kbytes) Print on card stock
- **Parts Sheet E** (24 Kbytes) Print on **regular paper**.

Here's where you can obtain the Adobe Acrobat Reader® software, free of charge, for reading and printing .pdf files including those above.

Once you have downloaded the files, print them on the appropriate paper. After printing, thoroughly read each sheet. Notice the names of the parts. Read all the mini-instructions for folding and scoring. Sheets A, B, C, and D need to be printed on card stock, and Sheet E needs to be printed on lighter-weight, regular copy paper. Next, go to the Assembly Instructions to continue. As you progress through the instructions, you'll see when to cut out each part.

Click below to build your 34m BWG DSS 1/250 Scale Model.

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

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Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

Assembly Instructions for Your 34m BWG DSS 1/250 Scale Model

1. **Collect What You'll Need.**
   You'll need the free Adobe ® Acrobat Reader, white glue, scissors, and some other stuff. It's all listed here.

2. **Read All the Instructions.**
   Click on each of the headings on this page, and read through **all** of the instructions before you even think about starting. This will give you an overall idea of the magnitude of the project at hand, and how difficult or easy you think it will be for you. While reading, you might come up with ideas for planning to modify your version of the model to suit your own situation.

3. **About Team Building.**
   Will more than one person be working on construction? Here are some hints.

4. **Download and Print the Parts.**
   Click above for a page with information about the parts files, and the option of downloading them. After printing, thoroughly read each sheet. Notice the names of the parts. Read all the mini-instructions for folding and scoring. Sheets A, B, C, and D need to be printed on card stock, and Sheet E needs to be printed on lighter-weight, regular copy paper.

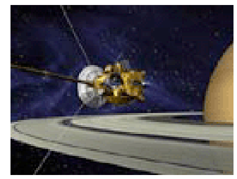
5. **Start with the Basement.**

6. **Build the Alidade Structure.**

7. [Build and Install the Main Reflector.]

8. Build and Install the Subreflector and Counterweight.

9. Communicate with Interplanetary Spacecraft.



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INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Curator: Shirley Wolff
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FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
Children
Middle & High School
Other Programs
GAVRT
Image Tutorial
Build Your Own DSN Station
GALLERY
LINKS

Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

The Basement

View this stage of DSS construction.

The basement, or pedestal, of a 34m BWG DSS is a major structure. The undertaking requires much excavating, building forms and reinforcements, pouring and curing concrete, and installing lots of equipment. The construction results in a large cylindrical concrete structure with a circular, flat top. A steel track is mounted on its perimeter, and it has a hole in the center of its "roof".

For this model, we'll skip all that!

(Of course, you may wish to design a scale basement pedestal for your model, especially if you're building it in connection with a professional display or science project. There are plenty of images and diagrams linked to this site that will help out. But you're on your own there. Click the image for more views of the basement.)

Assemble the Model Base*

- Obtain the base for the scale model. You'll want a flat surface at least as large as the AZIMUTH TRACK on Parts Sheet A, and smooth enough for spray glue to adhere.
- From Parts Sheet A, cut out the circular AZIMUTH TRACK. Apply a light coating of spray glue to the non-printed side of the circle. Set the circle onto the base material, and burnish thoroughly.
- From Parts Sheet A, cut out the small, rectangular AZIMUTH PINTLE. Curl it around a pencil so it will form a ring, on its own, about 1 cm in diameter.

COMPLETED BASE WITH AZIMUTH TRACK AND AZIMUTH PINTLE

- Apply white glue to the marked end of the AZIMUTH PINTLE. Curl it around on itself, up to the reference line near the end. Press together while aligning into a neat ring 1.2 cm in diameter. Adjust its shape to be very nearly circular.
- Dip one end of the AZIMUTH PINTLE ring in white glue. Set it glue-side down onto the black circle in the middle of the AZIMUTH TRACK. Apply more glue as necessary. Let dry.

- This completes the base structure for your DSS scale model.

The black circle in the center of the AZIMUTH TRACK represents a hole in the roof of the basement, or pedestal, of the DSS. Through this hole, microwave radio signals are exchanged with distant spacecraft via the DSS's massive reflectors and waveguides atop the basement.

The actual DSS's AZIMUTH PINTLE is a massive structural component responsible for serving as the center of rotation for the huge alidade structure, while its railroad-like AZIMUTH TRACK and steel wheels provide for motion in azimuth. It is fitted with a precision steel pintle bearing.

In the model, though, no distinction is made between the waveguide and the pintle. This arrangement is strong enough for the model, and it simplifies construction while it offers insight into how the real waveguide communicates with equipment in the basement room. It is hardly noticeable a compromise. But of course the actual DSS's waveguides are much too delicate, comparatively, to serve in this fashion.

- **Go on to the next step.**

---

* The steps on this page may be accomplished separately, while progress is being made on other tasks. This is convenient if more than one person is working on the project, or while one waits for glue to dry on a different step.

Click below to build your 34m BWG DSS 1/250 Scale Model.

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Curator: Shirley Wolff
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FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
Children
Middle &
High School
Other Programs
GAVRT
Image Tutorial
Build Your Own
DSN Station
GALLERY
LINKS

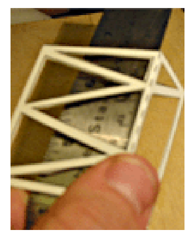
Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

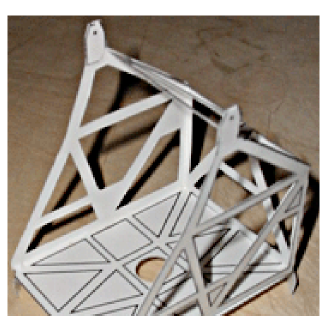
Assemble the Alidade Structure*

View this stage of DSS construction.



CREASING A SCORED PART USING METAL RULER

- From Parts Sheet A, cut out the ALIDADE BOTTOM. Use an art knife with a fresh new blade, to cut out this complex shape. Don't bother to cut out the triangles and rectangles drawn on the part.
- Cut out the central black circle.
- With printed side up, fold down all four WHEELS assemblies 90° at each corner of the part. Place a drop of white glue inside the folds, to hold their shape. Prop the four folded WHEELS assemblies somehow, to hold shape while glue dries. The large rectangular section must be kept flat.
- From Parts Sheet B, cut out the large ALIDADE BACK & SIDES. Use a metal ruler to guide your knife for the long straight cuts. Carefully cut out the 17 triangles marked X. There are four small unmarked triangles that do not need to be cut out.
- Score lightly for folding along the 3 dashed lines, guiding your art knife with a metal ruler. Be careful not to cut through the paper, or to cut in too deeply.
- Crease along each score by pressing against the edge of a metal ruler. Complete the crease neatly by folding each panel all the way back away from the printed and scored surface.
- After creasing, fold the ALIDADE side panels 90° to the BACK panel. Unprinted sides face each other inside. Fold the upper part of the BACK panel down to meet



ALIDADE FINISHED FOR NOW

the slanted sides. Glue together. You may find it helpful to devise and use a lightweight clamp by impaling two small scraps of cardboard on a bamboo skewer.

- There is a tab at the top of each of the ALIDADE's sides, marked ELEVATION BEARING TAB on the parts sheet, with additional marks for scoring and folding. Smear some glue inside each, and fold them each down on themselves. This will strengthen the paper for use as part of the ELEVATION BEARING. Bore or punch a small hole, about 3 mm wide, at the black dot on each of these two tabs.
- Set the ALIDADE BOTTOM printed side up on your work surface, so it stands on its four WHEEL assemblies. Fit the glued ALIDADE SIDES & BACK down onto the ALIDADE BOTTOM, as shown at right. With a long bamboo skewer, apply a drop of glue inside each of the two back corners where the parts meet.
- When the glued corners have dried, align the ALIDADE side panels with the BOTTOM and apply glue sparingly. Let dry.
- From parts sheet B, cut out the ALIDADE FRONT. Cut out the 8 triangles marked X. Score and crease along the dashed line. Set this part aside for now. It will go in place after the WAVEGUIDES are installed inside the ALIDADE.

The ALIDADE in your model reproduces the DSS's structure with pretty good accuracy, although there are some equipment platforms not represented, in order to help simplify.

The image below shows the ALIDADE mostly complete, with most WAVEGUIDES installed -- this is the next step for the model.

The big semi-circular COUNTERWEIGHT appears near the top of the image below. It had to be held in place before the MAIN REFLECTOR could be installed, to balance it. Since we don't have to worry about balancing massive steel structures during assembly, the counterweight will be the last thing installed in your model.

- **Go on to the next step.** **(Previous step)**

FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
Children
Middle & High School
Other Programs
GAVRT
Image Tutorial
Build Your Own DSN Station
GALLERY
LINKS

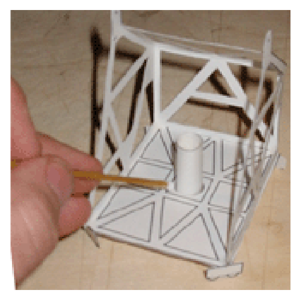
Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Prepare the Beam Waveguides*

View this stage of DSS construction.



KEEP THE WAVEGUIDE VERTICAL WHILE GLUE DRIES

- First, take a look at a diagram that shows what the waveguides are for.
- From Parts Sheet C, cut out the LOWER VERTICAL WAVEGUIDE #3. Curl it around a pencil so it will form a tube, on its own, about 1 cm in diameter.
- Apply white glue to the marked end of the WAVEGUIDE. Curl it around on itself, slightly past the reference line near the end. Press together while aligning into a neat tube 1.1 cm in diameter. Adjust its shape to be nearly cylindrical. One end of this part will need to fit snugly and rotate within the PINTLE on the model base, so test its fit, and adjust its diameter accordingly.
- Set the ALIDADE on your work surface. Stand the WAVEGUIDE inside the central hole in the bottom of the ALIDADE. It should drop loosely through the hole and stand vertically on your work surface. The WAVEGUIDE should be nicely perpendicular to the ALIDADE BOTTOM.
- Apply white glue between the WAVEGUIDE and the ALIDADE BOTTOM, forming a bead all the way around. Be careful to keep the WAVEGUIDE standing upright. Let the glue dry. After the glue dries, turn the ALIDADE upside-down and apply a small bead of white glue around the WAVEGUIDE where it protrudes. Be sure the ALIDADE BOTTOM doesn't deform while the glue dries.

MAKE AND INSTALL THE LOWER PERISCOPE

- From Parts Sheet C, cut out the LOWER PERISCOPE. Carefully cut out both black circles with a sharp new blade in your art knife.

- Curl the LOWER PERISCOPE around a pencil so it will form a tube, on its own, about 1 cm in diameter.


COMPLETED LOWER PERISCOPE

- Apply white glue to the marked end of the LOWER PERISCOPE. Curl it around on itself, up to the reference line near the end. Press together while aligning into a neat tube 1.1 cm in diameter. Adjust its shape to be nearly cylindrical. Some of the glued end surface might protrude into one of the circular holes. Trim it out with a sharp art knife.
- Cut out two squares from Parts Sheet C and glue them to both ends of the LOWER PERISCOPE. When the glue dries, carefully clip the squares with scissors to make circular end caps.
- From Parts Sheet C, cut out the MAIN VERTICAL WAVEGUIDE #2. Curl it around a pencil so it will form a tube, on its own, about 1 cm in diameter. Glue into a neat cylinder as with the others.
- Insert one end of the MAIN VERTICAL WAVEGUIDE into one of the holes on the side of the LOWER PERISCOPE. Twist and rotate to get it in. It should be a very snug fit. Don't glue it yet.


WAVEGUIDES AND LOWER PERISCOPE

- Set the LOWER PERISCOPE's other hole down on top of the LOWER VERTICAL WAVEGUIDE that comes up from the ALIDADE BOTTOM. Again it will be a very snug fit. Don't glue yet.
- Carefully twist the LOWER PERISCOPE so it points toward the starboard side of the ALIDADE. That side of the ALIDADE is marked with a small "S".

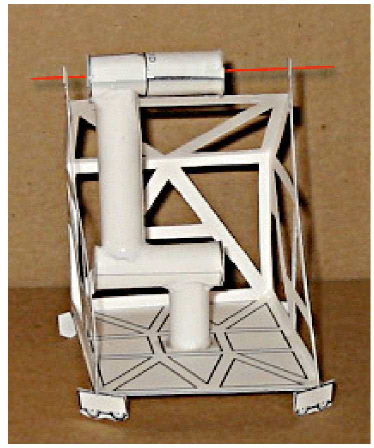
MAKE AND INSTALL THE UPPER PERISCOPE

- From Parts Sheet C, cut out the two halves of the UPPER PERISCOPE. Carefully cut out the black circles. Curl each piece around a pencil so it will form a tube, on its own, about 1 cm in diameter. Glue into neat cylinders as with the others, paying close attention to the guidelines marked GLUE, so their diameters will be correct.
- The tube marked INSIDE will fit snugly within the tube marked OUTSIDE. Notice the two thin diagonal lines near corners on the INSIDE piece. Bend these corners inward slightly, making a dent in the INSIDE tube. This will make it easier to insert and rotate one within the other.
- Insert the "dented" end of one tube into the other tube where it is marked OUTSIDE, and check that the fit is snug, and that it is easy to rotate one within the other. The completed UPPER PERISCOPE will resemble the LOWER PERISCOPE.
- Cut out two squares from Parts Sheet C and glue them to both ends of the UPPER PERISCOPE. Be careful not to let glue interfere with its slip-rotation capability. When the glue dries, carefully clip the squares with scissors to make circular end caps.
- Find the exact center of the circular end cap of the INSIDE part of the UPPER PERISCOPE. Mark the center with a dot on the outside of the end cap. This will called the ALIGNMENT DOT.

ALIGN AND GLUE THE WHOLE BEAM WAVEGUIDE

- Imagine a line going lengthwise through the UPPER PERISCOPE and passing through the ALIGNMENT DOT. This imaginary line will need to pass through the holes in both ELEVATION BEARING TABS on the ALIDADE sides.

- Spend a good amount of time adjusting the waveguides and periscopes to achieve the following:
    - Vertical waveguides are truly vertical and parallel with each other.
    - Upper and lower periscopes are parallel with each other and perpendicular to the vertical waveguides.
    - Waveguides are true and square as viewed from any angle.
    - The imaginary line passes exactly through the UPPER PERISCOPE and the two holes in the ELEVATION BEARING TABS.



WAVEGUIDES ALIGNED
"IMAGINARY LINE" SHOWN RED

- Once this is done and you are satisfied the waveguides are neat and square, carefully apply white glue at all the joints EXCEPT the UPPER PERISCOPE's swivel joint. You can reach through the ALIDADE structure with a bamboo skewer to apply the glue. Apply glue where the MAIN VERTICAL WAVEGUIDE contacts the ALIDADE structure. Be very careful not to disturb the alignment. Let the glue dry.

FINISH THE ALIDADE

- Fit the ALIDADE FRONT (which was set aside previously) up against the open section of the ALIDADE. Apply glue to the lower corners. When dry, bend in the upper section and glue in place.

- Remove the OUTER swiveling section of the UPPER PERISCOPE and set it aside.

- There's one more waveguide left, and it will be used in assembling the main reflector.

The DSS's WAVEGUIDES pass microwave radio signals between the reflector (and a distant spacecraft) and the equipment below the alidade in the basement pedestal. They contain optically flat metal mirrors (not represented in your model), two in each periscope, to maintain the microwave beam as the DSS rotates in azimuth and the reflector dish raises and lowers in elevation.

- **Go on to the next step.** **(Previous step)**

FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
Children
Middle & High School
Other Programs
GAVRT
Image Tutorial
Build Your Own DSN Station
GALLERY
LINKS

Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

At this point you have a completed alidade structure with waveguides in alignment. Congratulations. You have accomplished in days or hours what took months in reality.

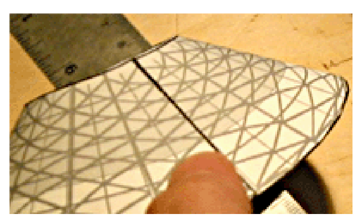
When you set the completed alidade on a flat surface, all four wheel-assemblies should be in contact, and the structure should not rock. If it does, try to make adjustments to the alidade base. Note that re-wetting with white glue can help remove a warp, provided it is held flat to dry.

With the actual DSS construction, much work goes on in parallel. The main reflector and its counterweight, as well as the quadrapod and subreflector have been delivered to the work site.

No need for the model builder to temporarily mount the counterweight in position on the alidade, because paper at 1/250 scale is lightweight. If you're using this website to build a larger scale model of different materials, you'll need to consider joining the main reflector and counterweight before installing on the alidade.

Assemble and Install the Main Reflector*

View this stage of DSS construction.



BURNISH SEAM IN MAIN REFLECTOR USING METAL RULER

- From Parts Sheet E (which must be printed on lighter weight paper such as regular copier paper) cut out the MAIN REFLECTOR.
- Place the MAIN REFLECTOR printed side up on a piece of cardboard. Set a couple pieces of scrap paper down on top of it to mask everything except the wedge marked LIGHT SPRAY GLUE.
- In an appropriate environment with lots of ventilation (and away from any source of ignition), give a VERY LIGHT application of spray glue to the unmasked wedge. Too much glue on the seam will soak the paper causing it to deform unacceptably.
- Discard the scraps of paper used to mask the MAIN REFLECTOR.
- Keeping the print outside, carefully bring the spray-glue coated wedge around to

the part's opposite end. Carefully match the end onto the glued wedge, forming a cone, and aligning the end with the guide line on the wedge. Make sure you have a fairly regular-looking cone. Press together to make the glue adhere.

- Insert a ruler beneath the glued seam and carefully burnish to press the glued surfaces together strongly, while being careful not to introduce any folds or creases. With scissors, trim any small irregularities at the cone's edge near the seam.
- A good final appearance of your model depends on making sure the MAIN REFLECTOR cone has no deformations. If at this point it is not a nice smooth cone, discard it, re-print Parts Sheet E, and repeat the previous steps.
- From Parts Sheet C, cut out the REFLECTOR CENTER. Make a near perfectly circular cut, following the dark black outline, cutting through any small irregularities in the gray pattern.
- Cut out its central hole.
- Flatten the piece by bending as needed. If your result is not very neat, flat and circular, re-print Parts Sheet C and repeat this step.

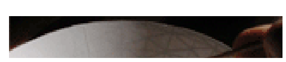
MAKE ONE LAST WAVEGUIDE

- From Parts Sheet C, cut out UPPER WAVEGUIDE #1. Wrap it around a pencil to make a ring about 1 cm in diameter. Apply white glue where marked, and press the seam together using a pencil inside, while adjusting to make a neat ring 1.1 cm in diameter. Let the glue dry.
- Insert one end of the waveguide into the REFLECTOR CENTER's central hole, going in the un-printed side. It should be a snug fit, but not so snug that it deforms the REFLECTOR CENTER piece at all. Insert about 1/4 of the way in, and straighten it to be approximately perpendicular. Do not glue yet, this is for temporary use as a handle.
- Set the MAIN REFLECTOR down into the mouth of a plastic drinking cup, unprinted side up. Center it in the cup.

SET REFLECTOR CENTER INSIDE MAIN REFLECTOR AND STRAIGHTEN

INSTALL THE CENTER PIECE

- Pick up the REFLECTOR CENTER by the waveguide. Set this assembly down into the center of the MAIN REFLECTOR as shown.
- Take some time and care to repeatedly rotate the cup containing the MAIN REFLECTOR and REFLECTOR CENTER, adjusting as needed to be sure the center is sitting evenly at the cone's center.
- When you're satisfied the assembly is evenly centered, carefully apply tiny drops of white glue around the seam at about 1-cm intervals. Avoid moving the parts out of alignment. Carefully hold the REFLECTOR CENTER, withdraw the waveguide, and set it aside.
- The white glue you use to connect the REFLECTOR CENTER to the MAIN



REFLECTOR needs to applied with some precision. It has to be a light and even bead. If the bead is too thick, it will soak too deeply into the MAIN REFLECTOR and deform it, instead of locking it into its proper shape. Use of the plastic drinking cup to hold the reflector helps minimize deformation.

SET REFLECTOR CENTER INSIDE MAIN REFLECTOR AND STRAIGHTEN

- Very carefully balance a second small plastic drinking cup atop the REFLECTOR CENTER to hold it down. Add a weight inside the cup if needed (the image shows an eraser being used). Apply a small, thin bead of glue around the entire seam. This will lock in the reflector's proper shape.

- Wait for the glue to dry on the reflector assembly, rotating if necessary to ensure even drying without any of the parts warping.

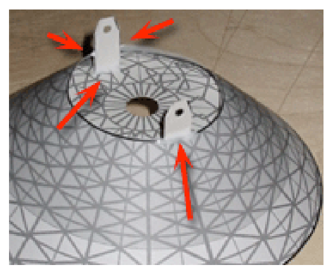
INSTALL THE REFLECTOR'S ELEVATION BEARING

- From Parts Sheet D, cut out the two pieces marked ELEVATION BEARING. With printing outside, fold one at the center, smear the inside with a little white glue, and close it down upon itself. Squeeze and let dry. Cut a hole through the piece at the dot, about 3mm in diameter, using a small punch, drill, or art knife. Repeat these steps with the other piece.

SET REFLECTOR CENTER INSIDE MAIN REFLECTOR AND STRAIGHTEN

- Place the main reflector assembly down, printing up, on your work surface. Dip the bottom of an ELEVATION BEARING piece (the end opposite the hole) in white glue, and set it on the REFLECTOR CENTER where it will rest upon the MAIN REFLECTOR, at its seam, as shown. Adjust to be vertical, and add a drop of glue where it touches the reflector.

- In the same way, install the other ELEVATION BEARING piece diametrically across from the first. Check its position carefully; it must be right across the center from the first one. Let the glue dry.



GLUE EACH ELEVATION BEARING IN THREE PLACES & ALIGN DIAMETRICALLY

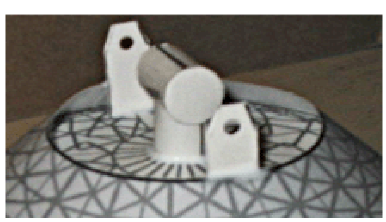
NOW BACK TO THAT WAVEGUIDE

- Take the outside swiveling half of the UPPER PERISCOPE that was set aside earlier, and the UPPER WAVEGUIDE #1 that was just used to handle the reflector center.

- Fit the UPPER WAVEGUIDE #1 into the hole on the SIDE of the UPPER PERISCOPE part. It should be a snug fit. Don't glue yet.

- Fit the other end of the UPPER WAVEGUIDE #1 into the back, printed side, of the main REFLECTOR CENTER.

- Once the



ALIGNMENT IN ELEVATION THRU WAVEGUIDE & BEARING

reflector has completely dried, and the bead of glue has completely hardened, re-insert the UPPER VERTICAL WAVEGUIDE #1 in through the printed side. Place it in a minimum distance for it to remain in place, and straighten.

- Finally, you're done with the main reflector. Next step is to put all this together.

The DSS's main reflector has a parabolic surface inside, which of course your model's main reflector does not have (but the fact that it's all white on the reflector side helps visually).

The structure that supports the DSS's main reflector does indeed, though, have on its outside, generally the shape of the printed graphics outside your model's reflector. The important visual cues of the DSS are preserved.

The model's reflector connects with the alidade, mechanically and in microwave radio waveguides, just the same as in the actual DSS.

- **Go on to the next step.** **(Previous step)**

---

* The steps on this page may be accomplished separately, while progress is being made on other tasks. This is convenient if more than one person is working on the project, or while one is waiting for glue to dry on a different step.

Click below to build your 34m BWG DSS 1/250 Scale Model.

Curator: Shirley Wolff
Webmaster: David Martin
Last Updated: 28-May-2003
Clearance No. **CL 03-1214**

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Build Your Own DSN Station

Learn all about Deep Space Network Tracking Stations by building this educational scale model of a 34m Beam Waveguide Deep Space Station

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

Last Step: Add the Counterweight and Subreflector

(In DSS construction, the counterweight, which is part of the assembly known as the elevation wheel, was installed temporarily as soon as the alidade was ready.)

ASSEMBLING COUNTERWEIGHT

- From Parts Sheet D, cut out the three pieces of the COUNTERWEIGHT. Take the long rectangular piece, and curl it by pulling between pencil and thumb, so it forms a semicircle about 5 cm in diameter.
- Place this piece edgewise onto the unprinted side of one of the other COUNTERWEIGHT, centering up the semicircles. Move the curled rectangle out to the edge of the flat piece. Apply a bead of glue inside and let dry.
- With the printed side facing up (out), glue the other flat COUNTERWEIGHT piece down on top of the curled edge to make a sandwich. Align the flat pieces. Let dry.
- If necessary, trim off any flanges protruding beyond the curled mid-section of the COUNTERWEIGHT, using scissors.

COMPLETED COUNTERWEIGHT

- Straighten the four "legs" and stand the piece on its legs to check if level. Snip off tips of legs as needed to make it stand straight and level. Don't remove much!
- Remove the DSS from its base, rotate the main reflector down to the horizon, and set the face of the reflector down atop a small drinking glass. Prop so that the alidade doesn't make it fall over.
- Dip the COUNTERWEIGHT's four "legs" in white glue.

- Fit the COUNTERWEIGHT down through the ALIDADE, straddling the UPPER PERISCOPE, until the glued tips contact the back of the REFLECTOR CENTER. Center it using the waveguides and markings on back of the reflector for references.

COUNTERWEIGHT GLUING

- Use a bamboo skewer if necessary to add more glue.

NOW FOR THE SUBREFLECTOR

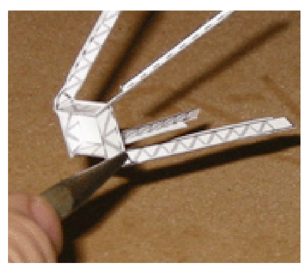

DSS QUADRAPOD & SUBREFLECTOR

View this stage of DSS construction.

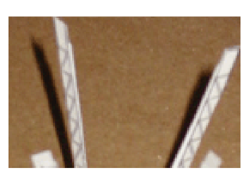
- Return the DSS to its base. Rotate the reflector to point straight up to zenith.
- From Parts Sheet D, cut out the four parts of the QUADRAPOD.
- OPTION: Print another copy of Parts Sheet D on lightweight paper, cut out and spray-glue QUADRAPOD printed structure to the unprinted sides of the first set. This will provide structure detail to see from any viewing angle.
- Score for folding on the dashed lines connecting the small lengthwise side panel that extends along each QUADRAPOD leg. Crease and fold this slim panel to provide stiffness to the legs.


BUILDING QUADRAPOD

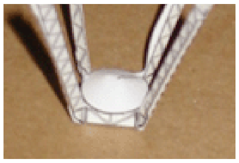
- Lightly score and fold up the marked square at the apex of each QUADRAPOD half. Apply a little glue to the top of one square, and set the other half's square on top. Align and squeeze the glued surfaces together.
- Insert and glue the two small rectangles, printed side out, onto the top of the assembly's apex, to complete the four sides of a box. Let dry.
- Grasp the top of a leg with long-nose pliers and twist it until the leg is protruding out from the corner of the "box" at the apex. Repeat with each leg.


SETTING QUADRAPOD LEGS

- From Sheet E, cut out the SUBREFLECTOR. Smear a little white glue on the printed triangle, and pull the edges together across the wedge-shaped gap to make a shallow cone. When dry, blunt the cone by pressing it against your work surface, crushing the cone's apex.
- Invert the QUADRAPOD on your work surface. Apply white glue and set the SUBREFLECTOR down onto the base of the QUADRAPOD's apex as shown.
- Set the QUADRAPOD down inside the main reflector, so it stands on its legs atop the REFLECTOR CENTER. Two legs need to align along the elevation



axis, that is one leg should be directly above each ELEVATION PINTLE. Glue down at least one leg to the REFLECTOR CENTER. Let it dry, then position another leg and glue it, repeating until all four legs are squarely set in place.


SUBREFLECTOR PLACEMENT

- **This completes your 1/250 scale model of a 34m BWG DSS.**


QUADRAPOD & SUBREFLECTOR INSTALLED

Click below to build your 34m BWG DSS 1/250 Scale Model.

INTRO PAGE
(1) WHAT YOU'LL NEED
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(3) ASSEMBLY INSTRUCTIONS
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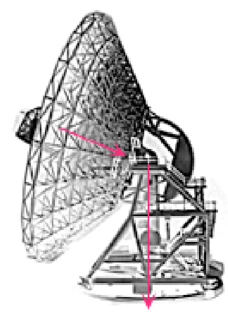
INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

About Your 1/250 Scale Model 34m BWG DSS



CLICK TO VIEW DIAGRAMS

It is possible at all to replicate a 34m Beam Waveguide Deep Space Station (DSS) tracking antenna using paper only for two reasons. The first reason is that the DSS's structure was designed to make optimum use of materials, minimizing mass. This is because the whole thing has to move. Paper card stock provides good enough structural strength due to the many triangles incorporated in the DSS design.

The second reason it works well in paper is that the waveguides that direct the path of microwave signals (both inbound to the receivers, and outbound to the spacecraft's receivers) are gigantic. And reproducing them in this paper model makes it clear, to one who builds or examines one, how this process works in principle.

The result is a scale model which rotates about axes in azimuth and elevation very much like the actual DSS. It incorporates the correct major structures, and articulating beam waveguides in their correct locations. It shows where two pairs of mirrors are located, and how they act as pairs of periscopes for microwave energy.

Of course there are many aspects of the real DSS that are approximated, or not represented at all, in your model.

Mirrors

The all-important mirrors are not represented in this model. These are the large reflectors within the waveguide tubes aboveground and belowground, which direct microwave radio signals in and out of the basement equipment.

Anyone who examines or builds this scale model needs to imagine that there is a pair of diagonal mirrors (like an optical periscope) within each of the two horizontal waveguide sections. The microwave beam is unbroken while the reflector rotates in elevation, and while the whole assembly rotates in azimuth about the central descending waveguide.

For those persons who are using this website to create a model much larger than the 1/250 size, for example in a science museum or college planetarium, consider using real optical mirrors, aligning them carefully, and letting them reflect a bright light from within the pedestal. Such a periscope would offer viewers proof of the concept of directing a beam between the communications equipment in the DSS basement and the main reflector (or at least the subreflector), as the reflector moves.

The image at left shows the mirror inside the beam waveguide that corresponds to the outboard section of model parts labelled "UPPER PERISCOPE."

Additional Differences

- The DSS's main reflector has a parabolic surface inside, which of course your model's main reflector does not have. The structure that supports the DSS's main reflector does indeed, though, have on its outside, generally the shape of the printed graphics outside your model's reflector.
- The DSS has platforms which are not represented in your model. One platform holds the elevation motor. Another at the top of the alidade provides access to the elevation bearing and the upper waveguides.
- Stairways, ladders, and railings are not represented.
- Your model permits the reflector to go too far over backwards in elevation. Normal travel is from about 0° elevation (pointing to the horizon) up to around 90° (pointing straight up).

How to Track an Interplanetary Spacecraft

1. Set the main reflector to the "stow" position, pointing straight up.

   This is the position the DSS normally takes during the "pre-calibration" period, for example an hour, before the DSS is scheduled to begin tracking its designated spacecraft.

   During "precal" as it's called, all the equipment in the basement of the DSS, and in the Signal Processing Center (SPC) located some distance away, are prepared for the tracking assignment. Frequencies are set. Measurements of the exact distance from the SPC to the DSS are checked. Systems are calibrated and made ready.
2. Rotate the reflector down all the way in elevation.
3. At the same time, rotate the whole assembly in azimuth until the reflector is pointing toward a point on the eastern horizon.
4. Wait for a spacecraft to rise.

   When Jupiter rises above the eastern horizon, the Galileo spacecraft, in orbit about Jupiter, is in view and its signal can be received. When Saturn rises, the Cassini spacecraft will be rising soon, too. (After July 1, 2004, Saturn will have moved east in its solar orbit enough to capture the arriving Cassini/Huygens spacecraft in its gravity, where the spacecraft will orbit during the rest of its lifetime.) When Mars rises, more spacecraft come into view.

   
5. Follow that spacecraft!

   For the assigned tracking period, the DSS constantly moves its main reflector in azimuth and elevation to keep signals from the spacecraft beaming down its pair of microwave periscopes, into the equipment in the DSS's basement. Normally, the subreflector is constantly making small motions of its own, keeping the signals in focus.

At an agreed time, a transmitter, also in the basement, may be turned on. Its beam of microwave radio energy, guided by the beam waveguide mirrors, travels out at the speed of light, eventually to reach the spacecraft. It takes around an hour and a half to reach Saturn. It takes over twelve hours to reach Voyager 1.

6. Send Data to JPL.

   All during the DSS's tracking period, which is normally planned weeks or months in advance during iterative negotiations within the user community, signals from the DSS travel to the SPC as "baseband" signals. There, in the SPC's equipment, they become binary digits, bits, of data. The data are forwarded to JPL in Pasadena, and then stored and distributed as needed to the user, for example the Cassini Program. Commands may also be sent from the user, through the SPC and DSS, out to the spacecraft. Monitor data, such as the DSS's azimuth, elevation, and other measurements, are also sent to JPL during the assigned tracking period.

7. Get a new assignment.

   At the agreed time, for example after the spacecraft has traversed the entire sky, and is setting on the western horizon, the DSS completes its tracking. Transmitters are turned off. The reflector points straight up to the stow position. Everything is made ready for a new assignment, for example to track another spacecraft that will be rising soon, or participation in a radio astronomy observation, or in a radar astronomy experiment. Perhaps it's time for a few hours of maintenance work, or the installation of new sensitive equipment in the basement.

DSS-55 - The Movie

Visit the DSN Video Gallery where you can select a time-lapse movie that shows the entire project of constructing DSS-55 at Madrid in just a few minutes. You can also select "The DSN Story," another informative movie.

Beam Wave of the Future

The three venerable giant, 70-meter aperture DSSs, one each at Goldstone, Madrid, and Canberra, are the world's best at gathering low-level signals from spacecraft, and transmitting powerful uplinks across vast interplanetary distances.

It is possible for four 34m BWG DSSs to track one spacecraft, and feed their signals into special combining equipment in the SPC, to create the equivalent of one 70m DSS. It is likely that additional installations of 34m BWG DSSs will continue over the years, to help satisfy the need need for additional DSN tracking capability, demanded by a growing user community.

Click below to build your 34m BWG DSS 1/250 Scale Model.

INTRO PAGE
(1) WHAT YOU'LL NEED
(2) DOWNLOAD PARTS SHEETS
(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL

FEATURES
ANTENNAS
SERVICES
TECHNOLOGY
SCIENCE
PUBLICATIONS
HISTORY
EDUCATION
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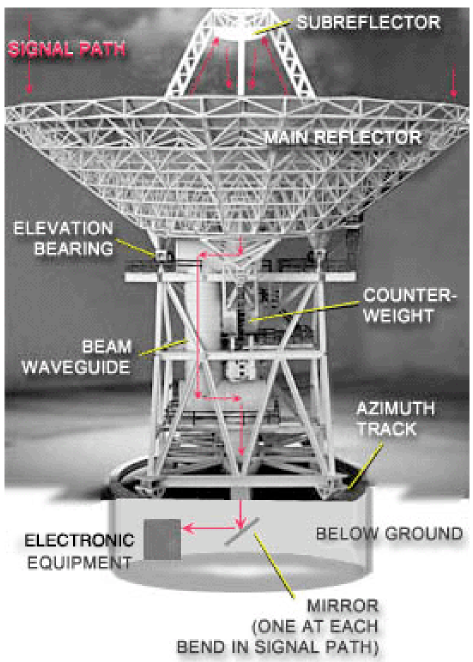
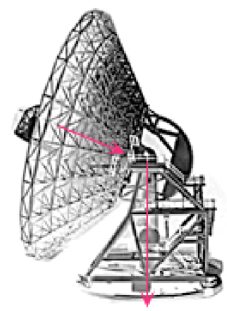
Diagram of a 34m Beam Waveguide Deep Space Station





In the diagram above, the antenna has rotated 90 degrees clockwise on its azimuth track from the position shown at left, and the reflector has slewed downward in elevation.

Note that the signal path continues to be reflected and guided into the equipment room below ground, thanks to microwave mirrors in the waveguides, arranged like the optical mirrors in periscopes.

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INTRO PAGE
(1) WHAT YOU'LL NEED
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(3) ASSEMBLY INSTRUCTIONS
(4) ABOUT YOUR MODEL