Educational Product	
Educators & Students	Grade 9 thru Adult

Educational Brief

Cassini Spacecraft 1/37 Scale Model

Learn by Building a Highly Detailed 1/37 Scale Model of the

Cassini Spacecraft

The Cassini Spacecraft is the largest interplanetary robot ever flown. Launched October 15, 1997, Cassini's mission is to orbit Saturn, deliver the Huygens Probe to Titan's atmosphere, and spend at least four years studying Saturn's atmosphere, magnetosphere, icy satellites, its largest satellite Titan, and of course its ring system. Too massive to fly directly to Saturn, Cassini orbits the Sun twice, flying by Venus and Earth, to gather the momentum for its trip to the outer solar system. Jupiter provides the final boost to Saturn.

You can keep up with Cassini's flight, and learn more about the mission, and about Saturn and Titan, by visiting the Cassini Web Site. This model is also available there, to download directly, as well as a much simpler model version at 1/40 scale:

http://www.jpl.nasa.gov/cassini

The Cassini 1/37 Scale Model is made by following the assembly instructions, cutting out the printed parts, folding and gluing. The project requires several hours, and a good deal of patience. By building the model, you'll learn all about the Cassini Spacecraft, in an effective, enjoyable way.

One model can be assembled by several people as a group activity. Numbered assembly instruction steps marked "•" can be accomplished at the same time, so more than one person can work together. Or one person working alone may do one "•" step while waiting for glue to dry on another "•" step. If more than one person is working, each person should explain what was learned about the spacecraft during their work, to the rest of the group.

The following pages contain everything you'll need to build your Cassini Model.

Cassini 1/37 Scale Model Assembly Instructions v 3.1

This scale model of the Cassini spacecraft, with Huygens Probe, is designed for anyone interested, although it might be inappropriate for children younger than about ten years of age. Children should have adult supervision to assemble the model.

A. YOU'LL NEED THE FOLLOWING:

- ❒ A good pair or scissors.
- ❒ An art knife, such as X-ACTO #11, with a sharp new blade. Children must have adult supervision, of course, to use an art knife. You'll also need a cutting surface such as a linoleum pad, or thick chipboard, when using the art knife. **Use caution**: one can hurt oneself, or the furniture, with an art knife.
- ❒ Wooden toothpicks for applying glue.
- ❒ Glue. Use regular white glue (Elmer's Glue-All® or equivalent). You might also try a thick white glue, sold in art and fabric stores, called "TACKY GLUE" (Aleen's or equivalent). Also, for the High-Gain Antenna (HGA), you'll need a low-moisture glue, such as a glue stick.
- ❒ A popsicle stick to help with assembly.
- ❒ A beverage cup, preferably a heavy ceramic cup or mug, for supporting parts during assembly.
- ❒ A thin clear sheet such as that used for making overhead transparencies. This will be used to fashion a stand for your model. You can instead use a small, clear plastic beverage cup with a hole cut in the bottom.
- ❒ A round pencil or dowel to wrap curvature into some parts.
- ❒ A metal ruler to use as a straight edge.
- ❒ A small pair of long-nose pliers to reach and squeeze some parts together while they glue. Small metal paper clamps may also be useful to hold parts together while glue dries.
- ❒ Space. Set up a well lighted, comfortable work area, with room to set glued parts to dry.
- ❒ Time. Don't hurry. Plan to spend several hours for assembly. About 6 hours would probably be minimum if you concentrate solely on assembly. It can easily be done in shorter steps, however, over a period of several days.
- ❒ Patience. There may be trying times. But remember that extra care, and time, will pay off with a surprisingly accurate representation of the Cassini spacecraft.
- ❒ Optional: Rigid wire for the RPWS antennas. If your use of the model would present no danger of eye injury, you might consider getting some thin, stiff brass or steel wire from a hobby store. Half a meter, or a couple of feet, should be enough.
- ❒ Optional: A straight pin which has a small metal head, for use in a science instrument.
- ❒ Optional: Gold leaf, or imitation gold leaf, to apply to the Huygens Probe shield. You'll need spray-glue to apply it.
- ❒ Optional: As you read through these instructions, you'll see that intersecting planes are used to simulate 3-dimensional objects like tanks and rocket engines. You might wish to do some creative searching for different objects to replace them, and increase the realism of your model. The High-gain Antenna (HGA) paper cone might also be replaced by a small curved bowl-shaped object painted white.

B. BEFORE BEGINNING ASSEMBLY:

- ❒ **Read all of these instructions**. Compare model parts with images. Examine the six Parts Sheets and read the names of all the parts.
- ❒ Get your bearings: this diagram defines "up," "down," etc. for the purpose of assembly. This will be the reference when words such as "top" and bottom" are used to describe sides of parts. Also, during assembly, you'll notice that the spacecraft's axes are indicated. These three imaginary lines pass through the center of mass of the spacecraft, and are labeled X, Y, and Z. The Z axis goes up and down; down, in this picture, is "plus Z" (+Z). The general directions for the X and Y axes are indicated on the parts. The axis directions can also be used to point to a side of the spacecraft, for example, the -Z side of the spacecraft is where the High-Gain Antenna dish is mounted.

INBOARD means toward the center ,
OUTBOARD means outward from center

C. IN GENERAL:

- ❒ Sections marked with a • may be accomplished at the same time if two or more people are working on assembly, or if you wish to work on one section while glue dries on another. In fact these steps were performed separately in building the actual spacecraft. For example, the Propulsion Module was being built at Lockheed-Martin in Denver while the Spacecraft Bus was being built at JPL in Pasadena, and the HGA was being built in Italy.
- ❒ What to cut out? Each part is drawn against a shaded background. This shading appears grey when printed on a black & white printer. Each part should be completely cut away from its shaded background. Some parts have areas within them of shaded grey. These areas should be cut out of the part. Spacecraft details are printed on most of the parts. Don't confuse these with background shading. If there's any question, look at it on a color computer monitor: all the background shading appears blue: if it isn't blue, don't cut it away.
- ❒ When you finish cutting out a part, flatten it.
- ❒ If an instruction doesn't say which way to fold something, fold in either direction.
- ❒ When instructed to fold a part, consider scoring it first. To do this, line up a metal ruler or straight edge along the line to be folded, and very lightly scratch it with an art knife, only breaking the surface of the card stock. You have to be very careful not to cut through if you do this. While this is more time consuming, it will result in much neater folds, and may help the parts fit together properly.

• 1. ASSEMBLE THE SPACECRAFT BUS

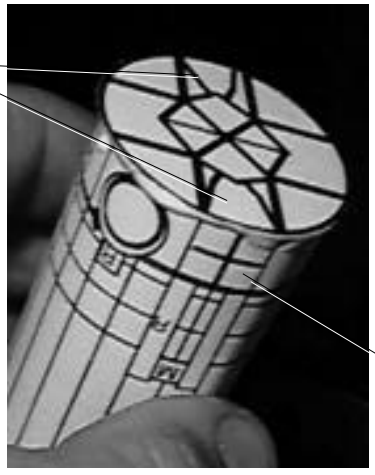
- ❒ Cut out the SPACECRAFT BUS from Parts Sheet 1. Be sure to cut out the shaded areas above BAY 1, BAY 7, and BAY 4.
- ❒ Put a crease into each of the vertical black lines where the twelve sections are joined, folding the BUS into a ring with the printing on the outside.
- ❒ Smear glue on the square marked GLUE. Overlap the other end onto the glue to complete the ring. Make sure it's straight, and squeeze the pieces together.
- ❒ Fold down the tabs marked IRU, towards the center of the ring. IRU stands for Inertial Reference Unit, which will be installed here later. Do the same to each of the six remaining similar tabs along the top of the BUS. Leave the four larger tabs standing.
- ❒ Cut out the BUS TOP from Parts Sheet 1. Smear glue on the area marked GLUE, and position it up inside the BUS so that the eight folded tabs will contact the glue. Press the tabs down so they will glue securely.

- ❒ Fold over the twelve small tabs around the bottom of the BUS toward the inside. Leave them at about 90° to the bus. Set the BUS upside down on your work surface.
- ❒ Cut out the BUS BOTTOM from Parts Sheet 1. Be sure to remove the central shaded circle. Smear glue on the area marked GLUE. Place the glued surface down onto the twelve folded tabs. You might want to reach inside with a pair of long-nose pliers and squeeze the tabs to the BUS BOTTOM to glue securely.
- ❒ Cut out one INERTIAL REFERENCE UNIT (IRU) from Parts Sheet 1. Fold back the two triangular sections away from the printing. Fold back the section marked GLUE in the same direction. Adjust so all sections are perpendicular, and secure with glue to hold their positions.
- ❒ Smear some glue on the section marked GLUE of the IRU. Place this down on top of the BUS, with the area marked GLUE covering the letters IRU on the BUS. The triangular sections point in toward the center of the BUS. Slide the IRU outward so it hangs out over the BUS about half the width of the GLUE-marked section.

- ❒ Cut out the other INERTIAL REFERENCE UNIT (IRU) and repeat the above steps.
- ❒ Cut out the UPPER EQUIPMENT MODULE (UEM) from Parts Sheet 1.
- ❒ Trace a copy of this part's shape onto a piece of paper. The tracing will be used later to fashion a stand for your model using a transparent sheet.
- ❒ Smear some glue on the UEM's section marked GLUE, and roll the piece around into a cone, overlapping the opposite end onto the glue. Squeeze together and let the glue dry. Adjust the part's shape to be an even cone.
- ❒ Set the SPACECRAFT BUS upside down on your work surface. Locate the +Y mark on the BUS. Set the UPPER EQUIPMENT MODULE down onto the bottom of the BUS, with its larger end touching the BUS. Rotate it so its +Y mark aligns with the one on the BUS. Secure in position with glue, keeping the parts centered.

• 2. ASSEMBLE THE PROPULSION MODULE

- ❒ Cut out the rectangular PROPULSION MODULE AND LOWER EQUIPMENT MODULE STRUCTURE from Parts Sheet 2. This model part will be referred to as the PM.
- ❒ Smear some glue along the end of this piece marked GLUE, and roll it around into a cylinder. Overlap the opposite end onto the glue, press together, and let the glue dry. It might be helpful to hold a popsicle stick inside the cylinder to help press the seam together.
- ❒ Adjust the shape of the piece into an even cylinder.
- ❒ Cut out the circular ENGINE GIMBAL ASSEMBLY (EGA) from Parts Sheet 2. This part is greatly simplified; on the spacecraft, it is an arrangement of trusses, actuators, etc. which support the main engines, and allow them to be swiveled back and forth.
- ❒ Glue the EGA onto the lower end of the PM. That's the end marked with an arrow labelled +Z. Align the EGA with its printed detail facing out, rotated so that its "M" shaped features line up with the two large + features on the PM (there's a third large + which will not line up).



- ❒ Cut out the BIPROPELLANT TANK HALVES from Parts Sheet 2. Fit them together at right angles, slot into slot, and secure with glue. These intersecting pieces represent two domed cylindrical tanks.
- ❒ Before installing the BIPROPELLANT TANKS, some trimming needs to be done. Set the SPACECRAFT BUS's attached UPPER EQUIPMENT MODULE (narrow end) down into the top of the PROPULSION MODULE. Stand the PROPULSION MODULE right-side up on your work surface. Align the two pieces so the BUS is perfectly level, in alignment with the PM.

❒ Without disturbing their alignment, mark with a pencil on the UPPER EQUIPMENT MODULE in a circle where the two pieces join.

❒ Separate the pieces again. Cut off the bottom of the UPPER EQUIPMENT MODULE below your pencilled circle, leaving a small amount, a couple of millimeters or an eighth of an inch, remaining below the circle.

❒ Set the BIPROPELLANT TANKS piece down inside the PROPULSION MODULE (PM), securing with a blob of glue at the bottom (don't put any glue near the top of the PM yet). The upper portion of the TANKS piece will protrude above the PM.

❒ Cut out one of the RCS THRUSTER CLUSTERS from Parts Sheet 2. RCS stands for reaction control subsystem. Fold the section marked GLUE back 90° toward the non-printed side, and apply glue.

❒ On the PM, find a long rectangle marked R. To the right of it, there is also a small rectangle marked R. Glue the THRUSTER CLUSTER's GLUE-marked section to the long rectangle, aligning the bottom of the GLUE section, with the heavy black line at the base of the long rectangle. Arm C faces downward. Align vertically, and let the glue dry.

❒ Find the short heavy black line marked A, and one near it marked C on the THRUSTER CLUSTER. Crease at these lines, folding back toward the non-printed side.

❒ Apply glue to the end of the THRUSTER CLUSTER arm marked R. Bring it in contact with the small rectangle marked R on the PM. Secure there with glue.

❒ Cut out one more RCS THRUSTER CLUSTER from Parts Sheet 2 and repeat the above steps, attaching it to the PM.

❒ Cut out another RCS THRUSTER CLUSTER from Parts Sheet 2. This time, make the folds toward the printed side, and install it on the PM at the unlabelled rectangles similar to the R-marked rectangles.

❒ Repeat the above steps with the last remaining RCS THRUSTER CLUSTER.

❒ On each of the four THRUSTER CLUSTERS, fold tab B downward to be approximately horizontal. Each of these tabs represents six small rocket thrusters which are used for attitude management and small course corrections.

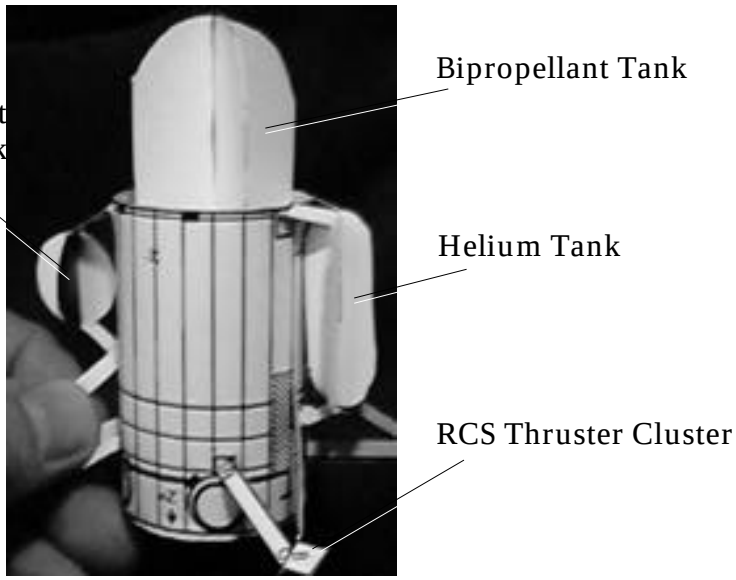
❒ Cut out the HELIUM TANK HALVES from Parts Sheet 2. Fit them together at right angles, slot into slot, and secure with glue. These intersecting pieces represent a domed cylindrical tank.

❒ Fold the two arms at the top end of the HELIUM TANK in the same direction the single arm is pointing on the bottom end. Fold over the two G-marked tabs, and apply glue to their outer sides.

❒ Press the glued tabs onto the squares marked H on at the top of the PM. The HELIUM TANK's bottom strut should contact another square marked H toward the bottom. Glue it there, aligning the HELIUM TANK vertically with the PM.

❒ Cut out the MONOPROPELLANT TANK HALVES from Parts Sheet 2, assemble and mount on the PM in the same manner as the HELIUM TANK, using the squares marked M. (If the top support arms don't quite reach the M-squares,

center them in between.)



- ❒ Cut out the PRESSURANT CONTROL PANEL from Parts Sheet 2, and smear some glue down the center of the non-printed side, in the long dimension.
- ❒ Set the panel onto the PM, its center covering the words PRESS PANEL. Align its top with the T on the PM. Its larger rectangle is on top. Leave the panel flat to stand out from the PM; don't bend it on.
- ❒ Cut out the PROPULSION CONTROL PANEL from Parts Sheet 2, and attach it to the PM in the same manner, centering it on the words PROP PANEL, and aligning the top of its larger rectangle at the short line above the wording.

  Monopropellant (hydrazine) supplies the RCS thrusters. Bipropellants (hydrazine from one bipropellant tank, nitrogen tetroxide from the other), which ignite when mixed, feed the main engine(s). Helium is used to pressurize the propellant tanks. The small circle on the PROPULSION CONTROL PANEL represents a small helium tank to be used as a "one-shot" helium recharge for the Monopropellant tank.
- ❒ Now is the time to make a stand for your model. Using the tracing of the UPPER EQUIPMENT MODULE made in section 1, cut out a sheet of clear plastic (such as an overhead transparency) in its shape. Roll its ends together and overlap them a bit, and secure neatly with clear tape. Alternatively, a small clear plastic beverage cup might be used: cut a circular hole centered in the bottom, 2.5 cm or one inch, in diameter.
- ❒ Cut out the MAIN AND BACKUP ENGINES halves from Parts Sheet 2. Fold over the rectangle marked GLUE 90° with printed side out.
- ❒ Fit the two small pieces together with the single larger piece at right angles, slot into slot, and secure with glue. These intersecting pieces represent two bell-shaped engine nozzles.
- ❒ Apply glue to the rectangle marked GLUE, and set the piece down onto the ENGINE GIMBAL ASSEMBLY at the bottom of the PM. Center it, and align it lengthwise touching the two M-shaped printed features.
- ❒ Glue your clear plastic model stand to the EGA at the bottom of the PM. The MAIN AND BACKUP ENGINES must be inserted into the small opening of the stand, and the larger opening will rest on the table. Center the stand with the model. Adjust your stand so it holds the PM nicely vertical, and rests squarely on a table surface.

3. INSTALL THE HUYGENS PROBE ADAPTER

- ❒ Cut out the PROBE SUPPORT RING BASE from Parts Sheet 5. Apply low-moisture glue (such as a glue stick) to the area marked GLUE, and roll the opposite end around to overlap it. Adjust to make an even, round ring (with arms attached).
- ❒ Cut out the PROBE SUPPORT RING from Parts Sheet 5, and place it flat on your work surface. Set the PROBE SUPPORT RING BASE down on top of it, with its round vertical ring contacting the flat ring near its outer edge. Join the rings at <u>one point</u> with <u>one drop</u> of glue.

- ❒ After the glue drop is thoroughly dry, adjust the PROBE SUPPORT RING BASE so that more of its vertical ring is circular and in position around the edge of the flat ring. Add another drop of glue at one or two points, and let it dry. Continue to glue and adjust, until the rings are securely joined, and nicely aligned.
- ❒ Temporarily fold the two long arms (marked with a dot) back away from each other.
- ❒ Set your PM down on the work surface on its side, supported by the THRUSTER CLUSTERs, with the -X side facing up. Near the -X mark, notice two black rectangles. Apply glue to these.
- ❒ Apply glue to tips of the two short arms marked +. Set them down on the glue in the black rectangles, with the ring about centered over the PM.
- ❒ When the glue dries, glue the two arms marked - (minus) onto the two black rectangles near the +Z mark on the PM. Let the glue dry thoroughly.
- ❒ Bring the two long arms, marked with a dot, into contact with the PM, and glue them there. (You'll have to tuck their ends under some tank support arms.)

• 4. ASSEMBLE THE HIGH-GAIN ANTENNA (HGA)

- ❒ Cut out the large circular MAIN REFLECTOR from Parts Sheet 3. Be sure to cut out the large keyhole (triangular opening with central circle), the two small rectangles, and center slots.
- ❒ For this step, use a low-moisture glue such as a glue stick. Smear a thin film of glue on the black radial line from the center to the outer edge. Also smear glue from there to the edge of the triangular opening. Overlap the opposite edge onto the glue, bringing the circle up into a cone, with the printed circles on the outside. Adjust so the edge aligns with, and just overlaps the black line.
- ❒ Once the glue is thoroughly dry, set the cone on your work surface with the point facing down, and crush the point by pressing the cone down onto the work surface. As you crush it, the central hole will become smaller, and the central slots will overlap. Continue to crush until there's a flat area about 35 mm or an inch and a half, at the center.
- ❒ Rest the piece upside down on your work surface, with the crushed center facing up. Apply some glue to the overlapping slots to hold their shape. Try to adjust the cone's shape so it is even, and sits flat on the table.

- ❒ Cut the HGA SUPPORT RING from Parts Sheet 3. Apply low-moisture glue to the end marked GLUE, and overlap the opposite end, forming a ring. Make sure the seam is straight, so the ring sits flat on the table. Adjust its shape to be very nearly circular.
- ❒ Rest the HGA upside down on your work surface, with the crushed center facing up. To force it against the table and hold its shape, stack some coins on the center.
- ❒ Set the HGA RING down onto the HGA and center it. Apply a bead of white glue all the way around inside the ring, to make a secure connection between the ring and the HGA main reflector. Don't press down the HGA RING or change its shape; let the bead of glue fill in any spaces between the circular ring and the slightly irregular HGA shape. Allow it to dry thoroughly before proceeding.

- ❒ Notice the location of a thin black radial line, about a centimeter long, on the outside of the HGA. Hold it to the light, and make a mark on the inside of the HGA dish corresponding to the line on the outside. This will be used later.
- ❒ Cut out the small circular HGA BASE from Parts Sheet 3. Set it flat onto the HGA RING, and secure it there with glue. Leave the HGA face down.

- ❒ Cut out an HGA SUPPORT ARM from Parts Sheet 3. Fold its tab marked G over 90° toward the non-printed side, and apply glue to the G. Glue this tab to the HGA RING at the point where the arm will reach out along the HGA main reflector, immediately over the visible seam. While the whole arm might not touch the HGA, the tip should. If necessary, force the tip to touch. Glue the tip to the edge of the HGA. If the tip protrudes past the edge, it will be trimmed off later.
- ❒ Cut out another HGA SUPPORT ARM from Parts Sheet 3, and install it in a similar manner directly across from the last one.
- ❒ Repeat this process with the four remaining HGA SUPPORT ARM, spacing them evenly around the HGA. After the glue dries, trim off any tips of arms protruding beyond the edge of the HGA.
- ❒ Cut out the FEEDHORN ARRAY from Parts Sheet 3. Cassini has an array of several feedhorns which are selected by the RADAR instrument, to steer the imaging radio beam without moving the spacecraft. This is represented by a Y-shaped piece. Apply glue to its edge below the area marked GLUE. Balance it with its two arms reaching up, centered inside the HGA bowl. Align it so that one arm is pointing toward the +Y mark on the outside of the HGA.
- ❒ Cut out the TRIPOD, and the SUBREFLECTOR HALVES from Parts Sheet 3. Fit the SUBREFLECTOR HALVES together at right angles, slot into slot, and insert the assembly into the cross slot in the TRIPOD. Slide it in until it stops, and secure with glue.
- ❒ Fold the three pairs of legs down in the direction of the curved part of the SUBREFLECTOR, making a crease where the leg pairs join near the center. The result will be a tripod which can stand on the table.
- ❒ Hold the HGA up to a light, and notice where the HGA SUPPORT RING comes closest to the short line you marked inside the dish in an earlier step. Place a drop of glue at that point, on the inside of the HGA dish. Set the HGA down, with the dish opening facing upward. Apply glue to one foot of the TRIPOD, and attach it to the glue drop in the HGA, with the TRIPOD standing up inside the HGA. Let the other two TRIPOD legs rest where they may while the glue dries.
- ❒ Glue the other two TRIPOD feet to the HGA just above the HGA SUPPORT RING, in such a manner that the SUBREFLECTOR is centered above the dish and level.

5. ASSEMBLE THE HUYGENS PROBE

- ❒ Cut out the HUYGENS PROBE SHIELD from Parts Sheet 5. This will be treated like the HGA was.
- ❒ For this step, use a low-moisture glue such as a glue stick. Smear a thin film of glue on the black radial line from the center to the outer edge. Also smear glue from there to the edge of the triangular opening. Overlap the opposite edge onto the glue, bringing the circle up into a cone, with the printed markings on the outside. Adjust so the edge aligns with, and just overlaps the black line.
- ❒ Once the glue is thoroughly dry, set the cone on your work surface with the point facing down, and crush the point by pressing the cone down onto the work surface. As you crush it, the central hole will become smaller, and the central slots will overlap.
- ❒ Apply some glue or tape to the overlapping central slots inside the cone, to hold their shape. Try to adjust the cone's shape so it is even, and sits flat on the table.
- ❒ Cut out the HUYGENS PROBE WALL from Parts Sheet 5. Smear low-moisture glue on the end marked GLUE, and overlap the opposite end onto it, forming a conical ring. Adjust so it's even.
- ❒ Cut out the PROBE TOP from Parts Sheet 5. Glue it to the small end of the HUYGENS PROBE WALL ring. Wait for the glue to dry.
- ❒ Glue the HUYGENS PROBE WALL down inside the cone of the HUYGENS PROBE SHIELD, with the larger, open end against the SHIELD. Adjust it to be centered within the cone.

❒ Optional: Cover the outside of the HUYGENS PROBE SHIELD with some kind of gold colored sheeting.

NOTE: This part is a very rough approximation of the Huygens Probe, which is actually a highly instrumented scientific package. The intent here is simply to complete the appearance of the Cassini Spacecraft, rather than attempt to represent the actual Huygens Probe in any detail.

6. POPULATE THE LOWER EQUIPMENT MODULE (LEM)

Note: The LEM is included as the lower portion of the PM in your model kit, to make things less complicated. The three circles on the LEM represent the reaction wheels which are used to control the spacecraft's attitude. On the spacecraft, the LEM was actually assembled separately, and then integrated with the PM later.

❒ Cut out the pair of RTG 2 HALVES from Parts Sheet 4. RTG stands for Radioisotope Thermoelectric Generator) (Any of the RTG HALVES pairs may be used. The numbers are just for information). Join them at right angles, slot into slot, and glue together.

❒ Notice an arrow printed on part of the RTG. This should point up toward the top of the spacecraft. Apply glue to the white end of the RTG, and set it onto the large + printed on the LEM between two of the THRUSTER CLUSTERs, on the +Y side of the spacecraft. Make sure it points straight out from the LEM, and is centered between the THRUSTER CLUSTERs. Let the glue dry.

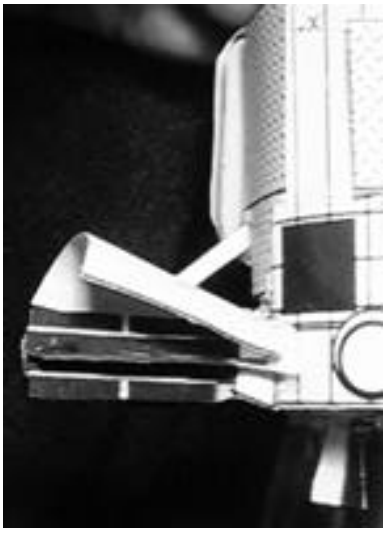
❒ Repeat with RTG-3, installing it directly opposite RTG 2. As the glue dries, keep it in direct line with RTG 2. Let the glue dry.

❒ Install RTG 1 on the remaining + mark, extending straight out from the LEM. Let the glue dry.

❒ Cut out an RTG SHADE from Parts Sheet 4. Make a tiny slot, about a mm long, into the SHADE from between the two triangular tabs. Roll the SHADE around a pencil to impart a curved shape, holding the pencil lengthwise along the part's longer dimension. Adjust the curvature to be about a third of a circle.

❒ Fold the two triangular tabs down 90° toward the inside of the curve. Re-adjust the SHADE's curve if needed. Apply a good amount of glue to the tabs by dipping them in the glue.

❒ Install the shade over an RTG. Do this by straddling the arrow-marked part of the RTG, near the LEM, with the tabs of the SHADE. Slant the SHADE up slightly, enough that at the far end of the SHADE, its whole curve is above the top of the RTG.



❒ Repeat the process with the two remaining RTG SHADES.

The purpose of the SHADES is to prevent Cassini's infrared-sensitive science instruments from receiving thermal interference (the RTGs are hot, and so they are bright sources of infrared light). RTG 1's shade is actually shaped a little differently from the others, but simplified in your model.

❒ Carefully cut out LGA-2 from Parts Sheet 4.

LGA stands for Low-Gain Antenna. LGA-1, by the way, is represented by the upper tip of the HGA's SUBREFLECTOR. While the HGA transmits and receives a narrow beam of radio, the LGAs can receive and transmit in larger, blanket-

patterns. This is useful mostly in the inner solar system when the HGA must be used as a sunshade, and cannot be pointed to Earth.

❒ Fold over the black tabs 90° in opposite directions, and apply glue to them. Glue the LGA to the +Z mark below the PROBE ADAPTOR RING, with the LGA pointing straight down and outward. The top of the glued tab should be right at the top of the Z. Now it's time to stack the spacecraft.

7. JOIN THE HGA TO THE SPACECRAFT BUS

❒ Set the SPACECRAFT BUS down right-side up on your work surface. The HGA is going to sit atop the four members that extend up from the BUS. Bend them inward slightly, if necessary, so they will all touch the HGA BASE when you set it atop them. Experiment with this, and trim off any tips as needed to let the HGA rest level with the BUS.

❒ Find BAY 4 and +Y on the SPACECRAFT BUS. Find +Y on the HGA. Rotate the HGA so these align, and glue the HGA in place. Let the glue dry. Actually, you might find it easier to do this by setting the HGA upside down in a cup, and placing the BUS down onto it, also upside down.

8. JOIN THE PROPULSION MODULE AND SPACECRAFT BUS

❒ Inspect the bottom of the UPPER EQUIPMENT MODULE (UEM) where you cut it off in an earlier step. The paper may have curled outward when you cut it. If so, curl it back, to narrow its bottom .

❒ Place the UEM down over the large PROPELLANT TANK, and insert its bottom into the PROPULSION MODULE (PM). It might be a tight fit. If the top of the PROPELLANT TANK interferes with the BUS TOP, trim the tank down.

❒ Rotate the UEM to align +Y over the center of the HELIUM TANK, being careful not to let the UEM pop out of the PM. BAY 7 should be centered over the PROBE ADAPTOR RING.

❒ Carefully align the UEM, BUS, and HGA vertically over the PM. Glue the UEM to the PM. You might want to apply only three or four drops of glue to retain the alignment, then apply more glue after they dry.

9. INSTALL THE SCIENCE INSTRUMENTS

Most of the science instruments were installed earlier in the process of assembling the actual spacecraft, but it is convenient to do them all at once, at this point in assembling your model.

THE COSMIC DUST ANALYZER

❒ Cut out the three parts of the CDA from Parts Sheet 6. On the rectangle, apply glue to the area marked GLUE, and overlap the opposite end onto it, forming a ring. Glue the circle to one end of it, closing it off and forming a drum.

❒ The part marked CDA has two tabs marked G. Fold these over slightly in opposite directions, and glue the drum down onto them, closed end facing down to the right as seen reading CDA.

❒ Two of the CDA's legs are marked with an X. Fold these slightly in opposite directions, so you'll end up with a mounting tripod. Put glue on the tip of each of the three legs.

❒ Mount the CDA on the UEM just below BAY 5 (not labelled, it's to the left of BAY 4). The open end points downward, and the short tripod leg touches the bottom of BAY 5. Let the glue dry.

THE OPTICAL INSTRUMENTS

❒ Carefully cut out the REMOTE SENSING PALLET (RSP) from Parts Sheet 6. Each science instrument is identified by its initials, and spelled out on the lower half of the Parts Sheet.

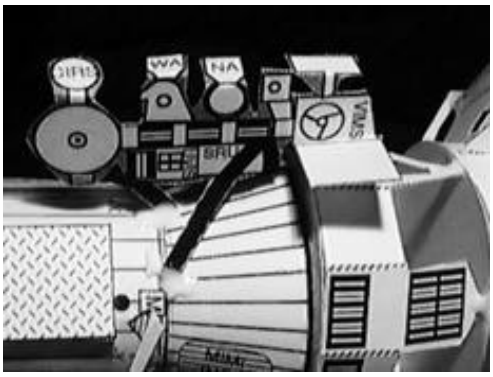
❒ There's a square to the right of the VIMS instrument. Fold it up 90° toward the printed side. This is a shade to protect VIMS against stray infrared light from the spacecraft bus.

❒ There are four appendages on the left side of the piece. Three are labelled with the name of the associated instrument. These represent radiator plates which cool the instruments' detectors by radiating heat into the cold depths of space. Fold each one back 90° toward the non-printed side.

❒ Rest the spacecraft on its side, with the +X side up, by centering it on top of a cup. By the way, notice an object marked DVD on this side of the PM. This represents the Digital Versatile Disk which contains all the signatures collected worldwide to fly to Saturn with Cassini.

❒ The three black legs on the right will become a tripod to connect the RSP to the UEM. Bend the long one forward (toward the printed side) slightly, and fold the upper leg (closest to VIMS) back slightly. Don't bend the bottom leg (near UVIS). Put some glue at the end of each leg.

❒ Mount the RSP to the UEM directly below BAY 1. Carefully adjust the bend in the two upper legs to make the RSP align vertically with the PM. The bottom leg glues right to the seam between the UEM and the PM, at exactly the +X side of the UEM. Alphabet soup!



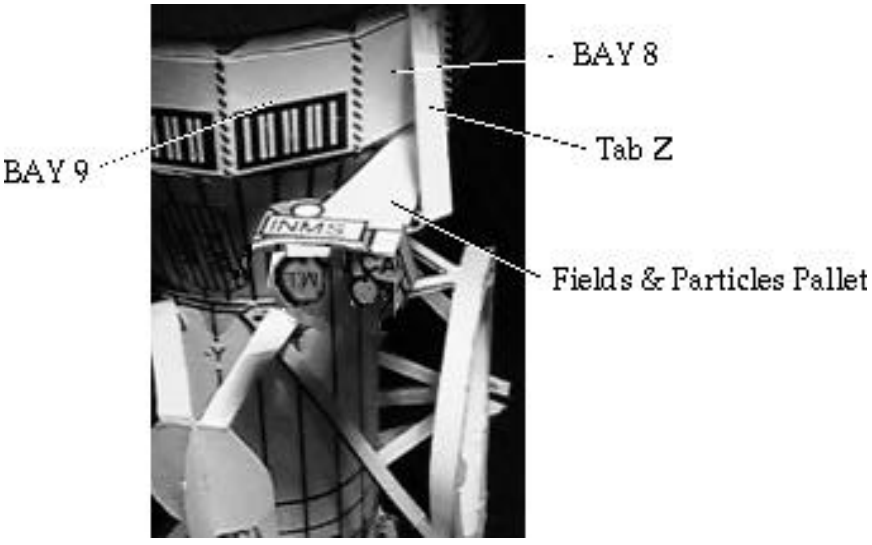
THE FIELDS & PARTICLES PALLET

❒ Cut out the FIELDS & PARTICLES PALLET from Parts Sheet 6. Fold CAPS and ML down 90° toward the non-printed side. Fold CAPS in half, back toward the non-printed side 90° by making a crease between the letters A and P. Fold MC down towards the non-printed side 90°.

❒ Tab Z has a slanted black line where it connects to the PALLET. Fold it up at an angle, toward the printed side, making a crease along the black line.

❒ Apply glue to the printed side of the PALLET's triangular point. Install it up under BAY 7 & BAY 8 (not labelled), so the MC is situated out from BAY 8, and the MC side of the PALLET is in line with the PROBE ADAPTOR RING. INMS sticks out in front of BAY 9.

❒ Apply glue to the end of tab Z, and bring it in contact with BAY 8, where it will connect, to support the PALLET level with the bottom of the BUS.



THE RPWS SEARCH COIL

❒ Cut out the two parts of the RPWS SEARCH COIL from Parts Sheet 6. Fold the three pairs of tripod legs down toward the non-printed side, and stand the tripod on your work surface. Trim the length of any legs that need it, so that the central, circular "table" will be level.

❒ Glue one arm of the + shaped piece into the central slot in the tripod's circular table, and adjust it to stand straight up as the glue dries.

❒ Optional: Obtain a straight pin which has a small metal head. Stick it into the circular table, near the edge and close to where a pair of legs connects. The head should be about a cm above the printed side. Secure the pin with glue. This represents the Langmuir Probe, part of the RPWS instrument.

- ❒ Set your spacecraft down on its side, supported by a cup, with BAY 7 (the -X side) facing up.
- ❒ Apply glue to the three feet of the tripod. Set the tripod down onto the triangle above BAY 7, with one tripod foot connected to each corner of BAY 7's triangle. Align it straight out from BAY 7. If you installed a Langmuir Probe, it should be on the upper right as you view BAY 7.

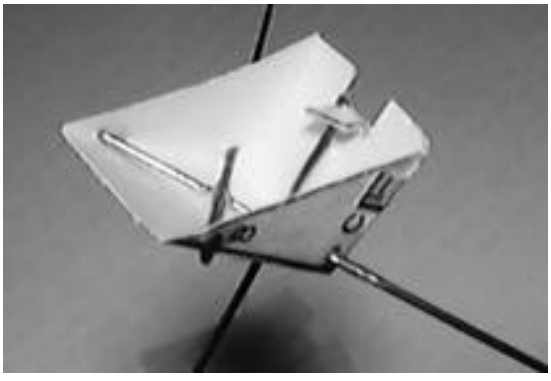
THE MAGNETOMETER BOOM

- ❒ Cut out the MAGNETOMETER BOOM from Parts Sheet 6. Lightly score along the two long black lines which run the length of the piece, using an art knife guided by a metal ruler. Fold along those lines, to make a boom with a triangular cross section, printing outside. Fold the three tabs over and glue them down to hold the boom's shape.
- ❒ One end of the BOOM has a blank white section. Smear glue on the end of this section, on the side opposite the seam. Make the smear about half the length of the blank section.
- ❒ Insert half the blank section of the BOOM into the opening above BAY 4 and glue it down to the BUS TOP, so that the BOOM protrudes straight out from the spacecraft. Prop the boom up on something to hold its position while the glue dries. Add extra glue here and there so the BOOM will be securely attached. Check to make sure that the BOOM is extending straight out in the +Y direction from the spacecraft.

OPTIONAL: THE RPWS ANTENNAS

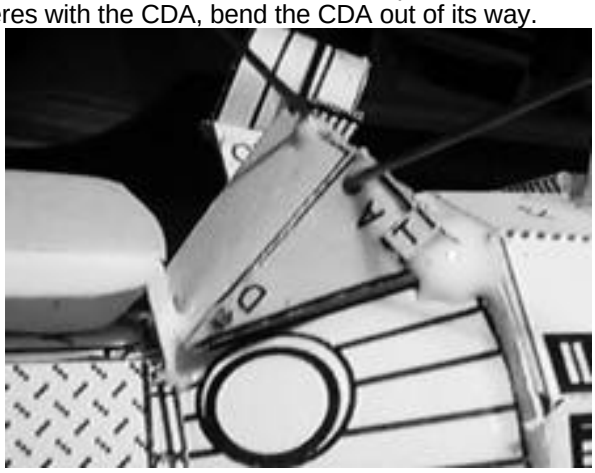
This part is optional. Only install wires if your use of the model would present no hazard of eye injury from stiff wires protruding from the model. Do NOT install wires if children will be handling the model: SKIP to THE HUYGENS PROBE.

- ❒ Obtain three lengths of thin, stiff wire, either steel or brass, about 13 cm or 5 inches long. The wire should be lightweight, and stiff enough that it doesn't sag from its weight here in Earth's gravity. Hobby stores typically offer a selection of wire.
- ❒ Cut out the RPWS from Parts Sheet 6.
- ❒ With a straight pin, punch a pinhole in the center of each of the six small circles, labelled A through F.
- ❒ Fold the two triangular flaps 90°; fold up the square flap to meet them; apply glue to the two small square flaps marked T, and fold them over to hold the part's shape. When that dries, apply more glue along the seams to hold it securely, but don't get any glue in the pinholes.
- ❒ Insert the end of one length of wire into corner pinhole A from the outside. Push the wire diagonally across the piece, and just out through pinhole B on the other side. The amount of wire coming out pinhole B should be only enough to cover with glue.
- ❒ Repeat with another length of wire from the other side, going in pinhole C, crossing under the first wire, and just out D. The amount of wire coming out pinhole D should be only enough to cover with glue.
- ❒ Apply glue to secure the wire at pinholes A, B, C, and D, and where they cross.
- ❒ Insert the third length of wire through pinhole E. Fold down the tab which holds pinhole F toward the inside. Push the wire just out through pinhole F, only far enough to cover the end with glue. Apply glue to the wire at pinholes E and F. Let all the glue dry thoroughly.



- ❒ Rest the model on a cup with its +Y side up. Apply glue to the upper supports of the HELIUM TANK where they meet the UEM. Also apply glue to the UEM where it meets the base of BAY 4.

❒ Install the RPWS with its wires onto the UEM. The open side goes toward the UEM; the end with pinholes B and D goes down against the glue at the top of the HELIUM TANK supports. The other end near pinhole F goes under BAY 4. Add more glue as necessary. Align the RPWS so that the bottom wire, in pinhole E, is immediately below the MAGNETO-METER BOOM. If one wire interferes with the CDA, bend the CDA out of its way.



THE HUYGENS PROBE

❒ Insert the small end of the HUYGENS PROBE into the PROBE ADAPTER RING. Twist it slightly so the friction points will hold the PROBE in place. The PROBE is removable from your model to simulate its operation. Optionally, glue it in place.

THIS COMPLETES YOUR CASSINI MODEL.

ABOUT YOUR CASSINI MODEL

Its scale is about 1/37. The Huygens Probe is included for completeness, but not much detail is represented on the Probe spacecraft. None of its scientific instruments are represented. The Magnetometer Boom is only about 2/3 scale length, and slightly thicker than scale, for convenience. The optional RPWS antenna wires, if installed, are much shorter than scale length, for convenience. They are each actually about as long as the Magnetometer Boom.

Model design completed
3 June 1997 by Dave Doody
Cassini Real Time Operations
Caltech/Jet Propulsion Laboratory
Updated 26 May 1999

AN AFTERHOURS PROJECT

No taxpayer dollars were harmed in the production of this model.

Please take a moment to evaluate this product at
http://ehb2.gsfc.nasa.gov/edcats/educational_brief
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

PARTS SHEET 1 The Spacecraft Bus

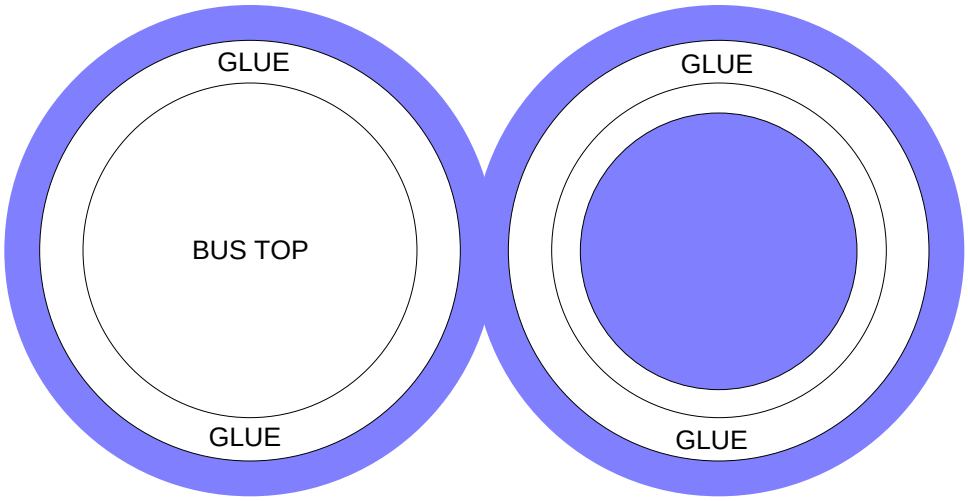
Parts Set version May 1999

Cassini's spacecraft bus consists of twelve equipment bays arranged in a regular polygon with three extra bays added as appendages to it. The bus contains electronics and computers used for radio communications, detection, storage, and execution of commands, data storage, attitude control, power switching and control. One appended bay is for the radar, and two are for inertial reference units. Many of the bays are equipped with louvers on their outward facing side, to control thermal radiation. The bus is connected mechanically to the Propulsion Module by an upper equipment module which supports scientific instruments and other equipment.

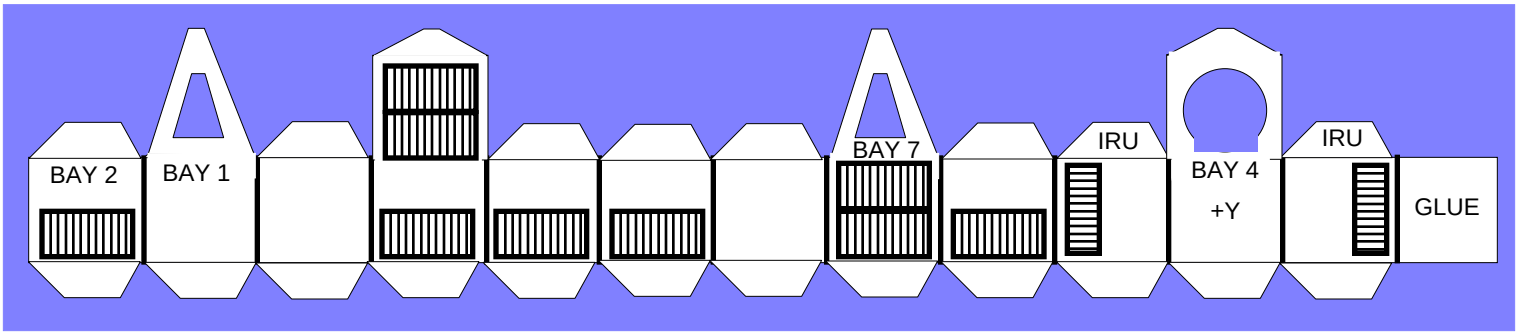
PRINTING CALIBRATION

1 CM

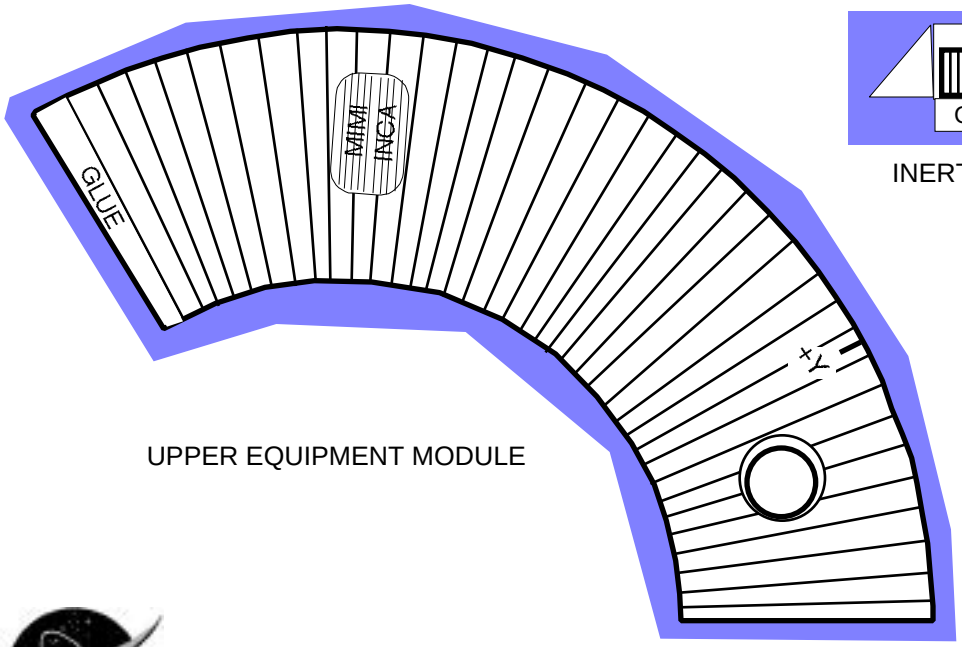
1 INCH



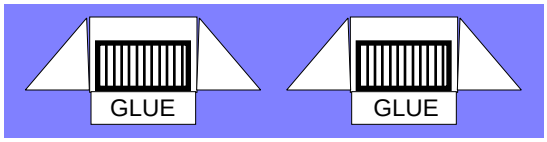
BUS BOTTOM



SPACECRAFT BUS



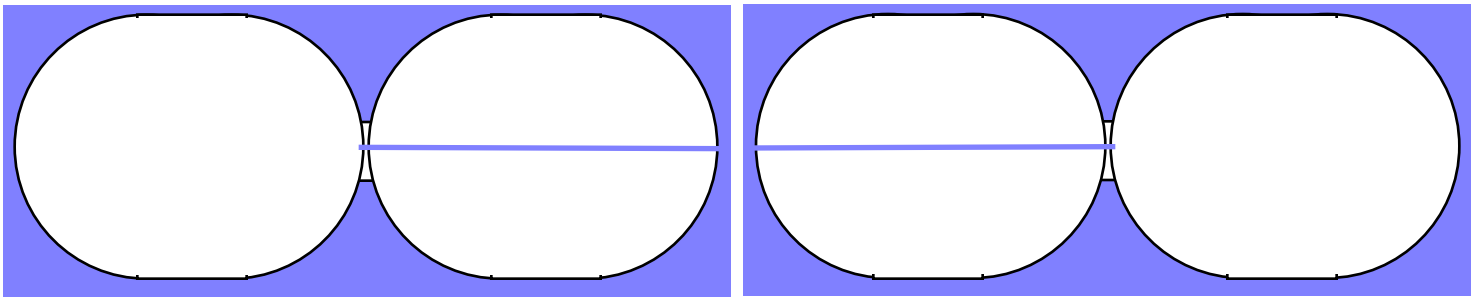
UPPER EQUIPMENT MODULE



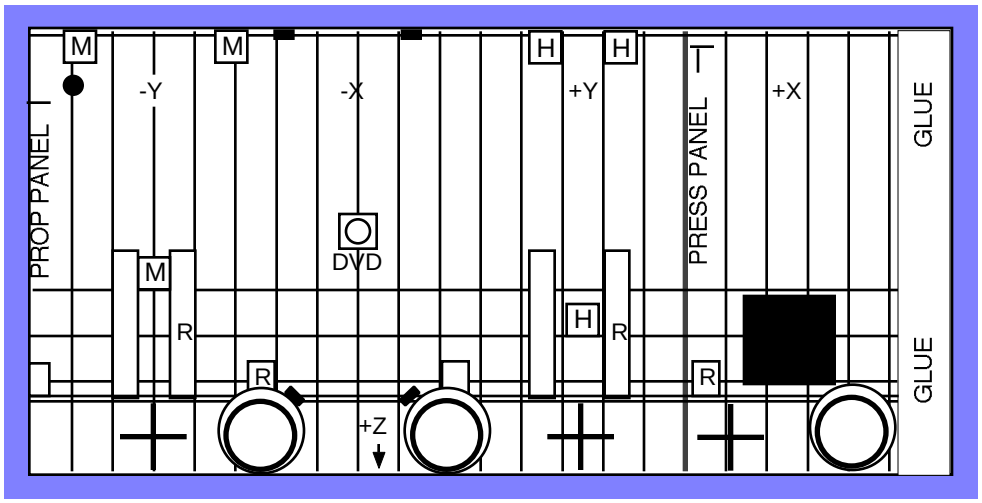
INERTIAL REFERENCE UNITS (IRUs)

PARTS SHEET 2 The Propulsion Module

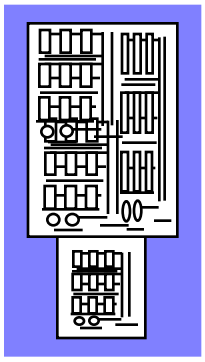
Cassini's Propulsion Module carries a large mass of propellant mainly to power its rocket engine for deceleration into orbit at Saturn, a maneuver called Saturn Orbit Insertion (SOI). The module also provides the means for managing the spacecraft's attitude, and for small propulsive maneuvers called Trajectory Correction Maneuvers (TCMs). To simplify model construction, part of the Lower Equipment Module (LEM) is also attached to the Propulsion Module. The rest of the LEM is on Sheet 4.



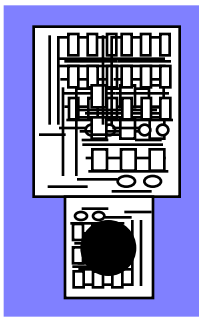
BIPROPELLANT TANK HALVES



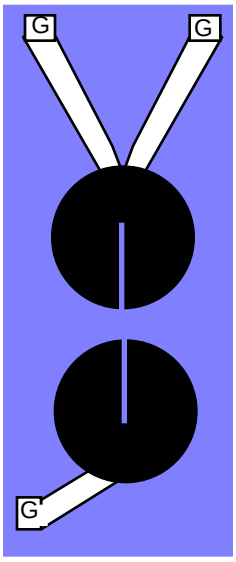
PROPULSION MODULE AND LOWER EQUIPMENT MODULE STRUCTURE



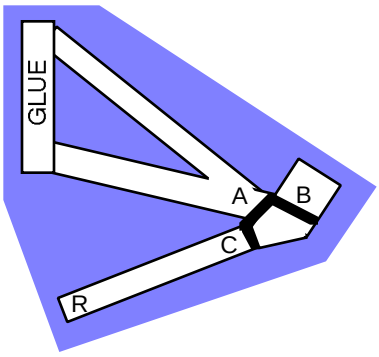
PRESSURANT CONTROL PANEL

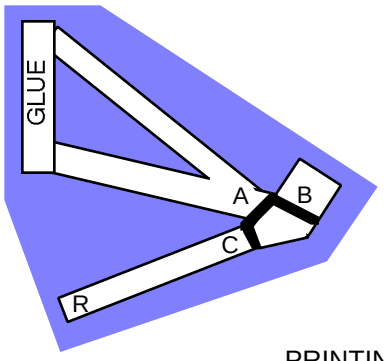


PROPULSION CONTROL PANEL

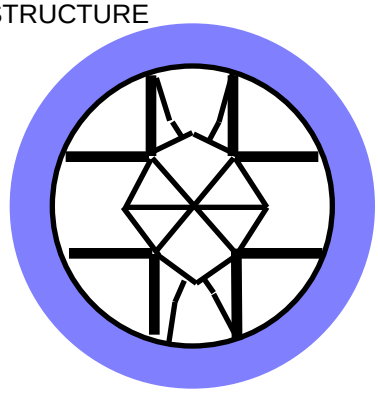


MONOPROPELLANT TANK HALVES

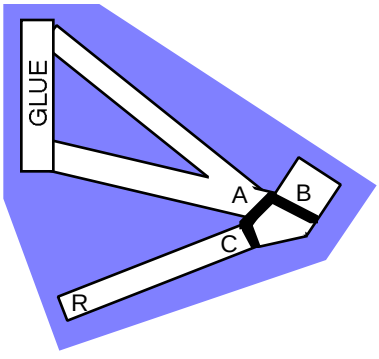


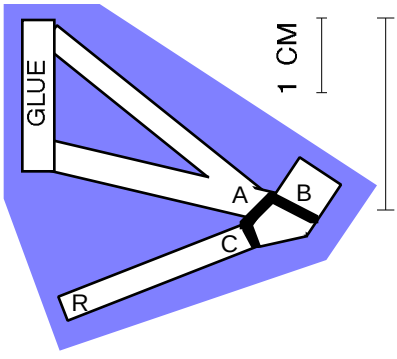


RCS THRUSTER CLUSTERS

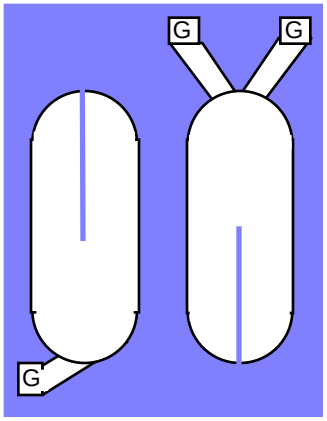


ENGINE GIMBAL ASSEMBLY

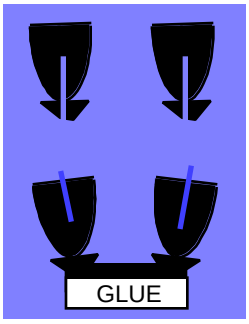




PRINTING CALIBRATION



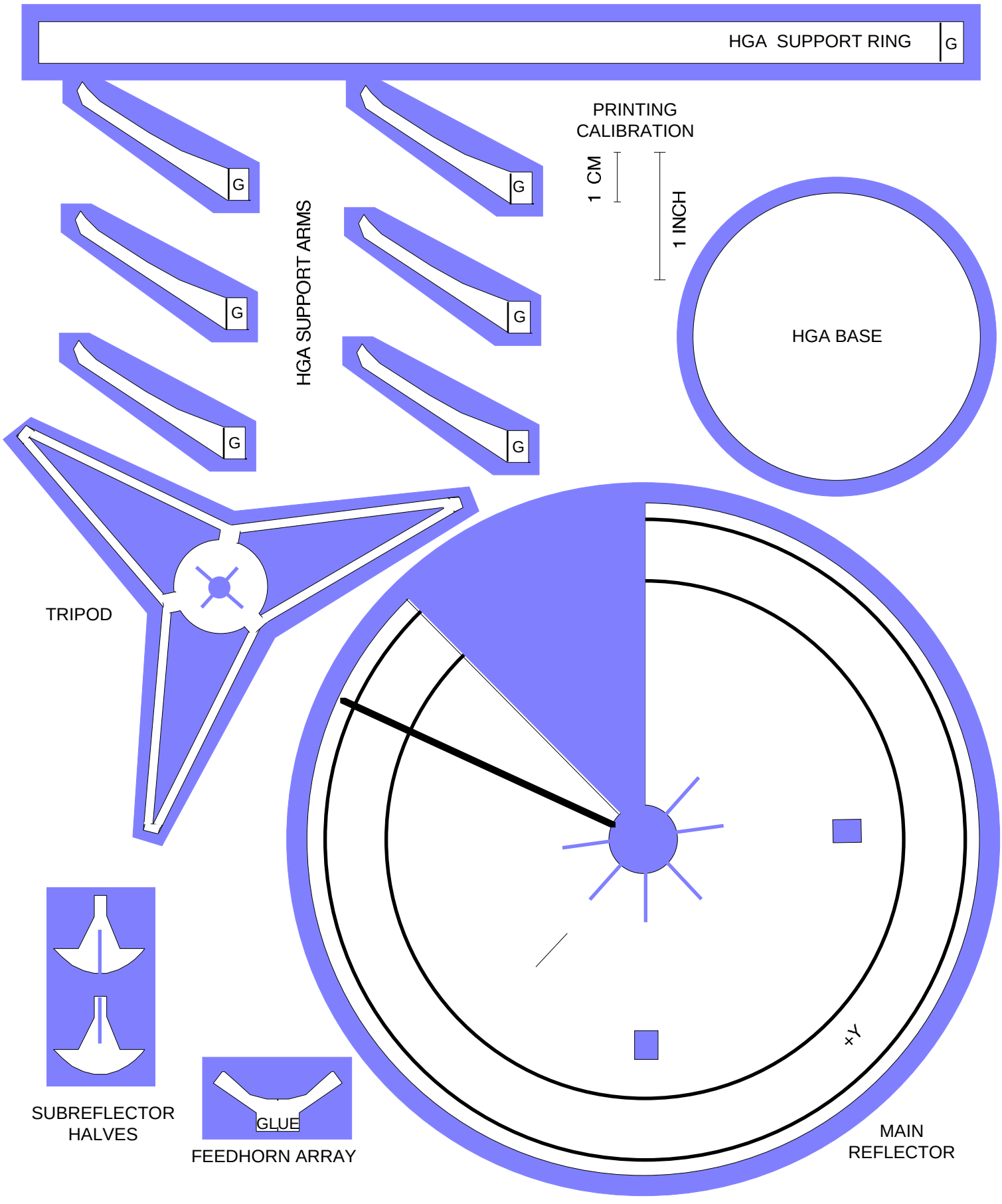
HELIUM TANK HALVES



MAIN AND BACKUP ENGINES

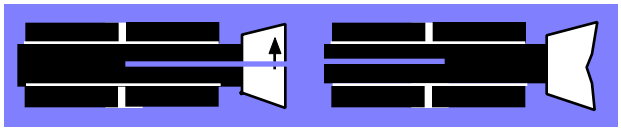
PARTS SHEET 3 The High-Gain Antenna (HGA)

Cassini's HGA is used for high-rate radio communications with Earth. It is also used as a radar dish for penetrating the hazy atmosphere of Titan, Saturn's largest sattelite, to image its surface. It works with the Radio Science experiment, and it also serves as a sunshade for the spacecraft while it flies in the inner solar system en route to Saturn.

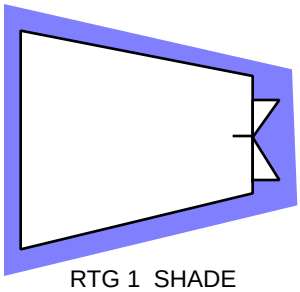


PARTS SHEET 4 The Lower Equipment Module (LEM)

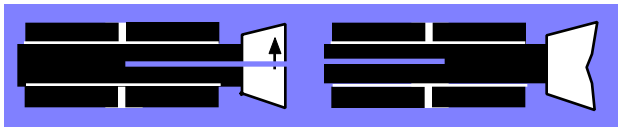
Cassini's Lower Equipment Module supports the three Radioisotope Theremoelectric Generators (RTGs) which provide electrical power and heat for the spacecraft, and three reaction wheels. The reaction wheels, also called momentum wheels, are massive discs driven by electric motors. Applying torque to one causes the whole spacecraft to rotate in the opposite direction. Three such wheels permit the spacecraft to be rotated about any axis. The fourth reaction wheel, a spare, is mounted on the upper equipment module. Low-gain antenna #2 is also mounted on the LEM.



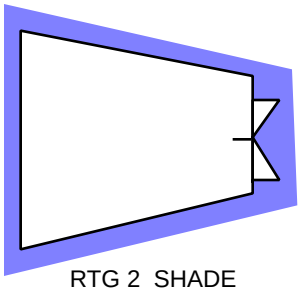
RTG 1 HALVES



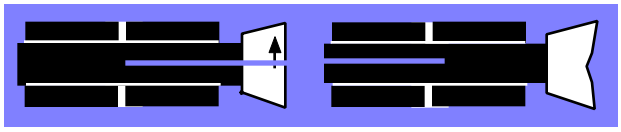
RTG 1 SHADE



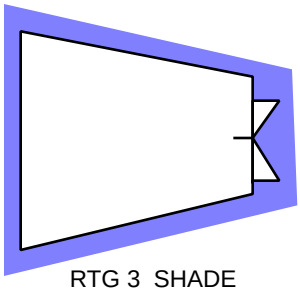
RTG 2 HALVES



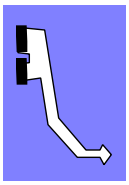
RTG 2 SHADE



RTG 3 HALVES



RTG 3 SHADE



LGA-2

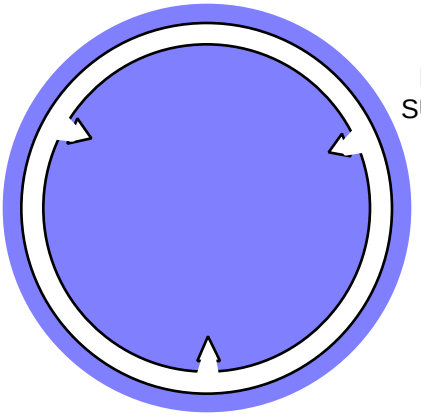
PRINTING CALIBRATION

1 CM

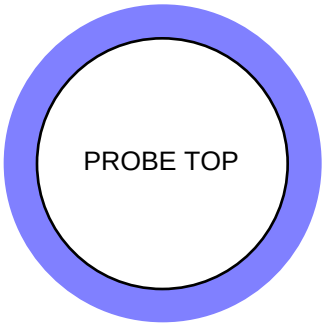
1 INCH

PARTS SHEET 5 The Huygens Probe

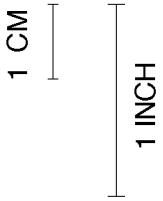
Cassini carries another spacecraft along for the ride to the Saturnian system. The Huygens Probe, built by the European Space Agency, will separate from Cassini once in orbit at Saturn, and will descend into the atmosphere of Titan, Saturn's largest moon. Huygens will radio images and other scientific data from Titan back to Cassini, which will then relay them back to Earth.



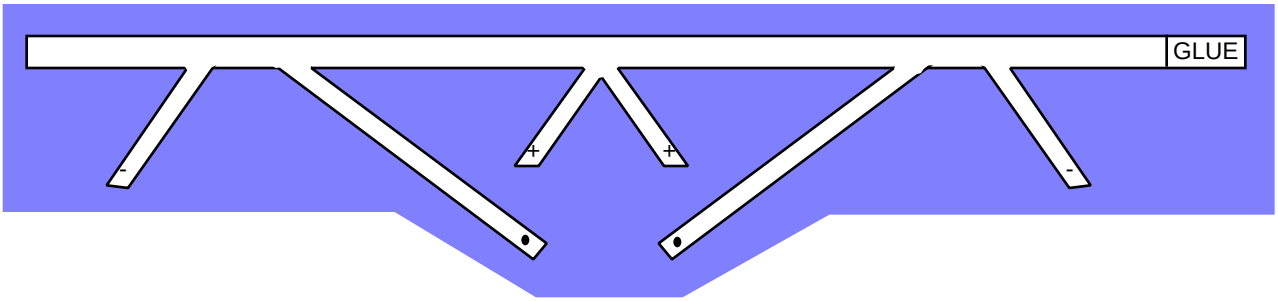
PROBE SUPPORT RING

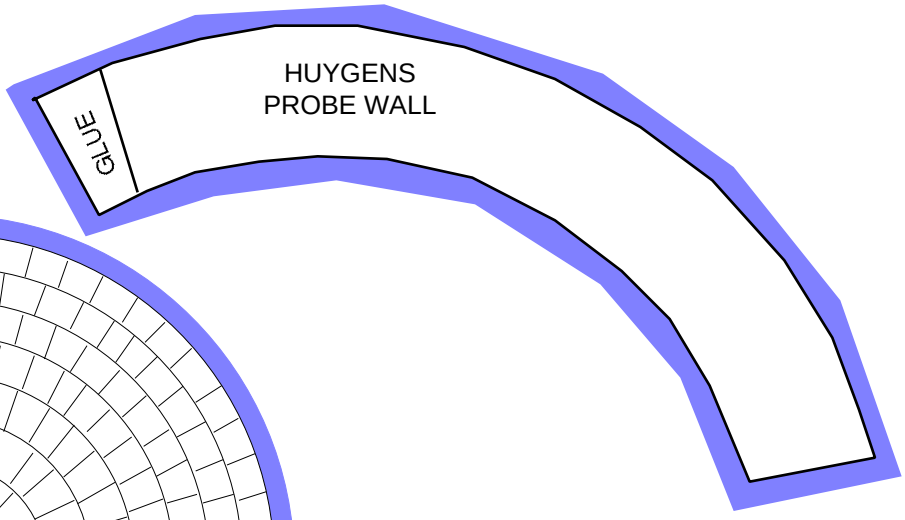


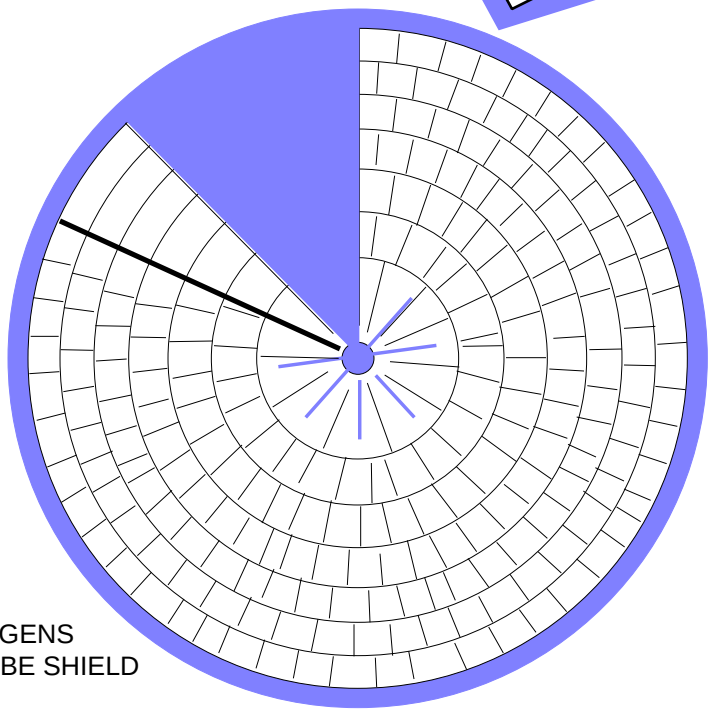
PRINTING CALIBRATION



PROBE SUPPORT RING BASE



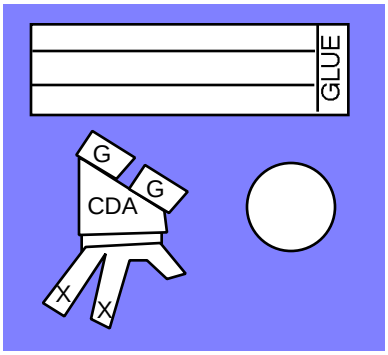




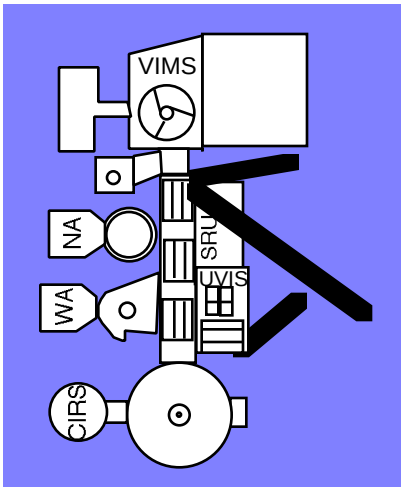
HUYGENS
PROBE SHIELD

PARTS SHEET 6 The Science Instruments

Cassini's scientific instruments are the reason for having a spacecraft at all. Remote sensing instruments, such as cameras and spectrometers capture light reflected from Saturn or other targets. Direct sensing instruments, such as the dust detector and magnetometers measure phenomena which they encounter in the spacecraft's immediate environment. Measurements taken by the instruments are sent back to Earth by the spacecraft either right away, or after being stored aboard for a convenient time for transmission. Note: the stellar reference units, mounted with the remote sensing instruments, are not scientific instruments, but part of the spacecraft's attitude control system.



COSMIC DUST ANALYZER

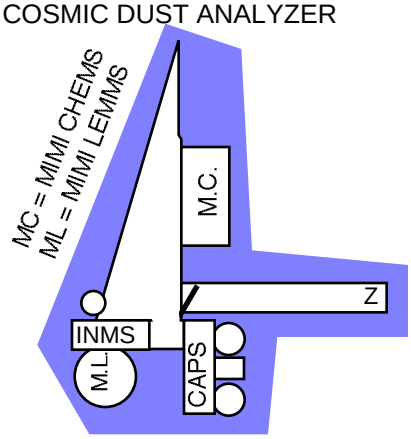


REMOTE SENSING PALLET

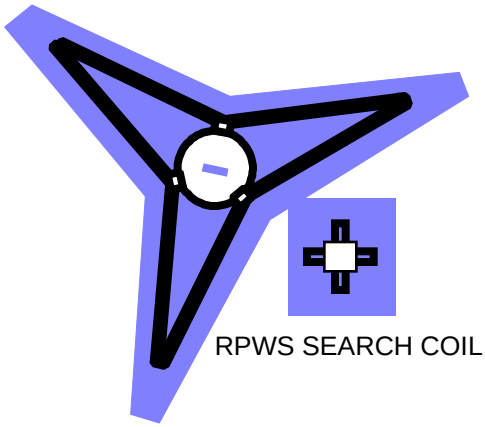
PRINTING CALIBRATION

1 CM

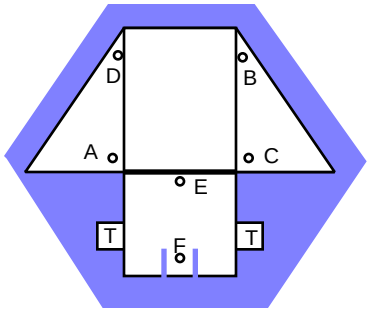
1 INCH



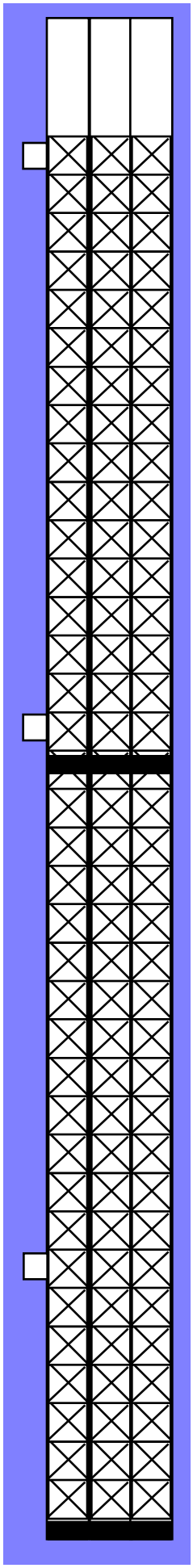
FIELDS & PARTICLES PALLET



RPWS SEARCH COIL



RPWS



MAGNETOMETER BOOM

Cassini's Scientific Experiments

Optical Remote Sensing:

- CIRS Composite Infrared Spectrometer
- ISS Imaging Science Subsystem
  - NA Narrow Angle camera
  - WA Wide angle camera
- UVIS Ultraviolet Imaging Spectrograph
- VIMS Visual & infrared mapping spectrometer

Fields, Particles, and Waves:

- CAPS Cassini Plasma Spectrometer
- CDA Cosmic Dust Analyzer
- INMS Ion and Neutral Mass Spectrometer
- MAG Dual Technique Magnetometer
- RPWS Radio & Plasma Wave Science
- MIMI Magnetospheric Imaging Instrument:
  - LEMMS Low energy magnetoshperic measurement system
  - CHEMS Charge energy mass spectrometer
  - INCA Ion and neutral camera

Microwave Remote Sensing

- RADAR Cassini Radar (uses HGA)
- RSS Radio Science Subsystem (uses communications system)