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ABSTRACT

The Hubble Space Telescope, the most complex and sensitive optical telescope ever made, was built to study the cosmos from low-Earth orbit for 10 to 15 years or more. The Compton Gamma Ray Observatory is a complex spacecraft fitted with four different gamma ray detectors, each of which concentrates on different but overlapping energy range and was designed to help astronomers learn about the most powerful celestial bodies and events in the universe. This educational product for grades 5 and up contains detailed descriptions to assemble a Hubble Space Telescope model and a Compton Gamma Ray Observatory model.

National Aeronautics and
Space Administration

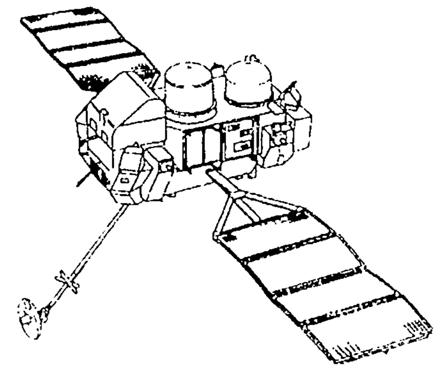
Human Resources and
Office of Education

Education Division

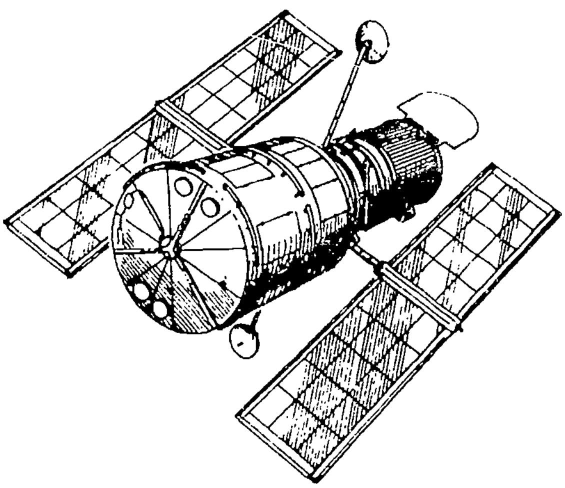
| Educational Product | |
|---|---|
| Teachers & Students | Grades 5 and up |

# NASA's Great Observatories
## Paper Model Kits

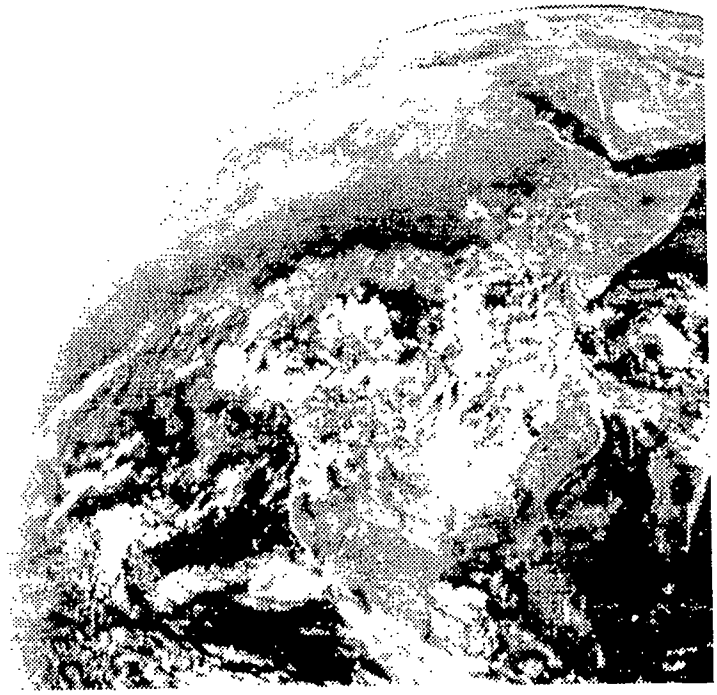




*Compton Gamma Ray Observatory*



*Hubble Space Telescope*



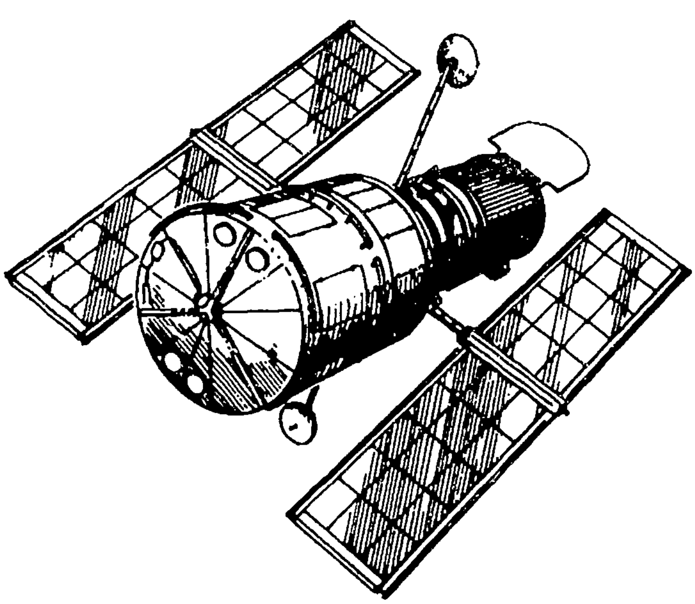
PED-136, August 1993

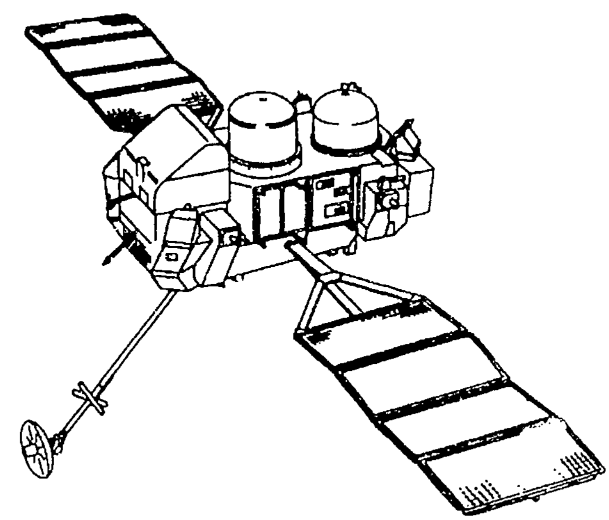
# NASA'S Great Observatories

Why are space observatories important? The answer goes beyond twinkling stars in the night sky. Pockets of cold and hot air in Earth's atmosphere act as a hazy veil that many visible rays of light cannot penetrate. The atmosphere absorbs the majority of radiation from celestial bodies and distorts the types of light that do reach Earth's surface. Some types of radiation (like gamma rays) seldom reach Earth's surface. The radiation that Earth's atmosphere absorbs and distorts limits scientists' observations of stars, galaxies, and other celestial bodies. Even the most powerful ground based observatories can collect only a limited amount of data, but observatories in space collect data free from the distortion of Earth's atmosphere.

Space observatories contain advanced, highly-sensitive instruments such as telescopes (Hubble Space Telescope) and detectors (Compton Gamma Ray Observatory) that allow scientists to study radiation from neighboring planets and galaxies billions of light years away. By analyzing the spectrum of radiation emitted or absorbed by an object, scientists can determine temperature, chemical composition, and motion of an object. The light emanating from these far off celestial bodies takes billions of years to reach the observatories, so scientists can actually look into the past and learn what was happening in the universe when the universe was young. The data that these observatories gather help scientists understand star and galaxy formation, and the origination and evolution of our universe.

Hubble Space Telescope





Compton Gamma Ray Observatory

NASA, in conjunction with other countries' space agencies, commercial companies, and the international scientific community, has built observatories like the Hubble Space Telescope and the Compton Gamma Ray Observatory to find the answers to these and other questions.

## Hubble Space Telescope

NASA's Hubble Space Telescope (HST) was deployed from Space Shuttle *Discovery* into Earth orbit in April of 1990. It is a product of two decades of research and development by 10,000 scientists and engineers at various NASA centers, private companies, universities, and the European Space Agency. The HST, the most complex and sensitive optical telescope ever made, was built to study the cosmos from low-Earth orbit for 10 to 15 years or more.

**Scientific Objectives of HST**

Scientists designed the HST to provide fine detail imaging, produce ultraviolet images and spectra, and detect very faint objects. Today, the HST is meeting the first two of these three objectives. A planned servicing mission will restore HST's ability to study very faint objects. HST has provided spectacular images and data of a giant storm on Saturn, unexpected clouds of hydrogen gas near our Galaxy, and the birth and rebirth of stars in older star clusters.

### The Primary Mirror's Spherical Aberration

Two months into the mission, scientists detected a 2 micron spherical aberration in the primary mirror that affects the telescope's ability to focus faint light sources into a precise point. This imperfection is very slight, one-fiftieth the width of a human hair.

Computer processing has been successful in overcoming some of the mirror's problems, and a Shuttle servicing mission scheduled for late 1993 or 1994 will add corrective optics to bring the scattered light of faint objects back into focus. After the servicing mission, the planned scientific capabilities of HST should be restored. This information will help scientists determine the age, size, and composition of the universe, and how it will end.

### Key Features

The HST is approximately the size of a railroad car with two large cylinders joined together and wrapped in what looks like aluminum foil. Wing-like solar arrays extend horizontally from each side of these cylinders, and dish-shaped antennas extend above and below the body of the telescope on rods. While there are 400,000 parts to the telescope, its design is modular so the Shuttle can replace and update units.

The telescope has three major sections: the support systems module, the optical telescope assembly, and the scientific instruments. The support systems module holds the optical telescope assembly and scientific instruments in place and insulates them from extreme temperature highs and lows, when the satellite is in full light or darkness.

The support system provides power, pointing control and navigation, and communications. The solar arrays provided by the European Space Agency consist of two "wings" containing 48,000 solar cells. These solar arrays will be replaced during the first servicing mission with new arrays designed to correct for jitter problems. The pointing control system aims the telescope to a desired position and locks it in place through the use of gyroscopes, star trackers, momentum wheels, electromagnets, and fine guidance sensors. Computers, high-gain antennas, and an electrical power system enable the HST to receive commands and transmit data back to scientists on Earth.

The optical telescope assembly contains one secondary and one larger primary mirror (238.76 cm) to collect and focus light from selected celestial objects. The primary mirror is housed near the center of the telescope. Light hits the primary mirror, bounces to the secondary mirror mounted near the aperture, and narrows and intensifies as it passes through a hole in the primary mirror to a focal point 1.5 meters behind the primary mirror.

The scientific instruments include the Wide Field/Planetary Camera, the Faint Object Camera, the Goddard High Resolution Spectrograph, the Faint Object Spectrograph, the High Speed Photometer, and the Fine Guidance System. The third Fine Guidance System serves as an astrometric instrument and is the sixth scientific instrument on HST.

The Wide Field/Planetary Camera is designed to investigate the age of the universe and to search for new planetary systems around young stars. It takes pictures of large numbers of galaxies or close-ups of planets in our solar system.

The Faint Object Camera, a contribution of the European Space Agency, focuses on smaller areas than the other camera and is used for producing sharp images at great distances. The data this camera will produce will help determine the distance scale of the universe and peer into centers of globular star clusters, binary stars, and other faint phenomena.

The Faint Object Spectrograph analyzes faint objects in the visible and ultraviolet light spectrum to detect chemical properties of comets and the composition of quasars.

The Goddard High Resolution Spectrograph solely studies ultraviolet light to determine the chemical nature, temperature, and density of the gas between stars, within quasars, and in planets' atmospheres.

The High Speed Photometer, a precise light meter for measuring the brightness of objects in visible and ultraviolet ranges, will be replaced by Corrective Optics Space Telescope Axial Replacement (COSTAR) during the first servicing mission. COSTAR uses precisely shaped mirrors to compensate for the spherical aberration in the primary mirror for the light entering the HST's observing instruments.

## Compton Gamma Ray Observatory Model

The Compton Gamma Ray Observatory is the second in a Great Observatory series of four spacecraft NASA plans to launch. The Compton Gamma Ray Observatory is a complex spacecraft fitted with four different gamma ray detectors, each of which concentrates on different but overlapping energy ranges. The instruments are the largest of their kind that have ever flown in space; each instrument weighs about six tons and three of them are about the size of a subcompact car. Size is important because gamma rays can be detected only when they interact with matter. The bigger the masses of the detectors, the greater the number of gamma rays they can detect.

Outer space is filled with electromagnetic radiation that tells the story of the birth and death of stars and galaxies. A small portion of that radiation is visible to our eyes. The rest can be detected only with special instruments. In a chart of the electromagnetic spectrum, gamma rays fall at the far right end after visible light, ultraviolet light, and X-rays. Gamma rays have very short wavelengths and are extremely energetic, but most of them do not penetrate Earth's atmosphere. The only way for astronomers to view these waves is to send instruments into space.

The process for gamma ray detection is similar to the way fluorescent paints convert ultraviolet light to visible light. When gamma rays interact with crystals, liquids, and other materials, they produce flashes of light that are recorded by electronic sensors. Astronomers can determine how energetic a particular ray is from the intensity of the flash. The brighter the flash of light from the interaction, the higher the energy of the ray.

**Scientific Objectives of GRO**

The Compton Gamma Ray Observatory helps astronomers learn about the most powerful celestial bodies and events in the universe. The GRO observes momentous gamma ray bursts such as those near the large Magellanic Cloud that radiate more gamma rays in 1/10 second than our Sun does in 1,000 years. The GRO gathers data to test theories on supernovae and the structure and dynamics of galaxies. The data the GRO collects on pulsars will enable scientists to explain how pulsars can produce more energy over its lifetime than the explosion it took to create it. The GRO monitors quasars, luminous bodies with unusually high energy outputs commonly found in the center of galaxies. In addition, the GRO observes very high temperature emissions data from black holes that will reveal information on the origin of the universe and matter distribution.

**The Compton Gamma Ray Instruments**

The four different kinds of gamma ray detectors on the Compton Gamma Ray Observatory are the Burst and Transient Source Experiment (BATSE), Oriented Scintillation Spectrometer Experiment (OSSE), Imaging Compton Telescope (COMPTEL), and the Energetic Gamma Ray Experiment Telescope (EGRET).

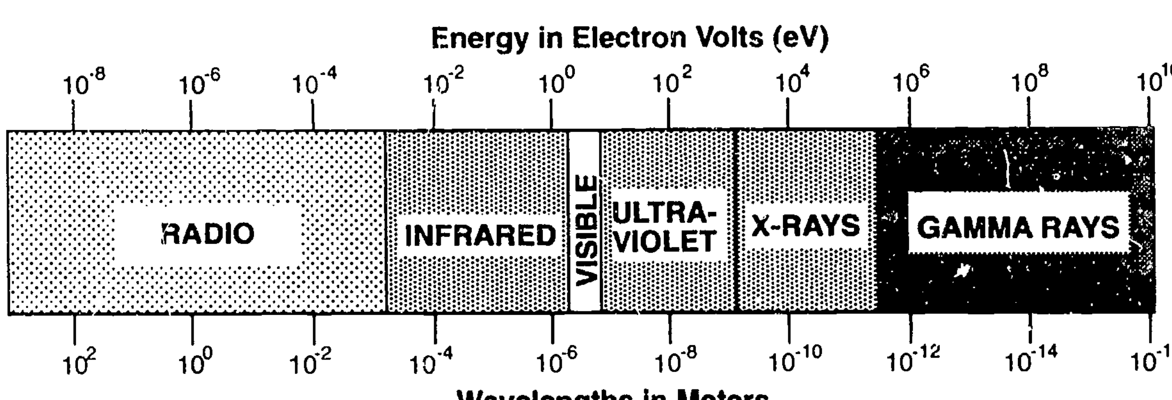
BATSE consists of eight detectors placed on the corners of the spacecraft in order to monitor as much of the sky as possible for gamma ray bursts. The reason for this is that gamma ray bursts are brief, random events. These bursts are in the lower energy range of gamma rays. However, since BATSE is the instrument with the widest view range when it detects higher range gamma rays, it signals the other instruments.

OSSE uses four precise crystal detectors primarily for plotting radioactive emissions from supernovae, pulsars, and novae. This experiment provides information such as temperature, particle velocities, and magnetic field strength.

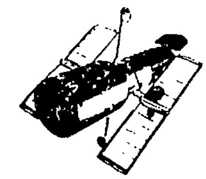
COMPTEL studies gamma rays with a higher energy range than OSSE. The Imaging Compton Telescope is a liquid detector that acts like a camera. Gamma rays enter through an initial detector that is similar to a lens and then pass through a second detector that acts like film. In this way COMPTEL reconstructs wide field view images of the sky. COMPTEL observes point sources such as neutron stars, galaxies, and other diffuse emissions.

The EGRET instrument detects the highest energy gamma rays, which are associated with the most energetic processes that occur in nature. EGRET was designed to collect data on quasars, black holes, stellar and galactic explosions, matter and antimatter annihilation, and high-energy portions of gamma-ray bursts and solar flares. The highly sensitive instruments of EGRET can observe fainter sources than was previously possible and with greater accuracy.

## The Electromagnetic Spectrum



# Hubble Space Telescope Model



*Copies of the model pattern should be printed on 60 pound weight white paper for proper assembly.*

Materials and Tools

- Sharp paper scissors
- Razor blade knife
- Dull knife
- Sharp punch (such as an ice pick or nail)
- Cutting surfaces (such as a wood board)
- Glue stick or rubber cement
- Cellophane tape
- 5X5 cm square piece of aluminum foil
- 2 20-cm pieces of 1/8 inch dowel rods
- Colored sharp point marker pens (yellow and red)
- Blue and orange highlighter pens

General Assembly Tips:

- Color all pieces as indicated before cutting any parts out.
- Cut out only those pieces needed for the section being assembled at the time.
- Use a cutting surface like a wooden board to protect the table or desk from scratches or gouges.
- Cut out pieces along the solid exterior lines.
- Using the dull knife, lightly score all dashed fold lines to make accurate folds possible.
- Apply glue to the insertion tabs on the pieces and flaps where the slots are located. If using rubber cement, apply cement to both surfaces to be joined and permit them to dry before assembling. Using a double coating of rubber cement makes a stronger bond. After the pieces are assembled, lightly rub pieces to remove excess.
- Some pieces may require small holes to be punched through them. Those places are indicated with the following symbol: ⊕.

#1 Assembling the Aft Shroud

1. Carefully cut out the following pieces: aft shroud cylinder, end cap, and the inner ring. Use the razor blade to cut small slits for insertion of the assembly tabs of the cylinder.
2. Shape the aft shroud cylinder by curling the paper around the edge of a table or desk. This will permit the paper to be easily rolled into a cylinder.
3. Curl the paper to form a tube and insert the tabs of the cylinder into the slits cut in step 1. Hold the cylinder together with a piece of tape pressed to the inside.
4. Fold the tabs of the inner ring downward. Dashed lines indicate where the folds should be. Coat each tab with glue and lay the ring upside down on a flat surface. Place the cylinder over the inner ring so that all tabs are inside. The seam of the cylinder should align with the word "small" on the inner ring. Reach in with a finger and press each tab to the inside wall of the cylinder. You will need to support the outer wall of the cylinder with another finger to achieve a good bond.
5. Fold the tabs of the end cap downward and coat each with glue. Place the end cap upside down on a flat surface and place the other end of the cylinder over it. Press the tabs in place. If you have trouble reaching the tabs, use the erasure end of a pencil in place of your finger.
6. The aft shroud is completed. Set it aside.

#2 Assembling the Forward Shell and Light Shield

1. Carefully cut out the forward shell and light shield assembly. Use the razor blade to cut the slits for the insertion of the assembly tab.
2. Shape the tube by pulling the paper over the edge of a table or desk.
3. Curl the paper to form a tube and insert the tabs into the slit. Use tape to hold the tube together.

#3 Joining the Aft Shroud and the Forward Shell and Light Shield

1. Bend the four glue tabs at the lower end of the forward shell and light shield inward and cover with glue.
2. Place the aft shroud on a flat surface with the inner ring pointed up. Insert the forward shell and light shield with the glue tab end down. Align the seam of the two cylinders.
3. Make sure the forward shell and light shield is standing straight up. Use a long piece of dowel rod to reach inside the tube and press the tabs to the end cap so that they will bond to the inside of the end cap.

#4 Assembling the OTA Equipment Section

1. Carefully cut out the OTA equipment section. Cut the slots for tab insertion with the razor blade knife.
2. Curl the bay section to form a semicircle.
3. Fold the tabs downward and the curved sections downward.

4. Apply glue to the tabs and insert them into the slots to join the segments as indicated in the diagram.

#5 Joining the OTA Equipment Section to the Aft Shroud

1. Apply glue to the OTA equipment selection where indicated.
2. Press the OTA Equipment Section to the inner ring where indicated.

#6 Assembling the Barrel Insert

1. Cut out the barrel insert, mirror support, and secondary mirror support.
2. Trace the circle of the mirror support on the aluminum foil and cut out the circle. Glue the foil to the mirror support.
3. Glue the secondary mirror support on to the aluminum foil.
4. Cut the slits for the assembly tabs on the barrel insert. Curl the paper to form a tube by dragging it over the edge of a table or desk.
5. Form the barrel insert by rolling the paper, with the black side inward, and inserting the tabs into the slits. Hold the tube together by applying tape to the outside.
6. Fold the glue tabs of the mirror support inward toward the foil side. Coat the tabs with glue. Bond the mirror support to the end of the barrel insert with the glue tabs to the outside.

#7 Joining the Aperture Door to the Barrel Insert

1. Cut out the aperture door.
2. Apply glue to the back side of the middle glue tab and to the front side of the remaining two tabs.
3. Spread the glue tabs and attach the aperture door to one end of the barrel insert over the seam. The middle tab should be on the inside and the other tabs on the outside. Press the tabs to the tube.

#8 Inserting the Solar Array and Antenna rods

1. Use the punch to make four small holes in the side of the forward shell and light shield at the places indicated. (Look for the ⊕.)
2. Carefully insert the two dowel rods into the holes so that each extends through to the opposite side. The antenna rod is inserted through the holes closest to the aft shroud. The solar array rod is inserted through the holes closest to the aperture end of the forward shell and light shield.

#9 Assembling the Solar Arrays

1. Cut out each solar array. Punch out the small circular holes in the two tabs. When the front and back sides of the arrays are together, both tabs should stick out. You will slide the tabs over the ends of the solar array rod you inserted into the forward shell and light shield in the previous step.
2. Fold the two back side panels of each array along the dotted line. Coat the inside of the front array with glue and press the back panels to it. When the glue is dry, slip the solar array rod through the holes in the two tabs for each array.

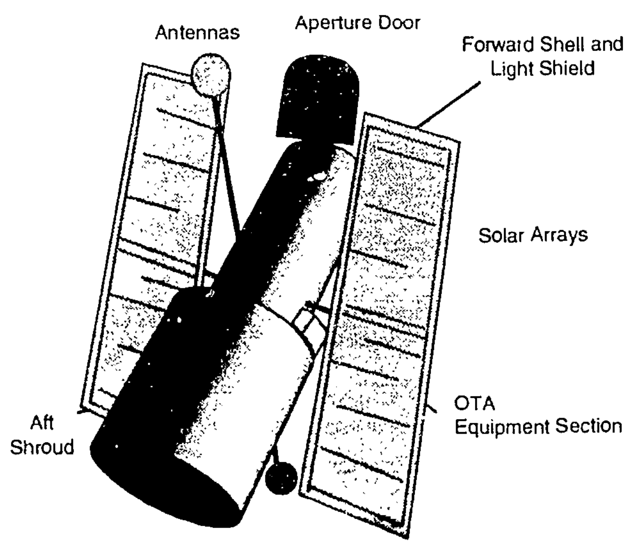
#10 Assembling the Antennas

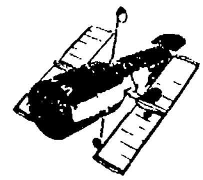
1. Cut out the antennas.
2. Glue the back side of each antenna assembly. Fold the front and back of each antenna over the ends of the antenna rod. Press the front and back together. Then, fold the reinforcing strips around the back of each antenna to help hold the pieces together.

#11 Inserting the Barrel Insert

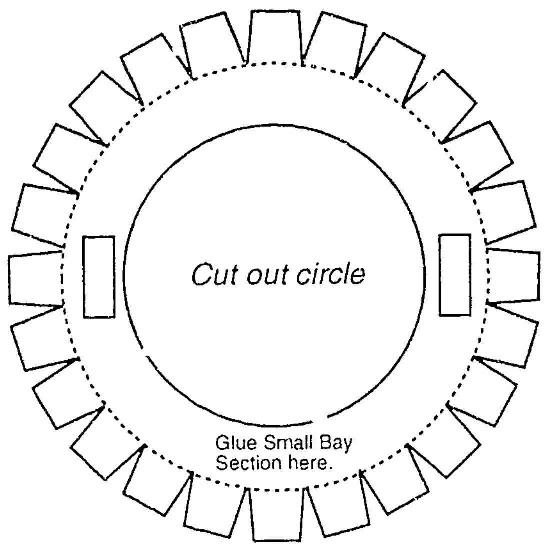
Insert the barrel insert into the forward shell and light shield so that the aperture door is opposite the seam of the cylinder.

The NASA Hubble Space Telescope Model is now complete. You can display it by suspending it from the ceiling by a piece of thread or monofilament fishing line or by creating a base for it.

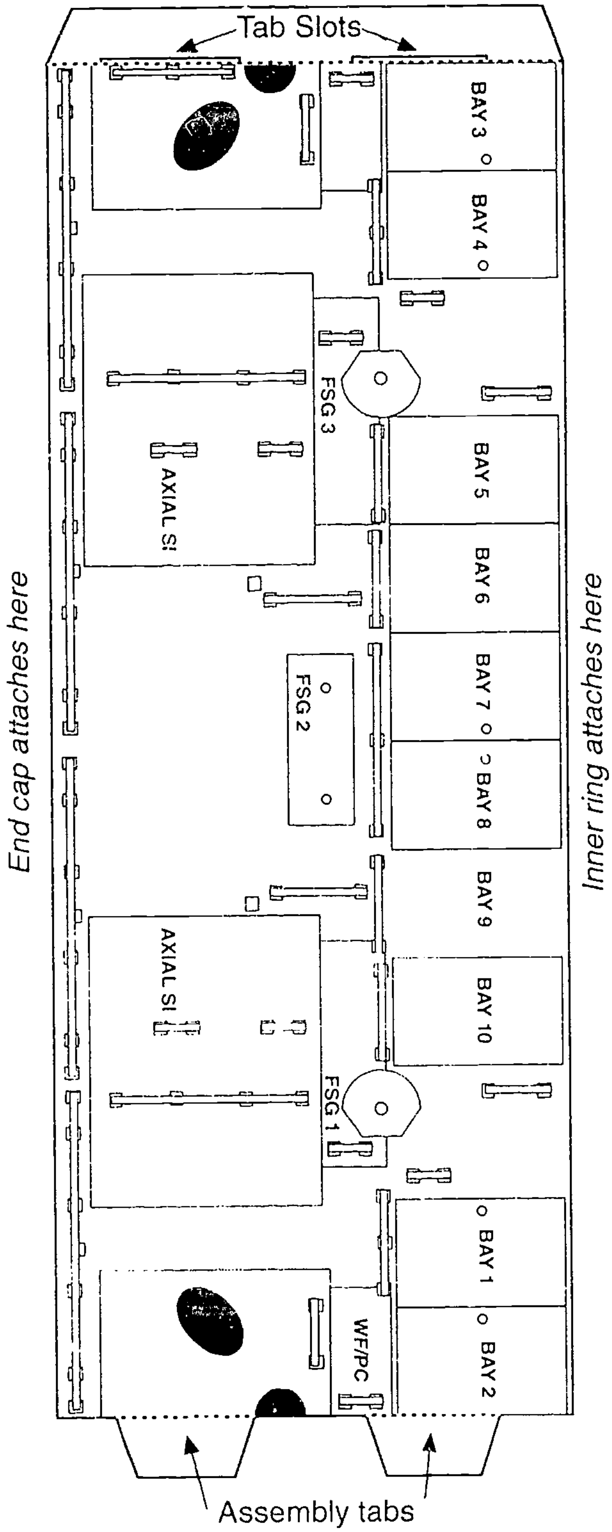




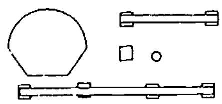
# Inner Ring



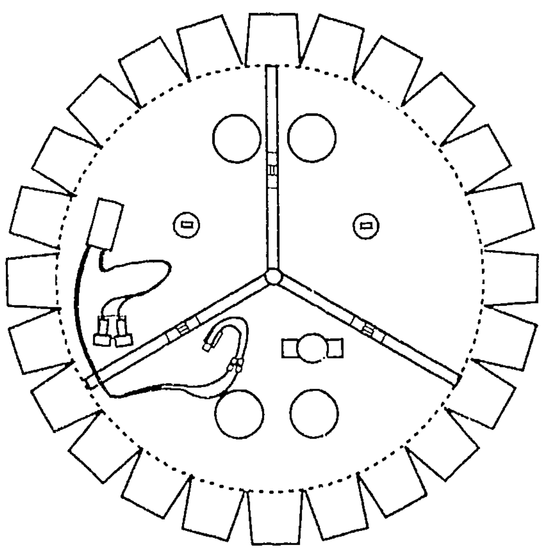

# Aft Shroud



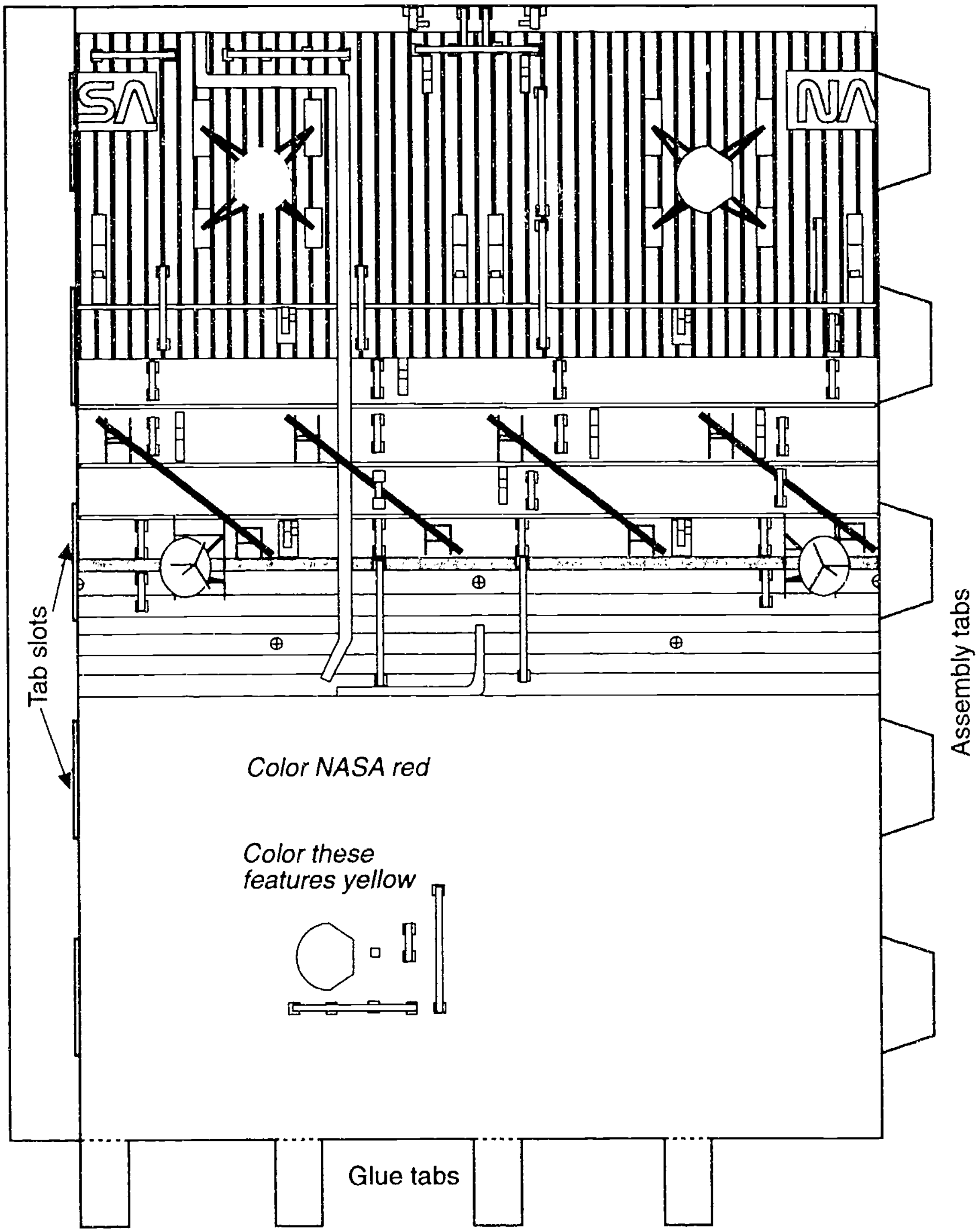

*Color these features yellow*

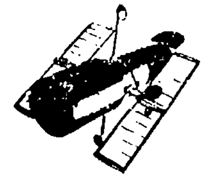


# End Cap



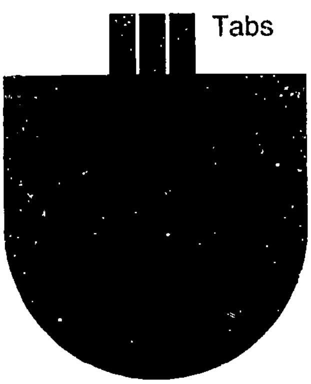
# Forward Shell and Light Shield



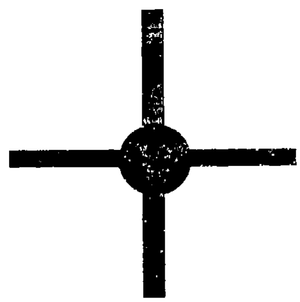


## Barrel Insert

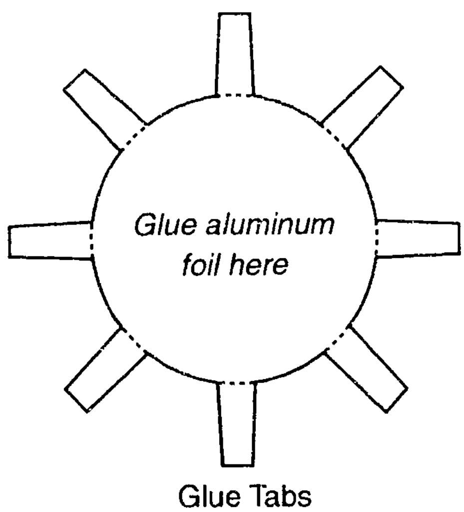

## Aperature Door



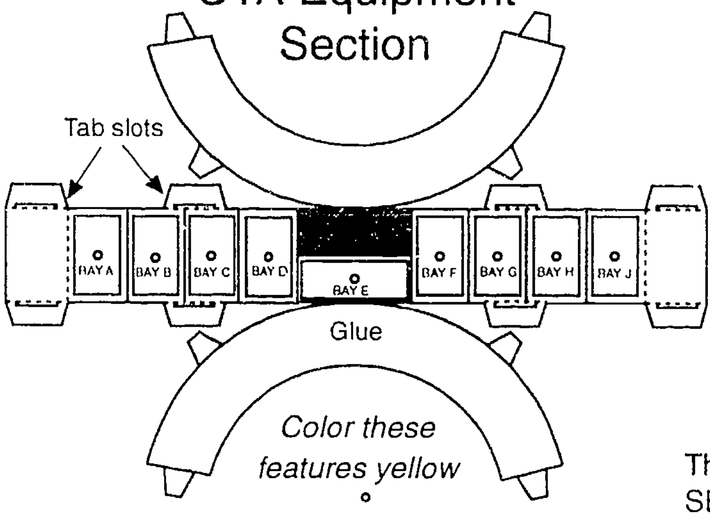

## Secondary Mirror Support

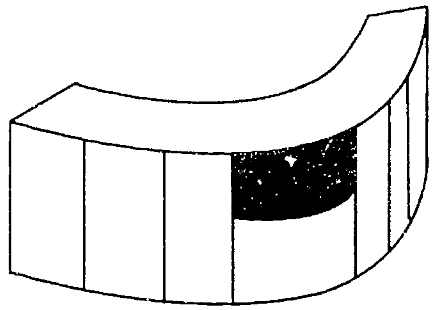


## Mirror Support



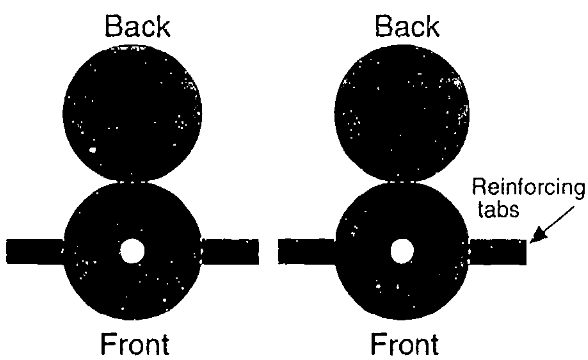
# OTA Equipment Section



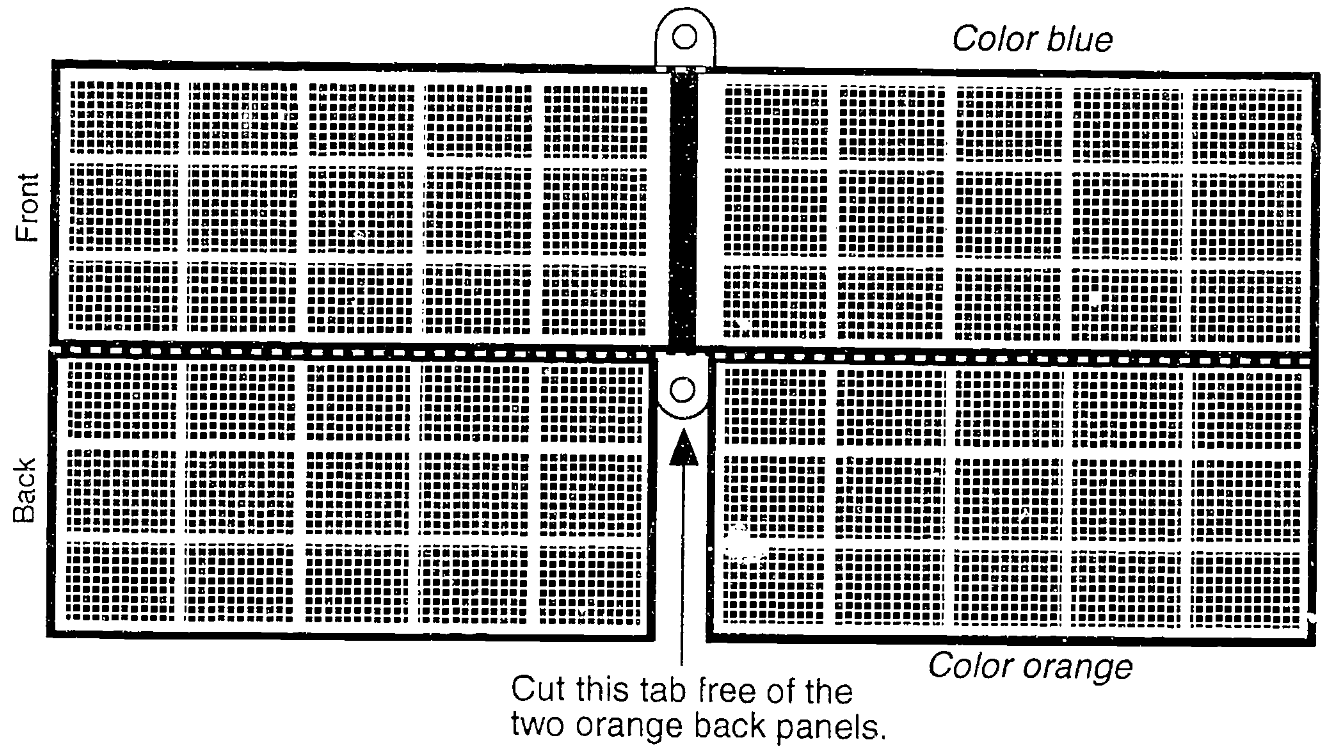



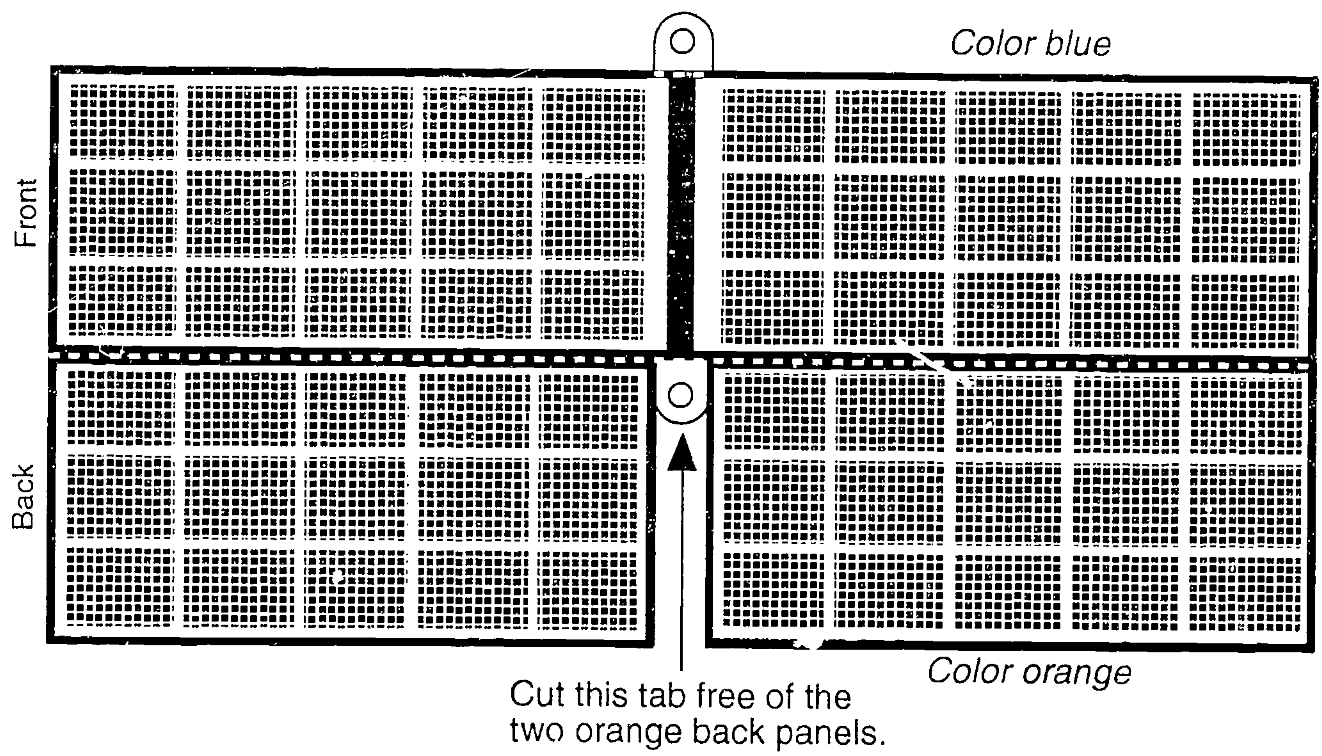
The completed OTA EQUIPMENT SECTION should look like this.

# Antennas

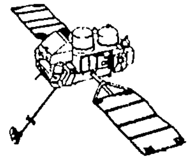


# Solar Arrays



# Compton Gamma Ray Observatory Model



*Copies of the model pattern should be printed on 60 pound weight white paper for proper assembly.*

Materials and Tools:

- Sharp paper scissors
- Razor blade knife
- Dull knife
- Straight edge
- Sharp punch (such as an ice pick)
- Glue stick or rubber cement
- Cellophane tape
- Cutting surface (such as wood board)
- Silver paint or grey, yellow, and blue marker pens
- Dowel rod (1/16 inch diameter)
- Two ping pong balls

General Assembly Tips:

- Color all pieces as indicated before cutting any parts out.
- Cut out only those pieces needed for the section being assembled at the time.
- Use a cutting surface like a wooden board to protect the table or desk from scratches or gouges.
- Cut out pieces along the solid exterior lines.
- Using the dull knife, lightly score all dashed fold lines to make accurate folds possible.
- Apply glue to the insertion tabs on the pieces and flaps where the slots are located. If using rubber cement, apply cement to both surfaces to be joined and permit them to dry before assembling. Using a double coating of rubber cement makes a stronger bond. After the pieces are assembled, lightly rub pieces to remove excess cement.
- Some pieces may require small holes to be punched through them. These places are indicated with the following symbol: ⨁.

<u>#1 Assembling the Bus</u>

1. Be sure to punch out the holes for the solar array rod out of the side of the bus (look for the two symbols⨁) and cut out the holes for the OSSE, COMPTEL, and EGRET.
2. This component is easiest to assemble by joining edge A to edge B. Follow with the assembly of the other sides.
3. Try to keep joints square at all times and smooth out any curves that might be produced.

<u>#2 Assembling the Propellant Tanks</u>

After forming this part, slip the four assembly tabs into the four slots in the bottom of the bus. The notched end of the piece should be aligned with the OSSE end of the model. The antenna rod will slide through this notch.

<u>#3 Assembling the OSSE</u>

1. Punch out the two holes indicated in the OSSE cradle. (Look for the ⨁.)
2. Begin joining each cradle by inserting tabs into the corresponding slots nearest the center folds. Work your way towards the upper end of the "U" shape.
3. Slide the cradles into their proper positions on the bus. To make this easier, bend the assembly tabs upward and gently push them into the corresponding slots. The tip of the razor blade knife can be used to assist in the insertion.
4. To provide extra strength to the model, glue the surfaces of the cradles and the propellant tanks that touch together.

<u>#4 Assembling the COMPTEL and EGRET</u>

1. After joining each cylinder, glue and insert a ping pong ball into the upper end of each. The ping pong balls should form a dome at the upper end of each cylinder.
2. Insert the EGRET cylinder into the model first. Use a short piece of cellophane tape to anchor it in place. Insert the tape through the COMPTEL hole. Next, insert the COMPTEL cylinder. Bend the assembly tabs on the bus upward and slip them into the cylinder slots as it is pushed downward. For a better looking model have the cylinder seams face each other.

<u>#5 Assembling the OSSE</u>

It is easiest to assemble this part by folding around the curved side pieces before folding in the bottom.

<u>#6 Assembling the BATSE</u>

Score the fold lines before cutting out the pieces. After making all eight BATSE pieces, glue each to the model in the places indicated in the completed model diagram.

<u>#7 Assembling the Solar Arrays</u>

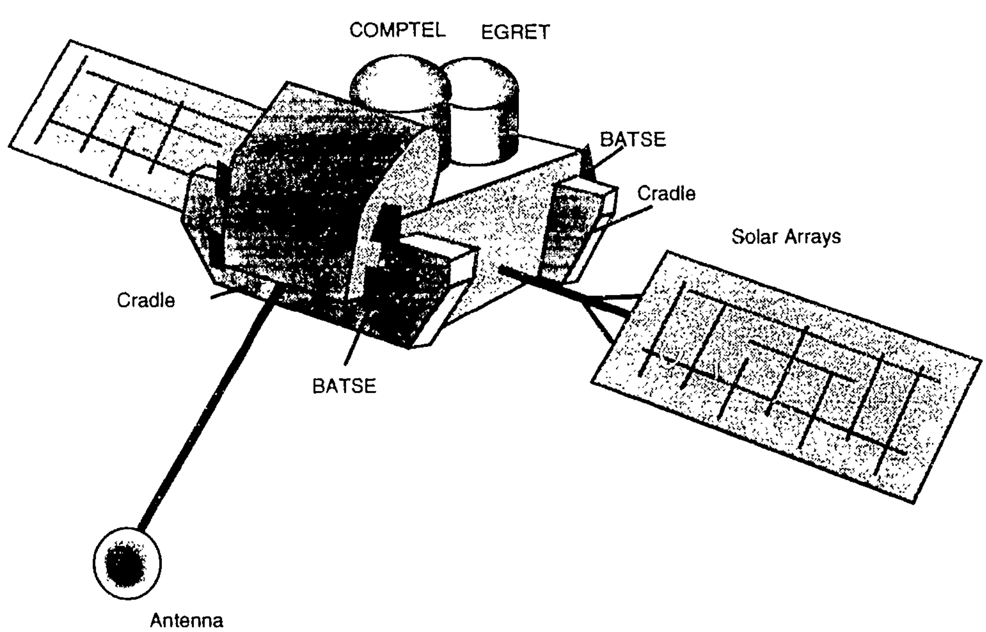
1. Be sure to punch the holes indicated in each array before cutting them out. (Look for the ⨁).

2. Coat the back side of each array with glue and fold them together along the dashed fold lines.
3. Cut one piece of dowel rod 45-cm long.
4. Slip the rod through the holes in the bus.
5. Carefully slide one array on to each end of the rod. The rod is inserted through the holes cut open in step 7-1.

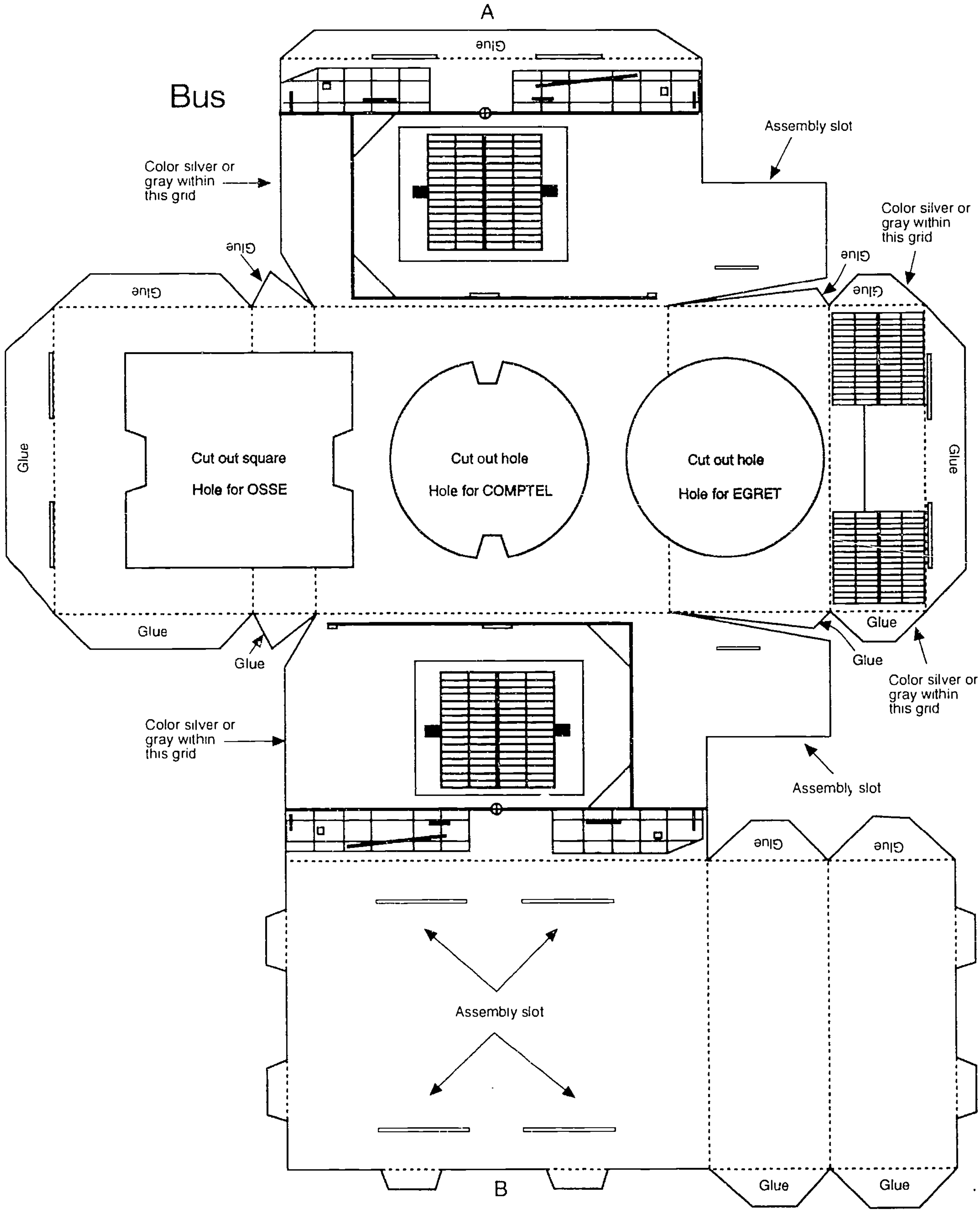
#8 Assembling the Antenna

1. Cut out both forms. Be sure to punch the holes first. (Look for the ⊕.)
2. Curl and glue the large form onto itself to form a shallow cone. Hold this piece together until the glue starts drying.
3. Coat the inside of the center of the cone and the back side of the smaller circle with glue. When dry, press the smaller circle into the center of the cone.
4. Cut a 14-cm piece from the remaining dowel rod. Slide the antenna on to one end of the rod. Slip the other end of the rod through the holes in the bottom of the cradle on the OSSE end of the spacecraft.

The NASA Compton Gamma Ray Observatory model is now complete. You can display it by suspending it from the ceiling by a piece of thread or monofilament fishing line or by creating a base for it.

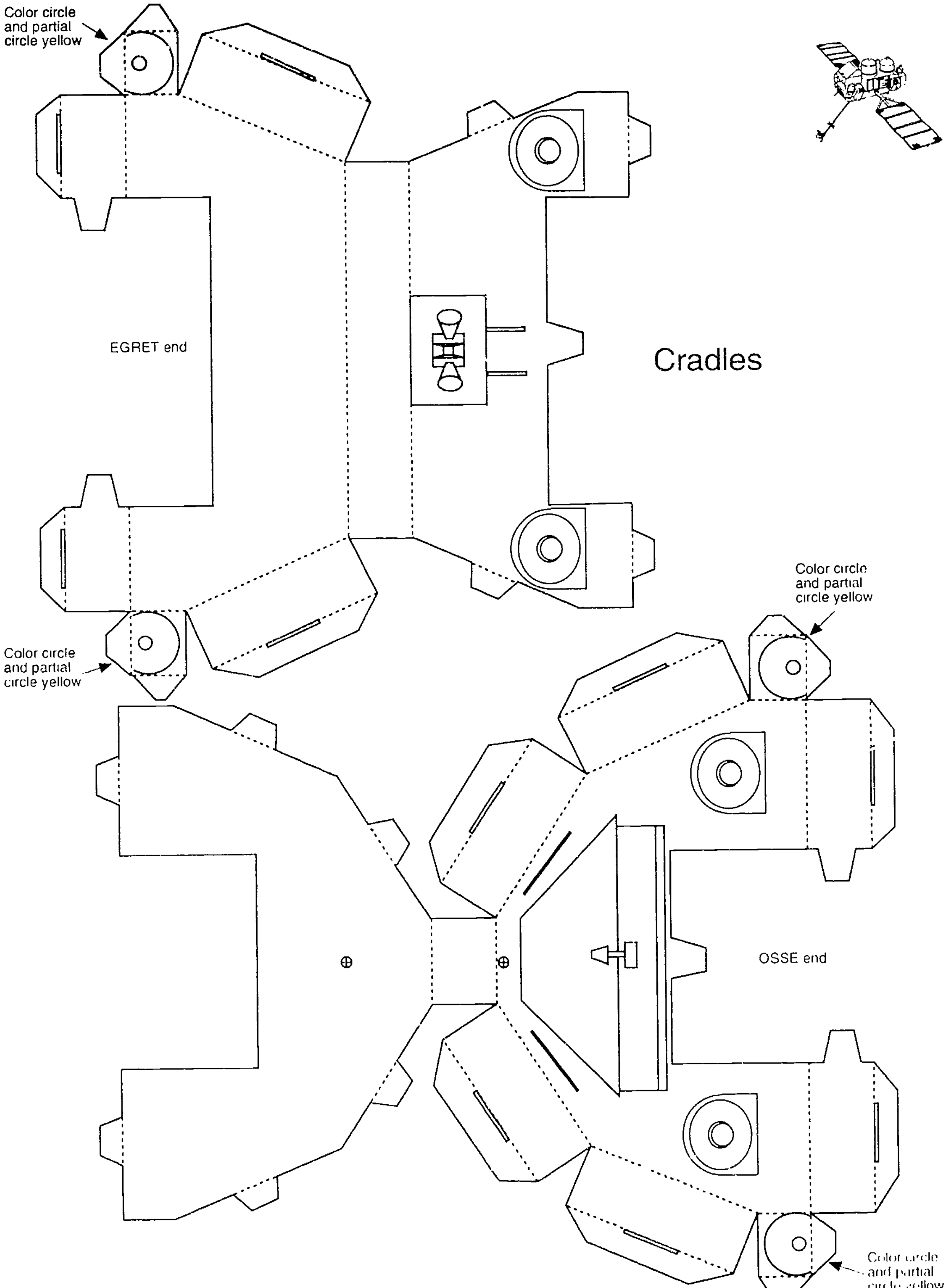


# Bus

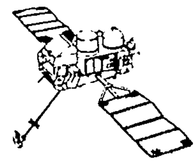


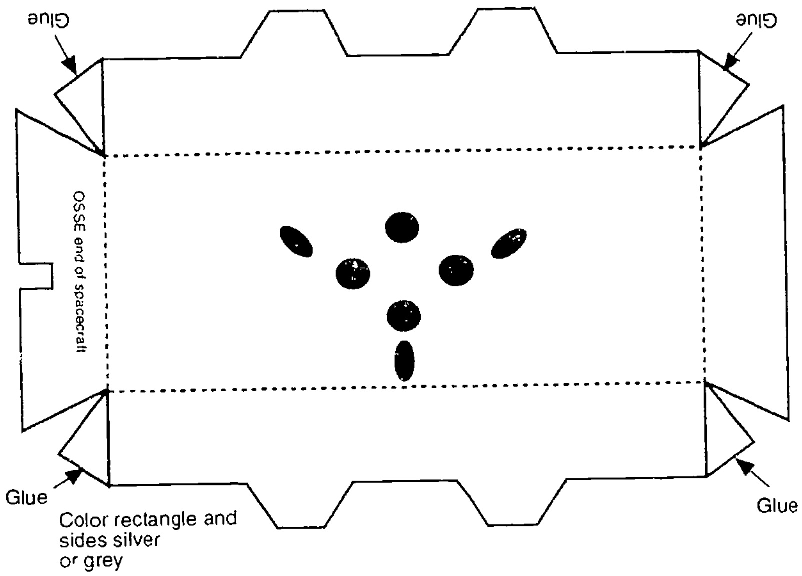
A
Glue
Assembly slot
Color silver or gray within this grid
Glue
Glue
Glue
Color silver or gray within this grid
Glue
Glue
Cut out square
Hole for OSSE
Cut out hole
Hole for COMPTEL
Cut out hole
Hole for EGRET
Glue
Glue
Glue
Glue
Glue
Color silver or gray within this grid
Color silver or gray within this grid
Assembly slot
Glue
Glue
Assembly slot
Glue
Glue
B

# Cradles



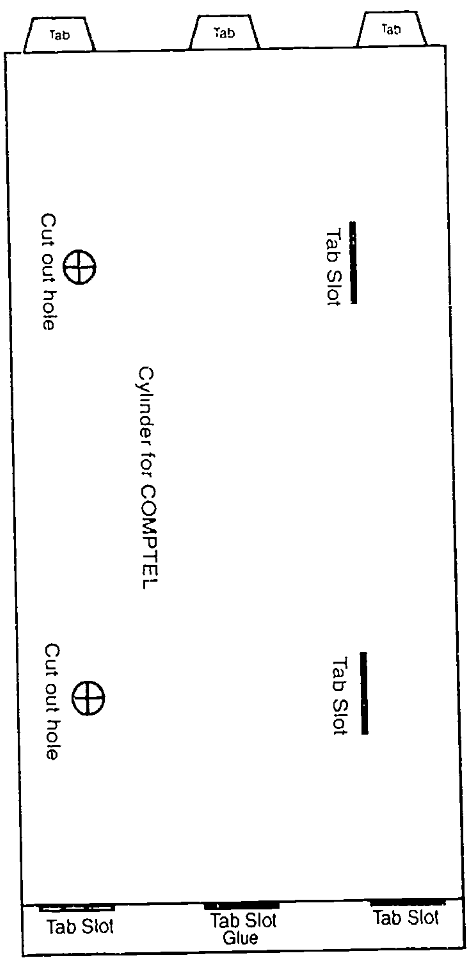
Color circle and partial circle yellow
EGRET end
Color circle and partial circle yellow
Color circle and partial circle yellow
OSSE end
Color circle and partial circle yellow



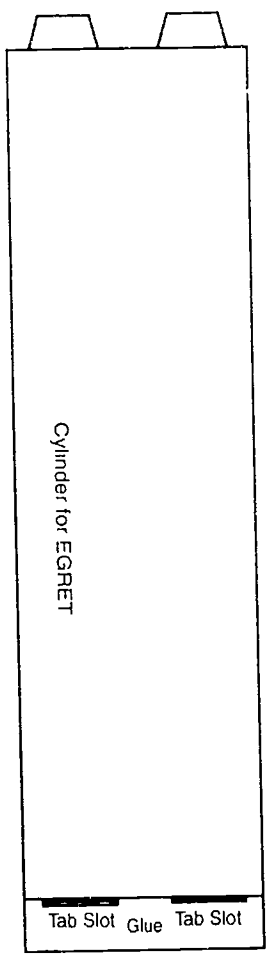



# Propellant Tanks

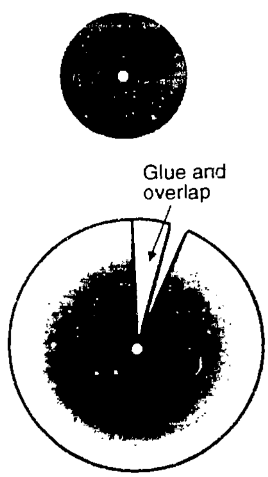
## COMPTEL

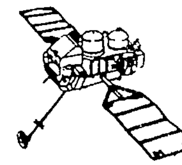



## EGRET

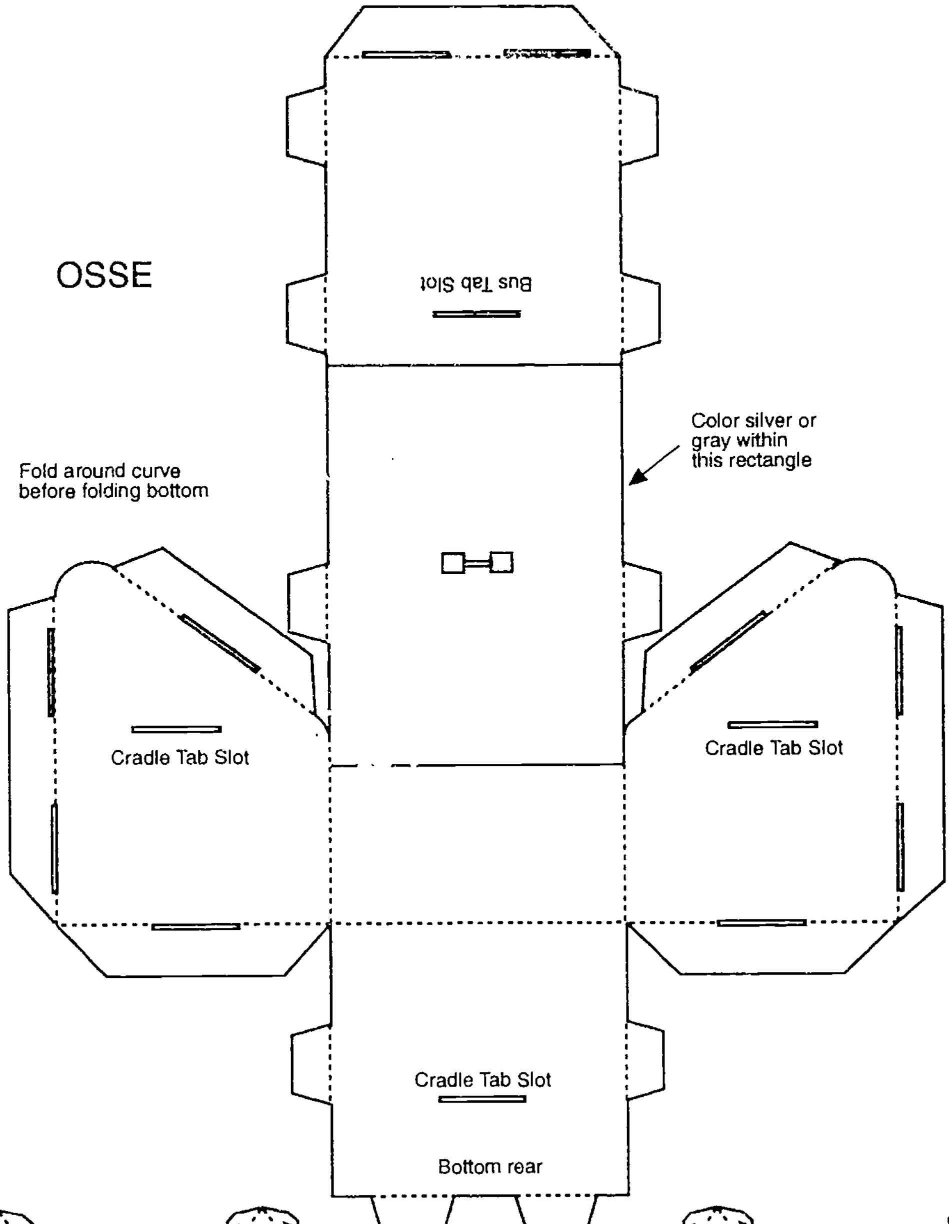



## Antenna

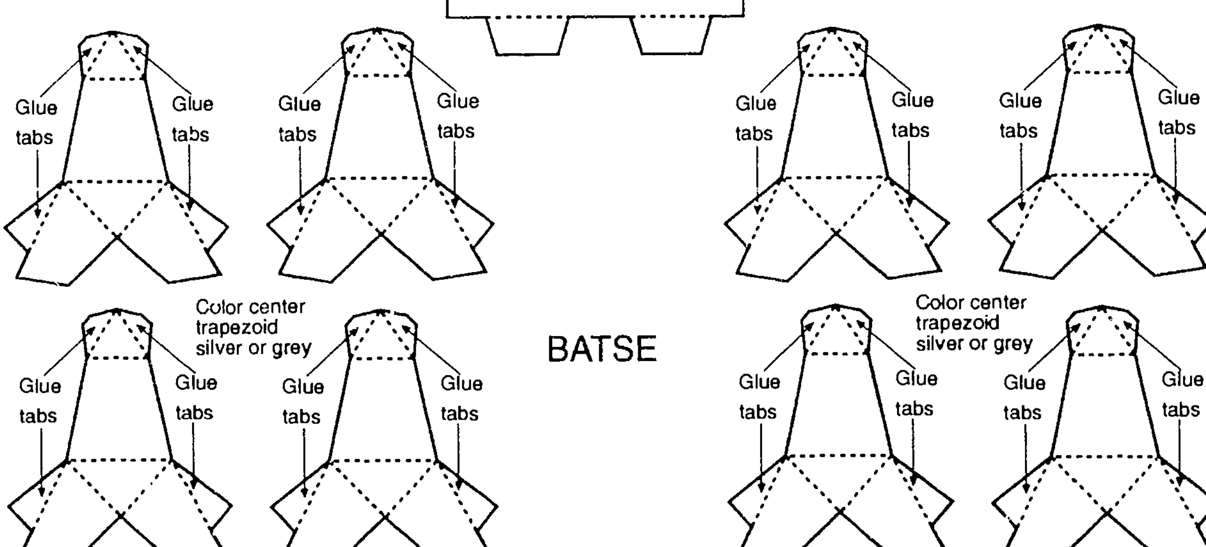




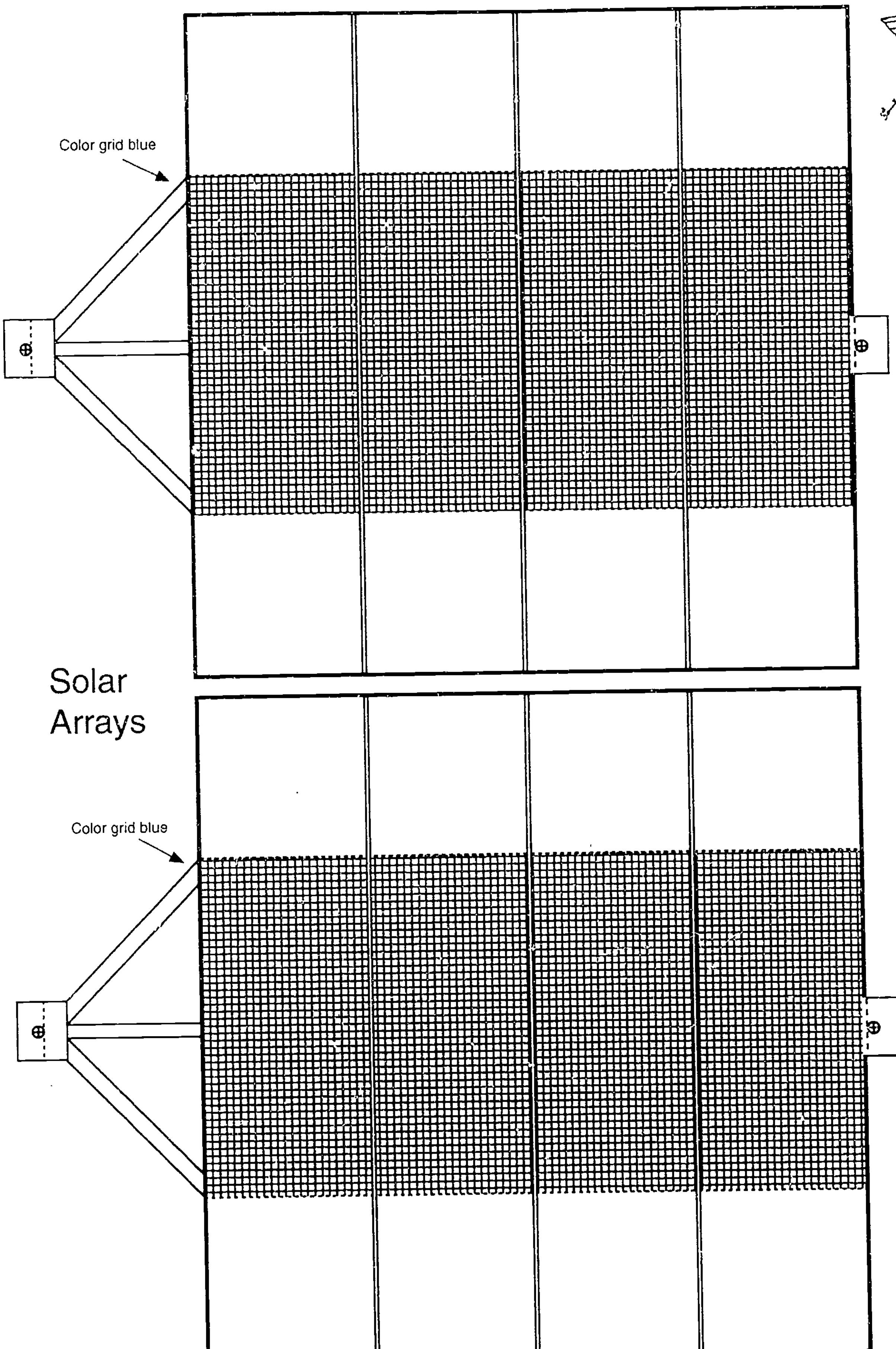
OSSE

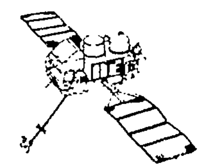

Bus Tab Slot
Color silver or gray within this rectangle
Fold around curve before folding bottom
Cradle Tab Slot
Cradle Tab Slot
Cradle Tab Slot
Bottom rear

BATSE


Glue tabs
Glue tabs
Color center trapezoid silver or grey
Color center trapezoid silver or grey

# Solar Arrays





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