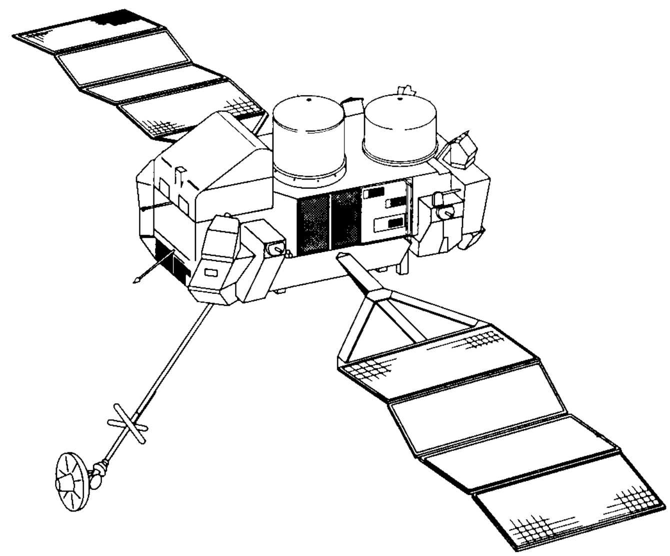
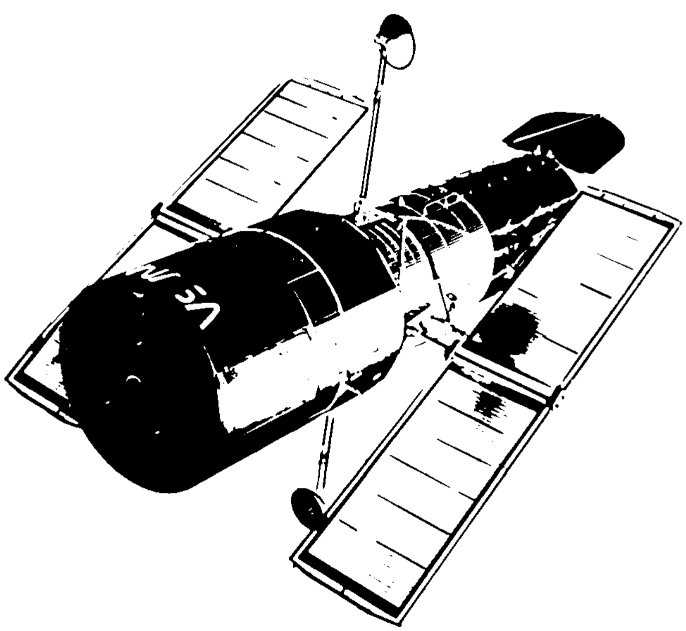
NASA's Great Observatories

Why are space observatories important? The answer concerns twinkling stars in the night sky. To reach telescopes on Earth, light from distant objects has to penetrate Earth's atmosphere. Although the sky may look clear, the gases that make up our atmosphere cause problems for astronomers. These gases absorb the majority of radiation emanating from celestial bodies so that it never reaches the astronomer's telescope. Radiation that does make it to the surface is distorted by pockets of warm and cool air, causing the twinkling effect. In spite of advanced computer enhancement, the images finally seen by astronomers are incomplete.

Observatories located in space collect data free from the distortion of Earth's atmosphere. Space observatories contain advanced, highly sensitive instruments, such as telescopes (the Hubble Space Telescope and the Chandra X-ray Observatory) and detectors (the Compton Gamma Ray Observatory and Chandra X-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 the temperature, chemical composition, and motion of an object. The light from these distant celestial bodies may take billions of years to reach the observatories, so scientists can actually look into the past and learn what was happening in the universe when it was young. The data that these observatories gather help scientists determine how stars and galaxies are formed and provide insights into the origin and evolution of the universe.





NASA, in conjunction with other countries' space agencies, commercial companies, and the international community, has built observatories such as the Hubble Space Telescope, the Compton Gamma Ray Observatory, and the Chandra X-ray Observatory to find the answers to numerous questions about the universe. With the capabilities the Space Shuttle provides, scientist now have the means for deploying these observatories from the Shuttle's cargo bay directly into orbit.

Who Are They Named for?

Each of the three spacecraft represented by models here are named for noted astronomers in the fields of optical and high-energy astronomy. The Hubble Space Telescope is named for Edwin Hubble. The Compton Gamma Ray Observatory is named for Arthur Holly Compton, and the Chandra X-ray Observatory is named for Subrahmanyan Chandrasekhar. "Chandra" was a nickname used by Chandrasekhar. Assign some students the task of researching these three astronomers and their accomplishments.

For more information about the NASA Great Observatories, visit the Office of Space Science web site at *http://spacescience.nasa.gov/missions/index.htm*

Chandra X-ray Observatory

NASA's Chandra X-ray Observatory (CXO) is the most sophisticated x-ray observatory ever built. It observes x-rays from high-energy regions of the universe, such as hot gas in the remnants of exploded stars. This observatory has three major parts: (1) the x-ray telescope, whose mirrors will focus x-rays from celestial objects; (2) science instruments, which record the x-rays so that x-ray images can be produced and analyzed; and (3) the spacecraft, which provides the environment necessary for the telescope and the instruments to work.

CXO will be boosted into an elliptical orbit by a built-in propulsion system. Two firings by an attached Inertial Upper Stage (IUS) rocket and three firings of its own onboard rocket motors after separating from the IUS will place the observatory into its working orbit. The onboard rocket motors, called the Integral Propulsion System, will also be used to move and aim the observatory. The orbit will take the spacecraft more than a third of the way to the Moon before returning to its closest approach to Earth of 10,000 kilometers. The time to complete an orbit will be 64 hours and 18 minutes.

The spacecraft will spend 85 percent of its orbit above the belts of charged particles that surround Earth. The radiation in these belts can overwhelm the observatory's sensitive instruments. Uninterrupted observations as long as 55 hours will be possible, and the overall percentage of useful observing time will be much greater than for the low-Earth orbit of a few hundred kilometers used by most satellites.

CXO's sensitivity will make it possible for more detailed studies of black holes, supernovae, and dark matter. It will also increase our understanding of the origin, evolution, and density of the universe.

Spacecraft System

The spacecraft system provides the support structure and environment necessary for the telescope and the science instruments to work as an observatory. For example, the sunshade door is one of most basic and important elements of the spacecraft system. This door remains closed until CXO has achieved pointing control in orbit. After being opened, it shadows the entrance of the telescope to allow it to point as close as 45 degrees to the Sun.

The thermal control system consists of a cooling radiator, insulators, heaters, and thermostats to control the temperatures of critical components of CXO. It is particularly important that the temperature near the x-ray mirrors be well controlled to keep the mirrors in focus. The temperature in many parts of the spacecraft is continually monitored and reported back to mission control.
The electrical power system generates electrical power from the solar arrays, stores it in three banks of batteries, and distributes it in a carefully regulated manner to the observatory. The solar arrays generate approximately 2 kilowatts of power for the heaters, science instruments, computers, transmitters, and so forth.

The communications, control, and data management system is the nerve center of the observatory. It keeps track of the position of the spacecraft in its orbit, monitors the spacecraft sensors, receives and processes commands from the ground for the operation of the observatory, and stores and processes the data from the instrument so that they can be transmitted to the ground. Typically, the data are transmitted to the ground during contacts with the NASA Deep Space Network about once every 8 hours.

The pointing control and aspect of determination system has gyros, an aspect camera, Earth and Sun sensors, and reaction wheels to monitor and control to very high accuracy where the telescope is pointing at any given moment. It is as if one could locate the bull's eye on a target 1 kilometer away to the precision of 3 millimeters—about the size of a pinhead. This system can also place the observatory into various levels of inactive, quiet states, known as "safe modes" of operation, during emergencies.

Scientific Instruments

The function of the science instruments is to record as accurately as possible the number, position, and energy of the incoming x-rays. This information can be used to make an x-ray image and study other properties of the source, such as its temperature.

The High Resolution Camera (HRC) will be one of two instruments used at the focus of CXO, where it will detect x-rays reflected from an assembly of eight mirrors. The unique capabilities of the HRC stem from the close match of its imaging capability to the focusing of the mirrors. When used with the CXO mirrors, the HRC will make images that reveal detail as small as one-half an arc second. This is equivalent to the ability to read a newspaper at a distance of 1 kilometer.

The primary components of the HRC are two Micro-Channel Plates. They each consist of a 10-centimeter-square cluster of 69 million tiny lead-oxide glass tubes that are about 10 microns in diameter (one-eighth the thickness of a human hair) and 1.2 millimeters long. The tubes have a special coating that causes electrons to be released when the tubes are struck by x-rays. These electrons are accelerated down the tube by a high voltage, releasing more electrons as they bounce off the sides of the tube. By the time they leave the end of the tube, they have created a cloud of 30 million electrons. A crossed grid of wires detects this electron signal and allows the position of the original x-ray to be determined with high precision. With this information, astronomers can create a finely detailed map of a cosmic x-ray source. The HRC will be especially useful for imaging hot matter in the remnants of exploded stars, in distant galaxies, and in clusters of galaxies and for identifying very faint sources.

The CXO CCD Imaging Spectrometer (ACIS) is the other focal plane instrument. As the name suggests, this instrument is an array of charged coupled devices (CCD's) similar to those used in a camcorder. This instrument will be especially useful because it can make x-ray images and measure the energies of incoming x-rays. It will be the instrument of choice for studying the temperature variation across x-ray sources, such as vast clouds of hot gas in intergalactic space.

In addition to the focal plane instruments, CXO will have two sets of finely ruled gratings, which can be swung into position between the mirrors and the focal plane. These gratings change the direction of incoming x-rays by amounts that depend sensitively on their energies. When used with either the HRC or ACIS, they will allow for the precise determination of the energies of the x-rays. The grating spectrometers, as they are called, will be useful for studying the detailed energy spectrum of strong sources to determine the temperature and chemical composition.

The science instruments are mounted on the Science Instrument Module, which contains mechanisms to move the science instruments in and out of the focal plane. This module also has insulation for thermal control and electronics to control the operation of the science instruments via the communication, command, and data management systems of the spacecraft.

The science instruments will be controlled by commands transmitted from the Operations Control Center at the CXO Science Center in Cambridge, Massachusetts. A preplanned sequence of observations will be uplinked to CXO and stored in the on-board computer for later execution. Data collected by observations with CXO will be stored on a recorder for later transmission to the ground every 8 hours during the regularly scheduled Deep Space Network contacts. The data will then be transmitted to the Jet Propulsion Laboratory and then to the Operations Control Center for processing and analysis by scientists.

Chandra X-ray Observatory

Materials and Tools

Sharp paper scissors
Razor blade knife
Dull knife
Straight edge
Sharp punch (such as an ice pick or nail)
Glue stick or rubber cement and white glue
Cellophane tape
Cutting surface (such as a wooden board)
Silver paint or gold and blue marker pens
Dowel rod (1/16-inch diameter)—if a 1/16-inch dowel is not available, use a piece of thin wire coat hanger
Round toothpick

General Assembly Tips

- Copy all model pieces on heavy weight paper.
- 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 such as 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 ⊕ symbol.

#1 Assembling the TELESCOPE Tube

1. Color the tube gold where indicated.
2. Punch out the holes (⊕). One hole is lined up on the seam.
3. Cut out the part, and use the razor blade to open the five slots along the left side, six slots at the wide end of the TELESCOPE, and the slot in the piece marked “1.”
4. Score the fold lines with the dull knife.
5. Curl the tube in your hands to shape it. Inset the tabs into the slots.
6. Close off the small end of the tube by folding inward piece 1, and insert the tab from piece 2 into the slot.

2# Assembling the SPACECRAFT MODULE

1. Cut out the SPACECRAFT MODULE, and score the fold lines for the module. Also cut out the assembly slots. Remember to cut the 16 assembly slots in the front end.
2. Punch out the holes (⊕).
3. Fold the module into a box shape. Use glue wherever possible to strengthen the structure.

#3 Joining the TELESCOPE and SPACECRAFT MODULE

1. Slip the narrow end the TELESCOPE through the large hole in the front end of the SPACECRAFT MODULE.
2. Align the tabs in the module with the four slots in the TELESCOPE. The holes in the module should be in a straight line with the holes in the TELESCOPE. A dowel will be inserted through both model pieces. The tip of the razor blade knife is a useful aid in slipping the tabs into the slots.

#4 Assembling the INTEGRATED SCIENCE INSTRUMENT MODULE

1. Cut out the INTEGRATED SCIENCE INSTRUMENT MODULE, open the six slots with the razor blade knife, and score the fold lines.
2. Fold the box together. The “arrowhead”-shaped ends will stick out from the completed part.
3. Cut the toothpick into two 1-centimeter-long pieces. Put a dab of white glue on each end of the pieces, and stand them up inside the “arrowhead” ends, as shown in the “ISIM COMPLETED” diagram. Set the part aside to dry.

#5 Assembling the HIGH RESOLUTION MIRROR ASSEMBLY and joining it to the TELESCOPE

1. Cut out the HIGH RESOLUTION MIRROR ASSEMBLY. Lightly fold downward the small triangles that extend to the sides of the small squares.
2. Coat the edge of the open end of the TELESCOPE with glue.
3. Push the mirror assembly onto the end of the TELESCOPE. Align the assembly so that the small black circle is at the position corresponding to 2:00 on a clock while the seam of the TELESCOPE is at the position corresponding to 6:00 on a clock.
4. Set the piece aside to dry. Check it occasionally to make sure the pieces are together.

#6 Assembling the SUNSHADE DOOR and joining it to the HIGH RESOLUTION MIRROR ASSEMBLY

1. Cut out the SUNSHADE DOOR, and glue the back sides together.
2. Fold the door where indicated.
3. When this piece is dry, glue it to the HIGH RESOLUTION MIRROR ASSEMBLY at the position corresponding to 12:00 on a clock.

#7 Assembling the SPACECRAFT MODULE EXTENSIONS and joining them to the SPACECRAFT MODULE

1. Cut out the two SPACECRAFT MODULE EXTENSIONS, open the slots with the razor blade knife, and score the fold lines.
2. Fold the pieces together.
3. Insert the lower two assembly tabs into the SPACECRAFT MODULE. Insert the third tab into the slot in the TELESCOPE.

#8 Assembling and joining the SMALL THRUSTERS to the SPACECRAFT MODULE

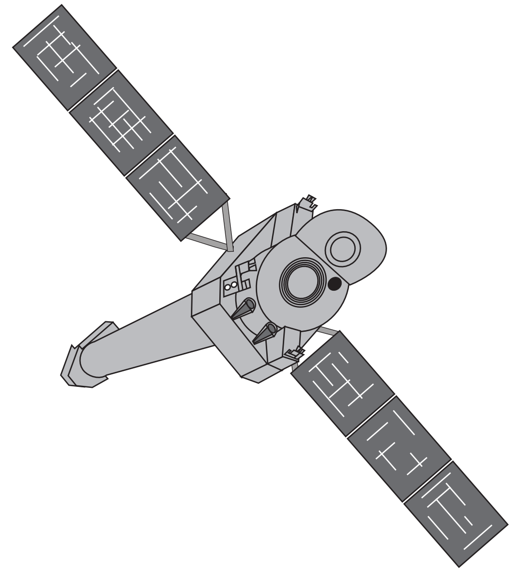
1. Cut out the smallest SMALL THRUSTERS, and fold them where indicated.
2. Insert the thrusters into the SPACECRAFT MODULE EXTENSIONS.
3. Cut out the larger thrusters, and fold them where indicated.
4. Insert these thrusters into the SPACECRAFT MODULE at the positions corresponding to 2:30 and 7:30 on a clock.

#9 Assembling and joining the LARGE THRUSTERS to the SPACECRAFT MODULE

1. Cut out the four LARGE THRUSTERS.
2. Curl the paper, and insert the tab into the slot. Fold the upper end down, and insert the tab into the slot. When completed, the LARGE THRUSTER should look like the diagram.
3. Insert the remaining two tabs of each thruster into the remaining slots of the SPACECRAFT MODULE.

#10 Assembling the SOLAR ARRAYS

1. Color the SOLAR ARRAYS blue and gold where indicated.
2. Cut out and score the two arrays for folding.



3. Fold over, and glue the back to the front. There will be a white gap running lengthwise on the back of each array.
4. Cut a 38-centimeter-long piece of the dowel.
5. Insert the dowel through the holes in the SPACECRAFT MODULE.
6. With the dowel centered, glue the SOLAR ARRAYS to the dowel. Glue them along the white gap on the array back sides. The arrays should face the same direction.

#11 Making the LOW GAIN ANTENNA

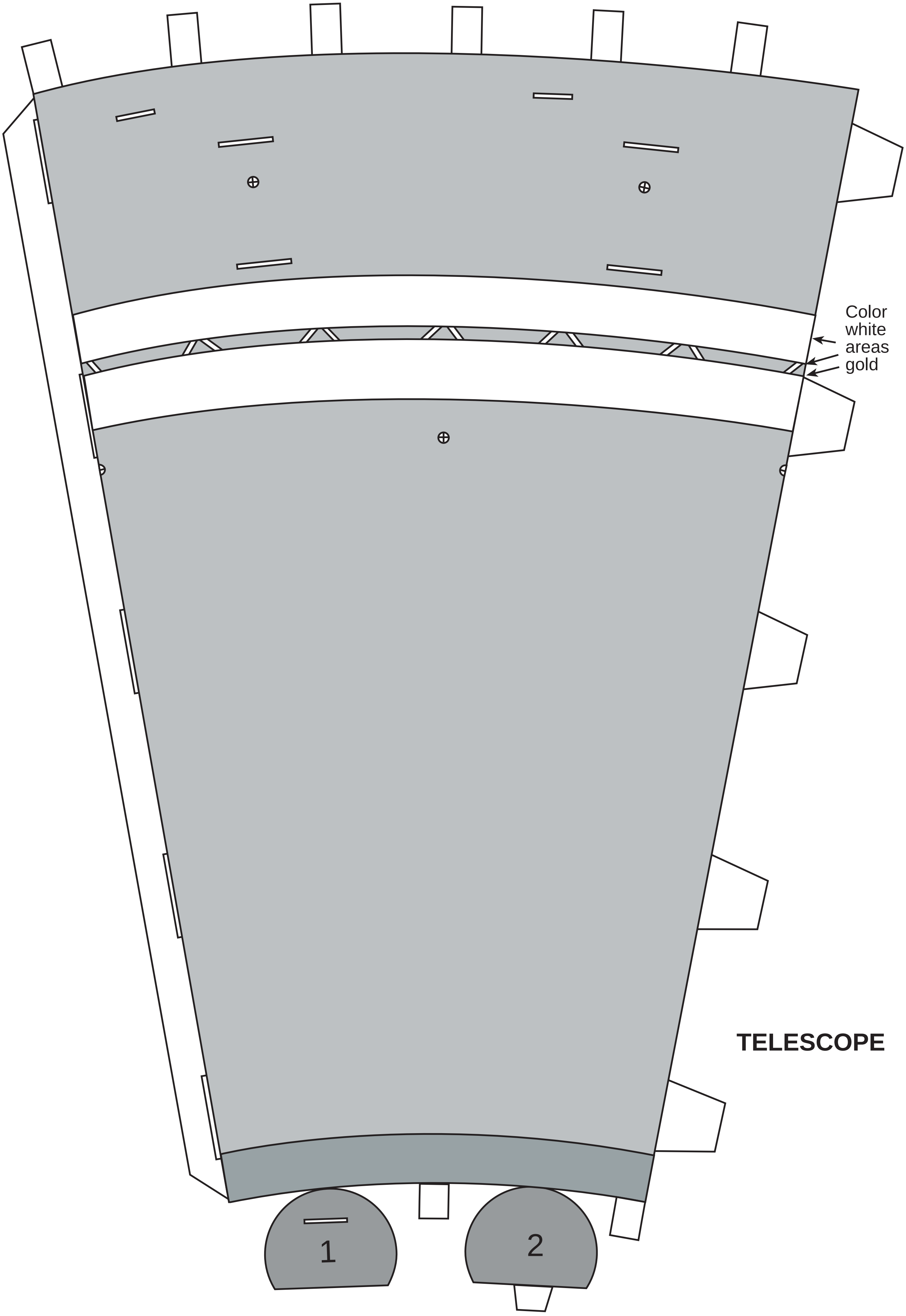
1. Cut an 8-centimeter piece of the dowel. Using the razor blade knife, sharpen each end to a point.
2. Insert the dowel through the remaining holes of the TELESCOPE.

#12 Completing CXO

1. Join the INTEGRATED SCIENCE INSTRUMENT MODULE to the small end of the TELESCOPE by inserting the two tabs from the TELESCOPE into the slots of the module.
2. Add some glue here to hold the module securely.

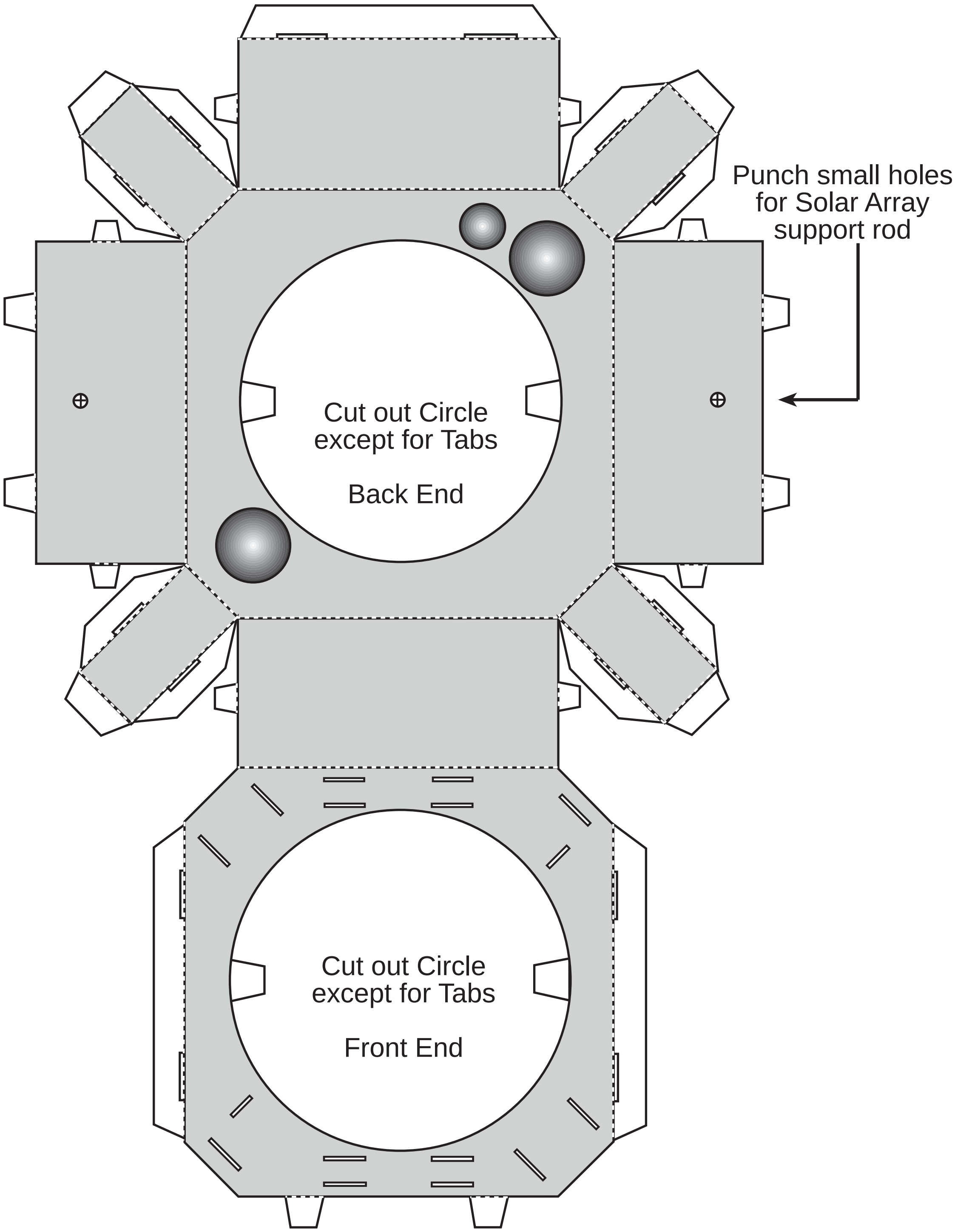
The NASA Chandra X-ray Observatory model is now complete. You can display it by suspending it from the ceiling by a piece of thread or monofilament fishing line or by creating a base for it.

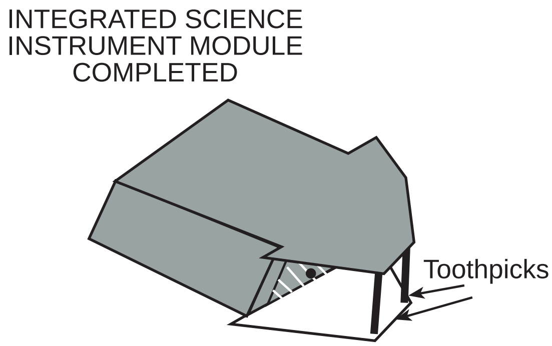
Model Builder Note: NASA is planning a fourth great observatory to study infrared wavelengths. When the Space Infrared Telescope Facility (SIRTF) is near launch, a model of this spacecraft will be added to the set.



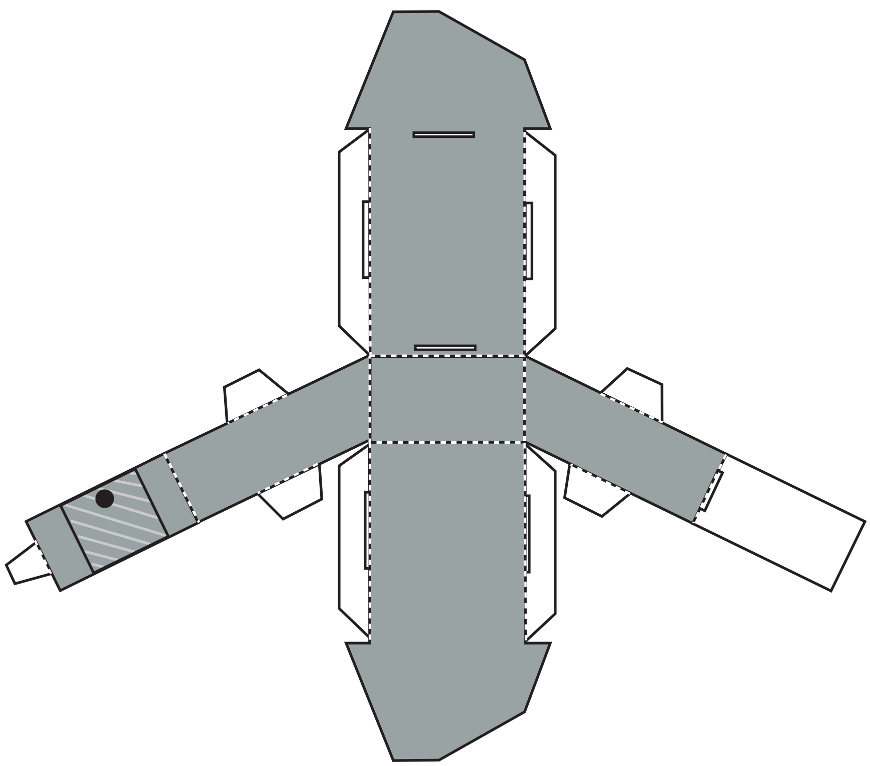
TELESCOPE

SPACECRAFT MODULE

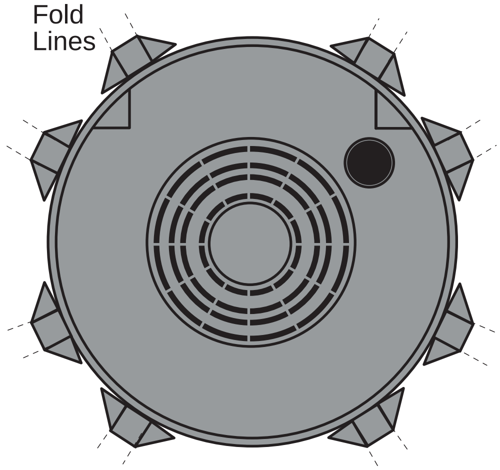




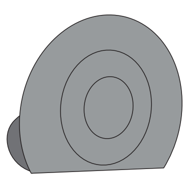
INTEGRATED SCIENCE INSTRUMENT MODULE

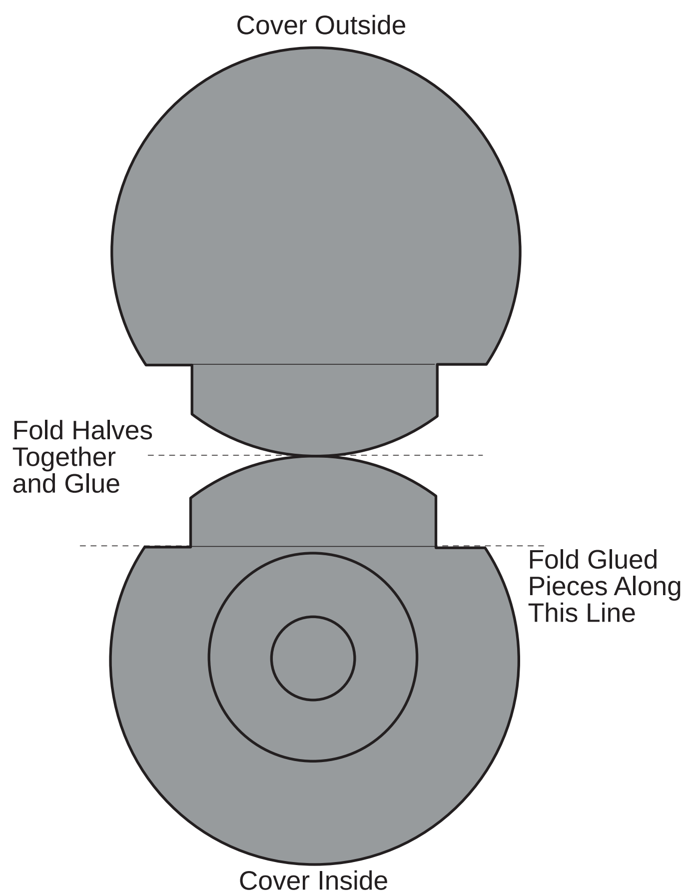


HIGH RESOLUTION MIRROR ASSEMBLY

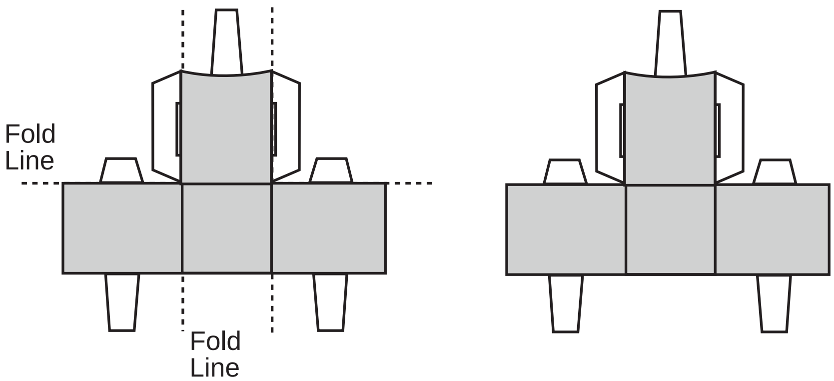


SUNSHADE DOOR

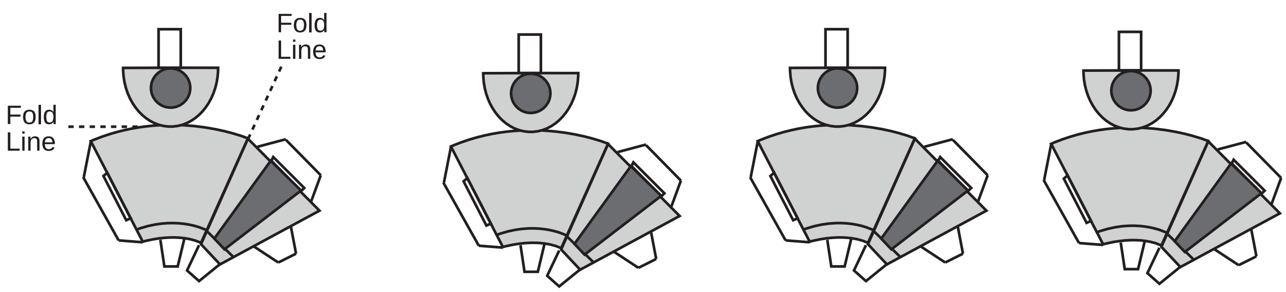

Sunshade Door looks like this when finished



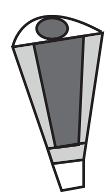
SPACECRAFT MODULE EXTENSIONS



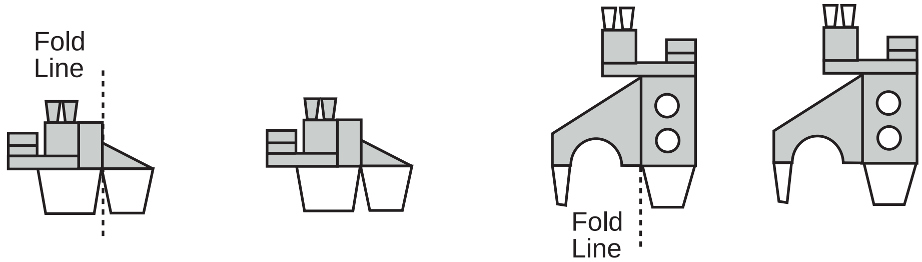
LARGE THRUSTERS



LARGE THRUSTER COMPLETE



SMALL THRUSTERS



SOLAR ARRAYS