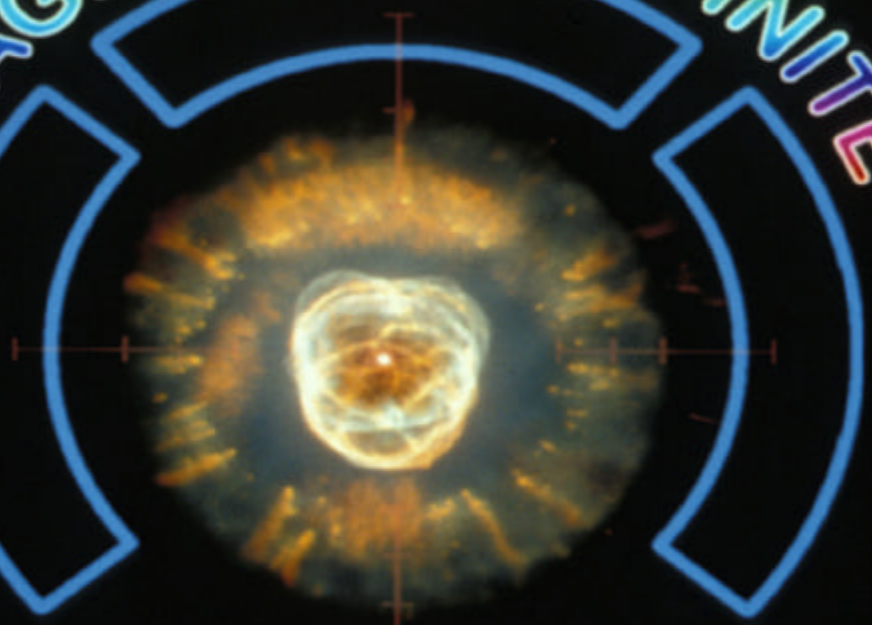
DETROIT THE NEW Science CENTER

DASSAULT SYSTEMES

PLANETARIUM

IMAGES of the INFINITE



HUBBLE

Teacher's Resource Kit

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Hubble: Images of the Infinite

Teacher's Resource Kit

Thank you for scheduling a field trip to the New Detroit Science Center and its newest facility, the Dassault Systèmes Planetarium. The Planetarium is a 50-foot wide tilted theater with 115 seats, room for 6 wheelchairs, and assisted listening devices for the hearing-impaired. Using advanced projection equipment, the Planetarium can create virtually any environment. You can be seated in the interior of a spacecraft, witness the birth of a star, stargaze at the night sky over Southeastern Michigan, or travel faster than light among the stars of the Milky Way galaxy.

About the Show

Hubble: Images of the Infinite will take you on a virtual journey, visiting planets, probing into large clouds of gas and dust in space called nebulae (nebula in singular), exploring the life and death of stars, and investigating galaxies using the Hubble Space Telescope. This show also introduces you to Edwin Hubble and his breakthrough discoveries about the nature of the universe.

This show is appropriate for

Grade Level(s): **6 - 12**
Program Length: **45 minutes**

Shuttle Astronauts service the Hubble Space Telescope from Earth orbit

Michigan Content Standards & Benchmarks

More information can be found at the Michigan Department of Education website at:
http://cdp.mde.state.mi.us/MCF/ContentStandards/default.html

The Detroit Science Center and the Dassault Systèmes Planetarium are dedicated to assisting all educators in building and utilizing curricula based on the above-mention standards and benchmarks. Each of our shows for school groups keeps you and your students needs in mind For Hubble: Images of the Infinite, the Standards & Benchmarks addressed include:

Middle School

Constructing New Scientific Knowledge I, 1
Reflecting on Scientific Knowledge II 1-1&3
Solar System, Galaxy & Universe V. 4-1,2,3,5,6

High School

Constructing New Scientific Knowledge I, 1,2,3
Reflecting on Scientific Knowledge II 1-2,3
Solar System, Galaxy & Universe V. 4-1,2,3,5,6

We welcome any suggestions, comments, or tips on the activities and resources in this kit, so we can improve these resources for you and your students in the Southeastern Michigan community! Thanks again for choosing the Detroit Science Center and the Dassault Systèmes Planetarium! Contact us @

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Program Objectives:
Upon completion of this program, students will be able to:

1. Identify the different types of objects visible in the night sky;
2. Explain how the development of the telescope and related technologies has increased our understanding of the universe and its evolution.
3. Discuss the breakthrough discoveries of Dr. Hubble and how this new knowledge changed our understanding of our place in the universe
4. Identify the structure of a galaxy and clusters of galaxies;
5. Understand the spatial relationships between our Solar System and other objects in the Universe,
6. Understand the limits of our knowledge of the universe.

Pre-visit Activities
Hubble-Images of the Infinite - Focus on Astronomy Questions
Questions for you and your students to ponder before your visit…

Q: What is a telescope?

A: This might sound like a simple question. There are, however, many ways this question can be answered. It would be easy to say that a telescope is a device that is used to look at the stars. While this is true, it is only part of the definition.
A typical telescope is made up of either one or two lenses (or mirrors), which collect visible light. The light is then magnified by an eyepiece for enhanced viewing. Most people believe that a telescope provides enhanced viewing of stars and other distant objects because it magnifies those objects. As you will see later in the tutorial, magnification plays a small role in the quality of a telescope.

A bucket provides a good analogy to a telescope. A bucket can hold much more water than your hand. It is therefore more efficient for collecting water. A telescope gathers light. Since it is much larger in diameter than your eye, it can gather more light. The light is then focused down to a smaller point where it can be viewed. The focused image can then be magnified for enhanced viewing by an eyepiece.

Q: How does a telescope permit astronomers to explore of the universe us?

A: The telescope was one of the most important inventions of the Seventeenth century. While lenses that could change the magnification of objects were known in the Western world at the end of the thirteenth century, it was not until 1608 that the first telescope was officially used. Both Hans Lipperhey and Jacob Metius were recognized in the Netherlands for creating the first low power telescopes. The instruments were largely proclaimed to be of use in spotting one's enemy on the battlefield but others soon found new uses for the device.
Galileo Galilei made the telescope famous for astronomical observations in 1609. His observations were more detailed than any ever made. He was the first to provide drawings of the moons of Jupiter and document the phases of Venus. Since the time of Galileo, the craft of telescope making has been continually refined By gathering large amounts of light and squeezing the light to fit into an astronomer's eye, the telescope permits us to see more of the universe that possible with just our two eyes.

Q. What is the Hubble Space Telescope?

The Hubble Space Telescope is a space-based telescope that was launched in 1990 from the space shuttle Discovery. From its position 380 miles above the Earth's surface, Hubble has expanded our understanding of the universe — and of star birth, star death, galaxy evolution, and black holes in particular.
The telescope's science instruments are the astronomer's eyes to the universe. They have included the Wide Field and Planetary Camera 2, Space Telescope Imaging Spectrograph, Near Infrared Camera and Multi-Object Spectrometer, and the Advanced Camera for Surveys.
When first launched, Hubble's lens was out of shape on the edges by 1/50th the diameter of a human hair. This very small defect made it difficult to focus faint objects being viewed by Hubble. Because the telescope is in low Earth orbit, it can be serviced by a space shuttle; thus, the defect was corrected during the first on-orbit servicing mission. The Hubble Space Telescope is scheduled for one more servicing mission before its planned retrieval in 2010. You may one day be able to visit the telescope at the National Air and Space Museum.

Q. Why is the Hubble Space Telescope ale to see better than earth-based telescope observatories??

A. Larger earthbound telescopes can see as far as Hubble can. All telescopes are essentially "time machines." Probing the secrets of "deep" space means looking farther back in time. That's because light from faraway galaxies takes millions to billions of years to reach Earth, providing astronomers with a record of how those objects appeared long ago.

But the "eye" in space has sharper vision because of its super location. At 368 miles above our planet, the orbiting observatory is outside Earth's turbulent blanket of air that makes star images wiggle.

Hubble can snap those sharper images while moving. Unlike terrestrial observatories, which are perched on mountaintops, Hubble doesn't stay put. It whirls around Earth every 90 minutes at 17,000 mph (27,200 kph). The telescope has no rocket motor: it is in orbit around Earth and runs on sunlight. Hubble also does what it's told. Earthbound computers send detailed instructions, telling it where to point and which cameras to use.

Other orbiting observatories have probed the secrets of space, but Hubble is the largest and most versatile. Its visible-light camera — called the Wide Field and Planetary Camera 2 — has consistently delivered stunning images of celestial objects, including the pillars of dust and gas that harbor nascent stars and the colorful death shrouds of aging, Sun-like stars.

Q. Who was responsible for dreaming up the idea for a Space Telescope?

A. It takes powerful telescopes to study the uncharted territories of the vast cosmos. But it became clear to astronomers that Earth's air distorted starlight, which made it difficult to obtain razor-sharp views of celestial objects. The idea of placing a telescope in space, above Earth's turbulent air, had been kicked around for several years. But scientists pondered how to transport a telescope into space. The rocket technology pioneered by Oberth, Von Braun, and Goddard and revolutionized by the Germans during World War II became the means of transportation.

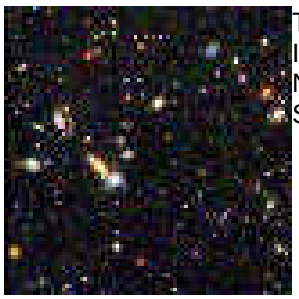
DREAM BECOMES REALITY After scientists figured out the means, they focused on coming up with the money to develop and build a space telescope. The newly established NASA (created in 1958) and well-known American astronomers such as Lyman Spitzer (see picture) began championing the cause, trying to convince Congress that such a project was useful. In 1977 Congress finally agreed to allocate the money. But it took a decade of research, planning, and testing before NASA successfully launched its first space observatory. And two more decades passed before NASA launched the Hubble telescope, which has expanded our heavenly vistas far more than its namesake ever dreamed.

Q. Who was Edwin Hubble, and what contributions did he make towards our understanding of the Universe?

A. In the 1920s, famed astronomer Edwin Hubble was discovering the vastness of the cosmos through the lens of his Earth-bound telescope.

Hubble majored in science as an undergraduate at the University of Chicago. A tall, powerfully built young man, he excelled at basketball and boxing (fight promoters reportedly tried to talk him into turning pro), and his combination of academic and athletic prowess earned him a Rhodes scholarship to Oxford. In England, Hubble kept up his muscular pursuits: he fought, ran track and played on one of the first baseball teams ever organized in the British Isles. His official academic focus shifted, thanks to a promise made to his dying father that he would study law rather than science (he also took up literature and Spanish). On his return to America, he took a position as a high school Spanish teacher. Though he was popular with students--Hubble longed to return to science.

After a year, he signed on as a graduate student at Yerkes Observatory in Wisconsin and embarked on the work that would one day make him famous: studying faint, hazy blobs of light called nebulae (from the Latin word for cloud) that are visible through even a modest telescope. Hubble's skills as an astronomer were impressive enough to earn him an offer from the prestigious Mount Wilson Observatory. World War I kept him from accepting right away, but in 1919 the newly discharged Major Hubble--as he invariably introduced himself--arrived at observatory headquarters, still in uniform but ready to start observing with the just completed 100-in. Hooker Telescope, the most powerful on earth.



The Hubble Deep Field Image-Courtesy NASA/Space Telescope Science Institute /AURU

During the past 100 years, astronomers have discovered quasars, pulsars, black holes and planets orbiting distant suns. But all these finds pale next to the discoveries Edwin Hubble made in a few remarkable years in the 1920s. At the time, most of his colleagues believed the Milky Way galaxy, a swirling collection of stars a few hundred thousand light-years across, made up the entire cosmos. But peering deep into space from the chilly summit of Mount Wilson, in Southern California, Hubble realized that the Milky Way is just one of millions of galaxies that dot an incomparably larger setting.

Hubble went on to trump even that achievement by showing that this galaxy-studded cosmos is expanding--inflating majestically like an unimaginably gigantic balloon--a finding that prompted Albert Einstein to acknowledge and retract what he called "the greatest blunder of my life." Hubble did nothing less, in short, than invent the idea of the universe and then provide the first evidence for the Big Bang theory, which describes the birth and evolution of the universe. He discovered the cosmos, and in doing so founded the science of cosmology.

Q. Why service the Hubble Space Telescope?

A. NASA decided early in the telescope's development to design the observatory for on-orbit servicing. Instruments were designed as modular units, comparable to dresser drawers that could be easily removed and replaced. In addition, designers equipped the telescope with handholds and other special features to make servicing tasks less difficult for astronauts wearing bulky spacesuits.

By periodically upgrading the science instruments, NASA also reasoned that it could provide the science community worldwide with state-of-the-art technology that takes advantage of Hubble's unique position high above Earth's obscuring atmosphere.

Q. What instruments and equipment did the astronauts add to the Hubble Space Telescope during Servicing Mission 3B?

The 2002 mission was aimed at improving Hubble's science capabilities and ensuring the continued effective operation of the telescope. Adding the Advanced Camera for Surveys (ACS) and restoring the use of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) by adding a cryocooler achieved the objective of improving the science capabilities of the telescope.

Q. What is the Advanced Camera for Surveys, and what will it do?

The Advanced Camera for Surveys (ACS) is a third-generation instrument that was installed on the Hubble Space Telescope during Servicing Mission 3B. By design, the three cameras of the ACS will advance Hubble's capability for surveys and discovery by about a factor of ten.

Its Wide Field Camera will make deep imaging surveys to search for galaxies and clusters of galaxies in the early universe. The High Resolution Camera will study the light in the centers of galaxies with massive black holes, as well as ordinary galaxies, star clusters, and gaseous nebulae. Finally, the Solar-Blind Camera will be used to find hot stars and quasars to study aurorae on Jupiter and investigate the formation of planetary systems.

Post - Visit Activities
How to Use a Star Map!

Just as people make and use maps to find their way around a town, city, state or country, astronomers use maps to find their way across the starry skies. Simple maps are available for no charge over the Internet. Teaching yourself and your students how to find objects in the night sky by using the enclosed star map is a skill that can last a lifetime.

You can get a map for the skies over Southeastern Michigan by going to… .

Heavens Above www.heavens-above.com.

On the main web page register as a user for free, and the web site will help you choose the right location. Once this is done, you will be directed to your home page. Now look down to the fourth section, listed as Astronomy. Click on Whole sky chart **Once there, be sure to check the bottom of the page and select a current date and time during the evening hours. Be sure to select the Black and White version, so it will be easy to print. Now all you need is your trusty star map, a flashlight with fresh batteries and a clear sky.**

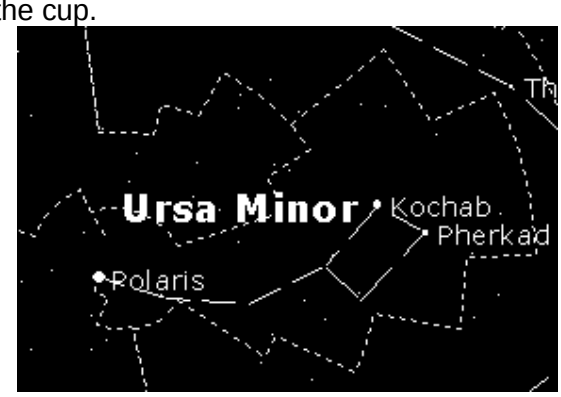
Start by folding your sky map in half, with the map on the outside of the fold. Make sure the fold is from East to Eest. Hold the map with North at the bottom of the page. The stars and constellations on the page will match up with your view of the night sky. Start by looking for the best known of all the star pictures – the Big Dipper. Look for four bright stars that make up the cup, and the three stars attached to the back of the bowl forming the curved handle.

Please note that the Big Dipper is not a constellation. It is a popular star grouping, but it belongs to the constellation of Ursa Major, Latin for Great Bear.

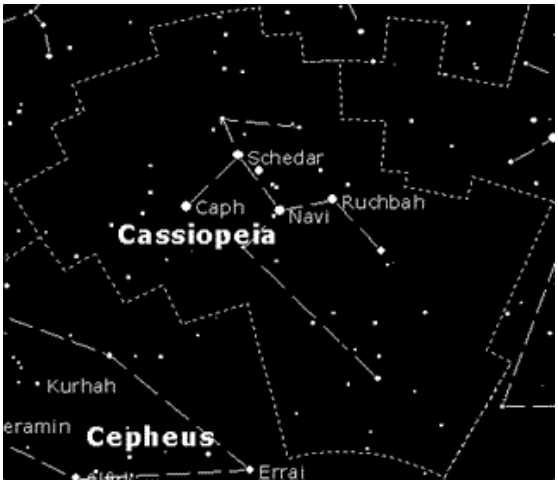
After you find the Big Dipper's bowl, look for the two stars at the end of the bowl. These are known as the Pointer Stars. Now draw a line through these stars away from the bottom of the cup. See below.

The Pointer Stars lead you to Polaris, which also is known as the North Star. Using one set of stars to find other stars is called ***star hopping*** by astronomers.

The North Star is part of another constellation, Ursa Minor, the Lesser Bear. Better known as the Little Dipper, it starts with Polaris at the tip of the handle, and finishes with two stars at the end of the cup named Kochab (pronounce as ko-chab) and Pherkad (pronounce fer cad) at the end of the cup.



Continue the line from the Pointer stars of the Big Dipper, past Polaris, on to what looks like a lazy M or W in the sky. This is Queen Cassiopeia, another northern constellation.



Cassiopeia is very close to the Little Dipper; and, along with the Big Dipper, is known as a circumpolar constellation. Circumpolar means that the constellation circles around the North Star, Polaris. This rotation also means that the Big Bear, Little Bear, and Cassiopeia never leave the skies over the northern half of earth. They travel in a never-ending circle, from low in the north and to nearly at the top of the sky six months later.

For each of the other directions, you will turn the map so that direction you face is at the bottom of the page. Remember to refold the map, East to West for looking at either the North or South, while folding across from North and South to observe the eastern or western skies.

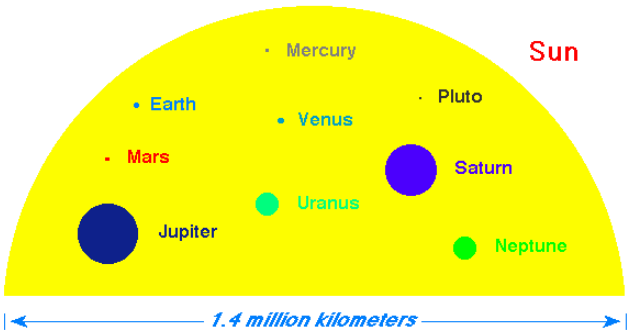


Illustration of a bright Meteor Shower

M31-The Great Andromeda Galaxy by Tony and Daphne Hallas. See more @ http://www.astrophoto.com

HUBBLESITE

HAND-HELD HUBBLE

Safety First!

This symbol, which appears throughout the instructions for building the model, reminds you to use caution when performing certain tasks and to have an adult present. You can click on this symbol anywhere you see it to return to the Safety First! page.

Complete Instructions

This page may take a while to load, but it contains all of the information needed to complete the project.

Safety First!

Before getting started, it's very important that you read and understand the following safety rules because you'll be using some tools (a saw and a drill) to build the model. While tools are easy and safe to use when used properly and with adult supervision, the improper use of tools — whether powered by hand or by electricity — can result in serious injury to yourself or others.

- Make sure you have an adult present before you begin using any of the tools.
- Have an adult inspect all tools before you use them. Do not use tools that appear damaged (frayed cords, cracks, dull cutting blades, etc.).
- Have an adult show you how to use each tool safely and supervise you while you use them.
- Keep your work area well-lighted and clear of clutter.
- Carry tools properly. All sharp-edged tools should be carried with the cutting edge down. Never carry sharp tools in a pocket!
- Do not wear loose or baggy clothing, ties, jewelry, or sandals. If you have long hair, tie it back or wear a cap — especially when drilling.
- Wear eye protection when sawing and drilling. Safety glasses or goggles are inexpensive and available at any hardware store.
- Do not hold your finger on the switch button while carrying a plugged-in tool — it may start accidentally.
- Grip all tools firmly.
- Keep your mind on your work. Avoid distractions such as loud music or conversation.

- When sawing or drilling, make sure you clamp the material you are working on securely to a table or other solid surface with a C-clamp or vise.
- When sawing, make sure to cut away from your body and to keep your hands away from the cutting zones.
- When drilling, pay attention to what is underneath the piece being drilled. Be sure that drilling is done into a secure block of scrap wood or into a clear space.
- Be careful when handling materials that have just been drilled or sawed — the edges may be sharp!
- Be sure to work at a safe distance from others.
- Do not use electric power tools in wet or damp locations.
- Never carry a power tool by its cord.
- Never leave a running power tool unattended.
- When unplugging a power tool, first be sure that it has stopped running. Then unplug it by grasping the plug — not the cord!

Start with a look at the materials you'll need.

Materials

In addition to the items described in the shopping list below, you'll need to download and print the model's paper "wrapper," which illustrates the Hubble Space Telescope's exterior details.

Downloading the Wrapper

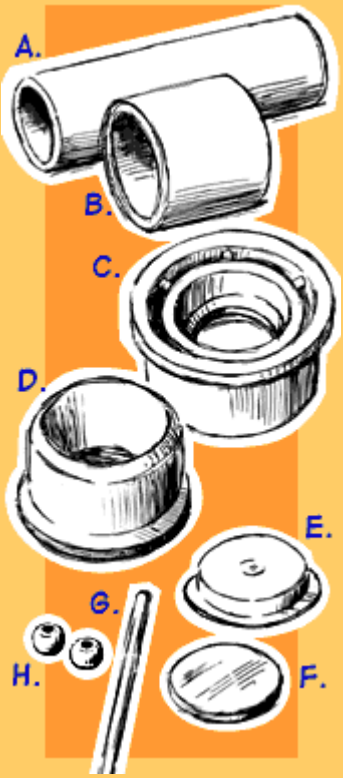
To download the model's wrapper, select one of the links below. If you have a color printer, choose the link for the color wrapper. If you don't have a color printer or you want to color the wrapper yourself, choose the link for the black-and-white wrapper.

Wrappers in color and in black and white can be found at **www.hubblesite.org/go/model**

(Both require Adobe's Acrobat Reader)

What is PVC?

PVC stands for polyvinyl chloride. It's often used to make plastic plumbing pipes. You can find PVC pipes in any hardware store that sells plumbing supplies. Since you need only a small piece of each size of pipe, see if they'll give you some cut ends or scraps.



Be sure to read all the directions before you make your shopping trip. You may have an idea for an improvement to customize your model!

Finding a Mirror

You can find a 2" mirror at most craft stores. If not, get a small, round "blind spot" mirror from an auto parts store or, alternatively, wrap some aluminum foil around the 2" plastic test cap (item E, at right).

Shopping List

Here's a list of the materials and tools you'll need (in addition to the wrapper) to build your model of the Hubble Space Telescope. You should be able to find all the items at craft and hardware stores. If you can't find certain items or want to customize your model, try substituting similar items.

Hardware (plumbing) supplies:

2" PVC pipe, at least 6 3/4" long **(A)**

3" PVC pipe, at least 2 3/4" long **(B)**

3"-to-2" PVC bushing to connect the pipes **(C)**

3" snap-in drain cap **(D)**

2" plastic test cap **(E)**

Craft supplies:

One 2" diameter round mirror **(F)**

One 3/16" diameter wooden dowel, at least 21" in length **(G)**

Two 1/2" diameter wooden beads with pre-drilled holes (holes should be big enough for the end of the dowel to fit inside) **(H)**

One sheet of 8 1/2" x 11" black construction paper

One sheet of posterboard, at least 11" x 17"

Silver paint (spray paint works best)

Small paint brush (not needed if using spray paint)

Cellophane tape

Duct tape

White glue and/or permanent gluestick

Dish soap for washing PVC

Tools Needed

- Drill with 3/16"drill bit
- Saw
- Miter box (optional)
- C-clamp or vise
- Sandpaper or file
- Scissors or craft knife
- Stapler
- Ruler
- Pencil

Now you're ready to start building!

Instructions

11. Measure and cut the PVC pipes. Clamp the pipe to a sturdy surface. From the 3" pipe, measure and cut a 2 3/4" length; from the 2" pipe, measure and cut a 6 3/4" length. (Figures A and B)

2. Sand any rough edges from the cut pipes. In addition, sand off any printing on the pipes to prevent it from showing through the paper wrapper later.

3. Wash the cut pipes with dish soap to get rid of any dirt, oil, or flakes left behind by the saw. Dry the pipes thoroughly.

4. Cut four 6 1/4" x 2" pieces out of the posterboard. Set aside the rest to use later.

5. Cut the black construction paper into one 5" x 6 1/2" sheet.

6. Cut the wooden dowel into one 12" length and one 9" length. (Figure C)

7. Paint the dowels and the beads with the silver paint and allow them to dry.

Cutting the dowel

Measuring and cutting PVC

Figure A

To line up each cut correctly, measure the length you need and mark it at four points around the pipe.

Figure B

You'll get a straighter cut if you use a miter box. Be sure it is secured to your work surface before you cut the pipes. An adult must be present for this step. **Safety First!**

pair of scissors. Twist the scissors around the dowel a few times until you see the groove. Then gently snap the dowel along the groove.

8. Cut out the Aperture Door and Aft Bulkhead sections from Page 1 of the printed wrapper pages (you needn't be accurate because you'll be trimming them once they're glued to the posterboard). Using white glue or a gluestick, attach each section to a piece of posterboard (don't use the 6 1/4" x 2" pieces you cut out earlier). Allow them to dry, then cut them out carefully and set them aside.

9. Cut out the remaining sections of the wrapper. Be sure to cut along the heavy outlines.

Aligning the Forward Shell wrapper

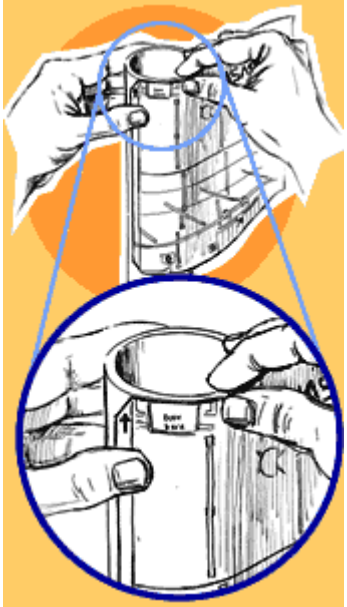


Figure D

When attaching the Forward Shell section of the wrapper, make sure that the edge marked “Attach door here” is lined up at one end of the pipe. There will be about 1/2" of pipe left bare at the other end.

10. Construct the Forward Shell. Tape the Forward Shell section of the wrapper securely to the 2" PVC pipe with cellophane tape. Be sure to first attach the end with the flap marked “Attach this end first.” Align the top of the Forward Shell wrapper with the edge of the pipe. (Figure D)

11. Prepare to drill holes in the Forward Shell. Determine the locations of the four holes to be drilled. They are marked with the symbol ⊗ in four places around the Forward Shell. Then clamp the Forward Shell securely to your work surface.

12. Drill four holes in the Forward Shell using a drill with a 3/16" drill bit. Drill right through the four ⊗ symbols in the wrapped pipe. (Figure E) Be careful not to drill all the way through the other side of the pipe!

13. Insert the unwrapped end of the Forward Shell into the wide end of the bushing. It should fit securely. (Figure F)

Drilling the holes

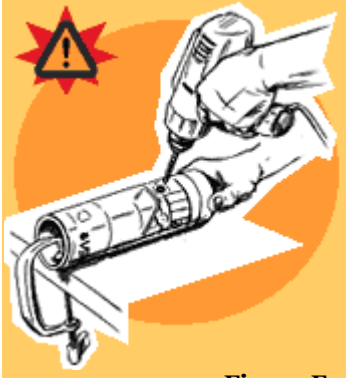


Figure E

Make sure the Forward Shell is clamped securely to your work surface. Drill right through the four ⊗ symbols marked on the wrapper. An adult must be present while you use the drill. **Safety First!**

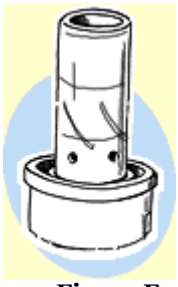


Figure F

Into the bushing...

The widest end of the bushing is the only end into which the Forward Shell assembly will fit properly. It should be a tight fit.

Constructing the mirror assembly

Figure G

Use a loop of duct tape to attach the mirror to the test cap (as shown). If you can't find a test cap, you can insert the mirror without it. Use plenty of tape to prevent the mirror from falling through the opening.

14. Attach the mirror to the test cap with a loop of duct tape. This is now the mirror assembly. (Figure G)

15. Insert the mirror-and-test cap assembly face-down into the open end of the bushing and secure it with cellophane tape. Make sure that the tape does not go outside the bushing. (Figure H)

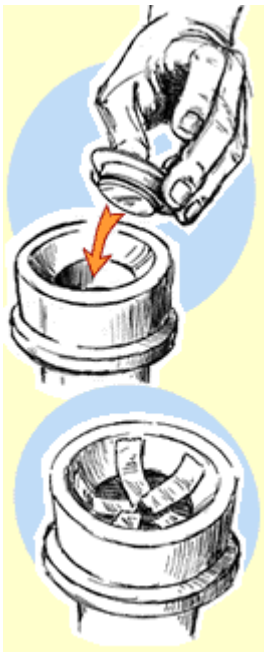


Figure H

Installing the mirror assembly

Install the mirror assembly into the open end of the bushing as shown. Once it's installed, you should be able to see your reflection in the mirror when you look down the barrel of the Forward Shell.

16. Prepare to construct the Aft Shroud by securing the 3" PVC pipe to the wide end of the bushing with several pieces of cellophane tape. (Figure I)

Constructing the Aft Shroud

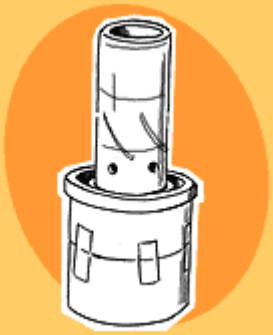


Figure I

Several pieces of cellophane tape placed lengthwise across the seam will hold the two pieces that form the Aft Shroud — the bushing and the 3" PVC — securely.

Aft Shroud wrapper (Part A)

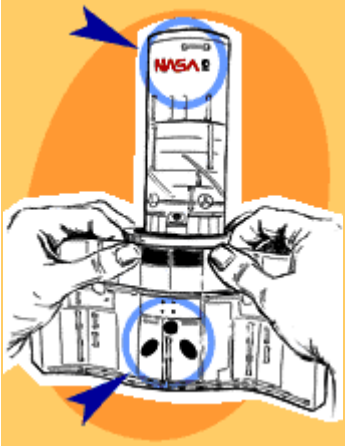


Figure J

When attaching Part A of the Aft Shroud wrapper, make sure that the NASA logo, the two rectangular vents, and the three circular shapes form a straight line.

17. Insert the drain cap in the open end of the 3" PVC and tape it together.

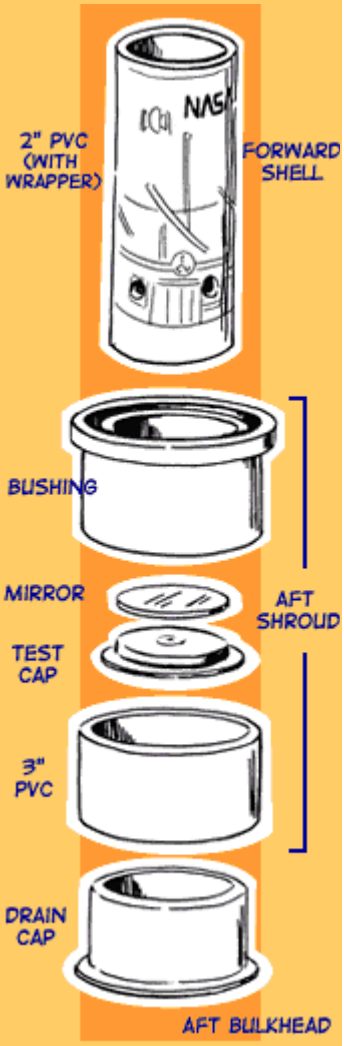
18. Attach the Aft Shroud wrapper (which comes in two parts) to the taped-together 3" PVC pipe. First, line up Part A of the wrapper so that the three circular shapes are directly below the NASA logo. Tape the wrapper in place with cellophane tape. (Figure J)

19. Line up Part B of the Aft Shroud wrapper along the dotted lines on Part A and secure it with cellophane tape. Check that the wrapper's features are lined up correctly. (Figure K)

Figure K

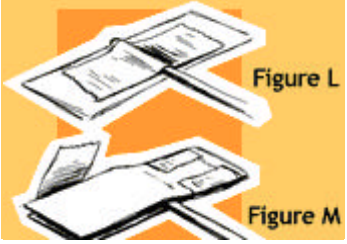
When attaching Part B of the Aft Shroud wrapper, note that the pattern continues underneath the overlap. Make sure everything is lined up correctly before you tape it down.

Snapshot: How it fits together



This is how the individual pieces of the Hubble model's body should be put together.

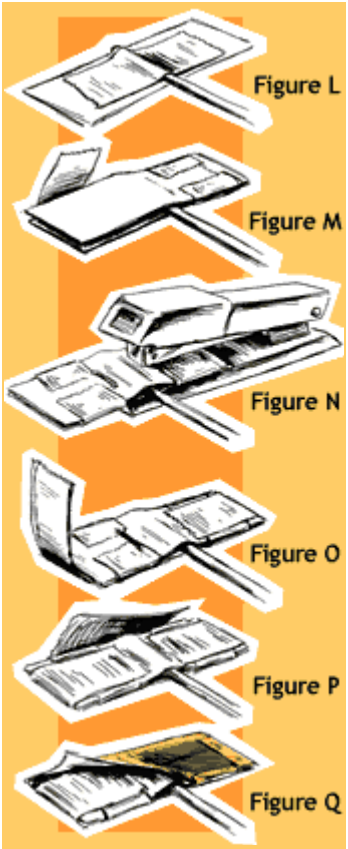
Assembling the Solar Panels



20. Begin assembling the Solar Panels. First, center one of the 6 1/2" x 2" posterboard rectangles over the end of the 9" length of dowel. Tape it securely with duct tape. (Figure L)

21. Line up a second posterboard rectangle on top of the first one, sandwiching the dowel between the two. Tape the pieces

Snapshot: The Solar Panels



If you follow all of these steps, the layers of tape and paper will make your solar panels strong.

together with duct tape. (Figure M)

22. Staple once on either side of the dowel for extra stability. Staple as close to the dowel as possible. (Figure N)

23. Seal both ends of the panel with duct tape. (Figure O)

24. Seal the outside edge of the panel (where the dowel ends) with duct tape. (Figure P)

25. Attach the Solar Panel wrapper by wrapping it around the posterboard "sandwich." First fold it along the dotted line — then secure it with cellophane tape. (Figure Q)

26. Insert the bare end of the dowel all the way through the set of drilled holes in the Forward Shell that are marked "Solar Panel."

27. Repeat steps 20–25 to construct the second Solar Panel on the bare end of the dowel you just inserted through the Forward Shell. Make sure both the panels have the same side facing up. Then center the completed Solar Panel assembly in the Forward Shell.

28. Insert the 12" length of dowel into the set of drilled holes marked "Antenna." Glue a bead onto each end of the dowel by applying a drop of white glue inside the bead's pre-drilled hole and then inserting the dowel. If the dowel is too big to fit into the bead's hole, sand it down to size with sandpaper.

This is what your model should look like with the Solar Panels attached. Remember to put the dowel through the holes **before** attaching the second Solar Panel!

Attaching the Aperture Door

29. Fold or lightly score the Aperture Door cutout on the dotted line so it will bend easily. Place a piece of cellophane tape across both sides of the fold to reinforce the

Inserting the Light Baffle

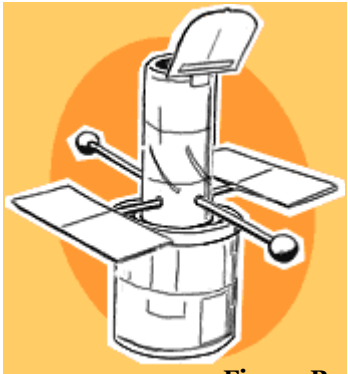


Figure R

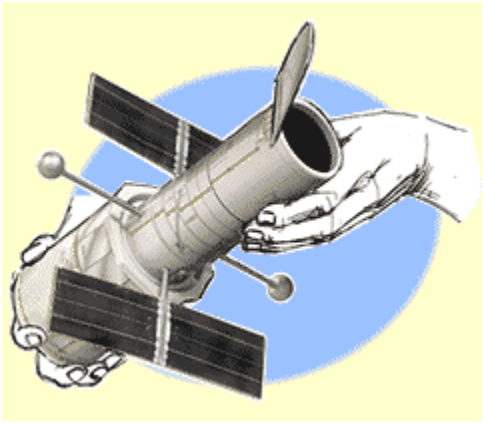
Once you've attached the Aperture Door (as shown), you might want to leave it open. On the real Hubble Space Telescope, the Aperture Door is usually open to allow light to enter... although it can be closed to protect the mirror and instruments from space debris.

"hinge." Then tape or glue the Aperture Door to the Forward Shell where marked with "Aperture door attaches here." (Figure R)

30. Tape the Aft Bulkhead cutout onto the bottom of the model (over the drain cap).

31. Construct the Light Baffle. Loosely roll the black construction paper (starting at the 5-inch side) and insert it into the front of the Forward Shell. The "roll" should be 5 inches tall. You may secure it with cellophane tape if you wish. (Figure S)

It's all done!



Feel free to customize your model any way you see fit. Bear in mind that many of the features illustrated on the wrapper are actually 3-dimensional, so be creative!

For more information about this project visit the website at www.hubblesite.org/go/model

To find out more about the Hubble Space Telescope and its amazing discoveries about the universe, including the latest news, visit us at **www.hubblesite.org**

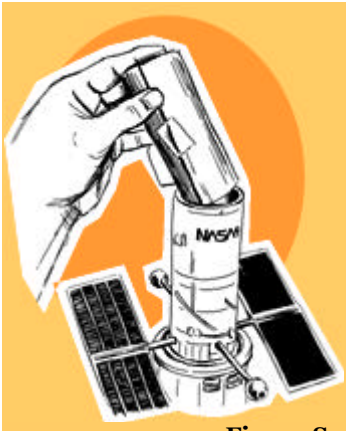


Figure S

Drop the rolled-up Light Baffle into the barrel of the Forward Shell (as shown). The dowel representing the Communications Anntennae will stop it from going in too far. On the real Hubble Space Telescope, the Light Baffle keeps stray (unwanted) light from bouncing around the inside of the telescope.

If you have any construction tips or tricks to share, we'd love to hear from you.

Please e-mail comments or suggestions regarding this project to outreach@stsci.edu, with "Hand-Held Hubble" in the subject line.

HAND-HELD HUBBLE

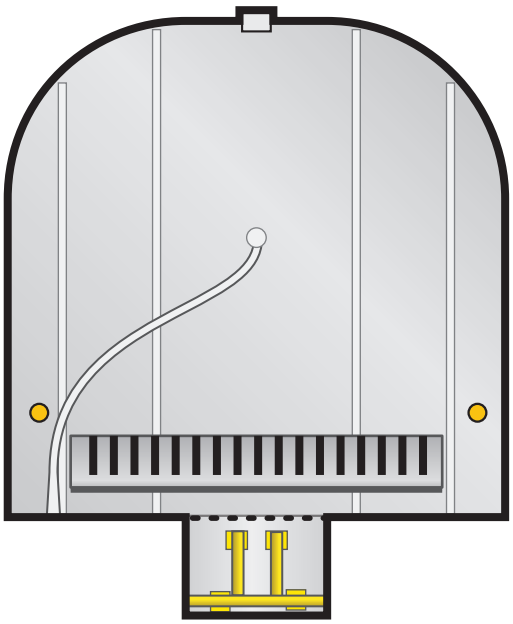
Model Wrappers

The wrappers show the Hubble Space Telescope's exterior features and the locations of its science instruments. On Page 7 you'll find a list of the abbreviations that appear on the wrappers along with brief descriptions of the parts they represent.

These pages contain all of the wrappers needed to complete the Hand-Held Hubble model. The assembly instructions can be found on the Web at: **www.hubblesite.org/go/model.**

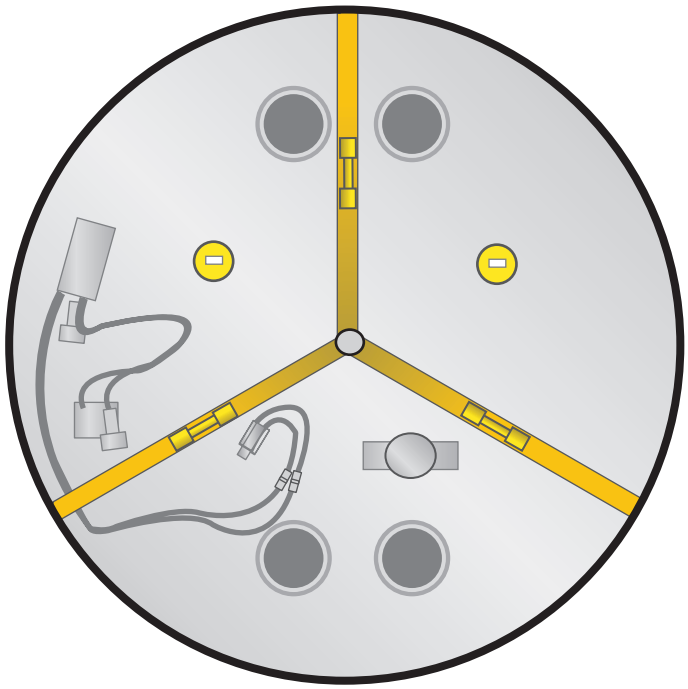
Glue the Aft Bulkhead and Aperture Door pieces to cardboard or posterboard before cutting them out.

Aperture Door



Fold Aperture Door at dotted line. Glue or tape flap to Forward Shell where indicated.

Aft Bulkhead



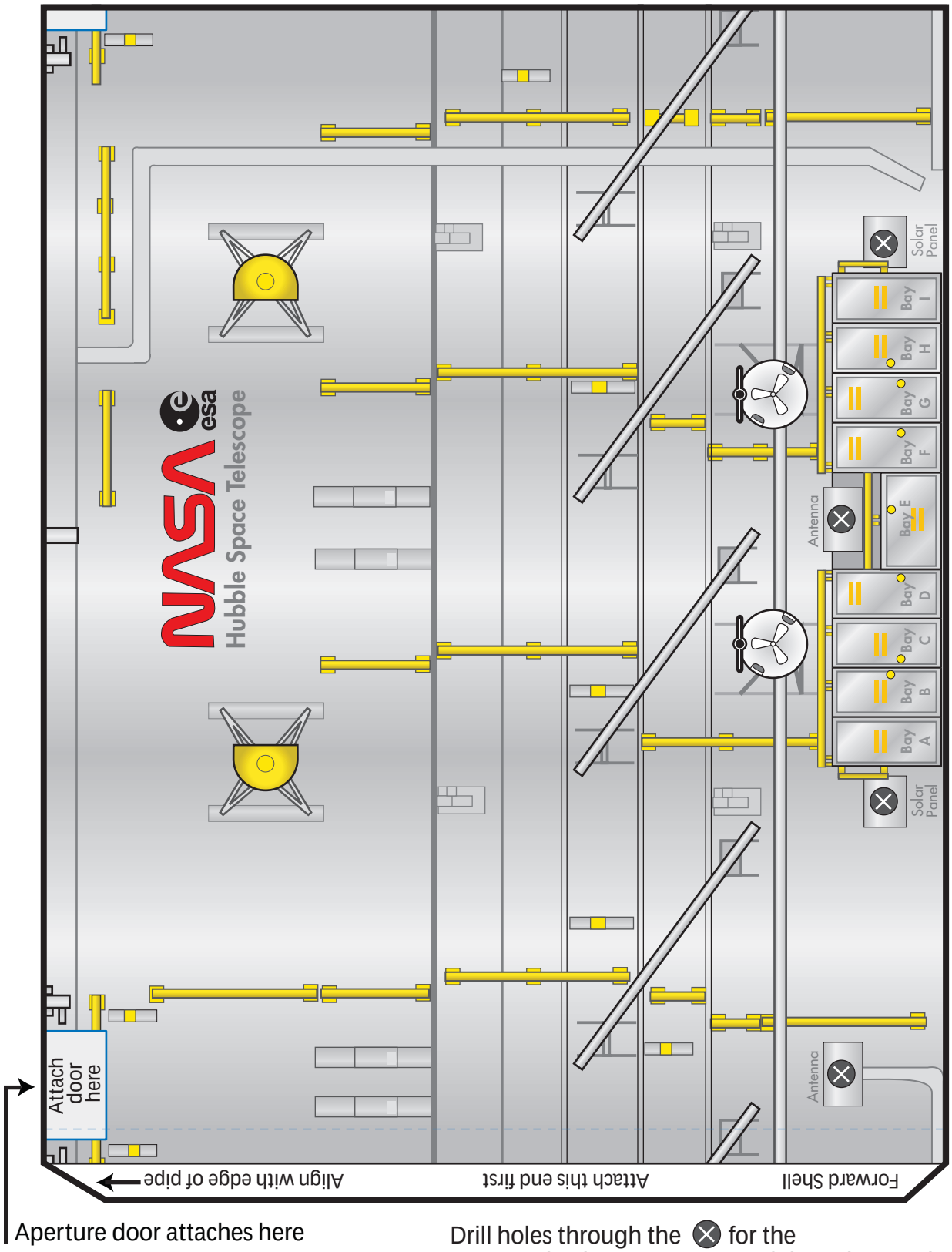
Measure the dashed line below to make sure your printer is making these pages at the correct scale.

If the line is not exactly 1" long, you may have to change your printer options. In the Print dialog box, do the following:

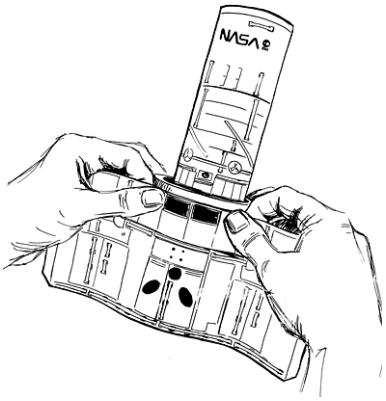
- If you're using Acrobat 5, **deselect** "Shrink Oversized Pages to Paper Size" and "Expand Small Pages to Paper."
- If you're using Acrobat 4, **deselect** "Fit to Page."

⊢–––––––⊣ 1 inch

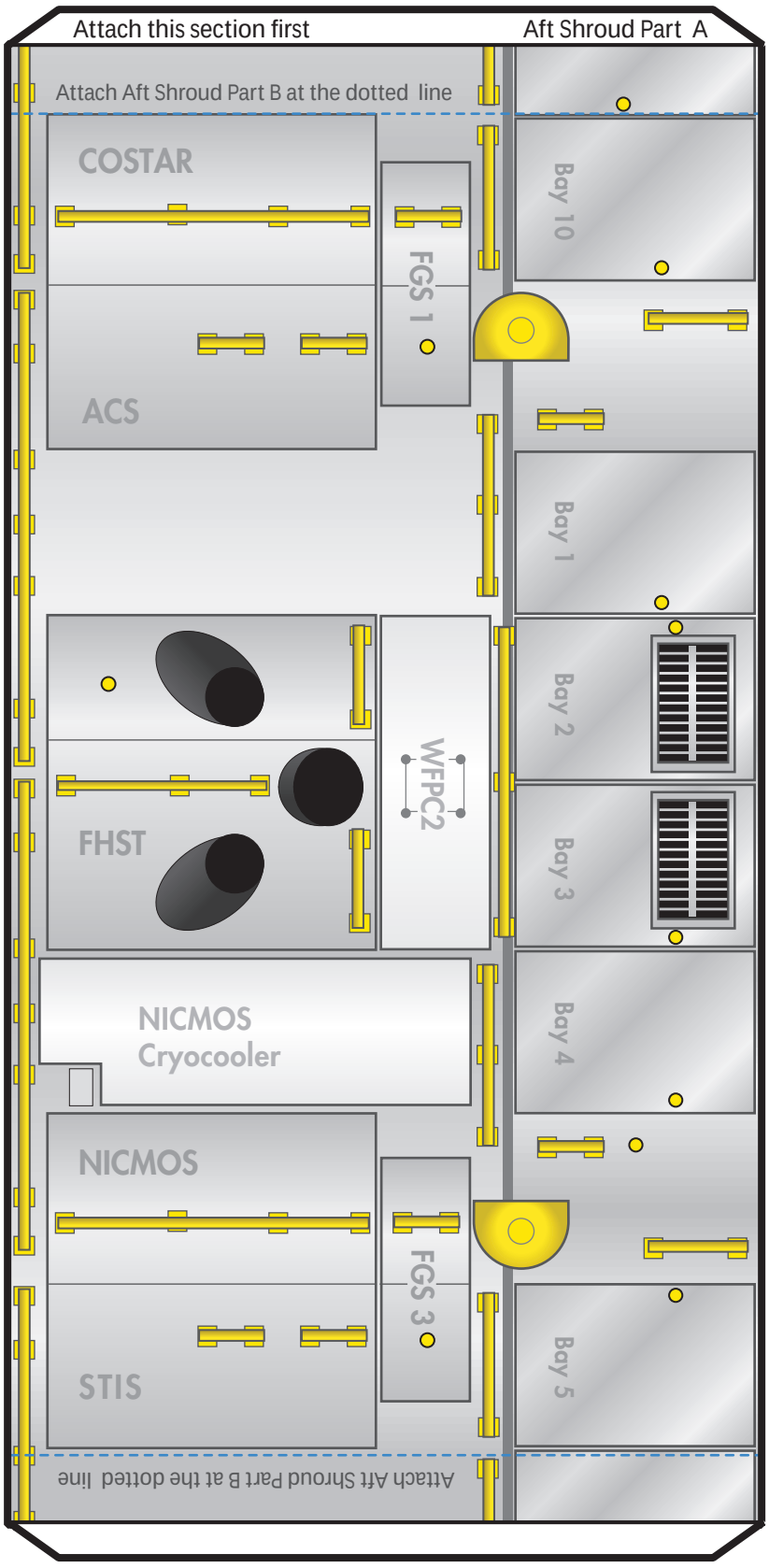
Forward Shell



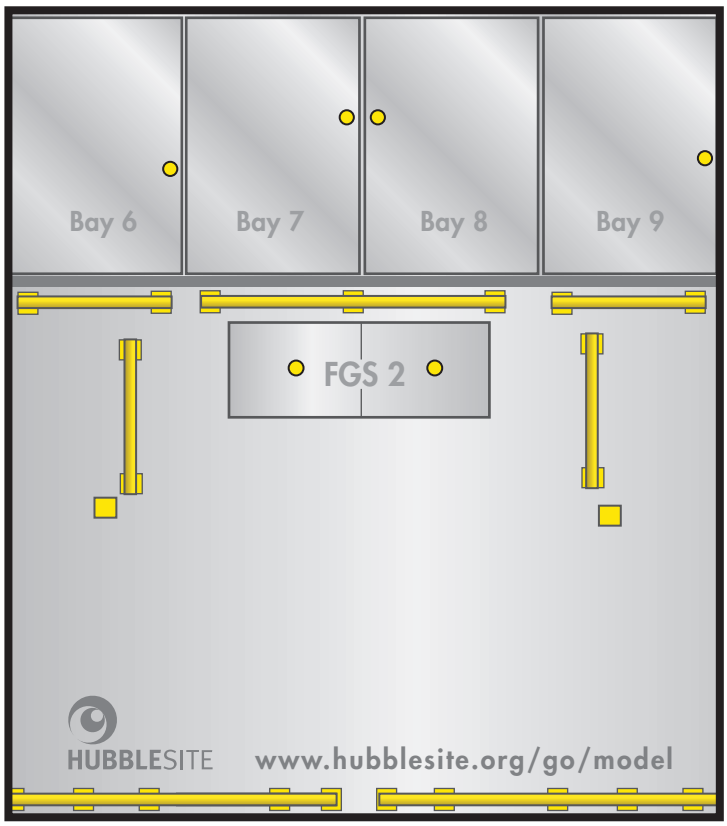
Aft Shroud Part A



When attaching Part A of the Aft Shroud wrapper, make sure that the NASA logo on the Forward Shell and the three circular shapes on the Aft Shroud Part A form a straight line.

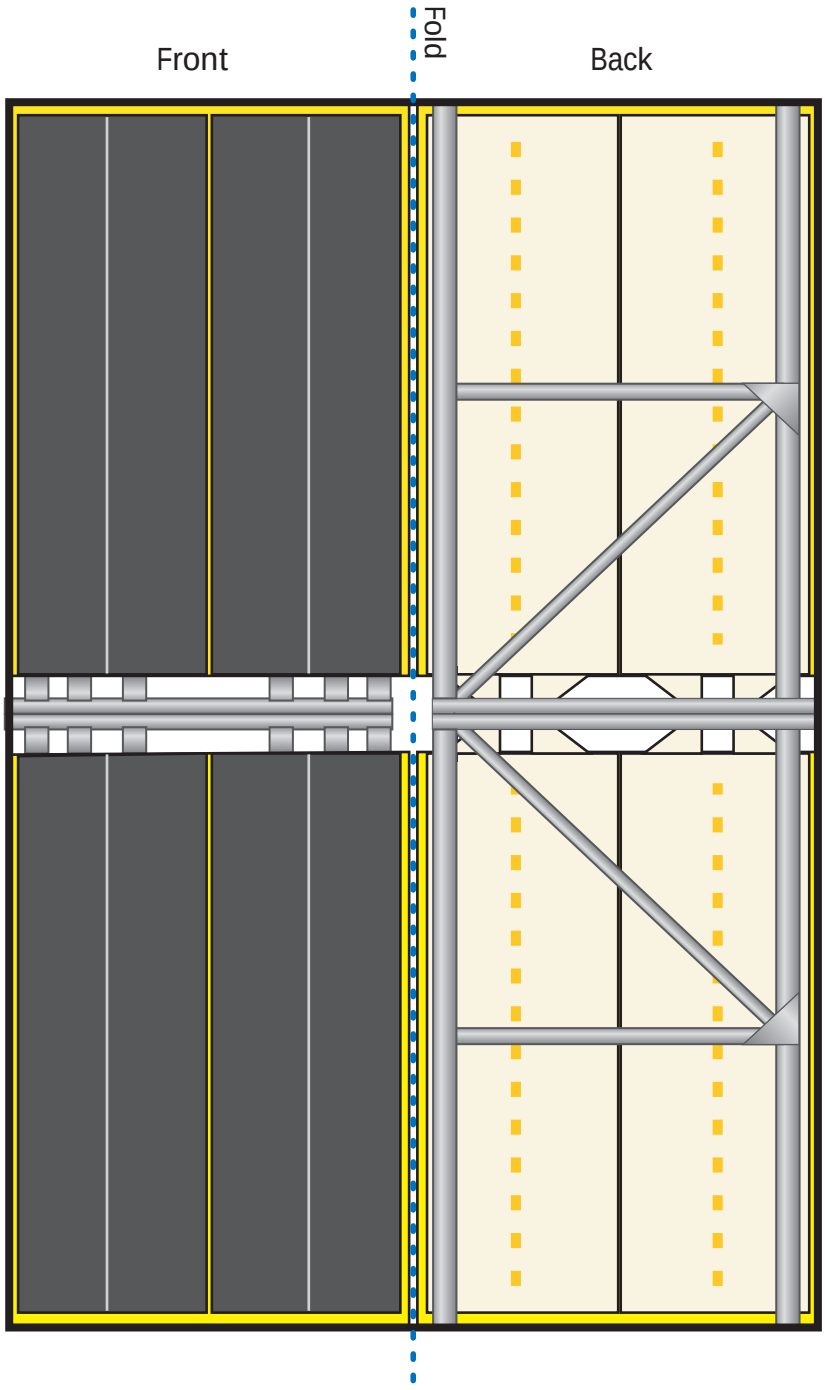


Aft Shroud
Part B

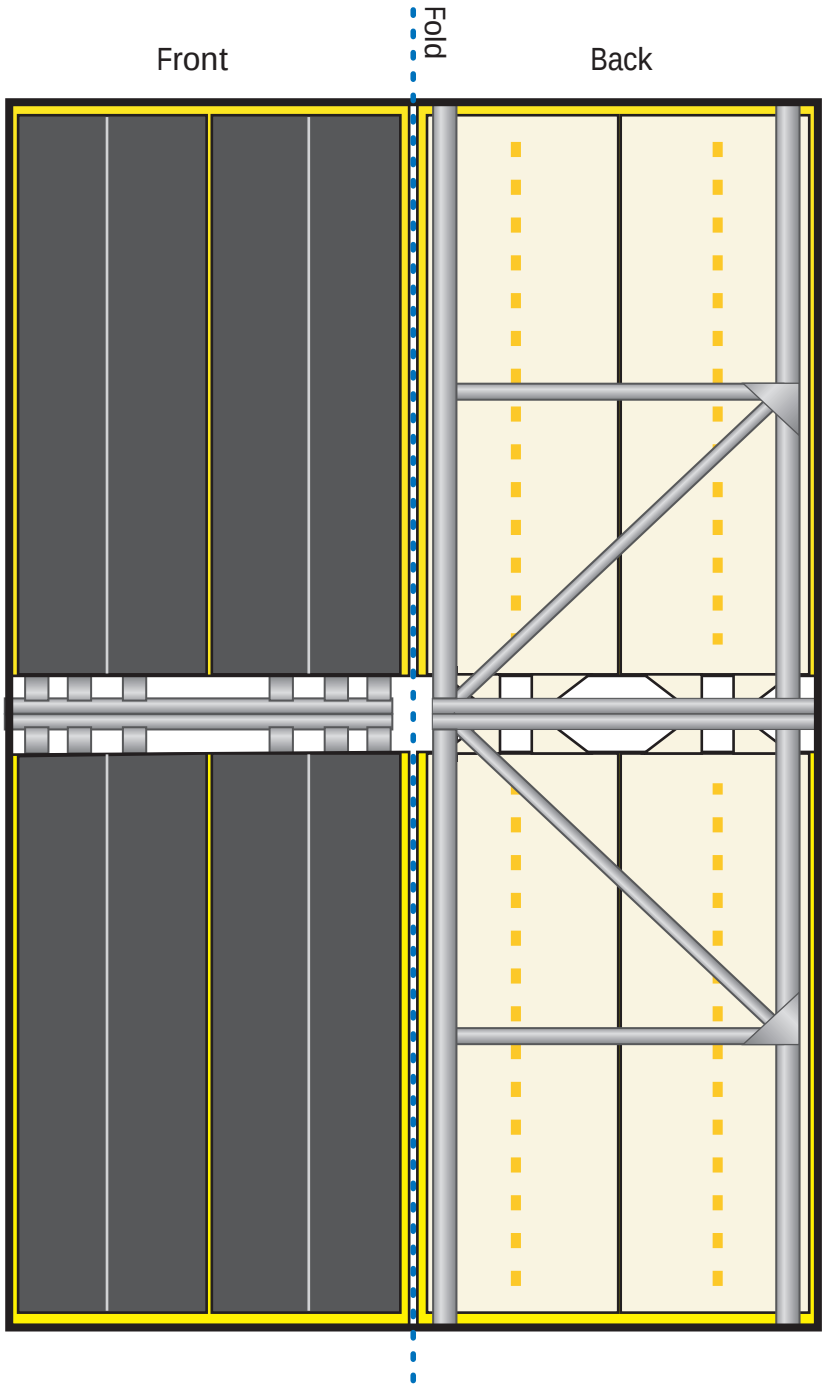


Line up Part B of the Aft Shroud wrapper along the dotted lines on Part A and secure it with cellophane tape. Check that the wrapper's features are lined up correctly in the area where the two pieces overlap.

Solar Panel 1



Solar Panel 2



HAND-HELD HUBBLE

What's What

All of the labeled items on these model wrappers represent working parts of the real Hubble Space Telescope. Here is a brief introduction to them.

For a more detailed description of how the telescope works, visit HubbleSite at **www.hubblesite.org.**

Abbreviations

ACS	Advanced Camera for Surveys
COSTAR	Corrective Optics Space Telescope Axial Replacement
FGS	Fine Guidance Sensor
FHST	Fixed Head Star Tracker
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
STIS	Space Telescope Imaging Spectrograph
WFPC2	Wide Field and Planetary Camera 2

ACS
The Advanced Camera for Surveys (ACS) is Hubble's newest camera. It is used to observe weather on other planets in our solar system, conduct new surveys of the universe, and study the nature and distribution of galaxies.

Aft Shroud
The Aft Shroud is simply the rear section of the telescope. It contains all of Hubble's science instruments.

Aperture Door
The Aperture Door "guards" the telescope's internal mechanisms. It is usually open, which allows starlight to enter the telescope and be picked up by the science instruments. Sometimes the door is closed to protect the mirror and instruments from space debris.

Bays
Hubble's 20 bays are "closets" that contain the telescope's instruments and electronics.

Communications Antennae
Hubble's communications antennae allow astronomers and technicians to communicate with the telescope — telling it what to do and when to do it. The antennae send and receive information between the telescope and the Flight Operations Team at the Space Telescope Science Institute.

COSTAR
The Corrective Optics Space Telescope Axial Replacement (COSTAR) apparatus functions like eyeglasses for Hubble. When the telescope was launched in 1990, the shape of the primary mirror was flawed, which resulted in "fuzzy" images. COSTAR's small, carefully designed mirrors, which sit in front of the telescope's science instruments, correct this problem.

NICMOS Cryocooler
The NICMOS cryocooler is a "refrigerator" that keeps the instrument very cold — below –321º F, or 77 degrees Kelvin. The sensitive infrared detectors in NICMOS must operate at very cold temperatures to avoid exposure to unwanted light in the form of heat.

FGS
Hubble's four Fine Guidance Sensors (FGS) are targeting devices that lock onto "guide stars" and measure their positions relative to the object being viewed. Adjustments based on these precise readings keep Hubble pointed in the right direction.

FHST
Fixed Head Star Trackers (FHST) are small telescopes with wide fields of view that are used in conjunction with the Fine Guidance Sensors. The star trackers locate the bright stars that are used to orient the telescope for scientific observations.

Forward Shell
The Forward Shell makes up the front part of the telescope. It houses Hubble's light baffle and mirrors.

Mirrors
Hubble has two mirrors: the primary mirror and the secondary mirror. The primary mirror reflects the light gathered by the telescope back to the secondary mirror, which focuses it and bounces it back toward the science instruments.

NICMOS
The Near Infrared Camera and Multi-Object Spectrometer (NICMOS) is Hubble's heat sensor. Its sensitivity to infrared light makes it useful for observing objects hidden by interstellar gas and dust (such as stellar nurseries and planetary atmospheres) and for peering into deepest space.

Solar Panels
The Solar Panels are Hubble's power stations. They gather sunlight and convert it to electricity, which runs the telescope's scientific instruments, computers, and radio transmitters. The Solar Panel's solar cell "blankets" generate 3000 watts of electricity — enough to power 30 household light bulbs.

STIS
The Space Telescope Imaging Spectrograph (STIS) is a versatile instrument that can act somewhat like a prism, separating light from the cosmos into its component colors. The colors of an object reveal many clues about its age and composition.

WFPC2
The Wide Field and Planetary Camera 2 (WFPC2) is the "workhorse" instrument behind nearly all of the most famous Hubble pictures. As Hubble's main camera, it is used to observe just about everything.

Complete instructions for building this scale model of the Hubble Space Telescope can be found at **www.hubblesite.org/go/model** on the World Wide Web.

HUBBLESITE

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... out of this world.

www.hubblesite.org

Credits

This model was developed by the Office of Public Outreach at the Space Telescope Science Institute. We would like to thank our colleague Max Mutchler for creating the original Hubble model and for assisting us with this upgraded version.

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Astronomy & Space Exploration Web Sites

http://www.boonhill.net - Master Web Site for local astronomical Societies, including Metro Detroit's Ford Amateur Astronomy Club and the Warren Astronomical Society.

http://www.nasa.gov - ***NASA HQ's*** Web Site. A great place to start your research!

http://www.stsci.edu - ***Hubble Space Telescope*** (HST) Headquarters-Find pictures and movies of the universe!

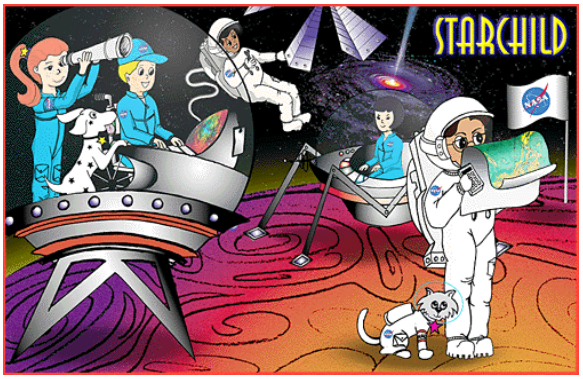
http://amazing-space.stsci.edu/ - *Amazing Space* a site with lots of Web-based activities designed for classroom use and for the general public.

http://origins.stsci.edu - *The Origins Program* studies events starting at the birth of the universe in the Big Bang, the forming of galaxies, stars, & planets, & the start of life on Earth and possibly elsewhere.

http://www.stsci.edu/exined - ***Welcome to Education!*** Please stop and take a look at our latest electronic offerings of Macintosh, Windows, and DOS software available for downloading!

http://www.jpl.nasa.gov/forum/indexpg.html NASA's Jet Propulsion Laboratory (JPL) supplies a master list of web sites for astronomy and space exploration!

http://photojournal.jpl.nasa.gov @ NASA's Jet Propulsion Laboratory (JPL) *Planetary Photojournal* will provide you with easy access to the images from various Solar System exploration programs.



http://imagine.gsfc.nasa.gov/docs/homepage.html *Go Imagine the Universe* is a learning center for **high school students-**14 years and up.

http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html *Starchild* is a learning center for **Elementary or Middle school** astronomers.

http://www.skyandtelescope.com - Home site for ***Sky and Telescope magazine***, started in 1936. S&T is the oldest and longest running astronomy magazine in the US

http://www.astronomy.com - ***Astronomy magazine***, started in 1973 and published by Kalmbach Publishing Corp.

http://www.jpl.nasa.gov/cassini/Kids/ Cassini *for Kids* - a site just for kids where they can explore the beautiful ringed planet Saturn and learn about the spacecraft currently on its way there!

http://www.jpl.nasa.gov/galileo/education.html *Galileo K-12 Educator's Resource Center* The materials gathered in these pages are aimed at K-12 teachers and students for NASA's and ESA's Galileo mission to study Jupiter and its moons.

http://www.estec.esa.nl/outreach @ *European Space Agency (ESA)* The main education and outreach web site for ESA missions and activities.

http://www.astronomy.com/Content/static/parentsteachers/default.asp - *Astronomy Magazine's* web site for Parents and Teachers