

NASA



NASA

LEFT: Kathryn Sullivan and Sally Ride flew on the first Space Shuttle mission to include two women in 1984. RIGHT: STS-31 Mission Specialist Kathryn Sullivan poses for a picture before beginning the procedure to put on the extravehicular mobility unit in the airlock of *Discovery*, Orbiter Vehicle 103. She became the first American woman to perform a spacewalk.

KATHRYN SULLIVAN

FIRST AMERICAN WOMAN TO PERFORM A SPACE WALK

OBJECTIVES

- Discuss Kathryn Sullivan's early life.
- Discuss some of her accomplishments with NASA.
- Discuss some of her accomplishments outside of NASA.
- Build the Hubble Telescope.

STANDARDS

NGSS

Science

- MS-ETS1-1
- MS-ETS1-2
- MS-ETS1-3
- MS-ETS1-4

ELA/Literacy

- RST.6-8.3
- RST.6-8.9
- RST.6-8.7
- WHST.6-8.9

NCSS

- III.b.
- IV.f.
- V.c.
- X.e.

On October 11, 1984, Kathryn Sullivan took a 3 ½ hour walk and made history. The walk was outside the Space Shuttle *Challenger*, and she became the first American woman to spacewalk.

There, from a vantage point of about 140 miles above Earth, she had a spectacular view. “It is an intriguing and wonderful experience,” she told writer Diane Wedner of the *Los Angeles Times* in 1997. “The view is obviously great. The experience lingers and grows for a long time after it’s over.”

Sullivan’s new perspective of being so far away from Earth was a big change from her previous scientific experiences, which brought her close to the oceans she could see from the shuttle – much closer. In fact, she was an oceanographer and participated in several oceanographic expeditions that studied the floors of the Atlantic and Pacific oceans.

In addition to the 1984 *Challenger* mission, Sullivan flew on two other Space Shuttle missions. As a mission specialist on STS-31 *Discovery*, in 1990 she helped launch the Hubble Space Telescope.

After leaving NASA in 1993, her career highlights included serving as the tenth administrator of the National Oceanic and Atmospheric Administration (NOAA) from 2014 to 2017. NOAA, in the U.S. Department of Commerce, is the nation’s top science agency for climate, oceans, and the atmosphere.

She is a private pilot, rated in both powered and glider aircraft.

Sullivan has written a book on the Hubble Space Telescope, *Handprints on Hubble* (2019), which recalls her experience as part of the team that launched, rescued, repaired, and maintained the telescope.

HER STORY

Kathryn D. Sullivan was born October 3, 1951, in Paterson, New Jersey, but she considers Woodland Hills, California, to be her hometown. She is the daughter of Donald P. Sullivan and Barbara K. Sullivan. She told the *Los Angeles Times* that her exposure to her father's engineering job at Lockheed Corp. sparked her interest in space. As a first-grader at Hayvenhurst Elementary in Encino, she was classmates with Sally Ride, the first U.S. woman in space.

As a girl, Sullivan liked exploring the area around her town. "Growing up here . . . it was semirural," she told the *LA Times*. In 1969, she graduated from Taft High School in Woodland Hills. She went on to the University of California, Santa Cruz, and graduated with a bachelor of science degree in Earth sciences in 1973 and a doctorate in geology from Dalhousie University in Nova Scotia in 1978.

While at Dalhousie, she participated in several oceanographic expeditions under the auspices of the U.S. Geological Survey and other organizations. The research included the Mid-Atlantic Ridge, the Newfoundland Basin, and fault zones off the Southern California coast.

Sullivan credits a requirement to take courses out of her major (languages) at UC Santa Cruz for inspiring her interest in ocean sciences.

In 1978, she was one of the first six women chosen to be Space Shuttle astronauts. After joining NASA, Sullivan's research interests were focused on remote sensing. She qualified as a systems-engineer operator in NASA's WB-57F high-altitude research aircraft in 1978 and participated in several remote sensing projects in Alaska.

Continued on PAGE 105



NASA

Astronaut Kathryn Sullivan gets help with her suit prior to an underwater simulation of an EVA.

“ It [spacewalking] is an intriguing and wonderful experience. The view is obviously great. The experience lingers and grows for a long time after it's over. ”

— Kathryn Sullivan

Achievements include

- Qualified as a Systems Engineer Operator in the NASA WB-57F high-altitude research aircraft (1978)
- Was the third American woman in space and first American woman to walk in space (EVA) (1984)
- Inducted into International Space Hall of Fame (1985)
- Completed three Space Shuttle missions, STS-41G, STS-31 and STS-45 (1984-1992)
- Received multiple NASA Medals of recognition (1984-1992)
- Served as an oceanographer U.S. Navy Reserve Officer (1988-2006)
- Helped launch the Hubble Space Telescope on Space Shuttle STS-31 (1990)
- Received the American Institute of Aeronautics and Astronautics Haley Space Flight Award (1991)
- Received a presidential appointment as chief scientist at the National Oceanic and Atmospheric Administration (NOAA) (1993)
- Inducted into the Ohio Women's Hall of fame (2002)
- Received the Public Service Award, National Science Board (2003)
- Served on the National Science Board (2004-2010)
- Inducted into Astronaut Hall of Fame (2004)
- Received the Aviation Week & Space Technology Aerospace Legend Award (2005)
- Inducted into the Women in Aviation International Pioneer Hall of Fame (2010)
- Served as acting administrator of NOAA (2013)
- Confirmed by U.S. Senate as Under Secretary of Commerce for oceans and atmosphere; the 10th administrator of NOAA (2014)
- Recognized by *Time Magazine* as one of 46 distinguished First Women (2017)
- Named National Air and Space Museum Charles A. Lindbergh Chair of Aerospace History (2017)



HER STORY (continued from Page 104)

Sullivan flew on three shuttle missions during her 15-year tenure logging 532 hours in space. Her first mission was in 1984, STS-41G *Challenger*. The mission, the first to include two women (Sally Ride and Sullivan), also made Sullivan the first American woman to walk in space. Sullivan and fellow astronaut David Leestma conducted a 3 ½ hour Extra-vehicular Activity (EVA) to test whether satellites could be refueled in orbit. “That sounds like a trivial thing,” she told the Smithsonian Institution’s David Rubenstein in an interview for the American Academy of Arts and Sciences, “but the loss of fuel in a satellite is often what ends the life of a satellite.”

Her next Space Shuttle mission was STS-31 *Discovery* (1990) that deployed the Hubble Space Telescope, and she was the co-investigator on the Shuttle Imaging Radar-B (SIR-B) experiment, which she flew on Mission

STS-41G. Her third and final mission was *Atlantis* STS-45 in 1992, during which the crew completed climate and atmosphere studies using ATLAS-1 cargo, an acronym for Atmospheric Laboratory for Applications and Science.

She retired from NASA in 1993 and was appointed the National Oceanic and Atmospheric Administration’s (NOAA) chief scientist. She was in charge of research and technology in a variety of areas including fisheries biology, climate change, satellite instrumentation, and marine biodiversity. She served as CEO of the Center of Science and Industry in Ohio, one of the leading science museums in the U.S.

From March 2014 until January 2017 she was the under secretary of commerce for oceans and atmosphere and administrator of NOAA.

Announcing her appointment, a White House administrator noted her

“impressive background as a scientist and astronaut” and her “team-building skills” among her many qualifications.

Team-building and trust were especially important traits for astronauts training and performing missions.

She was asked by the Smithsonian Institution’s Rubenstein if she had to pretend that she thought the men were better than the women in astronaut training or if she thought that actually, the women were better than the men. Her response was it was neither.

“I knew we each had to hold our own. I need each of my crew-mates – male, female, black, green, or otherwise – to know their stuff, to be completely competent, and hold their ground when things get crazy or squirrely or scary. And they need to be able to trust me, as well.”

QUICK BOX

Snacks in Space

Astronaut Kathryn Sullivan described how astronauts eat in the microgravity environment, or the condition in which people or objects appear to be weightless. This excerpt from a 2017 conversation with the Smithsonian’s David M. Rubenstein details what snack time aboard the shuttle was like.

“Up here you are your own clean-up crew, of course, so if you lose an M&M, if it wanders off somewhere, it is important that you know how the airflow circulates through the vehicle and where the dead spots are, because the stray M&Ms and lost socks and other things will be right there in about a half a day, and you can go scavenge them. If you think M&Ms are fun, Pepperidge Farm goldfish will display schooling behavior in this environment.

“Another very fun thing is how quickly people change their vocabulary. If you wanted me to give you a hand control or remote, in short order you would find you had ceased saying, ‘Would you please pass me the remote?’ or ‘Please pass me the M&Ms?’ Instead you would say, ‘Would you please send me ...,’ and you just give the object a little shove and it cruises across the cabin.”



REFERENCES

1. Clayton, C. (2014, March 6). NOAA News & Features. Retrieved from <https://www.noaa.gov/kathryn-sullivan-confirmed-noaa-administrator>.
2. Former astronaut and NOAA administrator Kathy D. Sullivan named National Air and Space Museum's Lindbergh Fellow. (2018, Jan. 9). Retrieved from <https://airandspace.si.edu/newsroom/press-releases/former-astronaut-and-noaa-administrator-kathy-d-sullivan-named-national-air>.
3. Gibson, K. B. (2014). Women in space: 23 stories of first flights, scientific mission, and gravity-breaking adventures. (pp. 99-104). Chicago Review Press.
4. Heiney, A. (2004, May 1). Space explorers inducted into Astronaut hall of Fame. Retrieved from https://www.nasa.gov/missions/shuttle/f_induction.html.
5. Kathryn D. Sullivan. (n.d.). Retrieved from <http://www.nmspacemuseum.org/halloffame/detail.php?id=90>.
6. Kathryn Sullivan. (n.d.). Retrieved from <https://www.rff.org/people/kathryn-d-sullivan/>.
7. Kathryn Sullivan: First American woman to walk in space. (n.d.). Retrieved from <https://time.com/collection/firsts/4921998/firsts-full-list>.
8. Kathryn D. Sullivan (Ph.D). (2014, April). Retrieved from https://www.nasa.gov/sites/default/files/atoms/files/sullivan_kathryn.pdf.
9. Ross-Nazzari, J., & Sullivan, K. D. (2007, May 10). Edited oral history transcript. NASA Johnson Space Center Info/History Portal. Retrieved from https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/oral_histories/SullivanKD/SullivanKD_5-10-07.htm.
10. Sullivan, K.D., & Rubenstein, D.M. (2018). Looking at Earth: An astronaut's journey. American Academy of Arts and Sciences Bulletin. Retrieved from <https://www.amacad.org/news/looking-earth-astronauts-journey>.
11. Watters, J. (2014, March 6). Five amazing facts about Dr. Kathryn Sullivan, our newly confirmed head of NOAA, [web log comment]. Retrieved from <https://oceanconservancy.org/blog/2014/03/06/five-amazing-facts-about-dr-kathryn-sullivan-our-newly-confirmed-head-of-noaa/>.

EXTENSION RESEARCH AND ART

EARTH AS ART

Astronaut Kathryn Sullivan describes the view of Earth from the Space Shuttle as “stunning.” “Every time you look out the window,” she told the American Academy of Arts and Sciences, “you are seeing about a thousand-mile swath: full continents are out your office window at every glance; history is just out your window.” The views, she said look like modern art. “The images could hang in the Museum of Modern Art. No one would know the difference.”

Let cadets and students experience these views in a variety of ways.

- Have students download the NASA Earth As Art app for iOS devices. NASA says this app “celebrates Earth’s aesthetic beauty in the patterns, shapes, colors, and textures of the land, oceans, ice, and atmosphere.” The app features images of Earth from the Terra, Landsat5, Landsat 7, EO-1, and Aqua satellites. It also includes time-lapse satellite images of places on Earth that have seen significant change over decades.
- For an activity that does not need iOS download, visit the U.S. Geological Survey’s website, USGS: Science for a Changing World, at www.usgs.gov. The site’s Earth Resources and Science (EROS) Center also has an Earth As Art satellite image gallery at <https://eros.usgs.gov/image-gallery/earth-art>.

- Sullivan has research experience in remote sensing. In classrooms and squadrons, youth can study satellite imagery with the Civil Air Patrol Teachers Educational Remote Sensing Program (CAP-TERS). This program provides satellite imagery, imagery viewer, and lesson plans. It is available free to CAP members and educator members by visiting eServices. For CAP-TERS, contact ae@capnhq.gov.

ASTRONOMY

In 1990, Sullivan was aboard the Space Shuttle mission *Discovery* that launched the Hubble Space Telescope. Youth can visit <https://hubblesite.org/> to learn about the latest news about this satellite.

- Explore images from the Hubble gallery. <https://hubblesite.org/resource-gallery/images>.
- Draw or paint and label favorite images from the Hubble.

VIDEO LINKS:

- Kathryn Sullivan Discusses the Criticism She Faced Before Being the First Woman to Walk in Space (Time) <https://www.youtube.com/watch?v=-ZakCA5immw>
- An Astronaut’s Journey – Kathryn Sullivan (American Academy of Arts and Sciences) <https://www.youtube.com/watch?v=1XWjHN-OwIQ>



BUILD A HUBBLE TELESCOPE

Students will build a highly detailed model of the Hubble Space Telescope. Kathryn Sullivan's second of three space missions was STS-31 *Discovery*, which launched the Hubble into low Earth orbit in 1990. The telescope remains in operation.

BACKGROUND



NASA



NASA/JSC

The Hubble Space Telescope (HST) is a space telescope that was launched into low Earth orbit in 1990 and it remains in operation. The HST was not the first space telescope but is one of the largest and most versatile, and is well known as a vital research tool. It has put Astronomy back as a highly desired career and occupation. The public relations boon for NASA and astronomy has been immense due to its images and data discoveries. The HST is named after the astronomer Edwin Hubble (November 20, 1889 – September 28, 1953) who discovered that many objects previously thought to be clouds of dust and gas and classified as “nebulae” were actually galaxies beyond the Milky Way.

Space telescopes were first proposed in the early 1920s, but it took until the 1990s for a practical way to put such a telescope into space. NASA and the European Space Agency worked together to make the HST a reality. The HST imaging target selection and processing imagery is tasked from the Space Telescope Science Institute, Baltimore, Maryland. The HST is controlled from the Goddard Space Flight Center in Greenbelt, Maryland.

From the beginning, the HST was planned to be maintained/serviced by astronauts using the Space Shuttle. Five Shuttle Missions changed out many components of the HST that were upgraded/replaced as technology improved /increased in capacity, as well as in components becoming more miniaturized. The HST today is much more capable than when first launched.

ORBIT PARAMETERS/ PERFORMANCE

- **Speed:** About 17,398 mph (28,000 kph)
- **Inclination of orbit:** 28.5°
- **Orbit period:** 97 minutes
- **Length of Mission:** 5+ years
- **Apogee:** 337 mi. (543 km)
- **Perigee:** 335 mi (539 km)
- **End of Mission:** Orbit decay date 2030-2040
- **Low Earth Orbit:** 338.6 miles (545 km)

MAIN TELESCOPE

- **Type:** Ritchey-Chretien Reflector
- **Diameter:** 7.9 ft. (2.4 m)
- **Focal Length:** 189 ft. (57.6 m)
- **Focal Ratio:** f/24
- **Collecting Area:** 48 sq. ft. (4.5 m²)
- **Wavelengths:** Near-infrared, visible light, and ultraviolet

ABOUT THE TELESCOPE

GENERAL CHARACTERISTICS

- **Crew:** 0
- **Launch Date:** 24 April 1990
- **Date Entered Service:** 20 May 1990
- **Deployed Length:** 43 ft. 4.5 in (13.2 m)
- **Deployed Diameter w/out the Solar Array Panels:** 13 ft. 7.75 in (4.2 m)
- **Deployed Weight:** 24,490 lb. (11,110 kg)
- **Electric Solar Power plant:** Power of ~2.8 kW plus and 6-large nickel hydrogen batteries
- **Solar Panel Arrays:** 2 Arrays (2.4 m x 12.1 m)
- **Solar Cell Area:** 86.9 ft.² (26.5 m²)
- **Communication:** 2 x antennas are linked with Tracking and Data Relay (TDRS) constellation satellites to have continuous communication and data links with the ground station in Maryland, USA.
- **Avionics Package:** A star tracker helps measure the position of stars and keep the satellite orbit predictable.
- **Propulsion and The HST has 6-gyros for stabilization.** Three are in use, and three are held as backups.
- **Reaction Wheels:** In the middle of the spacecraft, near its center of gravity, are four 100-pound reaction wheels used to reorient the observatory. Reaction wheels help to orient HST satellite. As a satellite tries to spin due to outside influences such as solar flares or solar wind, the wheels act like a watch spring and build up tension that can be used in a reverse direction later.
- **The Fine Guidance System (FGS)** keeps the satellite virtually motionless while locked on a target.

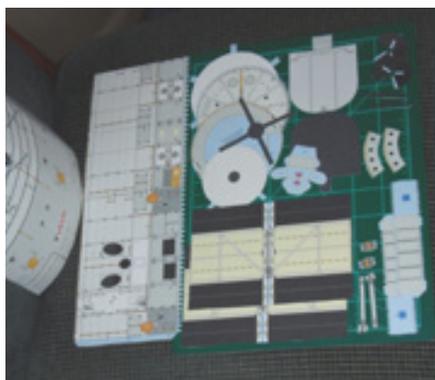
*READ FURTHER IN THIS CHAPTER
FOR A LIST OF INSTRUMENTS AND
DISCOVERIES MADE BY THE TELESCOPE*

PROCEDURE — Building the Hubble Telescope

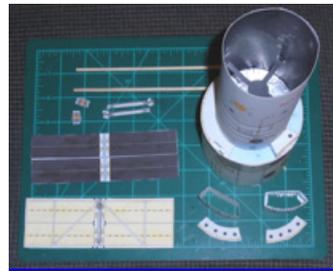
MATERIALS

- Cardstock for templates
- Flat, level, stable, and easily cleaned surface to work on
- Sharp-pointed (“X-acto”-type) hobby knife; ALWAYS cap it when not in use
- Sharp, precision sewing-type scissors
- A ruler or any other (truly) straight edge
- Toothpicks, round (and flat, if available)
- Elmer’s glue, super glue, or Aleene’s Fast Grab Tacky Glue
- Eyebrow-type tweezers, having a straight edge of comfortable angle
- Stylus of some kind, to make indented lines for folds
- A trash can nearby to be neat
- A small book for pressing pieces together

- 1** Print the Hubble Telescope plans (there are a total of 6 pages).
- 2** Set up work area with materials and tools.
- 3** Read all the instructions on the plan. NASA tells where to glue, cut, and fold/bend. Follow the steps and methods on how to build this paper model of the HST in the instructions sheet.
- 4** Cut out the parts as the project is built, including the 4 small squares on part 6.
- 5** Score and fold the tabs carefully; bend tabs with a straight edge ruler. Separate into sub-assemblies to combine later.



- 6** Start gluing the sub-assemblies together. The instructions are very good, but must be read and followed exactly. Once a sub-assembly is glued, leave it alone and allow the glue to dry.



- 7** The telescope and instrument module need to be firmly glued together. A small book will add the needed weight to make this bonding work perfectly. While this is happening, work on the other smaller subassemblies until everything is thoroughly dried.



- 8** The TDRS antennas and solar panels are the last items to be added to the HST. The instructions are very detailed for this step and easy to follow.



Hubble Space Telescope Paper Model



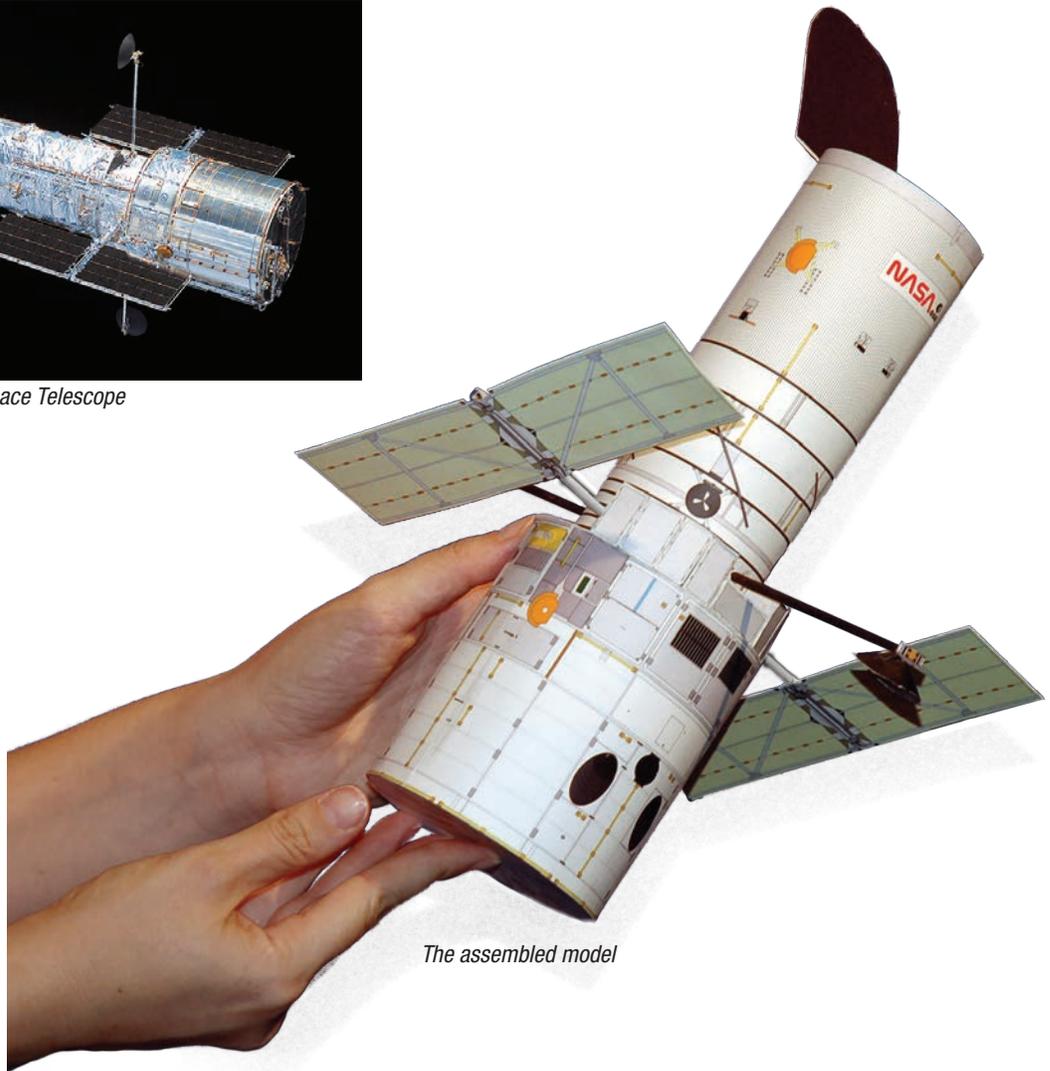
HUBBLESITE

Pattern Pieces: Print this document on cover-weight paper or cardstock.

Downloads, instructions, and other information at: www.hubblesite.org/go/model



The real Hubble Space Telescope



The assembled model

Based on a design by
Ton Noteboom

Distributed with permission by
Space Telescope
Science Institute

www.hubblesite.org



Hubble Space Telescope

This model is based on the configuration after Servicing Mission 3B, conducted by the crew of STS-109 in March, 2002

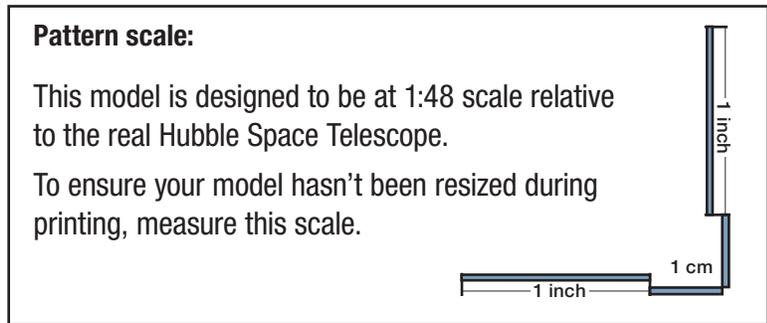
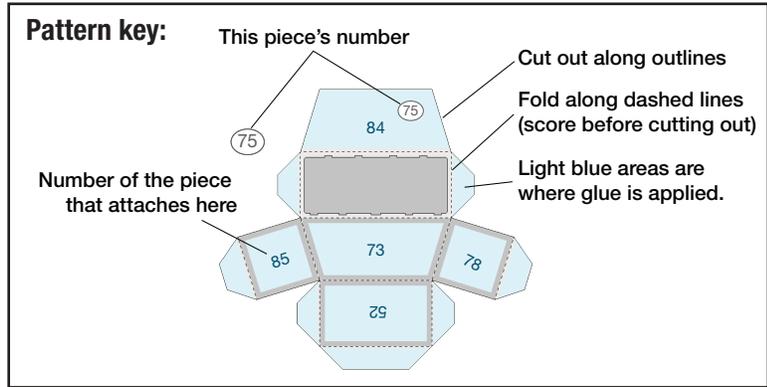


Construction tips:

When assembling your model, keep track of which pieces are which by only cutting out the pieces you need for the particular part you are assembling, and lightly writing the number of the piece in pencil on the back.

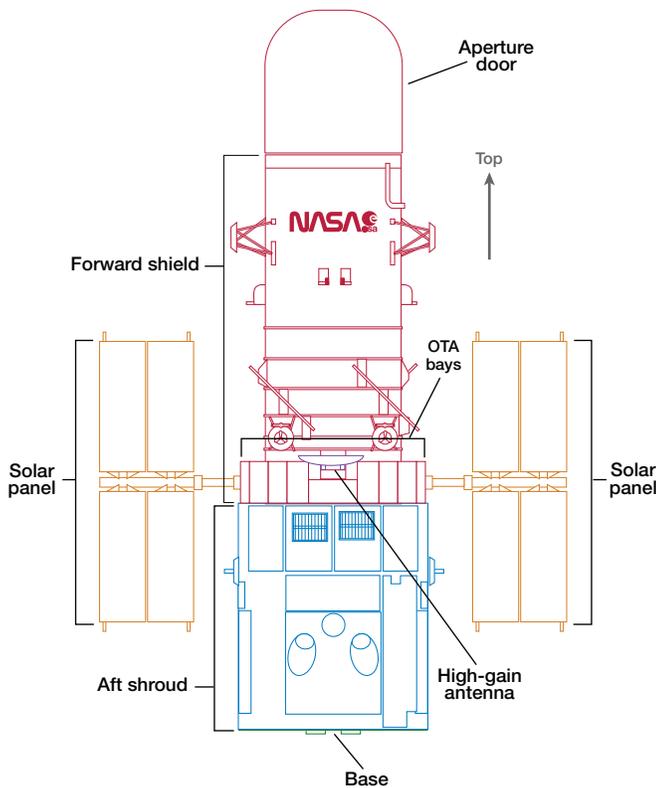
Print this pattern onto white cardstock; it looks best in color. You may want to have extra printouts handy in case you need them.

The directions (in a separate file) can be printed on regular paper in black-and-white.

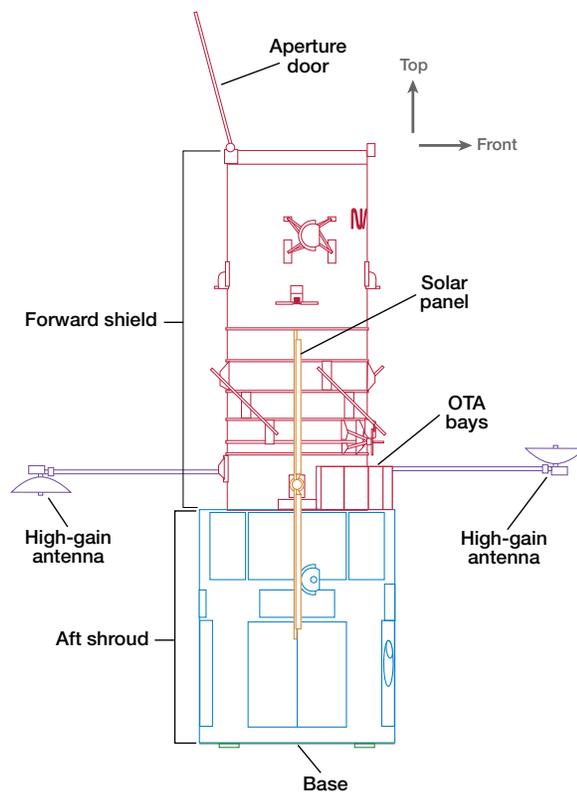


The Hubble Space Telescope

View from front

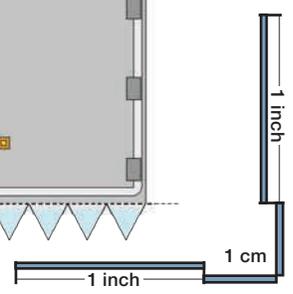
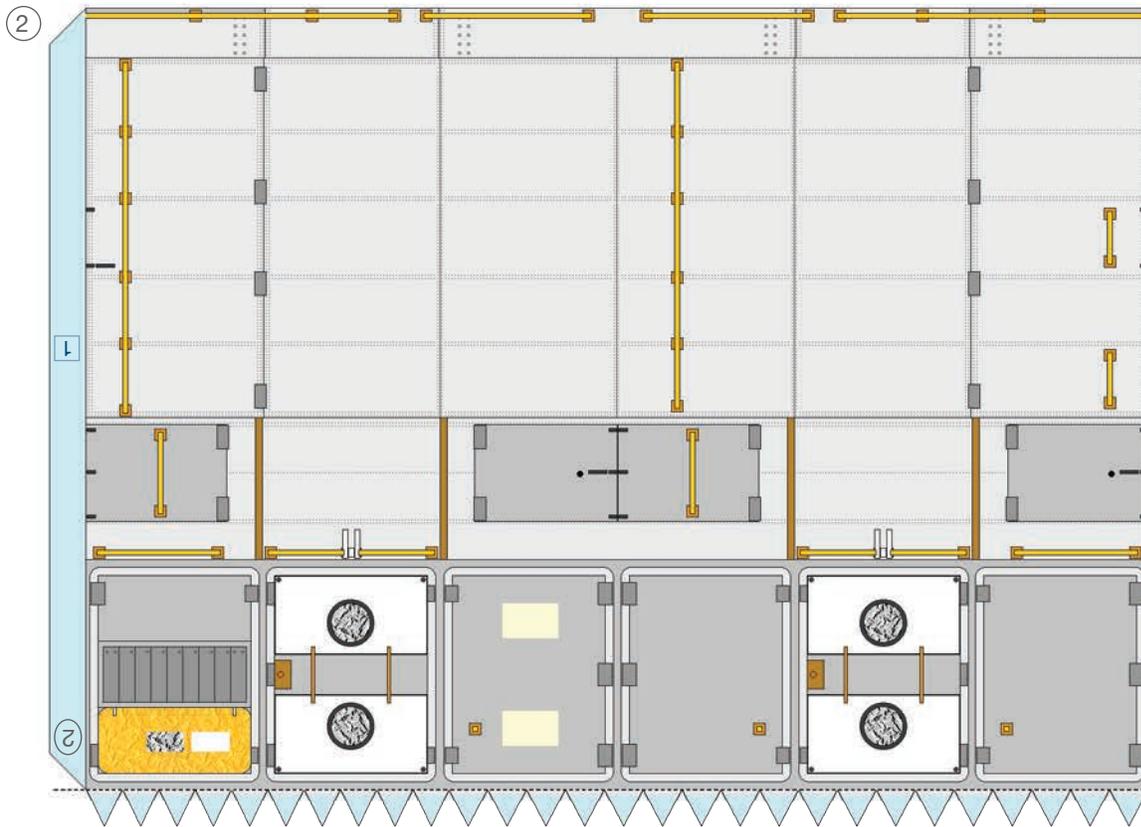
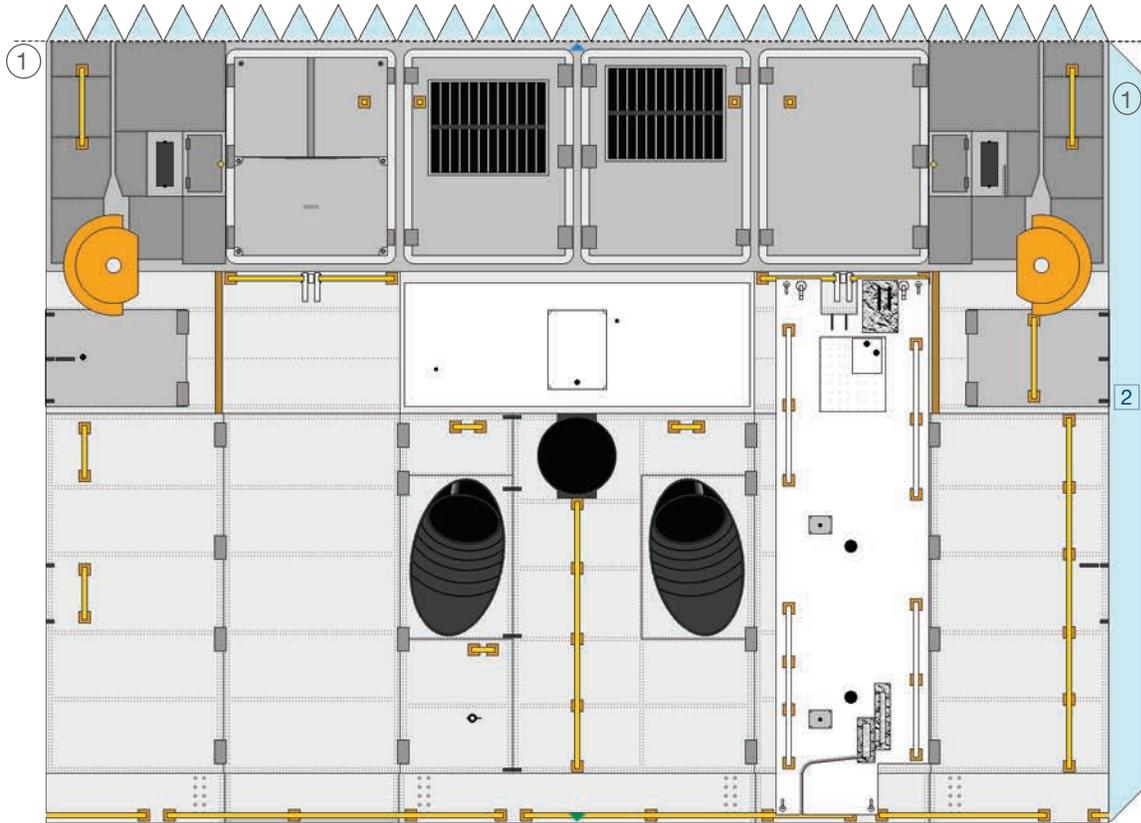


View from side

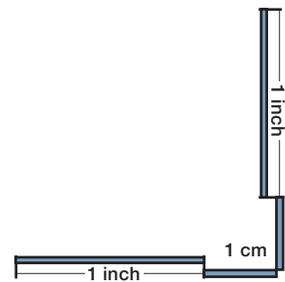
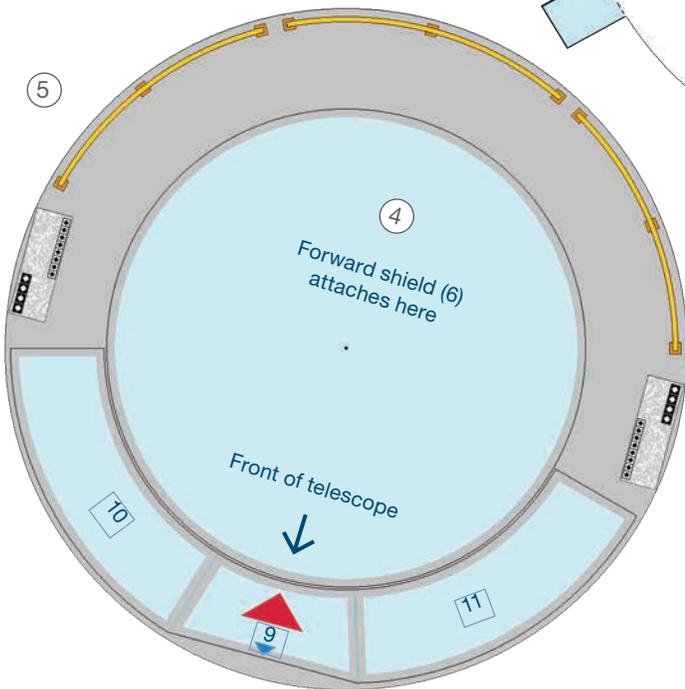
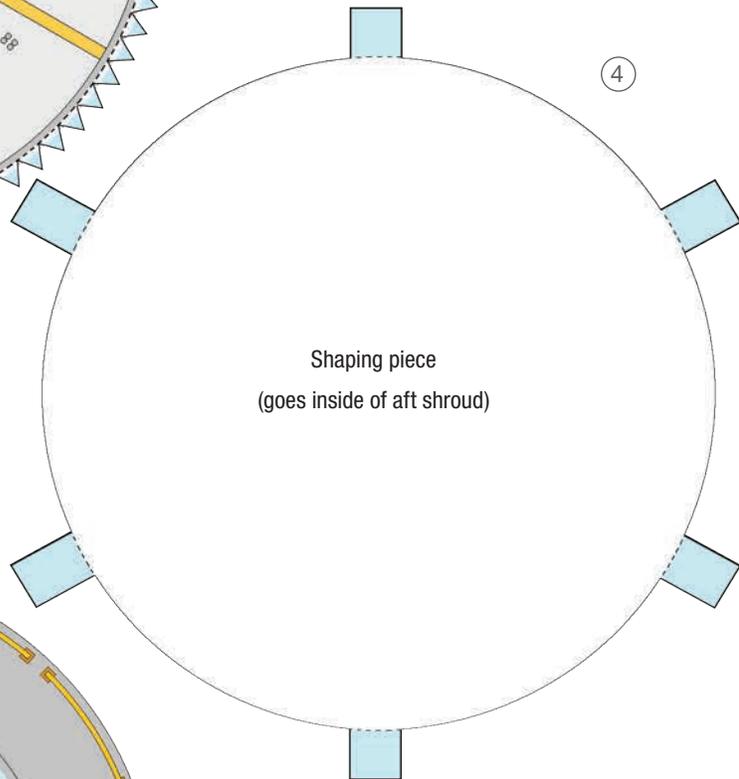
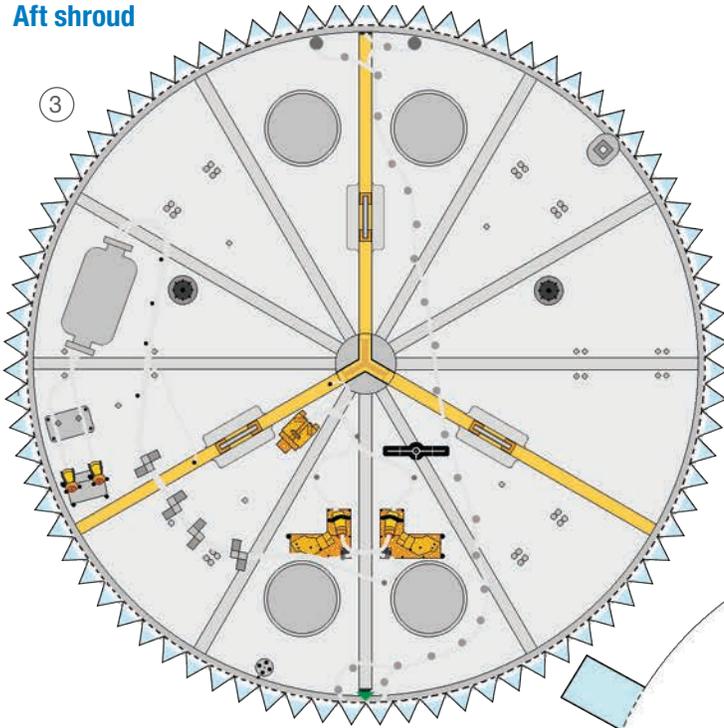




Aft shroud



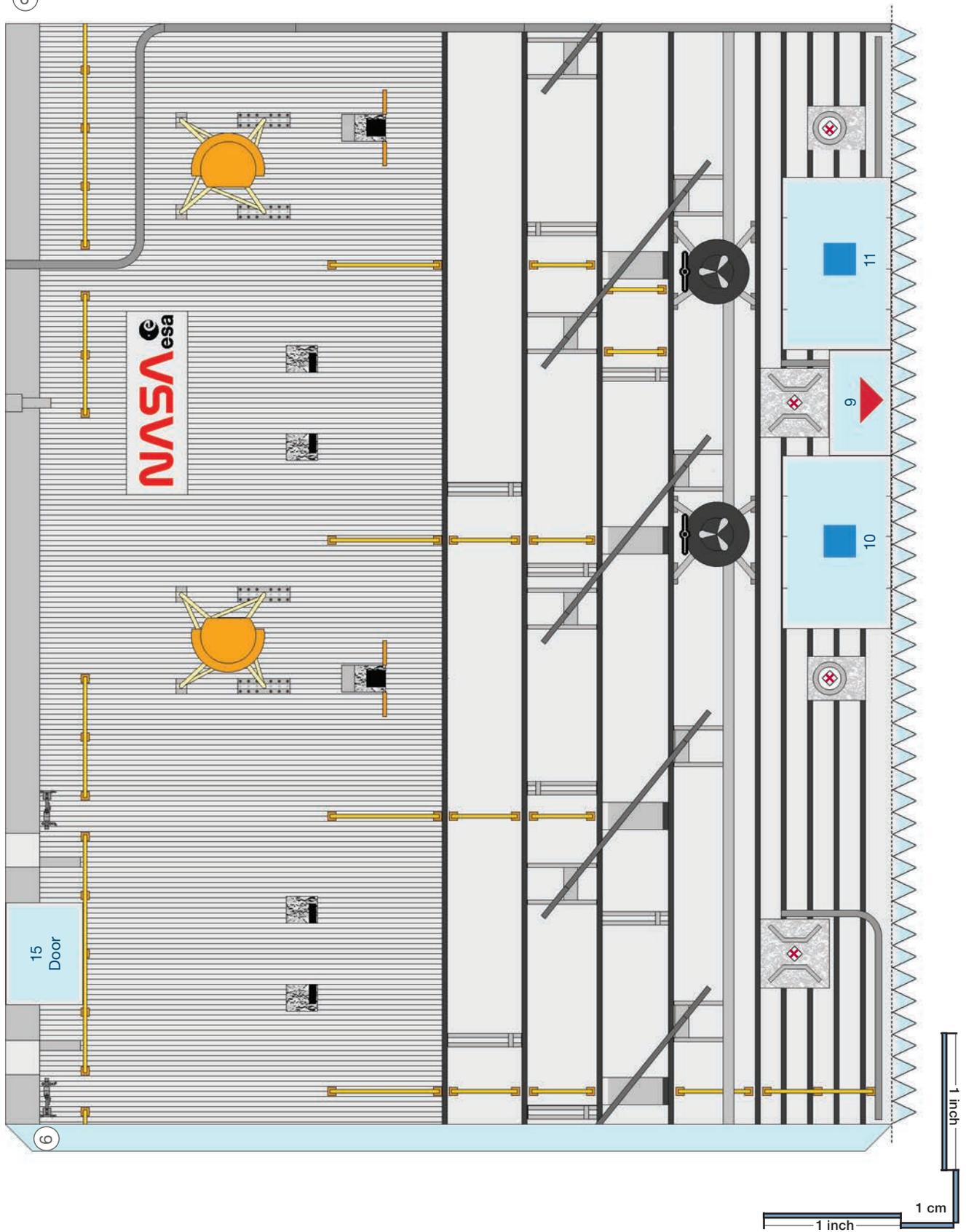
Aft shroud

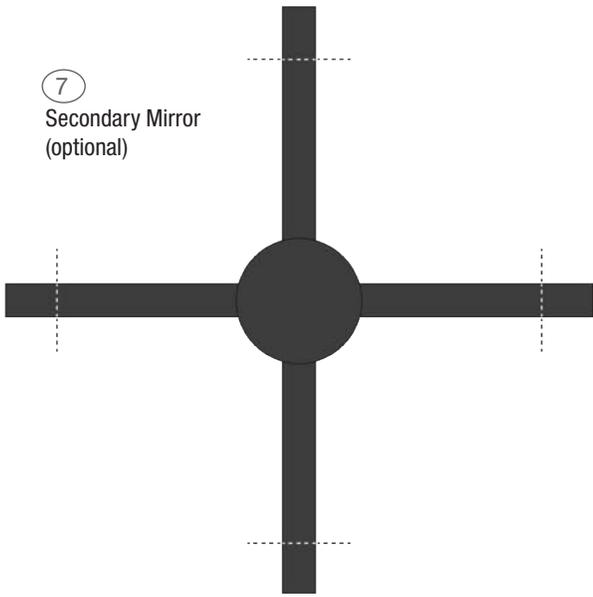


Cut out all four squares that look like: 

Forward Shield

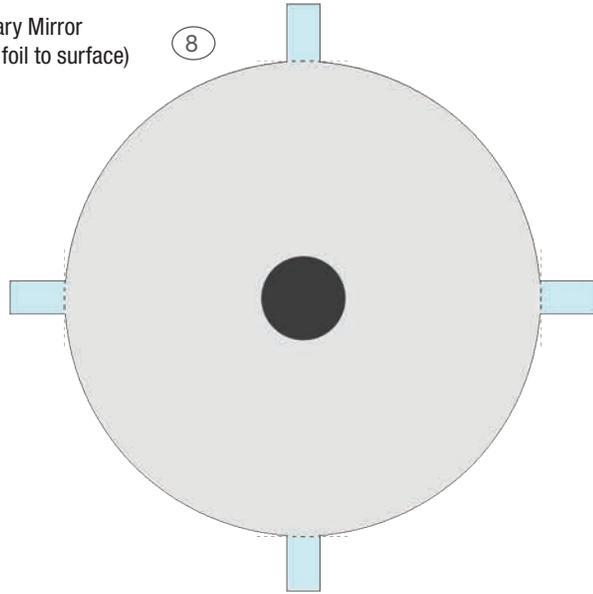
⑥





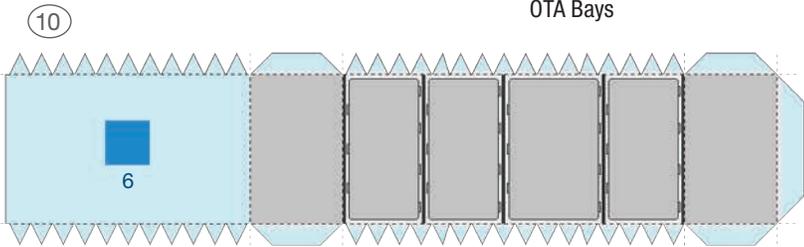
7
Secondary Mirror
(optional)

Primary Mirror
(glue foil to surface)

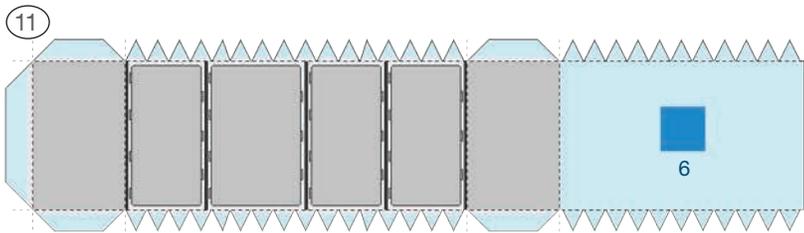


8

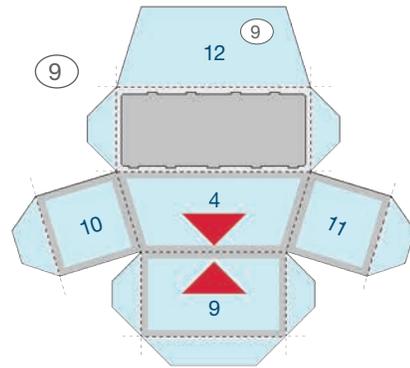
OTA Bays



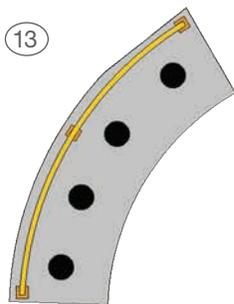
10



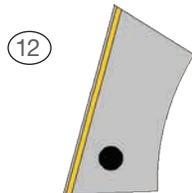
11



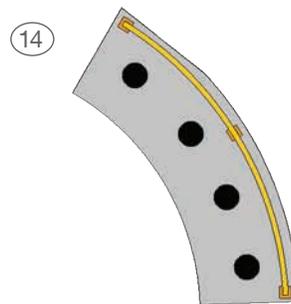
9



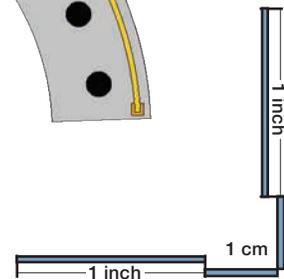
13



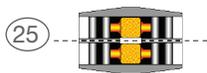
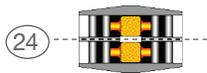
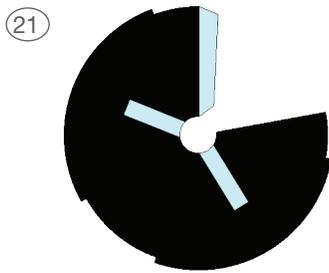
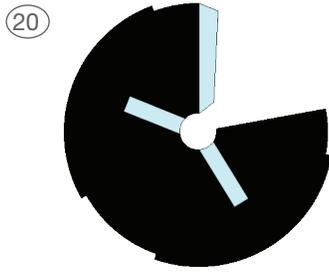
12



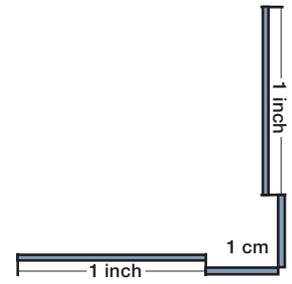
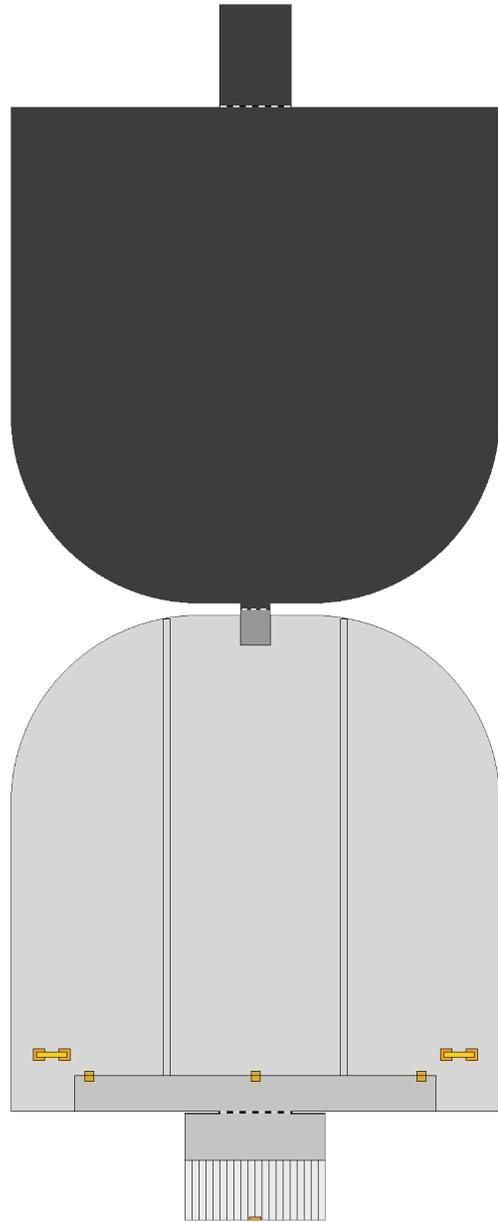
14



High-gain antenna

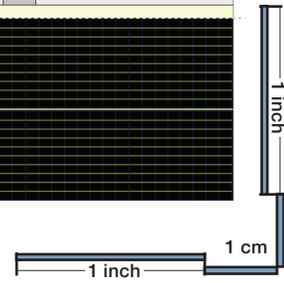
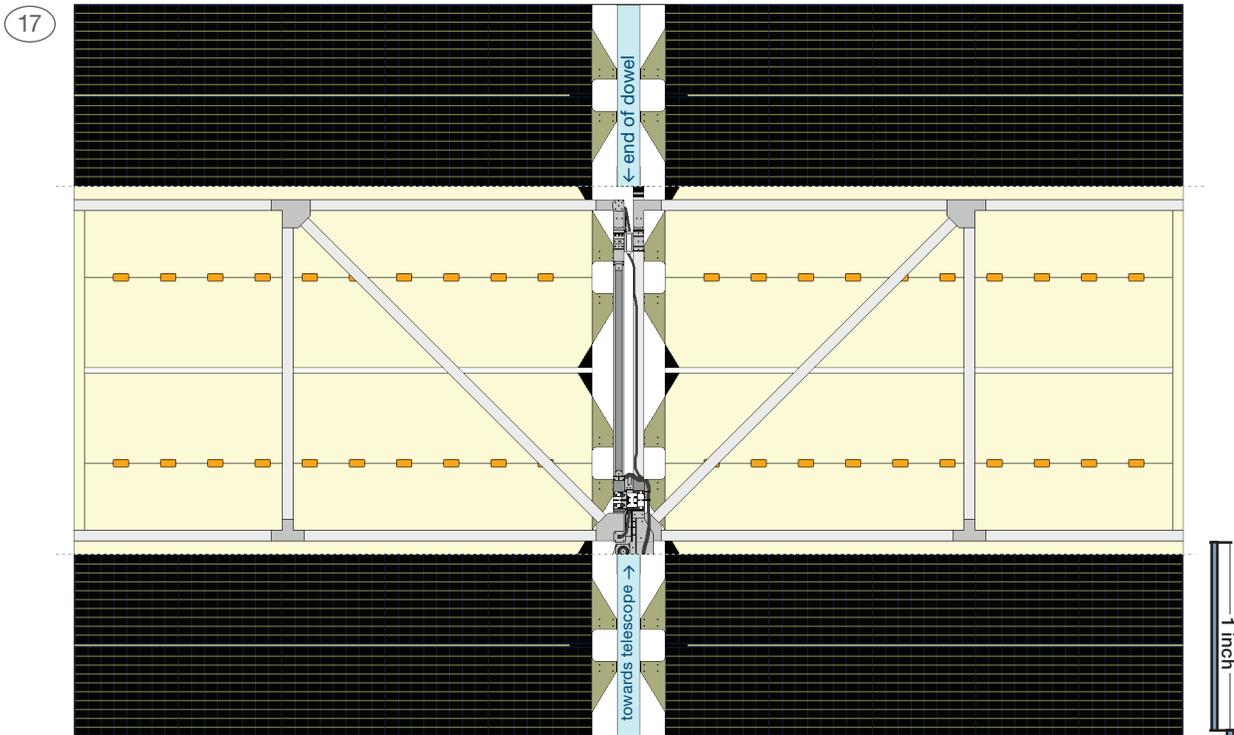
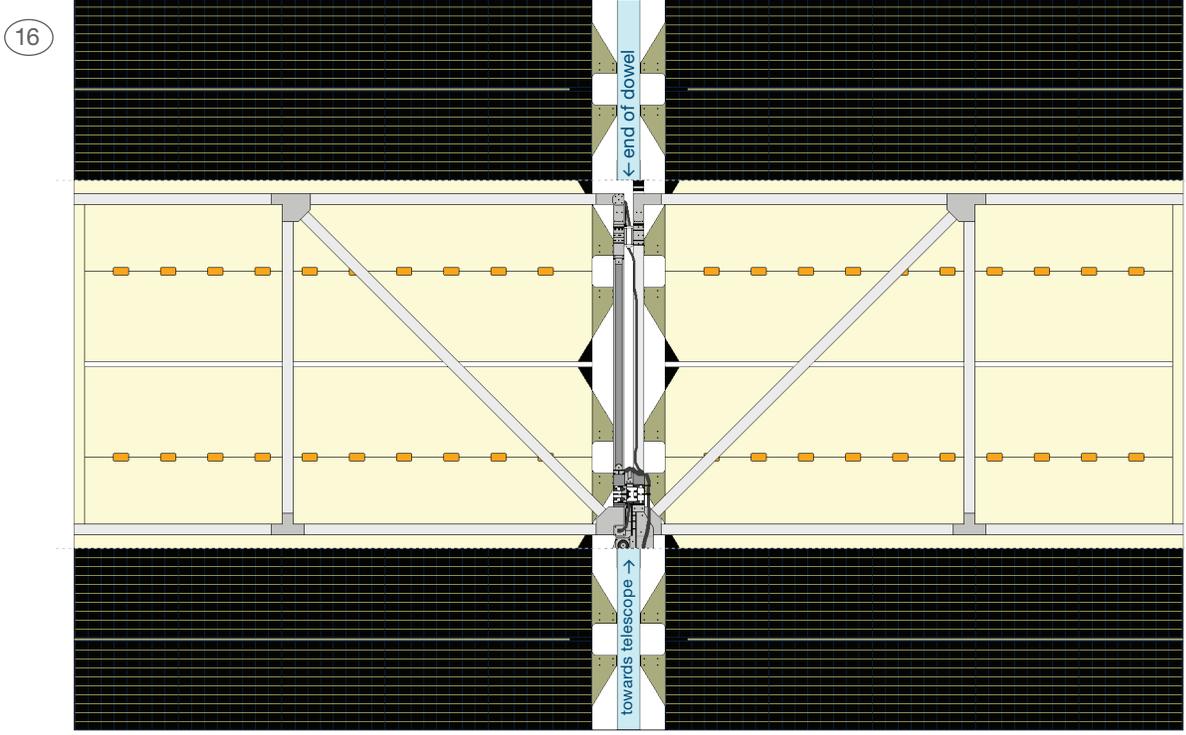


15 Aperture door



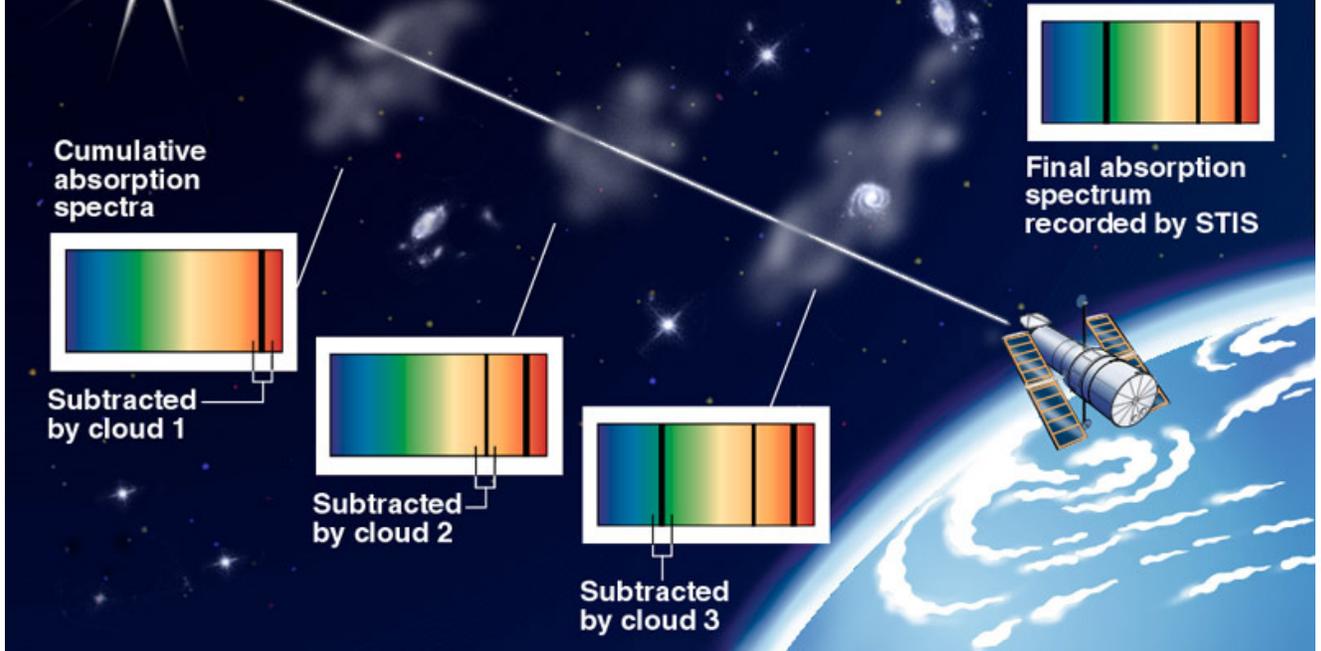
Solar Panels

dowel guide — dowels should be this length.



A STIS absorption spectrum

A beam of light coming to Earth from a distant quasar passes through numerous intervening gas clouds in galaxies and in intergalactic space. These clouds of primeval hydrogen subtract specific colors from the beam. The resulting 'absorption spectrum,' recorded by Hubble's Space Telescope Imaging Spectrograph (STIS), is used to determine the distances and chemical composition of the invisible clouds.



NASA/ESA

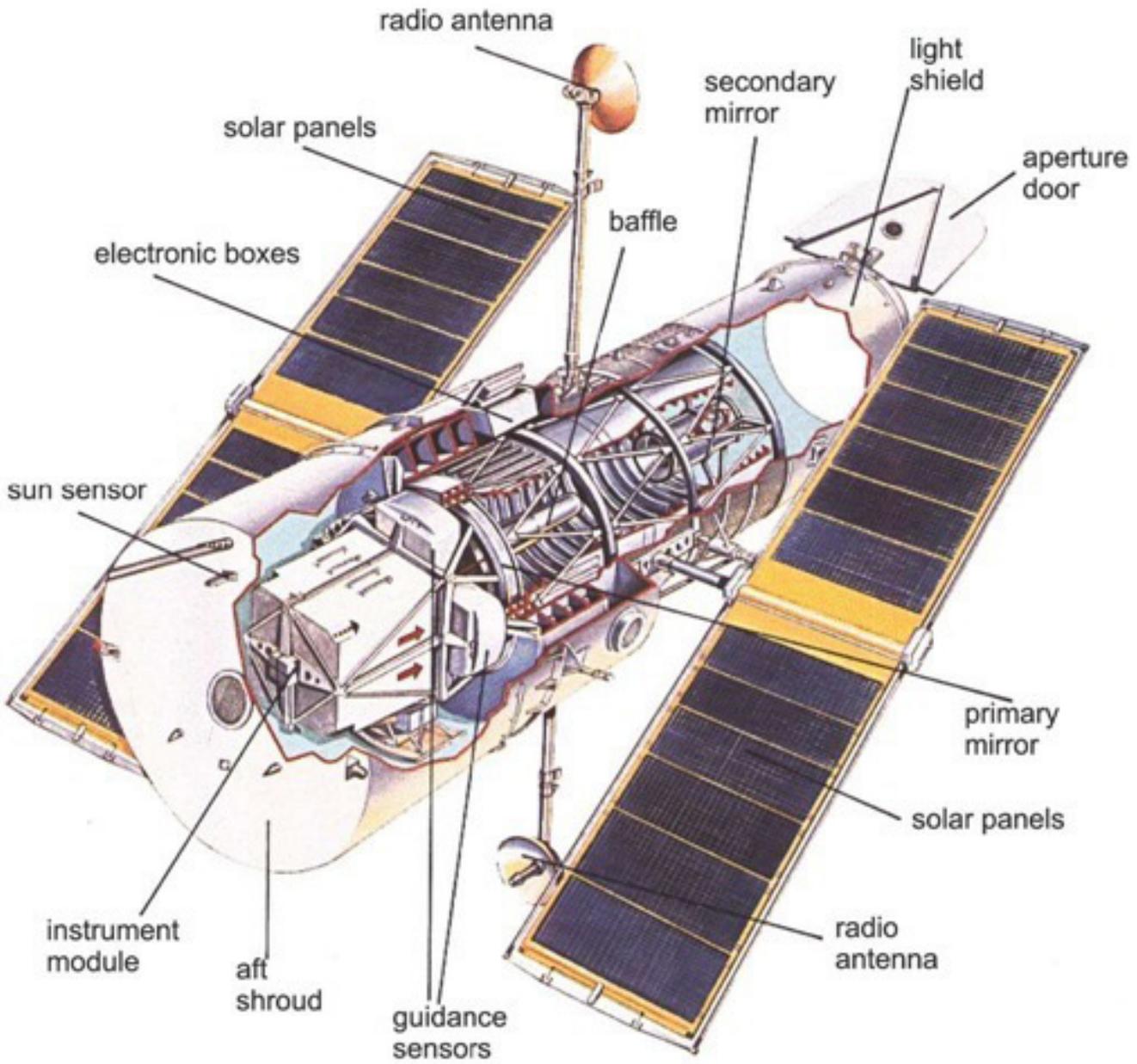
INSTRUMENTS

- **NICMOS:** Near Infrared Camera and Multi-Object Spectrometer - NICMOS has the ability to obtain images and spectroscopic observations of astronomical targets at near-infrared wavelengths.
- **ACS:** Advanced Camera for Surveys - ACS is a third-generation imaging camera. This camera is optimized to perform surveys or broad imaging campaigns.
- **WFC3:** Wide Field Camera 3: is the main imager on the telescope. It has a camera that records visible and ultraviolet (UV) wavelengths of light and is 35 times more sensitive in the UV wavelengths than its predecessor. A second camera that is built to view infrared (IR) light increases Hubble's IR resolution from 65,000 to 1 million pixels. Its combination of field-of-view, sensitivity, and low detector noise results in a 15-20 time improvement over Hubble's previous IR camera.
- **COS:** Cosmic Origins Spectrograph - focuses exclusively on ultraviolet (UV) light and is the most sensitive ultraviolet spectrograph ever, increasing the sensitivity at least 10 times in the UV spectrum and up to 70 times when looking at extremely faint objects. It is best at observing points of light, like stars and quasars.
- **STIS:** Space Telescope Imaging Spectrograph - STIS is a second-generation imager / spectrograph. STIS is used to obtain high resolution spectra of resolved objects. STIS has the special ability to simultaneously obtain spectra from many different points along a target.

- **FGS:** Fine Guidance Sensor: The FGS provides pointing information for the spacecraft by locking onto guide stars. The FGS can also function as a scientific instrument by precisely measuring the relative positions of stars, detecting rapid changes in a star's brightness, and resolving double-star systems that appear as point sources even to Hubble's cameras. Hubble has three FGSs onboard the observatory.

SOME DISCOVERIES HST HAS MADE ARE:

- Measuring distances to stars 50% more accurately.
- Refining the age of the universe.
- The prevalence of black holes in nearby galaxies.
- Hubble Deep field, Hubble Ultra-Deep Field, and Hubble Extreme Deep Field images to create the deepest ever obtained at optical wavelengths.
- Wide Field Camera 3 looked at these image areas in infrared and ultraviolet discovering the most distant object yet discovered.
- A large saltwater ocean under Jupiter's moon, Ganymede that is 60 miles deep, trapped under 90 miles of surface ice.



NASA

