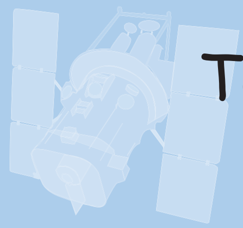
Catching Gamma-Ray Bursts on the Fly......

Swift Paper Model



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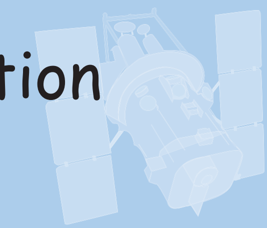
http://swift.sonoma.edu

Introduction



The Mystery of Gamma-Ray Bursts

Gamma-ray bursts (GRBs) are the most powerful explosions the Universe has seen since the Big Bang. Approximately once a day, satellites detect one of these brief, but intense, flashes of gamma radiation. They come from all different directions in the sky and last from a few milliseconds to a few hundred seconds. So far scientists only have a few clues as to what causes them.

Fortunately, besides the initial burst of gamma rays, there may be a lingering "afterglow" of X-rays and optical light revealing the GRB's location. Observations of an afterglow can give astronomers the precise position of the burst, allowing the "host" galaxy to be detected. This in turn can yield the distance to the GRB, the vital characteristic that determines other factors such as the total energy emitted by the GRB. Most GRBs with afterglows seem to be caused by supernovae in which the stellar collapse leads directly to the creation of a black hole. Still, some questions remain: do all signal the birth of a black hole in a massive stellar explosion? Are some the product of the collision of two neutron stars? Or is it another exotic phenomenon that causes some bursts?

NASA's Swift satellite may give scientists the tools they need to answer these questions and possibly solve the gamma-ray burst mystery. Its three instruments will give scientists the ability to scrutinize gamma-ray bursts like never before. Within seconds of detecting a burst, Swift will relay a burst's location to ground stations, allowing both ground-based and space-based telescopes around the world the opportunity to observe the burst's afterglow.

Background Information

The satellite weighs about 1550 kg and is about 5.6 m high and 5.4 m wide including the solar panels. Swift is able to swivel from one object to another in seconds, and detects over 100 bursts a year! The Swift mission's purpose is to precisely locate gamma-ray bursts, and study these amazing sources of energy, including the afterglows.

The Instruments: Swift's 3 instruments work together to glean as much information about each burst as possible.

- BAT (Burst Alert Telescope): The initial instrument on-board Swift is the BAT. It will detect and locate about two gamma ray bursts per week, relaying a 1-4 arc minute position to the ground within ~ 15 seconds. This position will then be used to "swiftly" and autonomously repoint the spacecraft to bring the burst area into the narrower fields-of-view of the instruments that have been designed to study the afterglow: The XRT and UVOT.

- XRT (X-Ray Telescope): The XRT is one of Swift's two narrow-field instruments. The XRT refines the BAT localization to 5 arcseconds accuracy, and measures fluxes, spectra, and light curves of GRBs and afterglows.

- UVOT (Ultra-Violet/Optical Telescope): This is a 30-cm reflecting telescope. The UVOT further improves the BAT and XRT localizations, giving a position to 0.3 arcsecond accuracy. The filtered observations acquired reveal the behavior of the burst and afterglow over time in different colors.

Swift will launch in 2004, on a Delta 2320 vehicle from the Cape Canaveral Air Force Station, Cape Canaveral, Florida. For detailed descriptions of Swift's instruments and science goals, see **http://swift.sonoma.edu**

Credits:

The Swift paper model original idea was developed by Monica Sperandio from the Public Outreach and Education sede di Merate, Osservatorio Astronomico di Brera, in Italy. This version of the Swift paper model was developed by Aurore Simonnet in the NASA Education and Public Outreach group at Sonoma State University, California, under the direction of Professor Lynn Cominsky.

Contributors include: Phil Plait, Logan Hill, Jen Price, Michelle Curtis, Gray Slater, Louis Barbier, Pete Roming, Ed Fenimore, Oren Sheinman and Guido Chincarini.

For Teachers

Note:

This material is not primarily designed to be used as a classroom activity, but can still be used as a supplementary school project.

Some guidelines are provided for the teachers who would like to use the **Swift Model** as a classroom acitvity.

The Swift Model as a Classroom Activity

Objective:

The students will build a paper model of the Swift satellite.

If this activity is done in a classroom, the students will learn about the different instruments Swift will be using to detect and analyze gamma-ray bursts. They will also gain vocabulary skills.

Procedure:

Briefly introduce the Swift satellite instruments and get the students excited about putting together a paper model of the spacecraft. As the students are cutting out the different parts, describe the various components of the Swift satellite by using the Background Information provided on page 1, and the website.

Remind the students to look for the "About " sections written in blue ink, which are located on the side bar of the instruction pages.

Have the students work in groups or individually. They should follow the instructions beginning on page 4.

Have the groups or individuals draw a sketch of the Swift satellite and label the different parts.

Have the students add words to the Glossary on page 13, with words they encountered for the first time by looking up their meaning in a dictionary or on the web.

Assessment:

4 Points
- Model assembled correctly and neatly
- Drawings are complete and labeled
- Words were added to the glossary

3 Points
- Model assembled correctly
- Drawings are complete and labeled

2 Points
- Model assembled correctly
- Words added to the glossary

1 Point
- Words were added to the glossary

0 Points
- No work done

Extension Activities:

Have the students report on the various components of the Swift satellite.
Have the students research and report on other NASA satellite missions.

Material List

You will need:

- 1 wooden stick or bamboo skewer about 30-32 cm long and 2-3 mm thick
- Glue: white glue, hot glue, or mini glue scrapbook dots
- A pair of scissors
- Blade (Xacto Knife)
- Silver paint
- A small paintbrush
- Silver sticky tape (such as duct or gaffer tape)
- Ruler
- Optional: aluminium foil to use instead of the silver paint

Tips are often provided on each page to help you build your model. When you come across this symbol " " look on the side bar or margin of the current page to read the tip in red ink.

Also look for this symbol "" which indicates the "About" section in the side bar, to learn more about the part you are building.

This warning symbol indicates that the supervision of an adult is recommended.

Tip:

All the parts on card stock should be scored on the reverse side before folding.

Main Body

Section A:

A1. Start with the main body parts on pages 15 - 17, figures 1, 2 and 3. You should have the 2 main body parts, plus the base.

A2. Cut out each part. Put the base aside, as you will use it later.

A3. Fold figure 1 and 2 along the continuous dark lines. Glue the two main body parts by overlapping the edge of figure 2 over the flap with the blue star of figure 1. This gives you a parallelepiped with an octogonal base. ⚠

⚠ If you use hot glue, be very careful. (Ask an adult to help you if necessary.)

A4. With your Xacto knife poke a hole in the two silver circles, This is where the 30 cm stick of the solar panels will be inserted later (diagram 1). Ask an adult for help!

You now have the main body part of the Swift satellite. Next you will add the accessories boxes and reaction wheel assemblies.

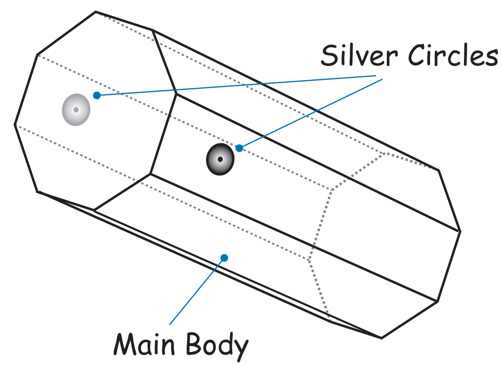


Diagram 1

Section B:

Paint the long wooden stick with silver paint, and set it aside. You will use it later for the solar panels.

Accessories

Section C:

C1. Proceed to the accessories boxes found on page 18, figure 4.

C2. Cut out all the parts: A1, A2, B1, B1 top, B2, and T1. Make A1, A2, and T1 into boxes.

For help with assembling the boxes (see right side bar).

C3. **Figure 4: assembling parts B1 and B1 top**
Make B1 into a box and glue B1 top on B1 (diagram 2).

C4. Glue all boxes on the main body as shown on diagram 3.

C5. Part B2 does not need to be folded. It is glued on the Main Body as in diagram 3.

Note: T1 will be used later.

Section D:

D1. Proceed to the accessories boxes, page 19, figure 5.

D2. Cut out the boxes and other parts: two C1s, C2, C3 Upper, C3 Lower, and C3 Base.

D3. **Figure 5: assembling C1s, C2, C3 U, C3 L and C3 Base:**
Fold C3 Base along the dark lines. Each side will be left "floating" (not attached) on the main body part. Make and glue boxes C3 U and C3 L on part C3 (diagram 4). Then, glue all the assembled parts on the main body.

You can learn about the role of the accessories, which make up a few of the Swift satellite's components, on page 14.

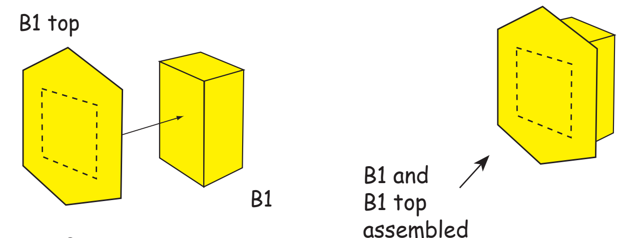


Diagram 2

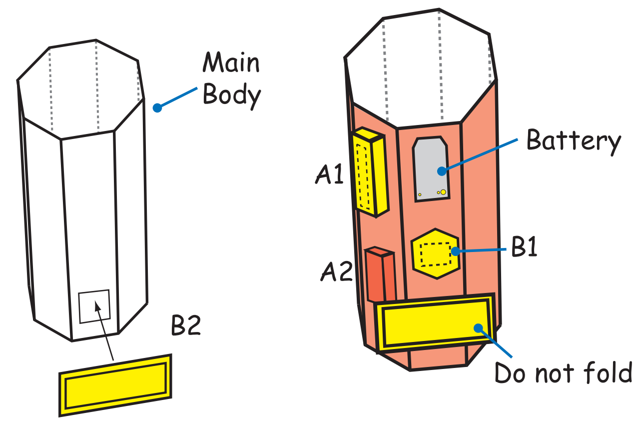


Diagram 3

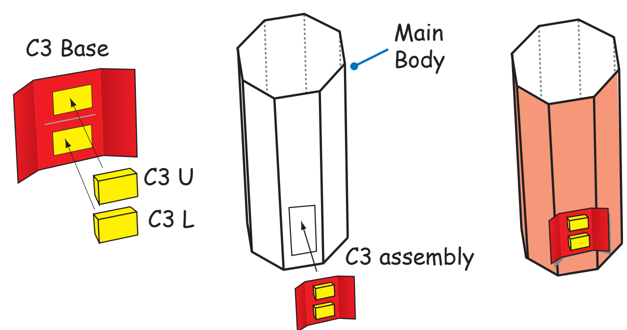


Diagram 4

Assembling Boxes
Fold all boxes along the continuous dark lines. Fold and glue the flaps to form each box. Glue the boxes on the main body as you build them.

For a detailed description of the accessories boxes, see page 14.

Tip:

If you decide to make all the accessories first and glue them on the main body all at once, you should label the parts that are not already labeled to remember what they are and where they should be placed on the main body.

Reaction Wheel Assemblies and Optical Bench

Tip:
Trace a line on the inside of D "top" part as a guide to fold it in half.

About Reaction Wheels:

Swift uses heavy spinning disks called "reaction wheels" to turn and point the spacecraft. The Magnetic Torque Rods (the 3 silver bars on the main body) use the Earth's magnetic field to help Swift maintain its ability to turn "swiftly".

About Optical Bench:

A very stable platform at the top of the satellite onto which the 3 telescopes are mounted.

Section E:

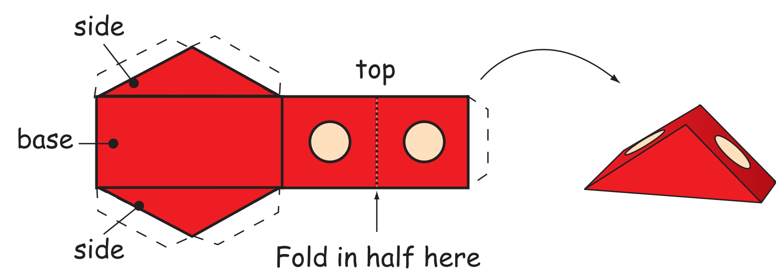
Reaction Wheel Assemblies

E1. Proceed to the Reaction Wheel Assemblies, page 20, figure 6.

E2. Cut out the 3 D parts.

E3. Fold the triangular-shaped box along the continuous dark line. Then fold the part of the box with the two beige circles in half to shape the box as a pyramid (diagram 5). Fold and glue the flaps to form the box. Repeat for all three Reaction Wheel Assemblies.

E4. Glue the three Reaction Wheel Assemblies (D) on the main body.



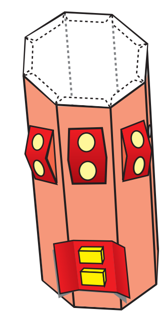


Diagram 5

Optical Bench

Section F:

F1. Proceed to the Optical Bench, pages 21 - 22, figures 7 and 8.

F2. Cut along the circle edge. Glue both parts together back to back.

F3. Cut out 4 slits along the red lines for the Sun Shade (diagram 6).

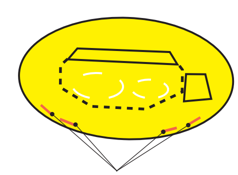
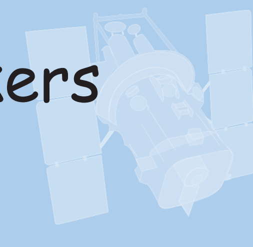


Diagram 6

Next you will assemble the parts that will be glued on the optical bench: BAT, Star Trackers, XRT & UVOT.



Section G:

BAT: Burst Alert Telescope

G1. Proceed to the BAT, page 23, figure 9 .

G2. Cut out the part.

G3. Fold the BAT along the dark lines and glue the flaps together, (diagram 7).

G4. You will glue the BAT on the Optical Bench later on.

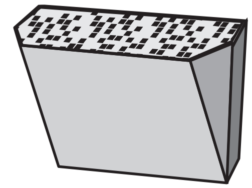


Diagram 7

Section H:

Star Trackers

H1. Proceed to the Star Trackers system (twoT2s and base) page 24, figure 10.

H2. Cut along the crossed slits on the two white circles of the Star Tracker base (diagram 8) and gently run a pencil through. Fold the box along the dark lines and glue the flaps together to form a box.

H3. Roll up and glue the Star Trackers (T2) to form two cones. You will glue them on the base you just built (diagram 9). To glue T2 on the base: put glue on the white circles where you cut the crossed slits and insert the cones through as far as it will go.

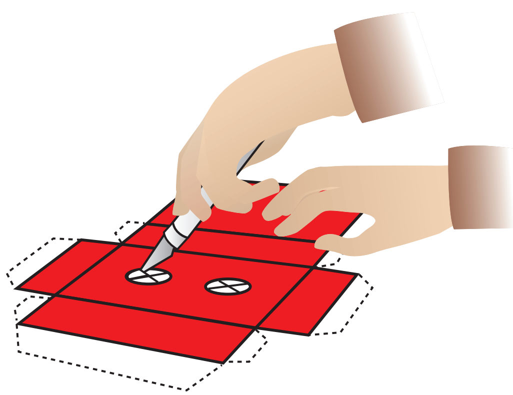


Diagram 8

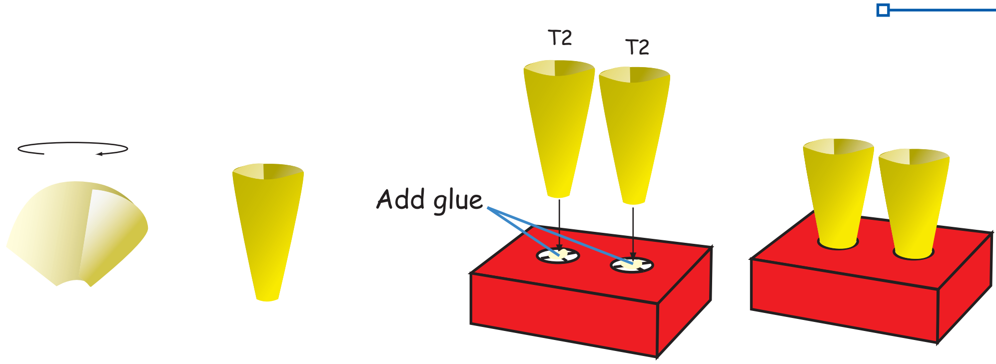


Diagram 9

About BAT:

The main instrument on board Swift is the BAT. Gamma rays pass through a coded aperture mask at the top of the BAT, and then are "seen" by BAT's Cadmium-Zinc-Telluride detectors.

About Star Trackers:

Star trackers are visible light telescopes that observe bright stars to determine which way the satellite is pointing.

XRT and UVOT

About XRT

The XRT uses CCDs to detect X-rays from GRBs after the X-rays are focused using a nested series of grazing incidence mirrors.

Tip:

You can also cut and paste a piece of aluminum foil on top of the mirror to make it look shinier.

About UVOT

The UVOT uses a CCD to detect optical and ultraviolet light, counting each photon as it hits the detector.

Section I:

I1. Proceed to the XRT, Mirror, UVOT, and inside covers, page 25, figure 11.

XRT: X-Ray Telescope

I2. Cut out the XRT and be careful not to detach the top circle which represents the "Mirror Module Cover" for the XRT.

I3. Cut out the XRT inside cover and glue it on the white side of the XRT cover.

I4. Roll up the XRT into a cylinder and glue the flap to the opposite edge.

I5. Fold the flap of the mirror and glue it inside the XRT at a depth of about 1 cm from the top (diagram 10).

UVOT: Ultra Violet Telescope

I6. Cut out the UVOT and be careful not to detach the cover.

I7. Cut out the UVOT inside cover and glue it on the white side of the UVOT cover.

I8. Roll up the UVOT into a cylinder and glue the flap to the opposite edge. The UVOT looks similar to the XRT.

Next you will assemble the XRT and the UVOT on the Optical Bench.

Fold and glue where indicated on the Optical bench, the three flaps of each cylinder (diagram 11) .

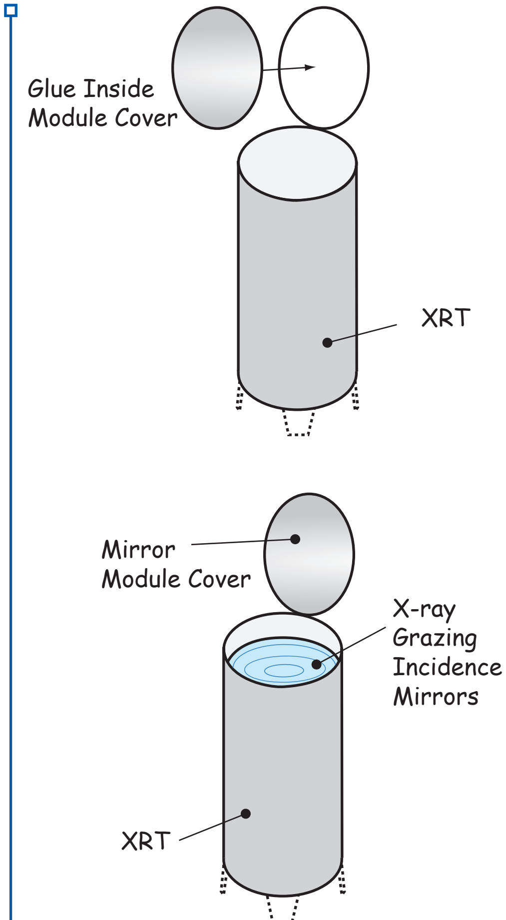


Diagram 10

Optical Bench Top view

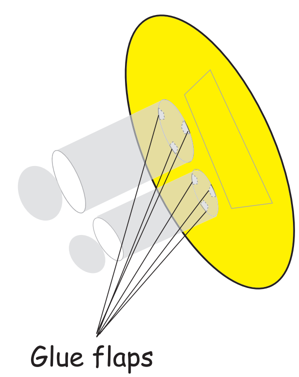


Diagram 11

Sun Shade

Section J:

J1. Proceed to the **Sun Shade**, page 26, figure 12.

J2. Cut out the part.

J3. Fold in half along the dark continuous lines, and glue the sides back to back with the silver and dark sides facing out. Then fold the sides in along the lines so the silver side faces out (diagram 12).

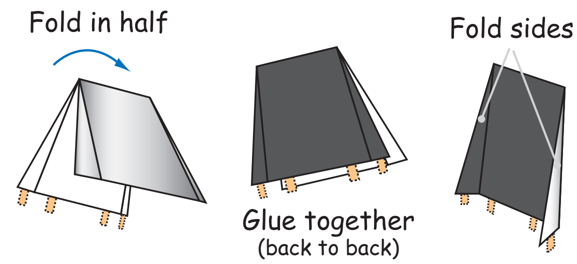


Diagram 12

Next you will assemble the BAT, T1, the Star Trackers, and the Sun Shade on the Optical Bench:

J4. Attach the Star Trackers onto the XRT so that the edge of the cones aligns to the XRT top edge, using the silver tape (diagram 13).

J5. Glue the BAT and T1 box on the Optical Bench. The large flat side of the BAT faces the XRT and UVOT.

J6. Place the Sun Shade on the Optical Bench by inserting the flaps through the 4 red slits in front of the XRT and UVOT. The dark side of the Sun Shade should face the XRT and UVOT.

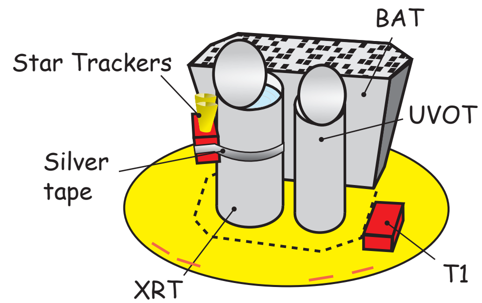


Diagram 13

J7. Fold and glue the flaps under as shown on (diagram 14).

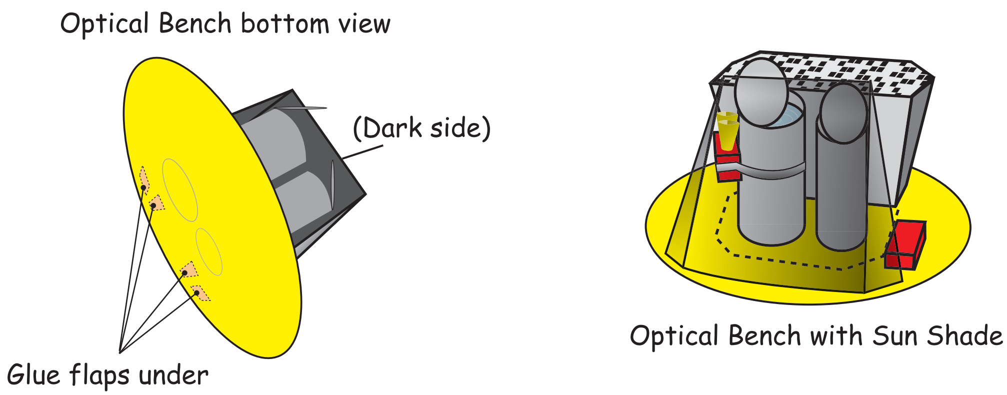
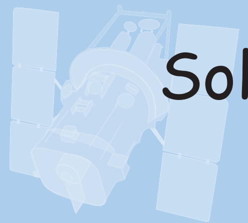


Diagram 14

About Sun Shade:

Heat and light from the Sun can interfere with observations made by space-based telescopes. To prevent that, a large shade is mounted on the top of Swift to block the sunlight from hitting the telescopes. The sunward side of the shade is made of a shiny material to reflect away the sunlight, and the other side is black to prevent the reflection of light into the telescopes.

Solar Panels



Tip:

You could sharpen each end of the stick with the blade to make it thinner and flatter before gluing in the Solar Panel Support shape

⚠ Ask an adult for help if necessary.

About Solar Panels:

The solar panels convert sunlight into electricity used to power Swift. This is called "the photoelectric effect", and was first explained by Albert Einstein, who won the Nobel Prize for it in 1921!

Section K:

The Solar Panel Support

K1. Proceed to the Solar Panel Support, page 27, figure 13.

K2. Cut out and fold each Solar Panel Support shape in half.

K3. Glue one end of the 30 cm long wooden stick in the middle of **one** folded surface (diagram 15). DO NOT glue the other end of the stick on the other Solar Panel Support shape yet!

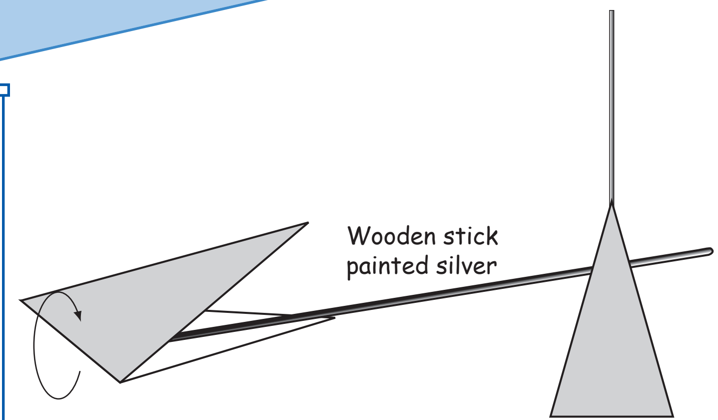


Diagram 15

Section L:

Solar Panels

L1. Proceed to the Solar Panels, pages 28 - 29, figures 14 and 15.

L2. Cut out the solar panels. Fold each panel in half. Glue the panel support assembly between one solar panel half, about half way through the middle, centered on the long side (diagram 16), and glue the edges of the solar panel together.

L3. Insert the stick of the solar panel assembly in the main body through one gray circle until it comes out through the other circle.

L4. Finish assembling the other solar panel support and solar panel following the instruction of section K3 - L2.

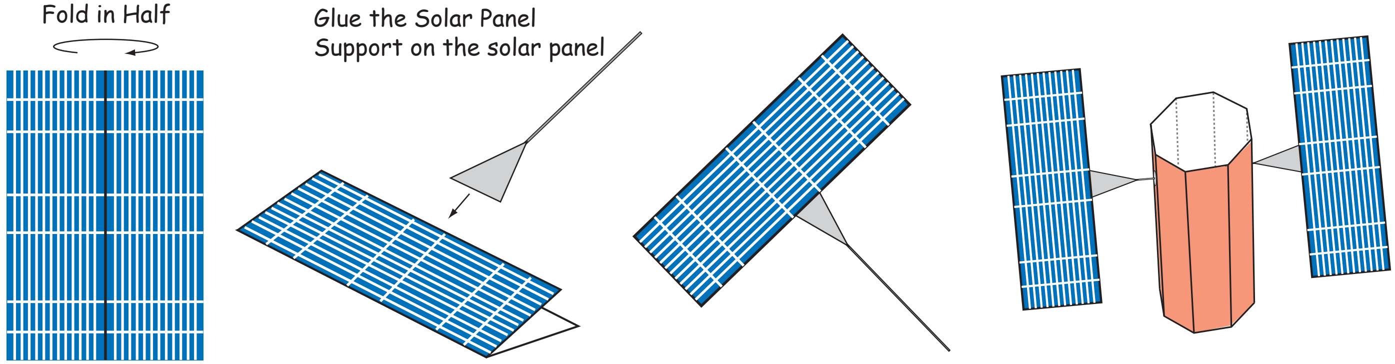


Diagram 16

Final Steps!

- Now glue the bottom part of the model (the octogonal shape) to the main body assembly
- Glue the Optical Bench assembly to the Top of the main body.

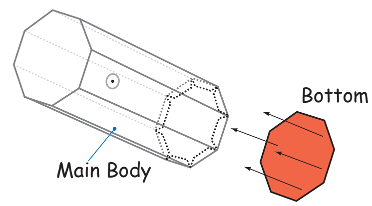
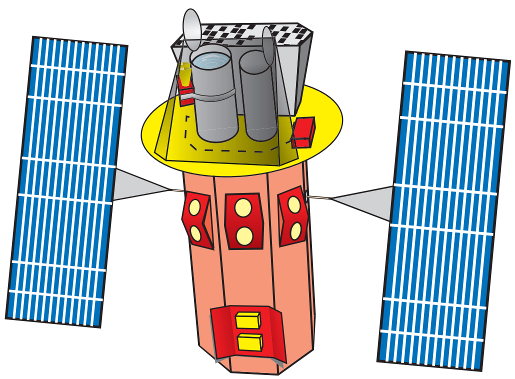


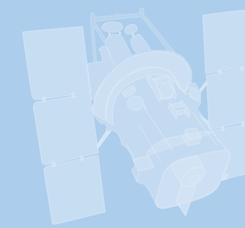
Diagram M

You're done!



Glossary

- **Arcminute:** an angular unit that is $1/60^{th}$ of a degree
- **Arcsecond:** an angular unit that is $1/60^{th}$ of an arcminute or $1/3600^{th}$ of a degree.
- **Afterglow:** the lingering emission from a GRB in lower energies (such as X-ray, ultraviolet and optical light) that may last from days to weeks.
- **CCD:** an abbreviation of "Charge Coupled Device", a CCD is a digital detector that is very sensitive to photons. Household digital cameras use a CCD to detect visible light instead of film. CCDs can also be manufactured to detect X-rays.
- **Cadmium-Zinc-Telluride (CZT) detectors:** a detector sensitive to higher energy x-rays and gamma rays. There are 32,768 CZT detectors in the BAT.
- **Coded Aperture Mask (CAM):** the "lid" of the BAT which is a grid of open and closed squares in a semi-random pattern. The CAM grid casts a gamma-ray shadow on the detectors, which can be used to determine the direction to the GRB.
- **Degree:** an angular unit that is $1/360^{th}$ the circumference of a circle.
- **Gamma ray:** the highest energy form of light. A gamma ray has at least 10 million times the energy of a visible light photon.
- **Gamma-ray Burst (GRB):** a brief but intense flash of gamma rays that comes from space. GRBs may release more energy in a second than the Sun does over its lifetime.
- **Grazing Incidence Mirrors:** X-rays pass through conventional mirrors, so Swift uses cylindrical mirrors made of metal that are nested inside one another like the layers of an onion. X-rays hit (graze) the mirrors at a low angle and are focused onto the detectors.
- **Ground station:** a facility on the Earth's surface used to capture the data transmitted from satellites.
- **Neutron:** a subatomic particle with no charge found in the nucleus of atoms.
- **Neutron star:** the core of a massive star after the star explodes as a supernova; the core is made up almost entirely of neutrons.



Optical Bench: a very stable platform at the top of the satellite onto which the three telescopes are mounted.

Optical telescope: a telescope designed to detect the kind of light seen by the human eye.

Photon: a particle of light. The energy of the photon determines what we call it; for example, visible, ultraviolet, x-rays or gamma-rays.

Reflecting telescope: a telescope that uses a mirror to reflect incoming light into a detector. Most large visible light telescopes are reflectors.

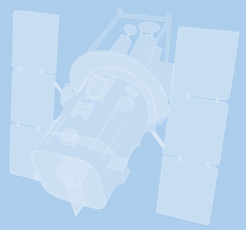
Supernova: a star that explodes at the end of its lifetime. Black holes and neutron stars are formed from the core of a star that goes supernova.

Ultraviolet: light that has more energy than a visible light photon, but less than an X-ray.

Visible light (also known as optical light): the kind of light our eyes can see.

X-ray: a photon that has more energy than ultraviolet photon, but less than a gamma ray.

X-ray telescope: a telescope designed to detect X-rays.



About the Accessories

A1: The BAT Power Supply (PS) distributes power to the BAT.

A2: The Solid State Recorder (SSR) houses the computer that controls the Spacecraft and all its functions. It is also where all the data from the instruments and observatory are stored before being transmitted to the ground.

B1: The Integrated Electronics Module (IEM) controls the signals from all the detectors to the spacecraft bus.

B2: XRT Radiator: A piece of metal, coated with a high emissivity paint, that is always pointed to a cold part of space in order to radiate the heat from the XRT's CCD. This keeps the CCD at temperatures less than -100 C.The heat is transferred from the CCD to the Radiator by means of heat pipes much the same as a car radiator.

C1s: The two BAT Image Processors (IP) house the computers that control the BAT and process the science data. One unit is prime and the other is redundant. The active IP triggers the imaging algorithm and burst alert messages indicating a potential new GRB.

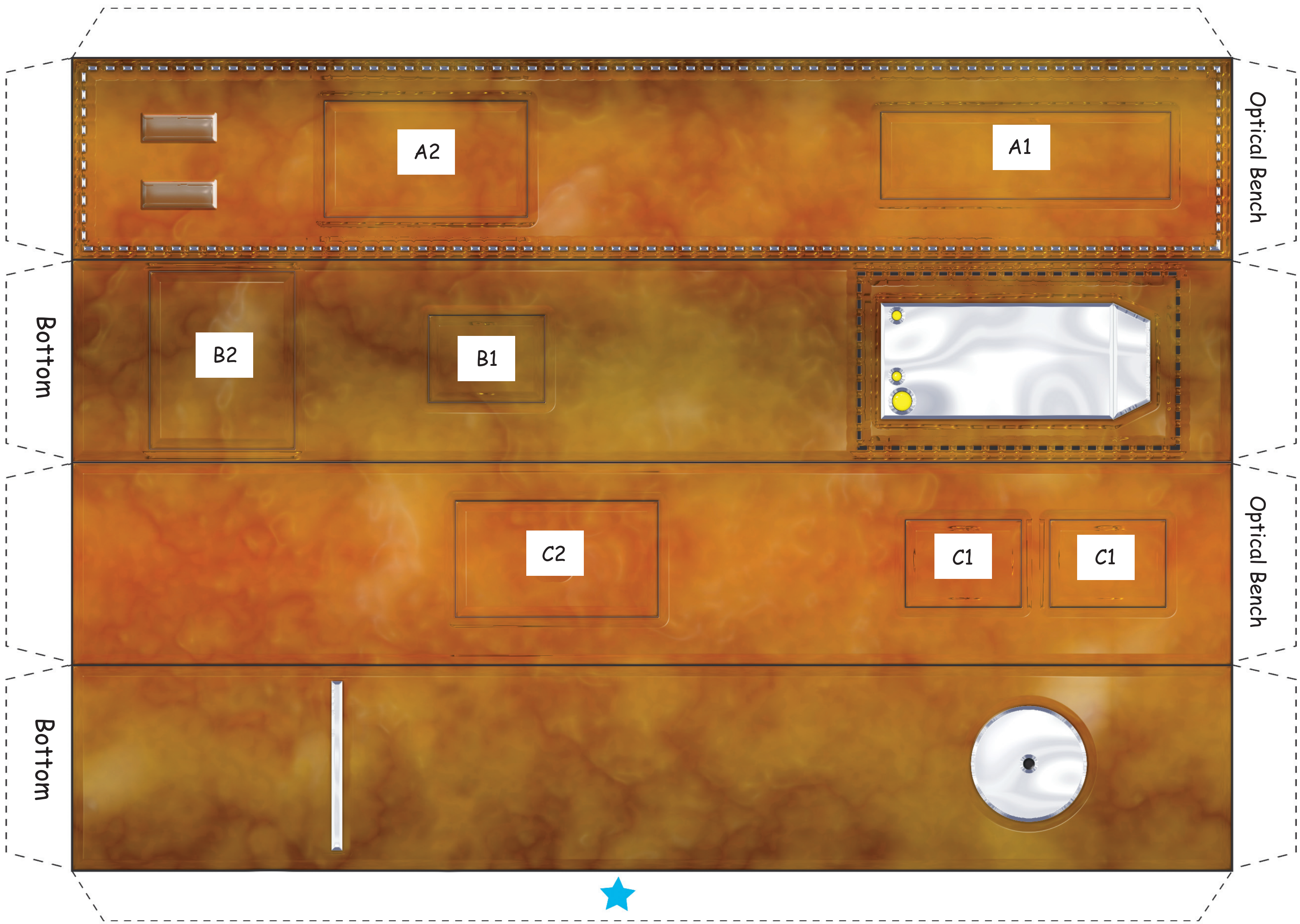
C2: Power Distribution Unit (PDU) for the observatory.

C3 Upper: Transponders that allow communication between the Spacecraft and the ground.
C3 Lower: The XRT Electronics Package (XEP) houses the computer that controls the XRT and processes the science data.
C3 Base: Heat radiator around electronics boxes.

T1: The Digital Electronics Modules (DEMs) house the computers that control the UVOT Telescope Module and processes the science data. One unit is prime and the other is redundant.

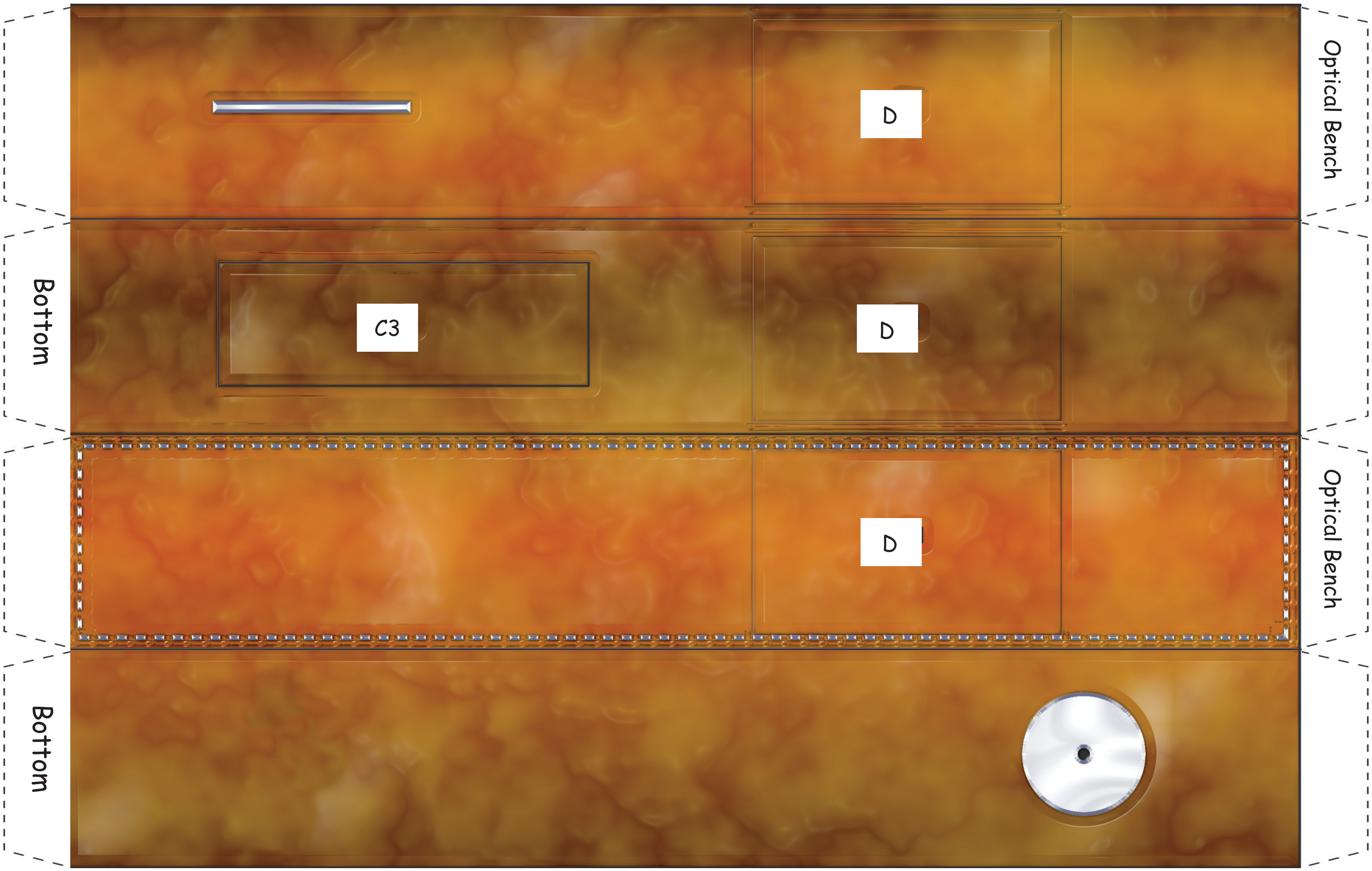
Drawn on the model parts:

- The 3 small silver bars are the Torque Rods (see the "About Reaction Wheels" on p.6).
- The white panel above B1 is the Battery for the Spacecraft.
- The 2 small boxes under A2 are the Magnetometers which indicate the satellite position in the earth's magnetic field.



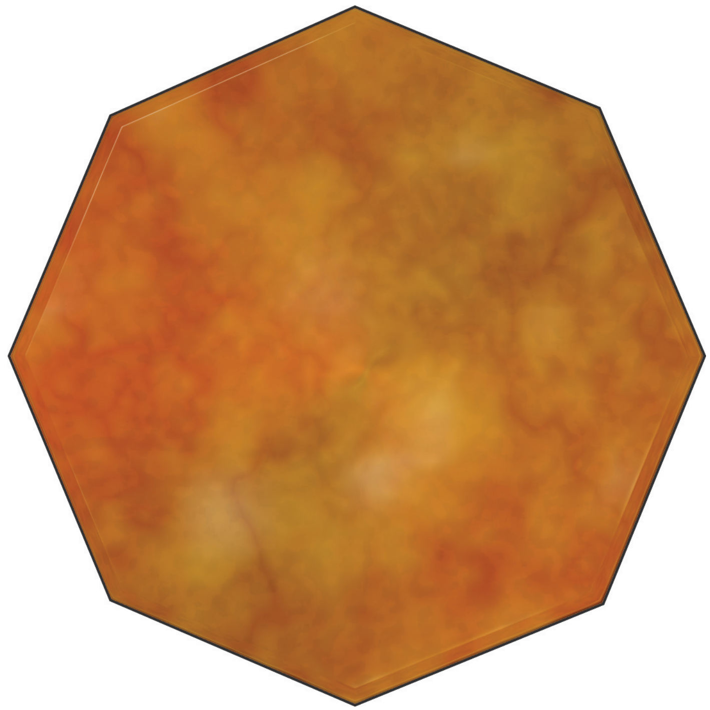
Main Body part 1

Fig. 1



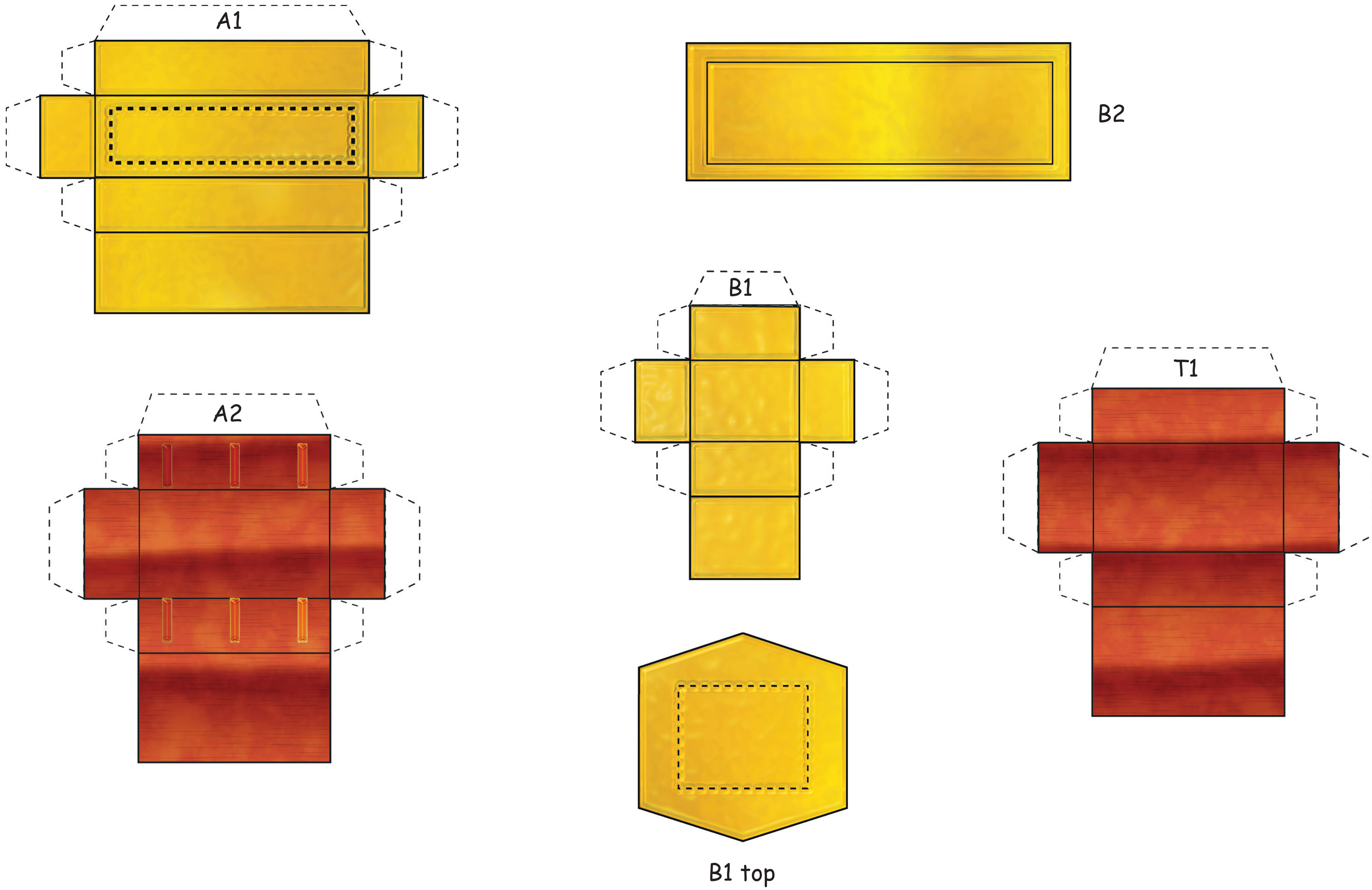
Main Body part 2

Fig. 2



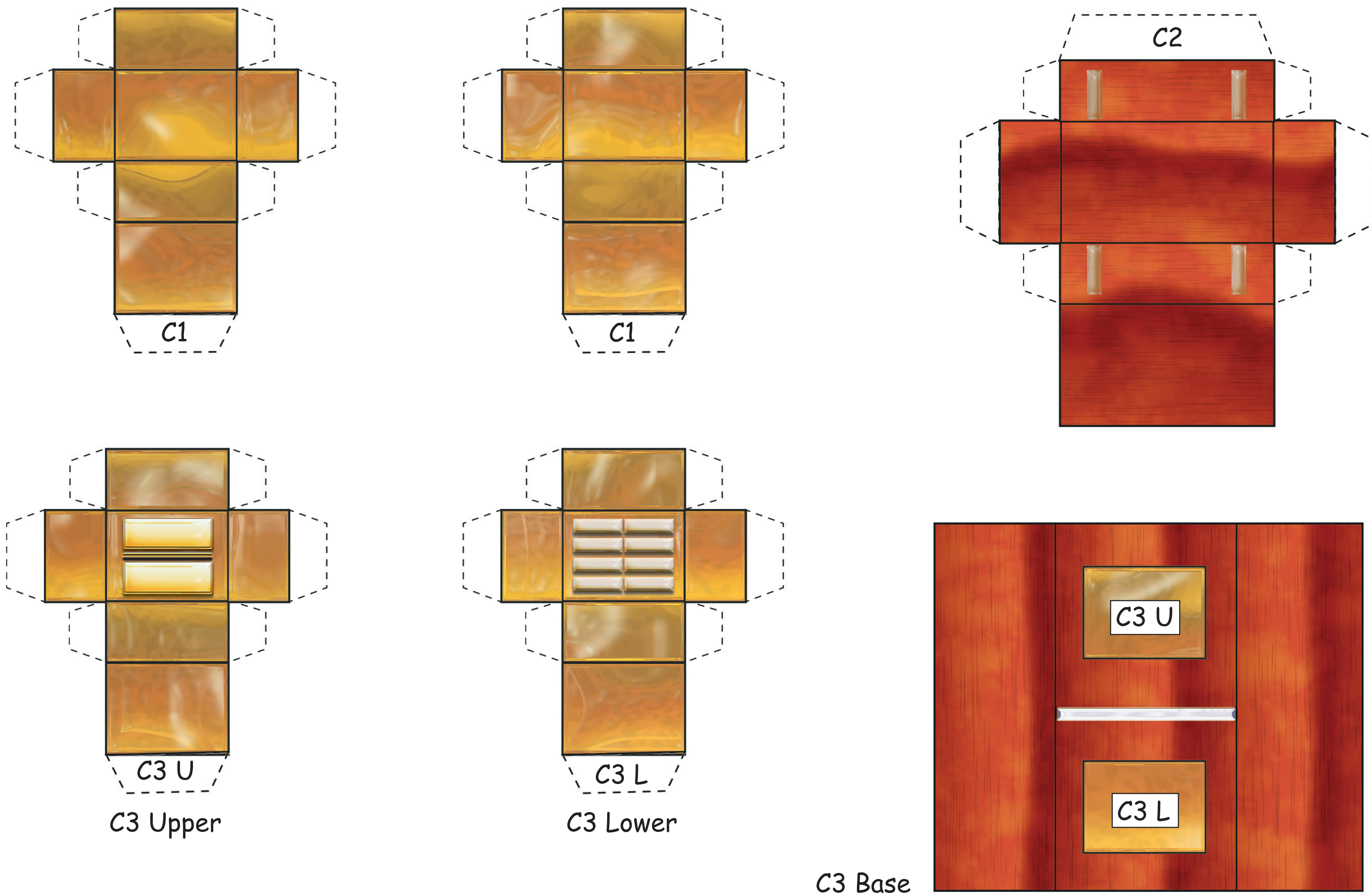
Main Body Base

Fig. 3



Accessories 1

Fig. 4



Accessories 2

Fig. 5

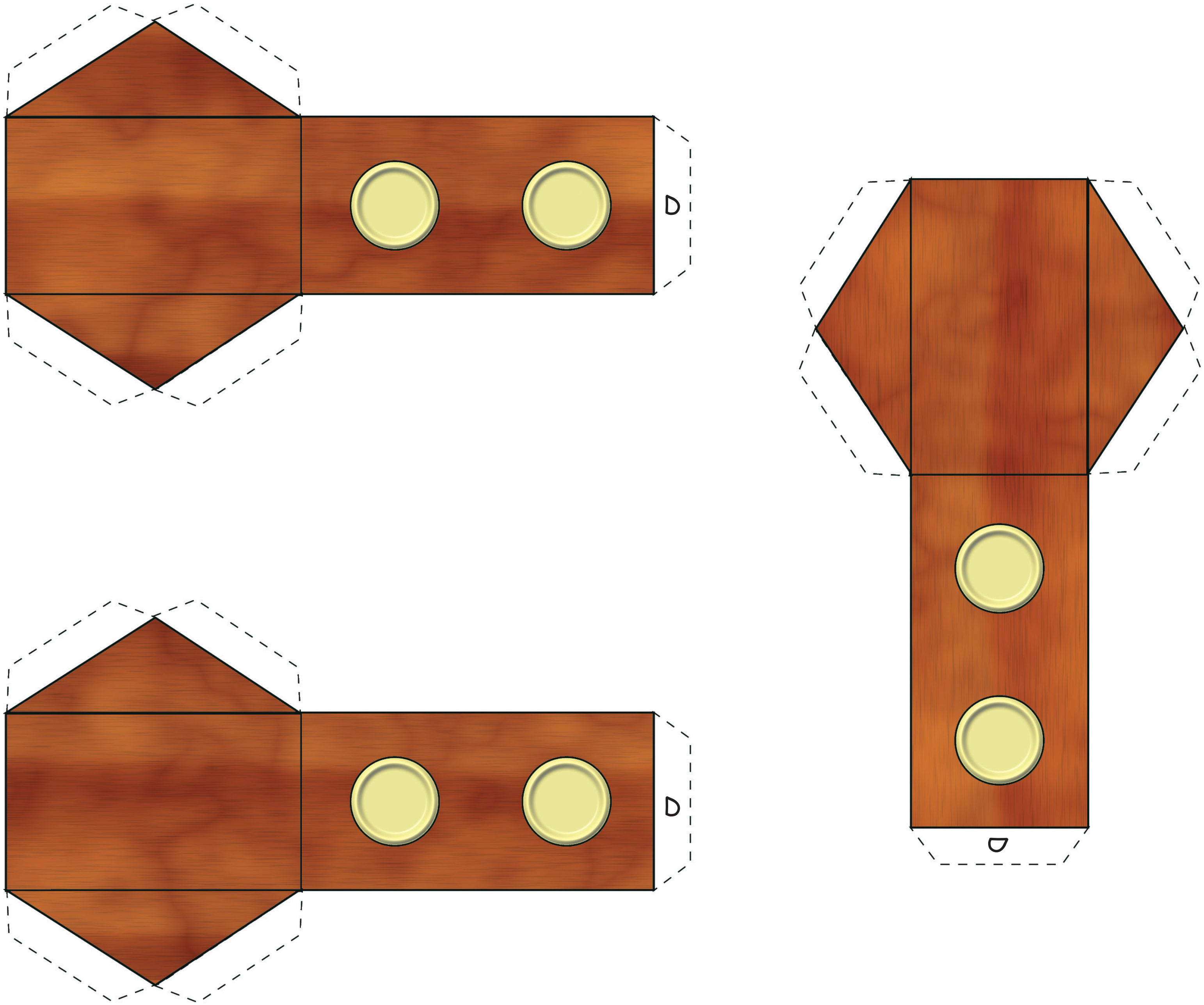
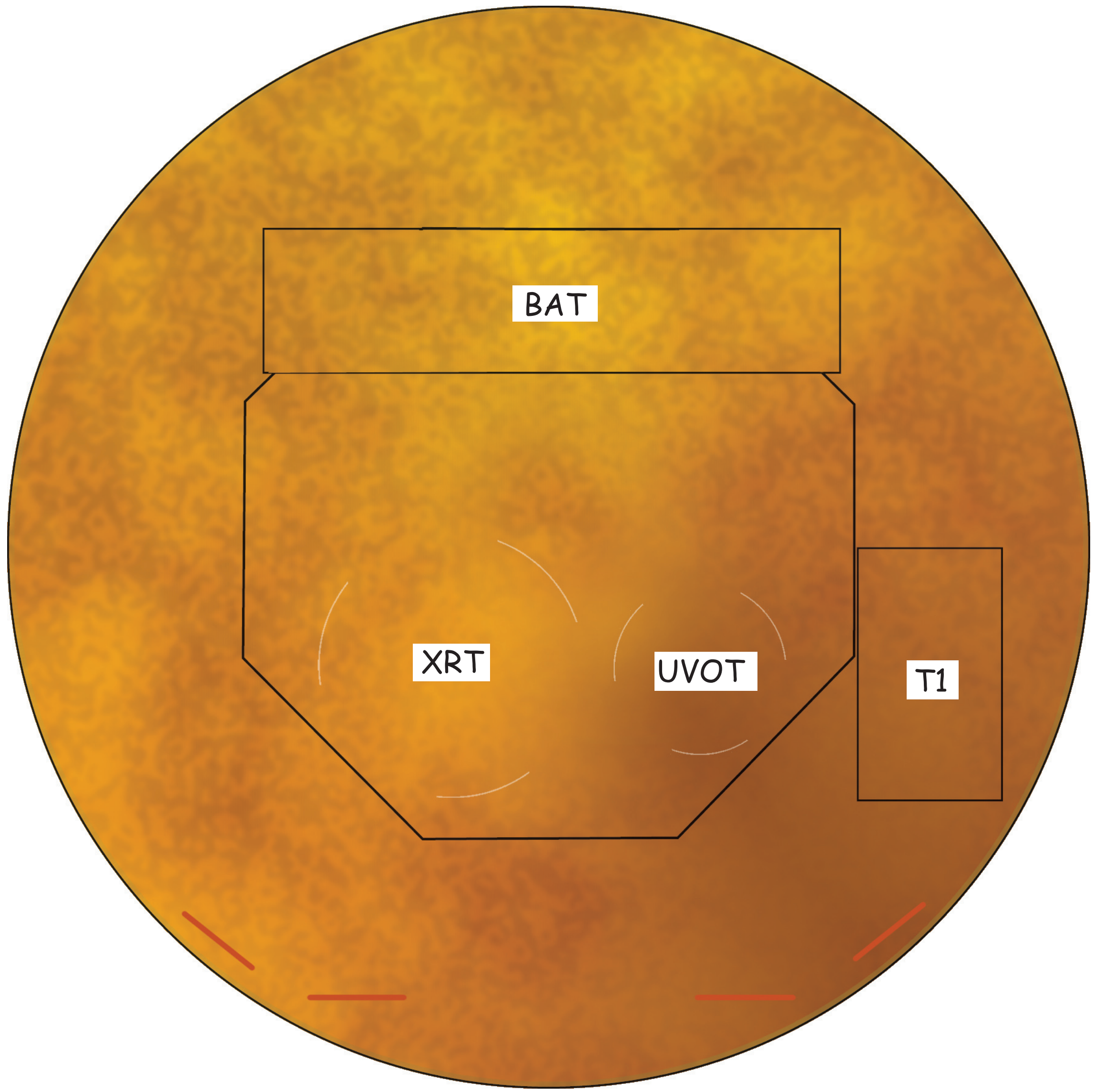


Fig. 6

Reaction Wheel Assemblies

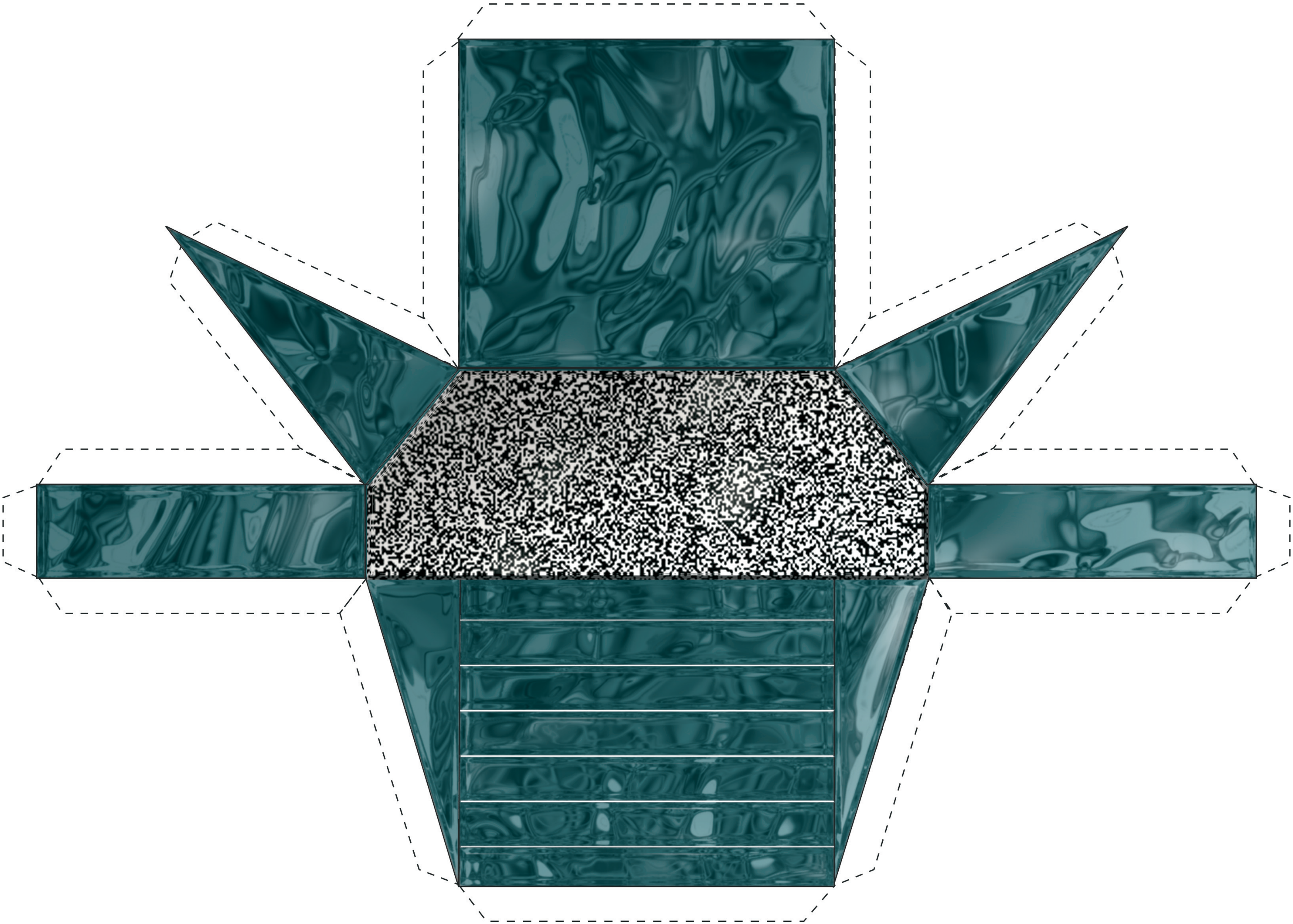


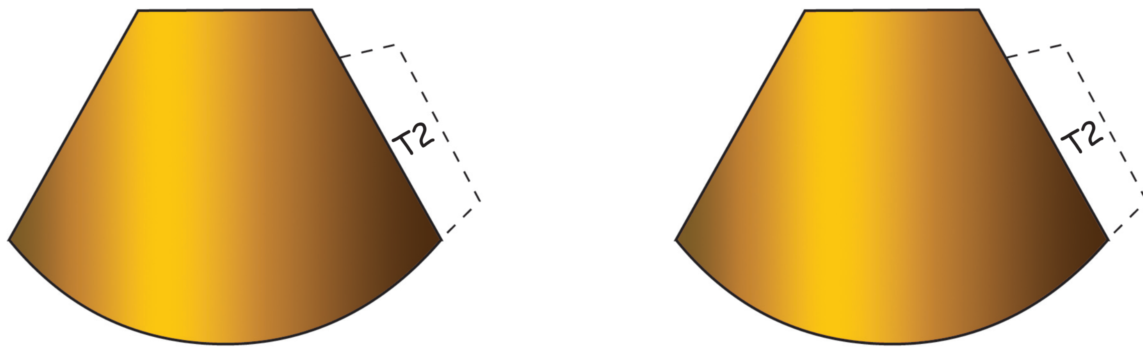
Optical Bench (top)

Fig. 7

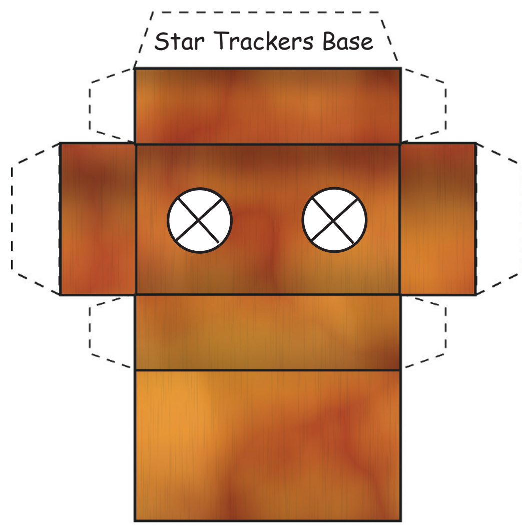
Optical Bench (bottom)

Fig. 8





Star Trackers



Star Trackers Base

Fig. 10

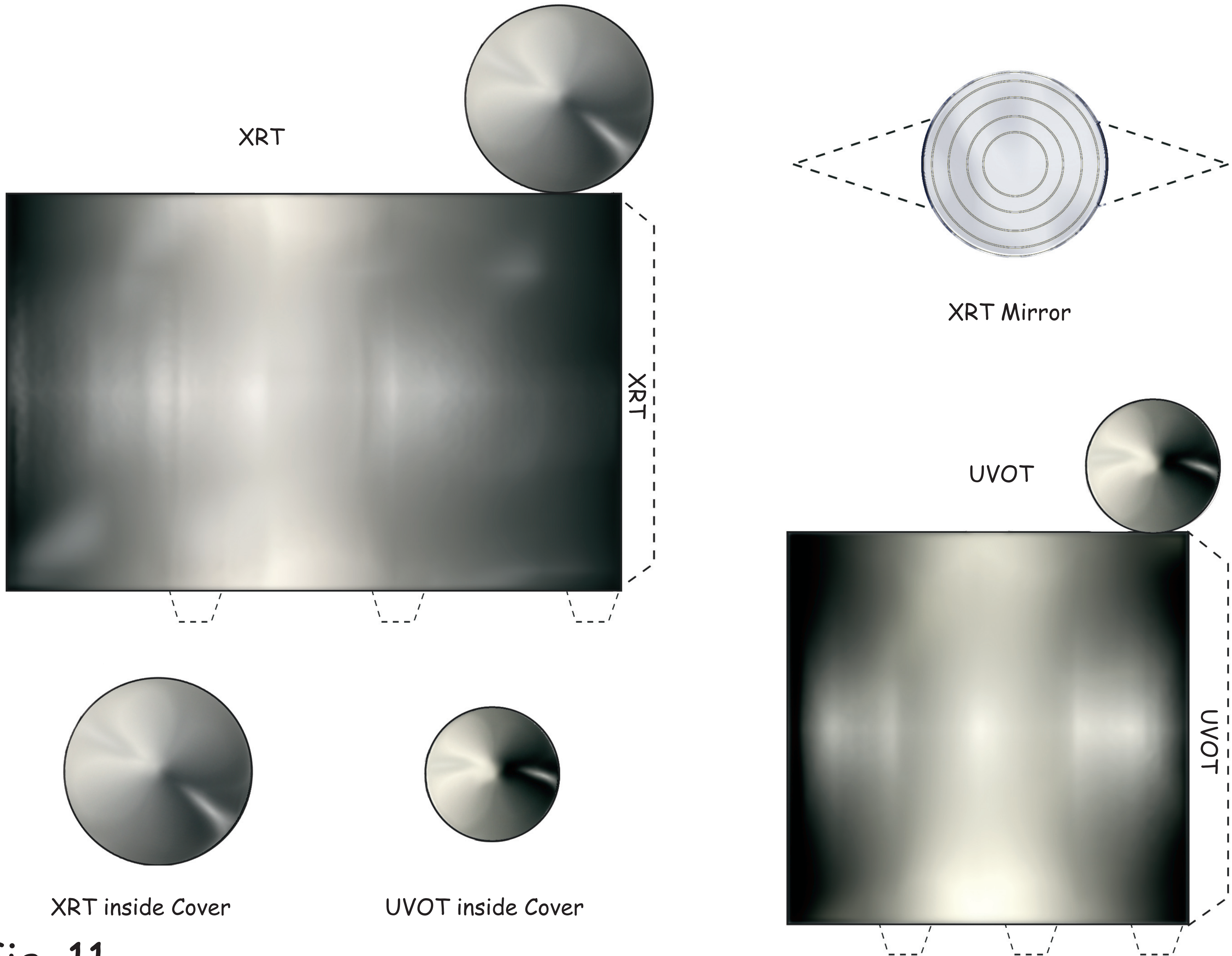
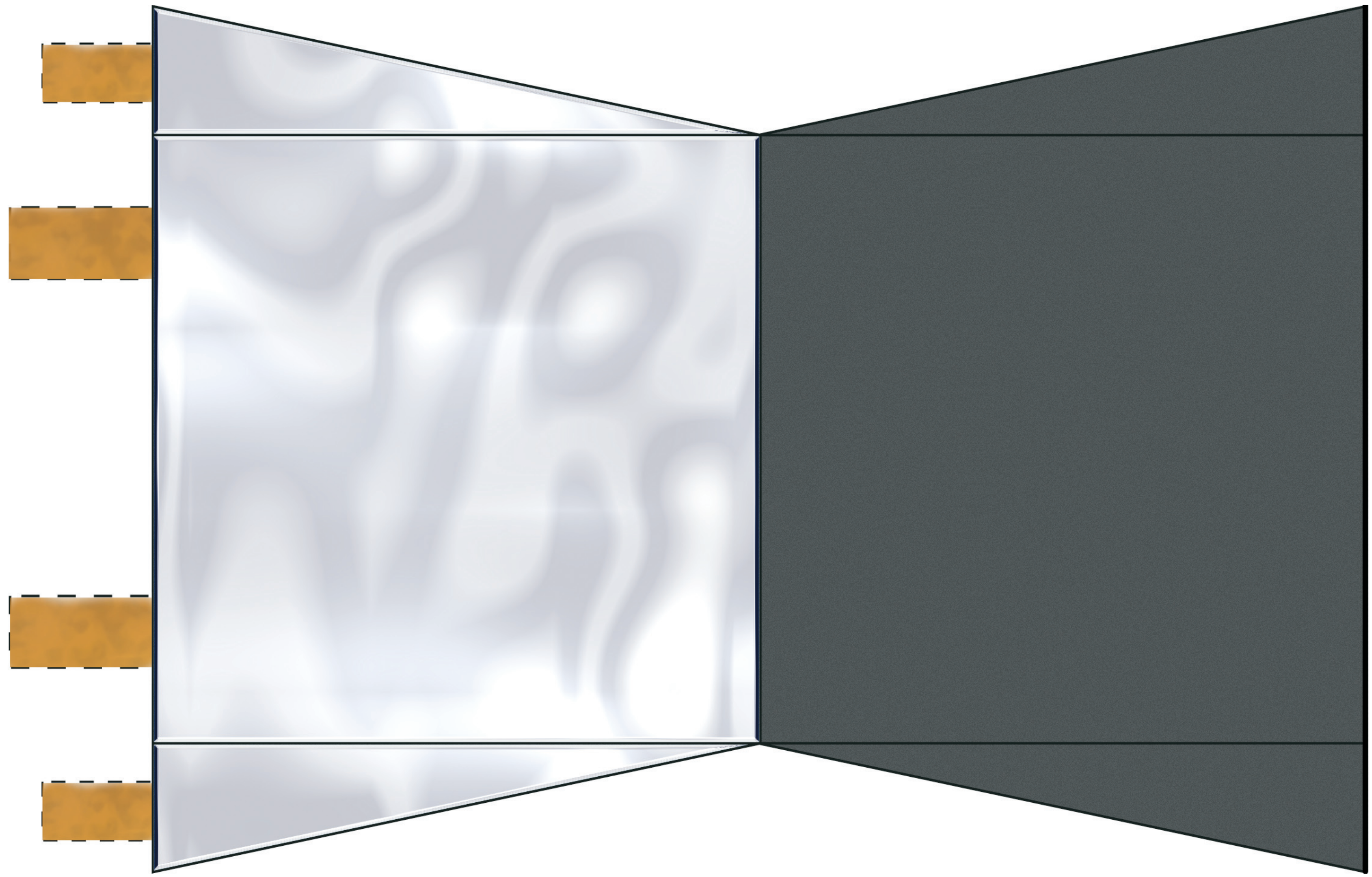
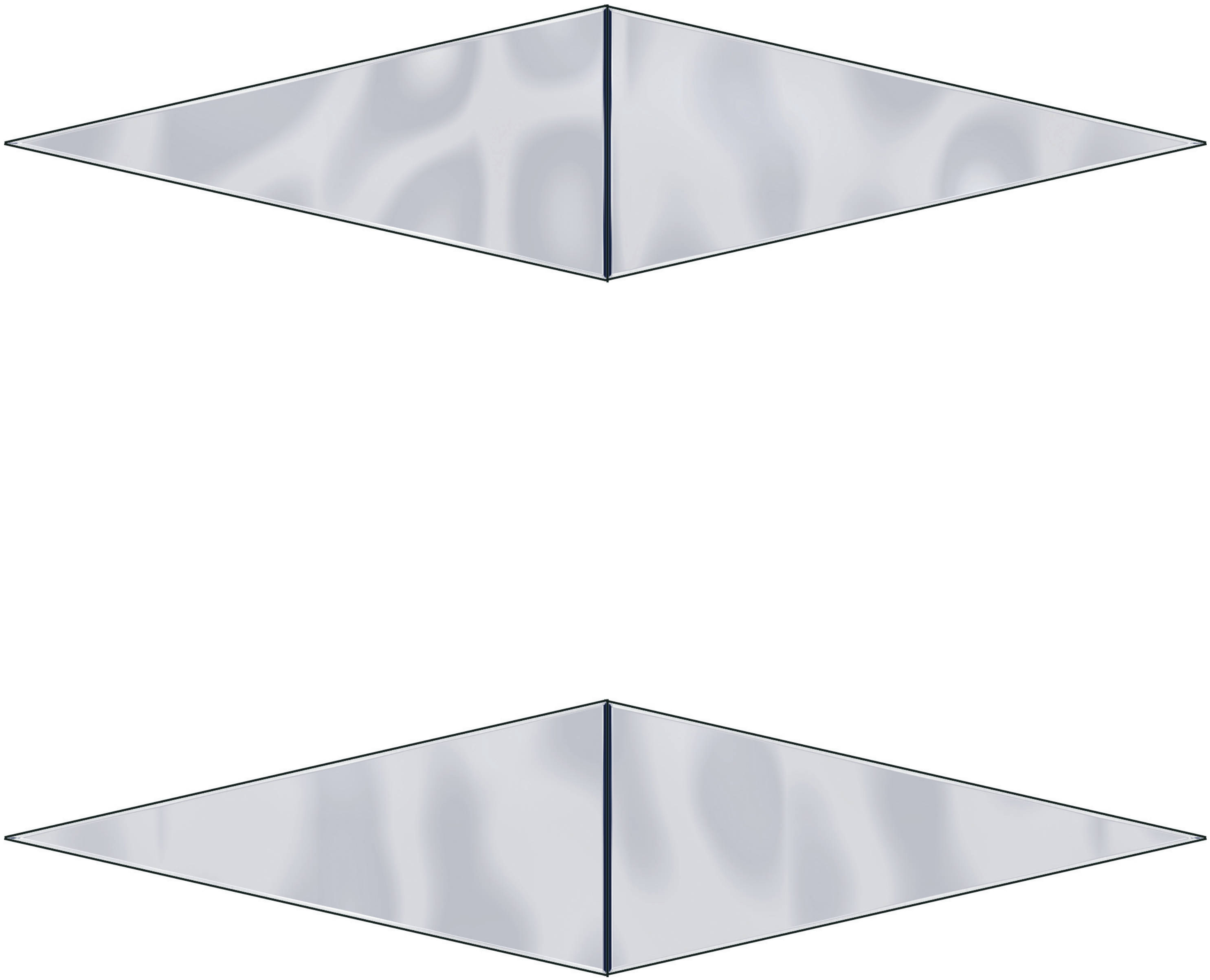

XRT
XRT
XRT Mirror
UVOT
UVOT
XRT inside Cover
UVOT inside Cover

Fig. 11



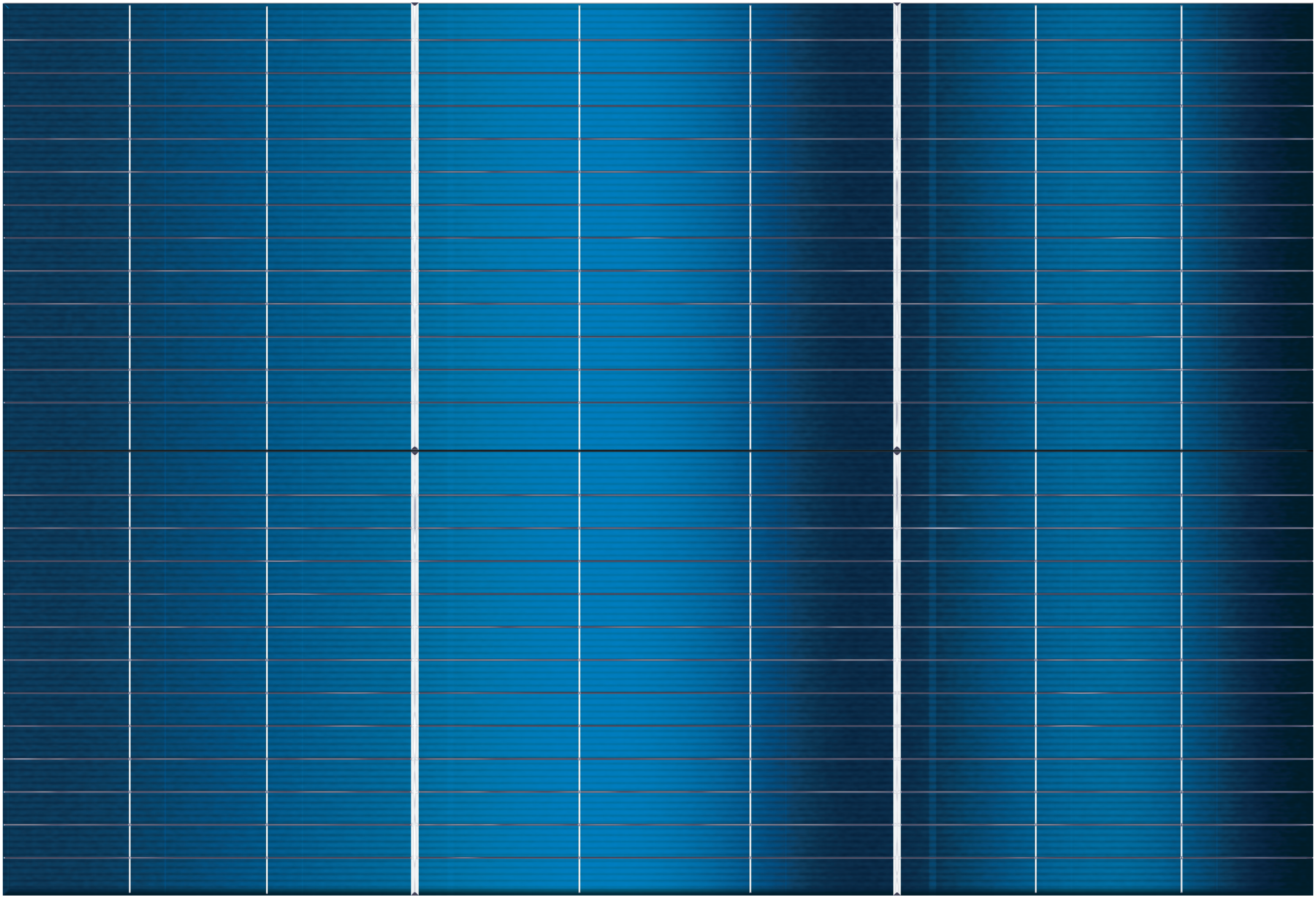
Sun Shade

Fig. 12



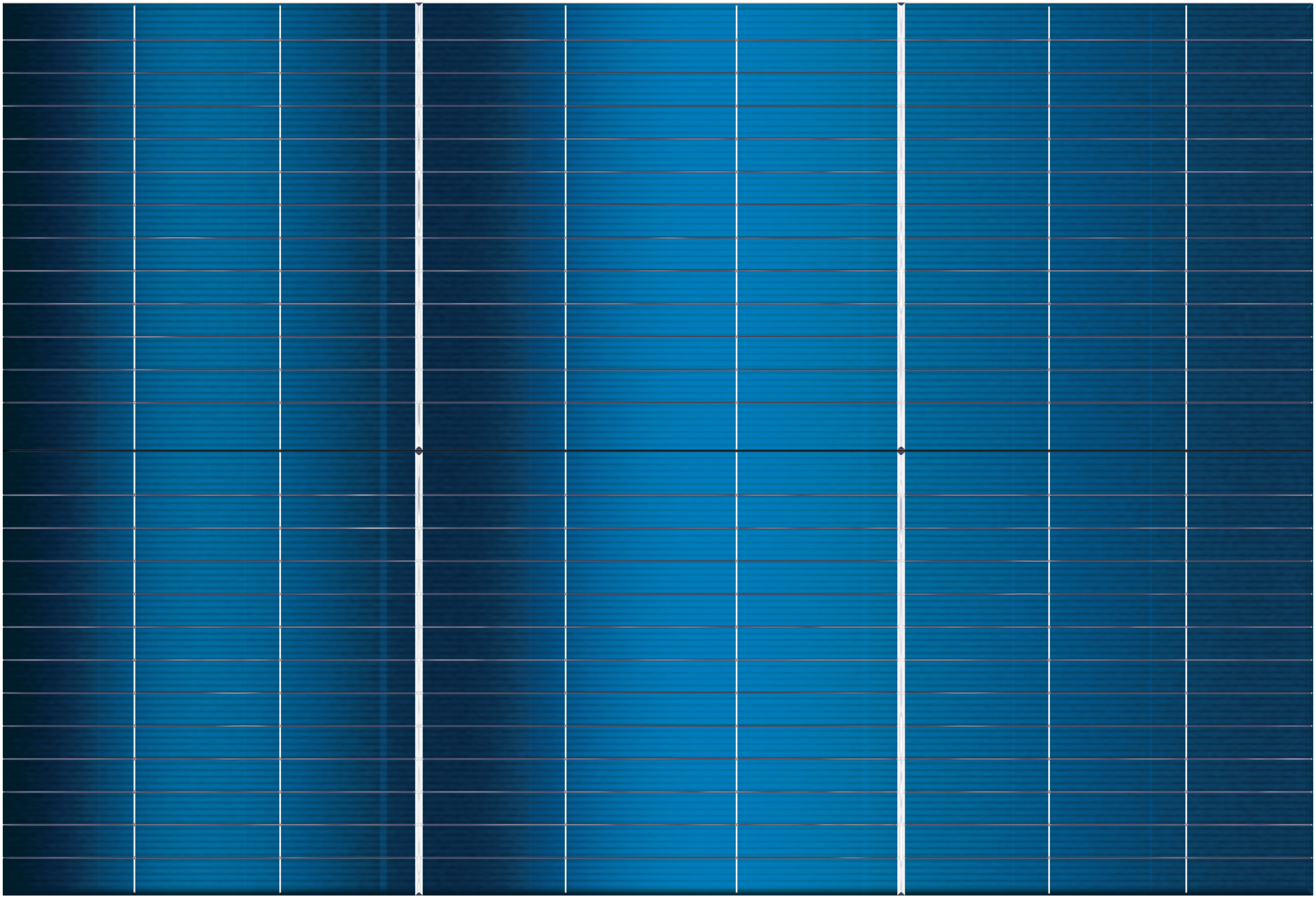
Solar Panel Supports

Fig. 13



Solar Panel 1

Fig. 14



Solar Panel 2

Fig. 15