ACTUALLY, IT'S
PHYTO-PLANKTON!

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EPISODE 3

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EPISODE THREE

RESOURCE PACK

ACTUALLY, IT'S PHYTO-PLANKTON!

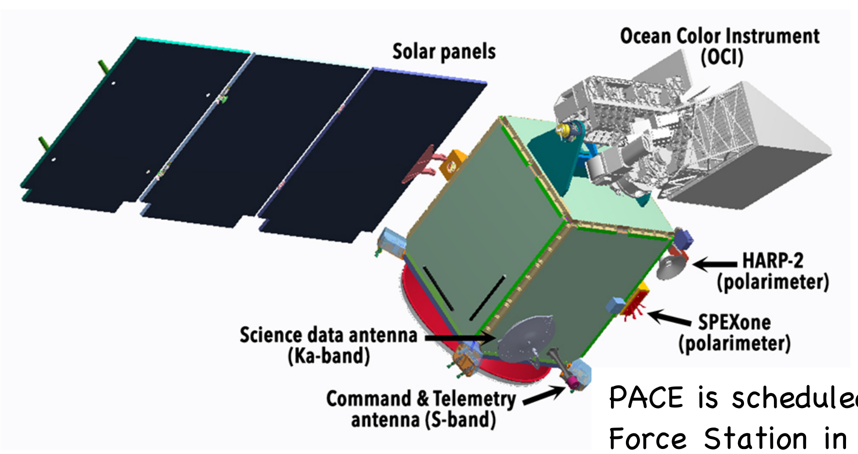
How does one build a spacecraft? In Episode 3, we get some answers from the engineer folk! PACE Project Manager André Dress and PACE Mission Systems Engineer Gary Davis.

A **Project Manager** is a professional organizer. André's job involves organizing and managing the daily operations of the huge NASA PACE team.

PACE is like a big puzzle. All the pieces need to fit together such as:

- The spacecraft
- The scientific instruments
- The ground system
- The science team
- The operations team
- And many more

In order to have a successful mission, everyone needs to play together, and the project manager is there to make sure they do. It's a very busy job for a person who loves working as part of a team.



There are many engineering teams working on PACE, individually in charge of little bits. **Misson Systems Engineer** Gary ensures all the satelitte sub-systems can actually work together as a whole.

Building a satellite is not so different to building a car. It has many thousands of pieces that form the whole finished machine. You might have one person building the engine, and another person building the transmission, but those two systems have to be attached somehow for the car to work. The mission systems team ensures all the individual parts work together in harmony. A spacecraft is essentially the same. It's a job with big responsibility, but Gary says a great team makes all the difference.

What's the lifecycle of the PACE Satellite?

PACE is scheduled for launch in 2023 from the Cape Canaveral Air Force Station in Florida at the Kennedy Space Center. It will be launched into space on a SpaceX Falcon 9 rocket. After launch, the satellite separates from the rocket and the solar array is deployed (this helps power the satellite using the Sun's energy). Antennas on the ground then make contact with the satellite and it's time to run some diagnostic tests. Then, the satellite is turned over to the Science Data Segment team. They collect and process all the scientific data throughout the life of the mission. There is enough fuel onboard for PACE to last for about 10 years, but in the end the fuel will run out. At that stage, the team performs a maneuver to crash the satellite into the Earth's atmosphere, where it will burn up.

How do you drive a satellite? Try PACE Yoga!

There's two ways:

a) **Reaction wheels.** These are spinning wheels. Their momentum can be adjusted to rotate the spacecraft.
b) **FIRE THE THRUSTERS!** These 8 small rocket engines can be engaged to adjust orbit. This is called a maneuver.

As the Earth rotates, PACE goes from south to north during the daytime, crossing the equator at around 1pm. Try Gary's PACE Yoga Pose.

How does the PACE satellite collect data?

It's similar to the way our eyes see colour. PACE uses a camera, but this isn't any normal camera. It has to be able to withstand the harsh vacuum of space. Including, very hot and very cold temperatures and radiation from the Sun.

PACE is equipped with a specially designed camera with detectors similar to your eyes. They can see different colours, they capture that data, turn it into a digitized format and store it onboard a computer.

PACE carries onboard a new groundbreaking hyperspectral sensor called the
OCEAN COLOUR INSTRUMENT (OCI).

1) Imagine you're in space.
2) Imagine you have a backpack on with 8 thrusters.
3) Raise your right arm to about 80–85 degrees. That's your solar array. It faces the sun and is nice and warm. Your left side is cold to keep detectors cool.
4) Look down past your toes and scan your eyes left to right. This is the sensor that scans the ocean every day.

NOW RUN BACKWARDS at 24,000km an hour to scan the whole Earth in 2 days.

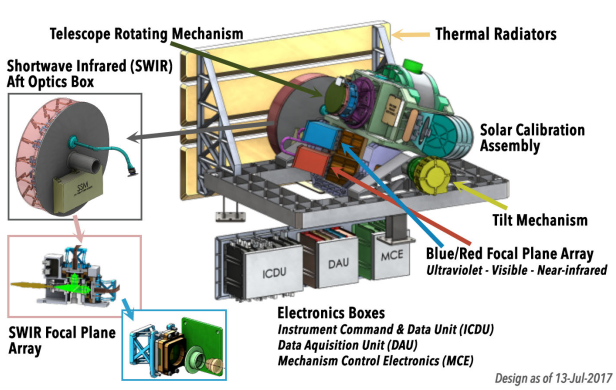
Ocean Colour Instrument (OCI) Fun Facts.

FUN FACT 1:
It's a telescope, but the optics SPIN. Imagine a telescope spinning around, and inside the telescope is a mirror also spinning at half the rate. These two different spins take the light reflected from the ocean and send it through the rest of the instrument optics.

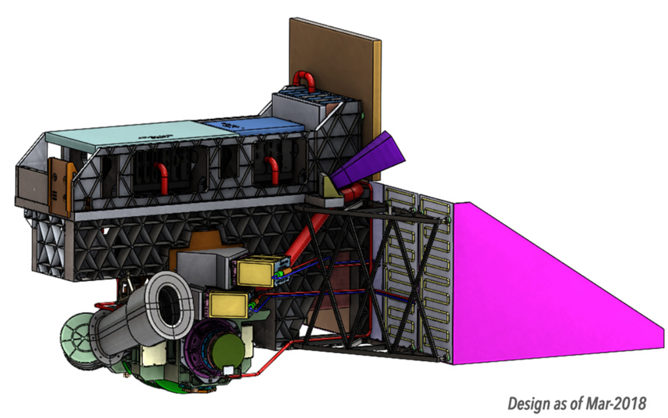
FUN FACT 2:
All the light gets divided into three streams (like Ghostbusters...?) Blue, red and shortwave infrared. Those streams are then sent to extremely sensitive detectors that will allow scientists to see very fine colour differences in the ocean.

FUN FACT 3:
The OCI will be the first of its kind, so scientists will be able to see more colours than ever before. They'll be able to not only see that there is phytoplankton in the ocean but be able to tell which types are present. The OCI is a real game changer for satellite oceanographers.

PACE Ocean Color Instrument



Ocean Color Instrument



PACE's advanced technologies will provide new insight into Earth's ocean and atmosphere, systems that affect our everyday lives by regulating climate.

PACE will observe the ocean and atmosphere together. This will improve knowledge of the role each system plays as our planet changes.

PACE data will be applied to some of the most pressing societal issues such as air quality and food safety.

PACE MISSION

PACE will extend and improve NASA's 20 plus years of global satellite observations of our living ocean, atmospheric aerosols, and clouds and initiate an advanced set of climate-relevant data records. By determining the distribution of phytoplankton, PACE will help assess ocean health. It will also continue key measurements related to air quality and climate.

Science Goals

To extend systematic ocean color, atmospheric aerosol, and cloud data records for Earth system and climate studies.

To address new and emerging science questions by detecting a broader range of color wavelengths that will provide new and unprecedented detail.

Key Mission Characteristics

- **Hyperspectral ocean color instrument**
- **Two multi-angle polarimeters**
- **Launch readiness date: Fall 2022**
- **676.5 km (420 mi) orbital altitude**
- **Sun-synchronous, polar orbit**
- **Global coverage every two days**
- **Managed by Goddard Space Flight Center**

National Aeronautics and Space Administration

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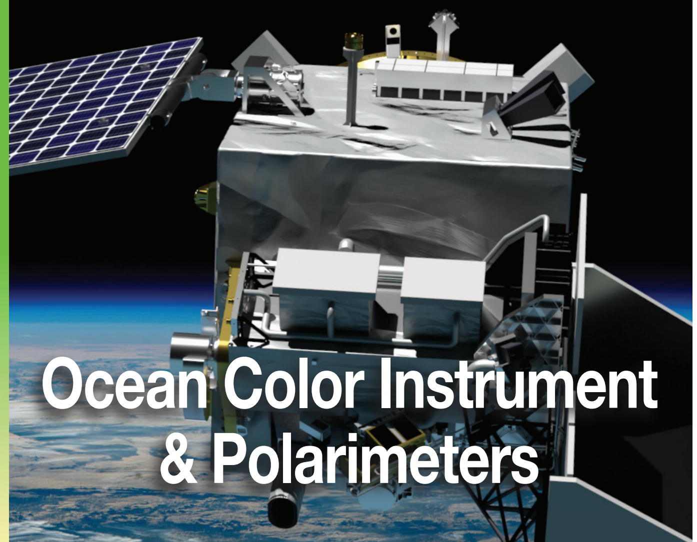


Ocean Color Instrument & Polarimeters

PACE's advanced technology will shed new light on our ocean and atmosphere.

Plankton, Aerosol, Cloud, ocean Ecosystem

More wavelengths.

Unprecedented information.

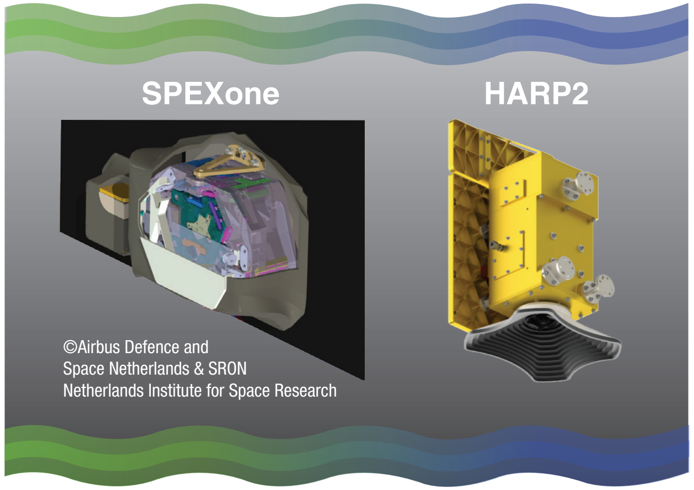
OCI & Polarimeters

The primary technology planned for PACE is the Ocean Color Instrument (OCI). Being built at NASA's Goddard Space Flight Center, it will be the most advanced instrument for observing ocean color in NASA's history. Its state-of-the-art optical spectrometer will measure properties of light over broad portions of the electromagnetic spectrum: from ultraviolet to shortwave infrared wavelengths. Even better, the OCI will enable continuous measurement of light at finer wavelength resolution than previous NASA ocean color sensors and its cross-track rotating telescope will minimize image striping.

The OCI's unparalleled spectral coverage will provide first-ever global measurements designed to identify the community composition of *phytoplankton*, microscopic algae that float in our ocean. These data will significantly improve our ability to understand Earth's changing marine ecosystems, manage natural resources such as fisheries, and identify harmful algal blooms.

PACE will also include two multi-angular imaging *polarimeters*, instruments that measure how reflected sunlight oscillates within a geometric plane. When light interacts with clouds or suspended particles – known as *aerosols* – it comes away from that interaction changed. By measuring changes in the light's polarization or color, we can infer properties of the clouds or aerosols themselves. This type of data is crucial to deciphering the way sunlight is reflected and absorbed by our planet and how aerosols affect cloud formation.

PACE will be NASA's most advanced ocean color and aerosol mission to date.



Why do we need PACE? To continue climate data records and unveil new insights on life in our ocean.

The PACE polarimeters, Spectro-Polarimeter for Planetary Exploration (SPEXone) and Hyper Angular Rainbow Polarimeter (HARP2), will sample visible to near-infrared bandwidths over various angles within the OCI's coverage *(see table)*. Their compatible spatial coverage and measurement accuracies will lead to a comprehensive set of aerosol and cloud science products. In addition, polarimeter data will improve OCI results by helping to "clear away" portions of the atmosphere that obscure ocean color signals.

	OCI	SPEXone	HARP2
Spectral range *[bandwith]*	342.5 - 887.5 @ 5 nm steps *[5 nm]*	385 - 770 nm @ 2-4 nm steps	440, 550, 670 *[10 nm]* & 870 nm *[40 nm]*
Shortwave infrared (OCI) / Polarized bands (SPEXone, HARP2)	Seven bands centered on 940, 1038, 1250, 1378, 1615, 2130 & 2260 nm	Same range in 15 to 45 nm steps	All
Number of viewing angles *[degrees]*	Fore-aft tilt +/- 20° to avoid sun glint	Five [-57°, -20°, 0°, 20°, 57°]	10 for 440, 550, 870 nm & 60 for 670 nm *[spaced over 114°]*
Coverage *[swath width]*	+/- 56.5° *[2663 km at 20° tilt]*	+/- 4° *[100 km]*	+/- 47° *[1556 km at nadir]*
Days for global coverage	1-2	About 30	2
Ground sample distance	1 km at nadir	2.5 km	3 km
Institution(s)	Goddard Space Flight Center	SRON Netherlands Institute for Space Research, Airbus Defence and Space Netherlands, TNO	University of Maryland – Earth and Space Institute

Together with the OCI, SPEXone and HARP2 will continue systematic records of key atmospheric variables needed to improve forecasts of air quality, weather and climate. As a result, PACE will be a major advance in satellite observing technology. Its instrument suite will provide new opportunities to monitor and respond to changes in our environment, while clarifying interactions between the ocean and atmosphere with exceptional detail.

Plankton, Aerosol, Cloud, ocean Ecosystem

Learn more at pace.gsfc.nasa.gov

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Build Your Own PACE!

The **Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)** spacecraft is designed to provide new insight into Earth's ocean and atmosphere. PACE will provide the first-ever global measurements to identify communities of microscopic algae that float in our ocean: phytoplankton. This will help us understand Earth's changing marine ecosystems, manage natural resources such as fisheries, and detect harmful algal blooms. Its atmospheric data will be used to study key issues such as air quality.

It usually takes years to build a satellite that can survive the extremes of space. This paper model replica of PACE has five parts plus an optional "Hinge." Just like NASA, you will create the final spacecraft model by assembling the parts together...but in a tiny fraction of the time!

Materials

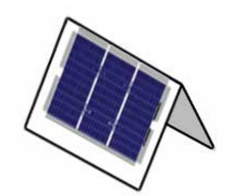
- Scissors
- Glue
- Metal ruler to make sharp folds
- *Optional: Hole punch (3/8 inch is best)*

Patterns

Dashed line

- - - - - - - - - - - -

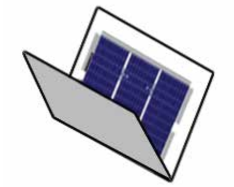
Mountain fold
Fold so that the printed pattern faces out.



Dotted line

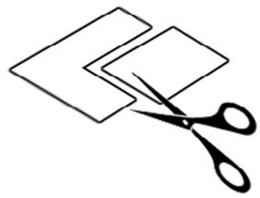
. . . .

Valley fold
Fold so that the printed pattern faces in.



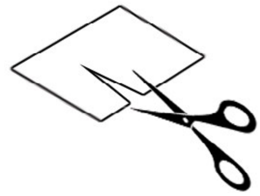
Solid line

Cut parts out along this line.



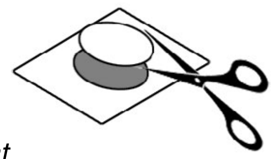
Solid red line

Cut a notch along this line.



Diagonal red lines
Cut these areas out.

Green dots
Glue tabs to another place on that.



Check out the PACE model build videos:
https://pace.oceansciences.org/paper_model.htm

BUS

The central part of PACE is called a "bus." It serves as the hub for the spacecraft, providing places to mount science instruments, solar array, communications equipment, etc. It also houses electronic systems that distribute power and information needed to operate the spacecraft.

DIRECTIONS

- Cut solid lines, including red circle and two small red notches.
- Cut out the "Bus End Piece" and save until later.
- Fold along all dashed lines, creating a cube shape.
- Glue tabs marked "1" to corresponding inner walls of the Bus, leaving the top open until the **Beam** and **Solar Array** are built.

BEAM

SOLAR ARRAY

*An array of solar panels are needed to power PACE. Before launch, the solar array is folded and then unfurls in orbit. For this model, the **Beam** is a single piece that connects the **Solar Array** to the **Bus**.*

DIRECTIONS

- Cut out the **Beam**. *(If using thin paper, shorten or omit red notches.)*
- Fold along the *long* dashed lines. Leave ends unfolded.
- Glue along the green dots to form a rectangular piece.
- Cut out the **Solar Array** and its "End Piece." Fold along all lines.
- Glue tabs marked "1" to long edge of the **Solar Array**.
- Following directions printed on the **Beam**, place it in the **Solar Array**.
- Glue **Solar Array** tabs marked "2."
- Fold back the ends of the **Beam** oriented *away* from the **Bus**.
- Glue the "Solar Array End Piece" over the **Beam's** folded end.
- Insert the **Beam's** other end in the hole in the **Bus**. Fold back its ends.
- With the **Beam** sitting in the notch, glue the top of the **Bus** closed.
- Glue the "Bus End Piece" on top of the **Beam's** folded end.

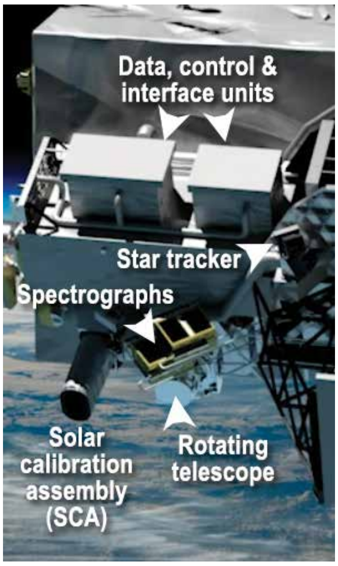
RADIATOR SHIELD

*A **Radiator Shield** maintains a delicate balance between the deep freeze of space and the Sun's blazing heat.*

DIRECTIONS

- Note the direction of red arrows and cut out the **Radiator Shield**.
- Fold along all lines. There is one dotted line ("valley fold").
- Glue tabs marked "1" to short sides of triangles (per red arrows).
- Push folded paper into the **Radiator Shield**, over the tab marked "2."
- Glue the tab marked "2" to the bottom of the folded paper.

OCI



***The Ocean Color Instrument (OCI)** is designed to measure light at finer wavelength resolution than previous NASA sensors. Its spectrographs will split light down to 5 nanometers (5 one-billionths of a meter)!*

DIRECTIONS

- Cut out the **OCI**. Make all folds, including valley above spectrographs.
- Glue areas marked "1" to form rectangular solar calibration assembly. Glue tabs marked "2" to form the back of the **OCI**.
- Glue tabs marked "3" to form the data, control & interface units.
- Glue tabs marked "4". Each tab can be pinched closed separately. Be careful to maintain the angle along the edge of the spectrographs.
- Glue tabs marked "5" to finish the front side of the **OCI**.
- Glue areas marked "6" to finish the bottom and the port side (i.e., side facing left when looking along PACE's flight direction).
- Finish your PACE paper model by doing the following:
  - Glue **Radiator Shield** to **OCI**. Be sure to align the two white boxes.
  - Glue **OCI/Radiator Shield** to **Bus** (or optional "**Hinge**," see below).
  - Slightly bend down the **Beam** (see image at top left).

Estimated completion time of 90 minutes.

NASA's OCI will tilt up and down... want your paper model to do that? Build the options "Hinge"!
Instructions available at https://pace.oceansciences.org/paper_model.htm

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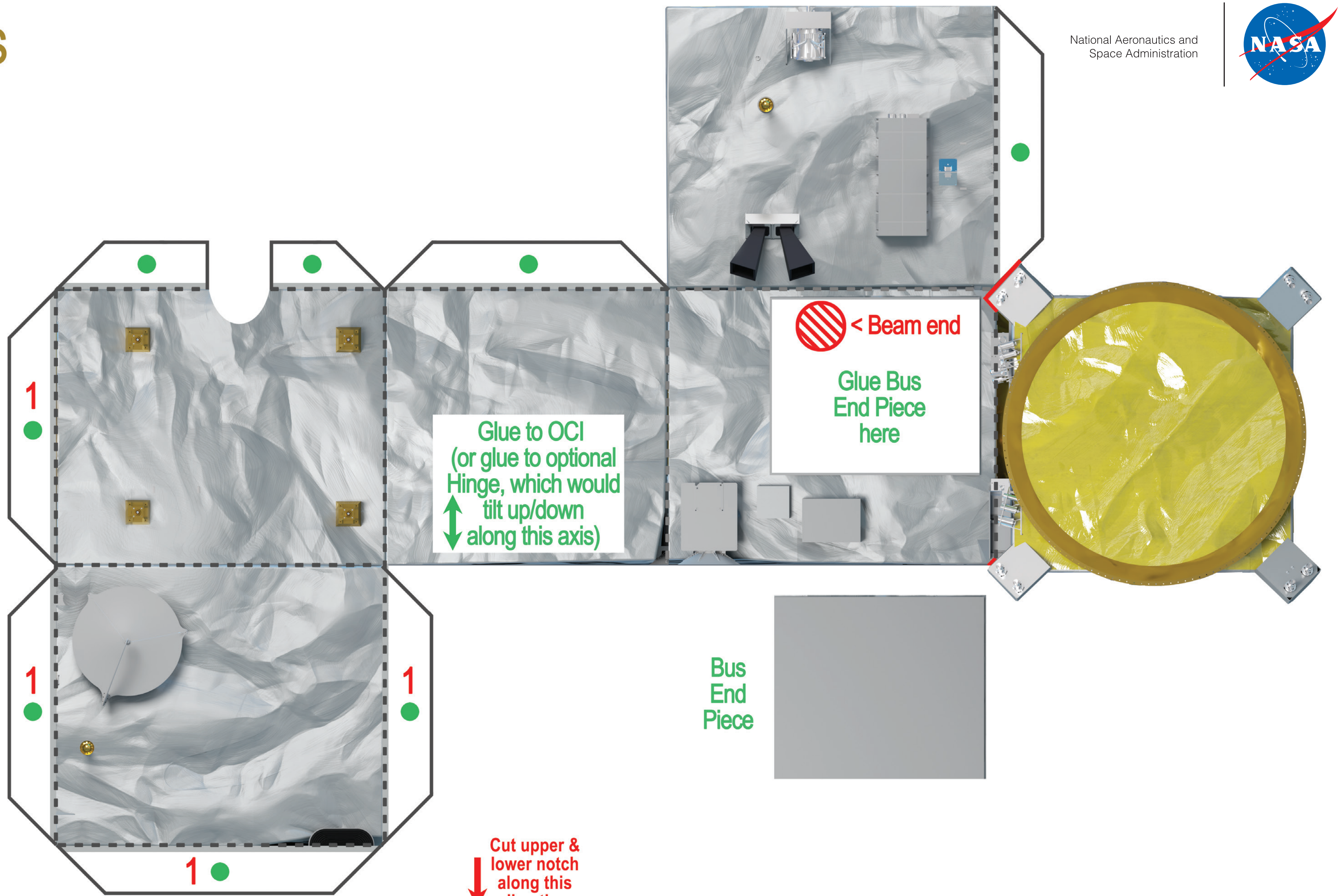
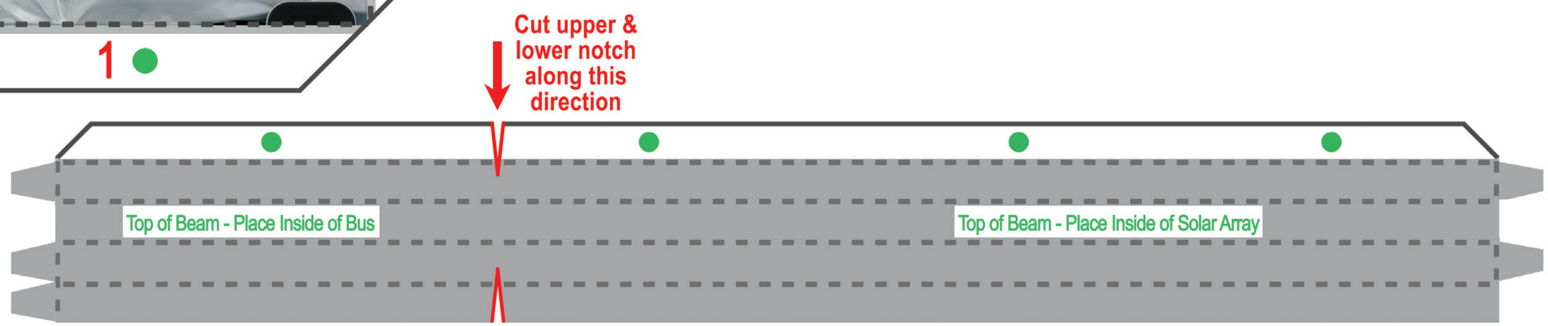
BUS



BEAM



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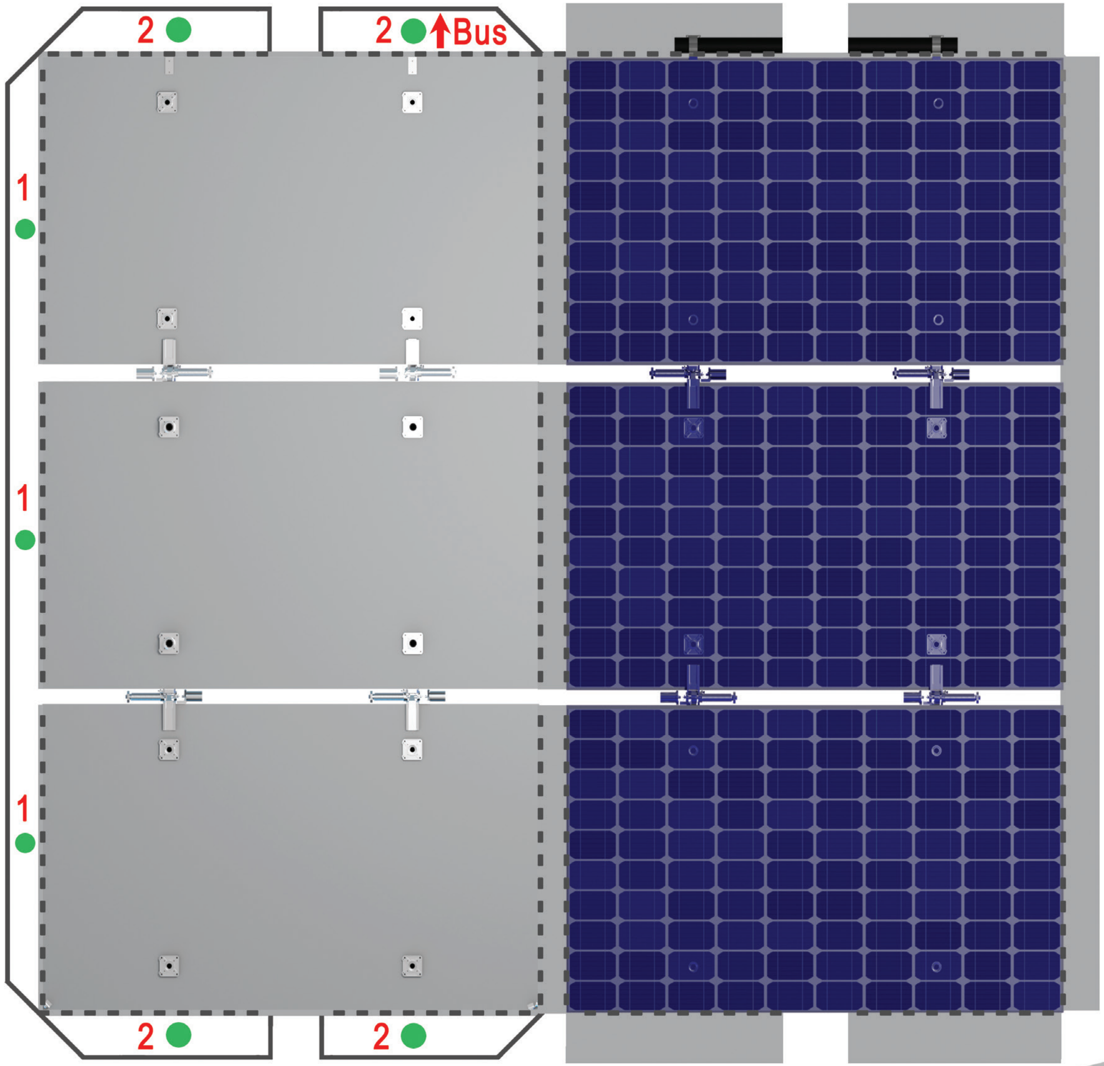
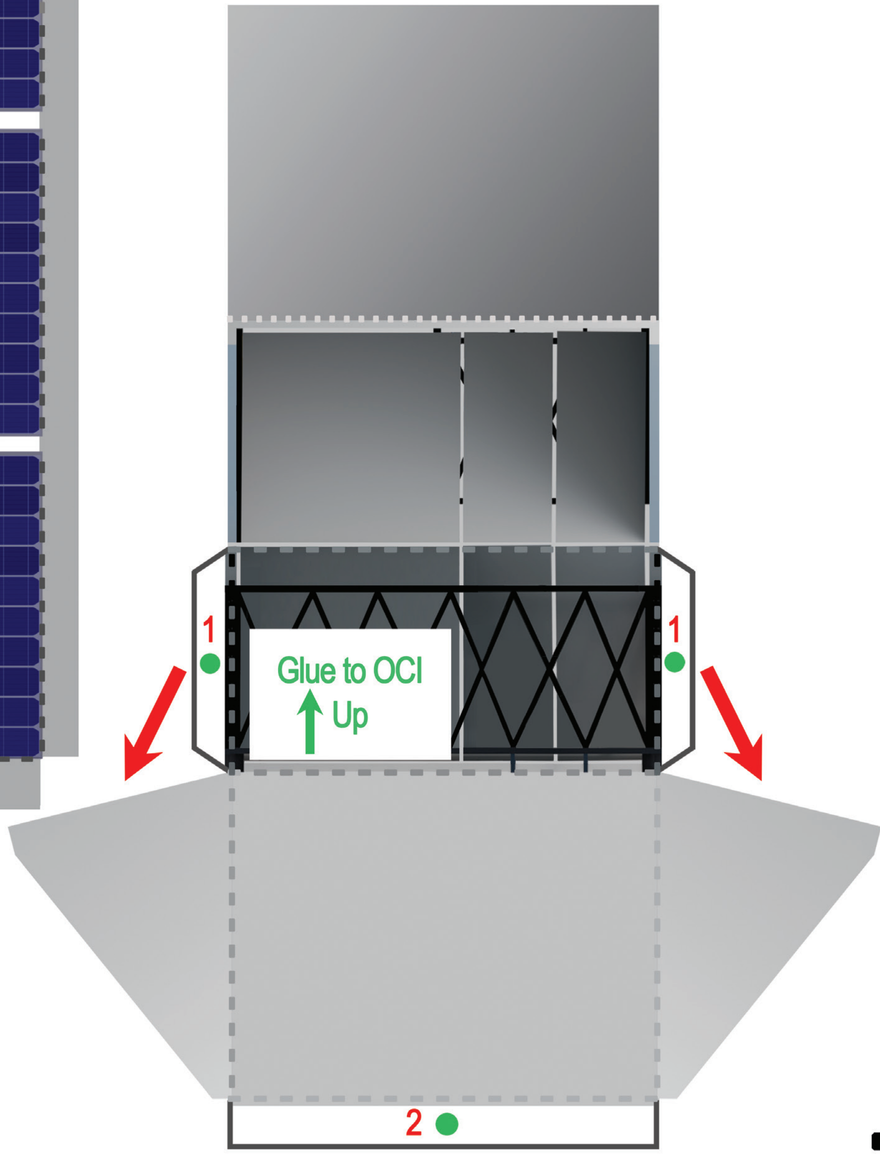
SOLAR ARRAY



Solar Array End Piece (Glue to to this end after Beam is in place)

RADIATOR SHIELD



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