National Aeronautics and Space Administration

**GRADES 5-12**

# Solar Power


future flight

Aeronautics Research Mission Directorate

Museum in a BOX Series

www.nasa.gov


(Photo courtesy of NASA - www.nasaimages.org)

# Solar Power

## Lesson Overview

By observing this demonstration, students will learn about energy and matter when light is converted into electricity using a solar panel. They will then see this electricity in use, powering a small car.

## Objectives

Students will:

1. Convert solar energy (potential energy) into kinetic energy to power a small car.

**Materials:**

In the Box

Thames & Kosmos™ Fuel Cell Car & Experiment Kit

Phillips head screwdriver

Provided by User

Sunlight / lamp

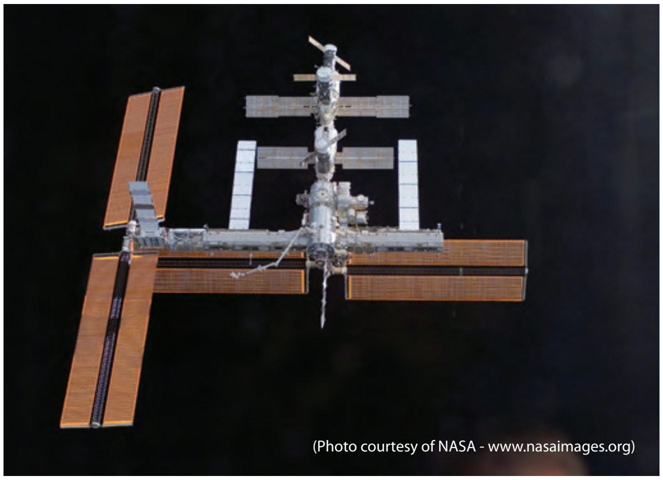
**GRADES 5-12**

**Time Requirements:** 30 minutes

# Background

## Solar Power

The ability to produce power without damaging the environment is a continuing challenge. Fossil fuels like gasoline, natural gas and coal, all come from non-renewable sources and when burned, increase the levels of air pollution and may harm the environment. Batteries, such as those found in flashlights and MP3 players, have limited lifetimes and often end up being disposed of in landfills. There are many environmentally friendly alternatives available today, such as wind power, geothermal and hydroelectric power, but in this lesson, we shall look at solar power.




**Img. 1** The International Space Station

The Sun emits a tremendous amount of energy every second of every day. The exact amount is unknown but scientists have estimated it to be $4 \times 10^{26}$, or 400,000,000,000,000,000,000,000,000 watts. Another way to quantify it is in comparison to a large power station. The sun emits as much energy in a second as 2 BILLION power stations would generate in an entire year!


**Img. 2** The solar array of the Hubble telescope

Now of course, only a very small fraction of the Sun's energy ever makes it to the Earth, but it's still an incredibly large amount. A lot of that energy is already used in the form of heat, or by plants needing the light for photosynthesis, converting carbon dioxide into sugars and eventually releasing breathable oxygen, but it still leaves a large portion un-used and ready for capture.

The photo-voltaic cell (or solar cell) is simply a thin slice of chemically treated material such as silicon or gallium arsenide. Sunlight is absorbed by the material which causes it to release electrons. These "free electrons" as they are known are present in any conductive material and are what allows an item to be conductive. The electrons "float" to the top of the cell and are collected on metal plates. Finally, by attaching wires to the top and bottom of these plates we can harness this electricity and put it to use.

A single solar cell isn't sufficient to provide much power, so they are typically joined together to create a solar panel. The panel in the kit, for example is comprised of 6 cells, each generating 0.5 volts, for a total of 3 volts.

For further information on the design, physics and operation of photo-voltaic cells, please refer to pages 32 – 48 in the Thames & Kosmos® Fuel Cell Lab Manual included in the Museum in a Box.

## NASA's Solar Aircraft

NASA has developed four solar powered aircraft: the Pathfinder, Pathfinder Plus, Centurion and lastly, the Helios.

The Pathfinder (Img. 3) is a lightweight, remotely piloted aircraft based on a flying wing design, meaning that it has no body or fuselage, just wings. Its purpose is to demonstrate solar power technology as used in long-duration, high-altitude flight. It is NASA's hope that this concept vehicle will lead to a fleet of solar-powered aircraft that could stay airborne for months at a time on scientific sampling and imaging missions.


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 3** The Pathfinder over runway in Kauai, Hawaii

Solar arrays cover most of the upper wing surface and provide power for the aircraft's electric motors, avionics, communications and other electronic systems. It also has a backup battery system that can provide power for up to five hours, which gives it a limited amount of flight time after dark.


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 4** The Pathfinder Plus in flight

Pathfinder is slow in terms of modern aircraft, flying at an airspeed of only 15 to 25 mph. Pitch, or the up/down motion of the aircraft, is controlled by the use of tiny elevons on the rear, or trailing edge of the wing while turns are accomplished by slowing down or speeding up the motors on the outboard sections of the wing.

In 1997, the Pathfinder set an altitude record of 71,530 feet over Kauai, Hawaii.


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 5** The Centurion during takeoff

The Pathfinder Plus (Img. 4) and Centurion (Img. 5) were based on the original Pathfinder but were designed to carry more weight or fly higher for longer. The Pathfinder Plus reached 80,201 feet while the Centurion was designed to fly up to 100,000 feet!

The Helios (Img. 6) became NASA's fourth design after seeing the performance gains achieved in the Centurion. It has the largest wingspan of any of NASA's solar aircraft at 75 meters (247 feet), which provided more room for additional solar panels as well as space underneath for electronics.


**Img. 6** The Helios Prototype in flight

On August 13th, 2001, the Helios reached an altitude of 96,863 feet, a world record for a winged aircraft. Not only did it break the previous record by 11,000 feet, it also spent more than 40 minutes at that altitude. In addition, it was the first to use a hydrogen fuel cell to provide additional electrical power to the motors.

Unfortunately in June of 2003 the Helios suffered a catastrophic failure over the Pacific Ocean about 10 miles west of Kauai, when excessive turbulence caused the aircraft to exceed its designed speed limits and literally break apart.

As NASA scientists and engineers work to improve solar power technology, the practical applications can help to develop a fleet of solar-powered, high altitude aircraft, improve the efficiency of solar-powered cars, and lead to new developments in solar-powered technologies.

# Activity 1 Solar Powered Car Demonstration

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## Time Requirements: 30 minutes

### Materials:

In the Box

Thames & Kosmos™ Fuel Cell Car & Experiment Kit

Philips head screwdriver

Provided by User

Sunlight / lamp

Worksheets

None

Reference Materials

None

### Key Terms:

Gallium arsenide

Geothermal energy

Hydroelectric energy

Photo-voltaic cell

Photosynthesis

Silicon

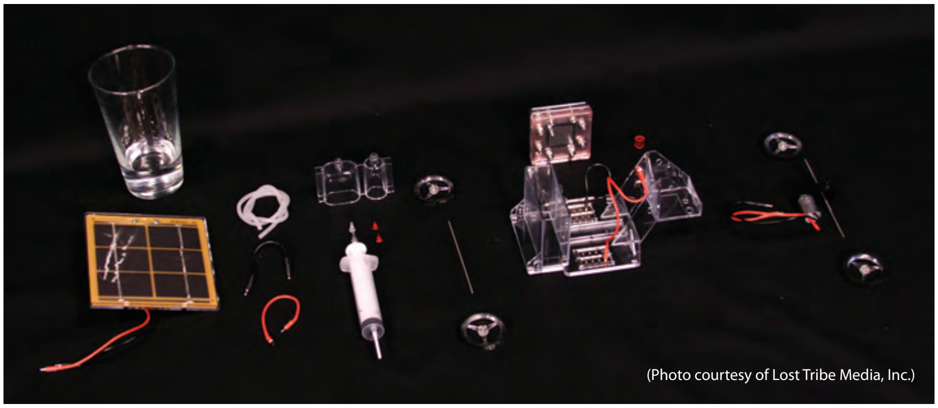
Solar cell

### Objective:

Students will convert solar energy (potential energy) into kinetic energy to power a small car.

### Activity Overview:

By observing this demonstration, students will learn how light is converted into electricity using a solar panel. They will then see this electricity in use, powering a small car.



(Photo courtesy of Lost Tribe Media, Inc.)

### Activity:

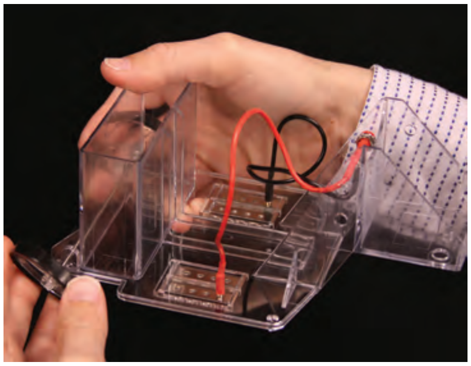
The kit may require time to build prior to the demonstration. It takes approximately 20 minutes to assemble the vehicle itself (if not previously used), with an additional 10 minutes required to complete the demonstration.

*Caution: The kit contains many small, easily breakable parts. It is important to exercise caution during both the setup and the demonstration.*

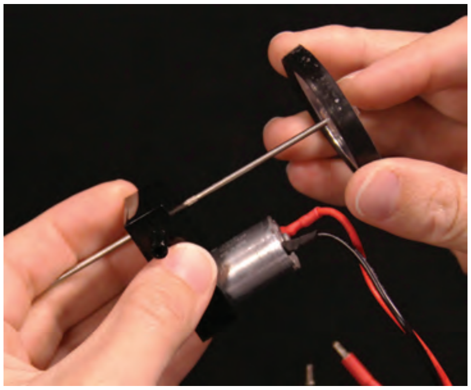
1. **To begin, review the Background information with your students.**

2. **Next, assemble the car as follows:**

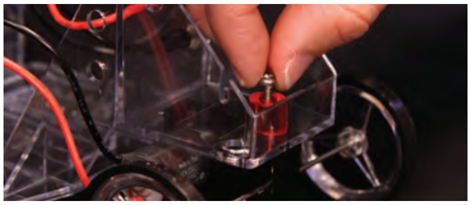
a. Pass a metal axle through the holes in the rear of the body and attach a wheel to each end.



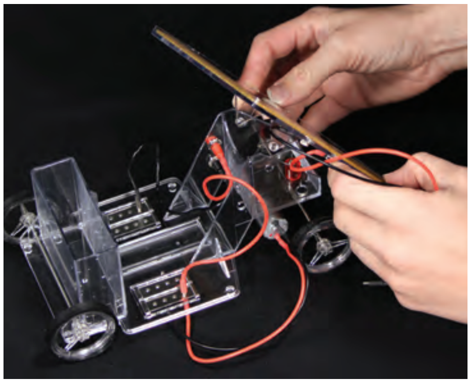
b. Attach a wheel to each end of the axle on the motor assembly.



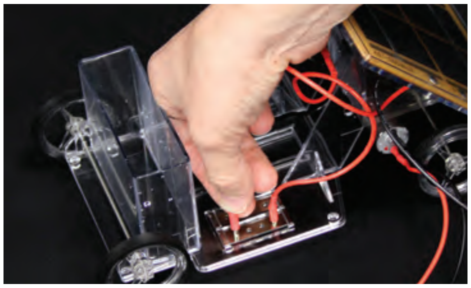
c. Attach the motor assembly to the body of the car using the Phillips screw and spacer.



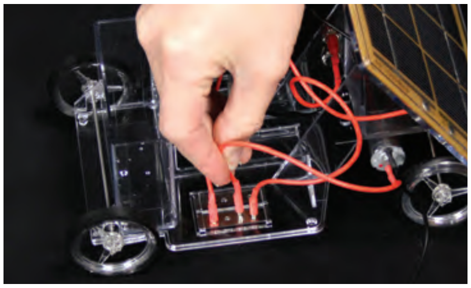
d. Attach the solar cell to the car's body by inserting the plastic tabs into the holes in the front of the car.



e. Connect the wires of the solar cell to the car, ensuring that the red wire connects to the right side of the car and the black wire to the left side.



f. Attach the wires from the motor to the plugs in the body. Connect the red wire to the right side of the car, the black wire to the left.
*At this point there may already be sufficient light to power the motor. You may wish to raise the wheels of the car while connecting the motor.*



g. Take the car outside, or to a brightly lit area. Place the car on the ground and let it go!

## Discussion Points:

1. **What just happened?**
*The solar panel, or more accurately, the silicon in the photo-voltaic cell, absorbed the photons in the light. This allowed electrons already within the silicon to break free and move throughout the cell, creating electricity. This electricity was used to power the motor, whose energy was transferred to the wheels, causing the car to move.*

2. **What is the difference between a solar cell and a solar panel?**
*A solar cell is the smallest unit of a solar panel. A single cell cannot produce much electricity, but when combined in a large quantity (solar panel) it is quite effective. While we could use many individual solar cells to power the car, it is much quicker to connect a single panel.*

3. **What is the difference between a solar cell and a photo-voltaic cell?**
*A solar cell was designed specifically to work with sunlight, while a photo-voltaic cell can work with any form of light, including infra-red. In practical use however, a group of cells is nearly always referred to generically as a solar panel.*

4. **How do living organisms currently use the Sun's energy?**
*Answers will vary but may include (1) plants using sunlight for photosynthesis, (2) cold-blooded animals using the Sun's heat to warm their bodies, and (3) migrating animals or plants using diminishing light levels and dropping temperatures as a cue to begin their annual journey or to shed their leaves.*

5. **Name some ways we can put the Sun's energy to use.**
*Answers will vary but should include using sunlight to power electrical devices, heating water, powering cars, etc.*

*This demonstration is just one of many experiments that can be performed using this kit. The other activities available with this Solar Power kit are listed below. Detailed instructions can be found in the Thames & Kosmos® Fuel Cell Lab Manual.*



1. **Page 17 / Experiment 2: The Brighter the Faster**
   In this experiment, students will compare the performance of the solar panel in a variety of lighting conditions.

2. **Page 20 / Experiment 3: Measurement of Short Circuit Current and No-load Voltage**
   This experiment expands on Experiment 2 above, quantifying the results using a multimeter.

3. **Page 24 / Experiment 4: Calibration of a Radiation Meter**
   Students completing this experiment will calibrate their solar panel and graph the relationship between light input and voltage output.

4. **Page 26 / Experiment 5: Direct and Diffuse Radiation**
   In this experiment, students will compare the effects of direct light with those of reflected and refracted light.

5. **Page 28 / Experiment 6: Daily Cycle of Solar Radiation**
   Students will compare the power available from the Sun at various times of the day.

6. **Page 38 / Experiment 7: Characteristic Curve of a Solar Panel**
   By adding varying amounts of resistance (or load) to a circuit, students will graph the performance of the solar panel.

7. **Page 47 / Experiment 8: Determining the Efficiency of a Solar Cell**
   Students will evaluate the efficiency of a solar cell by comparing the amount of radiation entering the cell with the amount of electricity generated.

# NATIONAL SCIENCE STANDARDS 5-8

## SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

## PHYSICAL SCIENCE

- Properties and changes of properties in matter

## SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

# NATIONAL SCIENCE STANDARDS 9-12

## SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

## PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter

## SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

# Reference Materials

# Glossary

**Flying wing:**
A style of aircraft that is constructed of just a single large wing; it has no fuselage (body), or tail sections

**Gallium arsenide:**
A compound (mixture) of Gallium and Arsenic and was designed to have better electrical properties than Silicon; is also identified by the letters GaAs

**Geothermal energy:**
Thermal energy that was created when the planet was formed and stored within the Earth

**Hydroelectric energy:**
The generation of electricity using the kinetic energy of water

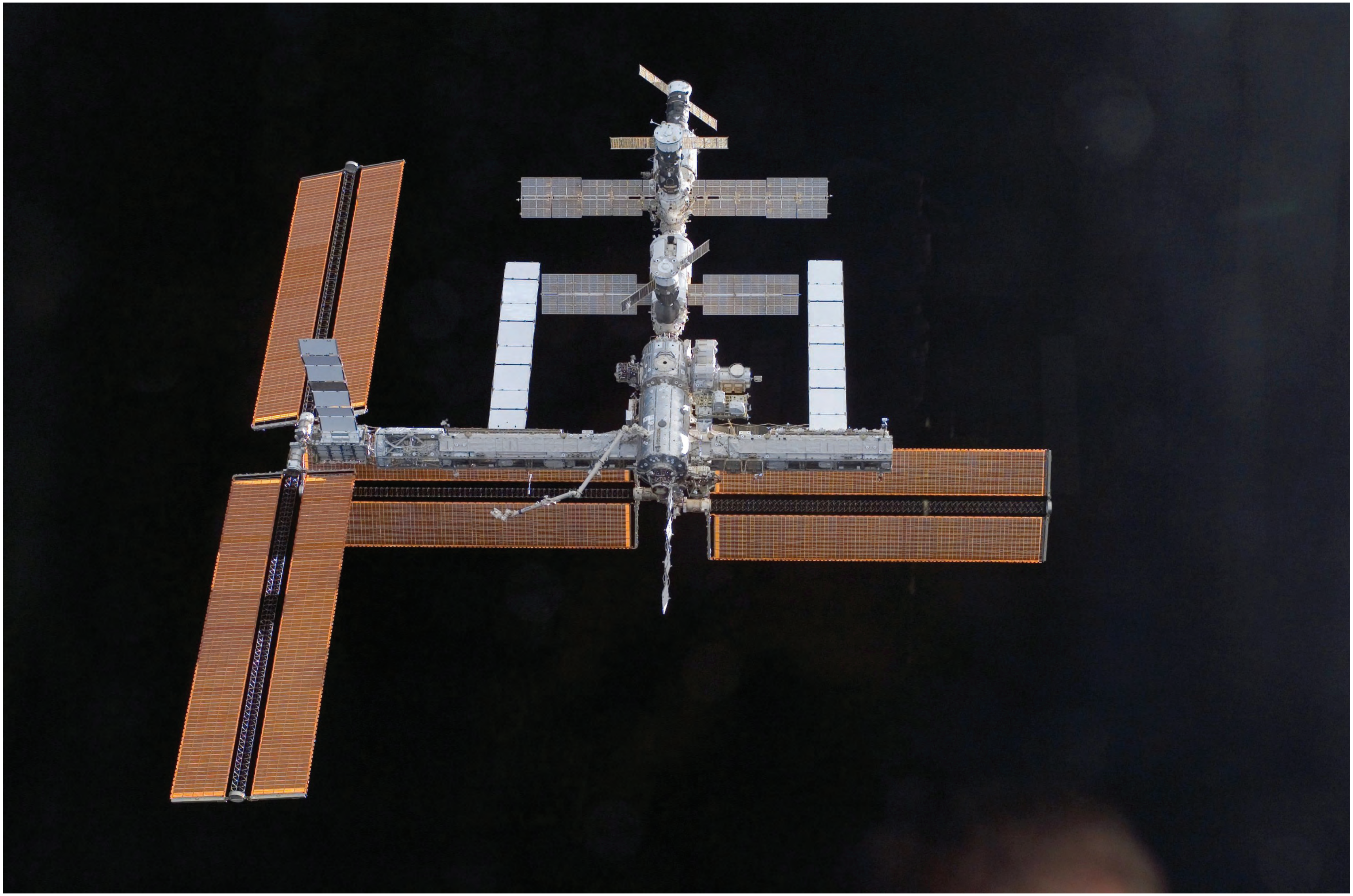
**Photo-voltaic cell / Solar cell:**
A solid-state electrical device designed to convert light energy into electricity

**Photosynthesis:**
From the Greek word meaning "putting together", is the process by which plant matter converts carbon dioxide into sugars, which are then ingested by the plant, releasing oxygen in the process

**Silicon:**
A chemical element with an atomic number of 14; is also identified by the letters Si

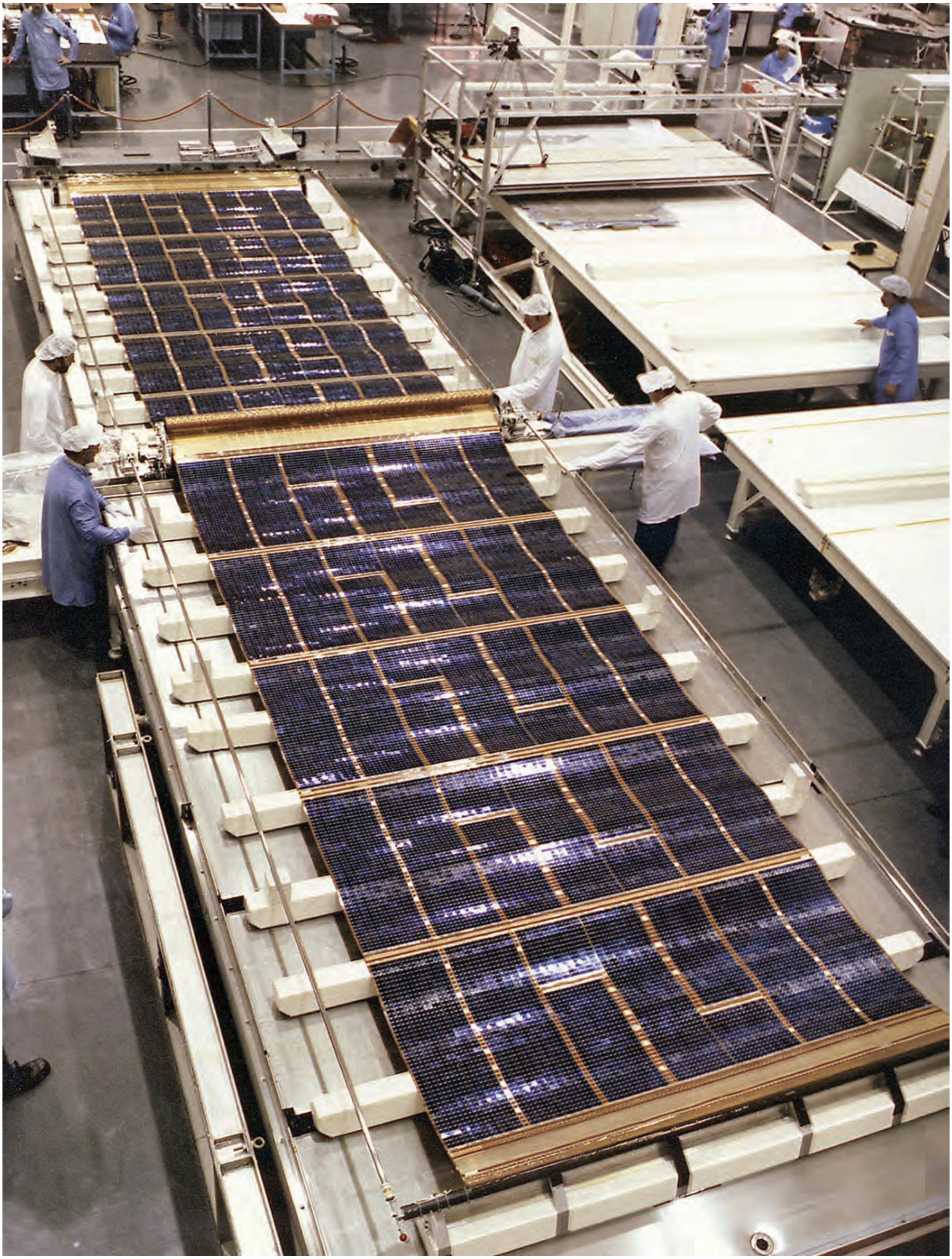
# Images

**Img. 1** The International Space Station



(Photo courtesy of NASA - www.nasaimages.org)

**Img. 2** The solar array of the Hubble telescope



(Photo courtesy of NASA - www.nasaimages.org)

**Img. 3** The Pathfinder over runway in Kauai, Hawaii


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 4** The Pathfinder over runway in Kauai, Hawaii


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 5** The Centurion during takeoff


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

**Img. 6** The Helios Prototype in flight


(Photo courtesy of the NASA Dryden Flight Research Center Photo Collection)

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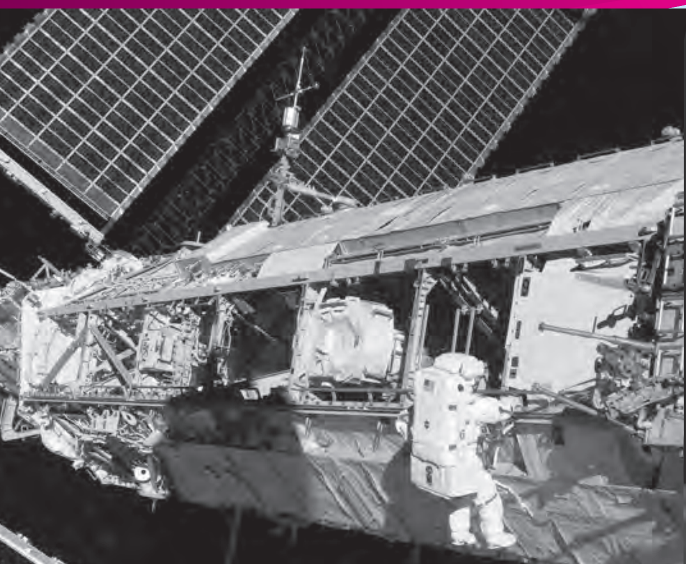

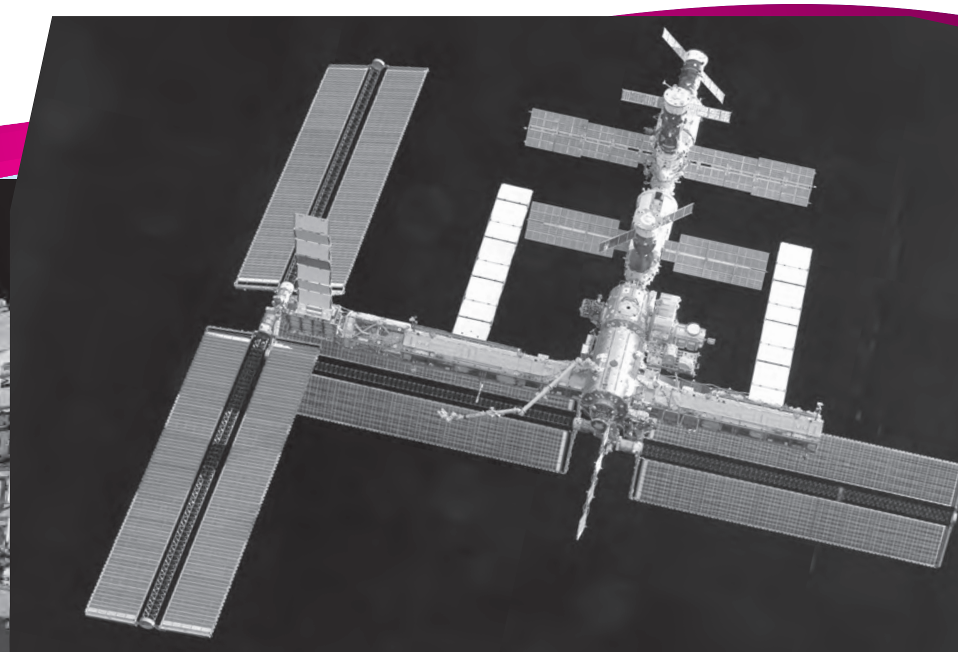



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