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Many astronomy spacecraft have orbited above Earth over the last 30 years. The data collected by these satellites have changed and enlarged our conceptions of the universe.

While the activities in this guide address the technologies used in studying the universe from above Earth’s atmosphere, little attention has been paid to what those instruments have actually accomplished. The best way to study astrophysics results is by examining the actual data and imagery collected. Pictures taken in visible wavelengths and enhanced through computer processing are stunning in their beauty as well as their scientific value.

NASA’s Astrophysics Division has assembled a colorful set of 35 mm slides on its astrophysics spacecraft and some of their results. Each slide is accompanied with abbreviated and detailed captions.

It is easy to obtain a copy of the slides. They are available from the Central Operations of Resources for Educators (CORE) in Ohio or from NASA’s Teacher Resource Centers. Please refer to pages 90 and 91 of this guide for details on how to contact CORE or the NASA Teacher Resource Center that serves the state you live in.
NASA's Great Observatories Paper Model Kits

NASA's Great Observatory Paper Model Kits permit students to construct detailed spacecraft models in the classroom or at home. Completed models may be used in space dioramas or hung from the ceiling. The kit contains background information on the mission of the observatories and their instruments. The kit contains reproducible masters for the models that should be copied on to paper stock 60 pounds or greater. Models may be enlarged on a copier if bigger models are desired. The pieces of each observatory are labeled with detailed, step-by-step instructions and a listing of additional materials required for assembly. To obtain a kit, contact the NASA Teacher Resource Center that serves your region. See pages 90-91 for a list of these centers.
Glossary

Absorption lines - Dark lines that are produced in a spectrum because intervening atoms absorbed photons of specific wavelengths.

Angstrom - A unit of measure equal to $10^{-12}$ meters.

Astronomy - The branch of science focusing on celestial objects, dealing with their size, location, composition, dynamics, origin, etc.

Astrophysics - Investigation, through remote sensing, of the physical principles of astronomical objects.

Binary numbers - A system of numbers that has two as its base and can be used for numerical coding of data.

Black hole - A body (usually a collapsed star) whose surface gravity is so great that neither matter nor light can escape from it.

Charged coupled device (CCD) - An electronic device that consists of a regular array of light sensitive elements that emit electrons when exposed to light. CCDs are used as the light-detecting element in telescopes, television cameras, etc.

Concave lens or mirror - A lens or mirror with an inward curvature.

Continuous spectrum - A spectrum unbroken by absorption or emission lines.

Convex lens or mirror - A lens with an outward curvature.

Diffraction - The spreading out of light waves as they pass by the edge of a body or through closely spaced parallel scratches in a diffraction grating.

Dispersion - Breaking up of light into its component colors.

Doppler shift (effect) - Changes in the wavelengths of sound or light as the distance between the emitter and the receiver changes.

Earth-based telescope - Telescope mounted on the surface of Earth.

Electromagnetic spectrum - The complete range of all wavelengths of electromagnetic radiation.

Enhancement (computer) - Boosting the color or contrast of a faint image through computer processing.

Excitation - The state that occurs when electrons are raised by an external input, such as light or an electronic current, to higher energy levels.

Fluorescence - A spontaneous emission of a photon of light that occurs when an electron drops down from a higher energy level (See excitation.) to its original level.

Frequency - The number of waves that pass a point in one second. Frequency is usually expressed in units of hertz (waves or cycles per second).

Gamma rays - Electromagnetic radiation with wavelengths shorter than $10^{-12}$ meters.

Geostationary satellite - A satellite placed in an orbit 35,900 kilometers over Earth's equator that remains in the same place at all times.

Infrared - Electromagnetic radiation with wavelengths ranging from approximately $10^{-4}$ to $10^{-6}$ meters.

Light gathering power (LGP) - The ability of an optical instrument to collect light.
Long wave UV - Ultraviolet light with wavelengths (about $10^{-7}$ meters) just shorter than the optical range of the electromagnetic spectrum.

Microwaves - Electromagnetic radiation with wavelengths ranging around $10^{-3}$ meters.

Nanometer - One billionth of a meter ($10^{-9}$ m).

Neutron stars - A star about 10 kilometers in diameter composed entirely of densely-packed neutrons.

Objective lens or mirror - The large lens or mirror of a telescope. Sometimes referred to as the primary lens or mirror.

Ozone layer - A region in Earth's upper atmosphere (between 15 and 30 kilometers) where small concentrations of ozone absorb ultraviolet radiation from the Sun and other celestial bodies.

Persistence of vision - Momentary visual retention of light.

Photometry - Measurement of the intensity of light.

Photons - A quantum or individual packet of electromagnetic energy.

Photosphere - The visible surface of the Sun.

Pixels - The smallest element of a picture.

Pulsars - A stellar radio source that emits radio waves in a pulsating rhythm.

Radio waves - Electromagnetic radiation with wavelengths ranging from approximately $10^4$ to $10^2$ meters.

Refraction - Bending of light rays as they pass through the interface between two transparent media.

Resolution - The degree to which fine details in an image can be seen as separated or resolved.

Resonance - Sympathetic vibration of one body when exposed to vibrations or electromagnetic radiation emanating from another.

Scientific Notation - Scientific notation, or powers of 10, which can simplify writing large numbers. Numbers with positive powers mean the decimal point moves to the right (e.g., $3 \times 10^6 = 3,000,000$). A number with a negative power means that the decimal moves to the left (e.g., $3 \times 10^{-6} = 0.000,006$).

Short wave UV - Ultraviolet light with wavelengths nearest the x-ray range (around $10^{-8}$ meters) of the electromagnetic spectrum.

Space-based astronomy - Astronomical investigations conducted from above Earth's atmosphere.

Spectrograph - An instrument used for dispersing and recording specific wavelengths of the electromagnetic spectrum.

Spectroscopy - The study of spectra.

Speed of light - The speed at which light travels—300,000,000 meters per second.

Supernova - A stellar explosion which increases the brightness of a star by a factor of several million times in a matter of days.

Ultraviolet (UV) - Electromagnetic radiation with wavelengths ranging from
approximately $10^{-7}$ to $10^{-8}$ meters.

**Visible light** - Electromagnetic radiation with wavelengths ranging from approximately 400 to 700 nanometers.

**Wavelength** - The distance between one wave crest to the next wave crest (or one trough to the next trough).

**White dwarf** - A small star that has exhausted its nuclear fuel but continues to shine from residual heat.

**X-rays** - Electromagnetic radiation with wavelengths ranging from approximately $10^{-8}$ to $10^{-10}$ meters.

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### NASA Educational Materials

NASA publishes a variety of educational resources suitable for classroom use. The following resources specifically relate to spacecraft and space exploration. Resources are available from different sources as noted.

#### Educational Videotapes

Educational videotapes and slide sets are obtainable through CORE.

**Electromagnetic Spectrum: A Symphony of Light**
- Length: 19:30
- Grades: 5-8
- Application: Earth Science, Physical Science

The crew of the orbiting Astro-1 Mission (December, 1990) discusses the range of the electromagnetic spectrum and why it is important to climb above Earth’s filtering atmosphere to study astronomical objects. Includes a teacher guide. Available through NASA Johnson Space Center.

**Hubble Space Telescope, “The Best Is Yet To Come . . .”**
- Length: 07:15
- Grades: 5-12
- Application: Astronomy, Physical Science

This program focuses on the human endeavor involved in restoring the **Hubble Space Telescope** to its original scientific potential on the STS-61 mission. It features the most visually striking moments and interweaves stories from the astronauts.

#### Space Classroom: Assignment the Stars
- Length: 27:00
- Grades: 5-8
- Application: Astronomy, Physical Science

The crew of the orbiting Astro-1 Mission (December, 1990) deliver a live astronomy lesson to middle school students. Students learn about the electromagnetic spectrum and how it relates to an astronomy mission. Includes a teacher guide.

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### Educational Software

Educational software is available through the NASA Teacher Resources Center Network and CORE.

**Astronomy Village; Investigations in Astronomy**, a NASA Educational Product by Classroom of the Future
- Software: CD-ROM, Macintosh-based
- Grades: 9-12
- Application: Astronomy

This multimedia program provides teachers and students with ten investigations in astronomy. Students conduct a scientific inquiry working in teams of three, interfacing in a village setting with a
mountain top observatory. The resources available to the team on CD-ROM include: full motion video clips; images from the Hubble Space Telescope and other instruments, audio clips by astronomers, NASA publications, information from astronomy journals and books; and computer animation and graphics.

Hubble Space Telescope Educational Software by Oklahoma State University (1990)
Software: Apple II and Macintosh (PageMaker 3.02)
Grades: 5-8
Application: Astronomy, Physical Science
This software package chronicles the history of astronomical observations culminating in the Hubble Space Telescope, examines the design and science of telescopes, describes Hubble's instruments, and illustrates how Hubble captures and transmits images from space. Includes fact sheets, lithographs, software, activities, bibliography, models, and evaluation materials.

Publications

Educational and background information publications are available from NASA Headquarters. Please address requests to:
NASA Headquarters
Code FEO-2
Space-Based Astronomy Teacher's Guide
300 E Street, SW
Washington, DC 20546-0001


Suggested Reading

Books

These books can be used by students and teachers to learn more about space-based astronomy.


Bonnet, R. & Keen, G. (1992), Space & Astronomy, 49 Science Fair Projects, TAB Books, Blue Ridge Summit, PA.


Smith, P. (1992), Project Earth Science: Astronomy, National Science Teacher's Association, Arlington, VA.

Sneider, C., et al. (1989), Color Analyzers, Lawrence Hall of Science, Berkeley, CA.


Magazines


Astronomy Magazine, Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187


Odyssey, Cobblestone Publishing, Inc., 30 Grove Street, Peterborough, NH 03458-1454

Sky & Telescope, Sky Publishing Corporation, 49 Bay State Road, Cambridge, MA 02138
NASA Educational Resources

NASA Spacelink: An Electronic Information System

NASA Spacelink is a computer information service that individuals may access to receive news about current NASA programs, activities, and other space-related information, including: historical data, current news, lesson plans, classroom activities, and even entire publications. Although it is primarily intended as a resource for teachers, the network is available to anyone with a personal computer and a modem.

Users need a computer, modem, communication software, and a long-distance telephone line to access Spacelink. The Spacelink computer access number is (205) 895-0028. The data word format for direct and Internet access is 8 bits, no parity, and 1 stop bit. It is also available through the Internet, a worldwide computer network connecting a large number of educational institutions and research facilities. Callers with Internet access may reach NASA Spacelink at any of the following addresses:

- spacelink.msfc.nasa.gov
- xsl.msfc.nasa.gov
- 192.149.89.61

For more information, contact:
Spacelink Administrator
NASA Marshall Space Flight Center
Mail Code CA21
Huntsville, AL 35812-7015
Phone: (205) 544-6360

NASA Education Satellite Videoconference Series

During the school year, NASA delivers a series of educational programs by satellite to teachers across the country. The content of each videoconference varies, but all cover aeronautics or space science topics of interest to the educational community. NASA program managers, scientists, astronauts, and education specialists are featured presenters. Broadcasts are interactive: a number is flashed across the bottom of the screen, and viewers may call collect to ask questions or to take part in the discussion. The videoconference series is free to registered educational institutions. The programs may be videotaped and copied for later use. To participate, the institution must have a C-band satellite receiving system, teacher release time, and an optional long-distance telephone line for interaction. Arrangements may also be made to receive the satellite signal through the local cable television system. For more information, contact:

Videoconference Coordinator
NASA Teaching From Space Program
Oklahoma State University
300 North Cordell
Stillwater, OK 74078-0422

NASA Television

NASA Television (TV) is the Agency's distribution system for live and taped programs. It offers the public a front-row seat for launches and missions, as well as informational and educational programming, historical documentaries, and updates on the latest developments in aeronautics and space science.

The educational programming is designed for classroom use and is aimed at inspiring students to achieve—especially in science, mathematics, and technology. If your school's cable TV system carries NASA TV or if your school has access to a satellite dish, the programs may be downlinked and videotaped. Daily and monthly programming schedules for NASA TV are also available via NASA Spacelink. NASA Television is transmitted on Spacenet 2 (a C-band satellite) on transponder 5, channel 8, 69 degrees West with horizontal polarization, frequency 3880.0 Megahertz, audio on 6.8 megahertz. For more information contact:

NASA Headquarters
Technology and Evaluation Branch
Code FET
Washington, DC 20546-0001
NASA Teacher Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Teacher Resource Center (TRC) network. TRCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Because each NASA field center has its own areas of expertise, no two TRCs are exactly alike. Phone calls are welcome if you are unable to visit the TRC that serves your geographic area. A list of the centers and the geographic regions they serve starts at the bottom of this page.

Regional Teacher Resource Centers (RTRCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RTRCs in many states. Teachers may preview, copy, or receive NASA materials at these sites. A complete list of RTRCs is available through CORE.

NASA Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue of these materials and an order form by written request, on school letterhead to:

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
Phone: (216) 774-1051, Ext. 293 or 294

<table>
<thead>
<tr>
<th>IF YOU LIVE IN:</th>
<th>Center Education Program Officer</th>
<th>Teacher Resource Center</th>
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<tbody>
<tr>
<td>Alaska</td>
<td>Mr. Garth A. Hull</td>
<td>NASA Teacher Resource Center</td>
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<tr>
<td>Arizona</td>
<td>Chief, Education Programs Branch</td>
<td>Mail Stop T12-A</td>
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<tr>
<td>California</td>
<td>Mail Stop 204-12</td>
<td>NASA Ames Research Center</td>
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<td>Hawaii</td>
<td>NASA Ames Research Center</td>
<td>Moffett Field, CA 94035-1000</td>
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<td>Idaho</td>
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<td>PHONE: (415) 604-5543</td>
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<td>Montana</td>
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<td>Connecticut</td>
<td>Mr. Richard Crone</td>
<td>NASA Teacher Resource Laboratory</td>
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<td>Delaware</td>
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<td>Maine</td>
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<td>Maryland</td>
<td>PHONE: (301) 286-7206</td>
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<td>Massachusetts</td>
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<td>Colorado</td>
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<td>Houston, TX 77058-3696</td>
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<td>Florida</td>
<td>NASA Johnson Space Center</td>
<td>PHONE: (713) 483-1257</td>
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<td>Virgin Islands</td>
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<td>Chief, Education Services Branch</td>
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<td>Kentucky Space Center, FL 32899-0001</td>
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<tr>
<td>Kentucky</td>
<td>Ms. Marchell Canright Center Education Program Officer Mail Stop 400</td>
<td>NASA Teacher Resource Center for NASA Langley Research Center Virginia Air and Space Center 600 Settler's Landing Road Hampton, VA 23699-4033 PHONE: (804)727-0900 x 757</td>
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<td>North Carolina</td>
<td>NASA Langley Research Center Hampton, VA 23681-0001 PHONE: (804) 864-3307</td>
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<td>Illinois</td>
<td>Ms. Jo Ann Charleston Acting Chief, Office of Educational Programs Mail Stop 7-4</td>
<td>NASA Teacher Resource Center for NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135-3191 PHONE: (216) 433-2017</td>
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<td>Minnesota</td>
<td>NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135-3191 PHONE: (216) 433-2017</td>
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<tr>
<td>Alabama</td>
<td>Mr. JD Horne Director, Executive Staff Mail Stop DXO1</td>
<td>NASA Teacher Resource Center for NASA Marshall Space Flight Center U.S. Space and Rocket Center P.O. Box 070015 Huntsville, AL 35807-7015 PHONE: (205) 544-5812</td>
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<td>Arkansas</td>
<td>NASA Marshall Space Flight Center Huntsville, AL 35812-0001 PHONE: (205) 544-8843</td>
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<td>Mississippi</td>
<td>Dr. David Powe Manager, Educational Programs Mail Stop MA00</td>
<td>NASA Teacher Resource Center for NASA John C. Stennis Space Center Stennis Space Center, MS 39529-6000 PHONE: (601) 688-3338</td>
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<td>The Jet Propulsion Laboratory (JPL)</td>
<td>Dr. Fred Shair Manager, Educational Affairs Office Mail Code 183-900</td>
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<td>serves inquiries related to space and</td>
<td>Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91109-8099 PHONE: (818) 354-8251</td>
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<td>NASA Wallops Flight Facility</td>
<td>Wallops Island, VA 23337-5099 Phone: (804) 824-2297/2298</td>
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