Teacher's Guide

Live From the Hubble Space Telescope

Exploring Space and Cyberspace

An electronic field trip via interactive television and on-line networks into America's classrooms

PASSPORT TO KNOWLEDGE

Programs and Initial Air Dates and Times

Program 2 **Making YOUR Observations**
March 14, 1996, 13:00-14:00 Eastern

Program 3 **Announcing YOUR Results**
April 23, 1996, 13:00-14:00 Eastern

Please Note:

Program 1 **The Great Planet Debate**
first aired November 9, 1995, as an introduction to the entire project. (For videotapes, see below)

Primary Satellite Coordinates

Ku-band: PBS K-12 Learning Services: Telstar 401, 97 degrees West, transponder 8, horizontal, 11915 Mhz, audio on 6.2 and 6.8

Please note: this refers to carriage on the primary satellite used by PBS. Carriage on the satellite itself does not guarantee broadcast by any individual PBS station. Please check local listings well in advance of air time to verify local arrangements! An on-line listing of confirmed carriage by local stations and educational networks will be accessible between March 1, 1996 and April 23, 1996.

C-band: NASA TV: Spacenet 2, 69 degrees West, transponder 5, channel 9, horizontal, frequency 3880 Mhz, audio on 6.8

NASA TV has indicated it will carry programs at the time and date scheduled. However Shuttle schedules and other factors may modify this. Again, please check current schedules close to air time. NASA TV publishes its daily schedule over NASA Spacelink. The *Live from Hubble* Home Page (see under) will also provide a pointer to this information.

Videotapes Tapes of the programs as broadcast will be available from NASA's 10 Regional Teacher Resource Centers and NASA CORE. (For NASA addresses, see the accompanying publication, *Space Based Astronomy,* pp. 90-91) For NASA CORE, phone (216) 774-1051. For other availability, check the *Passport to Knowledge: Live from the Hubble Space Telescope* Information Hotline:

1-800-626-LIVE (1-800-626-5483)

Off-Air Taping Rights The producers have made the standard public television Extended Rights period of "one year after initial broadcast" available for free classroom use.

Live from the Hubble Space Telescope is a *Passport to Knowledge* project. *Passport to Knowledge* is supported, in part, by the National Science Foundation, under award ESI-9452769. Opinions expressed are those of the authors and not necessarily those of the Foundation.

This project was supported, in part, by the

National Science Foundation

Live from the Hubble Space Telescope is also supported by the **Information Infrastructure Technology and Applications Program (IITA)** of **NASA's Office of High Performance Computing and Communications,** the **Space Telescope Science Institute** (operated for NASA by the Association of Universities for Research in Astronomy, Inc.—AURA), the **NASA Astrophysics Division, NASA Education, NASA K-12 Internet Initiative** and **PBS K-12 Learning Services.**

Contingency Announcement

Field research on a scientific frontier is inherently unpredictable. Even traditional school trips are subject to weather and disruptions. An electronic field trip is no different: the *Live from the Hubble Space Telescope* programs are dependent on the HST operating normally, NASA's Tracking and Data Relay Satellites being available, and all domestic satellite links holding (see Activity 2D, page 24 below, for more background on how the electronic images get from Pluto to you!) The production team has put in place contingency plans for most eventualities. In the event of temporary loss of signal, live programming will continue from ground sites, interspersed with pre-taped segments.

Register for on-line *Live from the Hubble Space Telescope* updates or check our Web site:

http://quest.arc.nasa.gov/livefrom/hst.html

On-line Resources

On-line resources are a unique element of this project and are described in more detail in this Guide. Background information is already available, and will remain accessible indefinitely, so long as it remains current. The project's interactive and collaborative components, such as *Researcher Q & A* will commence March 1, 1996, and will be supported at least through April 30, 1996. To subscribe via e-mail, contact:

listmanager@quest.arc.nasa.gov

In the body of the message, write: **subscribe updates-hst.**

Need more Information?

Educators may contact the *Passport to Knowledge* Education Outreach Coordinator, Jan Wee
phone: **(608) 786-2767**
fax: **(608) 786-1819**
e-mail: **janw@quest.arc.nasa.gov**
with questions about on-line access, broadcast and tape availability, with feedback and suggestions, or with comments or queries on any other matter concerning *Passport to Knowledge* or this *Live from the Hubble Space Telescope* module.

Live From the Hubble Space Telescope

An electronic field trip via interactive television, computer networks and hands-on science activities.

Made possible in part by NASA, the National Aeronautics and Space Administration,
The National Science Foundation, PBS K-12 Learning Services and public television

Dear Educator,

Welcome to *Live from the Hubble Space Telescope!* This project marks the very first time that K-12 students have been directly involved in choosing which objects to observe with Earth's most powerful orbital telescope. And it's the first time that a unique mix of live interactive video and on-line interaction have given students across America and around the world the opportunity to visit—virtually—via an "electronic field trip," with the men and women who operate the Hubble. This Guide and the co-packaged hands-on materials are designed to help you and your students prepare for that experience, integrate it successfully into your course of instruction, and make it pay off long after the live videos are over. Many of the Activities you'll find here directly parallel the processes you'll see on camera or read about on-line. When your students chart which planets are safe to view with the Hubble (Activity 2C), throw a basketball around the gym to simulate the telecommunications path which brings the Hubble's data back to Earth (Activity 2D), or make a color image from black and white data (Activity 3A), they'll be mirroring the real-world activities they'll see the astronomers, mission planners and engineers doing on camera, in the real world of research.

Live from the Hubble Space Telescope is targeted primarily at middle schools, but can easily be adapted up or down in grade level. The project features cutting-edge science, but also provides extensive connections across disciplines, including math, social studies, language arts, technology education and computer skills, and it contains information about high-tech careers as well as "pure" research.

This is the third in our ongoing *Passport to Knowledge* series. Old hands will recognize many aspects of earlier Modules. But just like your students, we hope we've been growing and learning. We now have a full-time Education Outreach Coordinator, Jan Wee: you'll find her contact numbers on the inside front cover of this Guide. They are there for educators to use, with questions about any aspect of the project. Our innovative on-line resources continue to evolve. If you're new to the Internet, you'll find a section in this Guide designed to get you going. If you use the World Wide Web or have more extensive connectivity, you'll find graphics, a "Virtual Tour" of Space Telescope and its support network. We hope our project suggests ways in which your students can become authors, creators and publishers on-line, not mere "browsers." As one elementary teacher said, "*Passport to Knowledge* doesn't encourage students just to 'surf the Net,' but rather to 'make waves.' "

Is there a common feature to all our Modules, ranging as they do from penguins to planets, from the South Pole to Pluto? We hope you agree it's putting people into the process, so that students discover science not as history—with all discoveries done by others, many long dead—but as real life in which they can play a role. *Passport to Knowledge* is "Real Science, Real Scientists, Real Locations, Real Time."

Our project makes *interaction* with world-class scientists possible for students in schools, at home or from science centers and museums. And our project very much wants interaction with, and feedback from, YOU. On page 40, there's news about a special inducement to return the Teacher and Student Evaluation forms: a free CD-ROM. But your greatest reward will be to help shape future *Passport to Knowledge* field trips—the better to help you inform, inspire and educate your students. In Fall 1996, we plan to begin *Live from Mars*—a project which will extend over many years and multiple NASA and international missions. In Winter 1997, we expect to be back in the Antarctic, in the Palmer Peninsula, studying baby seals and and other wild-life close-up, as well as hunting dinosaur fossils. We hope your success with this current project means you'll be traveling with us then, and that *Live from the Hubble Space Telescope* will help you make "Reality" the fourth "R" in your classroom.

Thanks for your belief in our planet's most precious and, we believe, unlimited resource: the minds and imaginations of its young people.

Sincerely,

Geoff Haines-Stiles

Project Director, *Passport to Knowledge* and the *Live from…* specials

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Table of Contents

From our home on the Earth, we look out into the distances and strive to imagine the sort of world into which we are born. Today we have reached far out into space. Our immediate neighborhood we know rather intimately. But with increasing distance our knowledge fades, and fades rapidly, until at the last dim horizon we search among ghostly errors of observations for landmarks that are scarcely more substantial.

The search will continue. The urge is older than history. It is not satisfied and it will not be suppressed.

EDWIN P. HUBBLE

The worst thing that has happened to science education is that the great fun has gone out of it… (instead, science should be) …high adventure …the wildest of all explorations ever taken by human beings, the chance to catch close views of things never seen before, the shrewdest maneuver for discovering how the world works.

LEWIS THOMAS, researcher and essayist

…the telescope has released the human imagination as no other implement has ever done… the development of the telescope marks, indeed, a new phase in human thought, a new vision of life…

H.G. WELLS, "The Outline of History"

We hope to find something we hadn't expected.

EDWIN P. HUBBLE

ADDITIONAL PRODUCTION ASSISTANCE FOR LIVE UPLINKS SITES FURNISHED BY
BUHL PLANETARIUM, CARNEGIE SCIENCE CENTER, PITTSBURGH ✷ WQED, PITTSBURGH ✷ SETON HALL COLLEGE TALENT SEARCH ✷ CONNELLSVILLE JR HIGH WEST ✷ PROJECT ATHENA ✷ WASHINGTON STATE OFFICE OF THE SUPERINTENDENT OF PUBLIC INSTRUCTION ✷ MUSEUM OF FLIGHT, BOEING FIELD, SEATTLE ✷ STEP STAR/ESD 101 ✷ JET PROPULSION LABORATORY, PASADENA, CA ✷ LOS ANGELES UNIFIED SCHOOL DISTRICT ✷ TEAMS DISTANCE LEARNING, LA COUNTY OFFICE OF EDUCATION ✷ BAVARIAN TELEVISION ✷ HST EUROPEAN COORDINATING FACILITY, EUROPEAN SPACE AGENCY ✷ GODDARD SPACE FLIGHT CENTER, NASA

FOR CUSEEME AND VIDEOCONFERENCING ASSISTANCE,
HOUSTON MUSEUM OF NATURAL SCIENCE

FOR INTERNET PARTICIPATION IN BRAZIL,
COMPAQ COMPUTER, FUTUREKIDS, USIA WORLDNET

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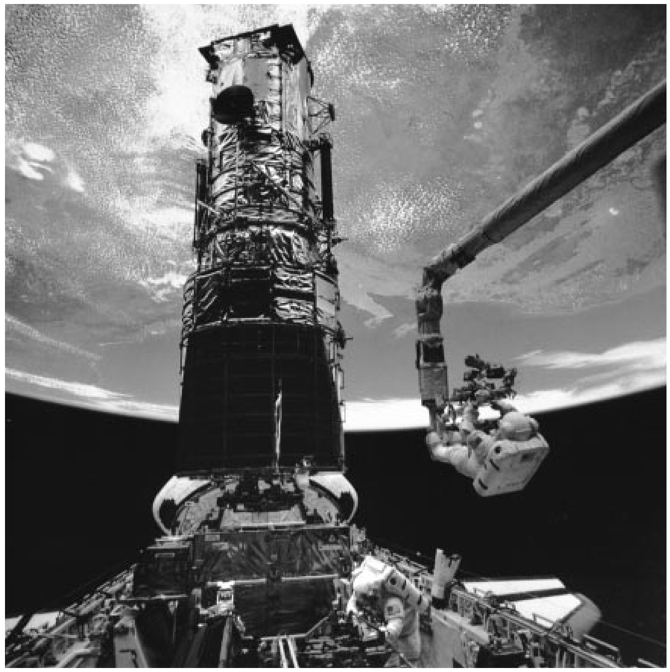


Turn your TV and computer into a "passport to knowledge" and reach out to Neptune and Pluto via NASA's Hubble Space Telescope

Passport to Knowledge is an ongoing series of "electronic field trips to scientific frontiers." It's designed as an innovative learning experience that integrates live interactive telecasts, pre-taped video backgrounders, responsive computer communications and hands-on in-class activities to allow you and your students to travel, virtually, to places that would otherwise be almost impossible to visit. Before now, no K-12 students have ever had the opportunity to suggest what the Hubble Space Telescope should observe, and then been able to participate as the actual orbits are planned and executed. This will be the first time, ever, that live cameras have been allowed into the Mission Operations Room at NASA's Goddard Space Flight Center, bringing students as close as it's possible to get to Space Telescope unless you're an astronaut on a servicing mission. Because of its educational mission, *Passport to Knowledge* is being allowed to boldly go where not even the commercial broadcast networks and NASA Associate Administrators were permitted! It's a unique privilege, and we hope you and your students take full advantage of it. You earned this access in large part by your commitment of time and energy to the "Great Planet Debate" which demonstrated to NASA how interested elementary, middle and high school students are in the planets, people and processes to be seen in *Live from the Hubble Space Telescope*, (*LHST*).

Project Components:

"The Three T's"

Live from the Hubble Space Telescope uses the complementary contributions of the three T's—Television, Telecommunications and you, the Teacher—to help students become active participants in some of the most challenging and exciting scientific research currently underway.

Television

The two upcoming live programs are key components, but they will contribute most to your students' learning experience if Activities and lessons precede and follow them, as many teachers chose to do as part of *Live from Antarctica* (*LFA*) and *Live from the Stratosphere* (*LFS*). You may find the 30 minute introductory program, "The Great Planet Debate" (first aired November 9, 1995, but still available on tape from NASA CORE and being re-broadcast by some PBS stations—please check local listings!) is still of interest, even though we now know the "winners" of the debate. The program provides background on HST, the target planets, and the overall timetable for the project.

"Making YOUR Observations" (March 14, 1996) will provide a "first look" at our collective observations of Neptune and Pluto, and we hope for considerable excitement as we see just what we've captured!

"Announcing YOUR Results" (April 23, 1996) will reveal the first substantive findings from the *Passport* observations: the 5 week period between the programs is relatively quick for analysis and review, but we hope for some significant announcements from our Planet Advocates and those students who'll be working alongside them, virtually, with the new images.

NASA's Interest in Promoting Public Uses of the Internet

Support for *Passport to Knowledge: Live from the Hubble Space Telescope* comes, in part, from the Information Infrastructure Technology and Applications Program (IITA) of NASA's Office of High Performance Computing and Communications. Our integrated multimedia project coincided with NASA's commitment to demonstrate and promote the increased use of the nation's vast but hitherto under-utilized treasury of Earth and Space Science Data. We hope you and your students will mine the wealth of information and marvel at the instructive and often beautiful images that await you, just an on-line connection away.

Telecommunications

No project could ever provide sufficient video uplink sites to connect all students who might wish to interact with researchers at the remote field sites, whether in Antarctica, the stratosphere or Baltimore (home of the Space Telescope Science Institute.) But on-line networks allow us to extend the interactivity symbolized by the live, 2-way video and audio into every school and class across the nation, and indeed, around the globe. We plan for participation from Brazil, Europe and elsewhere, by students watching over USIA's Worldnet or other links.

Our on-line components allow students to send e-mail to experts, some of whom have been seen on camera, and to receive responses to their specific, individual questions. *Field Journals*, or research diaries, provide personal behind-the-scenes insights into the people, places and processes seen on camera. Even more than in previous projects, *LHST* will support collaboration between teachers and students, and feature the results of such on-line collaboration during the live telecasts. (see Going On-line, p. 42 for more details)

This Guide provides basic information—and we hope some encouragement and motivation—to go on-line if you've not done so before. Once on-line, you'll find many more specific suggestions about how to use e-mail and the project's Web pages.

The Teacher

This Guide and the accompanying "mini-kit" of additional publications and discovery tools are designed for you, the Teacher. They provide practical, hands-on Activities for middle school students, often with suggestions about adapting them to lower or higher grades. You'll find icons indicating which Activities can connect across the curriculum, linking science with math, social studies, language arts, and other disciplines. We've also provided a Matrix or grid showing how the various Activities, grouped by program, embody the suggestions of the AAAS's Project 2061 (*Benchmarks for Science Literacy*) and the *California Science Framework*. We are very interested in how the entire project works for you, and welcome your feedback by mail or e-mail.

Format of the Teacher's Guide

Each activity in *LHST* is designed to:

- **Engage:** capture student interest by preparing them to experience the videos, or by encouraging them to use the suite of available learning tools.
- **Explore**: help students construct ideas from first-hand observation and experiment, using hands-on Activities.
- **Explain:** provide you, the Teacher, with sufficient background to allow you to facilitate student learning with specific content and teaching strategies, suggested in this Guide, accompanying publications and in the on-line materials.
- **Expand:** review and reinforce concepts, and reteach by tapping visual, auditory, tactile, kinesthetic and other learning styles. Several activities lend themselves to a form of embedded assessment: for example, Activity 4A, "Writing Across the Solar System" and 4B, "Lights… Camera… The Universe" require an understanding of the new science discussed in the programs, but also creativity, authoring, presentation and publishing skills. Such extensions of the project will also provide you with concrete evidence about what your students "got" from their participation.

What Teachers Said About "The Great Planet Debate"

It is really rewarding for me as a teacher to see student interest so high in something scientific. The Planet Advocates have almost reached the "star" quality that my students usually reserve for athletes and movie stars. They've been thrilled to read the messages that have come in on the computer from all over the United States and the world. They don't even realize that they are learning.

Ruth Wahl science teacher, Allegany-Limestone Central School, NY

While watching my students evolve from a class into a "think tank" I have been able to share in their excitement, enthusiasm and their learning process. They came to me and shared their new discoveries and information in a manner which filled me with pride in them. This is a great group, and remember these are High School soph., jr. and sr. It is not often they can be so outwardly enthusiastic. We are looking forward to the final decision, and whatever the outcome, we are already planning the "Observing Party!"

Rob Theriaque, Aerospace Studies, Nashua High School, NH

*ALL of us sitting in on this **discuss-hst** "debate" panel are…*

- *celebrating the empowerment of students, students actively participating not only in a decision-making process but in their own education, learning by working in collaboration*
- *celebrating the teaching of science involving hands-on research, careful observation, recording and reporting of data, comparing and sharing of information, and drawing conclusions*
- *celebrating student motivation to learn because they were provided with a real "listening" audience, acquiring confidence and expertise*
- *celebrating students becoming global citizens and understanding that the world is their community*
- *celebrating students experiencing the power of technology*

Marilyn Wall, 4th grade teacher, Wayland Elementary, Bridgewater, VA

How to Use this Guide

Tips to help you implement Live from the Hubble Space Telescope

This Teacher's Guide and mini-kit closely follows the format developed for *Live from Antarctica* and *Live from the Stratosphere*. Your feedback rated those materials high in quality, but we hope you also find we've added some "New and Improved" features. You should assume every Activity is great for Science classes, but we've added Computer and Art icons to those already indicating interdisciplinary opportunities for Social Studies, Language Arts and Math. There's a two-page overview of how *Passport to Knowledge* and the *Live from…* specials can help you, the Teacher, implement some of the most important recommendations which have been published by groups such as the National Academy of Sciences and AAAS's Project 2061. Written by Joe Exline (former head of Virginia's NSF-funded State Systemic Initiative, current Executive Secretary of the Council of State Science Supervisors and a Consultant to *Passport to Knowledge*), these suggestions may help you both in the classroom and in the front office, when an Administrator asks you just exactly what you think this "electronic field trip" does for education and your mandatory course of instruction! To help maximize the value of the videos, and to help you create a receptive "set" in your students, we'll be posting narrative scripts for the taped segments on-line, one week in advance of the live programs.

The Activities

As in previous projects, the Activities suggested here relate closely to the real-world research you and your students will see during the live videos and read about on-line. They were developed to help make otherwise abstract aspects of, for example, image processing come to life. "The Universe in Living Color" (Activity 3A, p. 30) provides a hands-on experience using the color filters co-packaged with this Guide to show how computers transform black and white images into stunning Hubble pictures, samples of which you'll also find enclosed. We've even researched which brands of colored markers give you the best results! (see Activity 3A, Materials, p. 30)

Throughout this Guide and in all the various media we employ, we've tried to make *LHST* a "turnkey" project, so that you'll find sufficient substance, suggestions and support to allow you to orchestrate a successful experience for your students, no matter your level of technology or prior training, whether you're an astronomy buff or relatively unfamiliar with the latest data.

Passport to Knowledge Guiding principles

- All students can understand and be successful in science. Science has applications for us all in resolving life's problems
- Science should be learned as both content and process to develop life-long learning skills
- New and emerging technologies should be used to provide effective learning, and these technologies should be used creatively
- Learning in science must reflect the latest research in science, and the science of learning (pedagogy)
- Science is best learned in an immediate environment that enables active learning and provides effective interaction with the extended environment
- The use of a variety of systematically-related instructional resources are important for effective learning
- The successful achievement of student learning is the ultimate aim of education and therefore student evaluation should be a valid measure of the learning objectives
- Active learning leads to meaningful understanding

PASSPORT TO KNOWLEDGE ICONS

Language Arts | Math | Social Studies | Technical Education | Computers/On-line | Art

Co-packaged Materials

Co-packaged with the *LHST* Teacher's Guide come several existing publications, and materials designed to support hands-on activities:

NASA's *Space Based Astronomy* provides background relevant to the Hubble field trips (specifically on the electromagnetic spectrum), an excellent Glossary, and a listing of other NASA resources and how to order them.

A selection of Hubble's "Greatest Hits," in and beyond our solar system: these color lithographs, supplied by the Space Telescope Science Institute, speak for themselves as stunning pictures, but when you want to go beyond the beautiful imagery you'll find explanatory captions on their reverse.

STScI also cooperated with *Passport to Knowledge* to permit us to print a special *LHST* edition of the Eagle Nebula poster, one of the most beautiful and thought-provoking space images ever.

Hubble Space Telescope: New and Improved from STScI's Starcatcher series provides background on HST and its operations, on the 1994 Shoemaker-Levy 9 comet impact on Jupiter, and other useful information.

Students can literally get their hands-on the Hubble with the copy master pages for a card or paper model of Space Telescope, duplicated from a NASA original. Since we're committed to making each *Passport to Knowledge* project as easy to implement as possible, we've also included samples of several items needed for various Activities: heat-sensitive paper and UV beads for Activity 2A, capturing InfraRed and UltraViolet radiation in memorable ways; color filters for 3A (you can find out how to order larger quantities of these materials in the Resources section, p. 44); and 4 pages of Earth and interplanetary weather images to be copied for Activity 3B.

Sufficient structure for success. Flexibility enough for local adaptation

Passport to Knowledge recognizes that each school and teacher is unique. We've tried to provide enough information to make *LHST* successful for you and your students, whether you only watch the videos and use this printed Guide, or go on-line with simple e-mail, or browse far and wide with full Internet access. There's no "one right way" to use the project. We encourage you to pick and choose those aspects which work best for you and your students, adding parts of your regular curriculum which can be enlivened by this electronic field trip to see HST, Pluto and Neptune close up. (Please, share your experiences, successes and frustrations with your peers and colleagues all across the nation and the planet, via **discuss-hst**, our on-line teacher co-laboratory.)

On-line: A Unique Opportunity

Though we encourage flexibility, we'd not serve you well if we did not emphasize that the on-line resources referred to throughout this Guide and referenced in the videos are extremely important. *Passport to Knowledge* is perhaps best utilized as a thoroughly integrated multimedia experience in which the Video, Print and On-line components are of equal value, delivering different but complementary experiences. The on-line materials permit a degree of interactivity with the Hubble team impossible through any other medium. The on-line collaborations, such as the Star Census (continued from *LFS* to permit more national and international participation) and "Weather or Not?"—new for *LHST* and specifically seen during Program 3—provide a model for communication with peers across space and time which is an introduction to the world of work your students will inhabit.

PASSPORT TO KNOWLEDGE

"Writing Science"

Throughout this Guide and on-line you'll find many samples of writing and using language. Our Planet Advocates recall what hooked them on astronomy, and middle school students offer poetry about the heavens. On-line you'll find *Field Journals* from STScI and other NASA centers, rich with anecdotes about working with the Hubble day-by-day, when things are running smoothly, or when someone has to pull an all-nighter to get the numbers right to catch a comet on camera. We hope you'll find these worth sharing with your students: they emphasize that cutting-edge astronomy engages the imagination as well as the intellect, and demonstrate that contemporary science involves communicating with others along with collecting hard data and crunching numbers. Above all, we hope the multiplicity of voices will emphasize the human dimension of the project, and engage and motivate your students.

In our Opening and Closing Activities, you'll find suggestions about how your students can write Journals and create other literary material. These Activities should help them first get into the project and later synthesize their learning. This allows you to assess what they've gained, and helps us all evaluate what works.

Edwin P. Hubble, 1889-1953

As a child, Edwin Powell Hubble wandered the Kentucky countryside, observing the habits of birds and animals. As an adult, he scrutinized the stars and galaxies. Although Hubble was always interested in science, he didn't settle on a career in astronomy immediately. He received an undergraduate degree from the University of Chicago in 1910, where he also lettered in basketball and almost became a professional boxer. He studied law under a Rhodes scholarship at Oxford University, in England, passed the bar exam, and practiced law briefly and half-heartedly. He "chucked the law for astronomy… I knew that even if I were second-rate or third-rate, it was astronomy that mattered." Hubble completed graduate studies at the Yerkes Observatory of the University of Chicago, where he began his examination of spiral nebulae. He earned his doctorate in 1917 and was invited to join the Mount Wilson Observatory in Pasadena, California. But Hubble didn't yet begin the studies which made him famous. Answering the call to World War 1, he enlisted in the infantry, telegraphing observatory personnel, "Regret cannot accept your invitation. Am off to the war."

Two years later he finally began working with the instrument that would enable him to make his greatest discoveries—the 100-inch reflector at Mount Wilson, at the time the largest telescope in the world. Except for four years of service in World War ll, Hubble was devoted to astronomy until his death in 1953.

Hubble's patient, painstaking observations revealed a much larger universe than anyone had imagined. He was enchanted by dim, foggy patches called "nebulae," the Latin word for cloud. One called Andromeda was the most spectacular nebula observed during the early decades of the century, but telescopes weren't powerful enough to see if it harbored any stars like the vast stellar populations of the Milky Way. Since the 18th century, scientists had argued about whether these areas were "island universes," separate galaxies, or simply clouds in our galaxy. Was the Milky Way the only galaxy? Was it the center of the universe?

In 1924, Hubble ended the debate when he reported stars in the outskirts of Andromeda, and found a special kind of star, known as a Cepheid variable, which reveals its distance by the way its light regularly brightens and dims. Careful observations of the Cepheids enabled him to measure the distance to Andromeda, far too many light-years away to be in our galaxy. He moved on to classify the galaxies, grouping them by size and shape, and established that many other nebulae were also galaxies, even more distant than Andromeda. Hubble measured the depths of space out to 500 million light years, distances far greater than any previous surveys.

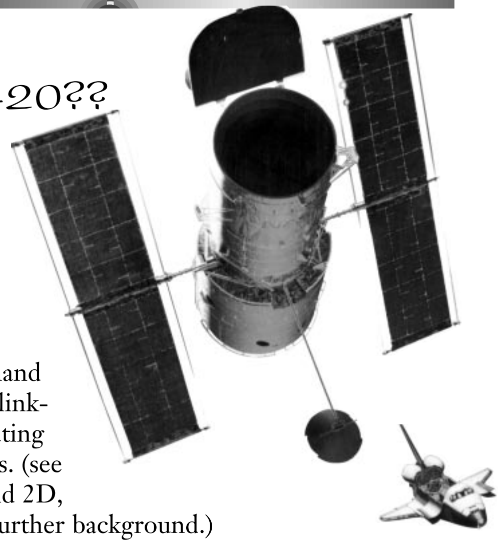
credit: American Institute of Physics

As he continued to study galaxies, he concluded that they were moving away from Earth at velocities proportional to their distance. This supported the concept that the universe originated in a cosmic explosion, and that all the matter in the universe was expanding from an initial Big Bang. The galactic survey resulted in "Hubble's law": the more distant the galaxy from Earth, the faster it moves away. Of course, if all the galaxies originated from one explosion, residents of other galaxies would see the same thing: a universe of fleeing galaxies with the more distant ones moving more rapidly. Hubble found that the ratio of the velocity of receding galaxies to their distance from Earth is constant —the "Hubble constant"— a significant astrophysical number still not calculated with certainty today. Current estimates of the "Hubble constant," and thus the rate of expansion of the universe, differ by a factor of two. Still more powerful telescopes are needed to make more precise measurements and determine whether the universe will expand forever, or halt and perhaps reverse.

The Hubble Space Telescope builds on Hubble's research, measuring distances with greater accuracy than ever before possible, and returning beautiful and instructive images of galaxies which Edwin Powell Hubble would have loved to see. It is altogether fitting and proper that this premier space observatory is named for the American astronomer whose work revolutionized modern astronomy. Hubble's research proved that larger, more powerful telescopes are needed to see more of the universe. He assisted in the design of the 200-inch Hale telescope at Mount Palomar near San Diego, and made the first observations with it. When asked what he expected to find with the new telescope, he said, "We hope to find something we hadn't expected." With the Hubble Space Telescope, this quest continues.

Adapted, with thanks, from *Exploring the Universe with the Hubble Space Telescope.* edited by Valerie Neal, NASA, NP-126, p. 18

The Hubble Space Telescope, 1990-20??



The Hubble Space Telescope (HST) is a cooperative program of the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA) to operate a long-lived space-based observatory for the benefit of the international space community. An observatory in space was first dreamt of in the 1940's, long before being designed and eventually built in the 1970's and 1980's and becoming operational in the 1990's. HST is a 2.4 meter reflecting telescope encased in a protective shell housing cameras and other instruments, solar panels for power and communications antennae. It's the size of a school-bus, 13.1 meters long, 4.27 meters in diameter, and weighing some 11,000 kilograms when launched. HST was delivered into low-Earth orbit (600 kilometers) by the crew of the space shuttle *Discovery* (STS-31) on April 25, 1990. To counteract the telescope's gradual fall from orbit (the result of the solar wind) and to protect the spacecraft against instrument and equipment failures, NASA planned regular servicing missions, for which Hubble has special grapple fixtures and 76 handholds. The first servicing mission by STS-61 (*Endeavour*) in December 1993 was an enormous success. During extensive and carefully-rehearsed space-walks, astronauts added corrective optics to fix a problem with the HST's main mirror, which had been mistakenly manufactured 2 microns too flat at the edge, resulting in less than optimal focus for many observations. Future servicing missions are tentatively planned for early 1997, mid-1999, and mid-2002.

Responsibility for conducting and coordinating the science operations of the Hubble Space Telescope rests with the Space Telescope Science Institute (STScI), situated on the Johns Hopkins University Homewood Campus in Baltimore, Maryland. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc. (AURA).

HST's current complement of science instruments includes two cameras, two spectrographs, and fine guidance sensors (primarily used to point the telescope precisely, and for astrometric observations). [Editor's note: for the *Live from…* observations, we'll be using both camera systems: WF/PC2, the Wide Field and Planetary Camera (pronounced "wiff-pik," and built by NASA's Jet Propulsion Laboratory) for Neptune; and the FOC, Faint Object Camera (built by ESA) for Pluto.]

Although HST operates around the clock, not all of its time can be spent observing. Each orbit lasts about 95 minutes, with time allocated for housekeeping functions and for observations. "Housekeeping" functions includes turning the telescope to acquire a new target, avoiding the Sun or Moon, switching communications antennae and data transmission modes, receiving command loads and downlinking data, calibrating and similar tasks. (see Activities 2C and 2D, pp. 22–24, for further background.)

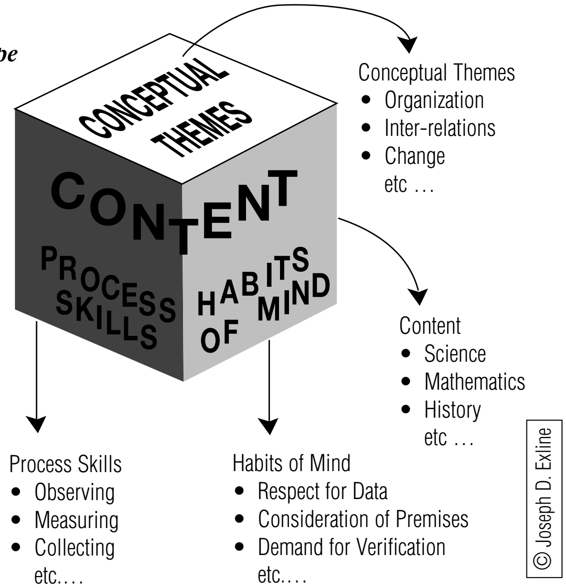
When STScI completes its master observing plan, the schedule is forwarded to Goddard's Space Telescope Operations Control Center (STOCC), where the science and housekeeping plans are merged into a detailed operations schedule. Each event is translated into a series of commands to be sent to the on-board computers. Computer loads are uplinked several times a day to keep the telescope operating efficiently. Some limited real-time commanding for target acquisition or filter-changing is performed, if the observation program has been set up to allow for it. Spontaneous control is not possible.

Engineering and scientific data from HST, as well as uplinked operational commands, are transmitted through the Tracking Data Relay Satellite (TDRS) system and its companion ground station at White Sands, New Mexico. Up to 24 hours of commands can be stored in the on-board computers. Data can be broadcast from HST to the ground stations immediately or stored on tape and downlinked later.

The observer on the ground can examine the "raw" images and other data within a few minutes for a quick-look analysis (which is what we'll see happening, live, during *LHST* Program 2.) Within 24 hours, GSFC formats the data for delivery to the STScI. STScI is responsible for data processing (calibration, editing, distribution, and maintenance of the data for the scientific community). Competition is keen for HST observing time. Only one of every ten proposals is accepted. This unique space-based observatory is operated as an international research center and as a resource for astronomers world-wide.

This HST "biography" is adapted, with thanks, from the "Overview" authored by Rob Landis, to be found on STScI's main Web page

How *Passport to Knowledge* and *Live from the Hubble Space Telescope* can help teachers implement the national science standards



JOSEPH D. EXLINE, Ph.D., Executive Secretary, Council of State Science Supervisors, former head, V-QUEST (VA)

At the national and state levels, standards have been developed in an attempt to make science education more relevant for ALL students. Guidelines, such as the *National Science Standards* (National Academy of Sciences/National Research Council), *Benchmarks for Scientific Literacy* (AAAS/Project 2061) and the *California Science Framework* have been promulgated to help direct local efforts. Central to these efforts is the argument that science taught as a kind of history course ("this is what your learned predecessors have found out") or lecture series ("this is what we experts already know for sure") is not as relevant, nor as effective, nor as exciting for most students as other approaches. Instead, science presented as "these are ways YOU can join with others to find out about the Universe we all inhabit" helps students understand the present and shape the personal and social future. An added benefit is that this approach even appeals to those who won't find their career in research. To make science as relevant "For All Americans" (in the words of one AAAS publication) as are reading and writing, students must become more involved in the "finding out" aspect, i.e. turning science into a process of "scienc-ing."

To help science reform succeed, efforts like those undertaken by the NSF-NASA funded *Passport to Knowledge* project (*PTK*) and its *Live from the Hubble Space Telescope* "Module" can become an integral and ongoing part of classroom learning. I believe that *PTK* activities help teachers address many of the objectives outlined in the *National Science Standards* and the *Benchmarks. PTK* certainly provides ways to make the classroom a place for active student learning and suggests relevant, flexible, immediate and practical ways to use new and emerging technologies. The use of free, broadcast tv and open access via the Internet also helps support the National Science Foundation's state, urban, and rural systemic initiatives, designed to reach otherwise under-served populations.

Passport to Knowledge and Science Reform

PTK hopes to assist the classroom teacher in two principal ways. First, *PTK* focuses on scientific literacy, emphasizing the "finding out" aspect of science. *PTK* believes that science content (varying from Module to Module) can be a means to that end and not just an end in itself, that how you come to know something is as important as what facts you know.

The philosophy of the *National Science Standards* and *Benchmarks* advocates using important and relevant science content to develop real-world connections, problem-solving skills and to nurture reasoning abilities. *PTK* parallels these national trends by involving students as active learners, and serves as a model for how to make science connect beyond the classroom, showing how science literacy may also apply to resolving non-scientific issues in modern society.

The second important way that *PTK* embodies the spirit of the new standards is by demonstrating the use of cutting-edge technology and demonstrating in specific ways how increasingly "school will be just one of the many places where learning will occur." Technology can make the whole world a classroom. Resources for learning are no longer confined to one school and to an isolated teacher working alone. The ability to interact with real scientists at remote locations, and to collaborate with other educators and students in the doing of real science, is well illustrated by *Live from the Hubble Space Telescope*. Too often modern telecommunications delivers merely "distance teaching": *PTK*, however, illustrates true "distance learning."

During the "Great Planet Debate," for example, students from around the world were interacting with scientists to help select which planets to study. During the remainder of the project they have the opportunity to interact "live" with astronomers and other working researchers as data is gathered and interpreted, and so can be part of the process of making new scientific discoveries.

Live from the Hubble Space Telescope: addressing the Standards

Classroom teachers often feel tortured on a Procrustean bed of content, stretched every day in every way to cover the demands of the curriculum. Given the requirement to deliver large amounts of content, there's a natural tendency to question why time should be taken away from existing obligations and spent on such projects as "electronic field trips." The value of projects such as *PTK* becomes more obvious if educators look beyond current demands for the mastery of content (as Dickens' Gradgrind or Joe Friday in *Dragnet* would say, "Facts… facts… facts!") to perhaps more important and relevant aspects of science education. Beyond the specific content of each *PTK* field trip (Antarctic geology, penguin biology, infrared astronomy, comparative planetology) are principles which can enliven any and all content. In order for all the talk about "Standards" to deliver real benefits to students, teachers and society, it's essential that we address four interrelated elements which together define scientific literacy.

These four elements are:

- conceptual themes or connectors which put isolated information into a meaningful context
- process skills which are necessary to observe, collect and analyze valid data
- habits of mind which encourage the validation and testing of the reasonableness of information
- the specific content of the discipline

These four interrelated elements can be easily remembered as illustrated by the cube on p. 10.

All four of these elements are essential and must be an integral part of all learning in order to develop scientific literacy. These elements also lead to the development of the attributes necessary for life-long learning in subjects other than science. Through skills in problem solving and scientific reasoning, learners can understand the content under study. More importantly, they can use these same abilities to understand new and different content they encounter later. The method or approach is the key to successful and meaningful learning. Science education is important for the learner to the extent that it enables him or her to understand, in an active way, how the natural world is organized and interrelates changes and interacts with the human-designed world. *PTK* is modeling this integration of process, content and active learning by having scientists, teachers, and students do scientific investigations in ways that have both personal and societal applications.

The following examples show how these four elements are an integral part of the design of *Passport to Knowledge* and the development of scientific literacy.

✷ **Conceptual Themes or Understanding**s are broad and interdisciplinary in nature in order to have cross-content application. They can be subdivided into more science-related themes such as evolution and energy. Themes are used to put the smaller details of information into a more meaningful context, such as learning how the natural and social worlds are organized, interrelated, and changed. *PTK* uses themes to organize information as follows:

- The interrelationship of the planets' essential characteristics, atmospheres and weather systems.
- How conditions on the outer planets relate to conditions we experience here on Earth

✷ **Skills of Problem-Solving** are developed when the learner becomes actively involved and takes more responsibility for his/her learning. These skills are important tools for future learning and make science as relevant as reading and writing. *PTK*'s programs help develop these skills as illustrated by the following:

- Experimenting with color filters, and generating rules for how colors appear
- Figuring out how to measure the speed and scale of storms on Jupiter, Uranus and Earth

✷ **Scientific Values** are attributes which predispose learners to take action (curiosity) and to test the judgment (respect for data) of their decisions. *PTK*'s on-line and on camera scientists model these attributes as illustrated by the following questions they'll be seen to ask:

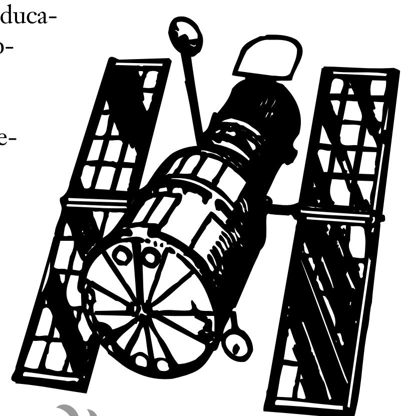
- How do we know the atmospheres differ? (Respect for Data)
- What conclusions do the data support? (Demand for Verification)
- Should we devote resources to study other planets? (Consideration of Consequences)

✷ **Relevant and Important Content** is essential in itself but it is much enriched if it serves as a means to an end in developing conceptual understandings and skills of problem solving, and nurtures scientific reasoning. *Passport to Knowledge* stresses important and relevant content as illustrated by the following:

- Latest findings on characteristics of the planets being studied
- Characteristics and unique advantages of using the Hubble Space Telescope

✷ **Conclusion**

PTK sees itself as a member of a larger learning community. The project evolves as the development team learns new things along with you. You'll see some changes from the design and format of our earlier Modules and this will continue. However, to keep our project of high quality both from a scientific and an educational perspective, we subscribe to certain Guiding Principles for design and implementation. (See sidebar on p. 6) We hope you'll agree that *Passport to Knowledge* can help you and your students do science.



Opening Activities

This section of the Guide summarizes what the *Passport to Knowledge* development team considers the most significant Content or Curriculum objectives for *Live from the Hubble Space Telescope*. For convenience and clarity, they are grouped by Opening and Closing Activities, and by Video program. However achieving these objectives will likely involve on-line as well as video and hands-on work.

While *LHST* is *not* intended as a plug-in replacement for sections of your existing course of instruction, we do believe this 3-5 week project can be justified in terms of at least three criteria: (1) what **content** your students know after participating which they might not have known before; (2) what positive **attitudes** they develop towards what they now know; and (3) what research and technical **skills** they gain and practice (see also pp. 10–11 for thoughts on *PTK* and science reform, and, of course, the Teacher and Student Evaluation pages.) Each individual Activity also states a specific Instructional Objective in clear-cut performance or behavioral terms.

We hope these project objectives and program overviews also provide you with tools to create an "anticipatory set" for your students, so that they approach each Activity or viewing experience as active learners rather than passive consumers.

Project Objectives

After Program 1 and Activities 1A-1C, students will be able to:

- describe the scale and structure of the solar system in terms of distances between the planets, compare/contrast their relative sizes and distinctive characteristics, and differentiate between "terrestrial" and gaseous bodies.
- develop collaborative learning and research skills to create multimedia reports illustrating the complexity and diversity of our solar system.

After Program 2 and Activities 2A-2E, students will be able to:

- describe the Hubble Space Telescope as both a spacecraft AND a telescope, and compare and contrast the importance of each role.
- describe the extensive network of people, places and processes needed to design, deploy and operate the HST.
- summarize current knowledge about Neptune, Pluto and Jupiter, and explain what might be learned about these planets through the use of HST during the *Passport to Knowledge* observations.
- identify the main parts of the electromagnetic spectrum, and compare and contrast the use of various wavelengths to study the planets.
- compare/contrast HST with other telescopes, and describe how its unique advantages are being used during the *Passport to Knowledge* observations.
- describe how HST observes the "moving targets" of the planets of our solar system, and how the data is routed down to Earth for analysis.

After Program 3 and Activities 3A-3D, students will be able to:

- understand how images are constructed from digital data, and the process by which black and white images become color pictures.
- understand how the use of different color filters, time exposures and image processing techniques reveal different aspects of the same image.
- compare/contrast weather patterns on the HST target planets to storms on Earth, in terms of scale, speed of motion, vertical structure and duration.
- describe how scientists gather data, interpret it, test hypotheses, come to preliminary conclusions and publish results for review by peers.

After Closing Activities 4A-4C, students will be able to:

- synthesize and articulate, in media of their own choice, the individual learning they have experienced during *Live from the Hubble Space Telescope.*
- discuss/debate the value to society of such "Big Science" projects as HST.
- describe and evaluate the effects of advanced technology on the process of contemporary scientific research.
- demonstrate a greater interest in the study of astronomy, and a more positive attitude towards scientific research and/or high-tech employment as a possible career.

Program 1: The Great Planet Debate

Aired November 9, 1995, and available on tape from NASA CORE, (see inside front cover). The full script of this program may be found on-line.

This 30 minute program introduced the entire project, and announced the on-line discussion which led to a December 1995 consensus decision about which planets to observe. The four astronomers who served as "Planet Advocates" for the on-line debate (Reta Beebe for Jupiter, Marc Buie for Pluto, Heidi Hammel for Neptune and Carolyn Porco for Uranus) each presented reasons for using three HST orbits for "their" planet, and summarized key scientific goals which could be achieved. Presenter Bill Gutsch reviewed the history of Space Telescope (launch, servicing mission, most revealing and amazing images, current capabilities). Gutsch provided a project timeline, Internet addresses for on-line updates and encouraged participation in an unprecedented experiment in science education and outreach.

Activity 1A: Planet Tours, Inc.

Objective

To collaborate in teams and demonstrate the ability to use appropriate research, writing and presentation skills to create a fact-based travel brochure or poster for an exotic location elsewhere in our solar system.

Engage

Ask students to describe their favorite summer vacation. Take out a map of your state, America or another country, and have students place pins to show where they've traveled. Ask them what made their adventure special, and what features of the location they most remember. Ask them where they'd like to go if they could go anywhere in the world. Ask them where they'd like to go if they could go anywhere in the solar system!

Explore / Explain

Explain to students that for this Activity, they are going to imagine that it's not 1996 but rather far in the future. Tourist travel to the planets is just becoming possible and they are working for the first interplanetary travel agency, "Planet Tours, Inc." Their task is to research the wonders of the solar system (especially those of the *LHST* target planets) and create a series of brochures or travel posters designed to attract the first space tourists.

Materials:

- Advertisements from Sunday newspapers or travel magazines, and/or brochures and posters collected from area travel agencies
- appropriate art supplies, texts, back issues of astronomy and science magazines with space imagery, or computers with scanners and graphics software

Procedure: Divide the class into conveniently-sized teams, who will each work on a different solar system destination. Have students collect brochures, travel posters and other material advertising exotic destinations. Challenge them to create similar brochures and travel posters for the most exotic ports of call in the solar system. What wonders of Mercury or Mars do they feel would be most appealing? What adventures for the well-equipped adventurer—ballooning on Jupiter? Sulfur-surfing on Io? What creature comforts required to tame the chill of Mars, the heat of Venus? What incredible sights on Neptune or Pluto, Triton or Charon?

Have student teams discuss what factors make some posters and brochures more compelling than others. How is the writing they find in a travel brochure different from what they find in a book, the front page of a newspaper, or a magazine? Have students develop a list of "rules" for a successful travel poster or brochure

Turn students' attention skyward. Help students research the necessary factual information about our neighboring worlds and obtain the pictures they need from books, magazines, CD-ROMs or the Internet. (Check our Web page for links to some great on-line resources. See Activity 4B for tips on how to make slides from books or computer screen.) Challenge them to find the most exciting sites and sights offered by their chosen planet or its moons—from *Valles Marineris*, a Grand Canyon on Mars that would stretch across the entire United States, to sheer cliffs of ice on Uranus' satellite, Miranda, 8 miles high. What resort attractions might 21st century technology bring? A golf course on the moon? Snow machines creating a long downhill ski run from a mighty Martian volcano?

Have students make rough sketches of their posters or brochures. Through team discussion, encourage them to edit and refine. Have them compose the finished product before making an oral presentation to the entire class—and come prepared to respond to charges of false advertising or bad science!

A note from Jan Wee, Education Outreach Coordinator, *Passport to Knowledge*

Dear Educators,

Welcome to *Passport to Knowledge!* One of my top priorities is to provide support to all educators as you integrate our projects into your learning environment. My background of 18 years as science teacher, computer support services (especially in the area of Internet-based resources), library media director, and *Passport to Knowledge* team member gives me a broad perspective.

Please feel free to call, no matter your question (608-786-2767), or fax (608-786-1819), or e-mail (janw@quest.arc.nasa.gov), or write (Jan Wee, 431 North Youlon Street, West Salem, WI 54669).

Looking forward to assisting your efforts to make this experience an exceptional and successful one!

Expand

Lead a class discussion about what might some day be feasible, and what are likely to remain fantasies. (Be somewhat cautious about skepticism: in the late 19th century, eminent scientists were still saying heavier-than-air flight was utterly impossible.)

Give students an overall advertising budget for "Planet Tours, Inc." for a one month advertising campaign, and challenge students to develop a marketing plan. If a student has a relative who's a travel or advertising professional, they might be invited to give a talk before the class.

Have them make their presentations to another class (perhaps a lower grade, who can then also ask questions, turning your students into teachers) who will vote on their favorite planetary vacation destination.

Activity 1B: Painting Planets

Objective

Students will research and construct accurately-scaled models of the planets, reflecting each planet's currently-known physical characteristics and appearance.

Engage

Ask your students to close their eyes. Have several students describe the planets of our solar system. Challenge them to recall as much detail as possible. Ask other students to describe the sizes of the various planets relative to each other.

Explore / Explain

Explain that you are going to explore our solar system by creating visually-accurate scale models of all the planets, depicting currently known features.

Materials

- appropriately-sized spheres or balls, obtained from craft stores, art supply houses or other sources (hint: with the Coach's permission, search the gym for punctured sports equipment of the right relative dimensions: see chart)
- paints (and brushes) or other coloring tools (one teacher suggests covering the balls with masking tape, then using colored markers rather than paint)
- sheets of clear plastic, paper plates or sheets of stiff cardboard (to serve as planetary rings for the 4 planets that have rings)
- ruler or measuring tape, paper, marking pens

Procedure Divide the class into teams of 2-3 students, and have each team choose a planet to create. Copy and distribute Table 1B-1 as a reference for the actual sizes of the planets and to corresponding sizes (in inches or cm). Help students determine the relative size of their planet so that everyone is working on the same scale. If they are going to show the ring systems, supply Table 1B-2. Once students agree on the planets' sizes, assign each team the task of acquiring an object of the right dimension.

Have students research the appearance of each of the planets using books, magazines, CD-ROMs, Internet pages or other sources (see Resources for suggestions.) Challenge students to identify the most important surface or atmospheric characteristics of each planet, and to think about ways in which these features can be represented on their models.

As they research their planet, have them list its special characteristics, as an Artist's Think Pad, recording its color or colors, surface or atmospheric features, whether it has rings and, if so, whether they are light or dark? Have students use this as a guide to decide what coloring or painting techniques they'll need to use to create their model. How will they construct and assemble the giant planets' ring systems? (Remember Neptune's strange ring arcs: for more, see *LHST* Program 1.) If you're not sure about colors and textures, consult with an art teacher or art supply store. Consider whether larger planets need more student artists and let the painting begin.

When all the models have been painted, discuss where they can be displayed: the ceiling of the classroom, a school hallway or the auditorium. A special assembly, with students reporting on the completed *Live from the Hubble Space Telescope* project could be scheduled. Have students make a sign for each planet listing its name, size and other key data (see Activity 1C).

If you want to add the Sun to your solar system model, how big a ball would you use? (The Sun is 865,000 miles [1,392,000 kilometers] in diameter, about 109 times the diameter of Earth.) Have students research whether there's a ball or sphere around your school that's large enough. Could they paint a picture of the Sun this large to go with their planets? How big would it be? Where would you place it?

Dr. Marc Buie on Pluto Lowell Observatory, Flagstaff, AZ,

In 1988, Pluto passed perihelion, which is the point at which it's closest to the Sun, and it's going to begin its 125 year voyage to its most distant place in its orbit. And over this time Pluto is going to receive less and less sunlight, and cool off, so we now have an opportunity to study Pluto when it is at its warmest. If we don't take the opportunity now to make these observations we'll have to wait another 240 years to repeat the experiment.

Pluto is sort of the last "astronomers' planet." We haven't yet had a close-up view with a spacecraft. We have an opportunity here to see the development of a science and a knowledge-base about Pluto in our lifetimes. And certainly the past ten years have been exciting, watching what we learned about Pluto. I am certain we are going to learn a great deal more, but this is sort of the special epoch in human history where we are learning for the first time what this planet is all about.

Expand

As a math activity, using ratios and proportions, have older students calculate the planets' relative sizes, defining Jupiter (instead of Earth, as in the table below) as 1 inch, and all other planets scaled accordingly.

If resources permit, (and the drama department or tech crew has some stage lighting to loan!) students may wish to light their planet models dramatically in a darkened room and video tape "close encounters" with their planet, as if their video camera were a spacecraft like the twin Voyagers, or Galileo, slowly flying past. (See *LHST* Program 1, "The Great Planet Debate" for JPL's great computer graphics representations of the Voyagers' encounters with Jupiter, Neptune and Uranus. Remember Galileo will be orbiting Jupiter and its moons for the next 2 years.) Students may later wish to edit these sequences into a multimedia presentation as described in Activity 4B, p. 39.

As another math expansion, challenge students to calculate how far apart the planets would have to be from each other given the size scale of the planets that they adopted. Use the table of distances provided in Activity 1C, p. 16 Whether you use that Activity or not, they'll soon see that our solar system is a very large and empty place!

At the conclusion of *Live from the Hubble Space Telescope*, have students revisit their models of the planets we'll be studying (Neptune, Pluto and Jupiter) and see what "new" information they now have. As a writing activity, how would they update the textbooks or other sources they consulted? Perhaps you might even submit their reports to your text publisher as input for their next revision! (see also Activites 4B and 4C pp. 39–40)

Have students keep a journal as they create their model. What did they do, and discover, each day? What were the easiest, most fun parts of the project? What parts were more difficult or challenging? If another class were going to do this same project next year, what pointers would they give them? Consider keeping a photo-journal or video diary of their progress. Taking a picture of their model each day would provide a timelapse record of how it gradually changed into a planet. Paste such pictures into their journal entries for each day: think how in years to come, you'll also be able to paste video into your students' Web pages!

TABLE 1B-1 SIZE OF PLANETS

Planet	Diameter in Miles	Diameter in Kilometers	If Earth was 1 inch (cm)
Mercury	3,032	4,878	0.38 (a little more than 1/3)
Venus	7,523	12,104	0.95 (about like Earth)
Earth	7,928	12,756	1.00
Mars	4,218	6,787	0.53 (about 1/2 Earth)
Jupiter	88,863	142,980	11.2
Saturn	74,916	120,540	9.5
Uranus	31,771	51,120	4.0
Neptune	30,783	49,530	3.9 (about like Uranus)
Pluto	1,430	2,300	0.18 (about 1/2 Mercury)

TABLE 1B-2 SIZE OF RINGS

Planet	Diameter of Rings if Earth is 1 inch (cm) Inner Edge	Outer Edge
Jupiter	9.6	10.1
Saturn	11.6	21.4
Uranus	6.6	8.1
Neptune	8.9	11.0

PROF HEIDI HAMMEL, on Neptune Massachusetts Institute of Technology

What I like best about the planet Neptune is that every time you look at it, it's different. So Neptune can be your planet…No one else will have seen the clouds that you see and they'll probably never be seen again. And so that means that the pictures of Neptune your students take will be absolutely unique…

One of the biggest surprises when the Voyager spacecraft flew by Neptune was a huge dark spot on the planet. We called it the "Great Dark Spot." We weren't able to see it from Earth because Neptune is the most distant planet from us right now. When we looked with the Hubble Space Telescope last year that Great Dark Spot was gone! It had simply disappeared, it wasn't there anymore, which was a big surprise but when we looked very, very carefully, we saw a different big, dark spot on the planet, in the northern part of the planet— the other one was in the South—so that means Neptune's atmosphere just turned upside down!

When we look at Neptune this time we don't know what we are going to see. There might be a whole, new dark spot and that dark spot would belong to this (PTK) group. They would have discovered it!

Objective

Students will demonstrate the ability to convert distance data into a large-scale model of the solar system (using the "Astronomical Unit" as a yardstick) with students representing the planets.

Engage

Ask students to describe how the previous activity helped them understand the relative sizes of the planets. Tell them they haven't seen anything yet. Now they are going to calculate and show just how far apart they are.

Materials

- 10 white poster boards (Approximately 2 x 3 feet in size)
- thick black marking pen
- piece of brightly colored yarn, rope (corresponding to the length of your "A.U." (see below).

Explore / Explain

Tell students that they are going to measure distances to the various planets, and that some of them will "become" the planets, in an accurately-scaled representation of their correct distance from the Sun. Pass out copies of Table 1C, but cover the numbers in the last column before making copies. Point out the distances in miles or kilometers: ask them if they have their walking shoes ready!

Procedure Explain that to build this model, the class will have to scale down the distances involved, to numbers that can be dealt with easily. Look at Table 1C with them. Point out that if we try to deal with distances to planets in either miles and kilometers, we have to work with huge numbers. (Ask them if we could talk about distances to major cities around the world in inches? Ask them why we don't.) With this in mind, introduce them to a useful new unit of distance, the Astronomical Unit, which is the distance of the Earth from the Sun, just under 93 million miles or 150 million kilometers. This will become our new "yardstick." As a math exercise, have them calculate the distances from the Sun to all the planets in A.U.s, and then confirm their answers with the right-hand column of numbers in the table. Next, have them calculate the distance in A.U.s of each planet from its neighbor. Point out that now, when representing the solar system, instead of dealing with numbers in the hundreds of millions, we only have to worry about numbers up to about 40, at most.

Brainstorm where the class will create its Great Student Solar System. (Hint: Pick a space long enough to be impressive, and fun like a playground or athletic field.) Next, choose a reasonable length for the A.U. in your model. (Hint: Pre-measure the total length of the area likely to be selected for the model and divide this length by 40. This will mean that if the Sun is at one end of the space, Pluto will just neatly fit at the other, with all the other planets spaced out [sic] in between.)

Let students choose to be the different planets and the Sun. If you are preparing this Activity one day and making the model the next, suggest that they wear clothing appropriately-colored for their celestial object. (Mars is a nice, fashionable, rust-color, but Jupiter might require something tie-dyed.)

Discuss having more than one student be each planet, with the number of students indicating the relative size of the planet (see Activity 1B) Have students make posters with the names of their celestial object in large letters, with a picture, created by them, or found in a magazine (being sure only to use ones that are ok to cannibalize!)

The Gallery of the Sky

What is this gallery of the sky?
Images placed there by the gods,
like a pattern,
A pattern of diamonds spread
on a table,
A pattern of pins stuck in black cloth,
Memories,
Memories of forgotten heroes,
Memories of forgotten times,
An art book of love,
that soothes the soul,
An art book of hope,
to help us through it all.
A gallery,
A gallery of everything and
nothing at all

Emily Bernstein, Summit Middle School

To construct your model, go to the designated place with students, posters, and the piece of brightly-colored yarn cut to the length of A.U. chosen for your model. Start at the Sun and place that student in position. Select two or three students as Official Solar System Measurers (OSSMs). With A.U. yarn in hand, have them measure off the correct distance to each planet, using the numbers they have calculated. As the OSSMs reach the right position for each planet, have the student who will represent that planet take their place until the whole solar system is complete. Then, take a few pictures of your Great Human Solar System Model and return to class for discussion. (*Live from the Stratosphere*, Program 5, contains a similar Activity, presented by HST Guide author Bill Gutsch, done live on-camera at NASA Ames in an aircraft hangar: it might help to review that tape if you have it.)

See also Carl Sagan's *Pale Blue Dot* for a discussion of how when Voyager left our solar system, beyond the orbit of Neptune, it turned to take a farewell snapshot which emphasized just how small our Earth was against the huge dimensions of our solar system: think about doing something rather similar, looking out from the Sun to distant Pluto, and vice versa.

When the students reassemble, discuss what they discovered about how the planets were spaced. Most will probably be surprised to see how relatively close together the first four planets are, crowded around the Sun. Beyond Mars, however, the planets are vastly spread out.

Expand

Ask the students who represented each planet to work with a small team of other students to figure out how large each of their planets would be, if the actual solar system were really as small as the model you just created. Use Table 1B-1, and help them make scale cross-references as necessary. As follow-up to Activity 1B, ask them to figure out the distance their planet would be from the Sun if you used planets of that size in your model.

As a math and social studies activity, using local maps, have them figure out where in your community their models would need to be, if they used this larger scale, and the planets were properly distanced from your school, which would represent the Sun. See if, as a "Science Expo," project wrap-up, or year-end activity, you could distribute planet models made by the students around your town, at the right distances in public buildings for everyone to see. Invite the press, district administration, and parents to see math, astronomy, science and art in cooperative action!

Table 1C

Planet	Miles	Kilometers	A.U.
Mercury	35,985,000	57,900,000	0.39
Venus	67,247,000	108,200,000	0.72
Earth	92,977,000	149,600,000	1.00
Mars	141,641,000	227,900,000	1.52
Jupiter	483,717,000	778,300,000	5.20
Saturn	885,954,000	1,425,500,000	9.53
Uranus	1,788,129,000	2,877,100,000	19.23
Neptune	2,801,802,000	4,508,100,000	30.14
Pluto	3,701,057,000	5,955,000,000	39.81

"Moving Targets"

The position of any object on Earth can be plotted on a map using that object's unique longitude and latitude. In the same way, celestial objects can be plotted on maps of the sky using a similar set of coordinates. Declination (Dec.) takes the place of latitude and is measured in degrees and minutes of arc north (+) or south (-) of a line in the sky called the "celestial equator," which lies directly above the equator on Earth. Astronomers use Right Ascension (R.A.) in place of longitude. Just as longitude is measured from a line on Earth called the prime meridian, so Right Ascension is measured from a line that passes through a point in the sky called the "vernal equinox." Right Ascension keeps track of how the sky overhead rotates over time during the day and night, and so Right Ascension is measured in units of time (hours and minutes). The Right Ascension and Declination of stars don't change significantly on the time scales we need to worry about for contemporary astronomy. But the planets are all moving around the Sun at different speeds in different orbits so their Right Ascensions and Declinations are always changing along with that of the Sun (since the Earth, too, is moving).

It's important for HST mission planners to keep track of the ever-changing positions of the Sun and planets in planning observing times for astronomers because for safety reasons, the HST is usually not pointed within about 45 degrees of the Sun (although sometimes with the Earth acting as a kind of shield, it can—with great care—be pointed closer). In Activity 2C, students will act as Mission Planners for the HST. They'll be asked to plot the position of the planets and the Sun, for a series of dates, and to determine which planets are safe to view on those dates, and which will appear too close to the Sun to observe safely.

Program 2: Making YOUR Observations

First airs live, March 14, 1996, 13:00-14:00 Eastern

"Making YOUR Observations" will climax with a live "First Look" at the original astronomical data acquired as a result of the *Passport to Knowledge* observations. Planet Advocates Heidi Hammel, Marc Buie and participating K-12 students will see, at exactly the same moment, what we've collectively discovered about Neptune and Pluto, during a live uplink from the Space Telescope Science Institute, in Baltimore, Maryland (STScI). ("First Look" is what astronomers call their initial glimpse of new data: during the comet Shoemaker-Levy 9 collision with Jupiter, "First Look" was welcomed with whoops of delight and celebratory toasts, as we'll see during this program.)

There'll be another, equally unique "First Look" as—for the first time ever—live cameras are welcomed into the Space Telescope Operations Control Center at NASA's Goddard Space Flight Center. Though there's no live camera currently up in orbit to show us HST from outside, we'll see exactly where HST is at that precise moment, and exactly what HST is seeing. Via our live cameras, students will come as close, virtually, to HST as any human on Earth can ever be. Students will look over controllers' shoulders and see what happens as the telescope slews to acquire new guide stars, or "dumps" its data from the on-board tape recorder. If there is a spacecraft "Health and Safety" emergency, however, we will be unceremoniously booted out of the Mission Operations Room!

Videotaped sequences will show the wide variety of people it takes to operate HST, from astronomers and astronauts, to engineers, computer programmers, communications specialists, mathematicians, graphic artists, technical writers… secretaries. Footage from across America and around the world will show the diverse places, far from STScI and GSFC, where HST work is performed, and the processes which are involved. Students will see what HST has contributed to our understanding of the solar system, and will appreciate that while spacecraft missions have returned stunning, high resolution images of nearly all our local planets (except Pluto), HST provides ongoing coverage, functioning as a kind of "interplanetary weather satellite" for our cosmic neighborhood.

Heidi Hammel and Marc Buie will review what we know about Neptune and Pluto, what they hope the new images might reveal, and describe the hard work they'll be facing in the coming five weeks, to prepare the brand-new data for the April 23rd telecast. Students will find out how they also can work on the data, using custom software and lessons plans provided over the Internet by *Passport to Knowledge* and others. "Mrs. Jupiter," Planet Advocate Reta Beebe, shares images from the "bonus" orbit observing Jupiter which she's contributing to the project, and we see how researchers use the huge STScI data archive to compare and contrast past pictures to help make sense of new information.

The program will also provide an e-mail address where questions can be sent during the live broadcast, providing information about how to participate using e-mail or the World Wide Web. Students will meet some of the men and women on the Hubble team who've volunteered to write *Field Journals* and who'll be responding to student questions on-line as part of *Researcher Q&A*.

In addition to live uplinks from STScI and GSFC, students from Washington state will participate via satellite and interactive video: some of them played a role in the "Great Planet Debate" and will now witness results of the decision they helped make. In another first for *Passport to Knowledge*, students at the European Space Agency's ECF (European Coordinating Facility) in Garching, near Munich, Germany, will interact via videoconferencing. (ESA built the FOC, or Faint Object Camera, which will be used to image Pluto.) We expect e-mail input directly from schools in Brazil, some in Manaus in the Amazon rainforest, who will be watching the programs live via USIA's Worldnet.

Tony Roman, Program Coordinator, STScI

My job is to help astronomers specify all the technical details necessary to conduct observations with the Hubble Space Telescope… then to take that and process it so that the observation eventually becomes something that the computers on board the telescope can understand and perform. Sometimes when you work with these difficult observations it can be a significant challenge to get them to work, and sometimes when you are caught up in all these details, you kind of forget that what you're really doing is working on putting together observations for one of the most powerful observatories the human race has ever built…when the data comes back at last I feel pretty excited and pretty proud to have been a part of that.

I was interested in astronomy since I was a small child, I guess, and I studied physics in college, and mathematics. Those are very important backgrounds for astronomy… I became interested in astronomy through my father, an engineer who worked on the Pioneer and Viking missions. Even though he wasn't an astronomer, he was working on those missions. And even though, at the time, I didn't really understand what he did, just the fact that that's what he was doing got me interested. Also, a more specific example, was that Carl Sagan had a television show on PBS called Cosmos *that I found very inspirational.*

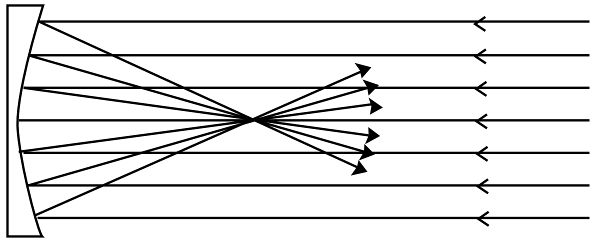
Activity 2A: Using a Concave Mirror to focus Radiation

Objective

Students will demonstrate the ability to explain how different forms of electromagnetic radiation can be focused using a concave mirror, and how HST's mirror functions.

Engage

Ask students why we use telescopes to study the universe. Answers may center on the power of various telescopes and their ability to show distant objects close up. Tell students that while telescopes do give us visually magnified images of distant objects, this isn't really their main function. (General background on the electromagnetic spectrum, as well as several hands-on activities, may be found in the *Live from the Stratosphere* Teacher's Guide, or in NASA's *Space Based Astronomy*, co-packaged with this *LHST* Guide.)



Explore / Explain

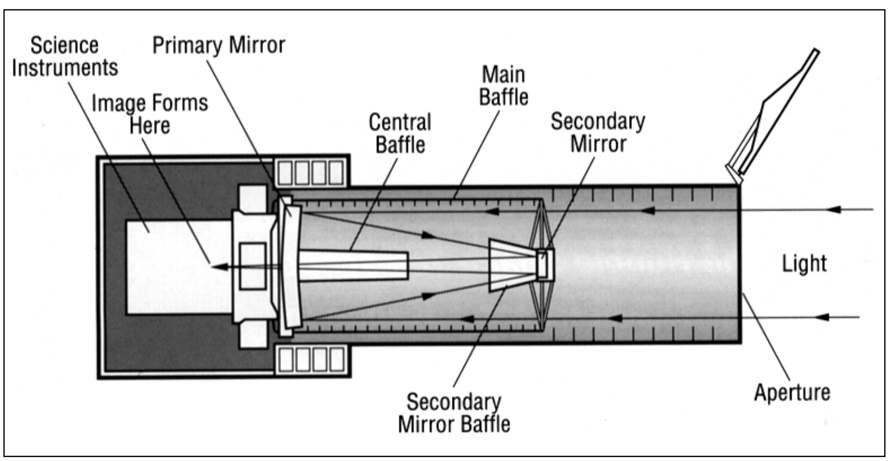
Explain that astronomers learn about objects in space by studying and analyzing the radiation that comes to us from these objects. The more radiation an astronomer can collect from an object, the more he or she can learn about that object because radiation is the carrier of information. So, really, astronomers are not as interested in the power of a telescope as in how much visible light and other radiation the telescope can collect and concentrate for study. This amount is usually far greater than can be achieved with the human eye alone. In this Activity, students will be able to calculate how much more radiation the HST can concentrate for study than can their own unaided eyes. They will see how a concave mirror, like that in the HST, focuses or concentrates radiation.

Materials For use in demonstrations by the teacher:

- concave mirror (such as is used for shaving or applying make-up, or as can be purchased from a supply company e.g., Edmund Scientific Catalog #S52,016 [$26.00] or #S42,427 [$9.95]).
- candle or other small, bright light source
- thermometer and/or the heat-sensitive paper co-packaged with this Guide
- source of UltraViolet radiation (a UV lamp such as Edmund Scientific Catalog # S35,485 [$36.95] or #S34,501 [$32.95]) (Middle and elementary schools may find they can borrow this from their high school.)
- piece of tracing paper or wax paper
- electric space heater
- small jar of fluorescent luminous paint (such as Edmund Scientific Catalog #S31,806 [$10.95] or as is available in some art supply stores.) or the UV-sensitive beads co-packaged with this Guide

For each team of students

- cup of paper circles (the stuff you usually throw away after making holes with a 3 ring binder punch)
- a circle of dark construction paper, 6 inches in diameter



Procedure Sketch on the chalkboard how a concave mirror focuses radiation using a simple ray tracing diagram, as shown above. Explain that the HST's primary mirror is curved like the drawing on the board (see cutaway HST diagram to left), and like the demonstration mirror you have acquired for this activity.

Proceed with one or more of the demonstrations on the following page.

1 Focusing Visible Light

Darken the classroom as much as possible. Light the candle or other small, bright source of light and place it several feet away from the mirror. Hold the mirror in one hand and the piece of tracing or wax paper in the other. Adjust the position of the mirror and paper until the candle flame or other light source is focused on the paper for the class to see.

2 Focusing Infrared Radiation

For this demonstration, the classroom can be fully lit. Explain that concave mirrors such as this one, and that on the HST, are also capable of focusing infrared (IR or heat) radiation from objects on Earth and in space, just as they do visible light. At this point produce a safe and handy source of infrared radiation such as an electric heater. Since infrared radiation is invisible to the unaided eye, challenge the students to suggest ways that you can know whether or not the mirror is indeed focusing this radiation from the heater. If a student suggests using the thermometer or heat-sensitive paper, let them go ahead and do the demo for you! If not, produce an answer by holding up the thermometer. Note the general temperature in the room. Then place the heater several feet away from the mirror at the same spot where you had placed the candle in the last demonstration and turn the heater on. After a few minutes, hold the mirror in one hand and the thermometer in the other. Place the thermometer at the same point where you placed the paper in the last demonstration. (Hint: as preparation you may want to have a C-clamp or other stand so that you can precisely mark the place to hold your detector in this and the following demonstration.) Have one or two students read off the temperature. It will rise as the mirror focuses the heater's otherwise invisible infrared radiation at this point in space. To parallel the first demonstration more precisely, use the heat-sensitive paper: it will turn white where the mirror focuses the IR radiation, and then turn colored once more when removed.

3. Focusing Ultraviolet Radiation

Explain that concave mirrors such as the one on the HST are also capable of focusing ultraviolet radiation from objects on Earth and in space. Hold up the ultraviolet lamp for the class to see, plus the UV-sensitive beads or the jar of fluorescent luminescent paint and a small piece of plain paper. Explain that the paint and/or beads contain special chemicals that glow or change color when exposed to ultraviolet radiation. Apply the paint to the paper.

This time, darken the classroom as much as possible, if you use the paint rather than the beads. Turn on the UV lamp and place it in the same position as the candle and heater in the previous demonstrations. Hold the mirror in one hand and place the beads or painted piece of paper at the same place where you placed the tracing or wax paper. Students will begin to observe the beads change color or the paint glow from the concentrated UV radiation. Removing the beads or paper from the focus of the mirror will cause the glow to become reduced or to cease.

Activity 2B; Hubble: A Very Big Eye in the Sky

Objective

Students will first estimate and then calculate the amount of light which can be gathered by HST's main mirror, and then compare and contrast this with the light-gathering power of the human eye.

Procedure Divide the students into teams. Give each team the disk of dark paper 6 inches in diameter and a cup with the white paper circles made by a 3 ring hole punch. Explain that the white circles are about the size of the pupil of the eye. Ask the students to spread the white circles out onto the dark circle and estimate how many white circles cover the dark circle, with no overlap of white circles but as little dark material as possible showing through. Tell them to make their best estimate. When the team are through, write down their answers and ask the class to compute the average. Explain that the HST's main mirror has about 248 times more area than do their 6 inch paper disks. Have them multiply the average they calculated by 248 for their answer.

Finally have them calculate the answer directly by using the formula for the area of a circle:

$A = \pi r^2$, where $\pi = 3.1416$ and r = the radius of the circle. (The relevant HST dimensions appear on the student worksheet.)

Expand

Discuss the reason for different answers to the above question using the two techniques. Which is more accurate? Also have students research and discuss what types of information might be learned about the planets by studying them in the infrared and the ultraviolet as well as in visible light.

Activity 2B: Hubble: A Very Big Eye in the Sky

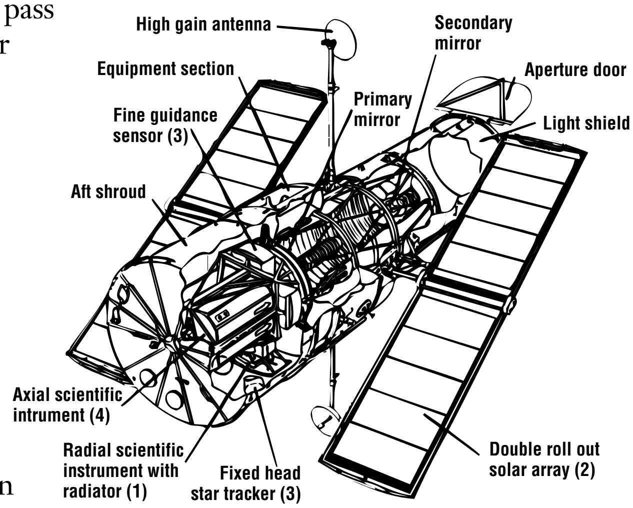
With our eyes alone, we can only see things down to a certain level of faintness at night or in a darkened room. We are limited by the amount of light that can pass through the pupils of our eyes which rarely widen to more than 0.25 inches across.

Telescopes allow us to see fainter objects because a telescope takes all the light that falls on its main lens or mirror and focuses, or concentrates, it down into a narrow beam that can usually pass through the pupil of the eye. Thus if an astronomer looks out at night with a telescope like the HST which has a mirror some 94.5 inches across, he or she is looking out on the universe with the equivalent of eyes that are 94.5 inches across! No wonder we can see more with telescopes.

How much bigger is the HST's main mirror than the human eye? Well, it's 94.5 inches divided by 0.25 inches, or 378 times the diameter of your pupil! But the true ability of the eye or a telescope to gather light depends on the **area** of its lens or mirror, not its diameter.

So how much more light does the HST focus than your eye? Let's use two methods to find out.

Cutaway diagram of the Hubble Space Telescope



Method #1: Estimation Using a Physical Model

Your teacher will distribute dark circles and cups with small white circles, which are about the size of the pupil of your eye. Carefully spread out the small white circles on the dark circle. How many does it take to completely cover the dark circle? Try to have as little overlap and as little dark material showing through as possible.

Write your estimate here. ________

Write the average estimate of all the teams in your class here. ________

The HST's main mirror has an area about 248 times greater than your dark circle. So how many little white circles would it take to cover the entire main mirror of the HST? ________

This is an estimate of how much more light falls on the HST than on your pupil, and so approximately how much more light the HST can focus.

Method #2: Direct Calculation

The amount of light a mirror or lens focuses depends upon its area. The area of a circle is given by the formula: $A = \pi r^2$, where $\pi = 3.1416$ and r is the radius of the lens or mirror, that is its diameter divided by 2.

How much more light does the HST focus than the lens in your eye? That's the same as asking how much greater is the area of the HST's main mirror than the area of the pupil of your eye. First, calculate the area of the HST's main mirror (All the information you need is contained in the Introduction to this Activity, at the top of the page.) Write your answer here ________

Next, calculate the area of the pupil of your eye. Write your answer here. ______ Finally, calculate how many times bigger the first area is than the second. Write your answer here ___

Compare your answers using method #1 and #2. Which do you think is more accurate? ________ Why? ______________________

Activity 2C: Observing "Moving Targets" with the HST

Objective

Students will demonstrate the ability to plan Hubble observations by plotting planetary positions at 3 specific dates on a sky-chart, determining a safety zone for HST, and verifying the accuracy of their results.

Engage

Point out to the students that most of the objects that astronomers look at in the sky are very faint and that, accordingly, most of the HST's instruments are very, very sensitive to light. Ask them to think about objects which HST cannot look at because they are so bright that they would blind and ruin the instruments. (The obvious answer is the Sun—but in fact the moon is also too bright). Tell them that for safety reasons the HST is usually not pointed within about 45 degrees of the Sun. (Note: A fist held at arm's length is about 10 degrees across.)

Explore / Explain

Tell the students that in this activity they are going to serve in the important role of Mission Planners for the HST (STScI calls such specialists "Program Coordinators," one of whom is Tony Roman, who'll appear on camera in Program 2, and whose comments may be found on p. 18 in this Guide.) For three different dates, students will determine which planets are safe for the HST to observe and which are not. As noted in the sidebar (p. 17), explain to the students that the planets and the Sun appear to move continuously relative to the "fixed" stars and so their changing positions need to be constantly tracked. Even though the planets of our solar system are close by, and relatively bright, they're literally "moving targets" and sometimes quite difficult to observe.

Materials (for each Mission Planning Team)

- copy of the HST "Zone of Solar Avoidance" disk (p. 23)
- Coordinate Tables for the Sun and planets for 3 dates (to right)
- 9 different colored marking pens
- scissors, pins or pushpins
- 3 copies of the Star Chart (p. 23)

Procedure Divide the students into Mission Planner Teams. Distribute materials to each Team. Ask them to make a color key for their own reference, and assign a different colored making pen to the Sun and each of the eight planets other than Earth. Point out the dates on the three separate Coordinate Tables and have them mark each of their three Sky Charts with one of the dates.

Illustrate how to plot a position on the first Sky Chart (March 14, 1996) using the Sun as an example. Have them mark their March 14 , 1996 chart making a small dot with the appropriate colored marking pen for the Sun. Then have them continue to plot and mark the positions of the planets on the same Chart. Have them proceed to the other two Charts and sets of coordinate data. Discuss how the position of the Sun and various planets has changed from one chart to the next.

Next, ask them to cut out their HST "Zone of Solar Avoidance" disk. Explain that this disk is designed to help them determine which planets are too close to the Sun to be safely observed with the HST. Make as many copies (or transparencies) as needed and give one to each team. Then, for each of the three Sky Charts, have the students carefully pin the center of the disk on the Sun. All planets lying within the disk are too close to the Sun to observe safely. For each Chart, have them complete the list on their Worksheets of which planets are safe, and which are not safe, to observe for the date of the Chart.

TABLE 1 March 14, 1996

OBJECT	R.A.	Dec.
Sun	23.6 hrs.	2.5 deg.
Mercury	22.9 hrs	–9.5 deg
Venus	2.4 hrs.	16.2 deg
Mars	23.5 hrs	–4.2 deg
Jupiter	19.0 hrs	–22.6 deg
Saturn	23.9 hrs	–3.0 deg
Uranus	20.4 hrs	–19.9 deg
Neptune	20.0 hrs	–20.3 deg
Pluto	16.3 hrs	–7.8 deg

TABLE 2 January 15, 1997

OBJECT	R.A.	Dec.
Sun	19.9 hrs	–21.0 deg
Mercury	18.3 hrs	–20.9 deg
Venus	18.5 hrs	–23.1 deg
Mars	12.3 hrs	1.3 deg
Jupiter	20.1 hrs	–20.8 deg
Saturn	00.2 hrs	–1.3 deg
Uranus	20.4 hrs	–19.8 deg
Neptune	20.0 hrs	–20.3 deg
Pluto	16.3 hrs	–8.7 deg

TABLE 3 March 14, 1997

OBJECT	R.A.	Dec.
Sun	23.6 hrs	–2.5 deg
Mercury	23.8 hrs	–2.9 deg
Venus	23.3 hrs	–5.9 deg
Mars	12.0 hrs	4.2 deg
Jupiter	20.9 hrs	–17.8 deg
Saturn	00.5 hrs	1.2 deg
Uranus	20.6 hrs	–19.0 deg
Neptune	20.1 hrs	–19.9 deg
Pluto	16.4 hrs	8.7 deg

Expand

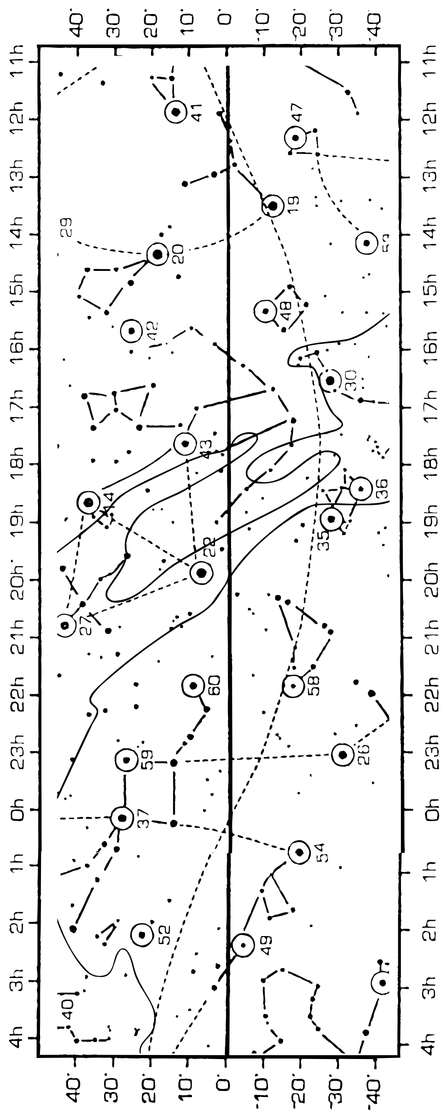
Ask students to research thoroughly the changing positions of planets to see if there's a planet which can **never** be observed with the HST.

Activity 2C: Observing "Moving Targets" with the HST

In this Activity you and your team are going to become Mission Planners for the Hubble Space Telescope. Astronomers cannot just look at any planet with the HST, anytime they wish. This is because planets change position in the sky relative to the Sun, and the HST's instruments are so sensitive they are usually not pointed within about 45 degrees of the Sun. Sometimes, the planets wander too close to be observed safely. Your job will be to figure out for the astronomers, for three different dates, which planets can and cannot be observed with the HST.

Your teacher will pass out Sky Maps and Tables of positions for the Sun and the planets on three different dates. As instructed, plot the position of all these celestial objects on the appropriate Star Charts. Use the HST Zone of Solar Avoidance disk to determine which planets are safe to view and which are not for each of the dates in question. Once you have plotted all your data, fill the appropriate spaces in the Table below with the words SAFE or UNSAFE

Star Chart



PLANET	March 14, 1996	January 15, 1997	March 14, 1997
Mercury			
Venus			
Mars			
Jupiter			
Saturn			
Uranus			
Neptune			
Pluto			

Then answer the following questions.

1. What can you say about the position of the Sun on March 14, 1996 and March 14, 1997. _________ Why? _________
   ____
2. Which two planets appear close to the Sun on all three dates? ____
   Why do you think so? ______________________________
3. The dashed line in your Charts shows the path of the Sun among the stars as seen from Earth (known as the "ecliptic"). All the planets (except Pluto) lie very close to this line. Why? (Hint: It has to do with the shape of the solar system)
   ____

Activity 2D: Bouncing Data around the World

Objective

Students will demonstrate the communications path between a distant planet and an observer on Earth, with data transmitted via HST, communications satellites and ground stations.

Engage

Ask students to relate how a letter, sent from far away, gets to their house. Have them brainstorm a list of places the letter may have passed through—including the Internet—what kinds of vehicles may have been used to carry it, how long it took to travel to its destination, etc.

Explore / Explain

Explain that scientists need to send instructions up to HST as it orbits the Earth as well as receive data back from it. This activity will help students better understand the communications path between a scientist such as our Planet Advocates, and they themselves as *LHST* "virtual co-investigators," and the Hubble Space Telescope, showing how data are sent and received.

Materials A minimum of eight students is necessary for this activity

- one 6" or 8" ball (slightly deflated)
- tennis ball (optional)
- Set of 8 signs mounted on cardboard and string that students can wear around their necks. Signs should read: Planet (Neptune or Pluto?), HST, TDRS, (Tracking & Data Relay Satellite) White Sands, DOMSAT, (domestic satellite) Goddard (or GSFC), STScI, P.I. (Principal Investigator)
- clear space enough for the demo (20' x 20' at least)—a gym is ideal. Everyone must be free to move—no tables or chairs in the way.
- overhead transparency of the HST satellite data flow (see inside back cover)

Procedure Show students the overhead transparency of the HST satellite data flow. Explain the diagram, following the data path as shown. Explain that the HST receives, stores, and later relays data that is detected by the telescope.

Explain that TDRS is operated by NASA and communicates with the ground station at White Sands, New Mexico. TDRS is in a geosynchronous orbit, meaning it is synchronized with the Earth's rotation ("geo" meaning Earth). TDRS is approximately 26,000 miles from the center of the Earth (all geosynchronous satellites are positioned at this distance. Their period of revolution is the same as the time it takes for the Earth to rotate once around its axis). (NASA actually operates two geostationary satellites for HST, TDRS East and TDRS West, but only one TDRS communicates with HST at a time.)

Earth Locations

Four students are placed back to back in the center of the room forming a circle that will represent the Earth. (This is done for ease of the demonstration although in reality, all of the ground stations are on the continental United States and therefore the satellites would actually only send signals to a portion of the Earth rather than to the whole globe.)

Each of the four students is given a sign to wear—in consecutive order from left to right: P.I., STScI, Goddard, White Sands. This may sound complex, but just look at the diagram looking down on Earth's north pole locations and with an arrow specifying rotation (see inside back cover) and all will become clear!

Adapted with permission from *NASA's EUVE Satellite Data Flow* by Marlene Wilson and Dennis Biroscak, with contributions from Bill Hammerman and Dan Reimer Thanks Marlene and everyone!
http://sdp1.cea.berkeley.edu:80/Education/dataflow/

Satellite Locations

- TDRS: one student is placed at the edge of the room exactly opposite White Sands, NM, and wears the sign TDRS.
- DOMSAT: another student wearing DOMSAT is placed just as far away from the Earth as TDRS, but is positioned between White Sands and Goddard. Explain that DOMSAT is another geosynchronous used by NASA which also relays TV programs and other communications.

At this point, you could start the Earth rotating SLOWLY and let the geosynchronous satellites move sideways to try to keep up with the Earth. They have to remain over the same spot on the Earth. You could also wait until everyone gets assigned a position before you start the rotation.

- HST: another student is given the HST sign to wear. Explain that HST is only 380 miles above the Earth. Position this student very close to the Earth. HST travels around the Earth approximately 15 times for every once that the Earth turns (15 times per day), so it moves around the Earth much faster than the rate at which the Earth rotates.
- PLANET: from a corner of the room or anywhere well outside of the outer satellites, a student is positioned with the PLANET sign.

The student is given the small, slightly-deflated ball that will representing star light. For the purposes of this demonstration the PLANET does not move, so the student stands still.

The path of data from the planet to the P.I. is as follows: Planet, HST, TDRS, White Sands, DOMSAT, Goddard, STScI, P.I.

Motion in Space

Make sure students understand the difference between rotation and revolution. Within the revolution category are two subcategories, geosynchronous (or geostationary) revolution and non-geosynchronous revolution. For this demonstration, the only satellite that is non-geosynchronous is the HST. At this point, you may want to do a small "sub-demo" by having one student stand at the center of the room representing Earth, who will then rotate while one person on the outside (a satellite) follows the face of the "Earth." Students will clearly see that the Earth needs to rotate very slowly to allow time for the satellite to follow (around the circumference of the room).

Then start the motion in space with everyone except the PLANET as described above. Now call out the path as the students throw the ball. Have them call out who they are as the ball is caught by each.

- The Planet throws the ball (planetary image) to HST.
- HST sends the ball to TDRS.
- TDRS sends the ball to White Sands.
- White Sands sends the ball up to DOMSAT located between White Sands and Goddard.
- DOMSAT sends the ball to Goddard.
- Goddard "hands" the ball to STScI (since the data are transported through ground-based phone lines at this point).
- Finally, the ball (planetary image) is handed from STScI to the P.I. (Surprisingly enough, this is usually done via FEDEX!)

Variations: Data Drop-out

When someone drops the ball, it can be considered data "drop-out" and the ball goes back to the planet again. Explain that a data drop-out can occur at any point in the communication path.

Commanding the HST

Another ball (tennis ball) could be used to represent a command from the P.I. to HST. The path of the command is the same but in the opposite direction (P.I., STScI, Goddard, DOMSAT, White Sands, TDRS and HST). For more of a challenge, this can be done simultaneously with the incoming data from the planet, as in real life.

After the physical demonstration is complete, have students diagram the activity, labeling all the locations, and using arrows to indicate the flow of data, as if from a perspective out in space. [Younger students might be given a copy of the diagram used to introduce the activity (remove arrows and labels before copying) on which to draw the path.] Illustrations and diagrams should be added to their HST portfolios. Your students might also enjoy working collaboratively to produce a hall display or large mural showing the datapath.

Expand

Calculate the total time it takes light to travel the satellite pathway from our target planets via HST to Goddard. (Hint: remember the formula: Distance = Speed x Time.) What else do you need to know? Speed of Light = 186,000 miles per second. What about the number of miles between Earth, the various satellites, and the planets? The necessary information is all provided above and in Activity 1C—but students will have to apply some geometry to figure things out! Watch on-line and on camera for more *Challenge Questions.*

Hubble as a Weather Satellite for Our Solar System

Earth has been called an "incredible weather machine." Orbiting satellites hourly scan the planet from pole to pole, tracking storms, recording temperatures and moisture levels, and helping meteorologists make better weather forecasts. Can you think of a satellite that's regularly used to study weather on other planets? It's the Hubble Space Telescope, often doing as much meteorology as astronomy—scanning our celestial neighbors and revealing amazing worlds of weather clear across the solar system.

Mars has a thin atmosphere of carbon dioxide that keeps the planet drier than the Sahara and far colder, on average, than Antarctica. Hubble has shown us that the planet's temperature is now, on average, some 20 degrees less than that recorded by the Viking spacecraft in the 1970s, a significant and puzzling change.

At the edge of the solar system, orbits tiny Pluto. Like Neptune's moon, Triton, Pluto may have a thin nitrogen atmosphere that sometimes propels frosts and fogs across its icy landscape, and at other times freezes in place as Pluto's "seasons" change. Only closer study will reveal Pluto's climate and weather.

Between Mars and Pluto are Jupiter, Saturn, Uranus and Neptune, giant worlds whose faces are but the tops of enormous, turbulent atmospheres, thousands of miles deep. Here weather is driven not by the Sun but by heat rising from within. Soaring air currents couple with the planets' rapid rotation rates to produce jet streams that can race at over 1,000 miles per hour and produce storms larger than the entire Earth.

When astronomers speak about the atmospheres of the other planets, you'll hear them talk of winds, temperatures and atmospheric pressures. Much of the vocabulary of interplanetary weather will sound familiar to you and your students from tv weather reports, but the scale will be very different. After all, we're talking about other worlds, giant, strange and fascinating. Using the Hubble Space Telescope to study our planetary neighbors, scientists are studying weather on a cosmic scale, with many more examples than were available before the Space Age. In the process, they are trying not only to understand weather on each individual planet but also the similarities and differences between these worlds, and what they mean for Earth, now and in the future.

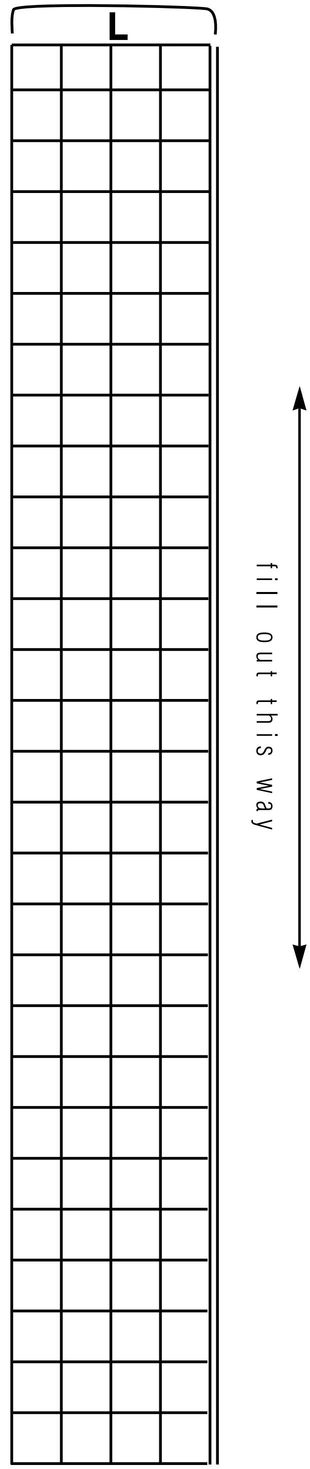
Activity 2E: Pictures from Outer Space

Objective

Students will simulate the interrelated processes by which spacecraft computers encode pictures of a planet, and computers on Earth later decode digitized data and transform it back into an image of the planet.

Engage

Ask students to think about the last time they or one of their family members took pictures with their still camera. Ask them how they think the image of the real world got from inside their camera into their hands as finished prints. (The answer is, of course, a physical thing called film which, after being exposed to light, is removed from the camera, chemically processed at the photo shop and returned as prints or slides). Ask them how they think we get pictures from the HST and other spacecraft? Early satellites did indeed parachute film packs back to Earth, but that's not the way it's done today. And astronauts aren't always popping up to change the film, so how does it work?



Materials (for each team)

- photocopy of the grid to the right
- set of 4 paper sheets of differing shades of black to white (black, dark gray, light gray, white)
- glue, scissors, four paper cups (to hold sets of paper squares)

Explore / Explain

Have the students examine a TV or computer screen with a magnifying glass. Ask them to describe what they see. They'll note the picture is actually made up of little dots (called pixels, or picture elements.) Explain that the HST and other spacecraft actually send images to Earth by radio as a long string of numbers which tell the location and brightness of each pixel in the image. Then computers put all the pixels together like a great cosmic jigsaw puzzle. Explain that in this Activity, they are going to take the place of NASA computers and convert a string of coded data from a spacecraft back into the image of an actual object in space.

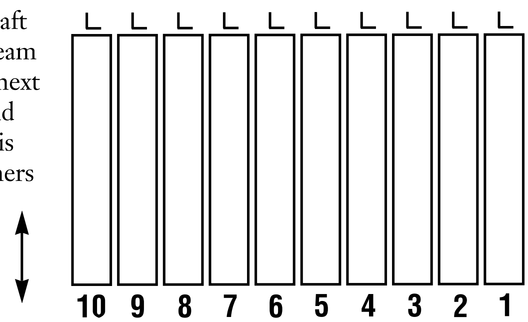
Procedure Begin by dividing the class up into ten Data Analysis Teams (and since this is a space-related project, you can call them DAT's. All space agencies love acronyms.) Give each DAT a copy of one of the coded lists of numbers (their "data stream") from your Master Code List. Also provide a copy of the grid to the right.

Tell them:

1. their grid provides the framework for one portion, strip or slice of the picture to be deciphered from space
2. the numbers in their data stream represent information on the brightness of the 1120 image pixels that they will be responsible for putting in place
3. the order of the pixels in their data stream is a clue to the order in which their pixels are to be arranged in their portion of the final image

Instruct them to place the grid horizontally on their desk tops (with the "L" mark on the left) and begin to encode the image by placing the first number in their data stream in the uppermost left box in their image grid. (Here they are doing, in a greatly simplified way, what the CCD detectors on board a spacecraft do when they observe a target.) Then place the second number in the data stream in the box on the same line immediately to the right, the third number in the next box, etc. When the first line is complete, tell them to begin filling in the second line of the grid, again from left to right, and continuing until their entire grid is filled in. Then one member of the team should re-read the numbers as the others check for accuracy.

Final image is constructed with strips in this orientation



When all teams have completed this task, pass out a set of paper sheets to each team. Explain that the shades of brightness and darkness correspond to the numbers sent down by the spacecraft with 0 representing pure white, 1 light gray, 2 dark gray and 3 representing black. Tell them to carefully cut the pieces of paper into small squares each the size of one of the grid boxes and to group each different color into a different pile. (An alternative is to use a paper-cutter, carefully, to mass produce squares in advance, then distribute them in paper cups) Have students glue an appropriately shaded square over each correspondingly-numbered grid box. Be sure to have one member of the DAT time how long the process takes to code their grids.

When all the DATs are finished, assemble all the pieces of the image to create the full image (as shown below left) on a larger piece of paper or card.

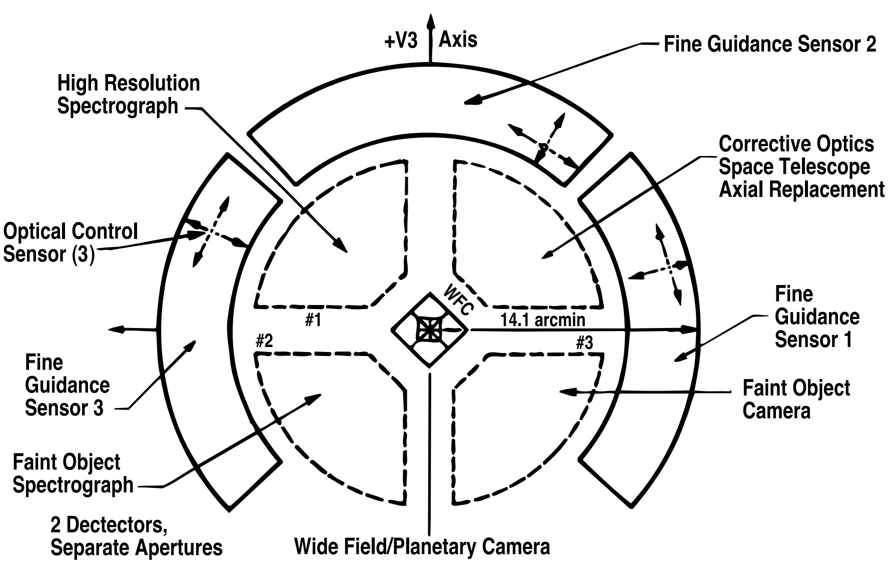
As the image comes together, challenge them to identify it, giving clues as you go. When completed, tell them the significance of Jupiter's Great Red Spot, and show them the actual image from Voyager 2 for comparison (to be seen in Program 1, "The Great Planet Debate" and on the HST lithographs co-packaged with this Guide).

Engage

Relate the coarsely-detailed (or "low resolution") image the students assembled to an actual image from the HST, as on the enclosed lithographs. These images clearly have more detail because they contain many more pixels in the same space and incorporate many more shades of gray between white and black. In short, it contains much more (picture and computer) information.

(See Activity 3A page 30 for how black and white data becomes a color image.) Have the students compare the number of pixels and shades of gray in their image and one from the HST, using the information given in their Worksheets. Finally, ask them to calculate how much longer it would have taken them to assemble the real image at the rate they worked.

How HST's Instruments Share the Telescope's Focal Plane & Incoming Electromagnetic Radiation



Incoming Image (View Forward +V1 Axis into Page)

From pixels to pictures

The Hubble Space Telescope and other spacecraft, including weather satellites, take pictures using video technology and devices known as charge coupled devices, or CCDs for short. Like a picture on a TV set or computer screen, each image is made up of thousands of tiny dots or picture elements ("pixels"). The pictures are not sent down to the ground as hard copy. Instead, the photons of light reflected off an object are collected by the sensitive CCDs, and recorded and analyzed pixel by pixel. Then, the information on the location of each pixel within the picture and the brightness of that particular pixel is radioed down to Earth. Computers convert this information back into light and dark spots and place these pixels in their correct positions, so that a complete picture is re-constituted by computer. Prints and slides can then be made. This is the process you and your students will see happening for images of Jupiter, Neptune and Pluto during the videos, and you'll be able to follow the Planet Advocates' image processing work on-line, during the hectic weeks between the live broadcasts.

Another key thing to appreciate is that the HST and other spacecraft take their images in black and white. Yet we see beautiful spacecraft images in full color, such as the M-16/Eagle Nebula picture co-packaged with this Guide. How is this possible? To make a color image of an object, the spacecraft takes several black and white images, each through a different colored filter. By carefully examining how bright different parts of the object look through the different filters, scientists using computers can figure out the true appearance of the object, and so re-create a realistic color image.

Activity 2E: Pictures from Outer Space

You and your Team of Data Analysts are going to take the place of NASA computers and decipher an image beamed down from space. (This is an actual image, created in 1979 even though it's been simplified for this activity.) Your team will be responsible for putting together part of the overall picture. Your teacher will pass out a special grid and a stream of numbers sent down by the spacecraft. Encode the grids with the numbers as instructed by the teacher. As you begin, notice what time it is and write the time here. _______

You'll receive several sheets of paper, 4 colors ranging from pure white to pure black. Carefully cut them into squares the size of the grid boxes and attach the correct squares to the grid as explained by your teacher.

When you are done, your team will have completed one portion of the image. Again, note the time here. __________ Now, answer the next five questions and when you're finished tell your teacher that your grid is complete. What was the total amount of time it took your team to complete its assignment? _________

How many pixels were there in your team's grid? _______

How many teams are there in your class? _________

How many total pixels are there in the overall image put together by the class? _________

Now your teacher will collect all the completed portions of the image and put them together so you can see what the spacecraft was seeing.

Finally, consider the following: The total number of pixels in the image that your class assembled was 1,120. Each pixel had one of four numbers assigned to it , designating one of four shades of gray, white and black. That means it took 1,120 x 4, or 4,480 pieces of information to make this picture.

That may seem like a lot but an image of Jupiter from the HST's Wide Field Camera would use about 640,000 pixels, each of which can have any one of 2,048 different shades of gray. That makes for a much clearer, smoother picture but it takes much more information to create it. How many pieces of information would it take to make such an image? _________

Based on how long your DAT took to assemble your part of the image, (put together 4,480 pieces of picture information) calculate how long it would take your team to assemble one entire HST image of Jupiter. Write your answer: _______

NASA computers take less than 5 minutes for the same task. Can you see why NASA likes to use computers?

DATA STREAM for *"Pictures from Outer Space"*

Team #1

0000	0001	1100	1100	0112	1112	3333
0000	0100	1211	1110	0120	2233	3333
0001	0010	1221	1111	1120	2333	3333
0001	0000	1122	1111	1122	2333	3333

Team #2

0011	1000	0022	1101	1122	2323	3333
0112	2100	1022	1101	1111	2223	3333
0122	2210	0102	2211	1111	2223	3333
0121	2222	0101	1111	2111	2122	3333

Team #3

1211	1112	2111	2211	2110	2212	2333
1211	1111	2211	1221	1101	2212	2333
1210	2211	2221	1222	1111	1122	2333
1210	2222	2221	2122	1111	1112	2333

Team #4

0210	2222	2222	1112	1222	1121	2233
0120	1122	3222	2111	2211	2121	2233
0021	1222	3322	3211	2100	1211	2233
0021	1223	3332	3212	1000	0121	2223

Team #5

1012	1112	3332	3212	2000	0021	1223
1012	1112	3333	2312	2000	0012	2223
2111	2121	2333	2322	2100	0002	1223
2111	2111	2333	3332	2210	0001	2223

Team #6

0210	1211	2233	3332	1221	0001	2313
0220	0221	1222	2232	1222	1001	2333
0211	0022	2222	2332	1212	2222	2233
1012	1002	2222	3232	1222	2222	2223

Team #7

2001	2101	2233	3332	1221	1122	2332
2300	1210	1123	3332	0122	1211	2332
3210	0012	2223	2332	0112	1212	2333
3221	1100	1222	1221	0011	1122	2333

Team #8

3222	2221	0123	1222	1011	2222	2333
3321	2212	1001	0112	1011	2232	2333
3321	1221	1000	0111	1001	1222	3233
3331	0122	2110	2111	1000	1212	1323

Team #9

3331	0122	2111	2121	1100	1122	1333
0001	0120	0000	2111	1100	1122	1333
3332	0120	0000	1210	2100	1122	2232
3332	1100	0010	1111	2100	1121	2332

Team #10

2323	2100	0011	1222	1110	0122	2222
2323	2110	0111	1122	2221	0112	2222
2332	2122	2211	1112	2121	0112	1222
2332	2111	1011	1122	2222	0112	2222

Program 3: Announcing YOUR Results

First airs live April 23, 1996, 13:00-14:00 Eastern

This program will take the form of a highly interactive scientific symposium, oriented to students, announcing the first results achieved by *Live from the Hubble Space Telescope*. A live student audience of over one hundred will join Marc Buie and Heidi Hammel in STScI's main auditorium in Baltimore, with e-mail and CUSeeMe input from other students around the nation and the world. Heidi and Marc will share preliminary findings, and respond to comments based on the parallel work that's been done by students. We'll review the questions which initially motivated student interest in Pluto and Neptune during the the "Great Planet Debate," and see which have been answered and which require more analysis or research.

Live uplinks in America will include the Buhl Planetarium at the Carnegie Science Center in Pittsburgh, Pennsylvania (where students helped make our original planet selections via interactive technology) and Los Angeles, California, a school district making a major push to integrate the Internet into the curriculum. The program will provide considerable "give and take" between the Planet Advocates and their student "Co-Investigators," as students witness live the process of testing scientific hypotheses, verifying results and sharing new findings with peers to substantiate their significance.

Videotaped sequences will document "A Day in the Life…," taking us behind the scenes as Heidi Hammel works to transform raw planetary data into new knowledge: Heidi also plans to post a *Field Journal* of her image processing successes and (only temporary, we hope!) frustrations on-line. A second sequence documents the parallel process in one of our participating schools, where students employ user-friendly and freely accessible graphics packages to analyze the same data. To help explain the technical steps in image processing, we see how the stunning images of the Eagle Nebula (as seen in the co-packaged poster) ends up on the cover of *Time for Kids*. Footage from giant storms on Earth, and images from HST and other spacecraft, allow us to compare and contrast weather on Earth and our neighboring planets: we come to understand the dynamics underlying the images of (possible!) bright or dark clouds on Neptune, and seasonal changes (perhaps!) on Pluto.

The concluding tape sequence shows "What's Next?," describing the next HST Servicing Mission (slated for early 1997), plans for the first-ever spacecraft mission to study Pluto and Charon closeup, and initial concepts for a Next Generation Space Telescope, one of whose main functions would be to search for planets around other stars.

Viewers will be reminded about how to participate on-line, and how to utilize the project on tape after the live telecast.

Alex Storrs, Planning Scientist, Moving Targets, STScI

It's unfortunate the way a lot of basic science starts in schools these days with a list of facts to be memorized, and lists of experiments and discoverers…this guy discovered that and that gal discovered this other thing. This lends a sort of inevitability to the process when it's really quite haphazard. Its all by guess and by gosh, it's not planned at all. The chances of finding something new are present in any observation, whether it's with the Space Telescope, with a ground-based observatory, or made by somebody from their back yard. People discover comets from their back yards all the time.

There is a chance, in any observation made by any person, that you'll find something new, and all you have to do is have an inquiring mind, and be open, and be alert, and be aware and don't accept as a given everything that you've been told. Don't accept that the universe is understood, but rather that the universe is a big, beautiful mystery that we are all trying to unravel.

Question Marks

Space,
deep, dark hellish space,
Continuing light years of nothingness
No one can discern the oddities of space.

The planets
lands of barren matter,

The blazing, flaming colossal sun
Continues to burn,
and burn,
and burn.

Perhaps a herd of bizarre creatures,
and maybe nothing at all,

Perhaps another dimension,
and maybe nothing at all,

No one really knows how we got here,
and maybe we're nothing at all.

Stephen Smethers, Summit Middle School.

Activity 3A: The Universe in Living Color

Objective

Students will experiment with color filters and be guided towards deriving the process by which HST converts B&W images into color pictures.

Engage

Show students some of the stunning HST color images, such as those of M-16, the Eagle Nebula (which also appears on the poster co-packaged with this Guide.) Ask the students if they realize that the HST can only "see" in black and white. Ask them how they think such color images are created.

Materials (for each team: color filters may need to be shared)

- set of three color filters (red, green and blue), co-packaged with this Guide
- copies of the student worksheet, p. 31, providing simulated black and white views of a hypothetical planet, as if taken through red, green and blue filters
- black, red, green and blue paper or other test objects or material (matching their color as closely as possible to that of provided colored filters)
- markers and crayons of colors chosen to match the filters (see box below)

Note: since this Guide is only black and white, before beginning the Activity, please prepare the answer by coloring-in the hypothetical planet as suggested by the color code. "Please try to keep within the lines!"

Explore / Explain

Explain that scientists use computers to create color images from HST and other spacecraft by combining information from several black and white images taken through different colored filters. Explain that this is because objects reveal different aspects of their surfaces through filters of different colors. In this Activity, students will be able to explore this phenomenon for themselves, and then deduce the "real" colors of a hypothetical planet, working only from black and white images—just like NASA's computers. (To repeat, the planet is hypothetical and, for clarity's sake, composed only of primary colors but the same principles and procedures apply to any image of any color or hue.)

Procedure Use the sidebar (right) as necessary to help explain the theory of why objects look the colors they do under white light and through filters of different colors. Pass out the sets of red, green and blue filters to each team. Have students look through their filters at pieces of paper that are white, black, red, green and blue, and fill in the chart on their worksheets in which they describe the color these objects appear, with and without the filters.

When students have completed their charts, distribute red, green and blue marking pens. Explain that these show three images of the same simplified and hypothetical planet. All the images are black and white, but each appears as if taken through the different color filters, as indicated. Using marking pens and their chart as a guide, ask students to study the three black and white images carefully, and then draw an image in color showing what they think the planet really looks like. When they are done, show students the correct answer you have prepared in advance, and guide them to appreciate the reasons why.

Expand

Have students apply the principles of this Activity to create "Hidden Messages" which can only be detected using filters of the appropriate color.

FOR OPTIMAL RESULTS

Use *Crayola Crayons* (24 pack, UPC# 7166200024): cerulean blue, red and green with the co-packaged blue filter.

Use *Magic Marker Presentation Plus* (6 marker pack, UPC# 71662 00747): red, green, and blue markers with the co-packaged red and green filters.

Light, color and the effects of colored filters

We suggest you use the red, green and blue filters co-packaged with this Guide (and others you can obtain or borrow) to allow your students to explore the properties of light and filters for themselves, before you begin Activity 3A. Have them use the enclosed HST lithographs and other color images for their experiments. Guide them to discovering the principles they'll use to transform black and white data into color pictures.

Normal sunlight and most classroom lighting is "white light," meaning it contains all colors of the spectrum. Opaque objects appear the color they do when illuminated by white light because their surfaces scatter only certain colors back into our eyes. A white object appears white because it scatters all the colors which together make white light. A pure black object appears black because its surface absorbs all the light which falls on it and scatters none of it back into our eyes. An object looks red because it scatters only the red rays in white light back into our eyes.

Colored filters only allow light of their particular color to pass through. Thus a red filter only allows red light to pass through; a green filter only green light. So a white object (which scatters all colors of light), will look the color of whatever filter it is seen through: red through a red filter, green through a green filter. A black object scatters no light, so it will look black through any color filter. A red object will look red through a red filter, but black (or gray) through a green or blue filter, because the object only gives off red light. Similarly, a green object will look green through a green filter, but black (or gray) through a red or blue filter. A blue object will look blue through a blue filter but black (or gray) through a red or green filter.

Note: depending on the exact color of red, blue and green in the images you use, and the exact color of the markers, crayons or pencils available to students, you will get more or less the "ideal" results described above. A red object through the blue filter may appear gray rather than pure black, but students should still be able to grasp the basic principles.

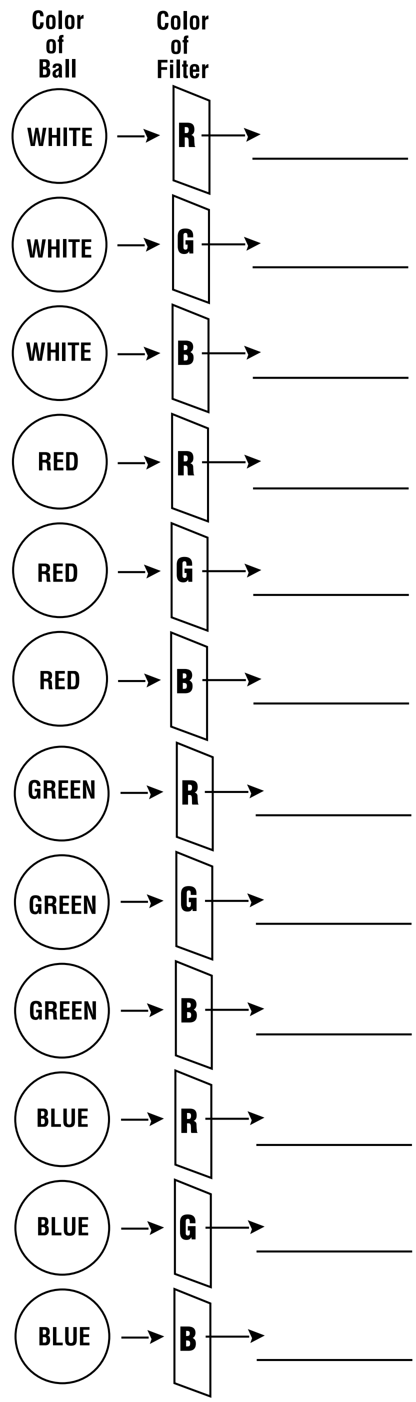
Activity 3A: The Universe in Living Color

In this Activity, you and your Data Analysis Team are going to create a color image of a planet, beginning with just three black and white images as clues to its “real” appearance. It’s a fancy piece of detective work. Your teacher will distribute color filters to your Team and ask you to examine samples of paper which are white, black, red, green and blue through the filters. Fill in the boxes in the Chart below with the color that each of these objects appears when seen through each of the different filters.

Study the diagram to the right. Each shows light from objects of a different color passing through different-colored filters. Apply what you learned from your “eyes-on” experiment, and fill in the blank space with the color which *you* think passes through the filter. This is the color the object will appear if it’s seen through that filter. If you think that no color would pass through, write “none.” This means the object would look **black** through that filter.

Below are three black and white images of a hypothetical planet. Each simulated image appears as if it was taken through the different color filter noted under the image. Examine these images carefully and applying the rules you generated, figure out the real colors of the planet’s features. Using colored pens or markers, create a color drawing of the planet in the blank circle below.

	FILTER COLOR		
SAMPLE	RED	GREEN	BLUE
White			
Black			
Red			
Green			
Blue			

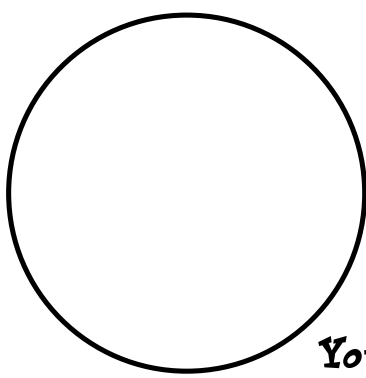


R = Red
G = Green
B = Blue

Red Filter

Green Filter

Blue Filter



Your planet to color

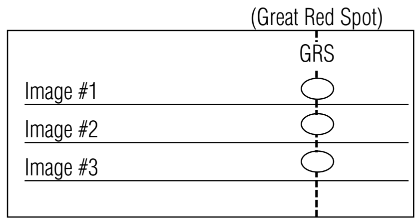
Activity 3B: Watching the Weather Move

Students will plot the movement of weather systems on Earth and other planets, compare/contrast and measure the size and speed of storms, supporting their conclusions with relevant data.

Objective

Engage

Have students collect and/or familiarize themselves with weather data in advance of this Activity, e.g. weather satellite images in newspapers, or by assigning them to watch television. In class, show students a picture of the weather taken by an Earth-orbiting satellite, as on the copy masters provided. Ask them to identify the geographical areas that are clear and cloudy. Ask them how the clouds move as weather systems develop and dissipate from day to day. Ask them if other planets have clouds and "weather" and, if so, do they think the clouds move there as well. (Does Mercury have weather? Does Pluto? Go on-line, and see what Planet Advocate Marc Buie has to say about weather and seasons on Pluto.) Ask them to suggest ways in which clouds can be used to monitor the direction and rate of motion of weather on a planet.



Materials (All to be found on the copy masters provided)

- Copies of Earth image #1 (without the dotted line on the clouds over the Northeast) and Earth image #2
- Copies of Jupiter images #1, #2, and #3
- Teacher version of Weather image #1

Explore / Explain

Explain that through the use of orbiting satellites and spacecraft, we are now able to see the weather over the entire Earth as well on other planets. Several satellites over the Earth's equator send us images every hour for a constant record of the Earth's weather. Other spacecraft like the two Voyager probes to the outer planets took images of the atmospheres of those remote worlds as they flew past in the 1970's and 1980's. But these images were all taken over brief periods of time, as if the newspaper printed a satellite image of Earth today, and no more for decades! The Hubble Space Telescope can image the weather of other worlds over time, looking for changes. It's for that reason that some call the Hubble an "interplanetary weather satellite."

Spacecraft cameras only take still images, but sequential images can be edited together by computer so we can see the weather in motion, as you typically see on the TV weather report, or in some of the dynamic images of Jupiter which Dr. Reta Beebe showed during *LHST* Program 1, "The Great Planet Debate." In this Activity, students will compare spacecraft images of the Earth and Jupiter and, by measuring the motion of the clouds, determine and contrast the speed of the particular weather systems shown.

Procedure Distribute copies of the images of Earth and Jupiter to your students. Begin with Earth. Ask them to identify the geographical area covered in the images and, for the first image, have them write a general description of where the atmosphere (the weather) is clear, and where it is cloudy. Next draw their attention to the second Earth image. Tell them that this image was taken 16 hours after the first image. Ask them if the general areas of clear and cloudy weather are the same. Suggest they look closely for changes.

Have them tape copies of Image #2 to a windowpane. Then carefully place Image #1 on top of it and line the pictures up. Holding the left margin of Image #2 in place, quickly cover and uncover Image #1. They will see the weather in motion.

Draw their attention to the large "comma-shaped" cloud formation over part of the eastern United States (a cold front), and have them notice, in particular, the line behind the front where clear skies are replacing cloudiness (indicated by a dashed line in the Teachers' Copy). In Image #1, have students mark 4 points along the "clearing line" (which we will call line "A") from Virginia down to Cuba and label them "A," "B," "C" and "D." Next, have them line up Image #2 on top of Image #1 and draw the position of the clearing line in Image #2 onto the clouds in Image #1. (See Teachers' Copy.) Call this line "B." Next, from points "A," "B," "C" and "D," have them draw straight lines perpendicular to line "A" until they intersect with Line "B." Mark these points of intersection "E," "F," "G" and "H." Using an atlas to measure scale, have them measure the distance between these pairs of points and, using the elapsed time of 16 hrs. between images, calculate the average speed of the clearing line.

Expand

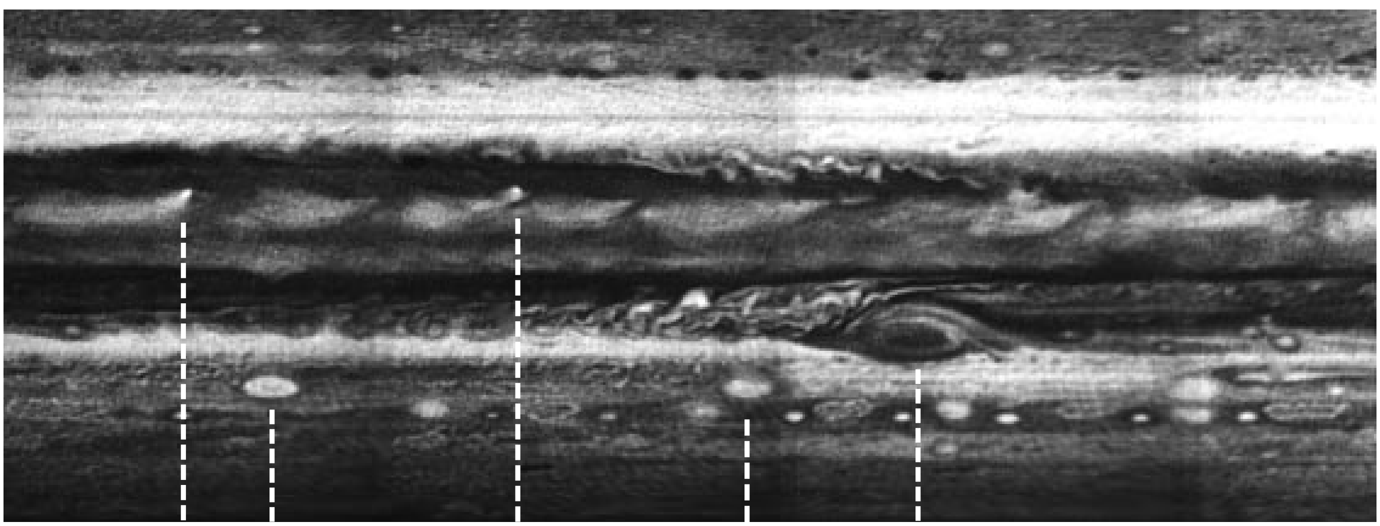
Jet streams are rapidly moving currents of air in a planet's atmosphere that steer and drive weather systems. Have students record the position of the jet stream from weather reports or newspapers for a few weeks and write a report on how the position and orientation of the jet stream caused the types of weather experienced during this time period.

Now call attention to the three images of Jupiter (taken by Voyager 1 in 1979.) Explain that in the first section of the Activity the students measured the speed of a cold front on Earth, relative to the ground. When we look at Jupiter, however, we see no solid surface for there is none, only the tops of clouds. In the second part of this Activity, students will measure the speed of cloud features at two different latitudes relative to the most distinctive "landmark" (sic) on the planet Jupiter's distinctive cloud feature, the Great Red Spot. In the process, students will be able to determine the speed of two of Jupiter's jet streams and compare their speeds to that of the cold front over the eastern U.S.

Explain that the images were taken on the dates and times noted. Jupiter's equator runs through the middle of each image. Jupiter's north pole runs across the top and the south pole across the bottom (thus these images are similar to Mercator map projections of Earth in that the size of features appears enlarged toward the poles).

Have the students proceed as follows:

1. Point out the Great Red Spot (GRS) in all three images. Ask the students to estimate the center of the GRS in each image, and place a small dot at these points.
2. Have students line up all 3 images of the GRS.
3. Draw a straight line through the dots drawn in step #1 that is perpendicular to the top of image #1 (as shown on p. 32) and tape the images to the desk top.
4. Point out the 2 white, oval-shaped clouds ("A" and "B" on your Teacher's Copy) on Image #1 and Image #3.
5. Have students carefully measure the distance in millimeters from the right edge of each of these clouds to the line drawn through the centers of the GRS.
6. Have students determine how many millimeters cloud A and cloud B have moved between the two images; then take an average.
7. Have students measure the east-west diameter of the GRS in millimeters.
8. The actual diameter of the GRS is about 20,000 kilometers. Have students determine the answer in kilometers to item #6. Then multiply by the "latitude conversion factor" (0.92). These images show clouds towards Jupiter's poles as *larger* than they really are, multiply the answer above by 0.92 to get the real answer.
9. Determine the total elapsed time in hours between Image #1 and Image #3.
10. Calculate the average speed of clouds A and B relative to the GRS in kilometers per hour (divide by 1.609 for the answer in miles per hour.)
11. Point out the white cloud features (marked "C" and "D" on your Teacher's Copy) on Image #1 and Image #2.
12. Carefully measure the distance in millimeters from the right edge of each of these clouds to the line drawn through the centers of the GRS.
13. Determine how many millimeters cloud C and cloud D moved between the two images; then take an average.
14. Again, using 20,000 kilometers for the east-west diameter of the GRS, convert the average movement of clouds C and D to kilometers. This time, for *this* latitude, the proper conversion factor is 1.07 (yes, 1.07 is correct).
15. Determine the total elapsed time in hours between Image #1 and Image #2.
16. Calculate the average speed of clouds C and D relative to the GRS in kilometers per hour (divide by 1.609 for the answer in miles per hour).
17. Compare the speed of these jet streams on Jupiter to the one on Earth calculated in the first part of this activity.



Cloud C   Cloud A   Cloud D   Cloud B   Great Red Spot

Activity 3B Watching the Weather Move

Carefully examine the two satellite images of the Earth that your teacher has given you. Briefly describe the portion of the world that they cover.

Take a look at Image #1. Write a general description of where the weather is clear and where it is cloudy.

Look at Image #2. Are the cloudy and clear areas generally the same? Do you notice some differences? This image was taken 16 hours after Image #1. By comparing the images, we can see where and how the weather has changed.

Tape Image #2 to a windowpane. Then place Image #1 on top of it and carefully line up the pictures. Next, hold Image #2 in place and tape the left margin of Image #2 in place. Holding the right margin of Image #2, quickly cover and uncover Image #1. You will see weather in motion.

Look, in particular, at the eastern portion of the United States that is shown in the images. The "comma shaped" cloud feature is a cold front and marks the leading edge of colder air advancing along the ground from west to east. We can determine how fast the front and its cold air is moving by carefully measuring the front's change in position from one image to the next, taking into account the time that elapsed between when the images were taken.

Using a pencil or pen, mark four points along the curved line where the air is clearing behind the front in Image #1. (Suggestion: Start in western Virginia and move down along the clearing line from there to southern Florida or western Cuba.) From north to south, mark these points A, B C, and D.

Next, from each of the four points, draw a straight line perpendicular to the clearing line at that point.

Now, carefully examine Image #2 and see where the clearing line is in this image. Draw the position of this clearing line over the top of the comma shaped cloud in Image #1. Notice where the four straight lines you drew through points A, B, C and D cross this curved line. Mark these four points E, F, G and H (from north to south).

In the time between when the two images were recorded, point A moved to point E, point B moved to point F, and so on. To find out how fast the clearing line moved, use the distance scale to measure from point A to E, from B to F, etc., and write your answer in the spaces below.

Distance in miles (kilometers) from :

A to E = ____________________

B to F = ____________________

C to G = ____________________

D to F =

Next calculate the average distance the clearing line moved. Do this by simply adding the four distances you measured above and dividing by 4. Write your answer below.

Average distance moved by the clearing line

____

Finally, determine the average speed of the clearing line. (How fast was that clear air moving in behind that cloudy front?)

____

You can determine the average speed at which something was moving if you know how far it traveled in a certain amount of time. Think about it. If a car travels 80 miles in 2 hours, what was its average speed? The answer is 40 miles an hours and you get the number by simply dividing the distance traveled by the time it took or

80 miles / 2 hours = 40 miles / hour.

The time between Image #1 and #2 was 16 hours. So divide the average distance you calculated above by 16 hours to get the average speed of the clearing line in miles or kilometers/hour. Write your answer here.

____

Activity 3C: Planetary Storms/Observing Convection Currents

Note: this Activity can be used as a Teacher Demonstration, if there are concerns for safety, or as a team hands-on activity for older students

Objective

To observe a fundamental motion of air responsible for certain large cloud formations on Earth and other planets, and to report these observations.

Engage

Show students pictures or—even better—video of thunderstorm clouds billowing, or ask them to describe in detail a thunderstorm they have experienced. Ask them if they have ever seen a day (especially in summer) start out clear, but become cloudy with thunderstorms by afternoon.

Explore / Explain

Explain that clouds, especially thunderstorm clouds, can frequently be created when the Sun heats the surface of the Earth. The surface, in turn, heats the air in contact with it, which begins to rise. The air cools as it rises and the moisture in it condenses to form clouds. When the upward-moving air rises rapidly, it can mushroom into towering clouds over 12 miles (app 20 kilometers) high. As the air cools, it descends back down to the ground to be heated anew, thus setting up a cycle, or cell of air, known as a "convection cell."

In this Activity, students will examine spacecraft images of the Earth and Uranus to find such huge "convection cell" clouds, and create a small convection cell in which they can see the motion of air at different temperatures.

Materials (for every two students, or team)

- shoe box (or other box of similar size with a lid)
- short candle
- metal top from a jar (2 to 4 inches in diameter)
- piece of clear plastic wrap (larger than side of the box)
- cardboard tube from a roll of paper towels
- adhesive tape and a pair of scissors
- Earth and Uranus images from copy masters supplied
- atlas, with distance scale for North America

Procedure

Part 1 Finding and Measuring Large Cloud Features on Spacecraft Images

Pass out copies of spacecraft images of the Earth and Uranus. Have students briefly describe the geographical area covered in the Earth image, and identify which areas are cloudy and which are clear. Explain that this image was taken on July 25, 1993, and that many of the clouds they see are due to large rising cells of warm air in the process of forming thunderstorms. Ask them to see if they can find any thunderstorm activity over the following states: California, western Texas, Arkansas, northern Georgia.

When they arrive at the large, white area covering Iowa, as well as portions of Nebraska, Kansas, Missouri and Minnesota, tell them that this is a very large group of thunderstorms known as a "Mesoscale Convective Complex," (MCC). Using a distance scale from an atlas, have them measure its size.

Next, have them examine the HST image of Uranus. Contrast it to the image of Earth, and have them identify the two large cloud complexes they find. Given that the diameter of Uranus is 31,771 miles (51,120 kilometers), have them estimate the size of these cloud features. How does the size of these convection cloud features on Uranus compare with the one over Earth. How much of the U.S. would they cover if brought to Earth?

Part 2 Creating a Convection Cell

Have students cut out most of one of the long sides of their shoe boxes and cover it with clear plastic, making a window. Have them cut two holes in the lid just large enough for the sections of cut paper tube to fit through, as shown in the illustration. When ready, carefully light the candles and close the lid, making sure that the candle lies directly under one hole. Carefully place the smoking tip of a punk, or the smoking end of a tight curve of paper, near the top of cardboard tube #2. Smoke introduced over the right "roof chimney" will descend since it's cool, and travel across the length of the box to rise out of the "left chimney" because of the rising current of warm air from the candle.

(Note: a similar activity can also be done as a demonstration using a fish aquarium. Place room temperature water in the aquarium, filling it to about 3/4 of the way up. Place an aquarium heater at one end, and drape a plastic bag with ice cubes into the water at the other end. Allow the water to settle, then gently place a few drops of blue food coloring into the water near the ice cubes, and red food coloring near the base of the heater, using a long-nosed dropper. Within a few minutes, the food coloring will begin to trace out the cycle of currents in the water.)

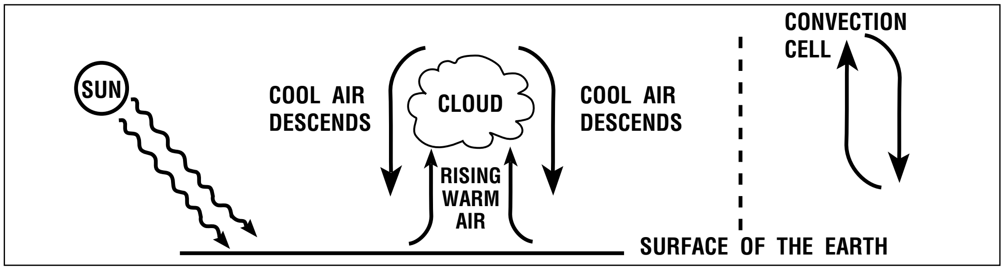
Pose the following questions to the students:

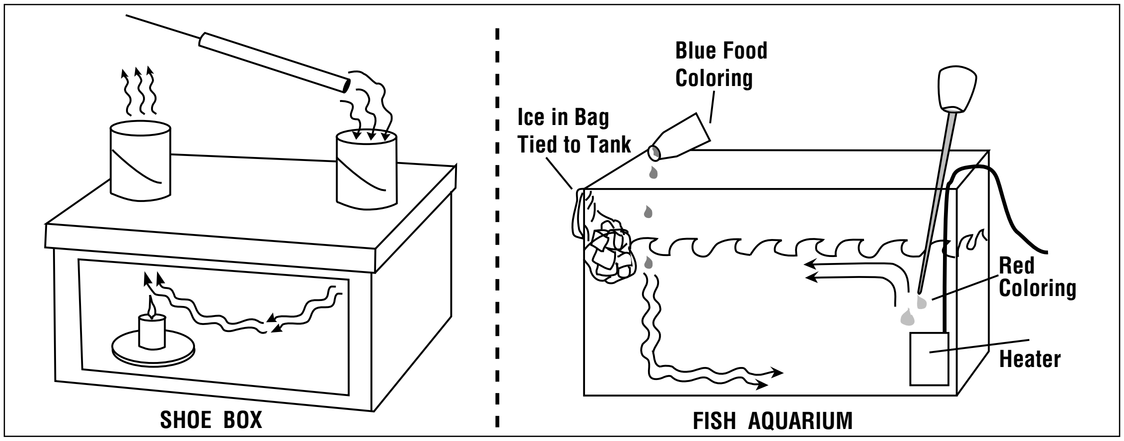
In the experiment you just completed, the candle supplied the heat causing the air to rise. What is the source of heat that causes air to rise and form clouds on Earth? What is the source of heat that does the same thing on the giant planets in our solar system like Uranus?

Expand

Go on-line and research the extensive weather-related materials which can be found there. The HST Home Page will provide some of the best links.

Send e-mail questions via *LHST*'s Researcher Q&A to astronomers and scientists who are awaiting your inquiries!





Activity 3D: The Interplanetary Weather Report

Objective

To compare/contrast weather on Earth and other planets in our solar system, and prepare a weather report similar to those on local newscasts, but interplanetary in scope.

Engage

Lead students in a discussion about weather, including how the weather is observed, recorded and forecast. Ask them about the role weather satellites play in allowing us to see and interpret the global weather situation every day. If possible, show a video tape of satellite images from last night's tv weather report, and explain what the satellite allows us to see: weather in motion. If you get cable TV, try to include a forecast segment that shows clouds over the entire Earth.

Explore / Explain

Ask students if they have ever seen a weather satellite image from another planet. If they say "no," show them an image of Jupiter or Neptune taken by the HST. Explain that as we have continued to explore, we have reached the point where we are starting to view and study the weather on other worlds. Tell them that for this project they are going to become meteorologists working for "The Interplanetary News Network." Their job: to issue the first TV weather forecasts for other worlds in our solar system.

Procedure Depending on students' backgrounds, use this Activity as an introduction to, or an extension of, the study of meteorology. Have students research the fundamentals of the Earth's weather including how it is measured and forecast. Draw attention to what can be measured at localized points around the globe (such as temperature, wind speed and direction, types of clouds, etc.) and what is more easily seen by looking at satellite images of large portions of the Earth including widespread areas of cloudiness, the location of jet streams, etc.

Assign students to study TV weather reports. To ensure they (and their parents) realize this is a serious assignment, ask them to record the channel # and call letters, name of weathercaster and length of report. Have them list topics shown or discussed in order of presentation: for example, Current Temperatures, Satellite Image, Weather Map, High Temperatures Tomorrow, Forecast, etc. What seems to be the important points about the weather which are covered? Did the weathercaster mention any severe weather? If so, what kind and where? Use this list to help students think about the topics that might be covered during a typical weathercast. Suggest students watch various channels, including the Weather Channel, to sample different styles and content. Notice how the weathercaster uses each visual, and what they say about each.

Divide students into teams and assign each the task of preparing a 5-7 minute TV weather report on a world other than Earth. Saturn's satellite, Titan and Neptune's companion, Triton, do have atmospheres and students may be challenged to take on some of this "moon meteorology" as well. Explain that in the case of other planets, there have been a few probes that have actually descended through some of their atmospheres to give a detailed set of readings at one or two locations (Venus, and more recently Jupiter). There have also been extensive satellite and spacecraft images of the planets from above. Challenge students to read about the weather on these other worlds and prepare a team weather report, dividing topic and presentation responsibilities among them. One member might want to report on overall temperatures, while another might give a special bulletin or update on some severe weather ("Over to you, Bob… Well, thanks, Jane…") Different students may want to act as if they are reporting from different places on the planets, or from different levels in its atmosphere ("I'm up here in Jupiter's clouds at about the height that the Galileo probe disintegrated, and let me tell you, Al…") Challenge them to make it fun but also informative. Assist them in preparing visuals to be used in their weathercast including charts and slides from various sources.

Again, you can provide a checklist to help them organize their thinking: Does your world have a thick atmosphere or a thin one? What is the atmosphere made of? Does the atmosphere allow us to see the surface of the planet or moon, or are there clouds or haze in the way? What's the surface like? What are temperatures in the upper parts of your world's atmosphere? At different levels in the atmosphere, or on the surface? What are the typical daytime highs on your world? Uniform, or different at different places? Typical nighttime lows? Are they different in different places?

Research the highest and lowest temperatures ever recorded in your region and across the Earth as a whole. How does your planet or moon compare? Does your world have seasons? How does this affect its weather? What is the air pressure deep in the atmosphere, or at the surface? Does the world have jet streams? How fast do they blow? Always in the same direction? How do these affect the weather? Is there rain, mist or fog? What is it made of, if not water, as on Earth? Does it snow? Is the snow made of frozen water like snow on Earth? Is there lightning? Are there storms? If so, what kind? Big or small compared to storms on Earth? Are there few, or many at one time? How long do the storms last? How does this compare to storms on Earth?

Ensure students have sufficient time to organize their research once they've collected it. Have them think about how to make it interesting and fun for others to hear and watch. What visuals would help? What props might be useful? Prepare a script or outline. Have each team member practice doing their part of the weathercast, alone at first, and then with the others on their team. Then, when they're ready … "The Weather on Other Worlds!"

Expand

Invite a local tv or radio meteorologist to speak about weather forecasting. Have the students prepare questions about the science of meteorology as well as how and why the guest speaker chose a career in this profession.

Go on-line and link from our homepage to "WeatherNet 4" to see how another NASA-funded IITA project has helped nearly 200 schools around Washington, DC, become real-time weather reporting stations. There are similar school-based weather networks in Houston and elswhere. Perhaps one of them will appeal to you, or your Administration, as an opportunity for ongoing weathercasting, on this planet, at least!

Activity 4A: Writing Across the Solar System

Objective

Students will demonstrate their ability to synthesize what they've learned during the project by creating literary works of fact, fiction and/or poetry.

Engage

Ask students about various ways people learn about the sky and objects in space. If they mention only books or programs about science, help expand their horizons. Read them a few poems about the stars, or a science fiction short story, or perhaps a Native American legend about the sky. (See Resources for several easily accessible examples.) Ask them to think about how such writings complement what science tells us. Ask them to think about the social role played by story-telling under the stars, at night around a camp-fire, before there were movies and television to entertain us. Share with them some of the examples of student writing about the stars spread throughout this Guide, and on-line resulting from *Live from the Stratosphere*.

Explore / Explain

Tell the class that they are going to explore space using the tools of written and/or oral expression. Challenge them to reach inside themselves for feelings they experience as they look up at a starry sky or gaze at exotic pictures of other worlds in books or magazines. Don't encourage sentimentality: if you live in an urban area, and they look up and see just sky glow, ask them to write about the contrast between what they know must be out there, and what they can actually observe. If they've been moved by an Imax movie, such as *Destiny in Space*, or a planetarium show they can certainly jump off from there. Tell them that the only limit is their imagination.

Procedure Assign students to discussion and work teams, or have them work solo. Have them research the planets of our solar system, or other objects in the universe, using the resources suggested for Activity 1B, but adding works of science fiction (especially short stories), poetry, or legends and tales from ancient mythology (Greco-Roman, Chinese, etc.), as well as various modern and near-modern cultures.

Ask them to choose and develop a subject and a form of expression. They may wish to write a short story set in the future, or a poem about a starry night last summer. If they are interested in story-telling as oral tradition, have them make-believe they are the chief storyteller of an ancient tribe, who tonight will gather the people and tell them a story of the sky. (Hint: the names of the Constellations are an obvious starting point for stories explaining the "pictures in the sky.")

Expand

When all the students have completed their assignments, have them present or perform their works in front of the class. Class discussion can follow about how such forms of expression complement what we know, through science, about the universe.

Students wishing to write a short story may set it at some point when humans have reached out to one of the HST's target planets. If so, have them incorporate what they've learned about that planet from this *Live from*… project. Challenge them to take into account the scientific wonders they will see, as well as the hazards they might face (intense radiation or the tedium of long-term space flight).

Some students might want to take on the challenge of writing a science fiction story in which the HST is the main character (like HAL in *2001*) and the reader sees and "feels" the excitement of exploration and discovery through the camera eyes and computer brain of the HST itself. How does the Hubble "feel" when these humans periodically come and go, doing eye-surgery, prodding and poking, and then leaving until the next servicing mission? How does Hubble feel, sharing the starlight with these puny, so-called astronauts, when it's he/she (there's a discussion to be had right there!) who's the true seer for the humans down on Earth?

Sharing student work via on-line Kids' Corner

Many of the Activities in this Guide provide opportunities to integrate technology in teaching and learning through the use of computer-based art, word processing, desktop publishing, and multimedia applications. *Passport to Knowledge* invites educators to submit student work to be shared on-line via Kids' Corner, a gallery of student creativity from participating classrooms. Be sure to save your students' work to Mac or IBM diskette, and clearly label file names, content, teacher, grade, school, full address, phone number, and other relevant background information. Send the diskette(s) to:

Marc Siegel, NASA Ames Research Center, Mailstop T-28H, Moffett Field, CA 94035

Student-created image and text files will be added to Kids' Corner as appropriate. Individual student e-mail addresses will not be included. Student name, school names, location, grade level will be cited, unless requested otherwise.

Activity 4B: "Lights... Camera... the Universe"

Objective

Students will collaborate and demonstrate the ability to use research, writing and presentation skills to create a multimedia report based on HST observations of the solar system or the Universe at large.

Engage

Ask students to think of ways that images and sound work together (TV commercials, videos on MTV and VH-1, animated and feature films). Ask them to think about how and why directors and writers compose words, music and pictures as they do. Say their homework is to become students of the media, to become media-literate. Tell them they will then have a chance to become multimedia authors, producers and directors, rather than passive consumers.

Do such works sometimes take their audience to places that are impossible to visit by any current technology, to a "Land before Time," on voyages of the *Starship Enterprise* in a future yet to come? Help them differentiate between fact and fiction, between science documentaries and dramatic imagination. Tell students of the impact made by works of fiction, such as H.G. Wells' *War of the Worlds* and Jules Verne's fictional trips to the moon, on the inventors of modern rocketry. Like art and science, fact and fiction are sometimes complementary. The trick, however, is always to know one from the other when it counts!

Explore / Explain

Encourage students to research the subject by looking at illustrated articles in magazines such as *Odyssey*, *Astronomy* and *Sky & Telescope*, as well, perhaps, as TV shows such as *Star Trek* or *Babylon 5*. Have them write and present an analysis of a piece they find compelling. Remind them that they are watching TV to learn ways in which images articulate the story. You can order slide sets by famous space artists for your class: see Resources for other suggestions.

Have them select a genre for their work. If they choose realism, challenge them to research the science behind the scenes they're going to create. What physical processes are at work? Does their planet have huge storms, gigantic lightning bolts or other interesting features? (see Activity 3C for a list of interplanetary weather.) How can this be effectively shown? If they choose fiction or fantasy, challenge them to develop a coherent, detailed vision of a world. What is this place like? How does it resemble or differ from our own world? (Space artist Adolf Schaller conjured up "Hunters, Floaters and Sinkers," hypothetical life-forms which might exist in the clouds of Jupiter, and an entire ecosystem of hunters and prey: fantasy, sure, but based on substance. Encourage similar creative leaps.)

Materials

- recorded music excerpts (examples: the classical music suite *The Planets* by Gustav Holst, Japanese composer Kitaro's film scores, works by Vangelis—*Bladerunner*, *Chariots of Fire*; the *Music of Cosmos* compilation soundtrack, or other music your students choose.)
- pictures from books, magazines, computer archive or Internet, especially NASA public domain images
- still camera, color slide film, slide projector
- audio tape player
- appropriate materials from art class
- computer Draw and Paint programs, if available

Procedure Have the students form creative teams. Each team will create a presentation utilizing no more than 2 minutes of music, and no more than 24 slides. Ask each team to pick a planet, and search books, magazines, and Internet sites, for pictures of that planet and its satellites.

Show students how to make slides of these pictures and images by properly pointing and focusing the camera. Don't use flash. Do use a tripod! Suggest they photograph books and magazines outside, or near a daylit window in indirect light if they are using film that is marked for daylight use. Photograph images from a computer screen in a darkened room to reduce glare.

As they are considering the pictures they'll use, have the students also listen to music for their presentation. Ask them to think about what type of music comes to mind when they look at the pictures, but encourage them to experiment with different kinds of music. Expose the techno fans to Holst, and the violinists to rock. But let them end up feeling that the choice is fully theirs.

When the Big Day arrives, have the teams of students introduce and perform their presentations. Depending on the social dynamics of your class, you might want to have a "Golden Planets—Students' Choice Award" for the "best" in the various categories.

Expand

If some students enjoy playing musical instruments, or creating music, allow them to tape their own music for the audio portion of a presentation.

Suggest to the Principal that your students might present to the school, to lower grades, to a PTA meeting (especially if your department needs extra support funds!), to the school board, if it has questions about just what those modems and computers do, or to local citizens on election day. Your students will gain confidence in themselves as authors, as teachers, as well as learners.

Have your students investigate the world of Space Art in greater depth including the International Astronomical Artists' Association and NASA's *Artist in Space* program. Discuss the role that art plays in our exploration of space and our attempts, as human beings, to better understand how we fit into the "big picture" called the Universe.

Review your students' work for Activity 4A or 4B. What knowledge, concepts, processes, skills, attitudes, do you see evidenced there which you can attribute to their involvement in *Live from the Hubble Space Telescope*? How does this relate to your school, district, state mandates, or course of instruction. Now turn to the Teacher Evaluation Forms, fill 'em out and send 'em in… and 500 of you will receive a free copy of NASA's *Astronomy Village* CD-ROM.

Lastly, assemble copies of your students' work, on paper, videotape, or computer disc, and ship to *Passport to Knowledge*, P.O. Box 1502, Summit, New Jersey 07902-1502, clearly indicating whether you need the materials back, and whether we have permission to use them for project evaluation. *PTK* hopes to create its own multimedia report on the new territories of knowledge and imagination your students have been exploring.

Activity 4C: Hubble in the Headlines

Objective

Students will demonstrate the ability to discuss and debate the value to society of major scientific and technological enterprises such as HST.

Engage

Passport to Knowledge feels privileged to have helped construct this unprecedented bridge between students and the *Hubble Space Telescope. (*Review *LHST* Program 1, "The Great Planet Debate") Explain what a truly world-class facility the Hubble is. As you'll learn from *LHST*, the Hubble was much in the news in early 1996, with a whole range of discoveries. Incredible numbers of faint galaxies were detected where none had been seen before. Spectacular regions of star birth were visualized in astonishing detail (as on the co-packaged poster); and planets were detected around distant stars. By getting their "virtual" hands on the Hubble, your students become members of a very select group of astronomers and scientists.

Explore / Explain

Tell students that when Hubble was first launched, astronomers were horrified to learn an imperfection in the construction of the mirror meant images were out of focus. Some in the press and public wrote off the Hubble and "big science" as too expensive, risky, and complex. Efforts by workers at many institutions in NASA and outside the agency—some of whom your students will "meet" on-camera or on-line—placed corrective optics and a new camera system (which we are using to image Neptune) aboard the Hubble, in the first of several always-planned servicing missions. Now Hubble's eye is crystal clear, and the science it had already accomplished took off.

Procedure Have students research the 1995-1996 Hubble discoveries, especially those not yet in textbooks: use on-line services, and current magazines. Tap libraries for books about HST which describe its initial problems, and the technical fixes which have made it the superb tool it is today. If you have access, download some of the **discuss-hst** archive, and see students' initial reasons for wanting to observe specific planets. Review our Planet Advocates' eloquent comments: how studying impacts on Uranus can give clues to the evolution of life on Earth, or how weather on Jupiter or Neptune can reveal new information about our own planet. Marc Buie is concerned with vision and human destiny, as well as scientific knowledge. He argued that our species always looks to new frontiers, such as Pluto, the only planet in our solar system not reconnoitered by our spacecraft, and that this is what keeps young minds and imaginations ("lifelong learners of all ages") engaged and growing.

Brainstorm these issues with students: elicit their opinions, provoke their comments. Group them into teams, based upon natural inclinations ("pro" or "con" Big science and projects like the Hubble), and have them research their opinion for a formal in-class discussion or debate. Remind them that in debate, success often comes to those who understand the best arguments of their opponents, not just their own.

Stage the debate. Record the arguments on audio or videotape. Have students edit the "official transcript" for the school, or local newspaper. As with Activity 4B, look over your students' arguments. What knowledge, concepts, processes, skills, attitudes, do you see evidenced which you can attribute to their involvement in *Live from the Hubble Space Telescope?* How does this relate to your school, district, and state mandates, or course of instruction. (Again, please turn to the teacher and student evaluation pages—and…fill 'em out and send 'em in.)

Glossary

Astronomical unit (A.U.) the average distance between the Earth and the Sun (app. 93 million miles, 150 million kilometers).

Atmosphere gases surrounding the surface of a planet, moon or star.

Blurring the bending (refraction) of waves of visible light or other electromagnetic radiation by Earth's atmosphere, thus preventing an observer from obtaining as clear a view as possible.

CCD a charge coupled device, an electronic detector of electromagnetic radiation, made of silicon chips that respond to incoming radiation by producing an electric current.

Centigrade (or celsius) temperature scale the scale of temperature that registers the freezing point of water as 0^0 and the boiling point as 100^0.

Color the visual perception of an object, which for a radiating object can often be considered an indicator of temperature.

Comet a small ball of rock and ice, typically a few kilometers across, from which emanates a long wispy tail of gas and dust while nearing the Sun in a huge, elongated orbit.

Concave lens/mirror a lens or mirror with an inward curvature.

Convection cell the physical upwelling of hot matter, thus transporting energy from a lower, hotter region to a higher, cooler region.

Diffraction grating a filter ruled with thousands of closely spaced parallel lines, thus causing reflected radiation to spread into its constituent wavelengths and frequencies.

Electromagnetic spectrum the entire range of all the various kinds of radiation; light (or the visible spectrum) comprises just one small segment of this much broader spectrum.

Energy the ability to do work.

ESA the European Space Agency, whose thirteen members are Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an associate member and Canada a cooperating state.

Extraterrestrial an adjective meaning "beyond the Earth."

Filter wheels aboard Space Telescope, wheels that hold 48 different filters, each of which removes electromagnetic radiation at particular frequencies and wavelengths from the beam of incoming radiation.

Fine guidance sensor (FGS) a device sensitive to ultraviolet and visible light, used aboard Space Telescope to detect guide stars astride the telescope's field of view, and thus to direct the telescope accurately toward a particular target.

Fixed head star trackers small telescopes with a wide field of view aboard Space Telescope, used to find relatively bright stars to serve as preliminary guide stars, in order for the fine guidance sensors to track the actual, fainter guide stars.

Geosynchronous orbit an orbit around the Earth at an altitude where a satellite moves at just the speed at which the planet rotates; hence, an orbit in which an orbiting satellite remains nearly stationary above a particular point on the planet.

Goddard Space Flight Center (GSFC) NASA's field center in Greenbelt, Maryland, from which the Space Telescope is controlled.

Gravitational force the (always attractive) force that holds matter together on a large scale, such as stars within galaxies, atoms within stars, and people on Earth. (**Gravity:** an abbreviated term for gravitational force.)

Great Red Spot a semi-permanent feature in the upper atmosphere of Jupiter, apparently a sort of cyclone, several times larger than the Earth.

Interplanetary space regions among the planets, moons, and related objects of the solar system.

Jovian planets the four, big, gassy planets in the outer parts of the solar system; Jupiter, Saturn, Uranus, and Neptune.

Kilometer a unit of distance equal to 0.6214 miles.

Light the kind of radiation to which the human eye is sensitive.

Light-year the distance traveled by light in a full year, equal to some 10 trillion kilometers (or about 6 trillion miles).

Mercator map a map projection in which the meridians are drawn parallel to each other and the parallels of latitude are straight lines whose distance from each other increases with their distance from the equator.

Milky Way Galaxy the specific galaxy to which the Sun belongs, so named because most of its visible stars appear overhead on a clear, dark night as a milky band of light extending across the sky.

Orbit a path described by one body in its revolution about another (as by a planet around the Sun).

Pixel a single element in an image, corresponding to a single dot in a mosaic picture.

Planet a rocky and/or gaseous body, generally much cooler and smaller than a star; the Earth is one such planet in orbit around the Sun.

Primary mirror the main mirror of a reflecting telescope, which gathers electromagnetic radiation and directs it toward a smaller secondary mirror, which in turn brings the radiation to a focus.

Prime focus the place to which a telescope initially directs its collected radiation.

Radiation a form of energy, consisting of mass-less particles called photons, which travels at the speed of light.

Reflecting telescope a telescope that uses a polished, curved mirror to gather light and reflect it to a focus.

Refracting telescope a telescope that uses a transparent lens to gather light and bend it to a focus.

Revolution the orbital motion of one object about another.

Rotation the spin of an object about its own axis.

Satellite a celestial body orbiting another of larger size.

Scientific method the investigative technique used by all natural scientists throughout the world. In general, some data or ideas are first gathered, then a theory is proposed to explain these hypotheses and finally an experiment is devised to test the theory.

Secondary atmosphere gases that a planet exhales from its interior after having lost its primary or primordial atmosphere.

Secondary mirror in a reflecting telescope, a small mirror mounted in the beam of radiation that strikes the primary mirror, and from which radiation is reflected and brought into focus.

Solar system a collection of 1 star, 9 planets, 60 moons, and innumerable smaller objects (asteroids, comets, meteoroids) orbiting about the Sun; both the Sun and Earth are members of the solar system.

Space Telescope Science Institute (STScI) an international research center operated by AURA for NASA and located at Johns Hopkins University in Baltimore, from which Space Telescope's science mission is designed and conducted, and where data is archived.

TDRS NASA's Tracking and Data Relay Satellite System, a network of communication satellites high in geosynchronous orbit, used to relay data from Space Telescope to Earth and to relay commands from Earth to Space Telescope.

Temperature a measure of the heat of an object, namely of the average kinetic energy of the randomly-moving particles in an object.

Terrestrial planets the four, small, rocky planets in the inner part of the solar system: Mercury, Venus, Earth and Mars.

Wavelength the distance between successive crests of a wave.

I can only imagine how access to this much information would have changed my own school experience. The highway will alter the focus of education from the institution to the individual. The ultimate goal will be changed from getting a diploma to enjoying lifelong learning.

BILL GATES, *The Road Ahead*, ©1995.

Whether you're a classroom teacher, home schooling parent, science center or museum educator, or an advocate of school reform and lifelong learning, on-line resources can radically transform the learning process. NASA's K-12 Internet Initiative, our on-line partner, provides a wide array of on-line materials and opportunities freely accessed via the Internet (often referred to as the "Information SuperHighway"). Teachers' responses to our previous projects convince us that going on-line will enhance and enrich your students' learning environment.

You needn't be an Internet expert to benefit from our on-line resources. *Passport to Knowledge* consciously tries to provide a wide and flexible menu of alternatives for those educators with limited time, technology, connectivity and support. Simple electronic mail (e-mail) via a slower, cheaper modem and regular phone line provides a great deal of information, as well as opportunities for interaction with working scientists and project participants. And it's easy to use, even for a newcomer to the Internet. At the same time, with *Live from the Hubble Space Telescope*, we've made a commitment to those of you with more advanced networking skills and access, by expanding our Web site to include special features such as Web Chat and videoconferencing.

What's Available?

Electronic Mail

Electronic mail provides an easy-to-use medium for exchanging ideas and receiving and sending information (some e-mail programs even allow you to attach graphics files). E-mail is the traditional first step for those who are new to the "net" and can be stimulating even if a little overwhelming at times!

Mail lists: **updates-hst** and **discuss-hst**

Two essential *Live from the Hubble Space Telescope* e-mail resources are the **updates-hst** and **discuss-hst** mail lists. When you subscribe to a mail list, you automatically receive all messages or "postings" sent out from the folks managing the list. In the case of **discuss-hst**, you may also send messages to the list.

The **updates-hst** mail list provides the key link between you and the project by keeping you informed of late-breaking project news, announcements, timely resources and special events. Once you've subscribed to this list, you will automatically receive all **updates-hst** postings, until you remove yourself from the list.

The **discuss-hst** mail list is a special conference or discussion forum for educators interested in sharing lesson plans and resources, teaching strategies, innovative ways to integrate the project into the classroom, coordinating collaborative efforts, and planning special events. It's also a great place to discuss concerns and questions (and even gripes!) as well as to make suggestions and provide input to the *LHST* project team. All members of **discuss-hst** should also be subscribed to **updates-hst**.

To join either or both of these mail lists:

1. Send a message to **listmanager@quest.arc.nasa.gov**
2. Leave the subject field blank
3. In the message body, write: **subscribe updates-hst**

You may also add a line stating: **subscribe discuss-hst** directly under the above line in the message body

Once your e-mail message is received by our automatic mail program, you will be sent a file providing essential introductory information about the operation of the list. Please save this information for future reference.

Researcher Q & A

Another resource is available to educators and students beginning March 1, 1996 and extending "live" through the end of April, 1996. This opportunity is known as *Researcher Q & A:* it enables students to ask questions about the Hubble Space Telescope, astronomy and what's been happening in the project, with answers coming back directly to each individual student inquiry. HST researchers, engineers, and support staff—some of whom will have also be seen on-camera during the videos—will correspond with classrooms, students, and educators in this interactive exchange. Questions will be acknowledged and answered as quickly as possible. All questions and answers will be archived on-line at our Web site. A useful keyword search function will allow quick access to existing Question and Answer pairs. Suggestions about submitting questions will be posted in the regular **updates-hst** newsletters, which will also provide tips for asking questions and practical logistics. Be sure to subscribe to **updates-hst** for this key information!

Field Journals via e-mail

From February through April,1996, the day-to-day lives of Hubble astronomers, researchers, and support staff will be shared via these research logs/diaries. Students and educators will meet the men and women who ultimately make the Hubble an unparalleled scientific resource. *Field Journals* from people at the Space Telescope Science Institute, Goddard Space Flight Center, from astronauts, university astronomers and other project participants around the world, will provide an "over-the-shoulder" view of their lives and work—rare, anecdotal and personal insights on the successes, challenges, and "human side" of contemporary astronomy and high-tech careers. Many educators have used previous *Field Journals* as models and motivation to help students document their own participation in the electronic field trip. These journals are intended to help students appreciate the great diversity of people and skills needed for success in a modern-day science project. *Field Journals* will be distributed via **updates-hst**, and also archived on our Web site for easy access.

World Wide Web Resources

NASA's K-12 Internet Initiative has provided an extensive array of resources, available to those who have access to the World Wide Web, a graphical interface allowing easy links between computer resources regardless of their location. Participants need special software called a "Web browser," such as Netscape or Mosaic, as well as an Internet account supporting Web access. Once you are connected with our Web site, you will find the following resources:

- Project News: Welcome, background files, recent updates
- HST Team: Biographical sketches, *Field Journals,* related files
- Video Broadcasts: Schedule and other key information about the live telecasts, including current public television and NASA TV schedules
- Featured Events: special time-critical activities
- Background on the Hubble Space Telescope and the target planets, and links to related Web sites
- *Researcher Q & A* access and database
- Photo gallery of interesting and relevant images including the HST planets, and Hubble's "Greatest—and latest—Hits!"
- Teachers' Lounge: a place for educators to meet and greet one another via an on-line database, Web chat, and sharing of curriculum resources. You can also check out the **discuss-hst** archive, respond to the latest on-line discussion topics and access an on-line version of the Teacher's Guide
- Kids' Corner: a place for sharing student work (computer, art, language arts, multi-media projects, desktop publishing, etc.)

Special Upcoming Features

- a Virtual Tour of the Hubble will be available for all to explore the inner workings of the Hubble Space Telescope and its support network
- Web Chat: weekly opportunities, at regularly scheduled times and dates, or as arranged by you and new-found, geographically-remote colleagues. Web chat enables real-time, text-based conversation with other people on the Web. You're likely to encounter K-12 teachers, students, HST project developers and *Passport to Knowledge* development team members. Web chat schedules will be posted to the **updates-hst** mail list and on our Web site.
- Videoconferencing: For those participants who have access to videoconferencing capabilities (which requires special software, camera, and higher speed connectivity: for CUSeeMe, this can be as low-cost as a $100 camera, with free software available: see on-line for more information) a regular schedule of videoconferencing sessions will be posted to **updates-hst** and on our Web site. We plan to have some of the HST team on hand for informative and fun interactions with students and educators.

We hope you find these Web and e-mail resources a key project component as you integrate *Live from the Hubble Space Telescope* into your own unique learning environment, and adapt it to your needs.

The URL (Uniform Resource Locator, or simply the "Web address") for *Live from the Hubble Space Telescope* is: **http://quest.arc.nasa.gov/livefrom/hst.htm**

Getting Connected

Whatever your unique situation, there are five essential ingredients to Internet connectivity:

1. Computer: updated Mac/IBM with expanded memory for World Wide Web use (8M recommended)

2. Modem: device which connects computer to the outside world via phone line. Recommended speed: 14.4 baud or higher (28.8 if you can)

3. Phone line which may be used for voice or fax when not in use by the modem.

4. Internet account: access to the Internet may be provided by local Internet providers, university accounts, commercial services like America Online, Compuserve, Delphi, Prodigy, Apple's E-World, Microsoft Network, etc. Check with your Department of Education regarding statewide education networks: many states provide reduced rate access for local teachers, so asking around with school colleagues and at the district level definitely pays off.

5. Software: communications software and Internet application software including e-mail program, Web browser, etc. are usually provided by the Internet service provider. Commercial services provide a package of software that is readily available by contacting their 800 customer service number.

Since there are so many regional variations, you are encouraged to check with your in-house or district technology expert about local Internet access and specific logistics about using your computer, software, modem and the Internet. If you have general questions which remain unanswered, or specific *Live from Hubble* issues, feel free to contact Jan Wee, *Passport to Knowledge* Education Outreach Coordinator. (See inside front cover for phone, fax and e-mail contact information.)

Poetry and Astronomy

Ackerman, D. "The Poetry of Diane Ackerman." in *Mercury*, Jul/Aug 1978, p. 73

Franknoi, A. & Friedman, A., "Images of the Universe" in *Mercury,* Mar/Apr 1975, p. 14. On astronomical poetry throughout history.

Marschall, L., "Modern Poetry and Astronomy." in *Mercury*, Mar/Apr 1983, p. 41

Marschall, L., "Comets and the Muse." in *Mercury*, Jan/Feb 1986, p. 10

Maynard, C., "Robert Frost: Poet of the Night." in *Sky & Telescope*, June 1992, p. 692

Weitzenhoffer, K., "Well Versed in Astronomy." in *Sky & Telescope*, Oct. 1990, p. 365 Brief introduction to astronomy in poetry over the centuries.

Mythology and Legends

Caduto, M.J. & Bruchac, J., *Keepers of the Night*. Fulcrum Pub., Golden ,CO, ISBN 1-555-91-177-3, (800) 992-2908. Native American Sky Legends.

Krupp, E., *Beyond the Blue Horizon: Myths and Legends of the Sun, Moon and Planets.* Harper Collins. Collection of astronomical tales from many cultures.

Krupp, E., "Along the Milky Way." in *Mercury* Nov/Dec 1991, p. 162 An excerpt from the above book on legends and stories about the Milky Way.

Monroe, J.G. & Williamson, *They Dance in the Sky.* Houghton Mifflin Co., ISBN 0-395-39970-X, Native American stories and legends.

Ridpath, I., *Star Tales.* 1988, Universe Books. A collection of myths about the constellations, mainly from Greek and Roman tradition.

Art and Astronomy

Chaikin, A., "Images of Other Worlds." in *Sky & Telescope,* Nov. 1982, p. 423

Davis, Don, "The Worlds of Don Davis." in *Sky & Telescope*, June 1985, p. 503

Hardy, D. *Visions of Space: Artists' Journey Through the Cosmos,* 1989, Limpsfield. Featuring the work of over 60 artists.

Hartmann, W. et al., *Cycles of Fire.* 1987. Workman Pub., Book on stars and galaxies with many paintings by an artist and planetary astronomer.

Hartmann, W. et al., *In the Stream of Stars: The Soviet/American Space Art Book.* 1991, Workman Pub. Over 200 paintings and text by artists in the U.S. and former Soviet Union.

Miller, R. *The Dream Machines.* 1993, Krieger Pub. An illustrated history of the spaceship in art, science and literature by a noted space artist.

Miller, R. & Hartmann, W., *The Grand Tour: A Traveler's Guide to the Solar System.* 2nd. ed., 1993, Workman Pub., Introduction to the planets with many artists' paintings.

Miller, R. & Durant, F., *Worlds Beyond: The Art of Chesley Bonestell.* 1983, Donning Pub., Album and tribute to space artist pioneer.

Olson, D. & Doescher, R. "Van Gogh, Two Planets, and the Moon." in *Sky & Telescope,* Oct. 1988, p. 408

O'Meara, S., "Kazuaki Iwasaki: Japan's Astronomer-Artist." in *Sky & Telescope,* July 1985, p. 64

Astronomical and Space Art may also be found in *Sky & Telescope, Astronomy* and *Odyssey* magazines. Also look in *Astronomy* and *Sky & Telescope* for ads on sets of color slides from various space artists.

On the Internet, view space art and learn about the International Astronomical Artists Association at:
http://www.novaspace.com/IAAA/IAAA.html

For bulk orders of the hands-on materials sampled in this "mini-kit":

Thermal paper and UV beads: Educational Innovations, (203) 629-6049, or e-mail: EdInnov@aol.com

Diffraction gratings and color filters: R&R Packaging (508) 433-6835

HST "Greatest Hits" and other space slides and videos: Finley-Holiday Films 1-800-345-6707

ON-LINE ON DISK

This may sound like a contradiction, but if you have no, or slow, access, you and your students can still take advantage of the extensive on-line materials described above, by using regular floppy disks, formatted to work with any computer and word processing program. You'll be able to read *Field Journals,* search the *Researcher Q & A* database, and—we hope—see so many things of interest, that you'll be sure to be on-line for future *Passport to Knowledge* projects!

Richard Seltzer of B & R Samizdat Express, a small Boston publisher, downloads all current files on our Web site and makes them available in Mac or IBM formats. You may order diskettes for $10.00 per 3.5" high density diskette. You are authorized and encouraged to make as many copies as you need to share with students and colleagues. *Live from the Hubble* diskettes will be available in late February and may be ordered by e-mail or postal mail. Be sure to indicate whether you want IBM or Mac format, your full name and address, and enclose a check, purchase order, or current credit card information. In the U.S., there is no charge for shipping and handling. Massachusetts residents should add 50 cents per disk for sales tax. Outside the U.S., add $2.00 for shipping per order.

For orders via postal mail: B and R Samizdat Express, P. O. Box 161, West Roxbury, Massachusetts, 02132-0002. For e-mail orders: samizdat@samizdat.com (Send payment via postal mail) For more information about the "Please Copy This Disk" service, call Richard Seltzer at 617-469-2269.

Check our 1-800-626-LIVE (626-5483) *Passport to Knowledge* Hotline, mailbox #6, for updated information about how many diskettes are offered.

Student Evaluation Form

The *Passport to Knowledge* team has tried to make *Live from the Hubble Space Telescope* informative and fun. Please tell us a little about your response to the project so we can do still better next time. Thanks!

Grade level: ________ Teacher name: ______________________________

School: ______________________________

Are you male/female? ________

1. I watched: Program 1: The Great Planet Debate yes ❑ no ❑ Program 2: Making YOUR Observations yes ❑ no ❑ Program 3: Announcing YOUR Results yes ❑ no ❑
2. Our class prepared for the electronic field trip by: (list any classroom activities you did before viewing the videos) ______________________________
3. Our class followed up the electronic field trip by: (list any classroom activities you did after viewing the videos) ______________________________
4. The BEST classroom activity we did was: ______________________________

   The WORST classroom activity we did was: ______________________________

5: The BEST part of the videos was: ______________________________

   The WORST part of the videos was: ______________________________

7. We accessed the on-line materials via computer and modem: yes ❑ no ❑
8. The MOST interesting material we found on-line was: ______________________________
9. The MOST interesting thing I learned from the whole *Live from the Hubble* project was:

   ____

10. Describe one thing you learned about:

    Astronomy: ______________________________

    How the Hubble Space Telescope operates: ______________________________

    How scientists work: ______________________________

    How school subjects are used in the world beyond school: ______________________________

11. *Live from the Hubble Space Telescope* gave me:

Factual Information about Astronomy	yes ❑	no ❑
Factual Information about Careers in Science	yes ❑	no ❑
Better understanding of basic Scientific Concepts	yes ❑	no ❑
Better understanding of the Scientific Process	yes ❑	no ❑
Increased interest in Science and Technology	yes ❑	no ❑
Increased interest in a Career in Science or Technology	yes ❑	no ❑
Increased appreciation for Teamwork	yes ❑	no ❑
Increased sense of Connectedness across distance	yes ❑	no ❑
Greater ability to use Computers and Telecommunications	yes ❑	no ❑
Greater ability to ask good questions and synthesize information	yes ❑	no ❑

12. If in the future you could take more electronic field trips like *Live from the Hubble Space Telescope*, where would you MOST like to "visit"? ______________________________

How about the following places? Check all that sound interesting: Dinosaur Dig ❑ Amazon Rainforest ❑ Ocean Deep ❑ Mars ❑ Return to Antarctica ❑

13. Next time I hope my teacher will once again DO: ______________________________
14. Next time I'd advise my teacher NOT TO: ______________________________

Teacher Evaluation Form

Live from the Hubble Space Telescope is the third in the ongoing series of *Passport to Knowledge* field trips. We've tried to incorporate feedback from teachers into our previous projects: please take a few moments to tell us how you used the video, print and on-line components so we can learn still more. Returning this form will also place you on our mailing list for future Modules. (A shorter evaluation form to be completed by students is also provided.)

Please note: *Passport to Knowledge* will distribute 500 free copies of NASA's new *Astronomy Village* CD-ROM to educators returning completed Teacher **and** Student evaluation forms by May 30, 1996. Yes, this also applies to home-schoolers with just a few students!

I. GENERAL INFORMATION

Your name: ____________________

Professional status (e.g. teacher, principal, Library Media specialist, etc.) ____________________

School/Contact Address: ____________________

Phone: ____________________

Grade Level taught: ____________________

1. Number of Classes who participated: ________ ________ # of Students ________ # of Teachers
2. Check all subjects in which this project was used.
   General Science: ❏ Biology: ❏ Earth Sciences: ❏ Physics: ❏ Math: ❏ Computers: ❏ Language: ❏ Social Studies: ❏ Other: ________
3. Was the project used as a "Team Teaching" activity? yes ❏ no ❏
4. Did your school/institution connect with local astronomers, science museums, planetariums, etc. to support your activities? yes ❏ no ❏
5. Please check yes/no to your use of the various Project Components
   Live videos yes ❏ no ❏
   Teacher's Guide (print) yes ❏ no ❏
   Other co-packaged print materials yes ❏ no ❏
   On-line resources yes ❏ no ❏
   Taped videos yes ❏ no ❏
   NASA's *Space Based Astronomy* yes ❏ no ❏
   Hands-on "mini-kit" (poster, filter, beads.) yes ❏ no ❏
   1-800 "Hotline" yes ❏ no ❏
6. Were you able to integrate this project with your teaching goals? yes ❏ no ❏

II. VIDEO COMPONENTS

1. Which program(s) did you and/or your students watch?
   Program 1: The Great Planet Debate yes ❏ no ❏
   Program 2: Making YOUR Observations yes ❏ no ❏
   Program 3: Announcing YOUR Results yes ❏ no ❏
2. Please indicate by checking your source of the videos: PBS: ❏ NASA-TV (NASA Select) ❏ Educational Network: ❏ Videotape ❏
3. How many lessons did you give *before* students viewed the videos? ________
4. How many lessons did you spend on *follow-up* after the videos? ________
5. On a scale where 1 is *lowest* and 4 is *highest,* please rate the Importance of the videos to the project, and rate their Quality:

	IMPORTANCE	QUALITY (1 = lowest, 4 = highest)
Live programs	1 2 3 4	1 2 3 4
Taped programs	1 2 3 4	1 2 3 4
6. Rate the Importance of the **Live** aspect of the project:	1 2 3 4	1 2 3 4

7. Please describe the most important learning that your students gained from the video components?
   ____
   ____
8. Do you plan to use the programs again, on tape, in the future? yes ❏ no ❏

III. PRINT MATERIALS

1. Rate the Importance and Quality of the Teachers Guide, "mini-kit" and co-packaged publications:

	IMPORTANCE	QUALITY (1 = lowest, 4 = highest)
Live from the Hubble Space Telescope Teacher's Guide (overall)	1 2 3 4	1 2 3 4
Individual Guide components:		
Broadcast Information	1 2 3 4	1 2 3 4
How to use an "electronic field trip"	1 2 3 4	1 2 3 4
Program Overviews	1 2 3 4	1 2 3 4
Classroom Activities	1 2 3 4	1 2 3 4
Materials and Resource Lists	1 2 3 4	1 2 3 4
"How to Get On-line"	1 2 3 4	1 2 3 4
Interdisciplinary matrix and icons	1 2 3 4	1 2 3 4
Glossary	1 2 3 4	1 2 3 4
Co-packaged materials:		
NASA *Space Based Astronomy*	1 2 3 4	1 2 3 4
Space Telescope Science Institute "Starcatcher"	1 2 3 4	1 2 3 4
Poster	1 2 3 4	1 2 3 4
Color Filters	1 2 3 4	1 2 3 4
UV Beads	1 2 3 4	1 2 3 4
Diffraction grating	1 2 3 4	1 2 3 4
Heat sensitive paper/cardboard	1 2 3 4	1 2 3 4

Teacher Evaluation Form page 2

2. Which classroom activities did you work on with your students? Please list ALL used, by page number in the Guide:
___
3. Was there sufficient information to adapt the activities/material to the needs/grade level of your students? yes ❑ no ❑
4. Please describe the most important learning that your students gained from the Print and "mini-kit" materials: ___
___

IV. ON-LINE COMPONENTS

1. Did you and/or your students use the On-line resources? yes ❑ no ❑
2. Please check all on-line formats used: e-mail ❑ gopher ❑ Web ❑
3. How did you access the materials? NASA Quest ❑ NASA Spacelink ❑ PBS ❑ Other (please specific) ___
4. On a scale where 1 is lowest and 4 is highest, please rate the Importance of the On-line components, and rate their Quality:

	IMPORTANCE	QUALITY	(1 = lowest, 4 = highest)
(a) Informational resources (i.e. non-interactive)			
Teacher's Guide	1 2 3 4	1 2 3 4	
HST Updates (newsletter)	1 2 3 4	1 2 3 4	
(b) Interactive opportunities			
Researcher Q & A (e-mail to and from the scientists)	1 2 3 4	1 2 3 4	
Field Journals/Logs	1 2 3 4	1 2 3 4	
Junior-HST *Field Journals*/Logs	1 2 3 4	1 2 3 4	
Discuss-HST	1 2 3 4	1 2 3 4	
(c) On-line collaborative activities, (e.g. star-census, weather)	1 2 3 4	1 2 3 4	

5. Did your students send questions to *Researcher Q & A?* yes ❑ no ❑
6. Did your students incorporate the results of their work with on-line materials in their own presentations/reports? yes ❑ no ❑
7. How would you rate the ease of use of the on-line materials, where 1 is very easy, 2 quite easy, 3 quite hard and 4 very hard 1 ❑ 2 ❑ 3 ❑ 4 ❑
8. Please describe the most important learning that your students gained from use of the on-line materials:
___
___

V. STUDENT LEARNING

1. On a scale where 1 is Least Valuable and 4 is Most Valuable, please rate what kind of student learning resulted from the project.

	Least Valuable	Most Valuable	(1 = least, 4 = most)
(a) Factual Information			
Factual Information about Astronomy	1 2 3 4	1 2 3 4	
Factual Information about Careers in Science	1 2 3 4	1 2 3 4	
Better understanding of basic Scientific Concepts	1 2 3 4	1 2 3 4	
Better understanding of the Scientific Process	1 2 3 4	1 2 3 4	
(b) Attitudes			
Increased interest in Science and Technology	1 2 3 4	1 2 3 4	
Increased interest in Career in Science or Technology	1 2 3 4	1 2 3 4	
Increased appreciation for Teamwork	1 2 3 4	1 2 3 4	
Increased sense of Connectedness across distance	1 2 3 4	1 2 3 4	
(c) Skills			
Ability to use Computers and Telecommunications in schoolwork	1 2 3 4	1 2 3 4	
Ability to ask good questions and synthesize information	1 2 3 4	1 2 3 4	

2. Please describe the most valuable learning outcome you saw in your students: ___
___

VI. Future *Passport to Knowledge* Modules

1. If your students could take more electronic field trips, where would they *most* like to "visit"?
Dinosaur Dig Amazon Rainforest Ocean Deep Mars Return to Antarctica Other: ___
2. What improvements can you suggest for future *Passport to Knowledge* Modules?
___
___
3. Other groups are offering electronic field trips at varying costs per school/student:
how much would you/your school pay for a *Passport to Knowledge* project such as *Live from the Hubble Space Telescope?* ___
Would/could not participate unless free/low-cost yes ❑ no ❑ $50 ❑ $100 ❑ $150 ❑ $200 ❑ $300 ❑ more ❑

Questions? Please contact *Passport to Knowledge:* fax (908) 277-9590: e-mail: **ghaines@quest.arc.nasa.gov**

Please mail this completed form, together with student evaluations, to:

LIVE FROM THE HUBBLE SPACE TELESCOPE,
P.O. Box 1502, Summit, New Jersey, 07902-1502

Cross-Curriculum Connections of Programs and Activities

	Science	Math	Language Arts	Social Studies	Tech. Ed.	Computers & on-line	Art
Opening/Program 1							
Activity 1A	x		x	x		x	x
Activity 1B	x	x			x	x	x
Activity 1C	x	x			x		
Program 2							
Activity 2A	x	x			x		
Activity 2B	x	x			x		
Activity 2C	x	x		x	x	x	
Activity 2D	x	x		x	x	x	
Activity 2E	x	x			x	x	x
Program 3							
Activity 3A	x	x			x	x	x
Activity 3B	x	x		x	x	x	
Activity 3C	x				x		
Activity 3D	x		x	x	x	x	x
Closing							
Activity 4A	x		x	x	x		
Activity 4B	x		x	x	x	x	x
Activity 4C	x		x	x	x	x	

Concepts, Themes and Interdisciplinary Connections

Correlation of *Live from the Hubble Space Telescope* programs and Activities with concepts and themes suggested by Project 2061 and the *California Science Framework*

Project 2061 *Ca. Science Framework*	Systems & Interactions	Constancy Stability	Patterns of Change	Evolution Evolution	Scale Scale and Structure	Models ***	*** Energy
Opening/Program 1							
Activity 1A	x	x	x		x	x	x
Activity 1B	x		x	x	x	x	
Activity 1C				x	x		
Program 2							
Activity 2A	x	x	x			x	x
Activity 2B	x				x	x	x
Activity 2C	x	x	x		x	x	x
Activity 2D	x		x		x	x	x
Activity 2E	x	x	x		x	x	x
Program 3							
Activity 3A	x	x	x		x	x	x
Activity 3B	x	x	x	x	x	x	x
Activity 3C	x	x	x	x	x	x	x
Activity 3D	x	x	x	x	x	x	x
Closing							
Activity 4A		x	x	x		x	
Activity 4B	x	x	x	x	x	x	x
Activity 4C	x				x	x	

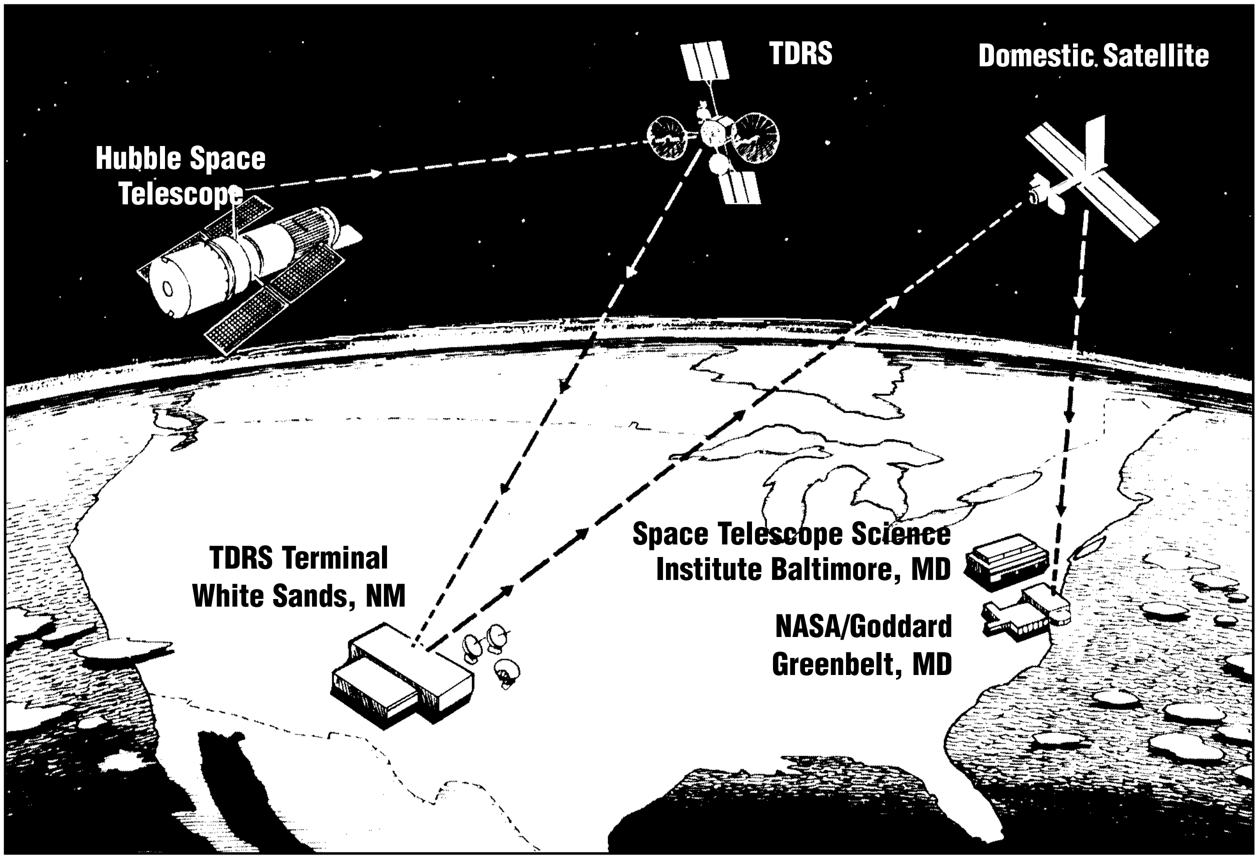
Dr. Anne Kinney, Education Manager/ Project Scientist, STScI

Scientists tend to ask the same questions that kids do when they play… They ask a question and that invokes another question… It's something that people know intrinsically when they are children and somewhere they forget it. Scientists still do it, and the more successful they are, the better they are at honoring the questions that come up.

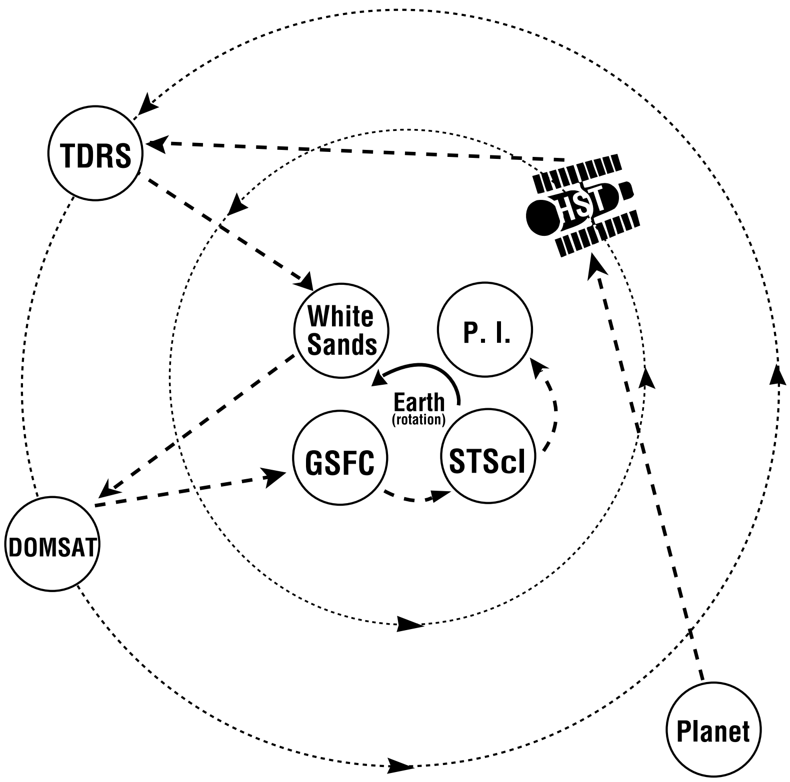
…Science is on-going, but the greatest criticism about the way I learned science is that it was always taught that someone else did it, and that they were usually wearing a white coat and, of course, they were usually male and they knew all the answers and, of course, what was the point. In fact it is really not that way. Science is on-going and if you want to know the answer to something you better be the one who is asking the questions—you yourself—not someone in another room with a different background than yourself.

Live from the Hubble Space Telescope is unprecedented, we never used Hubble Telescope orbits for classroom use before. Another unique thing… is that we are trying to have students involved in which planet to look at… I would be very happy if they had a feeling that they were the scientists. I would be very happy if they had a lot of unanswered questions. When it was over, I would be happy if they were not content with the plan that was chosen, in fact they wished it was of another planet because they didn't get their question answered. In other words, if we caused a lot of trouble I would be very happy!

Signal Path



Student Placement for Activity 2D: Bouncing Data...



Passport to Knowledge is looking to the future and hopes to work with you to design other new and exciting Modules. Some ideas for future programs are: *Live from Mars*, *Live from Antarctica 2*, *Live from the Amazon Rainforest*, *Live from the Ocean Deep*, *Live from the Place the Dinosaurs Died*, *Live from Shuttle/MIR*, *Live from the Fastest Planes on Earth* and *Live from the North Pole*. We hope you agree these are exciting and significant topics for "students of all ages"!

PTK invites you to be a member of a global learning community and come along for some very exciting adventures over the coming months and years. We look forward to working and learning with you on this exciting adventure.

Real Science

Real Time

PASSPORT TO KNOWLEDGE

Real Scientists

Real Locations