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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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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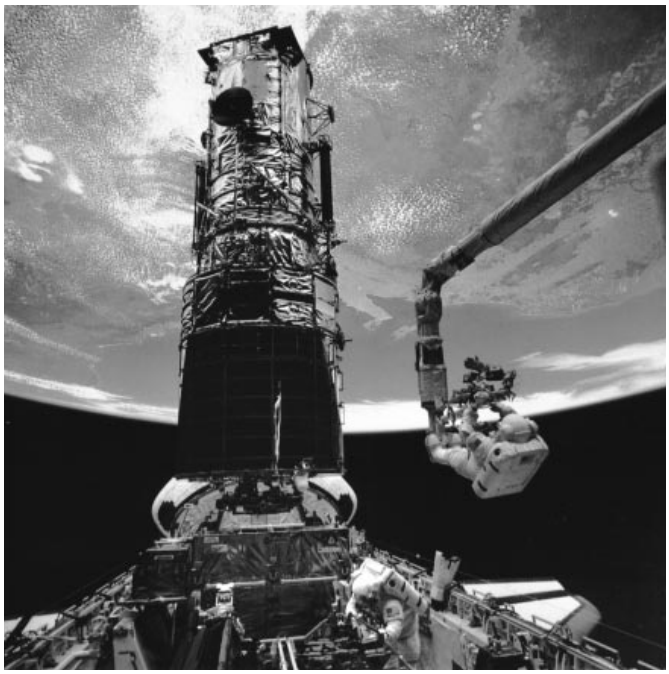
POEMS COURTESY
6TH-8TH GRADE STUDENTS from SUMMIT MIDDLE SCHOOL, NJ

Setting Out on an Electronic Field Trip

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

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.

"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

credit: American Institute of Physics

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?

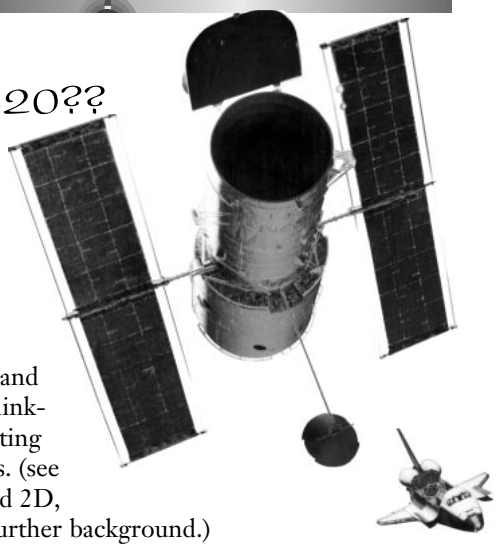
In 1924, Hubble ended the debate when he reported stars in the outskirts of Andromeda, and found a special kind of star, known as a Cepheid variable, which reveals its distance by the way its light regularly brightens and dims. Careful observations of the Cepheids enabled him to measure the distance 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.

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)

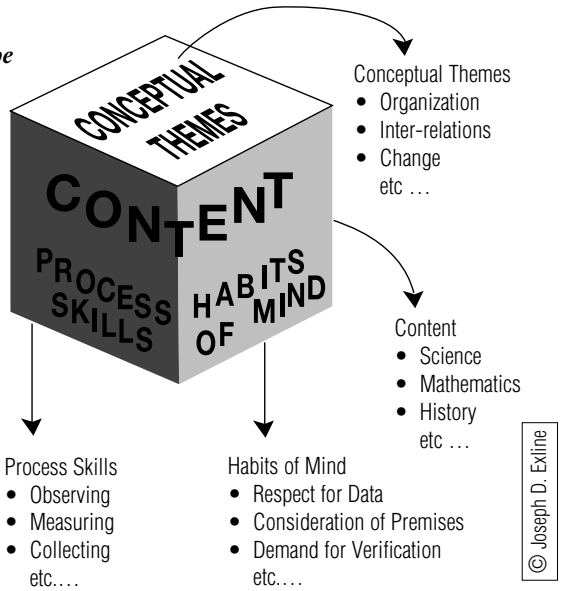
At the national and state levels, standards have been developed in an attempt to make science education more relevant for ALL students. Guidelines, such as the *National Science Standards* (National Academy of Sciences/National Research Council), *Benchmarks for Scientific Literacy* (AAAS/Project 2061) 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 Understandings** 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.