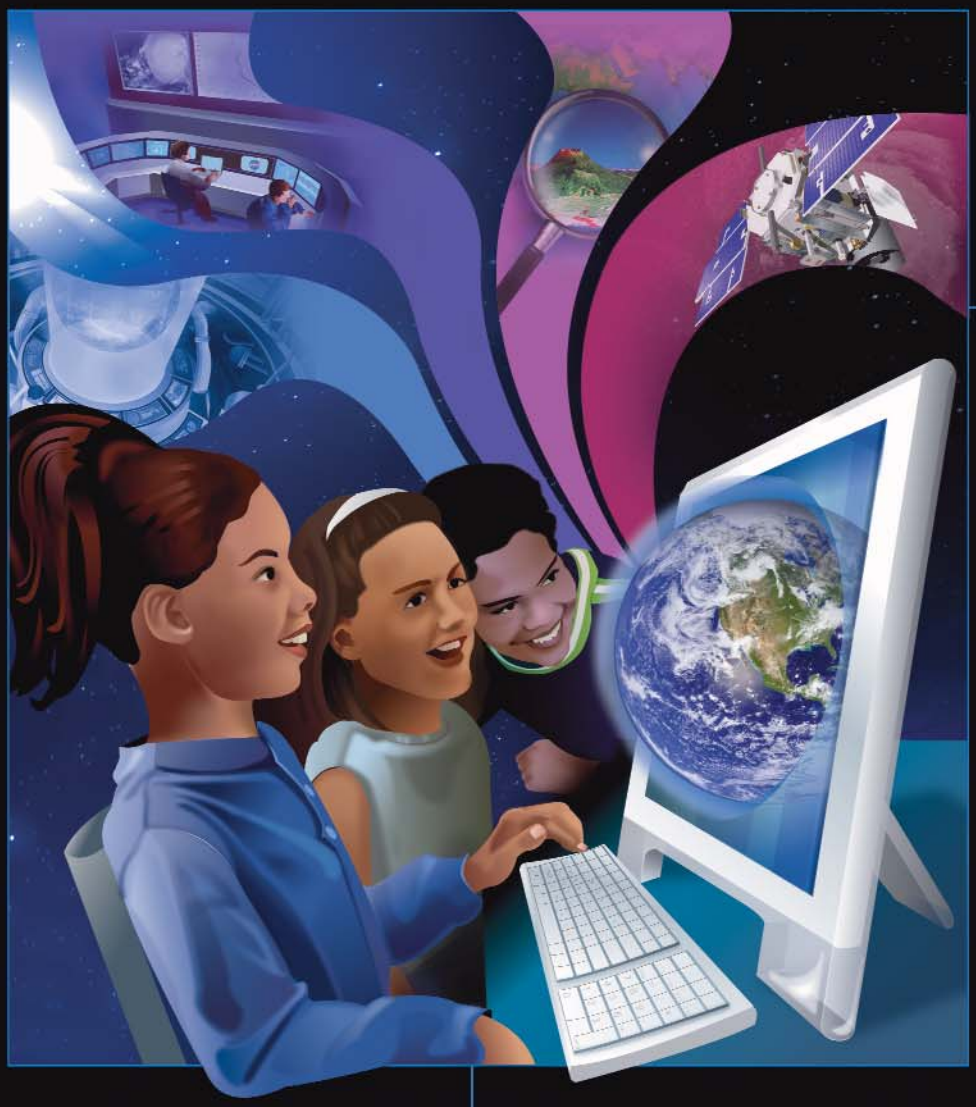

National Aeronautics and Space Administration

Earth Science Education Plan

Inspire the Next Generation of Earth Explorers

Foreword

We stand today confronted with new challenges and opportunities for Earth science education.

National Aeronautics and Space Administration (NASA) research and development have contributed to more than 40 years of Earth exploration from the vantage point of space. The current suite of satellite observations provides new perspectives of Earth, enabling us to see, explore, and investigate our world in ways never before possible. The concept of Earth as a dynamic and complex system of interconnected processes has become a dominant paradigm in scientific research. Upon this foundation lies the opportunity for Earth science to serve the national interest by enabling us *to understand and protect our home planet*. Beyond our own world, the knowledge we gain about planet Earth and the innovative technologies used in creating this knowledge contribute to NASA's mission *to explore the universe and search for life*. The intellectual capital needed to actuate this opportunity relies on the proficient scientific literacy of the general public and effective science education for all of our children.

NASA recognizes the role of space exploration in science education and has established *"to inspire the next generation of explorers . . . as only NASA can"* as a core mission. The importance of this action and the creation of the Education Enterprise within NASA have led to the Education Enterprise Strategy, the first Agencywide strategy for education. The Earth Science Enterprise adopts this framework in fulfilling our education mission.

The Education Enterprise Strategy, the expanding knowledge of how people learn, and the communitywide interest in revolutionizing Earth and space science education have guided us in developing this plan for Earth science education. This document builds on the success of the first plan for Earth science education published in 1996; it aligns with the new framework set forth in the NASA Education Enterprise Strategy; it recognizes the new educational opportunities resulting from research programs and flight missions; and it builds on the accomplishments that the Earth Science Enterprise has made over the last decade in studying Earth as a system. This document embodies comprehensive, practicable plans for inspiring our children; providing educators with the tools they need to teach science, technology, engineering, and mathematics (STEM); and improving our citizens' scientific literacy.

This plan describes an approach to systematically sharing knowledge; developing the most effective mechanisms to achieve tangible, lasting results; and working collaboratively to catalyze action at a scale great enough to ensure impact nationally and internationally. This document will evolve and be periodically reviewed in partnership with the Earth science education community.

We stand together with many friends and colleagues in the Nation and around the world in a mutual commitment *to inspire the next generation of explorers*.

Ghassem R. Asrar, Ph.D.
Associate Administrator for Earth Science

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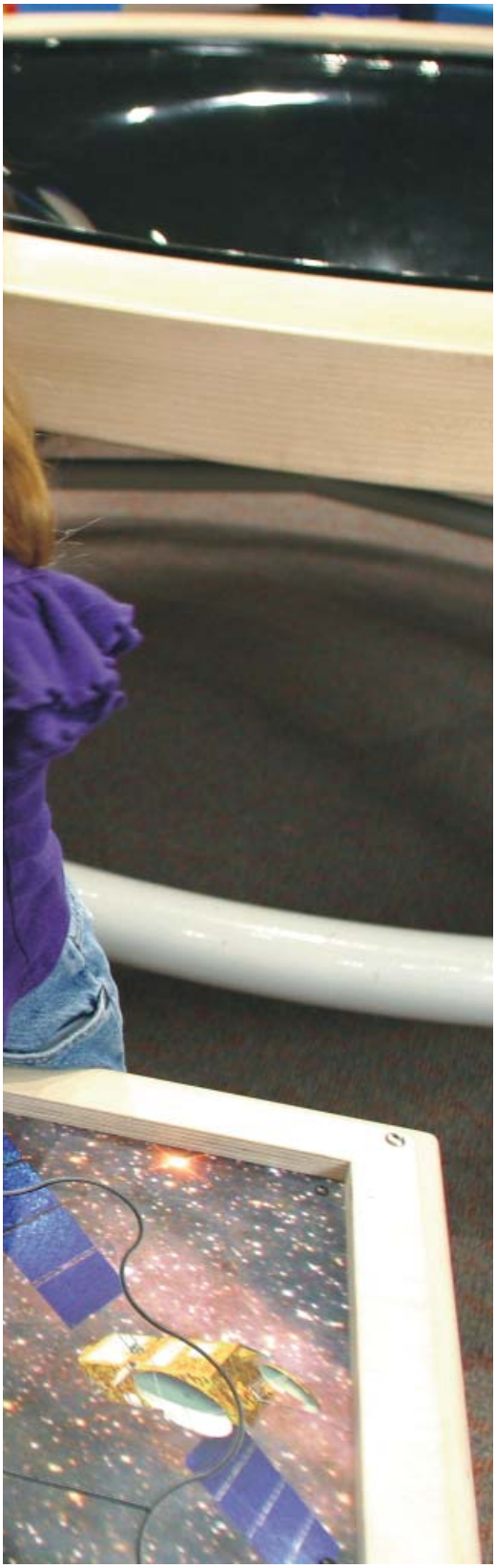
For those who have seen the Earth from space, and for the hundreds and perhaps thousands more who will, the experience most certainly changes your perspective. The things that we share in our world are far more valuable than those which divide us.

—Donald Williams, Astronaut, United States of America

1 Earth Science Enterprise Education

aWinds Satellite



1 Earth Science Enterprise Education

The NASA Vision—
To improve life here,
To extend life to there,
To find life beyond.

The NASA Mission—
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
. . . as only NASA can.

NASA's Earth Science Enterprise (ESE) has a **leading** role in NASA's mission to understand and protect our home planet. The ESE uses NASA's unique capabilities to understand the Earth system and apply Earth system science to improving prediction of Earth system change.

The ESE has a **supporting** role in NASA's mission to explore the universe and search for life. ESE advances in modeling complex Earth system phenomena, processing and distributing large volumes and varieties of data, and developing sophisticated Earth-observing instrumentation are directly applicable to the search for life elsewhere in our solar system and beyond.

The ESE has an **essential** role in NASA's mission to inspire the next generation of explorers. The Earth system science concept pioneered by NASA is changing how Earth science research is conducted, the way it is taught at elementary through postgraduate levels, and the way it is presented to the public by the media and informal learning communities.

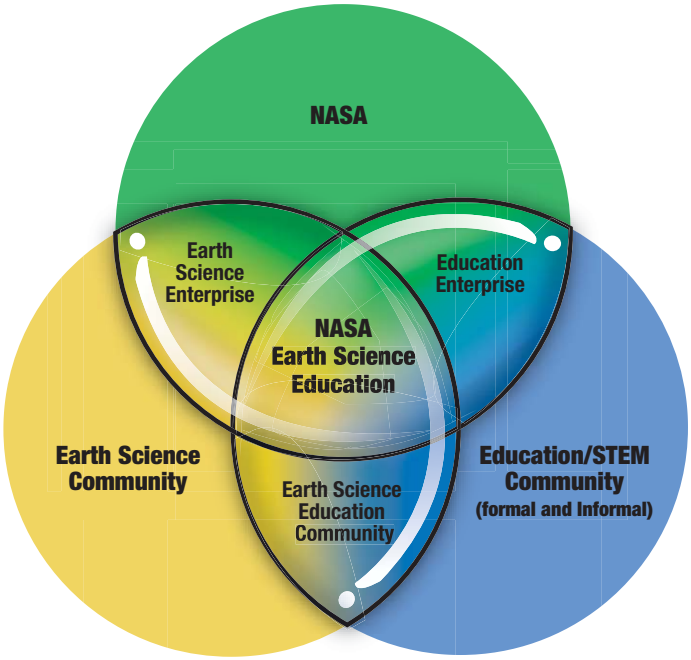
Young Earth explorers at the Oregon Museum of Science and Industry learn how satellites are used to study Earth with "Eyes on Earth," an interactive traveling museum exhibit. (*http://www.omsi.edu/visit/earth/eyesonearth*)

NASA's ESE Education Program systematically extends NASA's results in Earth system science and the development of remote sensing and geospatial technologies to support national priorities for STEM education. The ESE Education Program sponsors all levels of formal and informal educational activities to provide opportunities for learners to investigate Earth system processes using unique NASA resources as they progress through the academic pipeline and continue on their individual paths of lifelong learning.

NASA established the Education Enterprise (EE) in 2003 to unify all education program activities in NASA's Science and Technology Enterprises.[1] The EE has the leading role in the Agency's mission to inspire the next generation of explorers. The Education Enterprise captures and communicates the excitement of NASA activities both to inspire and motivate students to pursue careers in STEM and to effectively translate and deliver NASA content to formal and informal learning communities. The Earth Science Enterprise works in close partnership with the Education Enterprise to ensure alignment of ESE contributions with NASA's strategic goals, objectives, and outcomes for education.[2] This ESE Education Plan[3] has two parent documents, the Earth Science Enterprise Strategy (*http://earth.nasa.gov/visions*) and the Education Enterprise Strategy (*http://education.nasa.gov*).

The ESE contribution to NASA's education mission is to inspire the next generation of Earth explorers. The ESE views the concept of Earth explorers broadly. The elementary school student asking if El Niño events occur in oceans other than the Pacific, the researcher investigating the connections between Arctic ozone depletion and global climate change, the consumer comparing hydrocarbon versus hydrogen-powered cars, the citizen-scientist interested in how changing climate and/or changing land cover/land use affect animal migration patterns, and the business person projecting future needs for harvest, transport, and storage of crops are all Earth explorers. All share a vital interest in Earth system processes and the impact these processes have on sustaining life on Earth for current and future generations.

Figure 1.1



[1]NASA's Science and Technology Enterprises: Aeronautics, Biological and Physical Research, Earth Science, Exploration Systems, Space Flight, and Space Science.

[2]See the National Aeronautics and Space Administration 2003 Strategic Plan.

[3]Available at *http://earth.nasa.gov/education.*

The ESE Education Program stands at the nexus of NASA's Earth Science Enterprise, NASA's Education Enterprise and the broader Earth science education community (figure 1.1). Working in close collaboration with these three communities, the ESE Education Program provides unique inquiry-based Earth system science content to engage students in new technologies and prepare them for their participation in the 21st-century global society.

1.1 NASA Earth Science Enterprise (http://earth.nasa.gov)

The solid scientific and technological foundation laid by NASA over the past 40 years enables the ESE to play a leading role in NASA's mission to understand and protect our home planet. The ESE pursues answers to the fundamental question "How is Earth changing and what are the consequences for life on Earth?" by utilizing NASA's unique orbital and suborbital vantage points to observe, study, and improve the prediction of Earth system change. The ESE works with domestic and international partners to provide accurate, objective scientific data and analysis to advance understanding of Earth system processes and to help policymakers and citizens achieve economic growth and effective, responsible stewardship of Earth's resources.

The ESE has established six scientific focus areas for understanding complex Earth system processes: climate variability and change; atmospheric composition; carbon cycle and ecosystems; water and energy cycle; weather; and Earth surface and interior. The ESE seeks the input of the Earth science community to identify scientific questions to be addressed within each of these areas and to define effective strategies to pursue the answers to those questions. Table 1.1 (next page) identifies scientific questions pursued in each of the six focus areas.

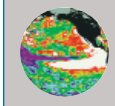
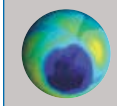
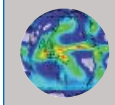
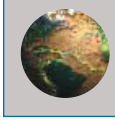
The ESE Mission

The mission of the Earth Science Enterprise is to understand and protect our home planet by using our view from space to study the Earth system and improve prediction of Earth system change.

The major enabling elements of the Earth Science Enterprise—research, education, applications, and technology—and their relationship to Earth system science research questions and socioeconomic benefit are portrayed in figure 1.2 (page 7). The Earth Science Enterprise collects over 2 terabytes of geophysical information daily using approximately 80 sensors operating on a suite of approximately 20 Earth observing research satellites. These polar-orbiting satellites travel at 7 kilometers per second hundreds of kilometers above Earth's surface, collecting key measurements of geophysical parameters. The measurements are used in computer models that simulate past and present conditions and predict future conditions of Earth system processes. Models, data, and information services enhance scientific understanding of Earth. They enable scientific assessments of Earth system processes,

Table 1.1

Earth Science Enterprise Research Focus Areas

Science Focus Area	Prediction Question
 Climate Variability and Change	How can predictions of climate variability and change be improved?
 Atmospheric Composition	How will future changes in atmospheric composition affect ozone, climate, and air quality?
Carbon Cycle and Ecosystems	How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?
 Water and Energy Cycle	How will water and energy cycle dynamics change in the future?
Weather	How can weather forecast duration and reliability be improved?
 Earth Surface and Interior	How can our knowledge of Earth surface change be used to predict and mitigate natural hazards?

support the development of educational resources, and drive decision-support tools. Each of these results enhances socioeconomic benefits.

The compelling context of Earth system science presents opportunities for engaging all students—independent of academic preferences, ethnic background, and socioeconomic status—in the process of scientific inquiry, helping them achieve in STEM while developing a deeper understanding of the complexities of the Earth system. Examples of how ESE resources are used to support STEM curricula include the following:

- Imagery from the Tropical Rainfall Measuring Mission (TRMM) satellite helps convey the water cycle concept by illustrating the three-dimensional distribution of rainfall over land and oceans.
- Earth system science comes to life as students view Terra satellite data showing the transport of African dust across the Atlantic and investigate possible connections to the health of coral reef populations in the Caribbean Sea.
- The global reach of El Niño events is illustrated as students view TOPEX/Poseidon animations of anomalous sea surface heights propagating across the Pacific and along the coasts of North and South America.
- The role of air-sea interactions in El Niño becomes apparent as students analyze the relationships among wind speed, evaporation, sea surface temperature, ocean current direction, clouds, and pre-

cipitation using TRMM and Aqua data in combination with other satellite and modeled data.

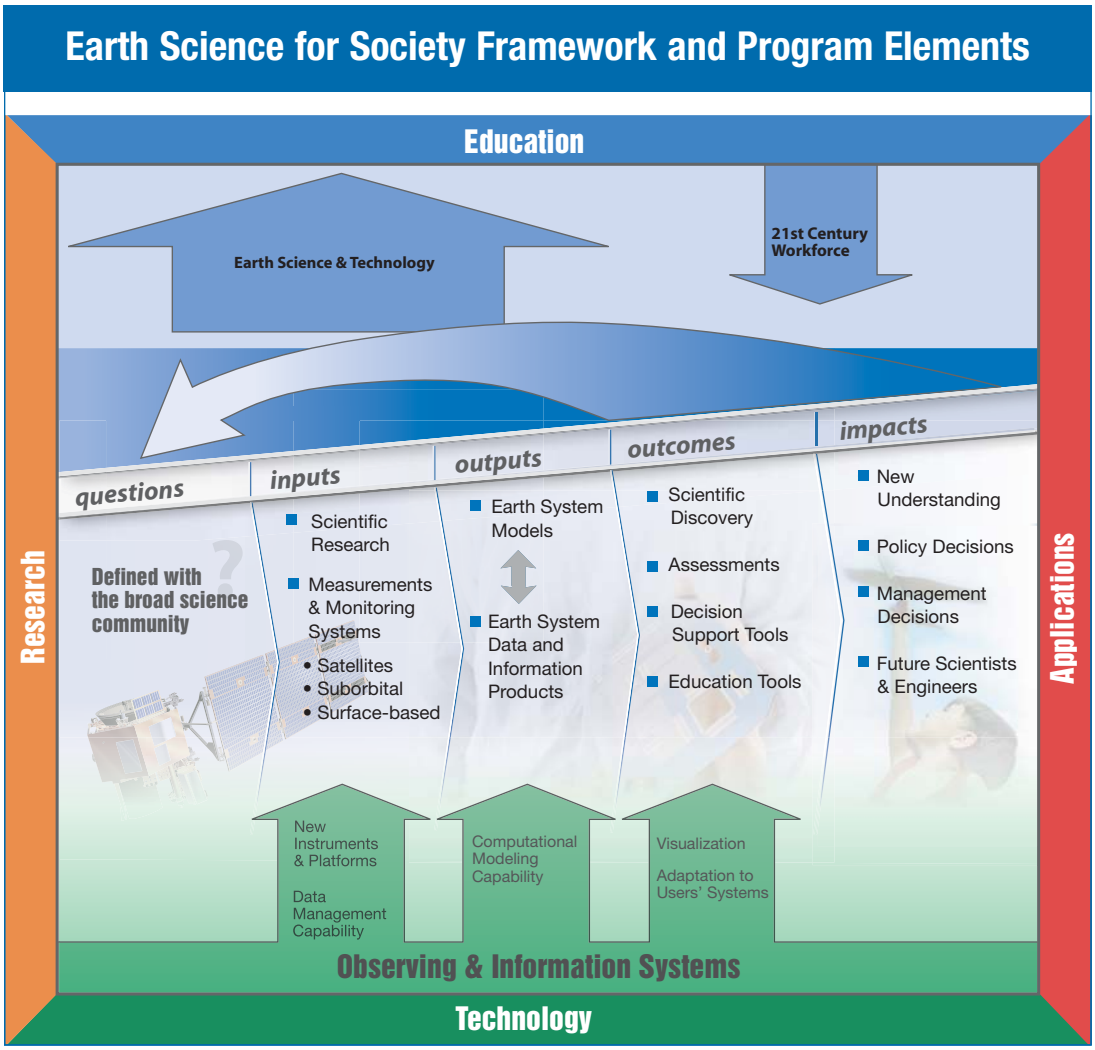
- TOMS data help students visualize the ozone hole as a dynamic, asymmetrical region over the Antarctic associated with stratospheric wind and temperature patterns rather than as a static, symmetrical "hole" through which ozone is lost to space, a common misconception.

- Students' understanding of scientific uncertainty is enhanced as they predict Earth's global average temperature in 2100 by varying projected greenhouse gas emission scenarios while running a simplified interface to a coupled atmosphere-ocean climate model.

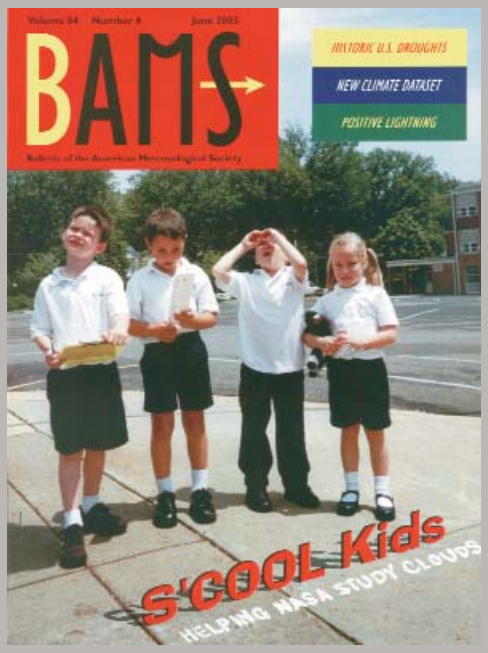
- The concept of anomaly is illustrated as students create their own time series of global average temperature anomalies using data from ground-based measurements over the past century and satellite data over the past decade.

The ESE Education Program is committed to the development of innovative methods for using ESE resources to enhance STEM education and deepen student understanding of Earth system science and related careers. Educational opportu-

Figure 1.2



S'COOL: Students' Cloud Observations On-Line



S'COOL engages K–12 students worldwide in active science as they provide ground truth measurements to assist scientists in the validation of the Clouds and Earth's Radiant Energy System (CERES) satellite-based instrument. Students observe and report on cloud conditions at the time CERES passes overhead on a NASA satellite. Student observations are available in an online database, along with corresponding data from the satellite. Students use these observations in a variety of inquiry-based activities.

http://scool.larc.nasa.gov

nities are embedded within ESE research programs and flight missions to increase the number of students that are inspired, motivated, and intellectually prepared to contribute to the Earth system science workforce and to increase the public's scientific literacy about the Earth system and the environment. The Earth Science Enterprise System Components chart (see *http://www.esa.ssc.nasa.gov/m2m/opening.asp*) summarizes current and planned flight missions, along with the geophysical parameters, Earth system models, and model predictions associated with these missions.

1.2 NASA Education Enterprise (http://education.nasa.gov)

NASA's founding legislation directs the Agency to expand human knowledge of Earth and space phenomena and to preserve the role of the United States as a leader in aeronautics, space science, and technology. High levels of achievement in STEM education are therefore essential to the accomplishment of NASA's mission. The Education Enterprise works to align NASA's education strategy with STEM priorities established by the U.S. Department of Education (ED), the National Science Foundation (NSF), the States, the District of Columbia, the Commonwealth of Puerto Rico, and the U.S. Territories.

NASA's Education Enterprise inspires and motivates students at all levels to pursue STEM and teaching careers. The EE partners with academic institutions, professional education associations, industry, and other U.S. Federal agencies to provide teachers and faculty with the experiences that capitalize on the excitement of NASA's discoveries to spark their students' interest and involvement. The EE provides students with opportunities for involvement in NASA's vast research efforts to promote STEM disciplines and encourage students to pursue higher education at the graduate and doctorate levels. The EE is working to ensure that students who are engaged in NASA learning experiences will be kept informed of new opportunities as they advance through the education pipeline. The EE supports and encourages lifelong learning by engaging the public in shaping and sharing the experience of exploration and discovery.

1.3 Earth Science Education Community

The importance of Earth science to the future of our planet is unprecedented. Challenging global environmental change issues, including climate and ecological change, freshwater availability, and management of Earth's natural resources, face our generation and our children's generations as we enter the 21st century. The continued delivery of up-to-date Earth system science knowledge in our Nation's elementary through postgraduate and informal educational institutions contributes

to the development of a workforce qualified to address global sustainable development issues and to a scientifically literate and informed citizenry. The *National Science Education Standards* present a holistic approach for developing student understanding of Earth and advocate presenting Earth science from an Earth system perspective over the course of K–12 education. Members of the Earth science education community—for example, the National Conference on the Revolution in Earth and Space Science Education—are working toward strengthening its ties to other STEM fields, including physics, chemistry, biology, technology, engineering, and mathematics, by integrating Earth science reform within larger science, mathematics, and technology education reform efforts.

The Earth science research community is directing efforts toward education and increasing diversity, recognizing that a diverse and productive science and technology workforce, along with a better and broader public understanding of Earth science, is essential to global sustainability. Concerted efforts between the Earth science education and research communities are underway to improve Earth science education for all students. Activities include stronger emphasis on understanding Earth as a system, inquiry-based learning, and the use of visualization technologies in Earth science education. In higher education, efforts emphasize the integration of research and education, the development of Earth system science courses and degree programs, the integration of the human dimensions of environmental change into Earth system science education, and the creation of cyberinfrastructure[4] to support education and research. NASA, other Federal agencies, and professional societies are taking leadership roles in increasing participation and retention of women, minorities, and persons with disabilities in the Earth sciences.

The Earth science community has an international dimension involving organizations and programs committed to global sustainable development and Earth observation, including the Committee for Earth Observation Satellites, the World Summit on Sustainable Development, and the World Meteorological Organization. The ESE Education Program supports the principles of these organizations, including their central emphases on international capacity building for utilizing satellite data for socioeconomic benefit and sustainable development, education of the broader public in global sustainability, and workforce development. Workforce development programs engage professional and scientific users in Earth observation technologies and geographic information systems.

1.4 As Only NASA Can

As one of three U.S. Federal agencies with education as a stated mission, NASA has a unique role in advancing the technical education agenda of our Nation. NASA has the inspiring mission of exploration and discovery, world-class laboratories and facilities, a talented workforce, and world-renowned university and industry partners. This wealth of resources and capabilities presents learners and educators with unparalleled learning opportunities and experiences. The phrase "as only NASA can" provides the fundamental guiding principle for all education efforts. NASA ESE educational activities are centered on and draw upon NASA's unique assets:

- **Knowledge** of Earth system processes acquired through science and technology programs provides stimulating and challenging content in support of STEM education.

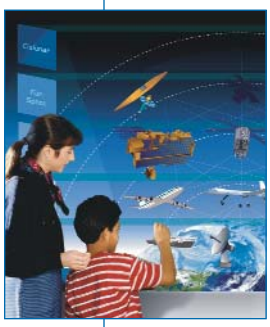
- **Facilities and tools** provide hands-on opportunities and include world-class ground-based, airborne, and inorbit laboratories; advanced technologies; observational data sets; and Earth system and subsystem models.

- **Earth system science professionals**, including NASA employees and NASA-sponsored scientists, as well as technical and engineering experts, are role and career models for students interested in Earth system science and related fields.

[4]NSF coined the term "cyberinfrastructure" to connote an infrastructure for research and education based upon distributed networks of computers, information resources, and online instruments. (See *Cyberinfrastructure for Environmental Research and Education,* National Science Foundation, *http://www.kgs.ukans.edu/Geoinfo2/cyber_report_new.pdf*).

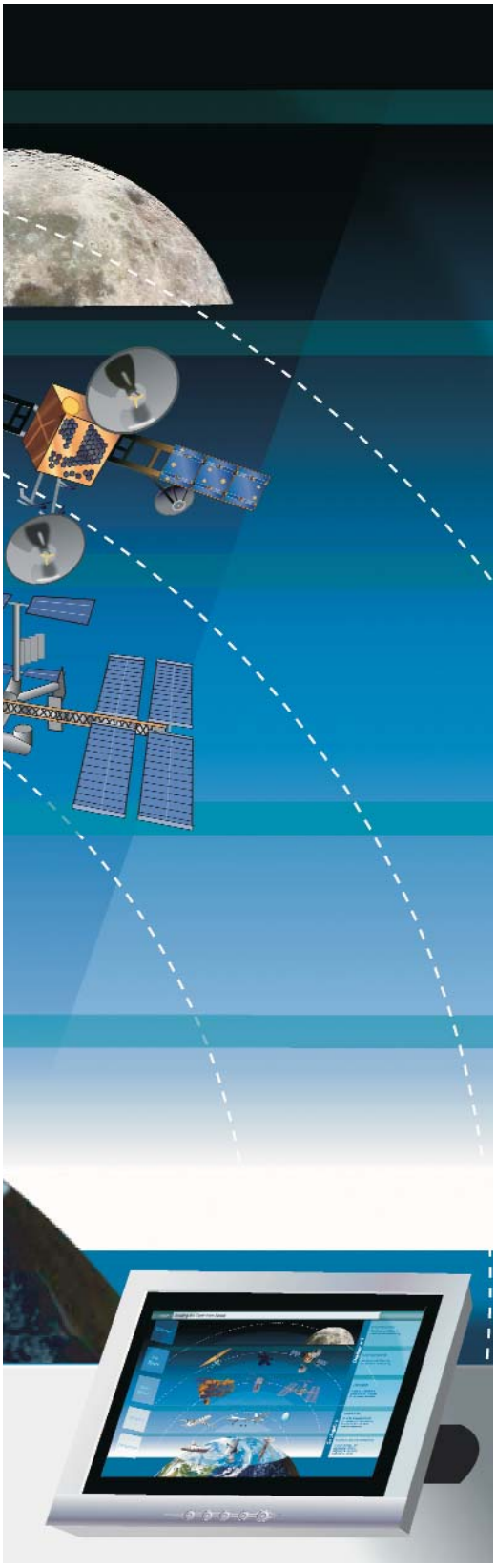
A mind once stretched by a new idea never regains its original dimensions.

—Anonymous



2 Achieving NASA's Education Goals and Objectives

Cislunar
Far-
Space



2 Achieving NASA's Education Goals and Objectives

The ESE contribution to NASA's education mission is *to inspire the next generation of Earth explorers*. ESE Education Program goals and objectives reflect Agency goals and objectives for education as outlined in table 2.1(next page).

ESE Education Program contribution to NASA strategic goal 6.—Inspire and motivate students to pursue STEM careers by providing stimulating and challenging content using the results of Earth system science research and Earth science applications.

The ESE supports NASA's education goal to help prepare a new generation of Americans to pursue challenging careers in STEM and teaching. The ESE Education Program sparks student interest in STEM at an early age by providing modern, stimulating, and challenging Earth system science content in support of STEM curricula. The ESE continues to provide Earth system science learning opportunities at all education levels to support teacher professional development and student achievement in STEM and to nurture the research careers of young scientists and engineers. Over the long term, Enterprise contributions to the formal education pipeline will continue to have a profound impact on ensuring a competitive and diverse science and technology workforce capable of approaching tasks from an interdisciplinary perspective.

The ESE Education Program has established four objectives in support of NASA strategic goal 6. These objectives, described below, focus on the education pipeline from the elementary to post-secondary levels. They foster participation by

NASA's suite of Earth observing platforms and sensors provides the foundation for the development of unique, stimulating, and challenging learning resources.

Table 2.1

NASA Education Enterprise Strategic Goals and Objectives	Earth Science Education Contribution
Goal 6: Inspire and motivate students to pursue STEM careers.	Inspire and motivate students to pursue STEM careers relevant to Earth system science and Earth science applications and technology.
Elementary and Secondary Education	
Objective 6.1: Increase the number of elementary and secondary students and teachers who are involved in NASA-related education opportunities.	Draw upon the compelling nature of Earth system science to promote student achievement and enrollment in STEM courses.
Higher Education	
Objective 6.2: Support higher education research capability and opportunities that attract and prepare increasing numbers of students and faculty for NASA-related careers.	Ensure the continued training of a highly qualified and diverse workforce to support Earth system science research and Earth science applications.
Underrepresented and Underserved Participation	
Objective 6.3: Establish and continually improve support systems that annually increase the number and diversity of STEM students, teachers, faculty, and researchers from underrepresented and underserved communities.	Inspire and support underrepresented and/or underserved communities through each sponsored education program.
E-Education	
Objective 6.4: Increase student, teacher, and public access to NASA education resources via the establishment of e-education as a principal learning support system.	Increase student, teacher, and public access to Earth system science education resources via electronic information infrastructures.
Goal 7: Engage the public in shaping and sharing the experience of exploration and discovery.	Increase public scientific literacy of Earth system science and climate change by engaging the public in shaping and sharing the experience of NASA's exploration and discovery.
Informal Education	
Objective 7.1: Improve public understanding and appreciation of science and technology, including NASA aerospace technology, research, and exploration missions.	Provide engaging Earth system science content and human resource support to informal learning institutions for the benefit of all learners. Cultivate citizens' abilities to get the data, resources, and information they need to satisfy their own curiosity about how the Earth system works and/or to take actions to meet individual or societal needs.

Student researchers discuss remote sensing capabilities with their mentor on a field trip to the Virginia Air & Space Center in Hampton, VA.

underrepresented and underserved populations and emphasize e-education as a principal learning support system.

ESE Education Program contribution to NASA strategic objective 6.1: Elementary and secondary participation.—Draw on the compelling context of Earth system science to support teacher professional development and promote student achievement in STEM.

The familiar and compelling context of Earth system science provides a stimulating context for the study of core scientific disciplines, including physics, chemistry, and biology, along with mathematics, engineering, and technology. The ESE Education Program for elementary and secondary education promotes student achievement in STEM by providing unique learning resources and experiences. These opportunities challenge students as they participate in the practices of scientists, experience the excitement and value of STEM education, and consider careers relevant to Earth system science. To continue challenging these students, the ESE Education Program provides opportunities for educators to use the tools of scientists and to participate in unique Earth system science learning experiences, thereby enhancing their knowledge of the inherent links between Earth system science and STEM education. By further developing their backgrounds, educators continue to challenge and motivate their students to achieve.

ESE Education Program contribution to NASA strategic objective 6.2: Higher education capability.—Ensure the continued training of a highly qualified and diverse workforce to support Earth system science research and Earth science applications.

In coordination with the EE, the ESE is strengthening its involvement with higher education institutions to ensure that NASA can meet future workforce needs in Earth system science research, Earth science applications, and related fields, as well as to improve the scientific education of students bound for other professions. Participation in ESE programs and research—Earth system science courses, graduate assistantships in science

Students visiting Cape Cod National Seashore learn how data from NASA satellites help improve our ability to monitor change in Earth systems.

and engineering, fellowships, research grants, and other ESE-sponsored activities—influences students and young professionals to continue their studies, earn advanced degrees, and develop individualized research programs in fields critical to Earth system science, including the core science disciplines, engineering, and computer science.

Earth Observatory

NASA's Earth Observatory is an interactive Web-based magazine where the science-attentive public can obtain new satellite imagery and scientific information about our home planet. The focus is on Earth's climate and environmental change. The site is also designed to be useful to public media and educators. Any and all materials published on the Earth Observatory are freely available for re-publication, re-use, or re-broadcast (except in rare cases where copyright is indicated).

http://earthobservatory.nasa.gov

ESE Education Program contribution to NASA strategic objective 6.3: Underrepresented and underserved participation.—Inspire and support underrepresented and/or underserved communities through each sponsored education program.

The nurturing of a highly qualified and diverse workforce is critical to expanding our scientific understanding of the Earth system and to applying research results for socioeconomic benefit. As we enter the 21st century, the demographics of the K–12 student body are changing to reflect the changing diversity of our national population. It is this diverse pool of candidates for future STEM professions who are counted upon to bring new perspectives and new talent to Earth system science research, applications, technology, and education. The ESE continues to join efforts with the EE to reach out to underrepresented and underserved communities, including individuals from diverse socioeconomic backgrounds, racial and ethnic minorities, women, and those who are physically challenged, and to encourage their par-

ticipation in STEM activities relevant to Earth system science.

ESE Education Program contribution to NASA strategic objective 6.4: E-education.— Increase student, teacher, and public access to Earth system science education resources via electronic information infrastructures.

ESE resources—including data sets of geophysical parameters, Earth system and subsystem models, and model predictions, along with the educational materials developed from them, are largely digital. They are observational and geospatial in nature and involve the assimilation and analysis of data sets obtained from a suite of different types of instruments and models. The ESE Education Program works to increase student, teacher, and public access to ESE educational resources through information infrastructures, including digital libraries, cyberinfrastructure, and e-education. E-education is an umbrella term for high-quality, content-rich, just-in-time, technology-mediated learning experiences that are customizable and can occur anywhere access is available. The ESE Education Program supports projects that develop innovative methods for delivering ESE resources to formal and informal education communities in support of lifelong learning.

ESE Education Program contribution to NASA strategic goal 7.—Increase public scientific literacy in Earth system science and climate change by engaging the public in shaping and sharing the experience of exploration and discovery.

The public is increasingly called upon to consider Earth system knowledge when participating in policy decisions that impact our quality of life, the national economy, and the overall health of the planet. From land use to water management to establishing policies based on the scientific knowledge of global climate change, informed and reasoned decisionmaking includes consideration of the scientific, technological, and societal perspectives of Earth system science. Education, law, science, policy, media, engineering, entertain-

"Signals of Spring" (*http://www.signalsofspring.net*) students compare sea surface temperature and ocean bathymetry maps to their model of the ocean floor and ocean current maps.

Students integrate math and Earth science concepts as they survey their schoolyard for habitat studies.

ment, and a broad spectrum of other professions have a responsibility and obligation to participate in maintaining and improving the overall health of the planet because it affects the quality of our lives, our children's lives, and those of future generations. The Earth Science Enterprise supports the continued education of the general public by providing opportunities for individuals, regardless of age or career choice, to participate in and develop an appreciation for the multiple dimensions of Earth system science. Two objectives, described here, guide ESE Education Program efforts in informal education.

ESE Education Program contribution to NASA strategic objective 7.1: informal education.—

1) Provide engaging Earth system science content and human resource support to informal learning institutions for the benefit of all learners.

Informal learning institutions are sources of inspiration and learning about Earth for individuals, young and old, with a variety of backgrounds and interests. Museums, aquariums, and science and technology centers have advanced technological capabilities for innovative delivery of ESE results in Earth system science research and Earth science applications. The ESE Education Program for informal education supports these types of

GLOBE

GLOBE unites students, teachers, and scientists worldwide in Earth system science research and education. Hundreds of thousands of students in over 100 countries have worked in partnership with scientists to collect data for research about Earth's environment. GLOBE students take measurements in the fields of atmosphere, hydrology, soils, and land cover, among others, and report their observations through the Internet. Students access these data for classroom studies, research, and worldwide school-to-school collaborations. GLOBE inspires the next generation of Earth explorers by providing opportunities for students to help develop the scientific, technical, and cultural skills needed to tackle important global environmental challenges.

http://www.globe.gov

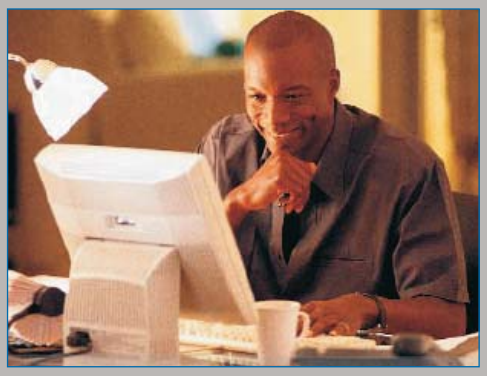
institutions, along with community-based organizations and other public education forums in the development of innovative methods for engaging learners of all ages in sharing the experience of Earth exploration and discovery and developing an appreciation for how Earth exploration and discovery improve the quality of life on Earth.

2) Cultivate citizens' abilities to get the data, resources, and information they need to satisfy their own curiosity about how the Earth system works and/or take actions to meet individual or societal needs.

The availability of the vast amount of ESE resources opens the doors to a world of possibilities for extended and customized investigations of Earth system change. A second component of the ESE Education Program for informal education is the development of tools delivered through digital information infrastructures for customized research experiences. The ESE Education Program works with its partners to provide easy and unlimited access to ESE knowledge, data, and tools so that individuals—including those with a passion for learning and members of the science-attentive public—have the opportunity to further their understanding of Earth system processes through self-designed and self-paced investigations.

The impact of the successful achievement of these goals and objectives is the continued growth of a broad, diverse, and cohesive Earth system science education community. Over the long term, the ESE envisions widespread public literacy about the Earth system and the environment, as well as the maturation of a highly competitive and diverse workforce for Earth system science, engineering, technology, resource management, public policy, and education.

ESSEA

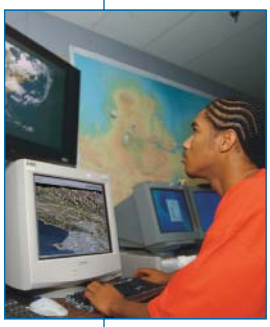


The Earth System Science Education Alliance (ESSEA) is leading the way in teacher professional development. During 2000–03, over 1,000 teachers from 41 States—impacting more than 50,000 students annually—have completed at least one online Earth system science course for elementary, middle, and high school teachers through 20 participating colleges and universities. These diverse colleges and universities include three Historically Black Colleges and Universities and one primarily Hispanic-serving university. Many ESSEA universities also serve rural and disadvantaged communities.

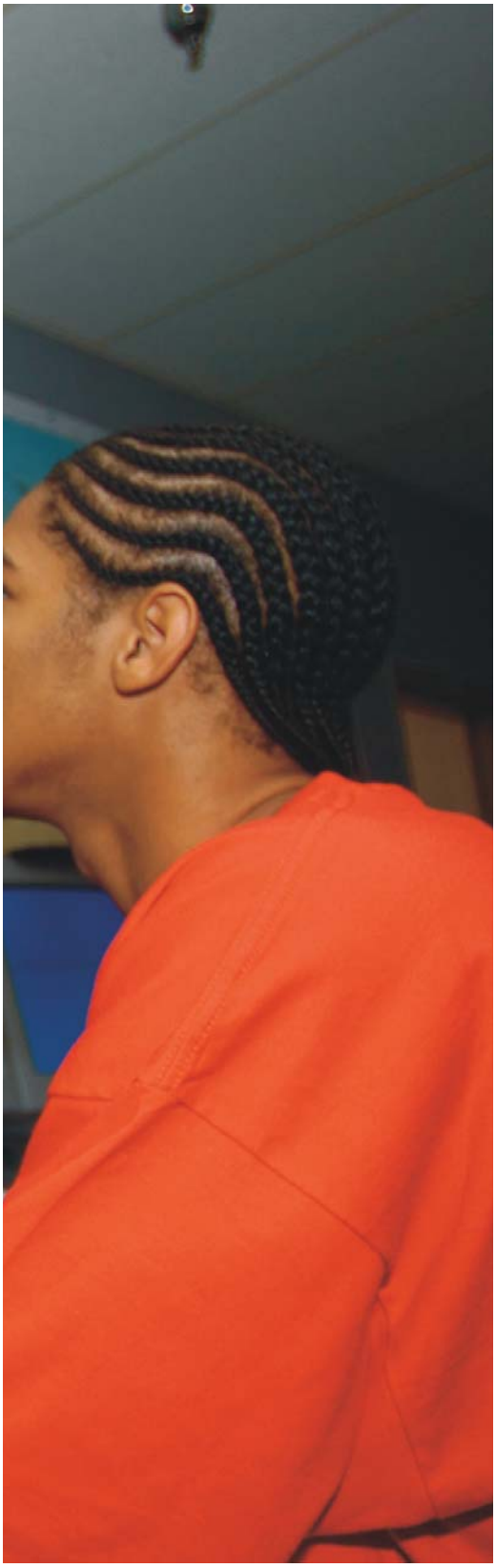
http://www.cet.edu/essea

Science must be taught well, if a student is to understand the coming decades he must live through.

—Isaac Asimov



3 Approach



3 Approach

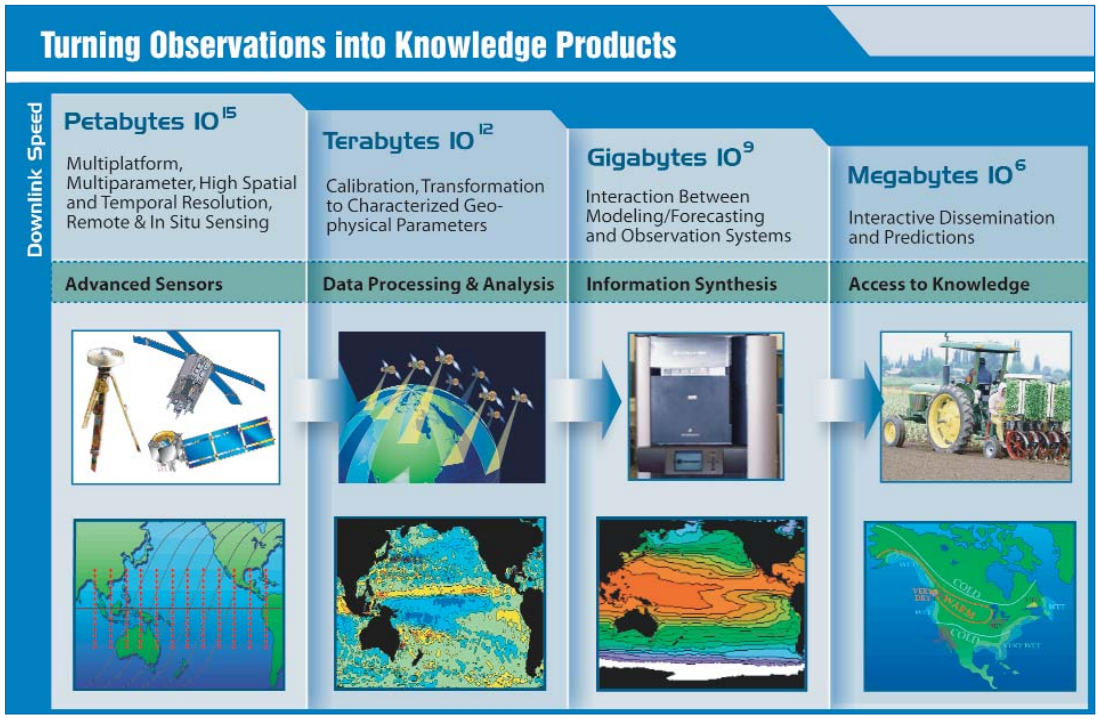
The ESE approach for inspiring the next generation of Earth explorers has two essential and complementary components. The first is the use of digital information infrastructures as a principal mechanism for the systematic delivery of unique ESE education resources. The second is the formation of a network of partners to facilitate the integration of ESE education resources into existing education programs and activities. Together, these two components support the continued expansion of a robust Earth system science education community. To ensure alignment with NASA's strategic approach to education, ESE Education Program activities are developed, implemented, and evaluated according to the Education Program Operating Principles described in section 3.3.

3.1 Information Infrastructures

Digital information infrastructures provide formal and informal education communities with ready access to ESE resources. The ESE is engaged in the ongoing production of very large geospatial data sets spanning the full spectrum of spatial and temporal scales. To be fully utilized by the education community, these data sets and other resources must be easily accessible and provided in an easy-to-use format. Figure 3.1 (next page) summarizes the challenge of turning vast quantities of data and information into knowledge products useful for education and policy decisionmaking. Toward this end, the ESE participates in ongoing national efforts focused on the systematic development and application of hardware and software for research and education. Activities include the following:

A student intern at NASA Goddard Space Flight Center (*http://www.gsfc.nasa.gov*) investigates the topography and land cover of Southern California.

Figure 3.1



- Evolution of ESE's data and information systems, which process, archive, and distribute scientific information products from satellite data and facilitate their use in research, applications, and education. These include the portals, gateways, and partnerships that make access to the ESE data easier for educational uses.

- Participation in Geospatial One Stop (*http://www.geodata.gov*) and the Federal Enterprise Architecture, which coordi-

The NASA ESE Reviewed Collection in DLESE

The Digital Library for Earth System Education (DLESE) is the geoscience "node" of the National Science Digital Library (NSDL), sponsored by the National Science Foundation. Resources in DLESE can include any Web-accessible teaching or learning material. Lesson plans, teacher's guides, books, periodicals, interactive Web sites, virtual field trips, and visualizations are just some of these resources.

Like a traditional library, DLESE is organized into various collections or groups of related resources that reflect a coherent, focused theme. The NASA ESE Reviewed Collection is one of these collections that can be searched within DLESE.

To be included in the NASA collection, education resources must first pass the ESE Education Product Review. This independent peer review includes panels of educators and Earth system scientists who are identified based on the type, content, and audience of the resources being evaluated. The review is based on the resources' relevance to NASA's Earth Science Enterprise, scientific accuracy, educational value, effectiveness of presentation, documentation, ease of use, and power to engage and/or inspire the target audience. After passing the review, resources are added to the ESE collection within DLESE.

To access the NASA ESE Reviewed Collection from DLESE (*http://www.dlese.org*), select "Collections" in the search menu and click on "NASA ESE Reviewed Collection." This collection is also available from the ESE Education home page: *http://earth.nasa.gov/education*.

To learn more about the ESE product review, visit *http://earth.nasa.gov/esereview*.

nate geospatial information principles and practices (interoperability, standards, metadata, etc.).

- Participation in NSF-led planning and development activities for cyberinfrastructure (*http://www.kgs.ukans.edu/Geoinfo2/cyber_report_new.pdf*), a revolutionary approach for strengthening science, engineering, and education at all levels.

- Collaboration with NSF on the Digital Library for Earth System Education (DLESE, *http://www.dlese.org*) to enhance the quality, quantity, and efficiency of teaching and learning about the Earth system. DLESE provides access to high-quality education resources and services through a community-based, distributed digital library.

These efforts work to ensure the utility of the vast quantity of ESE data and resources for an Earth system science education community with a range of technological needs and capabilities and to facilitate the increased use of e-education as a principal learning-support system.

3.2 Network of Partners

Partnerships are vital to the success of the ESE Education Program. The ESE partners with Federal agencies, education administrations, academic institutions, professional societies, international organizations, and industries of common purpose to ensure that customer needs are met and to leverage NASA's impact. Partnerships with these organizations promote alignment with national, State, and local STEM priorities, ensure alignment with national human capital priorities, and facilitate the widespread dissemination and effective use of ESE educational resources. The continued growth of a network of partners produces a multiplier effect by leveraging knowledge, identifying additional target audiences, sharing program resources, and building capacity among underrepresented and underserved groups at both national and international levels. It is imperative that organizations seeking NASA ESE sponsorship for the develop-

REASoN: Research, Education, Applications Solutions Network

NASA's Earth Science REASoN, a distributed network of data and information providers, addresses community needs with respect to timely and ready access to Earth and environmental data. Six education solutions were competitively selected for REASoN in July 2003:

Elementary and Secondary Education

- *Project 3D-VIEW (Virtual Interactive Environmental Worlds)* combines NASA Earth data and three-dimensional learning technologies for student explorers using 3-D viewers and the Internet.

- *Extending NASA Earth Science Data Use to the K–12 and Citizen Scientist Communities* makes Earth science data accessible and interesting to students by connecting it to their local environment or to a single developmentally appropriate concept.

Higher Education

- *Satellite Observations in Science Education* provides students with interactive learning experiences in remote sensing and exploratory data analysis through the development of a data analysis and visualization toolbox.

- *NASA Earth Observing System (EOS) Higher-Education Alliance* mobilizes NASA EOS data and information through Web service and knowledge management technologies for higher education teaching and research.

Informal Education

- *Immersive Earth* constructs volumetric image bases, transforming planetaria into interactive Earth theaters and enabling the public to explore and experience Earth in action.

- *Measuring Vegetation Health* engages students in Earth system science through investigation of a single leaf. Using hand-held instruments to measure the leaf's visible and infrared wavelengths, students observe how plants change over time and learn to distinguish healthy from stressed vegetation.

ment of educational materials and programs demonstrate participation in such national, State, and/or local partnerships.

The process by which information infrastructures and partnership networks facilitate the delivery of the results of ESE activities in education for socioeconomic benefit is depicted in figure 3.2. This two-dimensional approach focuses on scalable, sustainable, and systemic solutions for Earth system science education. Scalable solutions enable benefits to audiences beyond the initial recipient—funded groups contribute to and strengthen the Earth system science education community infrastructure by engaging the broader community. Sustainable solutions extend capacity beyond the initial funding period—mechanisms for achieving sustainable solutions include, but are not limited to, distribution through commercial publishers, distribution through discipline-based professional societies, and integration of programs and resources into teacher education programs. Systemic solutions employ systems infrastructure to lead to lasting change in how STEM education is approached and perceived—systemic solutions approach educational reform from multiple perspectives including curricular development, teacher education, and incentives for the teaching profession.

Students in the Access Earth summer program retrieve a salt marsh sediment core to help scientists reconstruct the historical record of sea-level changes and storm events.

This plan builds on the success that the ESE Education Program has accomplished to date. Exemplary programs, focused on the development of learning tools and materials, professional development, and institutional support, derive their content from the scientific knowledge about the Earth system that is enabled by ESE research and development. ESE observations, models, and technologies are infused whenever appropriate. ESE scientists, engineers, and program administrators are role models for careers in Earth system science, applications, and related fields. Continuous, engaging, and dynamic learning of the Earth system at all levels of formal and informal education occurs as NASA's Earth system science educational resources and programs are delivered through digital information infrastructures and integrated into existing educational programs through a network of partnerships. The resulting impacts include public literacy about the Earth system and the environment and a competitive science and technology workforce for socioeconomic benefits and national security.

3.3 NASA Education Program Operating Principles

NASA's Education Enterprise established Agency-wide Education Program operating principles (see table 3.1) to ensure alignment of all NASA education programs with the 2003 NASA Strategic Plan and to promote excellence.

The content for ESE educational resources and programs is based on the six major focus areas for ESE research: climate variability and change; atmospheric composition; carbon cycle, ecosystems and biogeochemistry; water and energy cycle; weather; and Earth surface and interior. NASA, along with other Federal agencies and affiliated laboratories, institutions of higher education, and non-governmental organizations (NGOs), engages in research supporting these six focus areas.

Figure 3.2

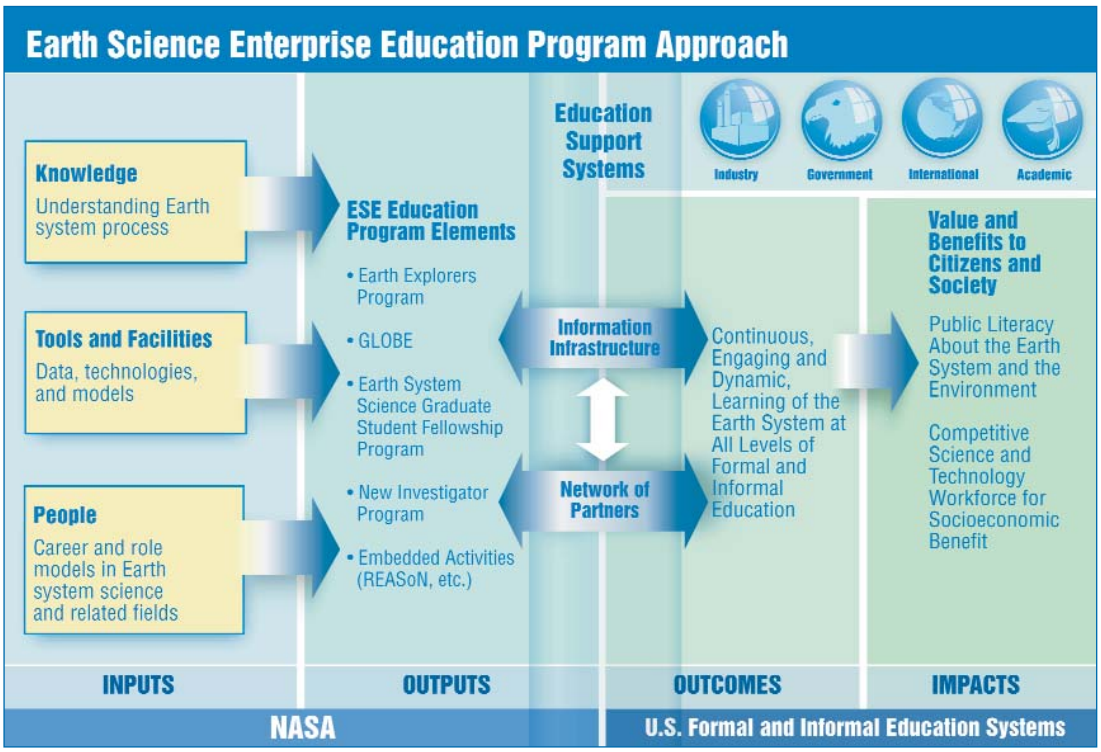
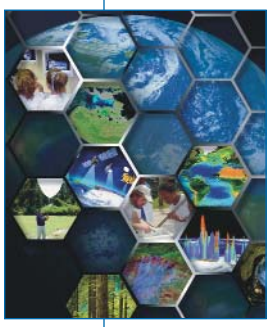


Table 3.1

NASA Education Program Operating Principles	
CustomerFocus	Programs or products have been designed to respond to a need identified by the education community, a customer, or a customer group.
Content	Programs or products make direct use of NASA content, people, or facilities to involve educators, students, and/or the public in NASA science, technology, engineering, and mathematics.
Pipeline	Workforce-related programs or products make a demonstrable contribution to attracting diverse students to NASA careers and lifelong learning in science, technology, engineering, and mathematics.
Diversity	Programs or projects reach identified targeted groups.
Evaluation	Programs or products implement an evaluation plan to document outcomes and demonstrate progress toward achieving goals.
Partnerships/Sustainability	Programs or products achieve high leverage and sustainability through intrinsic design or the involvement of appropriate local, regional, or national partners in their design, development, and dissemination.

The future belongs to those who believe in the beauty of their dreams.

—Eleanor Roosevelt



4 Program Implementation

4 Program Implementation

ESE sponsors educational projects through competitive sourcing with specific focus and through efforts that are embedded in Enterprise programs. Competitive opportunities offered by the ESE Education Program are as follows:

- **Earth Explorers Program**. The Earth Explorers Program offers competitive announcements for K–16 and informal education every 3 to 4 years.

- **GLOBE**. A cooperative agreement has been awarded to the University Corporation for Atmospheric Research for operating the GLOBE program for 5 years, beginning in October 2003.

- **Earth System Science Graduate Student Fellowship Program**. The fellowship announcement is issued annually. Selections address high priorities in the six focus areas of ESE research, as well as in ESE applications, technology, and data management.

- **New Investigator Program (NIP)**. The NIP announcement is issued every 18 months. Selections address high priorities in the six focus areas of ESE research, as well as in ESE applications, technology, and data management.

- **Embedded Activities**. The ESE Education Program is responsible for the review and recommendation of educational activities when they are embedded in

NASA ESE transfers a world of resources from Earth observing satellites for use in a range of formal and informal education settings.

"Signals of Spring" students (*http://www.signalsofspring.net*) explain how Earth's topography, vegetation, and weather affect the movement of migrating bald eagles tracked by polar satellites.

programs such as ESE flight missions and/or research, applications, technology, and data management initiatives (e.g., REASoN).

The ESE Education Program assists the Associate Administrator for Earth Science in ensuring that all ESE educational activities satisfy NASA Education Program operating principles.

The ESE approach to education set forth in chapter 3 represents a substantial commitment to advancing the ESE's contributions to the Nation's STEM education in terms of outcomes and impacts. Realistic and valid benchmarks to gauge program progress are established with ESE partners and members of the community. In 2004, a roadmapping initiative will establish a baseline for ESE Education Program outcomes and impacts and will develop a 10-year roadmap for program activities. The roadmap is anticipated to be published in late 2005.

4.1 Measures

ESE Education Program success is measured on three levels: descriptive statistics, evaluation, and performance measures.

Descriptive Statistics

Descriptive statistics provide general information about the ESE Education Program. Data reported reflect aggregate program activities (e.g., funding levels, total number of participants, and demographics of program participants), as well as activities within specific program components (e.g., duration of program activity, number of participants in program activity, and demographics of participants in each activity). Beginning in 2004, descriptive statistics are to be published in the ESE annual report.

Evaluation

Evaluation improves program activities and documents outcomes. All candidate ESE education activities undergo a rigorous peer-review process

to assess the quality of the proposed project, including the comprehensiveness of its evaluation plan. Individual projects provide internal evaluations to gauge project performance and assess student learning. The ESE participates in EE evaluation activities to ensure compliance of individual projects with NASA Education Program operating principles.

Performance Measures

Performance measures that are routinely collected and reported are related to the following:

- *Accessibility*: Increasing access to ESE education resources is fundamental to program success. The ESE Education Program Office records and categorizes the ways in which formal and informal education communities obtain access to ESE resources.

- *Partnerships*: Partnerships are critical to leveraging resources and building a national program for Earth system science education. The ESE Education Program Office records and categorizes partnerships with other agencies and organizations committed to improving STEM education to provide a qualitative and quantitative assessment of the impact ESE partnerships have on enhancing STEM education.

- *Community recognition*: Criteria used in award mechanisms established in the STEM community provide a measure of the degree to which ESE education investments are recognized and/or an indication of how the ESE Education Program is serving the community. Examples include both achievements by individuals who are active in the ESE Education Program and recognition of the value of program activities. Appendix A highlights community recognition awards. A sample of the recognition awards received during 2002–03 is listed in Appendix B.

4.2 Management

All elements of NASA work together as a single team to achieve Agency goals as described in the 2003 NASA Strategic Plan. Through common procedures, capabilities, and tools, the ESE works with other Agency elements to ensure that the overall functioning of the ESE Education Program is as smooth and efficient as possible, thereby reinforcing our shared commitment to common goals.

Roles and Responsibilities of the ESE Education Program Office

The ESE Education Program Office resides in the Office of Earth Science at NASA Headquarters in Washington, DC. The program office is primarily responsible for program planning, selection, integration, and performance reporting. These functions are accomplished in coordination with NASA's Office of Education.

ESSE 21

Earth System Science Education for the 21st Century (ESSE 21) advances community leadership for systemic change in interdisciplinary Earth system science education at the undergraduate level. The program offers colleges and universities small grants to engage a collaborative community of interdisciplinary educators and scientists as partners to jointly develop and share courses and learning resources focused on the fundamental understanding and application of the Earth system. Since 1991, 57 colleges and universities have been sponsored, developing over 100 Earth system courses and reaching tens of thousands of students with relevant and compelling STEM content to help foster a scientifically literate and informed citizenry.

http://esse21.usra.edu

At least 85 percent of the projects sponsored by the ESE Education Program are competitively selected and/or peer reviewed. The ESE Education Program supports NASA's Office of Earth Science and NASA's Office of Education in developing partnerships between NASA and other agencies and education organizations committed to large-scale systemic reform for Earth science education.

NASA's Office of Education manages the "+For Kids," "+For Students," and "+For Educators" sections of the NASA portal (*http://www.nasa.gov*), NASA's electronic point of entry for the Nation and the world. The ESE Education Program serves as a conduit for all Earth science education content that is made available through these three sections of the NASA portal.

The ESE Education Program Lead is a member of the leadership of the Office of Education and is collocated in the Office of Earth Science, thereby fulfilling Earth Science program responsibilities and serving as the bridge between the Offices of Earth Science and Education.

"Signals of Spring" (*http://www.signalsofspring.net*) oceanography students create a wall mural to set the stage for their remote sensing and marine animal explorations.

Graduate and Postgraduate Research Opportunities

The ESE sponsors graduate student research assistantships, research fellowships, and early-career research activities. Each year, hundreds of graduate students are sponsored through research grants awarded by the ESE. Since 1990, over 600 fellows have received their master's and/or Ph.D. degrees in Earth system science disciplines. The New Investigator Program in Earth Science sponsors approximately 40 early-career scientists and engineers annually in the development of integrated research and education programs. NASA's Earth System Science Fellows and New Investigators have begun to form a network to continue to advance Earth system science and Earth science applications.

Roles and Responsibilities of the NASA Centers

The education offices of the NASA Centers participate in the planning and implementation of Agency-level education programs and lead the development of education programs that are unique to their Centers. They are responsible for communicating Education Enterprise policies and strategies and implementing national programs. Those Centers with substantial competencies in Earth science participate in the planning, development, and implementation of education activities embedded in ESE research programs and flight missions. Centers also engage in educational opportunities made available through competitive sourcing. Earth science education activities are coordinated with the Center education offices to ensure compliance with the high priorities established by the ESE Education Program Office.

Mississippi's Global Education Mobile (*http://www.msgem.net/missions.htm*) is a mobile electronic classroom for enhancing instruction in remote sensing and geographic information systems.

Reporting

The ESE Education Program is an integral component of the Office of Earth Science Focus Area Reviews. Each of the six focus areas—climate variability and change; atmospheric composition; carbon cycling, ecosystems, and biogeochemistry; water and energy cycle; weather; and Earth surface and interior—undergoes an intensive review each year. The Focus Area Reviews are internal to NASA and serve as self-assessments for the individual programs, as well as for the ESE as a whole. The linkages between ESE education and research, applications, technology, and data management may be reviewed as a component of the Focus Area Reviews or can be reviewed as a separate entity.

Beginning in 2004, the ESE will issue an annual report and compilation of all Earth science educational activities in elementary, secondary, higher, and informal education. Enterprise outreach activities will also be published in the report. The annual report will be delivered through a portal hosted and maintained by the Enterprise's Chief Information Officer. The portal complies with the Presidential Management Agenda guidelines on creation and facilitation of responsive, citizen-centric government. The ESE publishes a directory of points of contact for all education and outreach activities conducted in conjunction with ESE missions and programs. A catalog of peer-reviewed Earth Science educational products is available online at *http://earth.nasa.gov/education/catalog.*

Relationship with ESE Outreach

There is a natural and inherent link between education and outreach for the ESE. Although both of these elements have unique implementation plans, education and outreach are mutually supportive toward the achievement of Agency goals, objectives, and outcomes. Education is concerned with what is being delivered, how it is being delivered, and the specific learning that takes place. Outreach is concerned with informing targeted audiences of what the Agency is accomplishing and learning, why it is doing so, and how Agency activities are relevant to those audiences. ESE outreach audiences are grouped into three broad categories: Public Communication, Stakeholder Communication, and Peer Communication. NASA strategic goal 7, "Engage the public in shaping and sharing the experience of exploration and discovery," has education and outreach components. Table 4.1(next page) illustrates Earth Science Education and Earth Science Outreach contributions to the Agency's strategic objectives for goal 7.

Table 4.1

NASA Strategic Goals and Objectives	Earth Science Education	Earth Science Outreach
Goal 7: Engage the public in shaping and sharing the experience of exploration and discovery.		
Objective 7.1: Improve the capacity of science centers, museums, and other institutions, through the development of partnerships, to translate and deliver engaging NASA content.	✔	
Objective 7.2: Improve science literacy by engaging the public in NASA missions and discoveries, and their benefits, through such avenues as public programming, community outreach, mass media, and the Internet.	✔	✔
Objective 7.3: Increase public awareness and understanding of how research and innovations in aerospace technology affect and improve the quality of life.		✔

MS PHD's

Minorities Striving and Pursuing Higher Degrees of Success (MS PHD's) in Earth System Science increases participation of underrepresented minorities in Earth system science. Student participants become engaged with the Earth system science community through attendance at scientific conferences, mentoring relationships, and virtual community activities. Working with the National Science Foundation, the American Geoophysical Union, the American Meteorological Society, the Ecological Society of America, and other partners, the ESE shares the commitment to diversity and provision of academic role models who are the inspiration to the next generation today. In 2003, 24 highly motivated minority students participated in the MS PHD's pilot program.

http://msphds.usf.edu

Appendices

Appendix A

Community Recognition Awards

The American Geophysical Union Excellence in Geophysical Education Award (*http://www.agu.org/sci_soc/sci_awards.html*) is awarded yearly to recognize and honor an individual, team, or group of individuals who have exhibited a sustained commitment to excellence in geophysical education, at any level, kindergarten through postgraduate. Such a commitment may be evidenced by, but not restricted to, such accomplishments as these:

- a specific program or project that has had a major ongoing influence on geophysical education
- outstanding teaching or training of individuals over a number of years
- long-lasting professional service related to geophysical education that has had a long-lasting positive impact

The National Science Board Public Service Award (*http://www.nsf.gov/nsb/awards/public/public.htm*) recognizes people and organizations that have increased the public understanding of science or engineering. Candidates for the individual and group awards should have met one or more of the following criteria:

- increased the public's understanding of the processes of science and engineering through scientific discovery, innovation, and its communication to the public
- encouraged others to help raise public understanding of science and technology
- promoted the engagement of scientists and engineers in public outreach and scientific literacy
- contributed to the development of broad science and engineering policy and its support
- influenced and encouraged the next generation of scientists and engineers
- achieved broad recognition outside of the nominee's area of specialization
- fostered awareness of science and technology among broad segments of the population

The National Science Teachers Association Distinguished Informal Science Education Award (*http://www.nsta.org/awardscomp*) honors one individual who has made extraordinary contributions to the advancement of science education in an informal or nontraditional school setting, such as a science and technology center, museum, or community science center. Types of outstanding service considered by the review committee are as follows:

- unique or extraordinary accomplishments in informal science education
- active leadership in informal science education
- noteworthy scholarly contributions to informal science education
- focusing of public attention on the need for improvement of informal science education
- direct and substantial contributions to the improvement of informal science education
- overall excellence of contributions

American Library Association Great Web Sites for Kids (*http://www.ala.org/Content/NavigationMenu/ALSC/Great_Web_Sites_for_Kids/Great_Web_Sites_for_Kids.htm*). The American Library Association evaluates Web sites to identify excellent sites for persons up to the age of 14 using criteria in the following categories:

- Authorship/sponsorship: Who put up the site?
- Purpose: Every site has a reason for being there.
- Design and stability: A great site has personality and strength of character.
- Content: A great site shares meaningful and useful content that educates, informs, or entertains.

SciLinks (*http://www.scilinks.org/content_provider/content_add.asp*) is a partnership between the National Science Teachers Association and U.S. textbook publishers. SciLinks are Web addresses that are published in textbooks and provide supplementary educational materials. The rubrics for selecting candidate SciLinks include, among others, criteria for the following:

- accuracy
- interactivity
- multimedia
- scientific inquiry

Tech Museum Awards (*http://techawards.thetech.org*) honor innovators and visionaries from around the world who are applying technology to improve the human condition profoundly in the categories of education, equality, environment, health, and economic development. Individuals, for-profit companies, and not-for-profit organizations are eligible. The Tech Awards showcase compelling stories and reward brilliant accomplishments. The purpose of the Tech Awards program is to inspire future scientists, technologists, and dreamers to harness the incredible power and promise of technology to solve the challenges that confront us at the dawn of the 21st century. Nominations and applications are evaluated according to the following criteria:

- The technology application significantly improves the human condition in one of the five award areas: economic development, education, environment, equality, or health.
- A serious problem or challenge with global significance is addressed by this use of technology.
- The technology application makes a noteworthy contribution that surpasses previous or current solutions.
- The technology application has the potential to serve as an inspiration or model for further innovation.

Appendix B

Recognition Awards Received in Earth Science Education, 2002–03

Raj Chaudhury of Norfolk State University, a participant in NASA's ESE Education Program and NASA's Minority University Education and Research Program, received the Carnegie Scholar from the Carnegie Academy for the Scholarship of Teaching and Learning (2003–04) for his proposal "Learning Science Through Visualization."

Arlene Levine of the Atmospheric Science Division at NASA Langley Research Center received the Dorothy Barber Lifetime Achievement Award in March 2003 for her efforts in providing workshops for Girl Scouts and their leaders on Earth system science and global change at Langley facilities. This award is the highest adult honor granted by the Girl Scout Council of the Colonial Coast.

Earth & Sky (*http://www.earthsky.com*) was awarded the National Science Board's Public Service Award for people and organizations who have increased the public understanding of science. *Earth & Sky* is only the third media organization and the first radio program ever to receive this award.

Exploring the Environment (*http://www.cotf.edu/ete*), created at NASA's Classroom of the Future, was honored in August 2002 by Science NetLinks, a part of the MarcoPolo Education Foundation, for providing a wealth of resources for K–12 science educators. MarcoPolo partners with the American Association for the Advancement of Science, the National Endowment for the Humanities, the Council of the Great City Schools, the National Council on Economic Education, the National Geographic Society, the National Council of Teachers of Mathematics, and the John F. Kennedy Center for the Performing Arts.

NASA Earth Observatory (*http://earthobservatory.nasa.gov*) received the 2003 Webby Award for Education and People's Voice Award for Education, along with the 2002 *Scientific American* SCITECH Web Award.

NASA SCIence Files (*http://scifiles.larc.nasa.gov/treehouse.html*) has been awarded the 2002–03 Mid Atlantic Emmy for Best Production Design in a Series.

The Space Place (*http://spaceplace.jpl.nasa.gov*), part of NASA's New Millennium Program, has been recognized by the American Library Association's Great Web Sites for Kids, SciLinks, and the Eisenhower National Clearinghouse Digital Dozen Award.

Appendix C

Acronyms

CEOS	Committee for Earth Observation Satellites
DLESE	Digital Library for Earth System Education
DMSP	Defense Meteorological Satellite Program
DUE	Division of Undergraduate Education
ED	Department of Education
EE	Education Enterprise
EOS	Earth Observing System
ESE	Earth Science Enterprise
ESSFP	Earth System Science Fellowship Program
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Program
NASA	National Aeronautics and Space Administration
NGO	non-governmental organization
NIP	New Investigator Program
NSF	National Science Foundation
NSTA	National Science Teachers Association
OSTP	Office of Science and Technology Policy
REASoN	Research, Education, Applications Solutions Network
SEEDS	Strategic Evolution of ESE Data Systems
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave Imager
STEM	science, technology, engineering, and mathematics
TOMS	Total Ozone Mapping Spectrometer
TOPEX/ Poseidon	TOPographic EXperiment/Poseidon
TRMM	Tropical Rainfall Measuring Mission
WCRP	World Climate Research Program
WMO	World Meteorological Organization
WSSD	World Summit on Sustainable Development

Appendix D

Glossary

diversity: A management philosophy and core value for maximizing potential, at both the individual and organizational levels, by fostering awareness, understanding, and respect for individual differences and by capitalizing on the knowledge, expertise, and unique background and life experiences offered by each individual, including, but not limited to, ethnic, gender, racial, religious, and cultural diversity.

e-education: An umbrella term for high-quality, content-rich, just-in-time, technology-mediated learning experiences that are customizable and can occur anywhere access is available.

Earth system science: A view of Earth as a synergistic physical system of interrelated phenomena, governed by complex processes involving the geosphere, atmosphere, hydrosphere, and biosphere. The Earth system science approach emphasizes the interactions of chemical, physical, biological, and dynamic processes that extend over spatial scales from microns to the size of planetary orbits and over time scales from milliseconds to billions of years.

evaluation: The systematic investigation of the merit or worth of an object.

formal education: The hierarchically structured, chronologically graded "education system," running from primary school through the university level and including, in addition to general academic studies, a variety of specialized programs and institutions for full-time technical and professional training.

informal education: The process of acquiring new knowledge and skills without the benefit of structured teaching; an educational setting that encourages and facilitates self-directed learning.

minority: Individuals whose race/ethnicity is classified as American Indian or Alaskan Native, Asian, Black or African American, Hispanic or Latino, or Native Hawaiian or Pacific Islander.

President's Management Agenda: A strategy for improving the management and performance of the Government, making it more citizen-centered and results-oriented through five Governmentwide initiatives: Strategic Management of Human Capital, Competitive Sourcing, Improved Financial Performance, Expanded Electronic Government, and Budget and Performance Integration. (*http://www.whitehouse.gov/omb/budget/fy2002/mgmt.pdf*)

scientific literacy: The knowledge and understanding of scientific concepts and processes required for personal decisionmaking, participation in civic and cultural affairs, and economic productivity. People who are scientifically literate can ask questions or determine answers to questions about everyday experiences. They are able to describe, explain, and predict natural phenomena. Scientific literacy has different degrees and forms; it expands and deepens over a lifetime, not just during the years in school. The National Science Education Standards outline a broad base of knowledge and skills for a lifetime of continued development in scientific literacy for every citizen; they also provide a foundation for those aspiring to scientific careers. (*http://bob.nap.edu/readingroom/books/nses/html/*)

STEM pipeline: Education programs that provide talented and diverse students and educational pathways into targeted opportunities and experiences leading to careers in science, technology, engineering, mathematics, or teaching.

systemic reform (for STEM): Fundamental, comprehensive, and coordinated changes in science, mathematics, and technology education through attendant changes in policy, financing, governance, management, content, and conduct. Systemic reform occurs when all essential features of schools and school systems are engaged and operating together, when policy is aligned with a clear set of goals and standards, when the forthcoming improvements and innovations become intrinsic parts of the ongoing education system for all children, and when the changes become part of the school system's operating budget.

underrepresented minority: Racial and ethnic populations that are underrepresented in the STEM professions relative to the size of the population at large. This term may encompass Blacks or African Americans, American Indians or Alaskan Natives, Native Hawaiians or other Pacific Islanders, and Hispanics or Latinos. The broader term "underrepresented" as opposed to "underrepresented minority" in the STEM arena not only refers to racial and ethnic populations, but also includes women and persons with disabilities because of the relative size of these groups to the total population at large.

Appendix E

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