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## 1. INTRODUCTION

The NASA/USRA Cooperative University-based Program in Earth System Science Education (ESSE), initiated a decade ago through NASA support, has led in the creation of a nationwide collaborative effort to bring Earth system science into the undergraduate classroom. Forty-five ESSE institutions now offer over 120 Earth system courses each year, reaching thousands of students annually with interdisciplinary content. Systemic change in the offering of courses and content and the organizational infrastructure of colleges and universities emphasizing cross disciplinary curricula, programs, degrees and departments are at the heart of this effort. Building on this successful experience and collaborative infrastructure within and among colleges, universities and NASA partners, a new program called ESSE 21 is being initiated with funding from NASA. Through expanded partnerships the Program seeks to further develop broadly based educational resources, including shared courses, electronic learning materials and degree programs that will extend Earth system science concepts in the undergraduate classroom and laboratory. These resources emphasizing fundamentals of Earth system science serve to advance the nation's broader agenda for improving science, technology, engineering and mathematics competency and are critical to extending and solidifying a knowledge based foundation for decision making in the future by both scientists and citizens.

ESSE 21 aims to annually solicit proposals from undergraduate institutions to create or adopt undergraduate and graduate level Earth system science content in courses, curricula and degree programs. The goal for all is to effect systemic change through developing Earth system science learning materials, courses, curricula, degree tracks or programs, and departments that are self-sustaining in the coming decades. Interdisciplinary college and university teams are competitively selected through a peer-reviewed Call for Participation. ESSE 21 offers an infrastructure to promote a robustly interactive community of educators and researchers that develops interdisciplinary Earth system science content utilizing NASA resources involving-global change data, models, visualizations and electronic media and networks. The ultimate aim of ESSE 21 is to expand and accelerate the nation's realization of sound, scientific interdisciplinary educational resources for informed learning and decision-making from the perspective of sustainability of the Earth as a system.

## 2. BACKGROUND

Since 1991, the NASA/USRA Cooperative University-based Earth System Science Education Program (ESSE) has contributed to the Earth system science approach by coordinating small, competitively selected grants to college and university faculty to develop Earth system science courses at the undergraduate level. NASA's highly leveraged investment for the classroom through ESSE has motivated and assisted forty-five colleges and universities to actively develop survey and senior level courses in Earth system science. In some cases, entire departments and schools have realigned courses to create degree programs in Earth system science. Faculty from these U.S. universities collaborated with one another and with NASA scientists to develop undergraduate curricula and offer courses in Earth system science. Each institution offered at least one survey course and one senior-level course in which faculty presented Earth systems issues as socially relevant, challenging, and important scientific problems. Universities and colleges participated in an exchange in which visiting faculty and scientists from other ESSE institutions and from NASA brought to the classroom expertise and perspectives different from those at the host campus. The Program held hands-on workshops and tutorials each year for faculty and teaching assistants to familiarize the group with new software resources and methods for the classroom.

All participants in ESSE have benefited from leading the interdisciplinary Earth system movement locally and nationwide. Targeted toward a diverse student population through introductory and advanced courses, ESSE has been a key instrument for creating the interdisciplinary knowledge base and professional identities of the next generation of scientists and educators engaged in Earth system education and research.

The ESSE Web site (<http://www.usra.edu/esse>) established in 1994 was among the first to foster the interdisciplinary geophysical perspectives needed to understand the Earth system by sharing relevant information among the ESSE participants and the Internet community at large. ESSE continues to foster the establishment of a national academic forum for Earth system and global change science, serving undergraduate education as a whole and expanding the interdisciplinary interests of future scientists who elect to pursue Earth system science research professionally.

The ESSE mission continues implicitly through its participants, faculty and students who have embraced

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Earth system science as a process. ESSE courses continue to be taught and refined, a visible legacy of the Program. Over 120 Earth system courses are being taught at ESSE institutions. ESSE II institutions funded between 1995 and 1999 continue to reach almost 3,600 students annually with focused Earth system courses. ESSE participants are full partners and leaders in the wave of systemic reform bringing Earth system science into the mainstream of the undergraduate curriculum. Many were early adopters of technology and are now leaders in electronic content delivery. ESSE participants who have formed productive partnerships and grown in new directions are living proof of the intrinsic merit of leveraging resources through university partners. ESSE participants are contributing to the development and implementation of new concepts and programs, among which are the Journal of Earth System Science Education (JESSE), the Earth Science Picture of the Day (EPOD) and the Digital Library for Earth System Education (DLESE). ESSE partners continue to assist with the organization of Earth system sessions at professional society meetings.

### 3. ESSE 21 - ITS EXPANDED MISSION

A key mission of ESSE 21 is to engage scientists and educators in the collaborative interdisciplinary development and offering of learning resources and courses focused on the fundamental understanding and application of Earth system and global change science in the undergraduate classroom and laboratory. Earth system science seeks to understand the Earth as an integrated system of processes involving the atmosphere, oceans, land and life. The need for an integrated concept has gained widespread acceptance over the past decade among the research community and in the undergraduate classroom, and serves as a vital framework from which to pose disciplinary and interdisciplinary questions about the Earth.

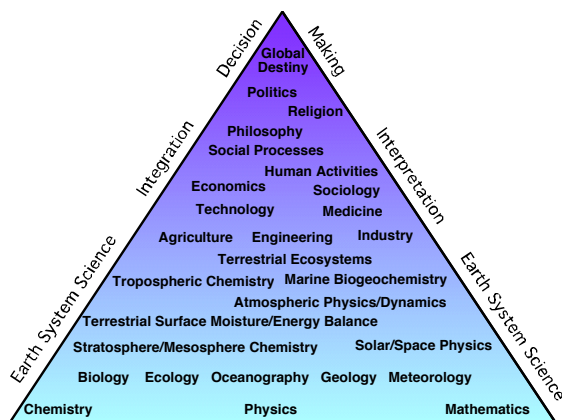


Figure 1 Earth system science connects and integrates disciplinary expertise

As part of an expanded mission and portrayed in Figure 1, ESSE 21 aims to motivate and bring about systemic change within colleges and universities by ensuring the adoption of curricula and degree programs in Earth system and global change science within the formal educational structure of colleges and universities. Through providing an infrastructure to support collaboration among faculty and scientists within and among educational institutions and with NASA programs and scientists, ESSE 21 aims to strengthen the foundations and expand the horizons of interdisciplinary Earth system and global change science education as part of the overall formal and informal education structure of this Nation.

Technology and data in combination with the need to understand Earth system processes and phenomena offer opportunities for new and productive partnerships between researchers and educators to advance the fundamental science of the Earth system and in turn through discovery excite students at all levels in the classroom. ESSE 21 aims to seize this opportunity to transcend classroom education by addressing fundamental needs for research partnerships and the communication of results that emerge from the current and future observational capabilities of NASA's Earth Observing System (EOS). By building upon the community experience and expertise of ESSE, ESSE 21 engages colleges and universities to underwrite the growth and development of fundamental Earth system science concepts in the undergraduate and graduate classroom focusing on NASA's unique contributions and priorities. Through focusing on interdisciplinary Earth system science education, ESSE 21 extends and emphasizes the application of Earth system science research to address real world problems; the development of technology for science and applications; and professional development of Earth system science skills for life-long learning.

ESSE 21 supports interdisciplinary teams of college and university faculty and graduate assistants to develop new programs, courses and learning materials in active partnership with NASA and other university researchers in effecting systemic change within undergraduate institutions. NASA's ongoing research and development investment at NASA centers and universities is leveraged by creating partnership opportunities between ESSE 21 participants and other NASA projects to extend fundamental research and science experience to the undergraduate education environment. A special emphasis is being placed on reaching minority-serving institutions. Formal and informal educational resources developed by ESSE 21 participants will emphasize an interdisciplinary approach to the science, application and technology of the Earth system. The ongoing goal for all is to effect systemic change through developing Earth system science learning materials, courses, curricula, degree tracks or programs, and departments for both formal and informal education that are self-sustaining in the coming decades.

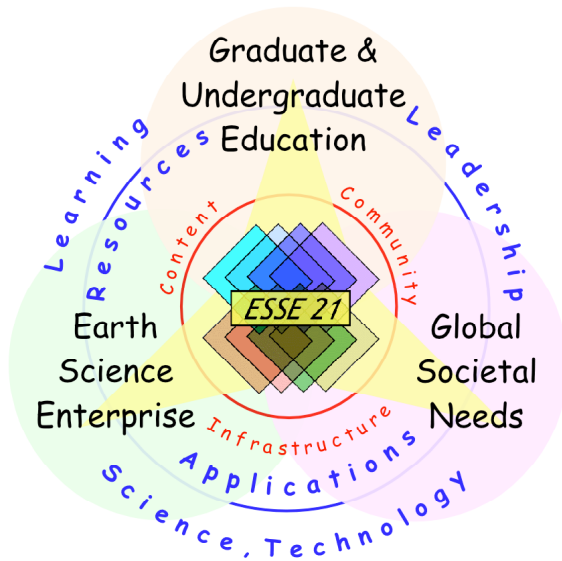


Figure 2 – ESSE 21 Stakeholders and Goals

ESSE 21 is crafted to respond to the broadly overlapping needs of three stakeholders: NASA's Earth Science Enterprise, the undergraduate/graduate education community, and global society in general (Figure 2). Understanding the Earth as an interdisciplinary system is a key objective of each of these interest groups. ESSE 21 recognizes and responds to the research and education goals of NASA in the context of the Earth Science Enterprise, as well as college and university needs for current relevant content in the classroom and society's broader needs for scientific literacy in general.

### 3.1 NASA's Earth Science Enterprise

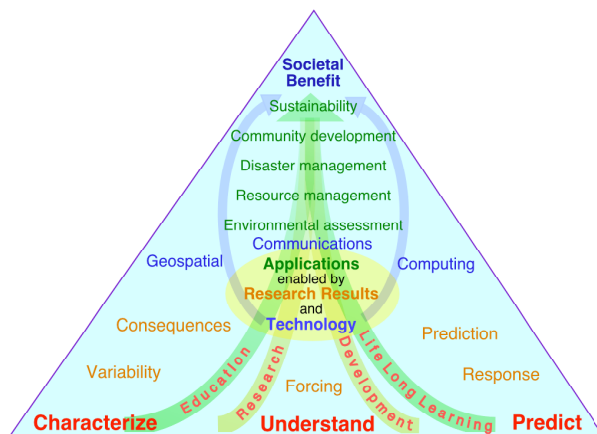


Figure 3 – NASA's framework for Earth system science – science, applications and technology

The Earth Science Enterprise mission is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.

The Enterprise aims to benefit society through the application of Earth system research enabled by technology. ESSE 21 views education and life-long learning as vital, driving forces contributing to the steady progress of the Enterprise (Figure 3).

The underlying need to characterize, understand and predict the Earth system motivates and informs the ESSE 21 approach to reaching college and university educators.

### 3.2 Colleges and universities

Colleges and universities play a key role in developing partnerships, and serve as a common meeting ground between academia (researchers, educators and students), government, industry and the community at large. The primary concern of colleges and universities is education — the dissemination of knowledge and the development of competency to use and expand that knowledge. Science, technology, engineering and mathematics (STEM) describe a body of knowledge that is vital to our civilized endeavors. Joined together within the framework of ESSE 21 the four areas offer high potential for impacting and influencing society in achieving sustainability.

The study of the Earth system embraces all of STEM more so than any other applied science, and ESSE 21 provides unusual opportunities to create and refine courses and learning materials tailored to local and regional interests and needs of learners, yet extensible and relevant to national and international audiences.

### 3.3 Global Societal Needs

Society seeks and realizes returns on its investment in basic scientific research to advance the quality of living and optimize humankind's balance with the natural world. As the new century unfolds, continued environmental challenges to sustainability, as well as promises of remediation enabled by technology, raise an urgent need for new and innovative partnerships across societal endeavors. No single department, school, university, discipline or activity of society itself has the resources to address the breadth and depth required for the challenging frontier of Earth system science. Partnerships must be formed which draw upon sound scientific principles from a range of disciplines. Collaborating partners must identify, understand and respond to local and global issues such as sustainable agriculture, urban/rural development, safe drinking water, habitat diversity, ozone loss, climate change, etc. The interdisciplinary approach of Earth system science invigorates partnerships where science and society work together on issues that are scientifically meaningful and relevant to humanity. ESSE 21 provides a natural starting point for such partnerships by focusing on the scientific basis of Earth system concepts.

#### 4. ESSE 21 GOALS

To fulfill the mission stated, ESSE 21 provides an infrastructure to create and support the needs of educators and scientists to establish courses, and minor and major degree programs in interdisciplinary Earth system and global change science within college and universities. The Program has three main goals:

- Support and expand an active and diverse **community** of university and college educators and scientists as partners dedicated to developing and offering courses and relevant curricula in Earth system science by joining of faculty from different disciplines. When opportunity presents itself, departments and degree programs in interdisciplinary Earth system science will emerge.
- Foster and enrich the development of interdisciplinary **learning resources** with substantive Earth system science content at the undergraduate and graduate level, incorporating research, data, models, visualizations, applications and technology for classroom and laboratory use.
- Provide an enabling **infrastructure** that fosters and supports broad collaboration among an interdisciplinary community in the development of content for the classroom, builds institutional capacity for Earth system and global change science education and serves as a focal point for sharing interdisciplinary ideas, resources, and talents.

ESSE 21 is implemented as a cooperative program with direct involvement of the participating colleges and universities, NASA's Earth Science Enterprise, and USRA.

The ESSE experience of the past decade has demonstrated the need and immeasurable value of coordinated like-minded efforts organized by dedicated facilitators to establish solid inter-institutional and interdisciplinary relationships. ESSE 21 is more than a collection of projects with a common theme. As mediator, catalyst and nexus for community discussion, USRA facilitates communication and collaboration and serves as a repository for interdisciplinary resources. ESSE 21 facilitates efficient information gathering about other relevant projects, and passes it on to participants for the purpose of forming partnerships and extending the Earth system science education collaborative. Through its overall efforts, ESSE 21 will contribute to overall science literacy and advance national goals for science, technology, engineering and mathematics (STEM) education. The study of the Earth offers a compelling and relevant way to introduce and reinforce key STEM concepts in bringing together the strength of the relevant disciplines to address the science of the Earth system.

#### 5. CALL FOR PARTICIPATION

ESSE 21 as an educational program emphasizes the importance of teaching and learning in the classroom and laboratory. Success in the classroom requires stimulating intellectual engagement of the teacher and student in which the minds of both teacher and student are solely focused on subject matter of common interest and during which there is continued probing of content through presentation and two way communication. Within a college or university, programs, departments and/or schools or like activities are in the best position to survey their current offerings and in turn define their own needs for Earth system science resources, curricula and degree programs.

ESSE 21 aims to support creative development of Earth system science content for the classroom and laboratory by issuing annually a Call for Participation (CFP). The CFP solicits the participation of colleges and universities dedicated to teaching about the Earth as a system at the undergraduate and/or graduate level. Through breadth in scope, the CFP accommodates proposals to develop new resources, refine existing resources, create new Earth system courses, establish degree programs, minors or certificates in Earth system science, etc. The first CFP for ESSE 21 was released on September 15, 2002.

ESSE 21 encourages participation from a wide range of undergraduate institutions – two-year city, community, technical and tribal colleges, 4-year liberal arts colleges and research universities. ESSE 21 also encourages participation from institutions in all stages of integrating Earth system and global change science content into the classroom – from those new to the concept to those with mature interdisciplinary Earth system programs.

A staged structure for organizing proposals by level of expertise has been defined to accommodate the anticipated wide range of Earth system experience among proposers. This staged approach fosters equitable opportunities for large and small institutions with programs ranging from newly developing to mature. Participants must commit to sharing electronically the learning materials they develop under the program, and must submit learning resources resulting from their effort to the NASA Product Review. Proposers are required to submit as a team representing two or more disciplines or departments within their institution(s).

In addition to soliciting proposals seeking funding, the CFP will also solicit shorter letter proposals from institutions seeking to participate in ESSE 21 as Associates without funding. Such participation (e.g., from non-U.S. institutions, NASA centers, other government organizations, etc.) will help to broaden the community of Earth system educators and extend the global and interdisciplinary nature of the Program.

## 6. PROGRAM IMPLEMENTATION

The annual ESSE 21 team meeting is an important venue for Program participants to come together and share ideas regarding Earth system science in the classroom learning from each other as well as from NASA scientists and educators and other invited speakers. The three-day meeting offers formal and informal opportunities to make presentations, demonstrate capabilities and techniques, report on progress and offer hands-on tutorials to acquaint attendees with the most recent innovations in Earth science learning.

To promote the exchange of Earth system science education concepts among partners, funds are designated for each university team to sponsor short visits by faculty, staff and researchers from other participating ESSE 21 university teams and NASA field centers. The purpose of these two- to three-day visits is to add breadth and foster collaboration by bringing to the classroom or workplace special expertise and perspectives different from those at the host institution.

ESSE 21 participants, as community members and leaders, actively seek out partnerships between researchers and educators, and carry NASA's Earth system approach to new venues and audiences. The Program exercises the leveraging ability of the interdisciplinary collaborating community, and focuses team building and proposal efforts to take advantage of funding opportunities that support the broad mission of understanding the Earth as a system.

ESSE 21 will create and maintain other electronic services for participants and the general community as well, including e-mail list servers; electronic forums; scheduled videoconference briefings and meetings using off-the-shelf tools such as NetMeeting; live, streaming internet video of portions of the annual meeting, etc.

The Program is committed to reaching minority institutions and offers a means to strengthen science courses and curricula with active partnerships and shared Earth system learning resources. The ESSE 21 community offers a rich and supportive framework for minority institution partners to explore and develop materials and courses that meet their specific institutional needs while fostering deeper and longer term relationships with research and education colleagues from around the country. NASA's unique data and research contributions serve as a starting point for these partnerships. The compelling nature of the study of the Earth as a system and the application of Earth system science to real world problems that affect underserved populations can translate into increased enrollments in science, technology, engineering, and math departments and an increase in the numbers of minority students choosing careers in NASA-related fields.

## 7. SUMMARY

ESSE 21 represents a vital next step for realizing the full potential of NASA's investment in observing the Earth system to impact classroom education of future citizens and scientists in colleges and universities. ESSE 21 enables NASA's remotely sensed data of the atmosphere, ocean, land and biosphere combined with other data including model assimilated data sets of the past and current decades to be leveraged for national and global impact in classroom education. The integration of research and education in the classroom through collaborative partnerships among scientists and educators is an essential step for future exploitation of the knowledge to be gained and applied to societal needs. Convenient and regular access to NASA data, analysis tools and research results enables students to spend needed time exploring interdisciplinary scientific and social arenas in search of creative solutions to increasingly complex problems at the intersection of the Earth system and society. In bringing Earth system science into the classroom, the complexity ranges from presenting the underlying theoretical basis of the physical and life sciences to mapping the physical and biological state of the system. Crucial to these efforts are the human dimensions of the climate system and global change and the need to realize sustainability.

ESSE 21 provides an infrastructure within which interdisciplinary partnerships can flourish, drawing upon a peer community of like-minded educators for creative solutions to common problems. The Program encourages systemic reform with the development and adoption of Earth system science learning materials, courses, degree tracks or programs, and departments that become self-sustaining within the regular offerings of an institution's curricula. The programmatic infrastructure offers common resources for institutional capacity building in Earth system science research and education. The end result will be a vital and active science education community committed to extending Earth system concepts to courses and entire departments while incorporating elements of NASA's vision, mission and products.

Additional information on the current status of the Program and the Call for Participation can be found at <http://esse21.usra.edu> or by contacting [esse21@usra.edu](mailto:esse21@usra.edu).

