THE NATURAL HISTORY OF PLANET EARTH ISE PROJECT SUMMARY ©Bob Field 062106

A. Intellectual Merit

Our project is a bold new replicable response to the growing crisis in science education. Teens have negative attitudes toward science as a result of peer opinion and the opinions of influential adults. California Polytechnic State University proposes to deliver a **Global Evolution disc** that helps people explore the structure and evolution of natural systems. **The Natural History of Planet Earth** section highlights the underreported two billion year story of the Proterozoic Era and the changes in the oceans, atmosphere, solid Earth, Sun, and biosphere that preceded the dazzling diversity of life that emerged from the Cambrian explosion. Our compelling story engages and informs the public with proven methods of thematic interpretation used for informal environmental education in nature venues around the world.

In **collaboration** with the San Luis Obispo Coast District of California State Parks, Cal Poly will use our integrated science disc to develop **three traveling Natural History of Planet Earth exhibits** consisting of museum quality wide-format posters, animated digital media exhibits, and related hands-on resources for display in the National Geographic Theater lobby at the world famous Hearst Castle, the Morro Bay State Park Museum of Natural History, and our campus library. We will also develop **living natural history programs** including walks, talks, tours, nature guides, a shared reading program, and special events for a county-wide **Summer of Change** while the exhibits are on display. Our exhibits and programs will educate our audiences and attract them to our website and to our **Global Evolution disc**. We will recruit students and educators to adapt and replicate our efforts in other venues.

Our **project design** selects the content, themes, educational approach, and marketing concepts necessary to address the total environment of teens including the adults who influence them in classroom, family, and social environments. We will overcome perceptions that science is boring, irrelevant, and difficult by making the familiar fascinating while making the unfamiliar familiar.

Our project builds on eight years of prior secondary research by the principal investigator (PI), who has developed, conducted, and evaluated many informal science education programs. His **unprecedented** approach provides audiences with **personal experiences that relate local natural history to global evolution** including recent advances in astrophysics, geophysics, oceanography, atmospheric science, and aquatic and terrestrial biology from ancient microbial ecosystems to contemporary biogeochemistry.

Our **project team** includes experts in science education, physics, chemistry, biology, and engineering. Their diverse interests and skills cover all fields of science and education required for this project. The talent recruited by the PI can provide the missing links that will enable us to document a clear, concise, comprehensive, and comprehensible story of the nearly five billion year history of five kingdoms of life on Earth in a form that facilitates its adaptation and replication at nature venues anywhere in the nation.

Our **collaborating organizations** include the local state parks and its natural history museum, the Hearst Castle National Geographic Theater, and the local county YMCA. The PI currently serves as science education coordinator for “walk and talk” docents in the local state parks and will share his intellectual property with this project cost-free. Our state parks are the largest public provider of informal science education programs in California. Our partners will provide free access to existing audiences, space and publicity for exhibits and programs, materials, volunteer artists, educators, and naturalists.

B. Broader Impacts

A **diverse public audience** of 100,000 students, educators, nature lovers, residents, and tourists should attend our county-wide **Summer of Change** exhibits and natural history programs. Our project will reduce the negative attitudes toward science that are prevalent among teens and the adults who influence them. We will attract them to our website and our **Global Evolution disc** which will stimulate interest in science and math careers, offer opportunities for lifelong learning, and document our efforts in a format that will enable K-16 and environmental educators to adapt and replicate our experience in other venues.

Our **impact evaluation** will determine how well we engage, inform, and recruit students, K-16 and environmental educators, scientists, and the general public to lifelong learning and project replication with a third year summative evaluation that will be included in the **Global Evolution disc** and on our website.

Our **strategic impact** will be to show that thematic interpretation linking local natural history to global evolutionary processes while respecting individual beliefs can provide a novel and affordable gateway to digital informal learning resources. Our disc will provide the resources necessary for other colleges to partner with nature venues and youth groups to adapt and replicate our content and themes everywhere.

Our project will have an unprecedented impact on how Americans think about science and nature by relating our local natural history to the unfamiliar but compelling story of the fantastic changes in the oceans, atmosphere, solid Earth, Sun, and biosphere associated with the Proterozoic Era.

A. Impact

1. AUDIENCE

China, India, and Mexico surpass America in engineering students. **How Long Will America Lead the World?** (Newsweek, June 12, 2006). **Look Who's Pumping out Engineers** (BusinessWeek, May 22, 2006).

Our growing crisis in science education requires bold new replicable approaches to reach the youth of America. California Polytechnic State University proposes to develop, demonstrate, and evaluate a highly scalable, affordable, audience-driven informal science education program to address this crisis. A publication by the National Education Association, **Making Science Cool: Strategies for changing students' negative attitudes toward science** by McCraight-Wetz [1], identifies classroom, family, and social environments as the contexts in which most students acquire negative attitudes. We can conclude that teens acquire negative attitudes from their peers and from the opinions of influential adults. Their attitudes inevitably influence younger students who imitate adults. Our multi-level approach addresses the total environment as recommended by Ash and Brown [2, 3].

Therefore the public audience for this project will include **youths and the adults who influence them in classroom, family, and social environments**. The adult population includes parents and other family members, youth group and other community leaders, K-16 and environmental educators, political and religious leaders, and members of the print and broadcast media. This section summarizes and simplifies the logic behind an audience-driven informal science education project that has evolved from eight years of study and practice by the principal investigator.

As reported in the Journal of Educational Research "Research suggests that students view science less favorably than most other subjects and that student attitudes toward science deteriorate during the schooling years" [4]. Many excellent programs provide hands-on nature and science activities for youth under age 12. Far too often, organizations do not offer informal science education for teens because of negative student attitudes, teen preferences for recreational and social activities, and insufficient organizational interest and skills to develop and conduct programs. Offering teens the same activities that they experienced as children will not convince them that science is cool. Offering teens adult programs developed by a college may engage their interest [5, 6].

Therefore this project emphasizes the underserved population of teens and will offer them adult-level challenges and experiences related to recreational and social activities based on grade-appropriate California state and national science frameworks and standards. Partnerships between colleges, informal science education venues, and youth-oriented organizations provide an excellent way to combine the resources needed to achieve these objectives, particularly in small town and rural communities [7, 8, 9].

This project focuses specifically on youths and adults who visit or reside in San Luis Obispo County, located on the relatively under populated (250,000), underdeveloped, and historically pristine central coast of California. Using our local natural and cultural attractions, we expect to attract 100,000 visitors to our summer informal science education program. The local and tourist demographics - a blend of small town and rural America, urban professionals and retirees, college campus, and Spanish language residents - provide an ideal test bed for a scalable project that will reach a diverse audience. [10, 11].

According to the Central Coast Natural History Association publication Nature Notes, May 2006, "The California State Parks is the second largest public educator in the state, directly behind the K-12 system, because it serves 500,000 students per year, with over 12,000 students attending on the Central Coast". For this reason alone the local state parks are great partners for informal science education. Many of the volunteers who collectively donate 35,000 hours of service per year to local state parks are retired educators leading indoor and outdoor educational programs for local and visiting youths and adults.

This district features a dozen state coastal parks including its 8000-acre crown jewel, Montana de Oro State Park, and Morro Bay State Park with the only Natural History Museum in the state park system. The progressive leadership of its new ranger manager, a highly regarded expert in thematic interpretation and exhibit development, and its award winning docent science education coordinator (who also serves as principal investigator for this project) are key human resources for this project.

The district includes several other popular tourist destinations, the 1000-acre Pismo State Beach, home of a famous Monarch Butterfly Grove and Pismo Dunes, which is adjacent to the Oceano Dunes State Vehicular Recreation Area whose 1500 acres of open sand dunes for off-road-vehicles ranks it among the

most popular and unique of California State Parks, drawing thousands of recreational visitors seeking relief in the mild coastal climate from California's 100º central valley in the summer.

Altogether more than a dozen local state parks provide access to over 20 miles of pristine coastline. One park contains two world famous historical and cultural attractions, the Hearst Castle and the National Geographic Theater in the Hearst Castle Visitor Center. The Hearst Castle attracts more than 800,000 visitors per year, a large potential audience for an informal science education program [12, 13].

Our third partner is the San Luis Obispo YMCA, which serves 5000 families with emphasis on recreational programs for youths including its teen expeditions programs that often involve state and national parks. The YMCA will provide access to an audience, publicity, volunteers who contribute artwork for exhibition, and opportunities to collaborate with national parks and other secular and faith-based youth groups.

The San Luis Obispo (SLO) County Director for the University of California Department of Agricultural and Natural Resources pioneered the SLO Scientists program for 4-H youth. State parks are starting to adopt his programs and he will be collaborating with our project whenever possible as a consultant.

The combined resources of a state university, state park, and non-denominational youth group provides a model for informal science education collaborations that can be replicated anywhere once we develop, demonstrate, and evaluate our educational themes, content, and approaches. Collectively, Cal Poly, the local state parks, YMCA, environmental organizations, and other youth groups, and schools have extensive experience with all of the target audiences. Our own undergraduate science majors have recent first hand experience with teen and adult attitudes toward science and can provide great assistance.

We propose to develop and demonstrate **traveling exhibits** and **living natural history programs** that can be adapted to any park, nature preserve, natural history museum, nature center, botanical garden, aquarium, marine park, zoo, science center, library, or educational institution with the help of a digital resource that we will also develop and disseminate in disc form and in limited form on our website.

The ideal science theme addresses the negative attitudes toward science and utilizes the resources and interests of the collaborating organizations. The natural wonders in our coastal state parks provide a highly accessible hands-on, feet-on, eyes-on, and minds-on experience for teens and adults who have "outgrown" traditional hands-on science activities and are very verbal, social, and recreational.

Any modern natural scientist examining the sea, sky, Sun, Moon, stars, land, plants, and animals will recognize that the unifying theme of all natural science is that the current observed complexity of natural systems is the result of evolutionary processes associated with interactions of energy and matter. Our theme must interpret local natural history in terms of the evolutionary processes that shape the natural history of the entire planet and that emphasize the unity and diversity of nature. **Our emphasis on global evolutionary processes is based on the position of the National Academy of Sciences that it is the role of science to provide plausible natural explanations of natural phenomena.** This provides a fast track from nature to science.

This theme also addresses two common sources of negative attitudes toward science held by teens and the adults who influence them. First it clarifies that the so called "evolution controversy", which is often used by special interest groups to undermine confidence in science in general, is actually based on religious and political considerations not scientific disagreements. Second, science is widely perceived as boring, irrelevant, and difficult in part because everyday science advances by focusing on detail and compartmentalized thinking, a reductionist approach. Our approach is constructivist because it focuses on the big picture and unifying themes and enables teens and adults to compare and contrast the properties and processes of diverse and complex natural systems through personal experience [14, 15].

Our exhibits, walks, talks, and tours challenge people to ask fundamental questions about nature and natural systems and motivate them to access online resources and paper and digital library resources. People discover that everything they see has a natural history and that some of the most important and fascinating things and processes may be unseen. They realize that science and its mathematical descriptions are difficult because nature is complex; that complexity grows when energy flows. Despite the complexity, they discover that nature is comprehensible and orderly, that complex structures arise from simpler building blocks, and that everything comes from somewhere. They learn that science provides enhanced tools for observation and analysis to enhance ordinary human experience [16, 17, 18].

We expect our traveling exhibits on local and global natural history and their associated special events to reach a diverse audience of 100,000 students, educators, nature lovers, residents, and tourists. Our most general venue, the Hearst Castle, has about 275,000 visitors in three summer months. We estimate that 30% will visit the lobby exhibit in the National Geographic Theater. The Morro Bay State Park Museum of Natural History has about 20,000 summer visitors. We expect programs and related publicity in the

local state parks, Hearst Castle, and other venues to significantly increase museum exhibit attendance. Cal Poly has 20,000 students and educators and thousands of visitors attend special events on campus; we expect to draw many residents in the fall. Thematic living natural history programs can serve as gateways to a highly accessible digital disc devoted to the natural history of our planet which can in turn foster ongoing interest in the STEM (science, technology, engineering, and math) fields [19, 20].

The principal investigator alone has devoted 5000 hours to developing and conducting indoor and outdoor informal science education programs of this type over the last eight years as a volunteer in the state parks and has devoted many more hours as an adjunct physics professor at Cal Poly to nature-based student science projects. What is needed is the county wide demonstration and digital resources to facilitate replication and adaptation to other communities.

The county wide demonstration – called the **Summer of Change** - will be based on living natural history programs in the state parks and three traveling exhibits, the **Natural History of the California Coast**, the **Natural History of Planet Earth**, and the **OASES and the Biosphere**. These in turn will be based on our new user-friendly digital **Global Evolution disc**, which will document the project content and themes to enable people to investigate the subjects as part of a lifelong learning tool, a nature-themed gateway to the STEM fields for informed citizens and a globally-engaged workforce. The **Global Evolution disc** will have a sitemap as well as links to library resources, online resources, and our own website. It will in no way be an encyclopedia or library of natural history facts and figures, but will concentrate on global themes which can be accessed through a few concrete examples of local natural history. It will motivate people to examine its extensive references to and links to other existing print and electronic resources.

This disc will have an educators' section that explains what we did, how we did it, how well it worked, and lessons learned. It will provide the resources necessary for educators to adapt our exhibits and living natural history programs to their community including animations and high resolution printable exhibit images. It will discuss the use of volunteers and student labor (low cost or rewarded with academic credit and/or recognition). The disc will make the replication process affordable beyond the period of the project.

We will help the Central Coast Natural History Association establish a student poster competition in 2009 with $1000 prizes to students and their classrooms in three categories (middle school, high school, or college). Participation will be limited to students who attend school in our county. The posters will be submitted through the schools; each school can submit one candidate in a category. This will engage the schools in the process and reduce the amount of judging that our team has to do. Naturally, the theme of the posters will be "**Evolution is cool because …**" This will require students to visit our website to understand the broad definition of physical and biological evolution and to study the rules and to look for ideas for posters. The exceptionally large prizes will attract interest in the schools and in the local media and help promote the summer events. It could well earn us national publicity and stimulate the replication process we seek. Winning posters will be displayed at Cal Poly and on our website along with runners-up.

By concentrating on the natural attractions of our county and by showing respect for all views, this project can reach a variety of underserved populations including rural and small town residents, state and national park visitors, minorities, and both genders. For example our bilingual translators will produce a Spanish language version of the exhibits and the digital resources. This will enable us to serve a more diverse population.

Our combination of local natural history and global evolution themes provides a novel gateway into the STEM content because the natural history of planet Earth is based on a highly interdisciplinary combination of physics, chemistry, biology, mathematics, engineering design, oceanography, atmospheric sciences, geophysics, astrophysics, cellular biology, microbial ecology, biogeochemistry, plant and animal biology, and aquatic and terrestrial ecology. Nature is a particularly attractive and refreshing alternative gateway into STEM fields for boys and girls who are bored by computer games and other technological wonders [21, 22].

In the first year, we will develop the **Global Evolution disc** and train the staff to think thematically and globally as they perform secondary research and develop heuristic models. In the second year, we will develop the three exhibits and the Living Natural History programs. In the third year, we will build the exhibits, train leaders, and organize, conduct, and evaluate the exhibits and living natural history programs in the county-wide **Summer of Change**.

2. AUDIENCE IMPACT

The three goals of this project are to **engage**, **inform**, and **recruit** our target audience by developing informal science education resources and programs using the proven methods of thematic interpretation which are summarized as **EROT**: programs should be **enjoyable**, **relevant**, **organized**, and **thematic**.

Engagement is the foundation of informal science education because a non-captive audience departs without it. Classroom educators should note that mandatory attendance and distant rewards related to grades and careers do not insure a captive audience; filling seats is not the same as filling minds, and filling minds is not the same as stimulating minds. Effective engagement enhances the learning experience rather than just introducing distracting gimmicks. Thematic interpretation engages audiences in informal learning venues around the world and is practiced by volunteers and professionals. Inquiry based learning engages the minds of participants who ask questions and/or respond to questions [23].

Information is the heart of any science program; it is the content. Generalizations cannot be drawn without concrete examples. But information should be conveyed in "plain English", not in fancy multi-syllabic educational jargon, nor in "plain Greek or Latin names", nor with streams of numbers quantifying the size or age of objects. Naming rocks, plants, and animals that are very similar in appearance is generally unnecessary unless the audience is already motivated to pursue the subject in depth later and often distracts audiences from larger themes and creates unnecessary barriers between the educator and the audience. Useful information is relevant, organized, and thematic. If nature itself is fascinating, it is not necessary to humanize it constantly with endless stories about scientists and about the benefits to society and the threats of civilization. An informative program provides a visitor with a few memorable facts and themes and the motivation to learn more. Informed participants can develop more positive attitudes toward science and education and may repeat program stories and themes to others [24, 25, 26].

Recruitment is the most challenging and most important part of an educational program. How many members of the audience will re-examine their own views about science and nature? How many will expect the journalists and politicians to access scientific inputs in decision making and to promote scientific literacy by example? How many will attend other programs, encourage others to attend, or follow up with visits to the library, an online resource, or our digital resource? How many will regard science as a lifelong learning experience? How many will become scientists or educators or nature-oriented volunteers? How many will help create or conduct informal science education programs in our community or in other communities? It is difficult but important to evaluate recruitment accurately. A good program encourages lifelong learning including visits to websites and other digital media and interest in STEM courses and careers. In our case, we also seek to recruit individuals and organizations to replicate and/or adapt our global evolution themes and content in new venues. Our experience is that many people are receptive to well told stories that illustrate scientific concepts in plain English and will follow up if provided with digital media that is clear, concise, and comprehensible. Many science educators will provide assistance for informal science programs if asked and provided a pathway [27, 28].

Our first year goals are to develop the digital resources for the **Global Evolution disc** and to train our staff to think thematically and globally as they perform secondary research and develop heuristic models. Students and volunteers will be used as trial audiences for evaluations in the first summer. Our second year goals are to revise the disc and to develop the **three exhibits** and the **Living Natural History** programs with the help of ideas and artwork provided by adult and teen volunteers from the state parks, Cal Poly, and the YMCA. Cal Poly's Central Coast Science Project will help us recruit a summer audience of educators to evaluate the program. In the third year, we build the exhibits, train leaders, and organize, conduct, and evaluate the exhibits and living natural history programs in the county-wide **Summer of Change**. Our third year activities will engage our collaborators and showcase our deliverables to recruit and train new collaborators including colleges, K-16 and environmental educators, and youth groups in order to initiate program replication in nearby counties (Monterey, Santa Barbara, and Fresno).

We believe the crisis in science education is related to a failure to address all three goals effectively. In our program, students, K-16 and environmental educators, and volunteers will examine our digital resources and provide evaluators with cost-effective in-depth responses to all three of these impacts [29].

3. IMPACT EVALUATION

Our independent evaluator, the Institute for Policy Research headed by Dr. Linda Shepherd, will help develop evaluation tools, train students and volunteers to collect data, and will analyze data in order to provide a summative evaluation that will be included in the last revision of the **Global Evolution disc**.

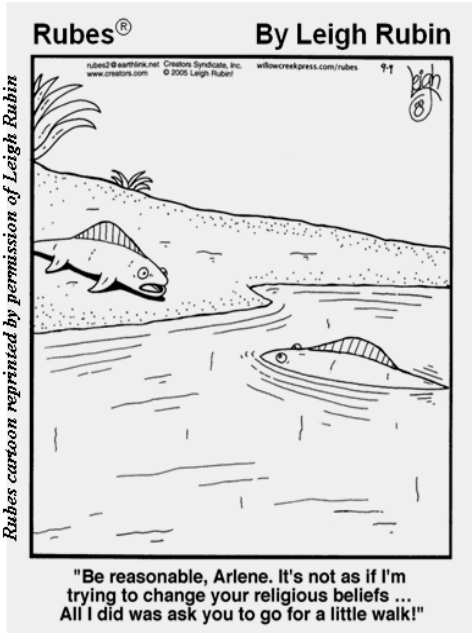
The three goals of this project are to **engage**, **inform**, and **recruit** audiences. The disc will be the primary device for evaluating audience response. Users will be asked to respond to evaluator generated questions before and after exploring the content of the disc. The questions will cover the three goals in the context of exhibits, living natural history programs, and disc use itself. Students, educators, and volunteers will spend one hour using the disc in a computer lab and then participate in a focus group.

One focus group will participate in an informal science education event and discuss the relationships between local and global natural history or the causes and consequences of key events in the Earth's

history such as the change in solar luminosity. The target audience should remember themes, understand the relationships between local and global natural history, and seek additional learning experiences.

The evaluator will do some selective follow-up interviews as well. The evaluator will train students and volunteers to collect data on audience attendance and participation at exhibits and programs. Information on home town, gender, and approximate ages of some audience members will be collected as well.

Our independent evaluator will attend most of the quarterly reviews all three years, observe and evaluate the presentations and subsequent discussions, and submit a brief subjective report on their observations. The evaluator will plan, conduct, and report their summative evaluation of the exhibits and activities in the **Summer of Change** project in the third year. Our independent evaluator will train and interview students and nature-venue volunteers who will collect data and make observations useful to their evaluations.



4. STRATEGIC IMPACT

Our five year plan is to adapt and replicate our program in three venues: two adjacent coastal counties, Monterey, home of the world famous Monterey Bay Aquarium, and Santa Barbara, which has an excellent university, natural history museum, and nature-oriented attractions, and the nearby inland county of Fresno, which has a very different environment, economy, and demographics, has a state university and is near three national parks including Yosemite. These projects will help us establish future collaborations with the California Academy of Sciences in San Francisco, the Los Angeles Zoo and the Natural History Museum of Los Angeles County, and numerous national parks.

We are promoting informal science education in order to overcome negative attitudes toward science and have devised an affordable, replicable approach to reach a large population. In addition to the impact on our target audience, we believe that our approach has broader applications in informal science education programs and informal learning. To the extent that our replication model has not been utilized, we believe that our success may help advance a valuable approach that can be used by other institutions.

The key elements are to address negative attitudes directly, to make science cool by making the familiar fascinating and the unfamiliar familiar, to use thematic interpretation to build programs around constructivist concepts rather than simply promoting one's own pet interests, to choose partners with outstanding resources who are representative of organizations that are already replicated throughout the country, and to use personal experiences at exhibits and on field trips to attract visitors to our digital resources to promote interest in STEM fields and in lifelong learning. Our emphasis on affordability is implemented readily in an academic environment where a wide range of student and faculty talent exists in the arts and sciences and can be utilized at low cost or for free as part of the educational experience.

We will allocate half the budget developing digital resources, and less than a quarter each on developing exhibits and living natural history events related to personal experiences in nature for the public. The actual cost of creating exhibits will intentionally be a small fraction of this project in order to show that we can replicate exhibits in underserved venues. The county wide event will demonstrate that we can develop portable, durable, affordable displays for a diversity of venues and organize many programs based on our global evolution themes to reach 100,000 people.

This project will maximize its potential for replication by translating complex scientific principles into "plain English" in entertaining and stimulating ways using a variety of media and personal experiences for professionals, volunteers, educators, students, group members, and visitors. The programs use concrete examples to illustrate concepts and encourage people to observe and analyze nature.

Our strategy emphasizes the formation, composition, structure, and evolution of systems. Learning to think in terms of system processes rather than simply learning facts about natural objects is a central goal of our informal science education project. Natural systems make no sense outside of the context of evolutionary processes. We aim to broaden the concept of evolution and demystify it. If educators avoid the word evolution, then we will not produce a well informed public.

Our programs respect people's beliefs while advancing natural explanations of natural phenomena. We do this by staying on message; we present the program we have prepared and we rule political and

religious debates out of scope (in accordance with state park policies). Often on a walk with a diverse audience, the walk leader will show the Rubes cartoon displayed here and then say, "I'm not trying to change your beliefs… I'm just asking you to go for a walk." A little humility minimizes potential problems whereas arrogance fuels conflicts.

We encounter many questions about the emphasis on a "controversial" word like evolution. People often suggest using change over time or adaptation. This would be a disaster for the reasons discussed above. Furthermore it is inaccurate, cumbersome, and an unnecessary compromise of scientific integrity to try to slide something past people as if they won't notice. The Sun evolves; it doesn't adapt. Kippenhahn and Weigert wrote a book on Stellar Structure and Evolution [30], Clayton wrote Principles of Stellar Evolution and Nucleosynthesis [31], Schwarzchild wrote Structure and Evolution of the Stars [32], and Meadows wrote Stellar Evolution [33]. They did not write books with titles like Solar Adaptations or Stellar Structure and Changes over Time! Dr. Joyce Guzik, Los Alamos National Lab astrophysicist, gave us a solar evolution code (18000 lines of Fortran), not a solar changes-over-time code.

Our natural history project aims to show the unity of nature and of physical processes and highlight the fact that evolution is a universal attribute of natural systems when energy flows under non-equilibrium conditions. This cannot be done by using euphemisms or by being afraid of people with opinions that are not based on facts. We feel that there is an urgent need to help the public gain a broader understanding of evolution and the nature of science.

The five year plan also includes collaboration with other colleges to replicate our concept in nearby counties using our global evolution themes documented in our **Global Evolution disc**. The use of scientists, educators, and artists on their campuses and in their communities represents a strategic breakthrough. We can advance the NSF goal of reaching underserved or underrepresented public audiences for STEM by mobilizing inexpensive and underutilized human resources to address a fundamental problem in science education: altering public understanding of the role of science and the nature of the physical world. This collaboration may enable us to reach tens of millions of Americans through adaptive radiation, a basic tenet of biological evolution. This will advance our goal to establish Cal Poly as a national resource center for informal science education based on global evolution themes.

Within five years, our partnership with the local YMCA will help us collaborate with more of the nation's 2,594 Y's. According to their website, "The YMCA is the largest not-for-profit community service organization in America, working to meet the health and human service needs of 20.1 million men, women and children in 10,000 communities in the United States. Our members are equally divided between male and female and between youth and adults. YMCAs are at the heart of community life across the country: 42 million families … are located within three miles of a YMCA."

We use thematic interpretation to relate personal experiences with nature to the evolving systems described in our **Global Evolution disc**. Our five year strategy will help other colleges leverage their existing scientific, educational, and artistic resources to combine the themes, content, and tools in our disc with their own local personal experiences in nature in order to create county-wide programs that collectively may reach tens of millions of Americans. Obviously these projects can be replicated and adapted to other nations as well.

Once the digital resources, exhibits, and programs have been developed and evaluated, we anticipate that other organizations will be able to adapt and replicate the materials and programs for their communities at minimal cost. Partnerships with cooperative organizations like the YMCA with its several thousand local units may be so cost effective that the programs become self-financed much as an organism is self-replicating and self sustaining.

B. Innovation

1. PROJECT DELIVERABLES

Cal Poly proposes to create a closely related set of digital resources, exhibits, and living natural history programs involving learning experiences with nature in order to provide novel gateways to the STEM fields. The heart of the project is the **Global Evolution disc** that explores the structure and evolution of physical and biological systems in the **OASES** (**O**ceans, **A**tmosphere, **S**olid **E**arth, and **S**un) and the **Biosphere** (organized into molecules, cells, organisms, and ecosystems).

By combining resources in our disc with principles of thematic interpretation, we will enable a diverse public audience to relate local natural history to global evolutionary processes. Our primary audience is mature teens and adults, including environmental and K-16 educators who need to understand our science content at an adult level regardless of their audiences.

In collaboration with the San Luis Obispo Coast District of California State Parks, Cal Poly will use the **Global Evolution disc** to develop three traveling exhibits consisting of portable, durable, and

affordable museum quality wide-format poster displays, animated digital media exhibits, and related hands-on resources.

- **The Natural History of the California Coast** display in the National Geographic Theater lobby at the world famous Hearst Castle will combine art, nature, and science for a general audience.
- **The Natural History of Planet Earth** display in the Morro Bay State Park Museum of Natural History will include a five billion year timeline featuring ancient ecosystems in **Proterozoic Park**.
- **The OASES and the Biosphere: the first five billion years of evolutionary change** will be on display in the Kennedy Library at Cal Poly and will emphasize the structure and evolution of eight natural systems in depth and with connections to library resources.

Cal Poly will also develop informal activities including walks, talks, tours, nature guides, a shared reading program, and special events in the local state parks, botanical garden, zoo, and other nature-oriented venues. Cal Poly will organize, conduct and evaluate a county-wide **Summer of Change** living natural history program that integrates all of these deliverables for a diversity of venues.

Our collaboration with the San Luis Obispo Coast District of California State Parks and other nature-oriented organizations will demonstrate the scalability of our concept and the summer exhibits and programs will help us follow up this program with additional collaborations with major centers of informal science education as well as with other colleges.

One intangible benefit of this project is that the process of creating the deliverables will stimulate minds and change thinking patterns of our students, educators, scientists, artists, and collaborators even before the target public audience receives any informal science education. The experiences of the project participants may dramatically change the university and its collaborating organizations. Educators may learn new tools for communicating in the classroom such as thematic interpretation. Environmental organizations may gain new volunteers recruited from students and faculty. This is also a fundamental goal of the project which aims to promote its evolutionary themes using the principles of descent with modification and adaptive radiation throughout the community.

By taking a constructivist and global approach, our project will provide a novel gateway to the many fine educational resources that already exist. Many NSF projects take existing scientific achievements in space technology or biotechnology and make them accessible to the public. Their efforts are funded by research agencies and the informal science education grant improves public access. Most nature programs are aimed at very young and/or very general audiences and emphasize naming and identifying plants, animals, rocks, etc. or provide grossly oversimplified and often inaccurate explanations of complex phenomena.

Our approach compares and contrasts the properties and processes associated with a variety of natural systems – oceans, atmosphere, solid Earth, Sun, and biosphere – and cannot be implemented without drawing the resources from many specialized and advanced textbooks and publications. While the principal investigator's website lists over 200 books, there is no single textbook or popular science publication that provides the content or even the framework for the digital resources that we are proposing. Nor is there a source of information that is organized from a natural history perspective with a comprehensive and accurate scientific rigor that is accessible in "plain English".

Most textbooks and courses provide facts and tools for future scientists or engineers or to humanize scientists, with big picture themes presented in introductory or concluding chapters or in sidebars. Our program is not focused on professional training or on the efforts of science or on scientific evidence; our emphasis is on what nature is doing. Generally our models are heuristic and our materials are based on secondary research, but our thinking is highly original. Most scientists emphasize what they know about nature or what is important to the human condition; we emphasize the important processes and historical events of nature regardless of our current understanding or current benefits. Sometimes it is important to ask fundamental questions and to try to explore them.

a. Exhibit Deliverables

Imagine you are waiting for a Hearst Castle tour and you see a graphic poster inviting you to explore **The Natural History of the California Coast** display in the National Geographic Theater lobby. Alternatively, you may have discovered the displays as you entered the lobby to see a film at the theater.

When you enter the lobby, you see a sign that says "The rugged beauty of the evolving coast reveals the powers of the sea, sky, land, and life itself." You see 16 large stunning photographs and works of art portraying local natural features, birds, marine mammals, kelp, plants, striated and textured rocks, a sand spit, rugged coastlines, dramatic and colorful skies, and restless seascapes. It turns out that the pictures are not randomly selected works of art, but are arranged to help tell a story. The accompanying text is unusual: it asks questions about the composition, processes, origins, and relationships of things you see.

These eight guiding questions are common to all of our informal science education programs:

- What do you see (observations and descriptions)?
- What are natural systems made out of (composition and structure)?
- How do natural systems work (material properties and interactions with energy)?
- How do natural systems change over time (evolutionary processes)?
- Where do natural systems come from (origin and/or formation from building blocks)?
- What are the relationships between the parts of a system (interactions and/or common origins)?
- What are the relationships between natural systems (interactions and/or common origins)?
- How do natural systems become more complex over time (entropy decreases)?

It answers those questions. You learn surprising things like which has more oxygen, a pint of sand, water, or air? What about a pound of sand, water, and air? Why are there flowers and fruits? How does a sea otter resemble the Sun? (They both survive by trapping internally generated heat.) What was on land before plants and animals evolved? Were the hills around the Hearst Castle ever below the sea? You may encounter an exhibit guide who shows you some artifacts and a digital display with animations explaining more fascinating stories about natural history and global evolution.

At the end of the exhibit, you notice displays highlighting **The Natural History of Planet Earth** in the Morro Bay State Park Museum of Natural History, **The OASES** (**O**ceans, **A**tmosphere, **S**olid **E**arth, and **S**un) **and the Biosphere** at Cal Poly, and related exhibits and programs scheduled throughout the county. Imagine that you go to the museum to learn more. There you meet others who heard about the exhibits on a walk in a state park where they are camping.

The permanent exhibits in the Museum of Natural History in Morro Bay State Park relate local natural history to the influence of the forces of nature. The new traveling exhibit for the museum entitled **The Natural History of Planet Earth** strengthens the global aspects. The centerpiece of this exhibit is a large (16') linear timeline of what happened and when, showing far more detail of critical early events than most similar diagrams, which often condense the scale of early eons. One display highlights the carboniferous period when life started producing an abundance of lignin but had not yet evolved efficient forms to decompose it, which resulted in a period of unusually rich coal deposits. Another display called **Proterozoic Park** portrays the planet's wealth of microbial life before plants and animals evolved.

Proterozoic Park focuses on the remarkable and underreported story of the two billion year period that preceded the dazzling diversity of life that began with the Cambrian explosion about 500 million years ago. If you are unfamiliar with the dramatic changes that occurred during the Proterozoic Era, then the Cambrian explosion may seem less plausible to you than the popular creation stories.

The Proterozoic began with a world ruled by cyanobacteria, those microbial masters of photosynthesis who over time transformed the atmosphere by removing most of its carbon dioxide and supplying it with the highly toxic gas oxygen that we treasure so much. While the resulting oxygen holocaust decimated vast populations of anaerobic microbes, the loss of greenhouse gases saved the oceans from evaporating as the Sun grew 15-20% hotter during this era. Late in the Proterozic, evidence reveals that "the entire Earth was ice-covered for long periods 600-700 million years ago. Each glacial period lasted for millions of years and ended violently under extreme greenhouse conditions. These climate shocks triggered the evolution of multicellular animal life, and challenge long-held assumptions regarding the limits of global change". (www.eps.harvard.edu/people/faculty/hoffman/snowball_paper.html). The whiteness of ice increased the planet's albedo, further reducing the amount of absorbed solar energy. Drastic reductions in global photosynthesis coupled with continuing volcanic activity in the Earth increased greenhouse gases and saved the planet.

The solid Earth changed enormously as well with an enormous increase in continental land masses and changes in the distribution of land on the surface. The solid core of the Earth grew significantly, the rotation of the Earth slowed significantly under the influence of the Moon, and tidal forces decreased as the Moon slipped further from the grip of the planet from which it emerged billions of years earlier.

By the close of the Proterozoic Era, all of the building blocks were in place to be assembled into the diverse forms of algae, fungi, plants, and animals that appeared in the last billion years. The surface of the land was preconditioned by combinations of physical processes like weathering as well as earlier terrestrial life forms including the symbiotic organism known as lichen. While the sudden appearance of a variety of large fossil forms may appear magical, the small changes associated with rearranging building blocks make it far more plausible than it appears at first glance.

The compelling story of the Proterozoic Era arouses our curiosity about the remarkable events that preceded it during the Hadean and Archaean Eras. Armed with our insights about the Proterozoic, we are now prepared to understand the earlier events in our history. The most remarkable event in the Archaean is obviously the origin of life, followed by the more familiar common ancestors of modern cells and metabolic processes. What were the conditions on Earth at that time? What was the composition and structure of the oceans, atmosphere, and land? How fast did proto-cells evolve into cyanobacteria?

What were the hellish conditions during the Hadean, whose rocks have not survived on the surface of the Earth? Did life begin in the Hadean repeatedly and become extinct due to the severe conditions associated with heat escaping from the Earth's interior and bombardment of the surface from extraterrestrial material raining down as the dust and gases and rocks large and small were cleared out of most of the solar system? Imagine the "Pre-Hadean" period when the Earth was still being formed and the Moon was born and even earlier as the Sun formed and thermonuclear fusion was initiated in its core. How about the earlier nine billion year history of the particles that formed our solar system?

Flat panel monitors in the exhibit show animations of the inner workings of the oceans, atmosphere, solid Earth, Sun, and biosphere including molecules, cells, organisms, and ecosystems. There is so much information that you have decided that you will have to come back for another visit in order to explore all of the materials. You learn about nature walks and talks in the state parks, which can be described as living natural history museums. On your next visit, you join a museum tour that links the four habitats in the permanent exhibits and the vistas of the estuary, sand spit, and Morro Rock to global evolutionary processes. The traveling exhibit may influence revisions in the permanent exhibits in the museum.

On the tour you are told that every thing you see has changed over time, the sea, the sky, the land, and life itself. The Sun has gotten nearly 40% brighter since life began on Earth. Talk about global warming! How did the oceans remain liquid throughout this time? You are reminded that the oxygen holocaust caused by photosynthesis by cyanobacteria killed off a great deal of life on Earth billions of years ago but ironically saved the life of the planet by reducing the greenhouse gas carbon dioxide in the atmosphere countering the effects of a warming Sun. You take the optional walk to White's Point with its spectacular view of the estuary and its many lichen-encrusted rocks.

If you are a student or other local resident, you may go to Cal Poly's library to see a college level science exhibit called **The OASES and the Biosphere** that emphasizes evolutionary processes in the oceans, atmosphere, solid Earth, Sun, and biosphere. This exhibit has eight 3' x 8' panels, one panel highlighting the natural history of the California Coast, two panels displaying the **Natural History of Planet Earth** illustrated timeline, one on **Proterozoic Park** which illustrates the world of microbial ecosystems, and four panels that provide in-depth explanations and illustrations of the structure and evolution of the eight natural systems. You learn a lot about convective heat transport in the OASES. Generally these system explanations are based on our heuristic models, our secondary research, and a lot of original thinking.

Flat panel monitors show animations of the OASES and the biosphere from the **Global Evolution disc**. Some animations illustrate the formation of the Sun and the Earth from a giant cloud of gas and dust. These animations include descriptions of the composition, structure, material properties, and physical processes occurring within the early Sun and Earth. Other animations describe the evolutionary processes that have changed the Sun and the Earth from its early form to its present state. Additional animations explain basic properties and processes involving the oceans and the atmosphere. Other animations illustrate the origin and evolution of the biosphere as the Earth evolved during the Hadean, Archaean, Proterozoic, and Phanerozoic time intervals. These animations also describe the influences of the biosphere on the oceans, atmosphere, and land. The underreported two billion year story of the Proterozoic Era can be used to demystify the origins of the dazzling diversity of life that emerged from the Cambrian explosion and to stimulate interest in the critical events that preceded it.

The excellent resources of the library are referenced throughout the exhibit and you learn about a lecture series and nature tours in the campus arboretum and on a three mile hike in Poly Canyon, as well as **Exploring Evolution** tours of the San Luis Obispo Botanical Garden and the Charles Paddock Zoo and other programs in the state parks.

You explore the **Global Evolution disc**. You notice that the animations on the flat panel monitors are available but that many questions are posed that compel you to search more deeply through the disc's resources for a more complete understanding of the natural history of planet Earth. If you are mathematically inclined, you examine the more detailed quantitative explanations including information about the changing composition, density, pressure, and temperature throughout the interior of the Sun and the solid Earth as well as the oceans and the atmosphere. As indicated before, our models are heuristic and our materials are based on secondary research, but our thinking is highly original. In other words we are modeling and illustrating the general properties and processes of the eight systems.

You also discover stories about the plausible natural history of photosynthesis, chloroplasts, and chlorophyll and other biological pigments. The natural history of photoreceptor systems is a fascinating story. Animations show the relationships between many pigments including hemoglobin, chlorophyll, luciferin, carotene, retinal, bacteriorhodopsin, and animal rhodopsins and the relationships between pigments for ultraviolet protection, photosynthesis, light sensing, photoperiodism, phototaxis, phototropism, vision systems, camouflage, warning colors, breeding signals, and bioluminescence. The evolutionary advantages of primitive light sensors and the progressive advantages of even the crudest imaging systems are revealed and explained by other animations. You also learn about molecular evolution and about the plausible natural history of many of the most important biological molecules.

b. Media (Film, Video, Radio) Deliverables

The **Global Evolution disc** is the primary media deliverable. The project will produce conceptual designs based on animations in the **Global Evolution disc** and may propose a film series with the National Geographic Society in the future.

c. Research Deliverables

We are proposing a novel approach to informal science education that is highly integrative and provocative. It is driven by the goal of remedying known deficiencies in the knowledge and attitudes of our target audiences. Teens have negative attitudes toward science as a result of peer opinion and the opinions of influential adults. The attitudes of teens and adults inevitably influence younger students who wish to be more adult. Our multi-level approach addresses the total environment. Our approach not only addresses the central processes of natural systems but uses these processes as models of how to replicate and adapt our informal science education project to other communities using their existing resources and our **Global Evolution disc**, sort of like digital DNA. Our entire process will be summarized in our digital disc and available for use by teens and adults, by educators, as elements in other programs, and for evaluation by educational experts.

d. Web Deliverables

Our multi-media and K-16 digital resources will be based on the previously described studies and deliverables. Appropriate portions will be integrated into a website with the remainder accessible in our searchable **Global Evolution disc**. The existing website www.calpoly.edu/~rfield provides raw material in graphical form for physics student projects and some outlines of natural history projects and hints at the extensive collection of material related to past informal science education projects and student based projects at Cal Poly that we have developed in prior work. The website is a far cry from the integrated and organized audience-driven, user-friendly form that we are proposing to do in the future. Like the disc described above, the online resources will be organized as inquiry based tools that access information by subject and by selecting fascinating questions that are based on thematic interpretation and align with K-12 science standards and other best practices. Links will be incorporated to help users understand the relationships between the four systems in the **OASES** (**O**ceans, **A**tmosphere, **S**olid **E**arth, and **S**un) and the four levels of organization in the biosphere, particularly in the context of the fascinating events of the Proterozoic Era and its preceding and subsequent periods in the Natural History of Planet Earth.

e. Youth and Community Program Deliverables

The YMCA will serve as our prototype youth group collaborator. We will provide them with free programs and they will provide us with target audiences, artists, and feedback about the merits of our programs. Our school poster contest will also provide us with collaborations with K-16 science teachers.

Our target audience includes adults, mature teens, K-16 educators, and environmental educators. To help them relate our local natural history to global evolution, we will develop three Exploring Evolution (EE) nature guides for our three exhibits: “Exploring Evolution on the California Coast”, “Exploring Evolution in the Museum”, and “Exploring Evolution in the Library”. We will also outline nature guides for many other venues. “Preface” is a Cal Poly Shared Reading Program which now includes a city-wide reading effort called “SLO City Reads”. We will request a book selection that relates to our global themes.

2. PROJECT DESIGN

This project is designed to produce the deliverables described above. Figure 1 shows the task list and timeline for the project. The first year develops the digital resources for the **Global Evolution disc**. The second year develops the **three exhibits** and the **Living Natural History** programs. In the third year, we build the exhibits, train leaders, and organize, conduct, and evaluate the exhibits and living natural history programs in the county-wide **Summer of Change**. The third year also recruits additional organizations and colleges to replicate programs in new venues.

The Natural History of Planet Earth an Informal Education Project	Timeline											
	2007				2008				2009			
Task List	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
evaluate and review project												
prepare Global Evolution disc												
develop exhibits and programs												
build exhibits and train leaders												
organize and conduct programs												

Figure 1: Project Task list and Timeline. Darker shadings represent a greater level of activity.

Our educational studies and visual and analytical models of the eight natural systems will be documented in the **Global Evolution disc**. This resource will include a comprehensive and comprehensible physical and quantitative description of the composition, structure, formation, and evolution of the systems with an emphasis on the internal processes and external interactions that involve energy flow and matter cycles and transformations. Our studies will not solve contemporary research problems, but will help us and others develop informal science education exhibits and programs. We will do secondary research and develop heuristic models in order to make complex natural processes comprehensible to our audiences.

The disc will include detailed visualizations of the properties and processes in the OASES and biosphere. State of the art advances in computational simulations of complex systems will be used to create educational models where appropriate. For example, in the OASES, 3-D animated flow patterns can show local velocities, thermal and pressure gradients, and turbulence. Advances in recent decades make it possible to quantify and visualize the inner workings of the Sun and the solid Earth as well as processes involving the oceans and atmosphere. These systems are characterized by partial differential equations that cannot be solved analytically, but recent advances in observational and computational tools are helping scientists understand complex systems.

Our goals for the biosphere are similar: advances in molecular evolution and microbial ecology, among others, will be incorporated into the content and themes of the **Global Evolution disc** and animated exhibits. We envision biological systems as organized at four levels: molecules, cells, organisms, and ecosystems. Molecules are building blocks of cells which are building blocks of organisms which are building blocks of ecosystems which are building blocks of the biosphere. The eight questions listed earlier can be applied to each of these systems.

Our goal is to advance science education by providing clear, concise, accurate, and comprehensive explanations of the structure and evolution of complex natural systems. The emphasis on evolution is fundamental for an understanding of the emergent properties of complex systems that are based on simple building blocks. A fundamental question is how do giant clouds of cold dilute gas and dust evolve into astronauts in spacecraft orbiting planets that orbit stars?

A more down to Earth question is how can we account for the diversity of life? This leads us into an investigation of the two billion year natural history of the Proterozoic Era, the biosphere and the oceans, atmosphere, solid Earth, and Sun. The transition from the unicellular Archaean world of microbes to a world of massive multicellular organisms interacting with unicellular organisms through a variety of complex transactions is a generally unfamiliar but fascinating story of the unity and diversity of life.

The **Global Evolution disc** will be organized as an inquiry based tool that accesses information by subject and by selecting fascinating questions. Links will be incorporated to help users understand the relationships between the four systems in the OASES and the four levels of organization in the biosphere.

This project is built around the quarterly review process that uses college and community expertise to minimize risk of failure on all fronts. The greatest risk remains that existing negative attitudes toward science will reduce the audience impact below our expectations. In this case our documented resources and experiences will still be available for future leaders to address the challenge.

3. STEM CONTENT

The Natural History of Planet Earth is an integrated science project that will provide learning experiences with nature that are novel gateways to the STEM fields. Our project compares and contrasts the structure and evolution of eight natural systems by drawing on the most important phenomena influencing a variety of scientific disciplines including oceanography, atmospheric science, geophysics,

geochemistry, astrophysics, biochemistry, geomicrobiology, cellular biology, marine biology, and ecology, as well as traditional academic fields of physics, chemistry, biology, mathematics, and engineering. Our senior staff and our advisors have expertise spanning many of these areas and our own secondary research and heuristic models will help us verify the accuracy and completeness of our content. One previously unstated benefit of this project is that it counters the compartmentalization and specialization of scientists and educators, which contribute to the difficulty in overcoming negative public attitudes toward science.

4. EDUCATIONAL RESEARCH AND PRIOR WORK

The key elements of our project are:

- developing the **Global Evolution disc**,
- incorporating global evolution themes in traveling exhibits and living natural history walks and talks,
- conducting the **Summer of Change** exhibits and programs, and
- recruiting additional organizations and colleges to adapt and replicate programs in new venues

Our approach is focused on the Earth and the celestial objects that directly influence it like the Sun and the Moon. We minimize the role of humans which have only influenced a very small fraction of our planet's history. This allows us to go into more depth on the fascinating and less well known periods of time like the Proterozoic Era when fantastic important events occurred despite the scarcity of historical records. Our approach serves college students and educators as well as teens.

Our project is based primarily on the experience of the principal investigator as an informal science educator, which is shaped by eight years of practice and is based on the well-established principles of environmental education developed and promoted by the world famous Dr. Sam Ham, author of **Environmental Interpretation: A Practical Guide for People with Big Ideas and Small Budgets** [34]. Our project design uses the gold standard for non-captive audiences, namely thematic interpretation, to provide audiences with enjoyable, relevant, organized, and thematic experiences with nature.

The principal investigator's engaging and informative Ocean Science Quest Natural Enquirer and Daily Sea Star tabloid newspaper poster display covered 200 square feet of wall space in the Cal Poly library in 2003. The display includes entertaining and thought-provoking stories of a sea otter in a kelp forest and explored ocean ecosystems, global climate change, tides, seasonal change, the diversity of marine life, and more. One front page is shown here.


The Natural Enquirer

Keystone Species Saves Kelp Forest From Urchin Attacks

Daily Energy Shortage Threatens Sea Otters

Sea Otters Relaxing After a Busy Day Restoring Balance in Kelp Forest By Thinning Herbivores - Monterey Bay Aquarium photo

sea urchin: voracious herbivore

Notice that the fronds of the Giant Kelp spread out when they reach the surface of the water. This increases their opportunity to gather sunlight while reducing opportunities for competitors. The kelp is a great habitat for many animals. The Monterey Bay Aquarium is a great place to view a kelp forest without getting wet and to take your own photographs of sea life.

The exhibit has eight three foot by eight foot panels that are stunning in color. Each panel represents four pages of a tabloid newspaper printed double size for easy reading and dramatic impact. The exhibit was displayed in the library for six weeks in a prominent location where perhaps a thousand or more people saw them. Public tours were offered and an Osher Institute Ocean Science Quest course was taught in the library based on the display and using our "ROAD reporters" educational approach which stands for read, observe, analyze, discuss, and report. The first half of the exhibit was installed in the biological sciences building for 14 months and was replace by the second half of the exhibit last fall.

The PI supervises Cal Poly science major projects that investigate the structure, formation, and evolution of the Sun and the Earth including the oceans, atmosphere, and biosphere. The PI has developed four evolution walks in the state parks. The PI has developed and presented 20 hours of original informal science education programs for a variety of audiences, mostly at the Morro Bay State Park Museum of Natural History, but also at teacher workshops for Cal Poly's Central Coast Science Project and physics and biology colloquia. Most of them are in slide show format, often with PowerPoint animations, and often accompanied with hands-on materials. The PI has also created and exhibited temporary museum displays on tide pools, seasonal change, and iridescence at the Morro Bay State Park Museum of Natural History. He has visited and evaluated the educational content and approaches of more than 100 natural and cultural attractions in 14 countries on five continents, all of which

have influenced our project design.

The impacts section of our proposal cites many educational references. We have singled out the central role of Dr. Sam Ham's training course on thematic interpretation. We have also mentioned that the PI has surveyed over 200 books, mostly popular science, that have inspired his informal science education projects, and all of which are listed on his website [35], being too numerous to be included in the citations.

Our project did not evolve in a vacuum: it incorporates the thinking of many scientists who are pioneering authors and experts in physical and biological evolution including Drs. Eric Chaisson [36], William Schopf [37, 38, 39], Andrew Knoll [40], John Tyler Bonner [41, 42], and Christian de Duve [43, 44]. Dr. Chaisson is the director of a science education center and has a superb website [45] devoted to cosmic evolution that serves as a role model for our more tightly focused global evolution project. The Museum of Paleontology at the University of California in Berkeley has a fine website [46] and some links between physical and biological evolution. Our approach will provide a major enhancement to their resources. Two other scientists and authors with expertise in informal science education are Dr. Art Sussman, author of Dr. Art's Guide to Planet Earth [47] and Dr. Art's Guide to Science, and Dr. Lawrence Krauss, author of six popular science books including Atom: An Odyssey from the Big Bang to Life on Earth… and Beyond [48]. Our project has been influenced by many informative books on geology and geophysics [49 - 57], climate and atmospheric science [58 - 62], evolutionary biology [63 - 84], and a few books that use an integrated science approach [85 - 91]. And this is our short list and does not include the multitude of science textbooks!

Earlier we described our plans for science courses based on broad evolution themes. The best example of the type of thematic course that we are familiar with is the Voyages Through Time high school science curriculum [92] that was produced by the SETI Institute in partnership with the California Academy of Science and with support from the NSF. This course includes six CDs and paperback readers, satisfies high school science requirements in California, and is used in many classrooms in several states. We have purchased and examined all six modules of instruction and will seek assessments of this course in practice. Our project will significantly enhance the use of and market for these resources.

C. Collaboration

1. PROJECT TEAM

a. Senior Staff

The project team includes five PhDs in physics, chemistry, biology, engineering, and English and education. Their diverse interests and skills cover all fields of science and education associated with this project. The principal investigator is Dr. Robert Field, an adjunct professor of physics who investigates the structure and evolution of the eight natural systems described previously. He has devoted 5000 hours over the past eight years to create and present dozens of informal science education programs and he currently serves as science education coordinator for "walk and talk" docents in the local state parks. Dr. Field and his co-PIs belong to the Cal Poly Center for Excellence in Science and Mathematics Education.

Dr. Seth Bush, assistant professor of chemistry education, and Dr. Michael Black, assistant professor of cell and molecular biology, will serve as co-principal investigators. Dr. Elizabeth Griffith, a physics lecturer and mechanical engineer, has experience in informal science education and in private sector engineering and is an expert in convective heat transfer, fluid mechanics, and thermal physics. She will help develop heuristic models to illustrate heat transport in the oceans, atmosphere, solid Earth, and Sun. Dr. Roberta Herter has a PhD in English and Education, is a consultant to the Central Coast Science Project, faculty associate and assessment consultant in the Center for Teaching and Learning, program coordinator and former chair of the Department of Graduate Studies in Education, and associate professor of Literacy Education and Reading. She also taught high school English teacher for nearly thirty years.

b. Advisory Committee Members

Our advisory staff committee includes Dr. Keith Stowe, professor of physics and author of textbooks on thermal physics and on oceanography, Dr. Dean Wendt, professor of marine biology, Dr. Chris Kitts, professor of biological science and expert in microbial ecology, Dr. Joseph Boone, professor of physics emeritus and author of a textbook on physical and biological evolution, Dr. John Poling, professor of physics who teaches astronomy and Earth sciences, Dr. Ken Hoffman, professor of physics and geophysicist, Dr. Lisa Lindert, assistant professor of chemistry with expertise in biochemistry and cell biology, Dr. Grace Neff, assistant professor, chemical educator and director of the Central Coast Science Project, and Dr. Lola Berber-Jimenez, chemistry lecturer and co-director of the Central Coast Science Project. The collective skills of our senior staff and advisors include science education, oceanography, atmospheric science, geophysics, geochemistry, astrophysics, biochemistry, geomicrobiology, cellular biology, marine biology, and ecology.

c. Consultants

Dr. Sam Ham, previously mentioned under impact evaluation, has agreed to review and evaluate this project to help us evaluate its success and improve its effectiveness in reaching its target audience. Sam Ham (Ph.D., University of Idaho; M.S., Washington State University) directs the Center for International Training and Outreach at the University of Idaho's College of Natural Resources (USA), where he is also a professor in the Department of Resource Recreation and Tourism. He has received numerous faculty awards, the National Association for Interpretation's Fellow Award, and an appointment in 1992 to the World Conservation Union's Commission on Education and Communication. Dr. Ham's research focuses on ecotourism guide training and the obstacles to environmental education in the Latin America/Caribbean and Asia/Pacific regions. He is also the author of many publications.

Dr. Mike Baird, internet consultant, nature photographer, state park docent, and author of a popular book on high tech businesses, will provide marketing and artistic assistance. Key advisor Marion Enfield is a retired high school history teacher and editor of four informal science education training manuals for school docents in the Morro Bay State Park Museum of Natural History. Richard Enfield is San Luis Obispo County Director for the University of California Department of Agricultural and Natural Resources. As 4-H youth development advisor, he pioneered the SLO Scientists program for youth and authors informal science education research papers. We will add one or two more consultants as needed.

d. Contractors

None.

2. PARTNERS

The primary partner is the San Luis Obispo Coast District State Park including the Morro Bay State Park Museum of Natural History. The museum manager, Rouvaishyana, is an enthusiastic and talented ranger with extensive experience in thematic interpretation and exhibit development. As the sector-wide interpretative specialist, he also supervises 200 docents (many retired educators and advanced degree holders) who serve in multiple state parks as well as in the museum. The science education coordinator of the state park "walk and talk" docents is Dr. Field, our principal investigator.

The San Luis Obispo County YMCA has also agreed to partner with us. They will help us reach target audiences, serve as examples for other organizations in future partnerships, help us evaluate the suitability of our programs for their audiences, and assist us with numerous logistical considerations in organizing and conducting programs intended for the population they serve. They have participated in programs affiliated with the California State Parks and they are interested in science-based nature and recreational programs for their youth and families. The YMCA serves kids, families, and communities.

The principal investigator, in his capacity as a state park docent and science education coordinator, is planning to conduct a program for fifth through eighth grade members of the YMCA this summer and a fall program for teens to demonstrate the benefits of collaboration. The combination of the scientific and educational resources of Cal Poly and the natural resources and informal science education programs in the California State Parks should attract many of the youth and families that the YMCA serves.

The Cal Poly library was very pleased with the popular Ocean Science Quest Natural Enquirer tabloid newspaper poster display that covered 200 square feet of wall space for the library in 2003 and the library has requested another display. They have agreed to exhibit our new project in 2009.

Nancy Merrifield, general manager of the National Geographic Theater Hearst Castle, has encouraged us to develop an exhibit for the Theater lobby. After examining a preliminary description which included examples of the artwork we envision for our project, **The Natural History of the California Coast**, she replied, "Your exhibit ideas are certainly right up our alley. It is subject matter that is in keeping with the State's mission as well as the Theater's goal to offer interest and additional educational opportunities to our guests. Your exhibit concept has been accepted by my State contacts. We would welcome the exhibit to be on display in our Theater lobby."

3. COLLABORATION PROCESS

The proposed project will provide benefits to our partners and will engage and inform their volunteer educators and existing paid professional staff. Our campus and our community have many artists, educators, and naturalists available as consultants or volunteers for this project. Collaborating organizations will provide access to audiences, free assistance, exhibit and program space, materials, volunteers, and publicity for exhibits and events. The principal investigator has produced many informal science educational programs for local organizations. His knowledge of the venues of the collaborating organizations, their audiences and their personnel are critical to project success. Knowledgeable individuals must be recruited and trained to facilitate the replication process in other communities.

The structure of our collaboration process is highly centralized because most of the collaborating organizations are led by highly multi-tasked individuals whose primary responsibilities are separate from this project. The same is true of the senior staff and advisors on this project. Our management model is based on twenty years of experience with large multi-disciplinary and multi-organization advanced aerospace projects. Many of our collaborators will play the role of customers who know what their audiences need and want when they see it but rely on us to develop and implement the programs.

Our collaborating organizations represent the interests of the audiences that they serve and which we intend to serve. The collaborators are not funded by this project and have independent missions to accomplish. Our goal is to help them accomplish their goals using our content, themes, and educational methodology in order to serve their audiences and to demonstrate our replication concept. The first Summer of Change will be coordinated in all ways by the principal investigator with assistance from the senior staff. Follow-up replications will move the co-principal investigators into leadership positions, a necessity in order to coordinate the multiple collaborations envisioned, a demonstration of the replication concept, and a practical use of labor given their experience in this project. The entire collaboration process is based on the concept of utilizing mutual interests in order to achieve affordable replication.

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Natural History of Planet Earth Informal Science Education Project

Assessment Plan and Formative and Summative Matrices

Prepared by Dr. Linda Shepherd, Interim Executive Director, Institute for Policy Research

The researcher has contracted with Cal Poly's **Institute for Policy Research–Assessment Division**, an independent evaluator, to deliver *formative* and *summative* assessments for the project. The attached formative and summative assessment matrices were developed in collaboration with Cal Poly's Institute for Policy Research. This collaboration will ensure effective monitoring and implementation of project objectives and will enhance project outcomes through the use of feedback mechanisms which are embedded throughout the project time period.

The Institute has scheduled ***Formative Assessments*** in project years one through three that are designed to evaluate ongoing project activities and to provide information that will assist in determining progress and improving the project at key stages. Components of the formative assessment strategy include *implementation evaluations* designed to determine whether activities are proceeding in the manner described in the proposal. Key questions in the formative evaluation determine progress in each aspect of the *Natural History of Planet Earth Informal Science Education Project* including staff training, research, Global Evolution Disc development, exhibit planning and implementation, and Living Natural History Program creation and development, throughout significant stages of the project. The *formative assessment* determines whether scheduled activities are taking place and whether they are occurring in the most efficient and effective manner.

The ***Summative Assessment*** is designed to determine and document program outcomes in areas of a) audience engagement, b) audience assimilation of information, and c) recruitment of individuals and organizations to replicate the *Natural History of Planet Earth Informal Science Education Project* in other communities. The planned use of the Institute for Policy Research's specific expertise for monitoring and assessment will add to the validity of findings and conclusions.

Formative Evaluation Matrix

Implementation: Formative Evaluation/Methodology Matrix:

Project Goals	Formative Evaluation Study Questions	Data Collection Methods *(see codes below)*					
		a	**b**	**c**	**d**	**e**	**f**
Natural History of Planet Earth Informal Science Education Project **Development of Global Evolution Disc**	Is project developing digital resources as expected for the Global Evolution Disc? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Is staff training in the development of thematic and global thinking proceeding as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Is secondary research proceeding as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Is the development of heuristic models proceeding as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Is the overall development of the Global Evolution Disc proceeding as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Does the Global Evolution Disc, as it is developing, appear to achieve educational objectives? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
Natural History of Planet Earth Informal Science Education Project **Development of Exhibits**	Is planning for the exhibits proceeding as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Are all exhibits moving forward to implementation phase with progress in building/construction as expected? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
	Do exhibits, as they are progressing, demonstrate the ability to achieve educational objectives? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X
Natural History of Planet Earth Informal Science Education Project **Development of Living Natural History Programs**	Is the development of the Living Natural History Programs proceeding as expected? If problems occurred at this stage, what were they? Why did these problems occur?	X	X			X	X
	Do the Living Natural History Programs, as they are progressing, demonstrate the ability to achieve educational objectives? If problems have occurred, what were they? Why did these problems occur?	X	X			X	X

DATA COLLECTION METHODS
a = interviews (students, volunteers, educators)
b = focus groups (students, volunteers, educators)
c = self-administered questionnaires completed by disc users
d = pre- and post-tests/surveys of audiences (trial and actual)
e = focus groups (Cal Poly faculty, PI, Co-PIs)
f = field observations

Formative assessments occur immediately after quarterly reviews during the three years of grant implementation.

Summative Evaluation Matrix

Evaluation/Methodology Matrix:

Project Goals and Outcomes	Summative Evaluation Study Questions	Data collection Methods *(see codes below)*					
		a	**b**	**c**	**d**	**e**	**f**
Natural History of Planet Earth Informal Science Education Project **Global Evolution Disc**	Did the Global Evolution Disc engage its viewers? In particular were viewers interested, involved, and participatory?	X	X	X	X	X	X
	Did the Global Evolution Disc result in enhanced information levels among audience members? Relevant methods will evaluate whether audiences were able to retain and use information and themes to think through scientific questions, realize the relationship between local and global natural history, understand natural systems, appreciate natural processes, comprehend natural system evolutionary changes, and seek additional learning experiences.	X	X	X	X	X	X
Outcomes	Did the Global Evolution Disc assist in recruiting individuals and organizations to help adapt and replicate the project in new communities?	X	X	X	X	X	
Natural History of Planet Earth Informal Science Education Project **Exhibits**	Did the Exhibits engage audience members? In particular were audiences interested, involved, and participatory?	X	X		X	X	X
	Did the Exhibits result in enhanced information levels among audience members? Relevant methods will evaluate whether audiences were able to retain and use information and themes to think through scientific questions, realize the relationship between local and global natural history, understand natural systems, appreciate natural processes, comprehend natural system evolutionary changes, and seek additional learning experiences.	X	X		X	X	X
Outcomes	Did the Exhibits assist in recruiting individuals and organizations to help adapt and replicate the project in new communities?	X	X		X	X	
Natural History of Planet Earth Informal Science Education Project **Living Natural History Programs**	Did the Living Natural History Programs engage audience members? In particular were audiences interested, involved, and participatory?	X	X		X	X	X
	Did the Living Natural History Programs result in enhanced information levels among audience members? Relevant methods will evaluate whether audiences were able to retain and use information and themes to think through scientific questions, realize the relationship between local and global natural history, understand natural systems, appreciate natural processes, comprehend natural system evolutionary changes, and seek additional learning experiences.	X	X		X	X	X
Outcomes	Did the Living Natural History Programs assist in recruiting individuals and organizations to help adapt and replicate the project in new communities?	X	X		X	X	

DATA COLLECTION METHODS
a = interviews (students, educators, volunteers)
b = focus groups (students, educators, volunteers)
c = self-administered questionnaires completed by disc users
d = pre- and post-tests/surveys of audiences (trial and actual)
e = focus groups (Cal Poly faculty, PI, Co-PIs)
f = field observations

Occurs during Summative Assessment of exhibits and activities in the **Summer of Change** phase in the third year of the project.