C. Project Description

1. Introduction

NSF is currently funding a partnership comprising the Southern California Earthquake Center (SCEC), the Consortium of Universities for Research in Earthquake Engineering (CUREE), and the Incorporated Research Institutes in Seismology (IRIS) to produce a pilot version of the web-based ***Electronic Encyclopedia of Earthquakes* (*E*^{3})**. The pilot project is on its way to success (see http://www.scec.org/ecube), and we are enthusiastic about continuing our collaboration, which brings together over one hundred research organizations in earthquake science and engineering. We therefore propose to expand ***E***^{3} into a major collection under the "Collections Track" of NSF Solicitation 01-55.

Earthquakes are a powerful theme for organizing a digital library and for providing educational access to a wide range of electronically available material. The largest earthquakes are planetary events generated by fault ruptures extending for a thousand kilometers or more, while the smallest earthquakes are fractures on the submillimeter scale, observed in the laboratory. Earthquakes are awesome natural phenomena and feared as agents of destruction; they cannot be controlled, nor does anyone yet know how to predict the time, place and size of individual large earthquakes. But earthquakes and their causes and effects are being studied by an increasingly rich array of observational and theoretical techniques, from high-precision satellite geodesy and high-performance seismometry to numerical simulations of strong ground motions and their destructive effects on buildings, lifelines, and urban systems. The scientists and engineers in our organizations are working with experts on the social and economic consequences of earthquakes to increase public awareness of earthquake dangers and reduce earthquake losses. An objective of this project is to further these twin goals by furnishing a well-organized portal for earthquake information.

The ***E***^{3} project has two further objectives: (1) to leverage student curiosity about earthquakes into a better understanding of empirical inquiry and the scientific method, and (2) to furnish compelling examples of physics and mathematics in real-world action. The collection is aimed at supporting high schools and colleges by providing educators and students with the tools and resources for instruction, study and research. Primary users will include teachers who employ inquiry-based techniques to explore specific topics and students seeking materials for independent projects and research. The site will provide access to a wide variety of teaching materials, and it will link curricula to interfaces for accessing many types of archived and real-time databases, including the data from global and regional seismic networks, the national seismic hazard maps, and elastic and inelastic response histories of structures exposed to real or simulated (e.g. shake table) earthquakes. Hence, the site will facilitate the use of large data sets as part of an on-line learning environment that encourages and facilitates inquiry and exploration.

E^3 will be a much-needed portal for students, educators, and others seeking information about the science of earthquakes, earthquake engineering, and the practical aspects of hazard characterization and loss reduction. There are many websites that contain excellent activities about earthquakes, but there is no unifying place where learners of all ages can access the information they need quickly and in an organized fashion. ***E***^{3} will make earthquake information relevant to all members of the community, promote scientific literacy, and stress empowerment by providing a resource that is easily navigated and utilized. To the reviewer of this proposal who finds these goals lofty and general, we would agree, but we offer a specific plan for realizing those aims based on the pilot project phase of ***E***^{3}.

E^3 will appeal to educators in formal and informal learning environments because it will provide a contextual and organized setting where they can obtain relevant information linked directly to the National Science Education Standards (NSES), which were published by the National Research Council in late 1995. ***E***^{3} will address the following NSES content standards for grades 5-8 and 9-12:

- Science as Inquiry
- Physical Science
- Earth and Space Science
- Science and Technology
- Science in Personal and Social Perspectives
- History and Nature of Science

2. Results of Prior NSF-Sponsored Research

Since 1991, the Southern California Earthquake Center (SCEC) has been the primary organization funded by the NSF and U.S. Geological Survey (USGS) for coordinating earthquake research in Southern California. The accomplishments of SCEC scientists have been published in more than 500 scientific articles and special publications, and the results have been synthesized into a "Master Model" of probabilistic seismic hazard in the Los Angeles region (http://www.scec.org/research/index.html). SCEC has also organized major data-collection facilities in Southern California, such as the Southern California Integrated GPS Network (SCIGN), and set up an infrastructure that allows researchers to share data, instruments and expertise (http://www.scec.org/research/data/index.html). It has developed on-line data archives for all available seismic records, geodetic data, and satellite radar images for Southern California, and it established the first on-line, web-based relational database for retrieving strong-motion data. SCEC's Education & Outreach program has built upon the methods, goals, and achievements of SCEC research to create products and services that meet the needs of students, educators, engineers, government officials, and the general public (http://www.scec.org/outreach/products/index.html) and to further geoscience education (http://www.scec.org/outreach/education/index.html).

The NSF-sponsored research most relevant to the current proposal is the pilot project for the ***Electronic Encyclopedia of Earthquakes*** [NSF Grant EAR-0085511, 09/01/00-08/31/02, $86,867], which began in August, 2000. The ***E*^{3}** partnership comprises SCEC, CUREE, and IRIS and is structured as a collaboration with the Digital Library for Earth System Education (DLESE).[1] Although the funding began only in August, 2000, we can report progress on several fronts:

DLESE collaboration. ***E*^{3}** staff have attended several DLESE workshops and participate in DLESE on-line discussion groups. DLESE is an information system dedicated to the collection, enhancement, and distribution of materials that facilitate learning about the Earth System.[2] It is a distributed effort, involving the Earth System education community as well as interested groups in information technology and library science.[3] In addition to individual resources (lessons, Java applets, videos, etc.) scattered about the Web on a multitude of sites, DLESE contains collections like ***E*^{3}** – thematically oriented and maintained by cooperating institutions.[4] Collaborating Partners agree to abide by the DLESE Articles of Federation and adhere to the policies set forth by the DLESE Steering Committee. In doing so, they benefit from access to coordinating, technical and community services.

Concept, scope and structure of the encyclopedia. The concept, scope and structure of the collection has been refined. Like a traditional printed encyclopedia, ***E*^{3}** is an entry-based collection, comprising a set of primary topics with cross-referenced explanations and sets of information. The root meaning of *encyclopedia* as a circle of knowledge also applies, because the expanse of topics will cover the earthquake subject in a way that is both multidisciplinary and integrated. The integration spans four basic fields of knowledge that correspond to common curricular categories—geoscience, engineering, physics, and mathematics—as well as selected topics related to the impacts of earthquakes on human systems.

At the same time, ***E*^{3}** differs from a traditional encyclopedia in many essential respects. A user will be able to access knowledge on a simple level quickly or probe deeper for more detailed information. Content will be available in animated and narrated (video or audio) formats, as well as in text and illustrations, and it will be dynamic—updated and constantly changing as new information is collected.

1 DLESE Articles of Federation, http://www.dlese.org/documents/policy/art_of_fed1-19-01.html.
2 DLESE Collections Policy, http://www.dlese.org/documents/policy/collection_policy.html.
3 DLESE Overview, http://www.dlese.org/about/index.html.
4 DLESE Collections Scope Statement, http://www.dlese.org/documents/policy/CollectionsScope_final.html.

Box 1. Sample of E^3 entry topics

Engineering	Geoscience
Building codes	Aftershock
Dynamic response of structures	Earthquake
Lifelines	Fault
Loss estimation	Ground Motion
Moment frame	Intensity
Response spectra	Liquefaction
Retrofit	Magnitude
Shake table	Plate tectonics
Shearwall	Seismic hazard mapping
Woodframe buildings	Seismograph

Most important, the inquiry process will be interactive between the user and the collection, allowing the learner to discover many different pathways through the subject matter or even to create new knowledge through the manipulation and synthesis of different types of information.

Much of our work to date has focused on the scope of $\boldsymbol{E^3}$—the range of topics ("entries") to include and the depth of information to provide for each. The objective of the pilot project is to complete 15 initial entries. However, proper planning required that we develop a prototype list of several hundred entries early in the project, a version of which we have already completed. A small sample of entry topics is provided in **Box 1**.

While a collection of this size will be comprehensive, we seek to ensure that the content will also meet high standards of accuracy (see **Section 5**). Of course, no collection can be ideal, so we have attempted to formulate a project plan that will allow us to address the tradeoffs of *accessibility* versus *accuracy*, and *quantity* versus *quality*. A key aspect of this plan is the layering of information illustrated in **Box 2**. The quantity of information provided will be consistent at the primary (glossary-definition) level, but, as users delve into the secondary and tertiary layers, the collection will become more heterogeneous, and the quantity will vary, based upon the availability of high-quality technical content.

3. Scope of Proposed Collection

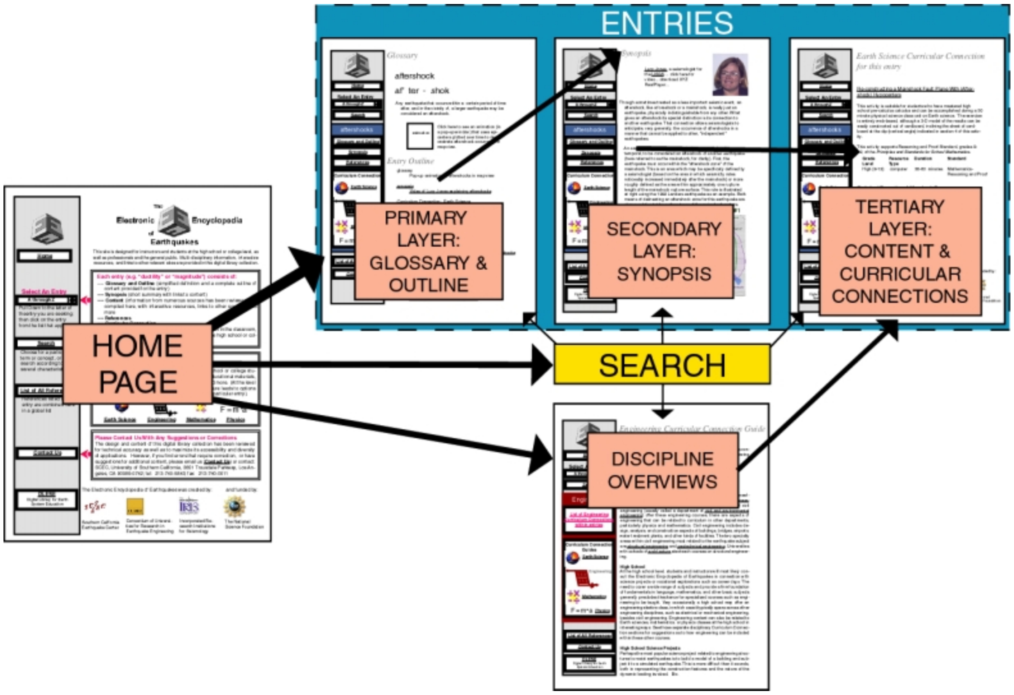
a. General features

$\boldsymbol{E^3}$ will feature knowledge and inquiry related to earthquakes in the areas of geoscience, engineering, physics and mathematics. This digital-library collection will be organized as several hundred primary entries, which will range from basic concepts to advanced methods in geoscience and engineering, including research methods. Supplements to these entries will be furnished in the form of archived and/or real-time data sets, maps and other images, catalogued resources available via the internet, and links to teaching materials. The goal is to provide clearly organized, dynamic information that allows the learner to discover many different paths through the subject matter. $\boldsymbol{E^3}$ will allow people of all ages and professions to learn not only about earthquakes and seismic safety, but also about basic topics that span the range of natural sciences, mathematics, engineering, and technology. The fact that the subject of earthquakes brings together knowledge from so many disciplines makes $\boldsymbol{E^3}$ an attractive gateway to problem-oriented learning and especially relevant for inclusion in NSDL.

As part of our responsibility as a collaborating partner with DLESE, we will base $\boldsymbol{E^3}$ on the DLESE collections policy and statement of scope.[1-4] Though the subject matter of DLESE is considerably broader than that of $\boldsymbol{E^3}$ (Earth system vs. earthquakes), the guidelines for resource types and the emphasis on interdisciplinary areas will effectively be the same. $\boldsymbol{E^3}$ will favor materials that bring the Earth into the classroom or other learning sites and connect the general with the specific, theory with evidence, and the global with the local. We will also favor materials that are well-documented, easy to use, motivational for learners, pedagogically effective, scientifically accurate, and which foster mastery of significant understandings or skills. We have built the DLESE categorization of grade level and type of learning activity into the pilot version of $\boldsymbol{E^3}$, in order to be consistent with, and to facilitate, higher levels of digital library cataloging.

Box 2. Structure of the *Electronic Encyclopedia of Earthquakes*

Content within the $\boldsymbol{E^3}$ collection will be organized into topics ("entries"), selected on the home page from an alphabetical list. A search engine, as well as map-based access, will guide visitors who know what type of information they are seeking. *Discipline Overviews* in geoscience, engineering, mathematics, and physics will suggest how to use the curricular material organized within the collection, based on user-specified parameters.



Primary Layer: Glossary and Outline. This primary page for each entry contains a glossary-type definition of the term and an outline of content accessible within the entry.

Secondary Layer: Synopsis. The synopsis page provides a detailed overview of the entry topic, summarizing the content in lower layers and linking it to other entries. For example, the synopsis of "liquefaction" entry will explain that the settlement and closer packing of granular (sandy) particles, if saturated with ground water, results in an increase in the pressure on the water in the pore spaces between grains of soil, in effect providing sudden lubrication to allow particles to move, resulting in a temporary fluidity of previously solid ground. Information about the effects of liquefaction on buildings will be provided (along with images and animations), and a basic summary of how liquefaction potential can be mitigated would be included.

Tertiary Layer: Content In Depth and Curricular Connections. The tertiary layer provides access to the heterogeneous resources of the $\boldsymbol{E^3}$ collection. In the liquefaction example, a geology student would open *Content In Depth* to learn what kinds of non-cohesive geologic materials are most susceptible to liquefaction, given the essential ingredients of strong shaking, sufficient duration, and water saturation. This information might be provided by an annotated listing of regional sedimentary sequences, with reference to published papers on the subject. For a geotechnical engineering student, the desired information would probably be related to soil mechanics, such as the properties of density, particle size, or field test data. An environmental planning student might be more interested in land-use planning and building-code microzonation. *Curricular Connections* for liquefaction would include sample laboratory experiments and other online teaching resources that are catalogued according to discipline (geoscience, engineering, mathematics, or physics), grade level (DLESE-defined increments spanning K-12 and college.) type (classroom, laboratory, online, etc.), duration (15 minutes, 1 class period, 2 weeks, etc.), or other criteria.

Other criteria for limiting the scope of our collection pertain to resource access. We will conform to DLESE standards regarding three types of access issues:[4]

1. *Technical Requirements:* Resources will be digital, such that they are viewable, usable, or downloadable with available WWW technology; i.e., browsers, plug-ins, scripting languages, applets. If a resource depends on technology beyond a standard browser, a description of the technical requirements must be provided in the catalog record.
2. *Language:* Resources will be primarily in English. If a resource is also available in other languages, these languages will be noted in the catalog record. All catalog records and library interfaces will be in English.
3. *Copyright:* The collection will be dominated by resources that (a) are available for personal or educational use, without restrictions, and for free or at low cost, and (b) can be indexed and distributed by DLESE without restrictions.

Content and features that will comprise ***E*^{3}** entries or be provided as annotated links include:

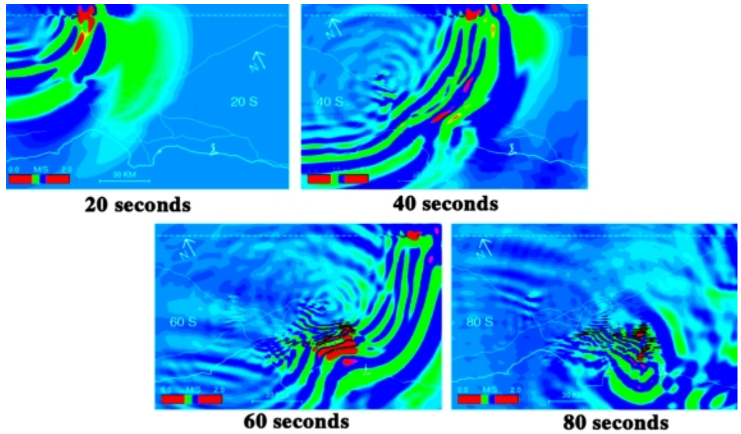
- Data, and tools to analyze or manipulate the data, such as the comprehensive data sets developed and maintained by SCEC and IRIS.
- Text from scientific papers, summaries, indices and abstracts, including those produced by all three organizations and their affiliated institutions.
- Images, including private collections of CUREE and investigators associated with SCEC and IRIS; models and simulations, such as those constructed by SCEC's Strong Motion Group and the Southern California Integrated GPS Network.
- Animations and videos, lesson plans and curricula; learning activities; educational multimedia, such as those created by SCEC and NASA/JPL for community colleges and accelerated high schools (*Investigating Earthquakes through Regional Seismicity*, http://www.scecdc.scec.org/Module/module.html, and *Exploring the Use of Space Technology in Earthquake Studies*, http://scign.jpl.nasa.gov/learn).
- Field trips, including downloadable maps and guides for "real" trips as well as on-line "virtual" trips.
- Student research projects, such as those collected by SCEC and IRIS as products of their summer internships programs.
- Brief video introductions by national experts in various earthquake-related fields will be included on selected synopsis pages as an additional overview.

b. Specific examples of content to be included within E^3

Following are geoscience, engineering, physics, and mathematics examples that illustrate how this project will present and format data, analytical tools, and other knowledge on its Webservice.

Geoscience: From either the entry on "magnitude" or the entry on "ground motion", the dependence of duration on magnitude will be presented by providing a map-based choice of scenario earthquakes having a range of magnitudes and locations. An animated simulation of a chosen earthquake will display the ground motions on a map, as in **Figure 1**. Waves spread out from the epicenter, continue emanating from the rupturing fault, and gradually die out. A few trials for various magnitudes quickly provides an intuitive grasp of the way duration increases with magnitude. The relationship between energy release and magnitude and the propagation of ruptures along a fault are communicated in a quite different way than possible in printed pages and static illustrations. Users with more in-depth needs can be linked to extensive databases of earthquakes, such as those maintained by IRIS and SCEC.

Figure 1. Representation of Animated Display of Propagation of Ground Motion (Magnitude-Duration Relationship) [See www.crustal.ucsb.edu/~kbolsen/SCEC.html for an animated version]



Engineering: The entry on "dynamic response of structures" will allow the user to select from an archive of accelerograms from past earthquakes and a set of structural models ("models" in the analytical sense of having structural layouts, members, typical material properties, etc. adequately defined to allow a program to quickly compute its response once the ground motion input is selected). A visual representation of the response of the 3D structure will then be shown, second-by-second, as the plot of the accelerogram unfolds. A menu could allow the user to see various results, such as a plot of peak displacements or peak accelerations experienced by the structure, story-by-story. Engineering schools at several universities have developed such "virtual shake table" websites, and our collection will catalog and incorporate this content. The fact that a particular ground motion record with a high peak acceleration may not cause as much response in a given structure as a record with a lower peak acceleration could be visually conveyed as one experiments with a few accelerograms. This can also be controlled and observed remotely (via tele-operation and tele-observation), as a physical experiment in addition to analytically, via a Webservice at the University of California at San Diego

Figure 2. Webshaker Live Simulation. This experiment can be controlled and observed remotely (via teleoperation and teleobservation), in addition to analytically, via a Webservice at the University of California at San Diego (http://webshaker.ucsd.edu).

(http://webshaker.ucsd.edu) or via a modeled ("virtual") shake table experiment at http://www.nd.edu/~quake/java/, a website at the University of Notre Dame funded through the Multidisciplinary Center for Earthquake Engineering (MCEER) (**Figure 3**). Integrating this kind of existing content into ***E*^{3}** is an example of the way this kind of information can be made more accessible and more widely used. The more demanding user, for example a graduate student, might wish to use a link to the SCEC Database of 5,000 strong-motion accelerograms (http://smdb.crustal.ucsb.edu) from 119 earthquakes where sets of accelerograms may be selected and used in research based on a number of characteristics or statistics.

Physics/Mathematics: ***E*^{3}** is providing examples of the physics and mathematics used in engineering and geoscience. For example, there will be illustrations of how structural engineers use vectors and trigonometric functions to calculate how a diagonal brace works to resist horizontal earthquake forces, given the angle of the brace and how strong the brace must be. The content already exists from published materials and course notes developed by SCEC and CUREE professors; making this interactive will be a matter of providing an appropriate interface, such as a diagonal brace the user can click on and drag to a steeper or less steep angle, with the resulting increase or decrease in strength required displayed and related to trigonometry.

Fault rupture, as quantified in earthquake magnitude, involves a use of exponents that fits nicely with high school mathematics classes. Each unit difference on the magnitude scale represents approximately 30 times the energy, so that a magnitude-8 event produces 30^3 times more energy than a magnitude-5 earthquake. Larger events are less frequent than smaller ones, but only by about a factor of ten per unit of magnitude (so-called Gutenberg-Richter statistics); therefore, the student will learn that more cumulative energy is released in larger events. The student might then be encouraged to examine questions that extend further into the field of seismology, such as the maximum magnitude set by the average annual earthquake energy budget of a region.

4. Collection Architecture and Technical Infrastructure

The challenge of a project like ***E*^{3}** lies not in hosting a collection of hundreds of resources on-line, but in quickly and accurately targeting those resources to any user—no small feat when the range of users may include middle-school science teachers, groups of high-school students, and university researchers. Research in information science that reveals that average Web users get frustrated and will consider leaving a site if it takes more than three "clicks" (hyperlinks) to find the information they seek. The method of content delivery is therefore critical to the success of a collection.

The entry-based, three-layer organization of content in ***E*^{3}** is one means of addressing this issue. Dividing the content of ***E*^{3}** into specific entries gives the user an extremely rapid way to find information by single keyword—in this case, the title of an entry. (The average Web user performs searches using at most one or two keywords.) Of course, not all possible keywords will be represented by entries, and some users will want to find resources within ***E*^{3}** that meet very selective criteria—e.g. a middle-school teacher may want to find a write-up of a hands-on classroom activity that demonstrates different fault motions and takes no more than 50 minutes to complete—so that mechanisms will be put in place to conduct custom searches of the collection.

Three types of search interfaces are proposed. The most basic is a keyword search engine that allows a user to find content within ***E*^{3}** by entering a set of terms, including optional Boolean operators. A more involved interface will feature menus of controlled vocabulary (resource type, discipline, grade-level, etc.) from which a user may select multiple options to search for specific types of content within the collection, as in the example of the middle-school teacher given above. A map interface will also be available for specified types of geographical searches, since much of the information about earthquakes is geographically specific. Regardless of the interface selected, the system will always return a list of items within E^3 that match the user-imposed criteria or, should the search produce no results at all, offer suggestions for a more productive search.

To provide the user with this kind of dynamically-delivered content rather than static web pages requires the development of a relational database management system with an accompanying metadata standard. This benefits not only the user (by allowing easily customized searches of the collection), but serves to ensure the sustainability of the system itself, because a database backbone allows the collection to evolve in ways that a static catalog cannot. This choice will ease transferring the collection to new computer systems, as advances in information technology render current systems obsolete. The use of a database to manage the collection will also assist in our self-assessments. For example, by tracking the number and types of database transactions conducted once E^3 goes public, we will be able to recognize the most common search strategies performed by users of the collection. Through this and similar investigations, we should be able to modify elements of the system to cater to what we identify as the more popular uses of E^3.

We have formed partnerships with two organizations already familiar with the challenges of creating and maintaining relational database management systems: DLESE and the Information Services Division (ISD) of the University of Southern California (USC). We are working with Barbara Shepard, the Digital Information Director for the ISD, to establish a relationship with the Collection Information System (CIS), the database back-end to USC's planned digital library. Our partnership with the ISD will not only provide us with access to their Oracle database repository, but also keep us informed of the latest research in information science, which we hope will translate into effective refinements of our user interface design, searching protocols, and other operational aspects of E^3. In addition, this coordination will guarantee a minimum standard of interoperability with the digital libraries developed at USC and other universities. We note that IRIS also has considerable experience in relational database management and that the IRIS Data Management System is also Oracle-based, providing uniformity and interoperability between partners.

As a Collaborating Partner with DLESE, we have committed ourselves to the highest practical degree of interoperability with the DLESE portal (http://www.dlese.org/). In particular, we will use the IMS (XML-based) metadata standard,[5] the same as that used by DLESE, to mark each of the resources within E^3, allowing the results of a user search to be dynamically assembled and displayed. By adopting this standard, E^3 will allow "federated searching" from the DLESE portal, which should ensure the full availability of our collection resources to users who begin their search at DLESE. At the same time, DLESE will note which resources in their search result lists belong to our collection,[4] so that DLESE users will know that E^3 is serving their needs.

5. Project Organization

The organization of the proposed project closely follows that of the currently funded pilot, although the roster of key personnel has been modified to reflect changes in the leadership and staffing of the participating organizations. SCEC will continue to collaborate with two subawardee partners, CUREE and IRIS. The Principal Investigator will be Professor Thomas H. Jordan, W. M. Keck Professor of Earth Sciences and Director-Designate, Southern California Earthquake Center.

a. *Qualifications of participating organizations*

Southern California Earthquake Center: SCEC is a community of scientists at 40 institutions engaged in interdisciplinary research on earthquakes and seismic hazard, with its administrative offices located at the University of Southern California (USC). SCEC was founded in 1991 as one of 23 National Science

[5] For more about IMS metadata, see IMS Global Learning Consortium, Inc. at http://www.imsproject.org/.

Foundation (NSF) Science and Technology Centers, co-funded by NSF and the United States Geological Survey (USGS). The Center's mission is to gather knowledge about earthquakes in Southern California, to integrate this knowledge into a comprehensive and predictive understanding of earthquake phenomena as a scientific basis for seismic hazard analysis, and to transfer this understanding through communication with scientists, engineers, emergency managers, and community leaders, and through education of students and the general public.

SCEC is known nationally and internationally for its effective alliances with government entities, academic institutions, industry, and the media; it has become a leading voice for earthquake science in the United States. Through partnerships with museums, schools, and the media, SCEC runs an effective outreach program in earthquake-related education that encourages public participation in, and understanding of, earthquake science. SCEC is a broker of information between the academic community and practitioners, between Earth scientists and engineers, between technical professionals and public officials, and between scientists and educators. Many sources of earthquake information are provided, including the SCEC InstaNET News Service, a feature that encourages interactivity among Earth scientists, engineers and the public via on-line articles and e-mailed announcements. Other information and resources, including the popular “Putting Down Roots in Earthquake Country” earthquake awareness brochure, recent earthquake activity and data, seismic hazard reports, and web-based undergraduate level education modules can be accessed via SCEC's web services. Workshops, short courses, field trips, and other activities are held regularly to distribute SCEC information and resources.

Consortium of Universities for Research in Earthquake Engineering: CUREE is a non-profit corporation formed in 1988, dedicated to earthquake engineering research and education, as well as the implementation of earthquake engineering knowledge. CUREE currently has 22 university members—essentially the Civil and Environmental Engineering departments of those universities—with members located in all regions of the country. It has previously collaborated with SCEC on the interface between earthquake science and engineering.

CUREE currently manages the CUREE-Caltech Woodframe Project, a $7 million FEMA-funded effort to reduce the vulnerability of wood buildings to earthquakes, and is a partner in the SAC Joint Venture’s $10 million effort, also funded by FEMA, to solve the steel frame problems that surfaced in the 1994 Northridge Earthquake. Following the 1994 Northridge Earthquake, CUREE took the lead in bringing together all National Earthquake Hazards Reduction Program NEHRP-funded researchers working on the Earthquake to produce a directory linking fellow researchers and publicizing the research to potential users, and a national conference was convened where research results were presented.

Incorporated Research Institutions for Seismology: IRIS is a consortium of 97 research institutions funded by NSF to provide facilities in support of seismological research and education. The core programs of IRIS include the Global Seismographic Network (GSN), the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), the Data Management System (DMS) and the Education and Outreach Program (E&O).

IRIS manages large seismic data sets from extensive national and global instrument arrays, both archived and real-time. It can leverage considerable additional content, expertise, and assistance through its national membership and foreign affiliates. The IRIS E&O program has activities designed to reach a broad audience and focus on IRIS’s strengths—in particular, access to seismological data and resources of a large scientific community.

b. Project organization and management

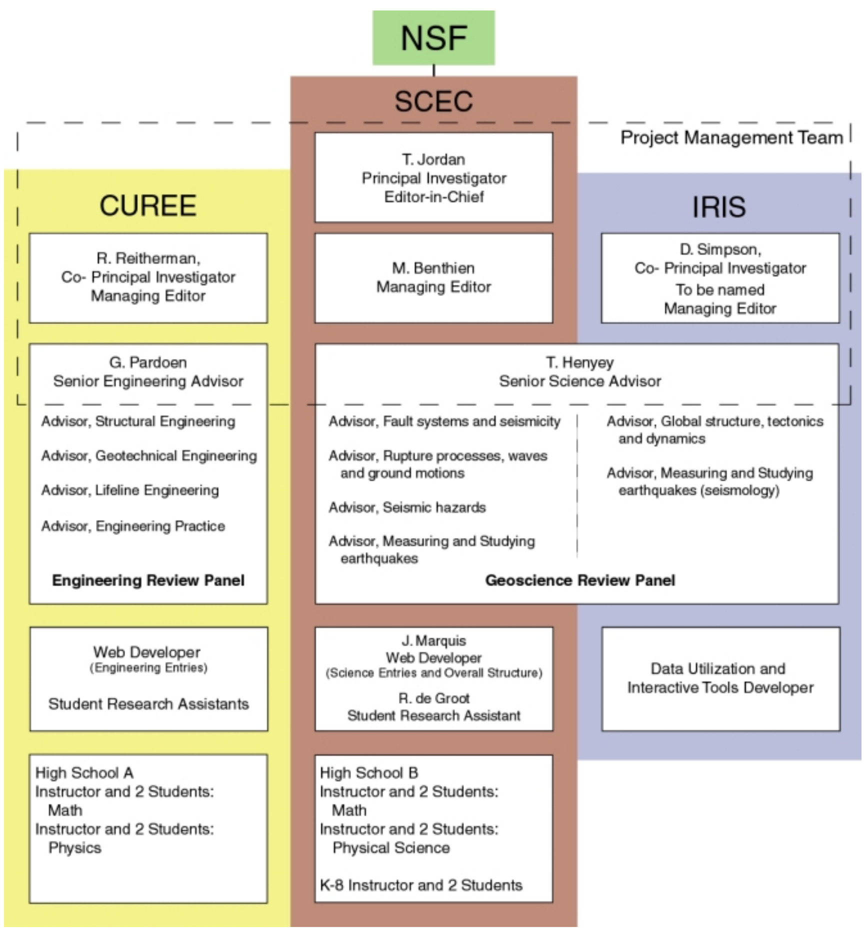
Figure 3 shows the E^3 project organization chart. SCEC will be the grant recipient, with Thomas H, Jordan, Director-Designate of SCEC as Principal Investigator and Editor-in-Chief. Mark Benthien, SCEC Associate Director for Outreach, will serve as Managing Editor for SCEC. Robert Reitherman, Executive

Director of CUREE, will be co-Principal Investigator and Managing Editor for CUREE. David Simpson, President of IRIS, will be co-Principal Investigator, and the next Education and Outreach Director for IRIS (being recruited now) will serve as Managing Editor. Professors Thomas Henyey of SCEC/USC and Gerard Pardoen of CUREE/UC Irvine will act as senior geoscience and engineering advisors, respectively. Together, this group will constitute the Project Management Team.

The Senior Science and Engineering Advisors will work closely with the Editor-in-Chief and Managing Editors to ensure appropriate treatment and quality control for each topic, including identifying the list of entries that will be added to $\boldsymbol{E}^3$. They will chair the geoscience and engineering advisory panels comprised of "Topic Advisors" whose expertise relates to a subset of the entries (**Figure 3**). The Topic Advisors will be primarily responsible for discovery of content, entry development, and evaluation. Advisors will include members of SCEC, CUREE, and IRIS that have experience in teaching or developing curricula for high school or college courses.

Each organization will provide additional staff to develop $\boldsymbol{E}^3$. John Marquis, SCEC Digital Products Developer, will serve as Web Developer for geoscience content and the overall structure of $\boldsymbol{E}^3$. Robert de Groot, SCEC Education Specialist and USC Science Education graduate student, will provide curricular development and review expertise as a student research assistantship. CUREE will provide a web developer for engineering content, as well as two undergraduate summertime research assistants recruited from the Engineering Co-op job placement program at UC Berkeley (the nearest university to the CUREE

Figure 3: Project Organization Chart



offices) and one summertime high school research assistant. IRIS will provide a specialist in data utilization and interactive web-tools for working with data, including visualization.

In addition, further review and beta-testing will be conducted by a cadre of teachers and college instructors who have worked as collaborators with SCEC's Education programs (such as development of on-line curricula, and summer teacher training workshops) for the last four years, including teacher trainers of the California K-12 Alliance and Project ALERT. Project ALERT is a consortium of ten California State Universities and NASA Centers (Ames and Jet Propulsion Laboratory) dedicated to improving Earth system science instruction for future teachers, through creation of teaching modules, course innovations, and NASA-CSU collaborative teaching, research, and internship opportunities (see http://projectalert.nasa.gov). Through the ALERT-***E***^{3} collaboration, $\boldsymbol{E^3}$ will be introduced to faculty at California CSU campuses and community colleges that are involved in the preparation of future teachers.

6. Collection Development and Review Process

The development of the $\boldsymbol{E^3}$ collection is designed as a six-step process. These steps—discovery, evaluation, entry development, curricular review, final-draft approval, and incorporation—are outlined below. The key quality control steps are: Step 2, Content Evaluation, when the Topic Advisors working at the level of their sub-disciplines organize and evaluate content; Step 4, Curricular Review, when the content is incorporated into the context of applications for different disciplines and grade levels; and Step 5, Final Draft, when the results of step 4 are reviewed by the Editor-in-Chief.

To assist in the initial stages of content discovery, the $\boldsymbol{E^3}$ project staff has created a list of expected encyclopedia entries. This list includes several hundred terms, a mastery of which is deemed important for a complete understanding of the earthquake phenomenon and its effect on human activities. As content is discovered, it may be incorporated within one of these pre-designated entries or it may necessitate the creation of an entirely new entry. The process for collection development and review outlined below accommodates either scenario.

Step 1: Content Discovery

The initial phase of content discovery will be largely dependent upon the work of individual members of the three participating institutions. From this pool of hundreds of earth science and engineering professionals, we expect to draw a large volume of content spanning the full scope of the collection. By raising internal awareness of $\boldsymbol{E^3}$ through mailings, direct contact with members, and special sessions at institutional meetings, we will encourage those with existing resources to take advantage of the free on-line publication of those materials, and the subsequent recognition that their publication will merit.

While we are confident that the combined resources of the three institutions participating in $\boldsymbol{E^3}$ will provide a large base of content upon which to build the initial structure of the encyclopedia, we recognize that much of the work involved in content discovery must be distributed among the community. Specifically, the initial metadata cataloging process can be extremely labor intensive; DLESE has learned that in the production of a digital resource, 2/3 of the cost is creating metadata.[6] Thanks to our collaboration with DLESE, we will save considerable effort in the process of content discovery and metadata entry by inviting the community to contribute resources to the encyclopedia by means of two web-based systems already created by DLESE. The simpler of these two ("Suggest a URL")[7] will be aimed at casual users to solicit suggestions for resources that would then be investigated at cataloged (if appropriate) by the $\boldsymbol{E^3}$ project staff. The more advanced discovery system would be a modified version of the DLESE Resource Cataloger,[8] a system that automatically converts the input from a web-based form (a

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[6] Metadata Focus Group PowerPoint presentation, DLESE Leadership Workshop, 30 June 2000.
[7] DLESE, "Suggest a URL", available at http://www.dlese.org/suggestor_forms/suggest_url.jsp.
[8] DLESE Resource Cataloger, accessed through http://www.dlese.org/catalog/forms/launch.html.

questionnaire about specific characteristics of a resource) into an IMS metadata record and places that record into a database on a preliminary basis.

Because the scope of ***E*^{3}** is more focused than that of DLESE, we will effect changes and additions to the DLESE Resource Cataloger and develop metadata extensions that meet the needs of our project. These extensions will allow a refinement of searches not currently possible on DLESE as a whole, owing to the broad nature of their collection. For example, the wide range of disciplines covered in Earth system education places a limitation on the specificity of their controlled vocabularies. To address this difference in scope, we will create our own analogous controlled vocabulary lists for our ***E*^{3}** Resource Cataloger to assist contributors of content in assigning resources to particular areas within the fields of earthquake-related science and engineering. This, in turn, will assist the Topic Advisors as they determine the proper entry placement of content in Step 2.

The work of the voluntary contributors from our participating organizations will be done without cost to the project. We do intend to provide incentives, however. Contributors who are not creators would receive a public note of thanks on a special page of our website; creators will have their material published with appropriate credit in a widely accessible electronic publication. In some cases, a creator's material might be enhanced, and the creator would, of course, be able to re-use his or her work with these new modifications. For example, if a static map is provided and is then converted into an active map that the user can click on to access geographically-related content, that on-line product will also be made available to its originator, so that this enhanced material can be mounted on his or her website.

Step 2: Content Evaluation

The online ***E*^{3}** Resource Cataloger and "Suggest a URL", in combination with active solicitations to our institutions, are expected to generate a large quantity of potential content from contributors. If enough information about a resource has been provided to create a record within our database, the Topic Advisors will investigate and evaluate this content for possible inclusion in ***E*^{3}**. In their evaluations, five considerations will be important:

1. *Relevance.* Is the resource relevant to earthquake education?
2. *Integrity*. Are there no blatant errors of fact in the resource? Are there no blatant political, religious, or commercial messages in the resource? Does it function reasonably; i.e., seem to be basically bug-free? These first two considerations are the same as the two primary filters applied to resources suggested for inclusion within the DLESE collection.
3. *Access.* Is this content easy accessible for potential users? Are there technical, linguistical, or copyright issues which might restrict access for many users?
4. *Classification.* Under which entry heading will this content fit, or does it require the creation of an entirely new entry in ***E*^{3}**? If the content was submitted through the ***E*^{3}** Resource Cataloger, has it been properly cataloged by the contributor?
5. *Quality.* ***E*^{3}** Topic Advisors will judge the quality of resources using the seven criteria DLESE has developed to select high-quality resources from their Broad Collection for promotion to their more prestigious Reviewed Collection. According the DLESE standards, high-quality resources are (a) easy to use, (b) well-documented, (c) scientifically accurate, (d) significant, (e) motivational, (f) robust and sustainable as digital resources, and (g) pedagogically effective.

The Managing Editors will be responsible for overseeing this task and managing the work of the Panels. It is expected that coordination and communication among the Topic Advisors and each Managing Editor can occur remotely without the need for face-to-face meetings, other than those provided by the partner organizations (e.g., annual meetings and research workshops) and at the special Curricula Review workshops described below.

Step 3: Entry Development

Having determined whether newly approved, raw content is part of a particular, pre-existing entry or warrants the creation of a new entry, the Topic Advisors will then assign that content to a specific place within $\boldsymbol{E^3}$ on a provisional basis (similar to, but distinct from, that of the initial, contributor-cataloged metadata record). Items marked with this provisional status will be password-accessible for reviewers as required for Step 4, but not visible to public browsers. If a new entry is needed, the process for its construction is as follows:

1. The new entry term is identified by the Panel;
2. This term is defined and the contents of the entry outlined (*Glossary & Outline* level);
3. A synopsis of the entry is developed (*Synopsis* level);
4. *Curricular Connections* and *Content In Depth* are identified and linked;
5. Other search parameters are assigned;
6. Any necessary permission for use of the material is obtained and the exact credit wording is established.

For content that fits within an established entry, the process will be similar, though the entry definition, outline, synopsis, and curricular connections will be modified only as needed to incorporate the new content. If necessary, these changes will be held within a revised copy of the entry visible only to reviewers. The database structure of the collection makes it relatively easy to add new content within existing entries. These draft materials will then await further curricular review and final approval before they are fully incorporated into $\boldsymbol{E^3}$.

Step 4: Curricular Connection Review

Once the Review Panels have identified and evaluated a significant set of resources for curricular use, the K-12 and college curricular reviewers will be convened at a small workshop. At this point, we will know which contributors have been the most helpful and interested in the project, and can allocate travel funds accordingly. Each workshop will deal with one of the four engineering or six geoscience topics. We should be able to schedule the four engineering workshops, each a half-day in duration, to occur consecutively over a two-day time span, in order to maximize participation and minimize travel costs. Similarly, at least three of the six geociences workshops can be scheduled together. In addition to the half-day of time allotted for the workshop, participants will be expected to devote additional time to reviewing the collection and making comments via an on-line input form. The workshop participants are shown below:

Curricula Review Workshops

Participants Unique to a Given Topical Workshop (5 to 7)

Panelist, plus his or her student (2); sometimes one or more other Topic Advisors depending upon the identified overlap in content
Two or three major contributors (3)

Participants Common to All Workshops (15)

Editor-in-Chief (1)
Managing Editor (1)
Senior Advisor (1)
Members of the K-12 community:
- K-8 instructor and 2 students
- High school A: 2 instructors, each with 2 students
- High school B: 2 instructors, each with 2 students

SCEC and CUREE web developers (2)

Step 5: Final Draft

Depending on the recommendations of the review panels and the results of each workshop for a given set of material, one of three outcomes will be determined by the Editor-in-Chief:

1. The content may be rejected if the Editor-in-Chief feels it does not truly meet the standards for relevance, integrity and access, or is otherwise deemed sub-standard in a way that cannot be remedied by reasonably simple revision.
2. The content may require some modification to overcome limitations.
3. The content may be accepted as-is, without need for revision.

In the case of the first outcome, the Editor-in-Chief may decide to send a notice to the creator of the material explaining the reasons why their resource did not gain approval and suggesting the kinds of modifications necessary for incorporation into the collection. The resource creator would then have the option to undertake those modifications and re-submit the material to $\boldsymbol{E^3}$. In the case of the second outcome, similar notification might also occur, though minor revisions or work-around solutions could be implemented by the $\boldsymbol{E^3}$ project staff with the approval of the creator. Once these revisions are completed, the material would gain final approval from the Editor-in-Chief.

Step 6: Incorporation Into The Collection

Content that has received final approval from the Editor-in-Chief will be incorporated into the collection by the SCEC web developer. This content may take the form of a new entry in $\boldsymbol{E^3}$ or be integrated as part of a pre-existing entry. Maintenance of this content—for example, the checking (and if necessary, re-establishment or removal) of links—is an extension of this step. Should an external resource degrade in such a way that it no longer meets the standards of $\boldsymbol{E^3}$ or serves the needs of the digital library community, the SCEC web developer will bring this to the attention of the Editor-in-Chief, who will decide if that resource should be removed from the collection.

An additional and ongoing part of collection development and review for $\boldsymbol{E^3}$ will occur once new content has been approved and mounted on-line. We will create a simple, user-friendly option for quickly rating the usefulness of resources contained within the collection and providing written reviews. These ratings and reviews will be stored within the metadata of that resource, updated when appropriate, and made available as an option in user search results. This system will give users the chance to make their voices heard and become part of the active digital library community. It will also provide collaborators with a peer-based quality check to assist them in further refining their materials. The user-review system will also provide a real-world assessment of the types or styles of resources most highly valued by students and educators. In a similar way, user reviews might ultimately begin to impact the efforts of contributors before they submit resources to $\boldsymbol{E^3}$. This type of feedback will ensure that the project continually evolves to suit the needs of the community it serves.

7. Long-term Management and Maintenance Plan

We do not have a detailed plan for the long-term management and maintenance of the ***Electronic Encyclopedia of Earthquakes***, because its future configurations will probably depend on digital-library technologies that are still in their early stages of development (e.g., those based on research funded under the Core Integration System and Services tracks in this RFP). However, all three of the proposing organizations have a vested interest in maintaining $\boldsymbol{E^3}$ as part of their Education & Outreach activities, and each is willing to expend resources to ensure its long-term success.[9] In fiscal year 2002, the combined expenditures of SCEC, CUREE, and IRIS in Education & Outreach are projected to exceed $1 million, and these E&O resources are likely to increase with time. The missions and objectives of the proposing organizations are entirely consistent with using some portion of these funds to support the continued development of $\boldsymbol{E^3}$ once this two-year NSDL project terminates.

In particular, SCEC is willing to take the lead in the long-term management and maintenance of the collection, and CUREE and IRIS are willing participate in future developments and periodic reviews to maintain quality control. As a facility to support NSF Earth science research programs, IRIS has a long-term commitment to the collection and archiving of primary seismological data. Special segments of the IRIS data archive are reserved for information related to significant earthquakes that are of special educational interest. Automated procedures are in place to extract data from new earthquakes as they occur. This process of augmenting and refreshing the database provides a natural mechanism for maintaining an educational collection of earthquake information that remains current and topical.

Most of the institutions participating in SCEC, CUREE, and IRIS are universities who have already made substantial long-term commitments to developing their own digital libraries, and we intend to take advantage of these resources in the management of $\boldsymbol{E^3}$. In Section 4 of this proposal, for example, we have outlined our arrangements to include $\boldsymbol{E^3}$ in USC's Collection Information System, which will provide the databasing needed to maintain the encyclopedia as a dynamic portal to earthquake information. As the long-term custodians of $\boldsymbol{E^3}$, we will leverage on these and other institutional resources.

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[9] SCEC CUREE, and IRIS already provide the long-term maintenance for a number of websites and databases. For example, CUREE has been maintaining the SAC Steel Project website (accessed via the CUREE website at http://curee.org) at its own expense following the conclusion of the SAC project in 2000. The $10 million, 6-year SAC Steel Project had the purpose of conducting research to provide design guidance for the earthquake-resistant design of steel frame buildings, and ready access to existing test data is a major part of the Project's usefulness. A scripted section of the website allows engineers to fill out a menu-driven form to specify the depth of a steel beam they are designing, the grade of steel, and other relevant characteristics and then have all available test results for those conditions retrieved and presented.