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PI/PD Name: Geoffrey C Fox

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other _____
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

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PI/PD Name: Andrea Donnellan

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other _____
- ☒ None

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PI/PD Name: Roscoe C Giles

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☒ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status: (Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other _____
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: David H Laidlaw

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
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- ☐ Mobility/Orthopedic Impairment
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PI/PD Name: John B Rundle

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race: (Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status: (Select one or more)
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- ☐ Visual Impairment
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- ☐ Other _____
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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 00-2

NSF99-167 **01/06/00**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

INFORMATION TECHNOLOGY RESEARC

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				790877419	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

596001138

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYMS(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

Florida State University

AWARDEE ORGANIZATION CODE (IF KNOWN)

0014894000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Florida State University
Tallahassee, FL. 32306

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

PERFORMING ORGANIZATION CODE (IF KNOWN)

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

IS AWARDEE ORGANIZATION (Check All That Apply)
(See GPG II.D.1 For Definitions) ☐ FOR-PROFIT ORGANIZATION ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS

TITLE OF PROPOSED PROJECT **ITR/ACS:Information Infrastructure for Distributed Collaborative Science applied to Earthquake Analysis**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PREPROPOSAL NO., IF APPLICABLE
$ **2,509,225**	**36** months	**08/01/99**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG 1.A.3)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.D.1)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG II.D.10)
☐ NATIONAL ENVIRONMENTAL POLICY ACT (GPG II.D.10)
☐ HISTORIC PLACES (GPG II.D.10)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.12)
☐ GROUP PROPOSAL (GPG II.D.12)
☐ VERTEBRATE ANIMALS (GPG II.D.12) IACUC App. Date _____
☐ HUMAN SUBJECTS (GPG II.D.12)
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES _____
☐ FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES (GPG V.G.)
☐ RESEARCH OPPORTUNITY AWARD (GPG V.H)

PI/PD DEPARTMENT
Department of Computer Science

PI/PD FAX NUMBER
315-443-4741

PI/PD POSTAL ADDRESS
Northeast Parallel Architectures Center
3-217 Center for Science and Technology
Syracuse, NY 132444100
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME **Geoffrey C Fox**	**Ph.D.**	**1967**	**315-443-2163**	**gcf@cs.fsu.edu**
CO-PI/PD **Andrea Donnellan**	**PhD**	**1991**	**818-354-4737**	**donnellan@earth.usc.edu**
CO-PI/PD **Roscoe C Giles**	**Ph.D.**	**1975**	**617-353-6082**	**roscoe@bu.edu**
CO-PI/PD **David H Laidlaw**	**Ph.D.**	**1995**	**401-863-7647**	**dhl@cs.brown.edu**
CO-PI/PD **John B Rundle**	**Ph.D.**	**1976**	**303-492-5642**	**rundle@fractal.colorado.edu**

CERTIFICATION PAGE

Certification for Principal Investigators and Co-Principal Investigators:

I certify to the best of my knowledge that:

(1) the statements herein (excluding scientific hypotheses and scientific opinions) are true and complete, and
(2) the text and graphics herein as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or individuals working under their supervision. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this application.

I understand that the willful provision of false information or concealing a material fact in this proposal or any other communication submitted to NSF is a criminal offense (U.S.Code, Title 18, Section 1001).

Name (Typed)	Signature	Social Security No.*	Date
PI/PD **Geoffrey C Fox**			
Co-PI/PD **Andrea Donnellan**			
Co-PI/PD **Roscoe C Giles**			
Co-PI/PD **David H Laidlaw**			
Co-PI/PD **John B Rundle**			

SSN's are confidential and are not displayed *ON FASTLANE SUBMISSIONS*

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding Federal debt status, debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 00-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuring award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflict which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Debt and Debarment Certifications

(If answer "yes" to either, please provide explanation.)

Is the organization delinquent on any Federal debt? Yes ☐ No ☒

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure Form to Report Lobbying,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME/TITLE (TYPED) **Pat Maybin**		**01/03/00**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
850-644-8948	**pmaybin@mailer.fsu.edu**	**850-644-1464**

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Information Infrastructure for Distributed Collaborative Science applied to Earthquake Analysis

Principal Investigator: Geoffrey Fox (Florida State University)
Co-Investigators: Andrea Donnellan (USC/JPL), Roscoe Giles(Boston), David Laidlaw (Brown), John Rundle (Colorado)
Senior Personnel: Jill Andrews (USC/SCEC), Yehuda Ben-Zion (USC), Gregory Beroza (Stanford), Lisa Grant (UC Irvine), Tom Henyey (USC/SCEC), Tom Jordan (MIT), Hiroo Kanamori (Caltech), William Klein (Boston), Jean-Bernard Minster (Scripps, UCSD), James Rice (Harvard), Charles Sammis (USC), Terry Tullis (Brown)

Collaborating Government Organizations: DoE Los Alamos, NASA JPL, USGS
International Collaboration: APEC International Cooperation for Earthquake Simulation (ACES)

Motivation and Project Team

We present a project of the GEM (General Earthquake Models) community involving 11 universities and 3 unfunded government partners, which addresses the computer science issues in building an information infrastructure to support the full range of activities of a modern scientific research field. The importance of and general role of modern information infrastructure for distributed scientific research has been understood for some time and tremendous progress has been made over the last few years. In particular distributed object and web technology has enabled access to and sharing of both data and simulations over time and distance. However there are many fundamental issues to be studied both from computer science (how should we build collaborative scientific environments and what are the needed services) and application science (what changes in the scientific method and what are the application requirements and impact) points of view. The unsolved research issues include the support of real time interactions between people, computer simulations, instruments and other information resources. However perhaps even more importantly we must support fundamental theory which develops over a time period of many years – often longer than the life of today's web on which we build the supporting information infrastructure. This proposal builds an interdisciplinary team where we focus on both the general computer science issues and one particular application area -- that of earthquake analysis and simulation. This application area is both important and needs a rich variety of worldwide services with time scales from seconds to centuries. The computer science research will be generalizable to other application areas using the existing collaborations and broad expertise of the proposal team. The earthquake area will focus on the needs of scientific research but the environments we create will be extensible to support the general needs of earthquake crisis teams with distributed interactions between control rooms, field personnel and experts responding to real time data streams.

1) **Computer Science Research**: We will build an information structure for a full application area from "scratch" using systematically distributed objects and services. We will research the appropriate architecture and base infrastructure for key services: real-time HPCC, multi-sensor scientific data, scientific datamining, visualization and collaboration. We hypothesize that building such an integrated web-based collaborative portal CPW (Collaborative Portal on the Web) will lead to a productive scientific environment with a single infrastructure supporting multiple timeframes. We will iterate short (around 6 month) prototyping efforts with test and evaluation. This modular construction approach fits today's rapid evolution in technology on "Internet Time".

2) **Application Effort**: We have identified three typical timeframes linking distributed scientists, data and simulations and these will be implemented as prototype collaborative environments using both existing and new application codes. With government partners (JPL, USC/SCEC, and USGS), we will link to the major earthquake sensor systems as part of the computational environments. We will include theoretical and observational scientific data analysis in the timeframes in both real-time decision support and more asynchronous collaboration modes.

3) **Outreach**: We will leverage the existing broad and successful outreach program of USC/SCEC, which will link us both to the public (for education), and to the state and federal emergency services. This effort will develop specific educational modules based on GEM work.

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1. Motivation and Project Overview

The importance of simulating earthquakes is intuitively obvious. For instance, the recent January 16, 1995 Kobe, Japan earthquake was only a magnitude 6.9 event and yet produced an estimated $200 billion loss. Despite an active earthquake prediction program in Japan, this event was a complete surprise. Drastic scenarios similar to those reported this year in Turkey and Taiwan are possible and indeed eventually likely in Los Angeles, San Francisco, Seattle, and other urban centers around the Pacific plate boundary. Over the last three years, we have built a team of Computer and Earthquake scientists from academia and government to initiate a program GEM "General Earthquake Models" [17], aimed at applying the latest computational technology in this area. This thrust contributes to the nationally identified importance of developing new approaches to Geoscience involving advanced instrumentation (EarthScope) and computing. Earthscope is an NSF/EAR/MRE initiative to develop extensive new networks of sensors in the western United States to monitor all aspects of earthquake phenomenology. As yet, there is no corresponding, comprehensive modeling and simulation initiative, a void, which the GEM collaboration proposes to fill. The GEM group includes representatives of several universities (11 are involved in this proposal), multiple government agencies and laboratories (DoE, NASA, NSF, USGS) and is coordinated with the major NSF Southern California Earthquake Center (SCEC) in this area whose outreach services we will use. There is substantial international interest in these problems and GEM works closely with an effort ACES (APEC Co-operation for earthquake Simulation [3]) among several Asia-Pacific nations including Australia, Taiwan, Japan, China, and the USA. This includes Japan's ambitious *Earth Simulator* project involving a 30 teraflop parallel computer and a correspondingly major software and science research effort [23]. Current funding for GEM is at the level of $100K/year from the NSF/SCEC and NSF/EAR, which has allowed important seed projects on which we build.

Earthquake science spans many scales in space and time and needs simulation techniques from partial differential equation, particle dynamics and statistical physics using concepts such as "correlation length" and "critical state" in understanding regional seismicity. GEM can impact all of these from real-time analysis of scientific data from an earthquake; the systematic longer term integration of data from multiple sensors into simulations and the fundamental study of earthquakes as an emergent phenomena in a complex system. This field is an attractive target for computer science due to the intrinsic richness of the applications and the societal importance and also because the use of computers is not yet too extensive and so modern approaches and infrastructure can be used without major distraction from existing legacy approaches. The field is naturally distributed with sensors, scientists and earthquakes scattered around the globe. Thus there is an immediate application of emerging concepts such as computational grids to link large-scale simulations, data and people in a distributed fashion. The computer science research focuses on the issues on building an integrated information infrastructure that can support collaborative distributed scientific research over a range of time scales and computational needs. The work in tools and distributed systems will be driven by three application area timeframes characterized by time scales of hours (post earthquake analysis), 6-12 months (data assimilation and development of new earthquake forecasting approaches) and ten years (fundamental theory). The work will contribute to earth science research in these three timeframes and to computational science where we have defined five thrust areas; distributed collaborative (shared) scientific objects, HPCC simulations including new uses of fast multipole techniques, multi-sensor metadata, data and simulation visualization, and interactive scientific datamining for earthquake pattern analysis. We give a more detailed discussion of the three application timeframes and the five computational science thrust areas after a brief discussion of some earth science issues. The preproposal ends with outreach and management sections.

2. Understanding Earthquakes

There are a variety of valid approaches to trying to understand earthquakes through modeling and data interpretation and GEM intends to be involved in a wide range of them, since it is not clear that any one will provide the best approach for any or all purposes. Perhaps all workers feel that at some level earthquakes might be regarded as either a stochastic nonlinear system, or an example of deterministic chaos, but there is a wide range of opinion concerning whether it is better to focus on the chaotic aspect, the stochastic behavior, or the deterministic properties. One view might be that it is impossible to ever know all of the relevant variables affecting their size, timing, and character of an earthquake, and that this means that we might as well give up trying to understand the physics at any detailed level. Another view, to which we tend to subscribe, is that earthquakes fall broadly into one of several universality classes, whose behavior is governed by one of a small number of fixed points. If this is the case, it will be possible to obtain fundamental understanding of the broad behavior of the system even if the details remain obscure. One can then focus on looking at patterns in earthquake occurrence in both real earthquakes and in earthquake simulations as an optimal way to gain understanding.

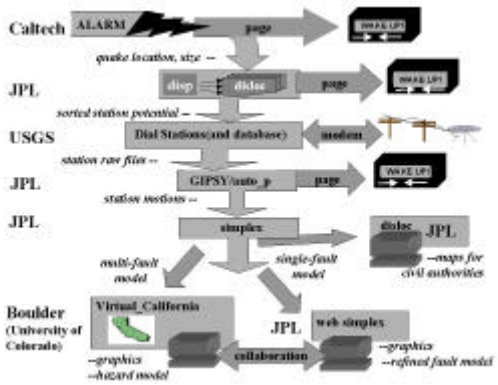
3 GEM Application Timeframes

3.1 Project Methodology

We have divided the earthquake science activity into three teams corresponding to modus operandi (timeframes) with (superficially) very different requirements for the supporting computational infrastructure. Each timeframe captures an aspect of earthquake science that contributes to a core understanding of the field. We will support each timeframe with the same integrated information system and test and evaluate this with special attention to the successful enabling of new and more effective models of collaborative scientific research. We will of course feed lessons back into both computer science and earthquake science and compare with related activities on an ongoing basis. The 3 timeframes are described in more detail in following sections.

3.2 Timeframe 1(minutes/hours): Real Time Science and Data Analysis after an Earthquake

Here we collect together the types of activity exemplified in the figure, which shows how decisions are made in real time as to what data should be gathered and fed into simulations that can aid both the forecasting of possible aftershocks and suggest which further data will be useful. The flow of actions moves down the figure starting with initial notification of an earthquake and followed by decisions as to which data to gather. At the bottom, we have iterative integration of simulations with the earthquake data. We have started to build a Problem Solving Environment enabling this type of interaction with synchronous interaction between the world wide distributed scientists, simulations and data visualizations. However, this effort is in its infancy and the support of this ITR proposal could bring it into a useful reality. Note we are restricting our attention to interactions between scientists but many of the tools and concepts can be applied to support the work of crisis management teams.



3.3 Timeframe 2 (month/years): HPCC Simulations and Data Integration

Achieving the goals of GEM and for instance meeting the challenge of Sec. 3.4 for theoretical understanding, will require the ability to simulate models on time and size scales presently unattainable, and to compare data sets from different models with each other and with observations of real faults. To accomplish these goals we will develop and refine both efficient algorithms such as fast multipole methods and explore acceleration techniques. For initial efforts we propose to develop a standard set of real data for calibration of models or comparison with results of simulations. By using the same real data set for all models and simulations we facilitate comparison of model effectiveness and establish real (rather than theoretical) performance standards for simulation results.

Note that earthquake science is benefiting from the rapid increase in quality and type of data and this is driving the urgent need for new GEM information infrastructure. GPS, InSAR and broadband seismic (TERRASCOPE) data, together with archived (in particular by the SCEC Data Center) and newly developed paleoseismic data can be used in conjunction with the simulation capabilities to establish the relevant model parameters. These parameters include, for example, the current geometry of faults; slip rates at any known point; recurrence intervals and historic variations in slip during earthquakes—leading to estimates of frictional parameters; deformation data leading to estimates of elastic plate thickness and sub-crustal stress; and so forth. Typically, different investigators are expert in the different types of data and a much improved collaborative environment is needed to integrate the different data together. The data is of course critical for earthquake understanding, especially now with the existence of only rudimentary models.

Several of the computer science activities directly support this scenario. We are designing systematic (XML based) metadata for the diverse data types; integrating parallel fast multipole methods into several simulations and designing visualization methods that will support effective viewing of the different data sets.

3.4 Timeframe 3 (years/decade): Fundamental Theory and Complex Systems

The primary goal of the theoretical research is to integrate current earthquake modeling approaches into a more general, comprehensive model, and to provide a theoretical framework through which the data generated by simulating this model can be understood. We expect that this model will cover time scales from seconds, the time associated with a rupture, to centuries, the scale of strain accumulation and release. In addition, this model will contain most of the aspects of real faults; characteristics of wave propagation, frictional behavior and fault interaction will be included. We hope to generate an understanding of earthquakes as a collective effect and relate the structure of quakes and their precursors to related complex systems. In order to develop such a model we need to understand the essential features of fault systems and how omission of selected features affects the physics obtained

from the model. This requires an investigation of a wide range of models to ascertain which aspects of the physics are robust and which aspects rely on model detail. Current models range from cellular automaton versions of single faults, to slider block and elastodynamic models with various friction forces, to stochastic models of fault systems. Each model provides insight into different, but overlapping aspects of fault dynamics.

Implementing this investigation will require the ability to simulate these models on time and size scales presently unattainable, and to compare data sets from different models with each other and with observations of real faults. This requires largely asynchronous collaboration with a sophisticated PSE that can support the rich range of model and data. The PSE will be used for both validation and assimilation. An area of growing importance is scientific datamining from both physical data and simulations to decide what are patterns that could signal a quake and what simplified coarse grain dynamics could describe these patterns [41, 35, 36]. Support of this will be an important thrust of our proposed GEM Information infrastructure.

4 Computer and Computational Science

4.1 Basic Distributed Object Information Technology Architecture

Problem Solving Environments (PSE) have been pursued for many years with the work at Purdue [21] pioneering many important concepts. The increasing power of computers and the increasing capability of distributed object and web technologies are making this approach increasingly attractive for users and system builders. One uses the "Object Web" (CORBA, COM, Java, XML etc.) and a browser based user interface to provide a single integrated view or portal [9] to the resources and tools needed by the scientist. In this proposal we focus on the issues needed to design a single information infrastructure to support multiple timeframes i.e. the development of multiple PSE's built from the same resources. We start with the successful Gateway and WebFlow systems [1,14,15] developed at Syracuse and applied to several DoD and NSF projects. These have a classic three-tier architecture with client, brokers/servers and services in the three layers. High performance is obtained even while using Java and CORBA in the middle tier, by careful separation of control and data. The middle tier provides a flexible control layer implemented with proxies and traditional high performance mechanisms such as Globus [18] and MPI are used for data transfer in the backend. This WebFlow distributed object technology has a powerful dataflow and coarse grain object computing model with all interfaces defined in XML and compatible with community activities [9,19]. In this sense it is more powerful than the earlier NILE system [26] while it is less ambitious than the Common Component Architecture [8], Legion [24] and POOMA [28], which provide a fine grain, object model. Gateway is fully consistent with commodity standards (CORBA and XML) and therefore suitable for the ambitious project proposed here which aims to provide an information infrastructure for a complete application area in three radically different timeframes.

We will implement early prototypes of the information infrastructure on Gateway but expect that one can better use one of the emerging set of "Object Web operating systems" such as E-Speak [12] or Ninja [27] as the basic framework. We will investigate these new possibilities over the next few months. The following sections 4.2 to 4.6 describe activities that provide resources and tools (services) that will be integrated into the Gateway systems and presented as the different portals to the scientists working in the three timeframes of section 3. One research result of this project will be an evaluation of different object web architectures and operating infrastructure in terms of their ability to support scientific PSE's.

4.2 Real-Time HPCC Simulations

Here we use the best known HPCC techniques with optimizations for both the real time needs of the first timeframe and the conventional large-scale analysis of the timeframe of Sec. 3.4. This domain is data-intensive and we expect to make extensive use of the resources and methodology developed by NPACI in this area [25]. Minster on our proposal is Earth Systems Science lead for NPACI. We are also developing collaborations with the Maui Supercomputer Center [28].

An early result of the seed funding for the GEM collaboration was the realization that fast multipole methods could be applied to many of the Green's function simulations [31-34,37]. As the complexity decreases from N^2 to N logN, this dramatically increases the simulation resolution with the maximum number N of elements moving from some tens of thousands to the many millions possible with multipoles on a fast parallel machine. We chose to work from a portable code developed by Salmon and Warren over the last few years [42]. Adapting this approach to our problem has the potential of both allowing realistic problems in fault mechanics to be investigated for the first time as well as presenting the opportunity for innovative modifications to be made to the fast multipole approach. For example, the Green's functions in our fault mechanics problem fall off as $1/r^3$, a faster falloff than in the situations in which the multipole approach has typically been used. Another important difference is that the multipoles are fixed in position but of variable intensity in earthquakes but have the opposite characteristics in

astrophysics. We will develop the appropriate new ansatz's, especially in situations of complex fault geometry, to determine both the order and geometry of the multipoles that are best used.

4.3 Multi-sensor Metadata

A team from JPL has already begun to design prototype XML based metadata [5,25,43] for some of the sensor-based data and we have used this in our early PSE mentioned in Sec. 3.2. As part of this project, we will extend this design to sensor, field and simulation data in a way that we can use it to integrate different data sources into our collaboration, visualization and assimilation tools. Our PSE environment [1] fully supports XML for job and data definition and its dataflow paradigm will allow files with compatible metadata to be exchanged between application components. This will require a hierarchical metadata design and the construction of services based on available XML tools to process data in the different parts of the computational environment. This activity will be linked to related work in our arena (e.g. the Grid Forum [19], NCSA and NPACI) and so be important in designing science wide approaches to metadata.

4.4 Data and Simulation Visualization

One of the aspects of the GEM community and research that is interesting from a science systems perspective (the meta-topic of "how to do science effectively") is the enormous heterogeneity of the data used by earthquake modelers. A major challenge of visualization in this proposal is to create methods of integrating the very different kinds of data and supporting their visualization with a common toolkit. Collaborative visualization will be needed and here we will base our approach on experiments Java systems developed in TangoInteractive [40] and the interesting general analyses of UNC [30] and Wood [44]

A variety of approaches will be investigated for scientific visualization of the data produced by simulations and observations. Because such data in the realm of earthquake processes involves both space and time, we plan to explore using volume rendering with time as a third axis for situations where the spatial coordinates can be adequately represented in the other two dimensions. Adoption of suitable thresholds for transparency of portions of the data set should allow the most interesting portions to be viewed and better understood. We plan to use the new NSF MRI-funded "cave" immersive virtual reality environment (The TAN Cube) at Brown University and similar three dimensional representations to view such models. This environment offers the opportunity to monitor the progress of a computation in real time by simultaneous visualization and computation. We will evaluate whether it is feasible or desirable to steer the computation and/or the visualization of it interactively during simultaneous computation and visualization in order to focus inspection and/or computing resources on the areas that are most interesting.

As discussed in sec. 3.3, an important component of our research will involve comparing simulations and observations. We will focus on ways to evaluate how well the simulations match the data, and we will investigate whether visualization can play an important role in this. For example visual comparisons of simulations and of data for synthetic cases with known degrees of goodness of fit can be rated for the quality of the agreement by teams of observers – including collaborating over a distance. These subjective evaluations can be compared with a variety of statistical measures of agreement to determine the accuracy of the visual perception. Teams of observers with different degrees of experience in the subject matter will be employed to discover how training affects the quality of the evaluation. One possible advantage of the use of visualization to compare simulations with observations is that if it proves to be as reliable as statistical tests, it may be more suitable for comparison in situations where devising appropriate statistical tests is more difficult.

4.5 Interactive Scientific Datamining

Recently a combination of simulation and observational data has been used to identify patterns that could be helpful in forecasting earthquakes [41, 35, 36]. This approach uses techniques first developed in the climate field and computationally involves matrix (eigenvector) analysis combined with visualization of geographic data related in a particular eigenpattern. This initial success highlights the role of scientific datamining as the appropriate way to generalize the classic earthquake related phenomenology to the proposed information infrastructure with many orders of magnitude more data from diverse sources and the corresponding need for a systematic approach. The datamining needs to exploit the hierarchical XML metadata structure proposed in Sec 4.3 and link to the visualization of the last section. Collaborative discussion of possible forecasting approaches (datamining methods and results) seems important. Thus we intend to build a collaboration-aware Java analysis system which can support access to data from simulations and observations and the type of computationally modest calculations found helpful so far. The computer science research will evaluate other data mining approaches and integrate them into the interactive analysis environment as either client side or backend computational resource. Research issues include architecture and integration of scientific datamining in a collaborative object based environment. We can expect interesting datamining algorithms to be needed in this relatively new field. For instance the initial work [41] found

signal to noise was greatly enhanced by assuming that the system is a pure phase dynamical system, ignoring changes in state vector normalization.

4.6 Collaboration over ranges of Distance and Time

We have found a mix of success and failure with initial collaborative systems such as Microsoft NetMeeting, NCSA's Habanero [20] and Syracuse's TangoInteractive [40]. Higher speed networking and quality of service will address some of the difficulties such as variable quality in digital audio video conferencing; here we track the ANL/NCSA Access Grid project. We have been quite successful in educational applications but have yet to develop collaborative computing applications which are both robust and of compelling value. We will use the existing collaboration systems in early experiments but we intend to build much of the collaborative infrastructure from scratch replacing custom protocols and services by those available from infrastructure like Ninja [27]. The timeframes in our proposal illustrates a critical challenge for collaboration systems – namely supporting asynchronous interactions (timeframe 3), real-time synchronous (timeframe 1) and mixtures thereof (timeframe 2). Our web-based PSE approach implies that collaboration is a service that shares web-based distributed objects. However we also need to support several collaborative modes; shared display and both collaboration-aware and collaboration-unaware shared event models. Previous systems have focussed on one of these mechanisms and have not been able to support the needed range of collaboration. Initially we will support these different modes with separate subsystems but will replace this by an integrated system CPW (Collaborative Portal on the Web) based on a generalized shared queued event service. This terminology indicates that our approach is to build first a portal with collaboration as one its services; this will be implemented using XML systematically to define the details of the collaboration and the portal infrastructure (e.g. Ninja's event service) as the building blocks of the collaborative system. We believe this will integrate collaboration directly into the scientific analysis and make it more useful than before.

5 Outreach

We are fortunate to be able to leverage the very successful SCEC [38] outreach program led by Jill Andrews whose mission is to promote earthquake loss reduction and to actively engage the public at large in activities that focus on earthquake-related education, research-based technology development and transfer, and systemic reform. Enhancing current SCEC-funded Web-based education modules now under construction by Andrews and Donnellan [39] with GEM material will complement this general goal. Because the education standards of today strongly encourage an inquiry-based, accessible approach to learning science, this SCEC work has met with enthusiastic acceptance among reviewers from the California Science Implementation Network. The first module on Investigating Earthquakes through Regional Seismicity, along with a second module on Global Positioning Systems (GPS) technology, created at an upper division high school / lower division college level, are being adapted to middle school curricula. A partnership with the GEM principal investigators will certainly enhance the material presented in the existing modules. As a first activity for this proposal we will create a mathematically-oriented Web-based module, using GEM as the illustrative example. This will acquaint high school instructors and students with the concept of an integrated approach to solving computational challenges, and to lead them through an exercise to produce their own earthquake forecast (probability) models.

6 Management and Budget

The management plan is based on our substantial experience with three large NSF center activities – SCEC (Science and Technology center in earthquake science), CRPC (Science and Technology Center for Research in Parallel Computing), and the NCSA Alliance (PACI Partnership in Advanced Computational Infrastructure). There is an overall GEM management structure similar to these activities, which will support this proposal as the major computer science activity with other projects mainly aimed directly at Earth Science. The proposal itself is divided into nine teams, whose leaders form a technical committee, covering the three application areas of Sec. 3, the five computer science thrusts of Sec. 4 and outreach described in Sec. 5. The principal investigators of the proposal will form a steering group that will review important project decisions and interface between the GEM executive board and the technical committee. GEM already meets approximately four times per year, often together with synergistic activities such as SCEC or AGU meetings. We will link the proposal technical discussions and workshops to this meeting series. We propose a total budget of $800K per year for a period of three years. This budget is split roughly equally between computer/computational science work at Boston, Brown, Florida State and USC and Earth Science activities. There is $65K per year in the outreach work led by SCEC/USC. SCEC will play an important management role on the earth science side as USC already has mechanisms to subcontract without overhead and we will use this for the smaller Earth Science sites.

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Geoffrey Charles Fox:
Florida State University (Principal Investigator)

gcf@npac.syr.edu , http://www.npac.syr.edu,
Phone: (315) 443-2163, Fax: (315) 443-4741
NPAC Syracuse University
111 College Place
Syracuse NY 13244-4100

Education:

B.A. in Mathematics from Cambridge Univ., Cambridge, England (1961-1964)
Ph.D. in Theoretical Physics from Cambridge University (1964-1967)
M.A. from Cambridge University (1968)

Professional Experience:

2000-	Professor of Computer Science, Florida State University
1990-	Professor of Computer Science, Syracuse University
1990-	Professor of Physics, Syracuse University
1990-2000	Director of Northeast Parallel Architectures Center
1979-1990	Professor of Physics, California Inst. of Tech.
1986-1988	Associate Provost for Computing, California Inst. of Tech.
1983-1985	Dean for Educational Computing, California Inst. of Tech.
1981-1983	Executive Officer of Physics, California Inst. of Tech.
1974-1979	Associate Professor of Physics, California Inst. of Tech.
1971-1974	Assistant Professor of Physics, California Inst. of Tech.
1970-1971	Millikan Research Fellow in Theoretical Physics, Caltech
1970	Visiting Scientist (April-May), Brookhaven National Laboratory
1969-1970	Research Fellow at Peterhouse College, Cavendish Lab.,Cambridge
1968-1969	Research Scientist, Lawrence Berkeley Lab., Berkeley, Calif.
1967-1968	Member of School of Natural Science, Inst. for Advanced Study, Princeton, New Jersey

Five Selected Publications

1) Fox, G. C., Messina, P., Williams, R., Parallel Computing Works!, Morgan Kaufmann, San Mateo Ca, 1994.
2) Fox, G.C. and Hurst K., Computational Science and Information Technology meets GEM, a chapter in AGU monograph on Physics of Earthquakes, edited by John Rundle and published by AGU in 2000. http://www.npac.syr.edu/users/gcf/gemagubookchapter00/gempaper.html
3) Erol Akarsu, Geoffrey Fox, Tomasz Haupt, Alexey Kalinichenko, Kang-Seok Kim, Praveen Sheethaalnath, and Choon-Han Youn , "Using Gateway System to Provide a Desktop Access to High Performance Computational Resources", Proceedings of HPDC-8 Conference, Redondo Beach Ca., Aug 3-6, 1999, IEEE Press.
4) Fox G.C., Furmanski W., "Computing on the Web,New Approaches to Parallel Processing,Petaop and Exaop Performance in the Year 2007", IEEE Internet Computing 1:2,38-46, 1997

5) Fox G.C., and Podgorny M, "Real Time Training and Integration of Simulation and Planning using the TangoInteractive Collaborative System", in Proceedings of International Test and Evaluation Workshop on High Performance Computing, July 1998, Aberdeen Maryland.

Andrea Donnellan: USC/JPL

Education

Ph.D., Geophysics, California Institute of Technology (1991)
M.S., Geophysics, California Institute of Technology (1988)
B.S., Geology, Ohio State University, *with honors and distinction in geology* (1986)

Professional Experience

Research Assistant Professor, Department of Earth Sciences, University of Southern California (1999–present)
Supervisor, Data Understanding Systems Group, Jet Propulsion Laboratory (1999–present)
Research Scientist, Satellite Geodesy and Geodynamics Systems Group, Jet Propulsion Laboratory (1997–1999)
Member of Technical Staff, Satellite Geodesy and Geodynamics Systems Group, Jet Propulsion Laboratory (1993–1997)
Visiting Associate, Seismological Laboratory, California Institute of Technology, (1995–1996)
National Research Council Resident Research Associate, NASA Goddard Space Flight Center (1991–1993)
Graduate Research Assistant, California Institute of Technology (1986–1991)
Research Assistant, Institute of Polar Studies, Ohio State University (1983–1986)

Professional Activities

Plate Boundary Observatory steering committee (1999–present)
General Earthquake Models (GEM) program planning committee co-chair (1998-present)
Convenor NSF/NASA Sponsored Autonomous Systems in Extreme Environments Workshop (1999)
AGU 2000 and 2001 Spring Meeting program committee geodesy section chair-elect (2000) and chair (2001)
AGU Geodesy representative for education and outreach (1999)
GEM Data committee co-chair (1999-present)
SCEC Crustal Deformation Working Group (1993–present)
SCIGN Coordinating Board and associated committees (SCEC rep: 1994–1998; NASA rep: 1999–present)
AGU Geodesy Section educational outreach representative (1999)
UNAVCO Field Operations Working Group, Chair (1995–1997)
Member American Geophysical Union (1986-present)
Development Oversight of SCEC GPS Educational Modules (1996–present)
Panel member National Earthquake Hazards Reduction Program External Research Program (1994–1999)

Awards

Southern California Earthquake Center Outreach Award for Education (1998)
Presidential Early Career Award for Scientists and Engineers (1996)
National Research Council Postdoctoral Fellowship (1991–1993)
Outstanding Student Paper Award, Geodesy Section, Fall AGU Meeting (1990)

Current Projects

Development of a fully three-dimensional finite element code for studying fault interactions.

Development and deployment of three of autonomous continuous GPS systems in Marie Byrd Land, Antarctica. Work involved assembling a team to develop and deploy the system, and collaboration with companies to develop and supply appropriate hardware.

Workshop convenor: Autonomous Systems in Extreme Environments.

GPS data collection and modeling of the Northridge earthquake region and Ventura basin.

Numerical modeling of Southern California Integrated GPS Network (SCIGN) data.

Modeling of postseismic results from the Landers earthquake.

Oversight of the development of SCEC DESC online web-based educational modules.

Recent Publications

Lyzenga, G.A., W.R. Panero, A. Donnellan, The Influence of Anelastic Surface Layers on Postseismic Thrust Fault Deformation, *J. Geophys. Res.*, in press.

Argus, D., M.B. Heflin, A. Donnellan, F.H. Webb, D. Dong, K.J. Hurst, G.A. Lyzenga, M.M. Watkins, and J.F. Zumberge, Shortening and Thickening of Metropolitan Los Angeles Measured and Inferred Using Geodesy, *Geology*, 27, 703–706, 1999.

Lundgren, P., M. Protti, A. Donnellan, M. Heflin, E. Hernandez, D. Jefferson, Seismic cycle and plate margin deformation in Costa Rica: GPS observations 1994–1997, *J. Geophys. Res.*, in press.

Donnellan, A. and G. A. Lyzenga, Fault afterslip and upper crustal relaxation following the Northridge earthquake, *J. Geophys. Res.*, 103, 21,285–21,297, 1998.

Donnellan, A. and F.H. Webb, Geodetic observations of the M 5.1 January 29, 1994 Northridge aftershock, *Geophys. Res. Lett.*, **25**, 667–670, 1998.

Relevant Publications

Heflin, M.B., D. Dauger, D. Dong, A. Donnellan, K. Hurst, D. Jefferson, G. Lyzenga, M. Watkins, F. Webb, J. Zumberge, Rate change observed at JPLM after the Northridge earthquake, *Geophys. Res. Lett.*, **25**, 93–96, 1998.

Hager, B.H., G.A. Lyzenga, A. Donnellan, and D. Dong, Reconciling Rapid Strain Accumulation with Deep Seismogenic Fault Planes in the Ventura Basin, California, *J. Geophys. Res.*, in press.

Bawden, G., A. Donnellan, L. Kellogg, D. Dong, J. Rundle, Geodetic measurements of seven decades of hortizontal strain near the White Wolf fault, Kern County California: I. Observations, *J. Geophys. Res.*, **102**, 4957–4976, 1997.

Grant, L. B., and A. Donnellan, 1855 and 1991 surveys of the San Andreas fault: Implications for fault mechanics, *Bull. Seism. Soc. Am.*, **84**, 241–246, 1994.

Donnellan, A., B. H. Hager, and R. W. King, Discrepancy between geologic and geodetic deformation rates in the Ventura basin, *Nature*, **366**, 333–336, 1993.

Ph.D. Advisor: Brad Hager (now at MIT)

Recent Collaborators: Bruce Bills (NASA/GSFC and Scripps), Danan Dong (JPL), Louise Kellogg (UCD), J. Lee (WPI), Bruce Luyendyk (UCSB), Greg Lyzenga (Harvey Mudd), Jay Parker (JPL), John Rundle (Colorado)

Student Advisees: Gerald Bawden (UCD), Maggi Glasscoe (UCD)

ROSCOE C. GILES: Boston University

Professor, Department of Electrical and Computer Engineering,
College of Engineering, Boston University, Boston Massachusetts, 02215
(617) 353-6082, EMAIL: roscoe@bu.edu, URL: http://roscoe.bu.edu

Professional Employment

1985-Present	Professor, Department of Electrical, Computer and Systems Engineering, College of Engineering, Boston University.
1979-1985	Assistant Professor, Department of Physics and Center for Theoretical Physics, Massachusetts Institute of Technology
1976-1978	Post-Doctoral Fellow, Center for Theoretical Physics, Massachusetts Institute of Technology.
1975-1976	Post-Doctoral Fellow, Theoretical Physics Group, Stanford Linear Accelerator Center (SLAC)

Education

Ph.D.,	Physics	Stanford University, 1975
M.S.,	Physics	Stanford University, 1973
B.A. Honors,	Physics	University of Chicago, 1970

Honors and Fellowships

Faculty Service Award, Boston University College of Engineering, 1996
DOE Undergraduate Computational Science Award, DOE, 1995
DOE Undergraduate Computational Science Award for "Introduction to Parallel Computing Course," 1994
Boston University Scholar–Teacher of the Year 1992-93.

Professional and Research Interests

My research focuses on the application of high performance and parallel computing to physics and materials problems. I have developed parallel algorithms for large scale micromagnetic modeling and molecular dynamics simulations.

As an outgrowth of these computational science research efforts, I have become committed to prototyping and building computational and educational infrastructure that will enable broad participation of scholars and students in high performance computing. As a co-PI on the NCSA Alliance (an NSF Partnership for Advanced Computational Infrastructure), I head the Education, Outreach, and Training teams of the Alliance and am part of the Leadership Team for the National EOT-PACI effort.

5 Selected Publications

Daniel Reed, Roscoe Giles, Charles Catlett. "Distributed Data and Immersive Collaboration", Comm. ACM. **40**, p 39, 1997.

Beazley, Lomhdal, Gronbech-Jensen, Giles, and Tamayo, "Parallel Algorithms for Short Range Molecular Dynamics," Annual Reviews in Computational Phyiscs, **3**, 1995.

H. Fu, R. Giles, M. Mansuripur, "Coercivity Mechanisms in Magneto-Optical Recording Media," Computers in Physics, 8, 80 (1994).

R. Giles and M. Mansuripur, “Computer Simulations of Magnetization Reversal Dynamics,” Journal of the Magnetic Society of Japan 17 (Supplement S1), 255 (1993).

R. Giles, P.S. Alexopoulos, and M. Mansuripur, “Micromagnetics of Thin Film Cobalt-Based Media for Magnetic Recording,” Computers in Physics, 6, 53 (1992).

David H. Laidlaw Department of Computer Science Brown University

a. Professional Preparation

1983 Sc.B. in Computer Science, Brown University, Providence, RI, *Topology and Mechanics.* Also completed requirements for an A.B. in Mathematics.

1985 Sc.M. in Computer Science, Brown University, Providence, RI, *Rendering Parametric Surfaces.*

1992 M.S. in Computer Science, California Institute of Technology, Pasadena, CA, *Material Classification of Magnetic Resonance Volume Data.*

1995 Ph.D. in Computer Science, California Institute of Technology, Pasadena, CA, *Geometric Model Extraction from Magnetic Resonance Volume Data.*

b. Appointments

1998- Assistant Professor, Computer Science Department, Brown University

1996-1998 Senior Research Fellow, Division of Biology, California Institute of Technology

1989-1996 Postdoctoral Research Fellow/Research Assistant, Computer Science, California Institute of Technology

1989-1993 Consultant Stardent/Advanced Visual Systems

1986-1989 Software Engineer, Stellar Computer

1983-1985 Research Assistant, Computer Science, Brown University

1983 Teaching Assistant, Brown University

1984 Consultant, Basel Institute for Immunology, Switzerland

c. (i) Five Publications Most Closely Related to Project

R. M. Kirby, H. Marmanis, and D. Laidlaw (1999). Visualizing Multivalued Data from 2D Incompressible Flows Using Concepts from Painting, Visualization '99 Proceedings.

Russell E. Jacobs, Eric T. Ahrens, Mary E. Dickinson, and Laidlaw, D. H. (1999). Towards a MicroMRI Atlas of Mouse Development, *Computerized Medical Imaging and Graphics,* 23(1).

Laidlaw, D.H., Fleischer, K.W., and Barr, A.H. (1998). Partial-Volume Bayesian Classification of Material Mixtures in MR Volume Data using Voxel Histograms, *IEEE Transactions on Medical Imaging.*

Shan, J. W., Laidlaw, D. H., Gornowicz, G. G., Lang, D. B., and Dimotakis, P. D., (1997). Three-Dimensional Space-Time Structure of Turbulent Jets, Proc. DFD 97 Meeting of the American Physical Society.

Upson, C., Faulhaber, T., Kamins, D., Laidlaw, D. H., Schleigel, D., Vroom, J. Gurwitz, R., and van Dam, A. (1989). The Application Visualization System: A Computational Environment for Scientific Visualization. *Computer Graphics and Applications,* 9(4).

c. (ii) Five Other Significant Publications

Laidlaw, D. H., Ahrens, E. T., Kremers, D., Readhead, C. (1998). Visualizing Diffusion Tensor Images of the Mouse Spinal Cord. *Proceedings of IEEE Visualization '98.*

Laidlaw, D. H., Barr, A. H, and Jacobs, R. E. (1997). Goal-directed brain micro-imaging. In *Neuroinformatics: An Overview of the Human Brain Project,* vol 1 of Progress in Neuroinformatics.

Tyszka, J. M. Laidlaw, D. H., and Silverman, J. M. (1997). Relative pressure mapping using high-speed three-dimensional phase contrast cine MR imaging. *Radiology,* 205, Suppl. S.

Fleischer, K. W. , Laidlaw, D.H., Currin, B. L., and Barr, A. H. (1995). Cellular Texture Generation, *Computer Graphics* (Proc. Siggraph 95), 29(4).

T. Banchoff, H. Koak F. Bisshopp, and D. Laidlaw (1986). Topology and Mechanics with Computer Graphics: Linear Hamiltonian Systems in Four Dimensions," Advances in Applied Mathematics.

d. Synergistic Activities

This year was the first for a new graduate/undergraduate class *Interdisciplinary Scientific Visualization.* Students wrote "funding" proposals for small, interdisciplinary research projects. "Funded" proposals were implemented and the results presented at a mock conference. Students learned about communicating and working with researchers in another field. http://www.cs.brown.edu/courses/cs295-5.

Organized panel at Visualization '98 conference on Art and Visualization (best panel at conference). Participated in followon Visualization '99 panel. Both probed issues of interdisciplinary collaborations.

The final publication above describes AVS, a visualization software product that I was a principal developer on at Stellar Computer. It is widely used to process and visualize MR images as well as other scientific data.

I have advised and continue to seek out undergraduates for research projects both at Brown and, previously, at Caltech. Some of the projects have culminated in research publications. Several have been with women in computer science, a traditionally underrepresented group. I organize the Brown Computer Science undergraduate research opportunities web pages.

e. (i) Collaborators: Eric T. Ahrens, Caltech, Joseph W. Asa, Matthew J. Avalos, Caltech, C. Bajaj, U. Texas, Thomas F. Banchoff, Alan H. Barr, Caltech, Celia F. Brosnan, Albert Einstein College of Medicine, Kristen L. Cook, Caltech, Mary E. Dickinson, Caltech, Paul E. Dimotakis, Caltech, John Donoghue, Brown Kurt W. Fleischer, Pixar, Geoffrey Fox, Felice Frankel, MIT, Scott E. Fraser, Caltech, Yuri M. Goldfeld, Caltech, Galen G. Gornowicz, Dreamworks SKG, Victoria Interrante, U. of Minnesota, Russell E. Jacobs, Caltech, David Kremers, Caltech, Daniel B. Lang, Caltech, H. Marmanis, Brown, Mark D. Montague, Caltech, P. T. Narasimhan, Caltech, Carol Readhead, Cedars Sinai Medical Center, Jerome Sanes, Brown, Jerry W. Shan, Caltech, Jeffrey M. Silverman, Cedars Sinai Medical Center, Michael Tarr, Brown, J. Michael Tyszka, City of Hope Medical Center, Terry Tulles, Brown.

e. (ii) Advisees Daniel Acevedo Feliz, Stuart Andrews, Daniel Keefe, R. Michael Kirby, Georgeta Elizabeth Morai, Paul Reitsma, Song Zhang.

e. (iii) Advisors Alan H. Barr, Caltech, Scott E. Fraser, Caltech.

John B. Rundle: Colorado

Education

Ph.D., Geophysics and Space Physics, UCLA (1976)
M.S., Geophysics and Space Physics, UCLA (1973)
B.S.E., Engineering Physics, Princeton University (1972), *magna cum laude*

Professional Experience

Professor, Department of Physics
Fellow, Cooperative Institute for Research in Environmental Sciences, University of Colorado (1996–)
Director, Colorado Center for Chaos and Complexity, University of Colorado
Associate Professor, Departments of Physics and Geology (1993–1996)
Physicist, Lawrence Livermore National Laboratories (1990–1993)
Member of Technical Staff, Sandia National Laboratories (1977–1990)
Visiting Scholar, Condensed Matter Theory Group, Department of Physics, Boston University (1988–1989, concurrent with above)
Visiting Associate, Calif. Institute of Technology (1981–1984, concurrent with above)
Postdoctoral Fellow, U. Calif. Los Angeles (1976–1977)
Teaching Fellow, Department of Physics, University of Illinois (1974–1974)

Honors and Awards

National Merit Finalist
Magna Cum Laude, Princeton University, 1972.
Phi Beta Kappa, Princeton University, 1972
Tau Beta Pi, Princeton University, 1972
Sandia National Laboratories: Exceptional Contribution Award for Fundamental Research ($2500 Award)
US Geological Survey, Branch of Geologic Risk Assessment, Best Paper 1989 (with G. King & R. Stein, $500 Award)
Association Lecturer, International Association of Seismology and Physics of the Earth's Interior, Wellington, NZ, 1994.
Award for Outstanding Contributions in Geosciences Research, given at the Geosciences Research Symposium, Lawrence Berkeley National Laboratory, April, 1996, by the Geosciences Research Program, Office of Basic Energy Sciences, US Department of Energy.
Distinguished Visiting Scientist, Jet Propulsion Laboratory, Pasadena, California, 1995 -

Recent Service

Science Advisory Panel, 1986 - Present, *Chairman* National Science Foundation, External Advisory Council for the Southern California Earthquake Center, *Member*, 1991 -*Chair*, 1995-1995; *Member*, 1997-1999

Office of Science and Technology Policy, Executive Office of the President of the United States, National Forum on Environment and Natural Resources, March 28-30, 1994, *Invited Participant*

Office of Science and Technology Policy, Executive Office of the President of the United States, National Earthquake Strategy Workshop, June 6-8, 1994, *Invited Participant*

National Aeronautics and Space Administration, Earth System Science Advisory Committee (Committee Advisory to the Associate Administrator OF NASA for Mission to Planet Earth , June 1994 - 1998, *Member*

American Geophysical Union, Technical Committee on Nonlinear Geophysics, 1997-, *Chair*

National Aeronautics and Space Administration, Solid Earth and Natural Hazards, Committee on Future Directions, Panel on Earthquakes and Crustal Deformation, 1997-1998, *Chair*

Five Recent Publications

Rundle, J.B. and W. Klein, New ideas about the physics of earthquakes, *Reviews of Geophysics and Space Physics Supplement , and Quadrennial Report to the IUGG and AGU 1991-1994 (invited)*, 283-286, July, 1995.

Rundle, J.B., W. Klein, S. Gross, and D.L. Turcotte, Boltzmann fluctuations in numerical simulations of nonequilibrium threshold systems, *Phys. Rev. Lett.,* **75,** 1658-1661, 1995.

Rundle, J.B., W. Klein and S. Gross, Dynamics of a traveling density wave model for earthquakes, *Phys. Rev. Lett.,* **76**, 4285 - 4288, 1996.

Klein, W., J.B. Rundle and C. Ferguson, Scaling and nucleation in models of earthquake faults, *Phys. Rev. Lett.,* **78**, 3793-3796, 1997.

Rundle, J.B. E. Preston, S. McGinnis, W. Klein, Why earthquakes stop: Growth and arrest in stochastic fields, *Phys. Rev. Lett.*, **80**, 5698-5701, 1998.

Recent Principal Collaborators (last five years)**:**

William Klein, Boston University
Donald Turcotte, Cornell University
Suanna Gross, University of Colorado
Bernard Minster, University of California San Diego
Charles Ferguson, University of Maryland
Geoffrey Fox, Syracuse University
Jose Fernandez, University Completense de Madrid, Spain
Ting To Yu, Acadmia Sinica, Taiwan
Eric Preston, University of Colorado
Seth McGinnis, University of Colorado
Joydeep Bhattacharyya, Yale University
Anne Sheehan, University of Colorado
Kristy Tiampo, University of Colorado
Louise Kellogg, University of California at Davis
Gerald Bawden, University of California at Davis
Andrea Donnellan, Jet Propulsion Laboratory
Danen Dong, Jet Propulsion Laboratory

Jill H. Andrews: USC

DIRECTOR FOR OUTREACH
Southern California Earthquake Center
University of Southern California
Los Angeles, CA 90089-0742
213/740-3459 voice mail
213/740-0011 facsimile
email: *jandrews@terra.usc.edu*

Jill Andrews directs the Education and Knowledge Transfer (Outreach) programs for the Southern California Earthquake Center (SCEC), a National Science Foundation Science and Technology Center administrated by the University of Southern California. Her professional background in academia includes 20 years as an administrator and corporate liaison with a focus on building mutually beneficial relationships with business and industry for the purpose of developing useful technologies for general application.

After obtaining a Bachelor of Arts degree in Journalism and Human Relations from Ambassador University in 1973, Andrews pursued social work in Indiana, Michigan and Arizona. Returning in the early 1980s to her hometown in Pasadena, California, she joined the administrative staff at the California Institute of Technology, where she served as Acting Director for Undergraduate Admissions, Associate Director for Corporate Relations, and then as Director of the Earthquake Programs Office.

As SCEC s Outreach director, Andrews currently serves as a member of its Steering Committee and oversees all outreach activities with technical practitioners, government agencies, business leaders, the media, K-16 educational and academic institutions, and the general public. She is chair and co-founder of the Earthquake Information Providers Group (EqIP), a coalition of 30 organizations whose common mission is to distribute information worldwide via the Internet. She is an advisor to the National Information Service for Earthquake Engineering (NISEE) libraries in New York and California and a member of the outreach advisory committee for TriNet, a California-based coalition to build a real-time seismic network. She co-chaired the Education and Information working group for the writing and production of the State of California s Earthquake Mitigation Plan, produced by the State Seismic Safety Commission, and currently serves on the Commission s Committee on Emergency Preparedness and Response and Recovery (EPARR). Andrews edits and produces the SCEC Quarterly Newsletter. She produced, with the US Geological Survey under the auspices of SCEC, Putting Down Roots in Earthquake Country, a personal handbook to earthquake safety. She chairs the Business Alliance for Earthquake Education and Mitigation, a group of corporate leaders in southern California who supported the production of the English version of the handbook, and is now supervising production of a Spanish language version. She chairs the Innovative Technology Transfer Forum for the Earthquake Engineering Research Institute, an organization dedicated to the advancement of the science and practice of earthquake engineering, and the solution of national earthquake engineering problems. Andrews served as a co-convenor for the 1998 4th International Conference on Corporate Earthquake Programs (Shizuoka, Japan). She manages the education program for the FEMA-funded Earthquake Hazard Mitigation of Woodframe Construction for the California Universities for Research in Earthquake Engineering (CUREe), and serves as an education consultant to the Pacific Earthquake Engineering Research Center

(PEER), headquartered at UC Berkeley, and the Incorporated Research Institutions in Seismology (IRIS) in Washington, DC.

SCEC-Related Publications

The Southern California Earthquake Center Quarterly Newsletter: Editor, Writer and Producer: Volume 1, No. s 1-4 (1995-96); Volume 2, No. s 1-4 (1996-97); Volume 3, No. s 1-4 (1997-98).

Lucile M. Jones et al., Putting Down Roots in Earthquake Country, published by the Southern California Earthquake Center and U.S. Geological Survey, October, 1995; Jill H. Andrews, Producer.

Andrews, J. H., Compiler, Editor, *Proceedings*, Research Utilization Council, published by the Southern California Earthquake Center, August, 1995.

Andrews, J. H., Compiler, Editor, *Proceedings*, Addressing Seismic Hazards in Southern California: Establishing Dialogue Among Academia, The Insurance Industry, and Risk Assessment Professionals, published by the Southern California Earthquake Center, November, 1995.

Andrews, J. H., Compiler, Editor, *Proceedings*, Addressing Seismic Hazards in Southern California: Earthquakes and Insurance, published by the Southern California Earthquake Center, April, 1996.

Andrews, J. H., Compiler, Editor, *Proceedings*, Exploring Options for Seismic Zonation in the City of Los Angeles, published by the Southern California Earthquake Center, October, 1996 and April, 1998.

Andrews, J. H., Compiler, Editor, Shattered Crust Series #1: The Newport-Inglewood and Whittier-Elsinore Fault Zones, published by the Southern California Earthquake Center, October, 1996.

Andrews, J. H., Compiler, Editor, Shattered Crust Series #2: The Palos Verdes Fault Guide, published by the Southern California Earthquake Center, October, 1996.

Andrews, J. H., Basic Research and Information, Knowledge and Technology Transfer, submitted to Earthquake Engineering Research Institute *Earthquake Basics* series, in review, 1997.

Edward H. Ned Field: Understanding Earthquake Ground Motion and Seismic Hazard Assessment, *Scientific American*, in review, April 1998. J. H. Andrews, Editor.

Naeim, F., M. Cochran, and J. H. Andrews: Hazards Posed by Nonductile Concrete and Tuck-Under Parking Buildings, in review, Southern California Earthquake Center, April 1998.

Andrews, J. H., Compiler, Editor, *Proceedings*, Earthquakes and Urban Infrastructure: A Workshop, published by the Southern California Earthquake Center, April, 1998.

Yehuda Ben-Zion: USC

Professional preparation:

B.Sc. Geology and Physics, The Hebrew University of Jerusalem (October 1982).
Ph.D. Geophysics and Seismology, University of Southern California (August 1990).

Appointments:

Assistant Professor of Earth Sciences, University of Southern California, 1997-present
Visiting Professor, the Earthquake Research Institute, University of Tokyo, Japan, 1996.
Research Associate of Geophysics, Harvard University, 1994 - January 1996.
Post-Doctoral fellow, Harvard University (with Professor J. R. Rice), 1991 - 1993.

Research Interests:

Physics Of Earthquakes and Faults, Self-Organization, Disordering and Regularization Processes, Complexity, Dynamic Rupture in Structures with Material Interfaces, Spatio-Temporal Seismicity Patterns and Earthquake Statistics, Information Content of Seismic Catalogs, Theory and Observation of Seismic Fault Zone Guided Waves, Earthquake Prediction, Local Amplifications in Dynamic Seismic Fields.

Publications:

(i) *5 recent publications closely related to the proposed project*

Ben-Zion, Y., Stress, slip and earthquakes in models of complex single-fault systems incorporating brittle and creep deformations, *J. Geophys. Res.*, **101**, 5677-5706, 1996.

Eneva, M. and Y. Ben-Zion, Techniques and parameters to analyze seismicity patterns associated with large earthquakes, *J. Geophys. Res.*, **102**, 17785-17795, 1997.

Ben-Zion, Y. and D. J. Andrews, Properties and Implications of Dynamic Rupture Along a Material Interface, *Bull. Seism, Soc. Am.*, **88**, 1085-1094, 1998.

Ben-Zion, Y., K. Dahmen, V. Lyakhovsky, D. Ertas and A. Agnon, Self-Driven Mode Switching of Earthquake Activity on a Fault System, *Earth Planet. Sci. Lett.*, 172/1-2, 11-21, 1999.

Ben-Zion, Y. C. Sammis and T. Henyey, Perspectives on the Field of Physics of Earthquakes, *Seism. Res. Lett.*, 70, 428-431, 1999.

(ii) 5 other recent significant publications

Fisher, D. S., K. Dahmen, S. Ramanathan and Y. Ben-Zion, Statistics of Earthquakes in Simple Models of Heterogeneous Faults, *Phys. Rev. Lett.*, **78**, 4885-4888, 1997.

Ben-Zion, Y. and J. R. Rice, Dynamic simulations of slip on a smooth fault in an elastic solid, *J. Geophys. Res.*, **102**, 17771-17784, 1997.

Dahmen, K., D. Ertas and Y. Ben-Zion, Gutenberg Richter and Characteristic Earthquake behavior in Simple Mean-Field Models of Heterogeneous Faults, *Phys. Rev. E*, **58**, 1494-1501, 1998.

Lyakhovsky, V., Y. Ben-Zion and A. Agnon, Distributed Damage, Faulting, and Friction, *J. Geophys. Res.*, **102**, 27635-27649, 1997.

Miller, S. A., Y. Ben-Zion and J.-P. Burg, A Three-dimensional Fluid-controlled Earthquake Model: Behavior And Implications, *J. Geophys. Res*., **104**, 10621-10638, 1999.

Collaborators and Other Affiliations:

(i) Collaborators (outside USC)
Agnon Amotz, Hebrew U. of Jerusalem, Israel
Andrews Joe, USGS, Menlo Park
Armbruster John, Lamont-Doherty Earth Observatory
Dahmen Karin, Univ. of Illinois at Urbana Champaign
Eneva Mariana, Maxwell Technologies (San Diego, CA)
Fisher Daniel, Harvard University
Ito Hisao, Geological Survey of Japan
Lapusta Nadia, Harvard University
Lockner Dave, USGS, Menlo Park
Lyakhovsky Vladimir, Hebrew U. of Jerusalem, Israel
Michael Andrew, USGS, Menlo Park
Miller Steve, ETH, Switzerland
Nishigami Kin'ya, Kyoto University, Japan
Igel Heiner, Munich University, Germany
Rice James, Harvard University
Seeber Leonardo, Lamont-Doherty Earth Observatory
Zheng Gutuan, IBM

(ii) Graduate and Postdoctoral Advisors
Ben-Zion's Ph.D. thesis advisor was Keiiti Aki and his postdoctoral advisor was James R. Rice.

(iii) Thesis Advisor and Postgraduate-Scholar sponsor
Current graduate advisor of 4 USC students: Shoshana Levin, Yunfeng Liu, Zhigang Peng, Eric Libicki

Current Postdoctoral advisor of Yueqiang Huang

Gregory C. Beroza: Stanford

EDUCATION AND PROFESSIONAL EXPERIENCE

1982	B.S., Geophysics, University of California at Santa Cruz.
1989	Ph.D., Geophysics, Mass. Institute of Technology.
1989-1990	Postdoctoral Associate, Massachusetts Institute of Technology.
1990-1994	Assistant Professor of Geophysics, Stanford University.
1994-present	Associate Professor of Geophysics, Stanford University.

HONORS AND AWARDS

1983	National Science Foundation Graduate Fellow.
1991	National Science Foundation Presidential Young Investigator Award.

SELECTED PROFESSIONAL ACTIVITIES

1993-1995, 1999	Panelist, USGS External Program (Process&Theory and Northern California).
1996-present	NAS/NRC Committee on the Science of Earthquakes.
1996-1999	Associate Editor, Journal of Geophysical Research.
1998-present	Panelist, NSF Seismology and Geophysics Proposal Review Panel.

FIVE PUBLICATIONS MOST RELEVANT TO THIS PROJECT

1996 Dodge, D. A., G. C. Beroza, and W. L. Ellsworth, Detailed observations of California foreshock sequences: implications for the earthquake initiation process, *J. Geophys. Res., 101*, 22,371-22,392.

1996 Beroza, G. C. and T. Mikumo, Short slip duration in dynamic rupture in the presence of heterogeneous fault properties, *J. Geophys. Res., 101*, 22,449-22,460.

1996 Beroza, G. C., and W. L. Ellsworth, Properties of the seismic nucleation phase, *Tectonophysics*, *261*, 209-227.

1998 Schaff, D. P., G. C. Beroza, and B. E. Shaw, Postseismic response of repeating aftershocks, *Geophys. Res. Lett.*, 25, 4549-4552.

1999 Mai, P. M. and G. C. Beroza, Source scaling properties from finite-fault rupture models, *Bull. Seismol. Soc. Am.*, (submitted).

FIVE ADDITIONAL RELEVANT PUBLICATIONS

1988 Beroza, G. C., and P. Spudich, Linearized inversion for fault rupture behavior: application to the 1984, Morgan Hill, California, earthquake, *J. Geophys. Res.*, *93*, 6275-6296.

1994 Cohee, B. P., and G. C. Beroza, Slip distribution of the 1992 Landers earthquake and its implications for earthquake source mechanics, *Bull. Seismol. Soc. Am.*, *84*, 692-712.

1995 Ellsworth, W. L., and G. C. Beroza, Seismic evidence for an earthquake nucleation phase, *Science*, *268*, 851-855.

1996 Beroza, G. C., Rupture history of the earthquake estimated from high-frequency strong-motion data, *U.S. Geological Survey Professional Paper 1550-A, The Loma Prieta, California Earthquake of October 17, 1989–Main-Shock Characteristics*, A9-A32.

1999 Bokelmann, G., and G. C. Beroza, Depth-dependent earthquake focal mechanism orientation: evidence for a weak zone in the lower crust, *J. Geophys. Res.*, (submitted).

(About 35 additional refereed publications)

STUDENTS AT STANFORD UNIVERSITY AND RECENT COLLABORATORS

Current: David Schaff (Ph.D.), Patti Guaterri (Ph.D.), Xyoli Perez-Campos (Ph.D), Martin Mai (Ph.D.), Eva Zanzerkia (Ph.D.), Vincent Quitoriano (Ph.D.)

Former: Brian Cohee (Ph.D., 1995), Hal Mendoza (M.S., 1995), Martijn Verwoerd (M.S., 1995), Doug Dodge (Ph.D., 1996), Karen Felzer (B.S., 1998)

Collaborators: Bill Ellsworth, Paul Spudich, Tom Jordan, Vernon Cormier, Takeshi Mikumo, Bruce Shaw.

Lisa B. Grant: Irvine

Office Address: Department of Environmental Analysis and Design, 262 SE I
University of California
Irvine, CA 92697-7070
(949) 824-5491 [office] (949) 824-5382 [lab]
(949) 824-2056 [fax]
lgrant@uci.edu

Citizenship: USA

Education: Ph.D. Geology and Geophysics, 1993
Caltech, Pasadena, CA.
Thesis Title: *Characterization of Large Earthquakes on the San Andreas Fault in the Carrizo Plain: Implications for Fault Mechanics and Seismic Hazard*

M.S. Geology, 1990
Caltech, Pasadena, CA.

M.S. Environmental Engineering Science, 1989
Caltech, Pasadena, CA.

B.S. with distinction, Environmental Earth Science, 1985
Stanford University, Palo Alto, CA.

Research Interests: Paleoseismology, active faults, seismic hazard

Experience Assistant Professor
Department of Environmental Analysis and Design
University of California, Irvine
7/98 - present

Assistant Professor of Environmental Science and Geology
Program Director for Environmental Science
Chapman University, Orange, CA
8/95 - 6/98

Senior Staff to Assistant Project Scientist
Woodward-Clyde Consultants
Santa Ana, CA
6/93 - 7/95 (part-time consulting 8/95 to present)

Graduate Research and Teaching Assistant, Graduate Fellow
Caltech, Pasadena CA
10/87 – 5/93

Research Scientist
California Research and Technology / Titan Systems (now Titan Technologies)
Chatsworth, CA
1/85 - 7/87

Selected Service:
Associate Editor, Bulletin of the Seismological Society of America, 1997 to present

Selected Publications:

Roddy, D., Schuster, S., Rosenblatt, M., Grant, L., Hassig, P., and Kreyenhagen, K., *Computer Simulations of Large Asteroid Impacts Into Oceanic and Continental Sites : Preliminary Results on Atmospheric, Cratering and Ejecta Dynamics,* **International Journal of Impact Engineering**, Vol 5, p.525-541, 1987.

Grant, L. B. and K. Sieh, *Stratigraphic Evidence for 7 Meters of Dextral Slip on the San Andreas Fault During the Great 1857 Earthquake in the Carrizo Plain.* **Bulletin Seismological Society of America**, Vol. 83, No. 3, p. 619-635, 1993.

Grant, L. B. and A. Donnellan, *1855 and 1991 Surveys of the San Andreas Fault:Implications for Fault Mechanics* , **Bulletin Seismological Society of America**, Vol. 84, No. 2, p.241-246, 1994.

Grant, L. B. and K. Sieh, *Paleoseismic Evidence of Clustered Earthquakes on the San Andreas Fault in the Carrizo Plain, California*, **Journal of Geophysical Research,** Vol. 99, No. B4, p. 6819-6841, 1994.

Grant, L. B., *Uncharacteristic Earthquakes on the San Andreas Fault,* **Science**, v. 272, 826 - 827, 1996.

Grant, L. B., J. T. Waggoner, C. von Stein and T. Rockwell, *Paleoseismicity of the North Branch of the Newport-Inglewood Fault Zone in Huntington Beach , California, from Cone Penetrometer Test Data* . **Bulletin of the Seismological Society of America**, v. 87, no 2., 277 - 293, 1997.

Grant, L.. B., K. J. Mueller, E. M. Gath, H. Cheng, R. L. Edwards, R. Munro and G. L. Kennedy, *Late Quaternary Uplift and Earthquake Potential of the San Joaquin Hills, southern Los Angeles Basin, California*, **Geology**, in press for Nov. 1999 issue.

Thomas L. Henyey: USC

A. Personal Information

Current address: Department of Earth Sciences
University of Southern California, University Park
Los Angeles, California 90089/0740

B. Education

A.B. Geophysics, University of California, Berkeley, 1962
Ph.D. Geophysics, California Institute of Technology, 1968

C. Professional Experience

Research Assistant, Caltech, 1966-1967
Teaching Assistant, Caltech, 1967-1968
Assistant Professor of Geological Sciences, University of Southern California, 1968-1974
Associate Professor of Geological Sciences, University of Southern California, 1974-1981
Sabbatical leave, U.C. Santa Barbara, Spring, 1976
Professor of Geological Sciences, University of Southern California, 1981-present
Sabbatical leave, DSIR, New Zealand, Summer/Fall, 1982
Professor of Geological Sciences and Chairman, Department of Geological Sciences, University of Southern California, 1989-1991
Professor of Geological Sciences, University of Southern California and Executive Director, Southern California Earthquake Center, 1991-1996
Professor of Geological Sciences, University of Southern California and Director, Southern California Earthquake Center, 1996-present

D. Some Recent Publications

Li, Y.G., T.L. Teng, and T.L. Henyey, Shear Wave Splitting Observations and Implications for the Stress Regime in the Los Angeles Basin, Southern California, Bull. Seis. Soc. Amer., 84 , 307-323, 1994.

Schiffries, C.M. and T. L. Henyey, A possible earthquake deficit in Southern California, Geotimes, June, 1994.

Henyey, Tom, One shock leads to another, News and Views, Nature, 375 , No.6258, p. 191, 1995.

Malin, P.E., E.D. Goodman, T.L. Henyey, Y.G. Li, D.A. Okaya, and J.B. Saleeby, Significance of seismic reflections beneath a tilted exposure of deep continental crust, Tehachapi Mountains, California, Jour. Geophys. Res., 100 , 2069-2088, 1995.

Jackson, D., K. Aki, A. Cornell, J. Dieterich, T. Henyey, M, Mahdyiar, D. Schwartz, and S. Ward, Seismic hazards in southern California: Probable earthquakes, 1994-2024, Bull. Seis. Soc. Amer., 85 , no. 2, 379-439, 1995.

E. Advisors, Collaborators, Graduate Students and Post-Doctoral Fellows

Graduate Advisors: Gerald Wasserburg, James Brune
Collaborators: S. Holbrook (Wyoming), N. Christensen (Wisconsin), T. McEvilly (UCB), R. Clayton (Caltech),
G. Fuis (USGS), P. Davis (UCLA), G. Jiracek (SDSU), T Stern (Victoria, N.Z.), F. Davey (IGNS-N.Z.);
Also, Scientists from the Southern California Earthquake Center and the publication list above.
Graduate Students and Post-Doctoral Fellows: Robert Clayton, Avijit Chakraborty, Mike Forrest, Ned Field, Rachel Abercrombie, Nicola Godfrey, Yong-Gang Li.

Tom H. Jordan: MIT

BIRTH:	October 8, 1948, Coco Solo, Canal Zone
S.S. NUMBER:	264-92-7023
CITIZENSHIP:	U.S.A.
EDUCATION:	B.S., Geophysics, California Institute of Technology, 1969 M.S., Geophysics, California Institute of Technology, 1970 Ph.D., Geophysics and Applied Mathematics, California Institute of Technology, 1972
EMPLOYMENT:	1969-1972: Graduate Research Assistant, California Institute of Technology, Pasadena, CA; 1972-1975: Assistant Professor, Princeton University, Princeton, NJ; 1975-1977: Assistant Professor, Scripps Institution of Oceanography, University of California, San Diego, CA; 1977-1982: Associate Professor, SIO; 1982-1984: Professor, SIO; 1984-Present: Robert R. Shrock Professor of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA; 1988-1998: Department Head, Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA
HONORS & AWARDS:	National Merit Scholar, 1965-1969; Alfred P. Sloan Fellow in Physics, 1980-1982; Fellow, American Geophysical Union, 1983; James B. Macelwane Award, American Geophysical Union, 1983; Fellow, American Academy of Arts and Sciences, 1996; Member, National Academy of Sciences, 1998; George P. Woollard Award, Geological Society of America, 1998.

Scientific Publications

Approximately 120, on various topics in seismology, geodynamics, tectonics, geodesy, and marine geology. Five examples relevant to the proposed work are:

96. 1991 Jordan, T.H., Far-field detection of slow precursors to fast seismic ruptures, *Geophys. Res. Lett.*, **18**, 2019-2022.

99. 1993 Ihmlé, P. F., P. Harabaglia, and T. H. Jordan, Teleseismic detection of a slow precursor to the great 1989 Macquarie Ridge earthquake, *Science*, **261**, 177-183.

109. 1995 Ihmlé, P. F., and T. H. Jordan, Source time function of the great 1994 Bolivia deep earthquake by waveform and spectral inversion, *Geophys. Res. Lett.*, **22**, 2253-2256.

113. 1996 McGuire, J. J., P. F. Ihmlé, and T. H. Jordan, Time-domain observations of a slow precursor to the 1994 Romanche Transform earthquake, *Science*, **274**, 82-85, 1996.

127. 1999 McGuire, J. J., and T. H. Jordan, Further evidence for the compound nature of slow earthquakes: the Prince Edward Island earthquake of April 28, 1997, *J. Geophys. Res.*, in press.

Recent Collaborators (last 48 months, exclusive of students)

D. Weidner, SUNY, Stony Brook; Y. Wang, University of Chicago; Paul Silver, Carnegie Institution of Washington; David James, Carnegie Institution of Washington.

Doctoral Dissertations Supervised

1979 S. A. Sipkin, *Constraints on Earth Structure Determined from Observations of Multiple ScS*, UCSD.

1981 K. A. Sverdrup, *Seismotectonic Studies in the Pacific Ocean Basin*, UCSD.

1982 A. L. Lerner-Lam, *Linearized Estimation of Higher-Mode Surface Wave Dispersion*, UCSD.

P. G. Silver, *Optimal Estimation of Scalar Seismic Moment*, UCSD.

1984 K. C. Creager, *Geometry, Velocity Structure, and Penetration Depths of Descending Slabs in the Western Pacific*, UCSD.
1985 M. A. Riedesel, *Seismic Moment Tensor Recovery at Low Frequencies*, UCSD.
D. K. Smith, *The Statistics of Seamount Populations in the Pacific Ocean*, UCSD.
R. G. Adair, *Microseisms in the Deep Ocean: Observations and Theory*, UCSD.
1988 K. M. Fischer, *The Morphology and Dynamics of Subducting Lithosphere*, MIT.
1989 J. Sauber, *Geodetic Measurement of Deformation in California*, MIT.
J. S. Revenaugh, *The Nature of Mantle Layering from First-Order Reverberations*, MIT.
G. C. Beroza, *Near-Source Imaging of Seismic Rupture*, MIT.
1990 L. S. Gee, *New Techniques for Seismological Studies of Earth Structure*, MIT.
E. Lavely, *Theoretical Investigations in Helioseismology*, MIT.
J. A. Goff, *Stochastic Modeling of Seafloor Morphology*, MIT.
1991 M. H. Murray, *Global Positioning System Measurement of Crustal Deformation in Central California*, MIT.
1991 K. L. Feigl, *Geodetic Measurement of Tectonic Deformation in Central California*, MIT.
1994 P. F. Ihmlé, *Teleseismic Study of Earthquakes of Long Duration*, MIT.
1995 P. Puster, *The Characterization of Seismic Earth Structures and Numerical Mantle Convection Experiments Using Two-Point Correlation Functions*, MIT.
1995 J. G. Gaherty, *Structure and Anisotropy of the Upper Mantle*, MIT.
1997 H. F. Webb, *A Qualitative and Quantitative Study of the Distribution of Pelagic Sediment in the Atlantic Basin*, MIT.
1998 R. Katzman, *Structure and Dynamics of the Pacific Mantle*, MIT.

e. Graduate and Postgraduate Advisors:

Ph.D. advisor: D. L. Anderson, Caltech
Postgraduate advisor: none

Hiroo Kanamori: Caltech

Born - 17 October 1936
Japan (Japanese citizen)

Address:

Office:
Seismological Laboratory, California Institute of Technology,
Pasadena California 91125
Telephone: (626) 395 6914, FAX: (626) 564-0715,
E-mail: hiroo@gps.caltech.edu

Home:
375 South Bonnie, Pasadena California 91106
Telephone: (626) 793-3120

Education:

B. S. (Physics), Tokyo University, 1959
M. S. (Geophysics), Tokyo University, 1961
Ph.D. (Geophysics), Tokyo University, 1964

Professional Experience:

Research Associate, Geophysics Institute, Tokyo University, 1962-65
Research Fellow, California Institute of Technology, 1965-66
Associate Professor, Earthquake Research Institute, Tokyo University, 1966-69
Visiting Associate Professor, Massachusetts Institute of Technology, 1969
Professor, Earthquake Research Institute, Tokyo University, 1970-72
Professor, California Institute of Technology, 1972-89
John E. and Hazel S. Smits Professorship of Geophysics, 1989-
Director, Seismological Laboratory, California Institute of Technology, 1990-April, 1998

Major Research Interest

Kanamori's research centers on the physics of earthquakes. His work includes: (1) quantification of great earthquakes using M_w scale, (2) quantitative study of tsunami earthquakes, (3) seismological study of volcanic eruptions, (4) real-time seismology for hazard mitigation, (5) study of atmospheric waves excited by volcanic eruptions, (6)

study of interaction between solid earth and atmosphere, (7) frictional melting due to faulting, (8) synthesis of microscopic and macroscopic physics of earthquakes.

Membership

Seismological Society of Japan
American Geophysical Union
Seismological Society of America
Earthquake Engineering Research Institute
American Academy of Arts and Sciences

Awards

Medal of the Seismological Society of America, 1992
Arthur L. Day Prize and Lectureship, U.S. National Academy of Science, 1993
California Scientist of the Year Award, 1993
The Asahi Prize, 1993.
Walter H. Bucher Medal, American Geophysical Union, 1996.

Selected Papers

Kanamori, H., and M. Kikuchi, The 1992 Nicaragua Earthquake: a slow tsunami earthquake associated with subducted sediments, *Nature*, **361**, 714-716, 1993.

Kikuchi, M., and H. Kanamori, The mechanism of the deep Bolivia earthquake of June 9, 1994, *Geophys. Res. Lett*, **21**, 2341-2344, 1994.

Kanamori, H., T. H. Anderson, and T. H. Heaton, Frictional melting during the rupture of the 1994 Bolivian Earthquake, *Science, 279*, 839-842, 1998.

Kanamori, H., E. Hauksson, L. K. Hutton, and L. M. Jones, Determination of Earthquake Energy Release and M_L Using TERRAscope, *Bull. Seismol. Soc. Am., 83*, 330-346, 1993.

Kanamori, H. and T. H. Heaton, Microscopic and macroscopic physics of earthquakes, accepted for publication in AGU monograph "Physics of Earthquakes", 2000.

William Klein: Boston University

Boston University
Department of Physics
Boston, MA 02215
617-353-2188
email: klein@phy40-pc157.bu.edu

Personal
Born, April 1, 1943, Philadelphia, Pa. ; married, two children.

EDUCATION
Ph.D. Temple University 1972, Physics
B.A. Temple University 1965, Physics

POSITIONS
Professor of Physics, Boston University, Sept. 1984-
Professor, College of Engineering, Boston University, January 1992 -
Visiting Scientist, Institute for Theoretical Physics, University of California at Santa Barbara, September, 1997 - January 1998
External Researcher, Santa Fe Institute, January, 1996-
Visiting Scientist, Lawrence Livermore Laboratory, Sept. 1,1990 - July 1993
Visiting Scientist, Oersted Institute, Copenhagen, July 1, 1992- Dec. 31, 1992
Visiting Professor, McGill University, January 1,1987-December 31, 1989
Visiting Scientist, IBM Bergen Scientific Center, July 1988
Visiting Scientist, University of Konstanz, August 1985
Visiting Scientist, University of Mainz, July 1985
Visiting Scientist, SUNY Stony Brook, August 1984
Visiting Scientist, St. Francis Xavier University, Nova Scotia, July 1984
Visiting Scientist, Harvard University, Sept. 1983-June 1984
Associate Professor of Physics, Boston University, Sept. 1981-Sept. 1984
Visiting Scientist, IBM Zurich, August 1983
Visiting Scientist, Kernforschungsanlage, Jülich, Germany, July 1983
Visiting Scientist, Kernforschungsanlage, Jülich, Germany, May 1982
Assistant Professor of Physics, Boston University, Jan. 1977-Sept. 1981
Visiting Scientist, Kernforschungsanlage, Jülich, Germany, May 1981
Research Associate, Boston University, Sept. 1976-Jan. 1977
Research Scientist, Institut für Theoretische Physik, Universität zu Köln, Sept. 1974-Sept. 1976
PostDoctoral Fellow, Mathematics Department, MIT, Sept. 1973-Sept. 1974
PostDoctoral Fellow, National Bureau of Standards, June 1972-Sept. 1973

Additional Positions
Consultant, Digital Equipment Corporation, 1984-1985
Consultant, Schlumberger-Doll, 1983-1985
Consultant, Lawrence Livermore National Laboratory, 1992-1993

PUBLICATIONS
[1] J. Yang, H. Gould, W. Klein and R. Mountain, ``Dynamics Study of Supercooled Liquids" *J. Chem. Phys.*, **93**, 711 (1990)

[2] L. Monette and W. Klein, ``Spinodal Nucleation as a Coalescence Process" *Phys. Rev. Lett.*, **68**, 2336 (1992)
[3] N. Gross, W. Klein and K. Ludwig, ``Structure and the Failure of the Linear Theory of Continuous Ordering"*Phys. Rev. Lett.*, **73**, 2639 (1994)
[4] A. Mel'cuk, R. Ramos, H. Gould, W. Klein and R. Mountain, ``Long Lived Structures in Fragile Glasses" *Phys. Rev. Lett.*, **75**, 2552 (1995)
[5] G. Johnson, A. Mel'cuk, H. Gould, W. Klein and R. Mountain, ``Molecular Dynamics Study of Long Lived Structures in a Fragile Glass Forming Liquid" *Phys. Rev. E* **57**, 5707 (1998)
[6] J. Rundle and W. Klein, ``Scaling and Critical Phenomena in a Class of Burridge-Knopoff Models for Earthquakes" *J. Stat. Phys.*, **72** 405 (1993)
[7] J. B. Rundle and W. Klein, ``Dynamical Segmentation and Rupture Patterns in a `Toy' Slider Block Model for Earthquakes" *Non-Linear Proc. in Geophys.* **2**, 61 (1995)
[8] W. Klein, J. B. Rundle and C. D. Ferguson, ``Critical Phenomena and Metastability in Models of Earthquake Faults" *Phys. Rev. Lett.* **78**, 3793 (1997)
[9] J. B. Rundle, E. Preston, S. McGinnis and W. Klein, ``Why Earthquakes Stop: Growth and Arrest in Stochastic Fields" *Phys. Rev. Lett.*, **80**, 5698 (1998)
[10] C. F. Ferguson, W. Klein and J. R. Rundle ``Spinodals, Scaling and Ergodicity in a Model of an Earthquake Fault with Long-Range Stress Transfer" *Phys. Rev. E*, **60**, 1374 (1999)

Jean-Bernard Minster: Scripps UCSD

IGPP, Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093-0225
jbminster@ucsd.edu, 619-534-5650, Fax 619-534-2902

1994-Present: Professor of Geophysics, Director, Systemwide, Institute of Geophysics and Planetary Physics
1995-present: Member, Committee on Environmental and Geophysical Data, National Research Council.
1993-present: Member, National Research Council Board on Earth Sciences and Resources
1990-present: Member, Board of Directors, Southern California Earthquake Center
Professional Associations & Memberships: American Geophysical Union, European Geophysical Union, Royal Astronomical Society, Seismological Society of America, Society of Exploration Geophysicists, European Geophysical Society, American Association for the Advancement of Science
Ph.D.: Geophysics, California Institute of Technology, 1974
Doctorat d'État : Géophysique, Université de Paris VII, 1974

5 Publications Related to the Proposed Project:

Baker, G.E., J.B. Minster, G. Zandt, and H. Gurrola, Constraints on crustal structure and complex Moho topography beneath Piñon Flat, California, from teleseismic receiver functions, *Bull. Seismol. Soc. Amer.*, 86, 1830-1844, 1996.

Shkoller, S. and J. B. Minster, Reduction of Dietrich-Ruina attractors to unimodal maps, *Nonlinear Processes in Geophysics*, **4**, 63-69, 1997.

Xu, H., S. M. Day and J. B. Minster, Model for nonlinear wave propagation derived from rock hysteresis measurements, *J. Geophys. Res.*, **103**, 29915-29929, 1998.

Hofton, M. A., J. B. Blair, J.-B. Minster, J. R. Ridgway, N. P. Williams, J. L. Bufton and D. L. Rabine, An airborne topographic survey of Long Valley Caldera, CA, 1995, using scanning laser altimetry, *Int. J. Remote Sensing*, **submitted**, 1998.

Calais, E. and J.-B. Minster, GPS, earthquakes, the ionosphere, and the space shuttle, *Physics of the Earth and Planetary Interiors*, **105**, 167-181, 1998.

5 Other Significant Publications:

Calais, E. and J. Bernard Minster, GPS detection of ionospheric perturbations following a Space Shuttle ascent, *Geophys. Res. Lett.*, **23**, 1897-1900, 1996.

Ridgway, J. R., J. B. Minster, N. Williams, J. L. Bufton, and W. B. Krabill, Airborne laser altimeter survey of Long Valley, California, *Geophys. J. Int.*, **131**, 267-280, 1997

Calais, E., J. B. Minster, M. A. Hofton, and M. A. H. Hedlin, Ionospheric signature of surface mine blasts from Global Positioning System measurements,*Geophys. J. Int.*, **132,** 191-202, 1998.

Hofton, M. A., J. B. Blair, J. B. Minster, J. R. Ridgway, N. P. Williams, J. L. Bufton, and D. L. Rabine, Using laser altimetry to detect topographic change at Long Valley caldera, California, Earth Surface Remote Sensing, *SPIE*, **3222**, 295-306, 1997.

Calais, E., J. B. Minster, M. A. Hofton and M. A. H. Hedlin, Ionospheric signature of surface mine blasts from Global Positioning System measurements, *Geophys. J. Int.*, **132**, 191-202, 1998.

Collaborators within the last 48 months:
Duncan Agnew, Scripps Institution of Oceanopgrahy
Yehuda Bock, Scripps Institution of Oceanography
Steve Day, San Diego State University
John McRaney, University of Southern California
John Rundle, University of Colorado, Boulder
Paul Rosen, Jet Propulsion Laboratory
Bob Schutz, University of Texas
Peter Shearer, Scripps Institution of Oceanography
Steve Shkoller, UC Davis
David Sandwell, Scripps Institution of Oceanography

Thesis Advisor in the last 5 years for:
Harrold Gurrola, Ph.D. 1995, Texas Tech. University
G. Eli Baker, Ph.D. 1996, Maxwell Technologies, San Diego
Heming Xu, Ph.D. 1998

Posdoctoral Sponsor in the last 5 years for:
Eric Calais, CNES, France
Michelle Hofton, University of Maryland
Steve Shkoller, California Institute of Technology and Los Alamos National Laboratory

Graduate Advisor:
Charles Archambeau, formerly at California Institute of Technology

James R. Rice: Harvard

Born: 3 December 1940, Frederick, MD

Employment:

9/81-present, Gordon McKay Professor of Engineering Sciences and Geophysics, Department of Earth and Planetary Sciences and Division of Engineering and Applied Sciences, Harvard University.

1/99-1/00: on leave as Blaise Pascal International Research Professor, Ecole Normale Superieure, Paris.

2/95-12/95: on leave as Allan Cox Visiting Professor, Dept. of Geophysics, Stanford.

9/88 - 8/89: on leave as Sherman Fairchild Distinguished Scholar, Div. of Engineering and Applied Sciences, Caltech.

9/64-8/81: Postdoc 9/64-6/65, Assistant Professor 7/65-6/68, Associate Professor 7/68-6/70, Professor 7/70-8/81, and L. Herbert Ballou Professor of Theoretical and Applied Mechanics 7/73-8/81, Division of Engineering, Brown University.

9/71-8/72: on leave as NSF Senior Postdoctoral Fellow, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, and Overseas Fellow, Churchill College.

Address: 224 Pierce Hall, 29 Oxford Street, Cambridge, MA 02138.

Education:

Lehigh University, Bethlehem, PA: B.S., Engineering Mechanics, 6/62; M.S., Applied Mechanics, 6/63; Ph.D., Applied Mechanics, 10/64.

Professional activities/awards (current or recent):

Member and fellow, AGU, ASME. Member, APS, ASCE.
Committee on Seismology, NRC Com. on Phys. Sci., Math. and Resources, 1992-8.
Committee on Science of Earthquakes, NRC Com. on Phys. Sci., Math. and Resources, 1996-9.
Francis Birch Lecturer, AGU, 1993. Timoshenko Medal, ASME, 1994.
National Academy of Engineering, 1980-. National Academy of Sciences, 1981-.
Foreign Member of the Royal Society (London), 1996-.
Honorary Doctor of Science: Lehigh, 1985; Northwestern, 1996; Brown, 1997; Paris VI, 1999.

Five most relevant publications:

Geubelle, P. H., and J. R. Rice, "A Spectral Method for Three-Dimensional Elastodynamic Fracture Problems", J. Mech. Phys. Solids, 43, 1995, pp. 1791-1824.
Rice, J. R., and Y. Ben-Zion, "Slip complexity in earthquake fault models", Proc. Nat. Acad. Sci. USA, 93, 1996, pp. 3811-3818.

Ben-Zion, Y., and J. R. Rice, "Dynamic simulations of slip on a smooth fault in an elastic solid"; J. Geophys. Res., 102, 1997, pp. 17771-17784.
Taylor, M. A. J., R. Dmowska and J. R. Rice, "Upper-plate Stressing and Seismicity in the Subduction Earthquake Cycle", Journal of Geophysical Research, 103, 1998, pp. 24523-24542.
Zheng, G., and J. R. Rice, "Conditions under which velocity-weakening friction allows a self-healing versus a crack-like mode of rupture", Bull. Seismol. Soc. Amer., 88, 1998, pp. 1466-1483.

Associates, last 4 years:

Collaborators: M. Cocco, R. Dmowska, R. Madariaga, P. Segall, W. D. Stuart, J. R. Willis, Y. Ben-Zion, E. Bouchaud, J.-P. Bouchaud, G. Perrin, P. Geubelle, A. Cochard, J. Schmittbuhl, T. Tada, J.-S. Wang, G. E. Beltz, N. Lapusta, J. Kysar, Y. Sun, S. Mesarovic, M. A. J. Taylor and G. Zheng.
Thesis advisor F. P. Beer, postdoctoral advisor D. C. Drucker.

Students graduating within last three years (J. R. Rice):

Gutuan Zheng, Ph.D. 1997, male, oriental, China, 6 years to complete.
Mark A. J. Taylor, Ph.D. 1998, male, caucasian, England, 5 years to complete.
John W. Morrissey, Ph.D. 1998, male, caucasian, USA, 6 years to complete.
Jeffrey W. Kysar, Ph.D. 1998, male, caucasian, USA, 6 years to complete.

Charles G. Sammis: USC

Present Position: Professor of Geological and Materials Sciences, University of Southern California

Visiting Professor, University College London

Born: 1944, Huntington, New York

Education:

Brown University, Sc. B. (Cum Laude, with honors in Physics) 1965
California Institute of Technology, M.S. (Geophysics) 1968
California Institute of Technology, Ph.D., 1971

Previous Positions:

N.A.T.O. Postdoctoral Fellow in the School of Theoretical Chemistry at the University of Bristol, 1971-72
Assistant Professor of Geophysics, Department of Geosciences, The Pennsylvania State University, 1972-75
Associate Professor of Geophysics, Department of Geosciences, The Pennsylvania State University, 1975-77
Associate Professor of Geophysics, Department of Geological Sciences, University of Southern California, 1977-1987
Professor, Department of Geological Sciences, University of Southern California, 1987-

Academic Awards:

United Aircraft Scholarship, Brown University, 1961-1965.
Title IV Fellowship, Caltech, 1966-1970.
N.E.R.C. Visiting Scientist Fellowship, Cambridge, 1983-1984.
Burlington Resources Foundation Faculty Research Award, 1991.
USC Associates Award for Excellence in Teaching, 1994.
Tomas Brody Honorary Chair at the UNAM Institute of Physics, Mexico City, 1999.

Professional Activity:

Department Chair:	Dept. of Earth Sciences, Univ. of Southern California 1994-1998
Visiting Scholar:	Cambridge University Engineering Laboratory, 1983-1984
Visiting Professor:	Institut de Physique du Globe de Paris, Universite Pierre et Marie Curie, Summer, 1987. Institute for Theoretical Physics (U.C. Santa Barbara), Fall, 1992
Associate Editor:	Journal of Geophysical Research, 1984-1987
Associate Editor:	Reviews of Geophysics and Space Physics, 1984-1987
Member:	NASA Planetary Science Review Panel, 1980-1982
Member:	AGU Mineral Physics Committee, 1984-

Member:	AGU Publicity Committee , 1988-1991
Member:	Geomechanics Committee of the Am.Soc.Mech.Engineers, 1988-
U.S. Organizer:	U.S.-Japan Seminar on "Fracture, Form, and Fractals", NSF U.S.-Japan Cooperative Science Program, Lake Arrowhead, CA. 1989.

FIVE RECENT RELEVANT PUBLICATIONS

Sammis, C.G., R.M. Nadeau, and L.R. Johnson, How strong is an asperity?, J. Geophys Res., 104, 10,609-10,619, 1999.

Sammis, C.G., and S.W. Smith, Seismic cycles and the evolution of stress correlation in cellular automaton models of finite fault networks?, in press, PAGEOPH., 1998.

Huang, Y., H. Saleur, C. Sammis, and D. Sornette, Precursors, aftershocks, criticality and self-organized criticality, Europhys. Letters , 41, 43-48, 1998.

Bowman, D.D., G. Ouillon, C.G. Sammis, A. Sornette, and D. Sornette, An observational test of the critical earthquake concept, J.Geophys. Res., 103, 24,359-24,372, 1998.

Saleur, H., C.G. Sammis, and D. Sornette, Discrete scale invariance, complex fractal dimensions, and log-periodic fluctuations in seismicity, J. Geophys. Res., 101, 17,661-17,677, 1996.

Terry E. Tullis: Brown

Education: B.A. Carleton College, 1964
M.S. UCLA, 1967
Ph.D. UCLA, 1971

Academic and Scientific Awards:

National Science Foundation Graduate Fellowship, 1964-1968

Alfred P. Sloan Research Fellowship, 1973-1975.

U. S. National Committee for Rock Mechanics Annual Award for 1990 for Outstanding Basic Research in Rock Mechanics for the paper "Roughness and wear during brittle faulting", *J. Geophys. Res.,93,* 15268-15278, by W. L. Power, T. E. Tullis and J. D. Weeks.

Editor's Citation for Excellence in Reviewing, Journal of Geophysical Research, 1998

Academic Appointments:

UCLA, Department of Geology: Acting Instructor, 1969-1970

Brown University, Dept. of Geol. Sci.: Asst. Prof., 1970-1976; Assoc. Prof., 1976-1989; Prof., 1989-

Other Professional Appointments:

Tectonophysics Field Assistant, summer 1964, Shell Development Co.

Research Assistant, 1968-1969, Institute of Geophysics, UCLA

Visiting Fellow, September 1976-January 1977, Australian National University, Research School of Earth Sciences

Geologist, Jan-June 1977, U.S. Geological Survey, Office of Earthquake Studies

Visiting Professor, April-May, 1984, Texas A & M University, Center for Tectonophysics

Visiting Professor, Sept-Oct, 1990, Harvard University, Dept. of Applied Sciences

Geophysicist, Oct-Dec, 1990, U.S. Geological Survey, Office of Earthquakes

Adjunct Professor, 1997-1998, South Dakota School of Mines and Technology, Department of Geology and Geological Engineering

Professional Societies:

American Association for the Advancement of Science

American Geophysical Union

Geological Society of America

International Society for Rock Mechanics

Five publications most relevant to the proposal:

Lorenzetti, E. A. and Tullis, T. E., Geodetic predictions of a strike-slip fault model: implications for intermediate- and short-term earthquake prediction, J. Geophys. Res., 94, 12343-12361, 1989.

Stuart, W.D., and T.E. Tullis, Fault model for preseismic deformation at Parkfield, California, *J. Geophys. Res., 100*, 24079-24099, 1995.

Tullis, T.E., Rock friction and its implications for earthquake prediction examined via models of Parkfield earthquakes, in *Earthquake Prediction: the Scientific Challenge*, ed. by Leon Knopoff, *Proc. Natl. Acad. Sci. USA, 93*, 3803-3810, 1996.

Beeler, N.M., Tullis, T.E., Self-healing slip pulses in dynamic rupture models due to velocity dependent strength, *Bull. Seis. Soc. Am., 86*, 1130-1148, 1996.

Tullis, T.E., Perspective - Deep slip rates on the San Andreas fault, *Science, 285*, 671-672, 1999.

Collaborators in last 48 months:

Joe Andrews, USGS
Nick Beeler, USGS
Mike Blanpied, USGS
David Goldsby, Brown University
Linda Reinen, Pomona College
Valerie Scruggs, California Institute of Technology
William Stuart, USGS
John Weeks, Wavemetrics, Inc.
Connie Worthington, Brown University
Shuqing Zhang, Australian National University

Postdoctoral scholars sponsored over past five years:

Shuqing Zhang, Australian National University
David Goldsby, Brown University

Graduate students advised over past five years:

Linda Reinen, Pomona College
Nick Beeler, USGS
Valerie Scruggs, California Institute of Technology
Ali Lochhead, Japan
Scott Costello, Brown University
Chaoxiao Lu, Brown University
Sarah Zaranek, Brown University

Total number of graduate students and postdoctoral scholars over past 5 years:

7

Thesis advisors:

David T. Griggs, UCLA (deceased)
John M. Christie, UCLA (retired)

SUMMARY PROPOSAL BUDGET YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **Florida State University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Geoffrey C Fox**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Geoffrey C Fox - Prof. (PI)**	**0.00**	**0.00**	**3.00**	$ **45,000**	$
2. **Andrea Donnellan - Prof. (USC)**	**0.00**	**0.00**	**0.00**	**0**	
3. **Roscoe C Giles - Prof.(Boston)**	**0.00**	**0.00**	**0.00**	**0**	
4. **David H Laidlaw - Prof.(Brown)**	**0.00**	**0.00**	**0.00**	**0**	
5. **John B Rundle - Prof.(Colorado)**	**0.00**	**0.00**	**0.00**	**0**	
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	**0.00**	**0.00**	**3.00**	**45,000**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL ASSOCIATES	**36.00**	**0.00**	**0.00**	**135,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**0**	
3. (**2**) GRADUATE STUDENTS				**96,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**24,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**300,000**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**26,618**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**326,618**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				**24,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
(**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**9,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,920,000**	
6. OTHER				**12,000**	
TOTAL OTHER DIRECT COSTS				**1,950,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,300,618**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **See Justif. (Rate: 46.5000, Base: 448618)**					
TOTAL INDIRECT COSTS (F&A)				**208,607**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,509,225**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **2,509,225**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE* **Geoffrey C Fox** DATE

ORG. REP. TYPED NAME & SIGNATURE* DATE

FOR NSF USE ONLY

INDIRECT COST RATE VERIFICATION

Date Checked	Date Of Rate Sheet	Initials - ORG

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: **Florida State University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Geoffrey C Fox**

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Geoffrey C Fox - Prof. (PI)**	**0.00**	**0.00**	**3.00**	$ **45,000**	$
2. **Andrea Donnellan - Prof. (USC)**	**0.00**	**0.00**	**0.00**	**0**	
3. **Roscoe C Giles - Prof.(Boston)**	**0.00**	**0.00**	**0.00**	**0**	
4. **David H Laidlaw - Prof.(Brown)**	**0.00**	**0.00**	**0.00**	**0**	
5. **John B Rundle - Prof.(Colorado)**	**0.00**	**0.00**	**0.00**	**0**	
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	**0.00**	**0.00**	**3.00**	**45,000**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL ASSOCIATES	**36.00**	**0.00**	**0.00**	**135,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**0.00**	**0.00**	**0.00**	**0**	
3. (**2**) GRADUATE STUDENTS				**96,000**	
4. (**2**) UNDERGRADUATE STUDENTS				**24,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**300,000**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**26,618**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**326,618**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				**24,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
(**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**9,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**1,920,000**	
6. OTHER				**12,000**	
TOTAL OTHER DIRECT COSTS				**1,950,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**2,300,618**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**208,607**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**2,509,225**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **2,509,225**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI / PD TYPED NAME & SIGNATURE*: **Geoffrey C Fox** DATE

ORG. REP. TYPED NAME & SIGNATURE* DATE

FOR NSF USE ONLY

INDIRECT COST RATE VERIFICATION

Date Checked	Date Of Rate Sheet	Initials - ORG

NSF Form 1030 (10/98) Supersedes all previous editions

C***SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.B)**

Budget Justification

This budget represents a 3 year cumulative budget. The division between participating organizations is:

Florida State University: $589,225 over 3 years
Boston University: $375000 over 3 years
Brown University: $345,000 over 3 years
Colorado University: $270,000 over 3 years
USC(including SCEC): $930,000 over 3 years
Total: **$2,509225** over 3 years (approximately $840K per year)

The **Florida State University** Budget supports
1 Summer Month a year for Principal Investigator Fox
1 Full year Postdoc at $45,000 per year (listed as a total of $135,000 for 3 years)
2 Graduate Research Assistantships
2 Undergraduate Research Students including summer research

Fringe Benefits are 18.4% for PI and 8.25% for Postdocs for whom Insurance of $180 per month is added. Fringe benefits are 0.6% for students.
There is Tuition of $2000 per year for each graduate student with is recorded in Item G6.

Overhead is charged on Total Direct Costs excepting tuition and all but the First $25000 of each of 4 subcontracts

The **USC Contribution** breaks into 3 components:

Co-PI Andrea Donnellan activity	$225,000
Outreach activity led by senior personnel Jill Andrews	$195,000
Funding for Senior Personnel at sites supported by SCEC (other senior personnel listed in proposal)	$510,000

The SCEC Site funding will be assignment by project management to satisfy the 9 identified tasks with personnel as suggested below.

Initial Roles of PI's and Senior Personnel

Earth Science TimeFrames

1. **Real Time Science**
   Leader: Donnellan
   Donnellan, Henyey, Kanamori, Jordan, Minster, Grant, Beroza

2. **HPCC Simulations & Data Integration**
   Leaders: Tullis & Rundle
   Tullis, Rundle, Rice, Ben-Zion, Beroza, Jordan, Minster, Kanamori, Grant

3. **Fundamental Theory and Complex Systems**
   Leaders: Klein, Ben-Zion, Rundle

Klein, Rundle, Sammis, Ben-Zion, Minster, Giles

Computational Science

1. **Basic Distributed Object Framework**
   Leader: Fox
   Fox, Giles, Donnellan, Minster, Laidlaw

2. **Real Time HPCC Simulations**
   Leader: Giles
   Giles, Klein, Minster, Tullis, Rundle

3. **Multisensor Metadata**
   Leaders: Donnellan & Grant
   Donellan, Grant, Kanamori, Beroza, Jordan, Ben-Zion, Sammmis, Henyey

4. **Data & Simulation Visualization**
   Leader: Laidlaw
   Laidlaw, Giles, Minster, Jordan, Donnellan, Grant

5. **Interactive Data Mining**
   Leaders: Rundle, Jordan, Fox
   Rundle, Jordan, Fox, Ben-Zion, Sammis, Donnellan, Beroza, Giles

Outreach
Leaders: Andrews & Donnellan
Andrews, Donnellan, Fox.