Part B:
CIG Software

Section I: Infrastructure

CIG has brought modern software engineering for the development, verification and maintenance of codes through good software design practices to our field, including techniques for automated build and test procedures, development of benchmarks and test cases, and documentation. The software repository and attendant web site (geodynamics.org) are central to facilitating collaboration and sharing of validated open-source software. We primarily use a single, open repository for developer and community use, a bug-tracking database to allow developers and external participants to register and comment on bugs or request new functionality, list-servs for each sub discipline, and editable Web pages (`Wiki-like').

Software Policies

Software Ownership and Licensing

The goal of CIG is to develop software in support of Earth science research and education. Since a major aim is for the widest availability and impact of all CIG developments and software, all software CIG develops will be open source. In order to uphold these principles, CIG's policy contains the following aspects:

1. CIG will maintain a software repository on the World Wide Web at geodynamics.org in which software can be checked out without restrictions as software is developed. In order to ensure the quality of CIG software, the privilege to check software back into the repository by members of the CIG community will be made on a case-by-case basis.
2. Some software will be solely developed by the CIG staff. In such cases, the copyright will be retained by the California Institute of Technology and distributed under the Free Software Foundation's GNU General Public License (GNU GPL), unless otherwise stated.
3. Some software will be written in collaboration between CIG staff and other organization(s) or individual(s). In each case, but before the collaboration is initiated, CIG must enter into an agreement that clearly specifies who the copyright holder(s) will be and the terms of the software release. When possible, copyright shall belong to all contributing parties, and the software released under the GNU GPL.
4. Some software will be preexisting and not necessarily free from existing third-party copyrights and licenses. In the event that CIG wishes to use or to modify, improve, and/or distribute such software, CIG will, with its collaborators, determine who the copyright holders are and enter into an agreement to have the resulting software released under an open source license, preferably the GNU GPL. In exceptional cases, CIG will consider a different license as long as it is free for non-commercial use but otherwise satisfies the principles of open source software.
5. In order to maximize the benefit to the Community, the details of this policy may change from time to time, but such changes will always be subject to Member input and discussion and then final approval by the CIG Executive Committee.

Software Support Policy

CIG provides three different levels of support for codes developed by CIG staff or donated by members of the community. The Science Steering Committee evaluates the codes on an occasional basis, and may change the level of support for a code in accordance with the priorities of the community at large as well as the resources available to CIG. CIG encourages members to donate codes that have scientific value for the geosciences community. Donated codes should be submitted with concise summaries of the code's purpose and capabilities, documentation, and test cases or benchmarks for users. Donors are made aware of the CIG open source software policy and the code's copyright status once donated.

Once a code is submitted to CIG, the Science Steering Committee (SSC) evaluates the code in regard to its capabilities and its suitability for community use, and assigns to it the appropriate support level, as listed below:

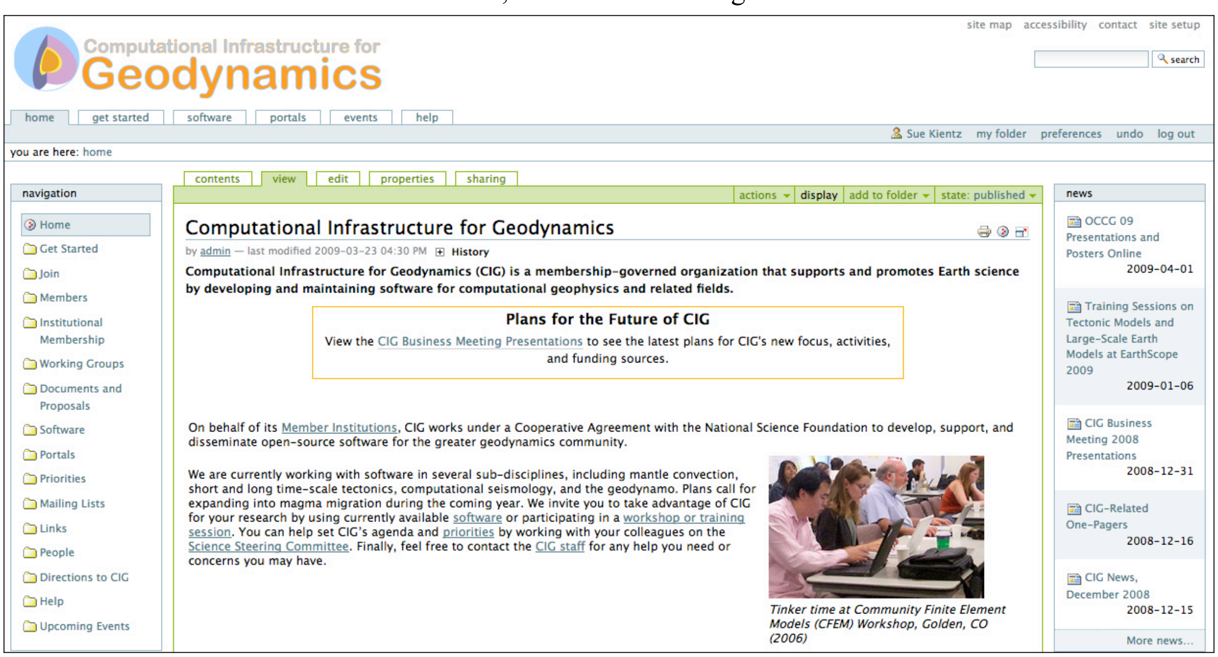
Level 1 (Highest Support) – These codes have been validated, passed benchmarks established by the appropriate community, and qualified as "state-of-the-art" in one or more areas of geodynamics. In most cases Level 1 codes have been developed by CIG staff, or they have originated through CIG-sanctioned projects. Level 1 codes are usually in active development or enhancement, and CIG makes a commitment to support, maintain, and provide technical assistance or training in their use, including documentation updates. Where appropriate, CIG will install and maintain Level 1 codes on the TeraGrid's Community Software Area for the geodynamics community.

Level 2 (Middle) – Codes in this category include those donated to CIG from members of our community, which are either being developed independently from CIG, or are no longer undergoing substantial development because they are already mature and well-tested. CIG commits to host codes in this level in its repository and to facilitate minor changes such as bug fixes, creating and upgrading of binaries, etc. Nevertheless, codes in this category are expected to meet community benchmarks and to have documentation, examples, references, and other attributes that make them useful research tools.

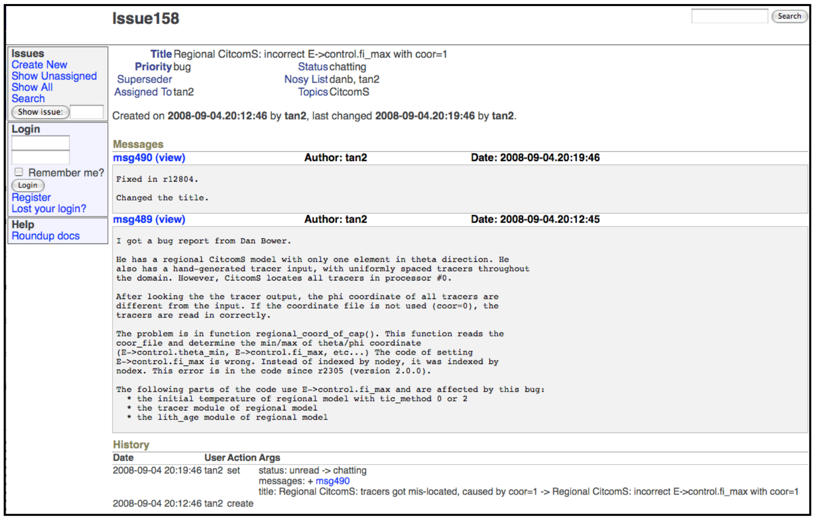
Level 3 (Lowest) – Level 3 codes are donated or developed by members of our community but CIG does not offer resources for their development, maintenance, or support. Examples thatt may fit this category include older legacy codes, codes with limited functionality or application, inadequate documentation, or not benchmarked. CIG will either offer server space to distribute these codes, or alternatively, provide links to web addresses where the software can be obtained. CIG will display a disclaimer to the effect that these codes are formally outside of the CIG purview.

CIG Web site

The geodynamics.org web site is a core component of CIG. It is the principal means by which we distribute CIG software and documentation, while also allowing the committees to interact with the



community. Members of the community submit short proposals for software development to CIG via the web; these proposals are then posted and available for public comment and discussion on the web. But the main use of the web site is to distribute the resultant open-source software, which is stored in a software repository.



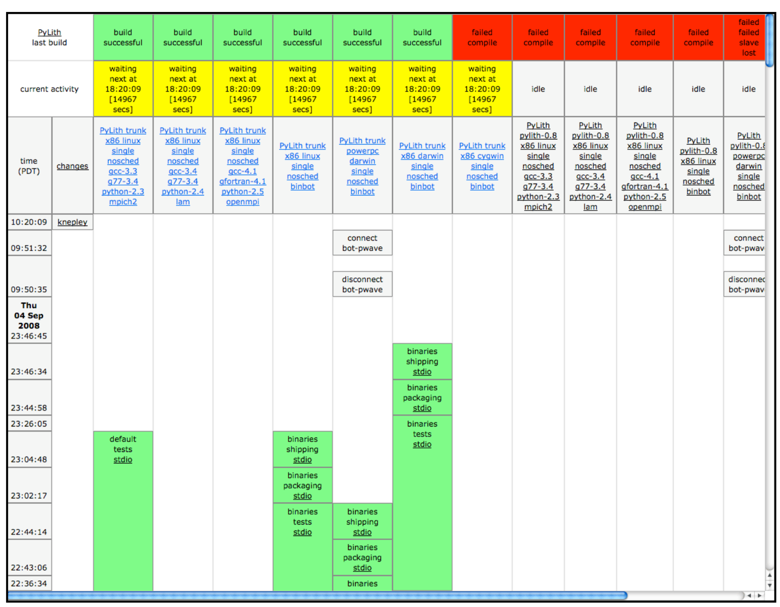
The repository is critical to bring modern software engineering practices to our community and CIG's software development team. We have repositories for developer use that manages multiple developers working concurrently on modular software components shared through the repository. We use the open-source package Subversion (SVN) for the main CIG software repository, which contains most of CIG's codes, and a Mercurial repository (hg) for the magma dynamics code *MADDs*. The entire contents of both repositories are navigable from our web site. Users can either directly check out the latest development version of a code, or they can download a "tar file." In addition, CIG provides a bug-tracking database (Roundup, above) to allow developers and external participants to register and comment on bugs and requests for new functionality in CIG software that can then be worked on by the developers of a program.

Quarter Ending	Downloads
Nov. 30, 2006	227
Feb. 28, 2007	61
May 31, 2007	346
August 31, 2007	531
Nov. 30, 2007	460
Feb. 29, 2008	428
May 31, 2008	741
August 31, 2008	845
Nov. 30, 2008	937
Feb. 28, 2009	812
May 31, 2009	959

CIG has tracked software downloads since Fall 2006. These totals do not include any downloads from Caltech or repeat downloads to the same computer on the same day. The numbers for all quarters are shown in the table at right. Statistics for each individual software code are found at right.

Buildbot

Building and testing in the SVN repository occurs either nightly or automatically in response to a software commit using *CIG-Regresstor*, a collection of Python codes written by CIG engineer Luis Armendariz. This software uses *Buildbot*, extended by CIG engineer Leif Strand, and the results of the testing are both stored in a database and made available interactively on our web site. Nightly regression testing generates an electronic report that contains the build and test failures (including the platforms on which



they occurred). Regression testing allows the Software Development Team (SDT) to rapidly identify when a change in a repository component or platform has caused an error or inconsistency. Regression testing gives users of the repository confidence in the robustness of the software. Strand extended *Buildbot* so that executable binaries for common platforms are automatically generated.

Cigma

The CIG Model Analyzer (Cigma) is a suite of tools that facilitates the comparison of numerical models, and performs error analysis, benchmarking, and code verification.

Originally implemented in Python, is now written in C++ for improved performance. *Cigma* reports back global and local mismatches in solutions, even if they use different meshes and basis functions. This capability will help in developing standard benchmarks against which to compare geodynamics models. Currently only subparametric elements are used, but the user may extend *Cigma* to use his own element types. *Cigma* beta version .9 was released in July 2007; version 1.0 was released in April 2009.

The short-term goal for using *Cigma* for the short time-scale tectonics benchmarks (currently only the strike-slip benchmark) has been met. *Cigma* can now compare arbitrary unstructured (hexahedral or tetrahedral) datasets from *PyLith* in a reasonable amount of time. A unit testing infrastructure, using CppUnit, is in place for making sure changes to *Cigma* remain consistent. Since *Cigma* is also available as a library, other codes can use it to perform comparisons inside their respective test cases/unit tests.

The intermediate goal for using *Cigma* in the mantle convection and long-term tectonics communities has also been met. This required adding support for reading parallel XML VTK formats. Currently this support is limited to reading data as unstructured datasets, so very large datasets need to be broken up manually. Codes involved in these benchmarks are *CitcomS* and *Gale*.

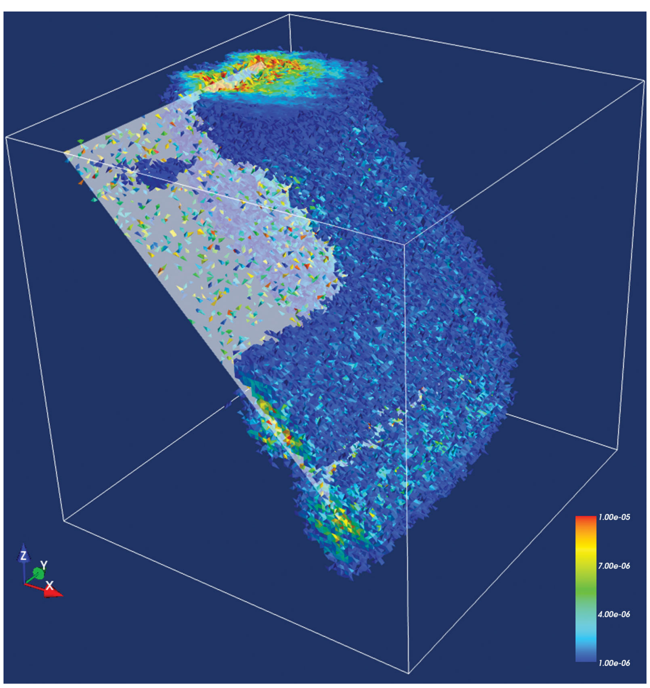


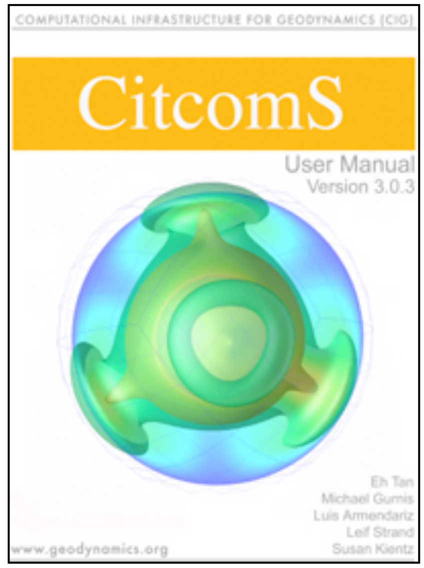
Figure 1 *depicts Cigma's 3D comparison between two different PyLith solutions to the reverse-slip benchmark problem. PyLith is a finite element code for the solution of dynamic and quasi-static tectonic deformation problems.*

This benchmark problem solves for the viscoelastic (Maxwell) relaxation of stresses from a single, finite, reverse-slip earthquake in 3D without gravity, with imposed displacement boundary conditions on a cube with sides of 24 km in length. On the boundary, we impose displacements obtained via the analytic elastic solutions. Additionally, symmetry boundary conditions are imposed on the y = 0 plane, so the solution is equivalent to that for a domain with a 48 km length in the y direction. We are visualizing the error in the displacement field between the 500m linear hexahedral and 250m tetrahedral solutions.

Section II: CIG Software Packages

CitcomS

CitcomS is a finite element code designed to solve compressible thermochemical convection problems relevant to Earth's mantle. Written in C, the code runs on a variety of parallel processing computers, including shared and distributed memory platforms. Widely used for solving mantle convection problems, CitcomS allows users to choose from a wide variety of features, including global and regional spherical geometries, models that incorporate plate tectonic evolution, embedding high resolution regional models within global, incompressible and compressible solvers, and temperature-, pressure-, stress-, and composition-dependent rheologies. The code is preinstalled on the NSF TeraGrid and users can test models directly with seismic data through our science gateway.



Complete User Manual with chapters on theory, installing and using the code, and 14 detailed examples that are used as tutorials.

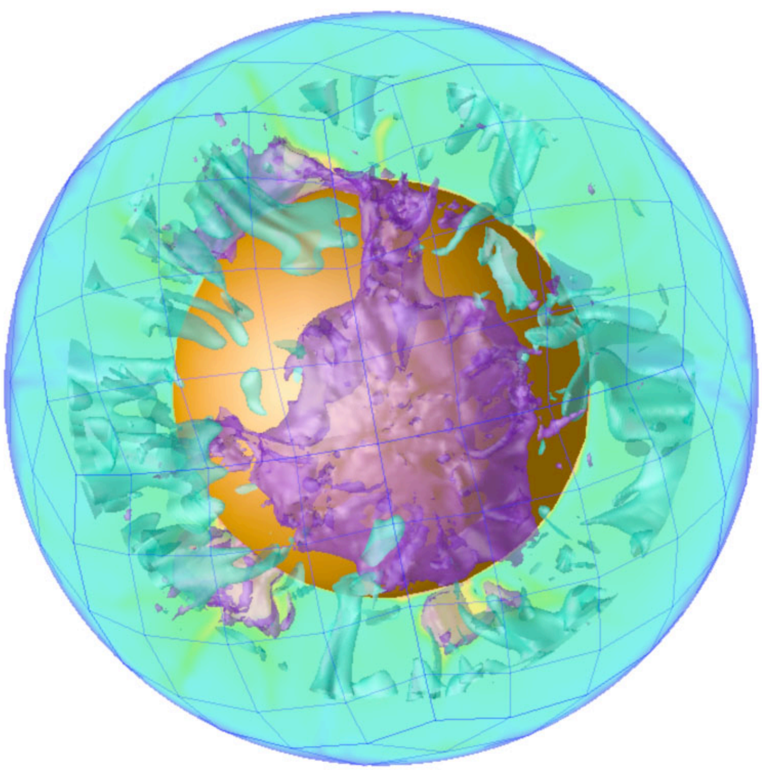


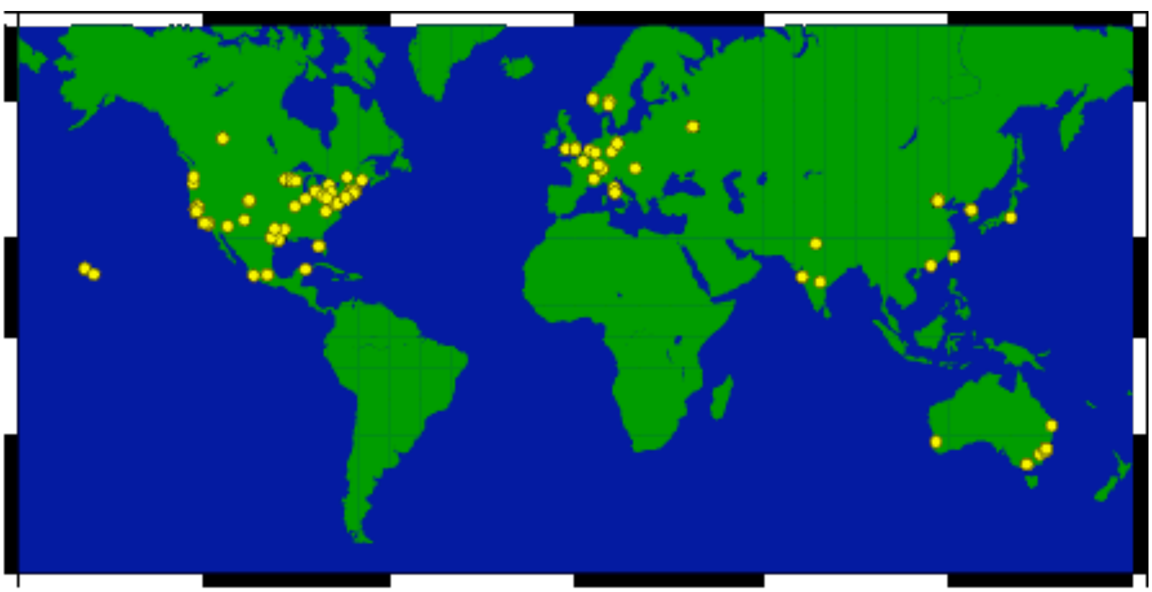
Figure (left) shows the chemical structures (purple) and the cold downwellings (cyan) in the lower mantle. The chemical structures stay roughly at the same location until gradually entrained.

CitcomS Software Download Statistics

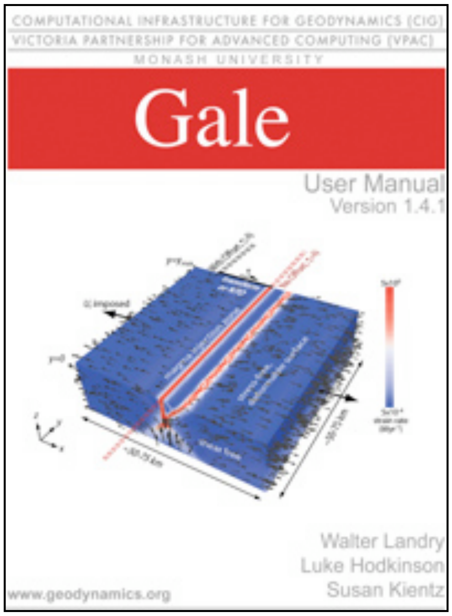
	Sep06-Feb07	Mar07-Aug07	Sep07-Feb08	Mar08-Aug08	Sep08-Feb09	Mar09-May09	Pkg Total
CitcomS 2.0.2	33	-	-	-	-	-	33
CitcomS 2.1.0	7	12	-	-	-	-	19
CitcomS 2.2.1	-	38	-	-	-	-	38
CitcomS 2.2.2	-	37	22	-	-	-	59
CitcomS 3.0.0	-	-	7	-	-	-	7
CitcomS 3.0.1	-	-	49	3	2	-	54
CitcomS 3.0.2	-	-	-	71	2	-	74
CitcomS 3.0.3	-	-	-	-	87	42	129
Subtotal	40	87	78	75	91	42	413
						Total CitcomS Downloads	413

CitcomS User Map

Shows location of all users who downloaded CitcomS as of June 2, 2009.



Gale



Gale is exhaustively documented, with a 100+ page User Manual that includes 13 cookbook examples, a geologic example, and benchmarks.

Gale is a 2D and 3D code targeted towards modeling tectonic processes on long geological time scales. Gales uses a mixed particle and finite element method, allowing it to accurately track material properties in large deformation scenarios. Gale has a wide variety of rheologies and boundary conditions, allowing simulation of phenomena such as isostasy, magmatic dikes, yielding, power law creep, erosion, free surfaces, friction, radiogenic heating, gravity, and thermal buoyancy. Gale can also simulate a number of different geometries, including realistic surface topography and tomographically deduced density variations.

Gale is tested with a number of high precision physics-based benchmarks. Gale runs on everything from Windows laptops to the largest supercomputers. CIG offers binary packages for Windows, Mac, and Linux, as well as a preinstalled binary on the NSF Teragrid, allowing researchers to start modeling immediately.

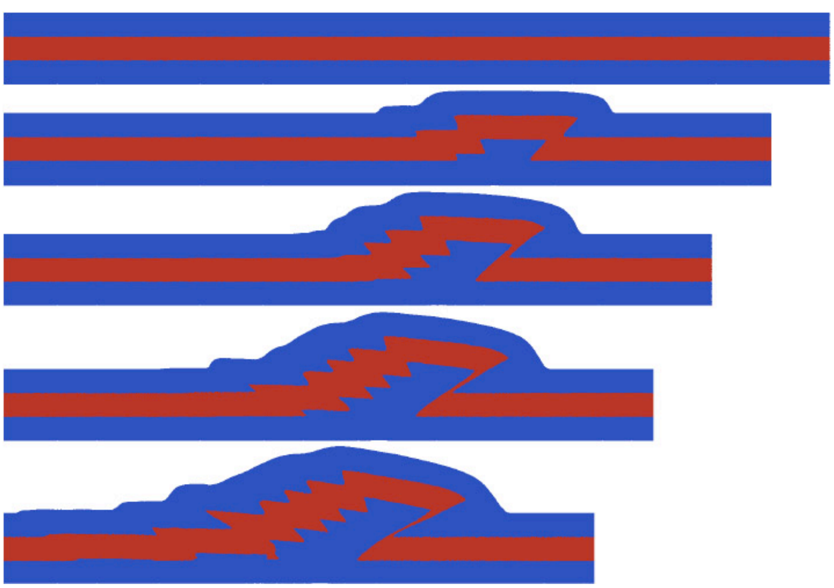


Figure at left is a simulated sandbox, where the right and left converge in the center. Plotted are the particles that show development of multiple faults as the convergence proceeds.

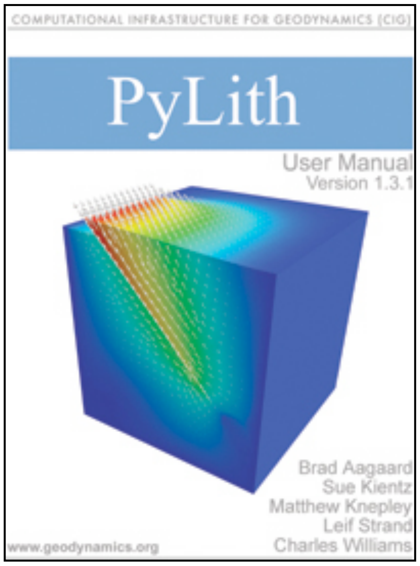
Gale Software Download Statistics

	Sep06-Feb07	Mar07-Aug07	Sep07-Feb08	Mar08-Aug08	Sep08-Feb09	Mar09-May09	Pkg Total
Gale 0.2.0	8	-	-	-	-	-	8
Gale 0.9.0	72	1	1	-	-	-	74
Gale 1.0.0	6	2	-	-	1	-	9
Gale 1.1.0	4	2	2	-	-	-	8
Gale 1.1.1	2	35	-	-	1	-	38
Gale 1.2.0	-	134	4	3	3	-	144
Gale 1.2.1	-	98	191	41	7	-	337
Gale 1.2.2	-	-	-	108	8	-	116
Gale 1.3.0	-	-	--	202	311	47	560
Gale 1.4.0	-	-				60	60
Gale 1.4.1	-	-				88	88
Subtotal	92	272	198	354	321	195	1442
						Total Gale Downloads	1442

Gale User Map

Shows location of all users who downloaded Gale as of June 2, 2009.

PyLith



PyLith solves the 2D or 3D elasticity equation for modeling dynamic and quasi-static crustal deformation. The target applications contain spatial scales ranging from tens of meters to hundreds of kilometers with temporal scales for dynamic modeling ranging from milliseconds to minutes and temporal scales for quasi-static modeling ranging from minutes to hundreds of years.

PyLith uses a suite of general, parallel, graph data structures called Sieve for storing and manipulating finite-element meshes. This permits use of a variety of 2D and 3D cell types including triangles, quadrilaterals, hexahedra, and tetrahedra. Current features include kinematic fault ruptures, Dirichlet (displacement or velocity), Neumann (traction), point force, and absorbing boundary conditions, linear elastic, generalized Maxwell, Maxwell linear viscoelastic, and power-law viscoelastic materials, gravitational body forces, and automatic time step selection for quasi-static problems.

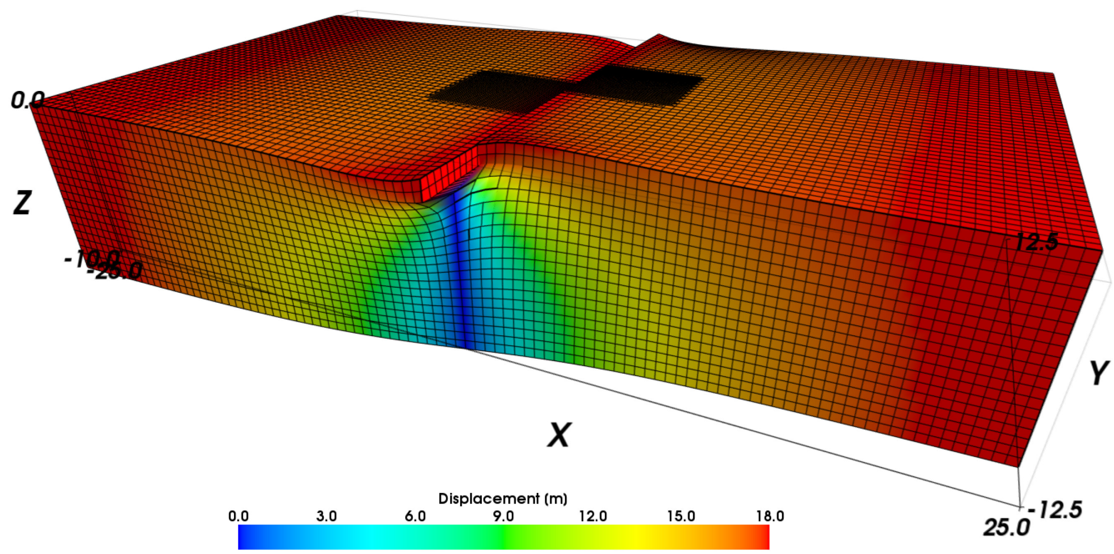


Figure above: Deformation (exaggerated by a factor of 5000) after 10 earthquake cycles for a strike-slip fault embedded in an elastic material overlying a linear Maxwell viscoelastic material. The mesh is refined in the region of interest for comparison with the analytic solution derived by Savage and Prescott (1978).

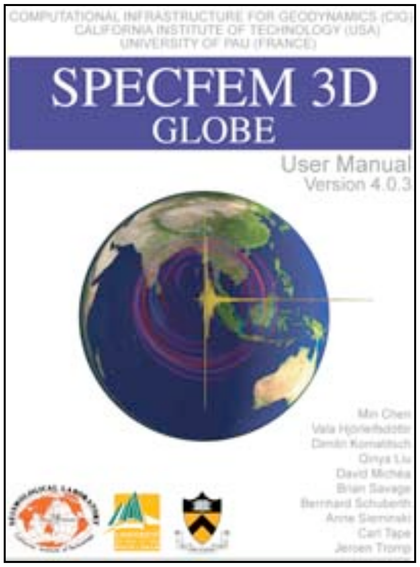
PyLith Software Download Statistics

	Sep06-Feb07	Mar07-Aug07	Sep07-Feb08	Mar08-Aug08	Sep08-Feb09	Mar09-May09	Pkg Total
PyLith 0.8.0	38	70	3	1	3	-	115
PyLith 0.8.1	27	38	1	-	-	-	66
PyLith 0.8.2	-	39	-	-	-	-	39
PyLith 0.8.3	-	12	45	36	16	-	109
PyLith 1.0.0	-	44	1	-	3	-	48
PyLith 1.0.1	-	82	101	-	3	-	186
PyLith 1.0.2	-	-	42	37	6	-	85
PyLith 1.1.0	-	-	-	62	28	-	90
PyLith 1.1.1	-	-	-	23	2	-	25
PyLith 1.1.2	-	-	-	123	4	-	127
PyLith 1.2.0	-	-	-	52	6	-	58
PyLith 1.3.0	-	-	-	14	134	-	148
PyLith 1.3.1	-	-	-	-	138	134	272
Subtotal	65	285	193	348	384	134	1368
						Total PyLith Downloads	1368

PyLith User Map

Shows location of all users who downloaded PyLith as of June 2, 2009.

SPECFEM3D GLOBE



SPECFEM3D_GLOBE is a spectral-element application enabling the simulation of global seismic wave propagation in 3D anelastic, anisotropic, rotating and self-gravitating Earth models at unprecedented resolution. A fundamental challenge in global seismology is to model the propagation of waves with periods between 1 and 2 seconds, the highest frequency signals that can propagate clear across the Earth.

These waves help reveal the 3D structure of the Earth's deep interior and can be compared to seismographic recordings. We broke the two-second barrier using the 62K processor Ranger system at TACC. Indeed we broke the barrier using just half of Ranger, by reaching a period of 1.84 seconds with sustained 28.7 Tflops on 32K processors. We obtained similar results on the XT4 Franklin system at NERSC and the XT4 Kraken system at University of Tennessee Knoxville, while a similar run on the 28K processor Jaguar system at ORNL, which has more memory per processor, sustained 35.7 Tflops (a higher flops rate) with a 1.94 shortest period. For the final run we obtained access to the ORNL Petaflop System, a new very large XT5 just coming online, and achieved 1.72 shortest period and 161 Tflops using 149,784 cores.

With this landmark calculation we have enabled a powerful new tool for seismic wave simulation, one that operates in the same frequency regimes as nature; in seismology there is no need to pursue periods much smaller because higher frequency signals do not propagate across the entire globe. We employed performance modeling methods to identify performance bottlenecks and worked through issues of parallel I/O and scalability. Improved mesh design and numbering results in excellent load balancing and few cache misses. The primary achievements are not just the scalability and high teraflops number, but a historic step towards understanding the physics and chemistry of the Earth's interior at unprecedented resolution.

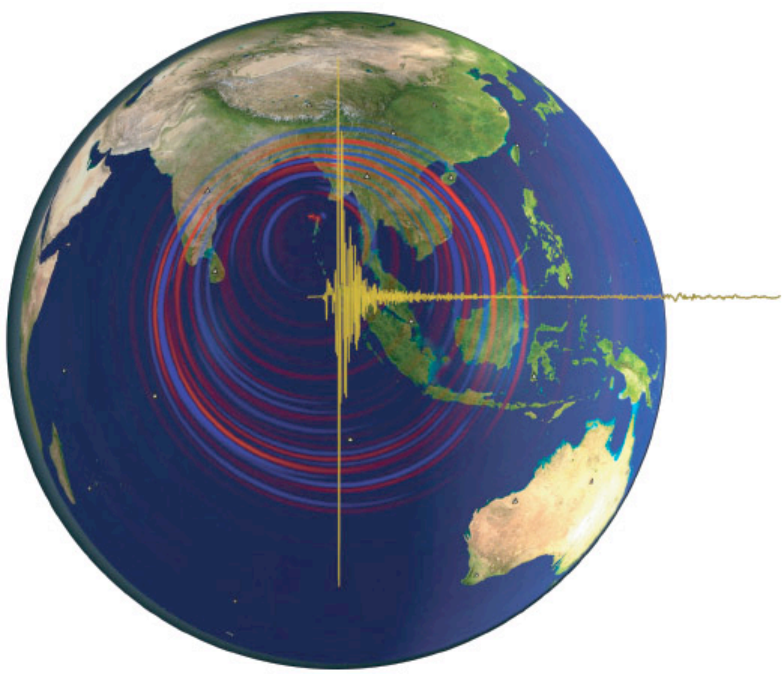
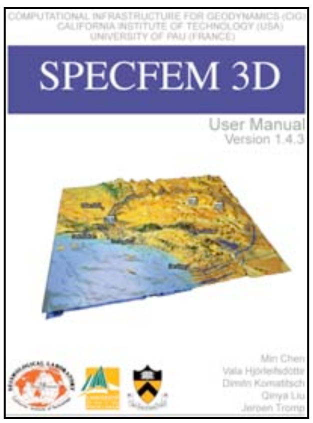


Figure: Snapshot of the vertical component of the simulated velocity wavefield generated by the M=9.2 December 26, 2004, Sumatra earthquake. The yellow vertical component seismogram was recorded at station PALK in Pallekele, **Sri Lanka.

SPECFEM3D_GLOBE Software Download Statistics

	Dec07-Feb08	Mar08-May08	Jun08-Aug08	Sept08-Nov08	Dec08-Feb09	Mar09-May09	Pkg Total
SPECFEM3D_GLOBE 4.0.0	71	38	1	-	-	-	110
SPECFEM3D_GLOBE 4.0.1	-	48	74	-	-	-	122
SPECFEM3D_GLOBE 4.0.2	-	-	4	1	-	-	5
SPECFEM3D_GLOBE 4.0.3	-	-	16	111	57	97	281
Subtotal	71	86	95	112	57	97	518
						Total SPECFEM3D_GLOBE Downloads	518

SPECFEM3D



SPECFEM3D simulates seismic wave propagation in sedimentary basins. The mesh generator is specifically written for the simulation of wave propagation in southern California but can be modified for use in other geographical areas. The solver is completely general and can be used to simulate seismic wave propagation on regional and local scales.

The 1.4.3 version added the Moho boundary kernel computation option for kernel simulations and allowed kernel computations with attenation on. Another option offered is the possibility of replacing Hauksson's background model by Lin's most recent southern California tomographic model.

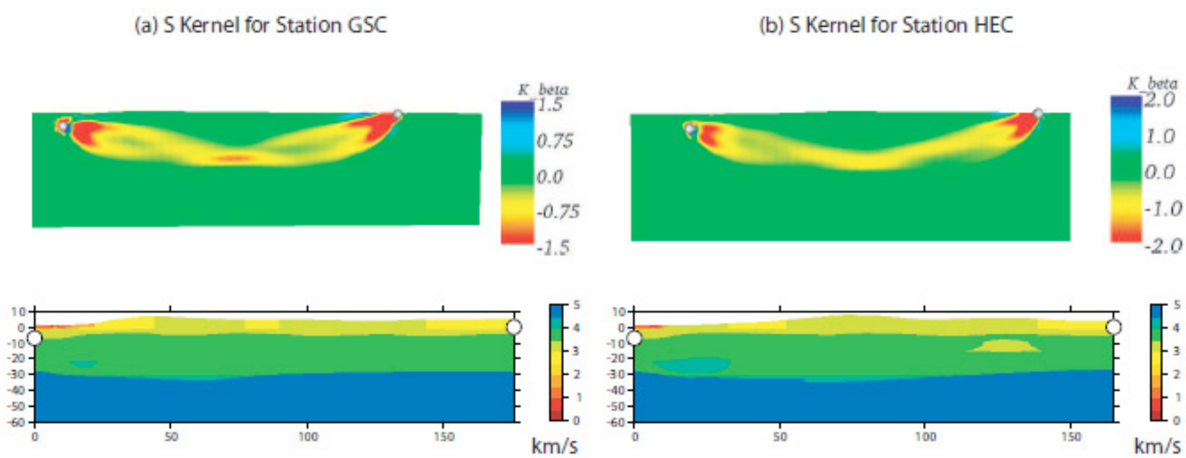


Figure above: (a) Top Panel: Vertical source-receiver cross-section of the S-wave finite-frequency sensitivity kernel K_ for station GSC at an epicentral distance of 176 km from the September 3, 2002, Yorba Linda earthquake. Lower Panel: Vertical source-receiver cross-section of the 3D S-wave velocity model used for the spectral-element simulations [Komatitsch et al., 2004]. (b) The same as (a) but for station HEC at an epicentral distance of 165 km [Liu and Tromp, 2006].

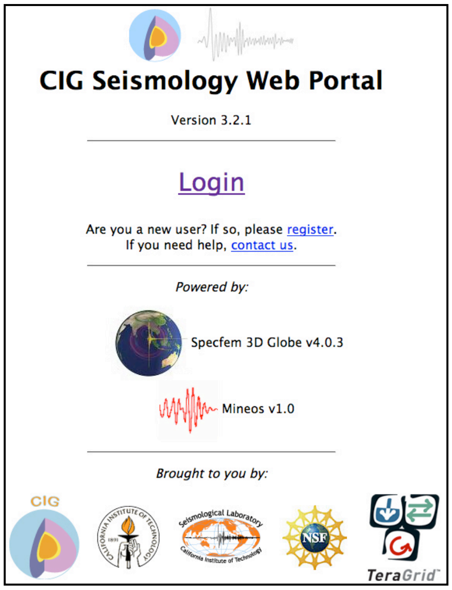
SPECFEM3D Software Download Statistics

	Dec07-Feb08	Mar08-May08	Jun08-Aug08	Sept08-Nov08	Dec08-Feb09	Mar09-May09	Pkg Total
SPECFEM3D 1.4.2	10	2	-	-	-	-	12
SPECFEM3D 1.4.3	23	71	61	92	68	88	403
Subtotal	33	73	61	92	68	88	415
						Total SPECFEM3D Downloads	415

SPECFEM3D_GLOBE and SPECFEM3D Combined User Map

Shows location of all users who downloaded SPECFEM3D and SPECFEM3D GLOBE as of June 2, 2009. Download location records were kept previous to December 2007 by the California Institute of Technology Seismology Laboratory, Pasadena, CA, and are included in the map below.

CIG Seismology Web Portal



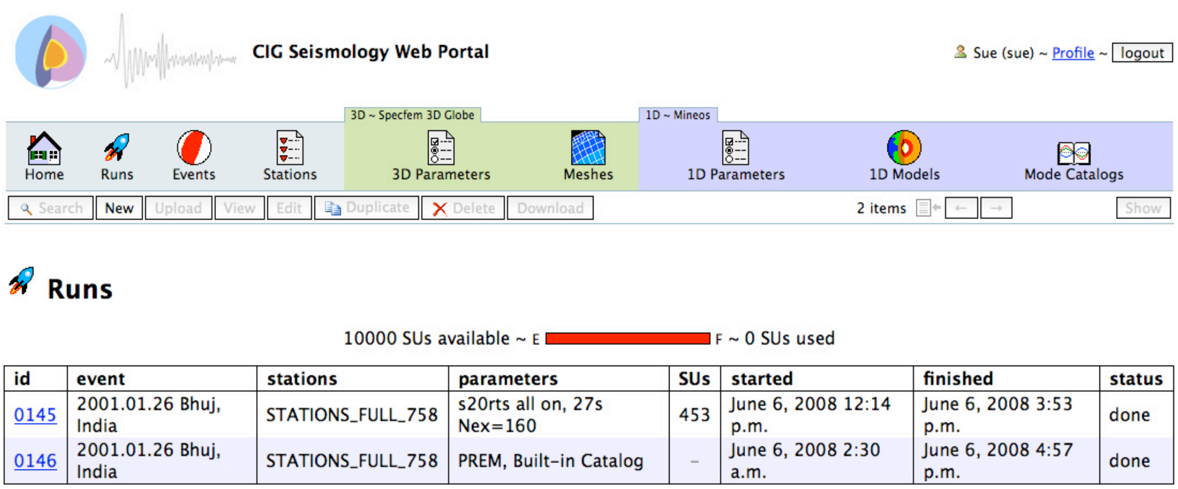
The CIG Seismology Web Portal provides on-demand simulations of seismic wave propagation using SPECFEM3D GLOBE and Mineos. Users can run either seismology code using custom parameters and data.

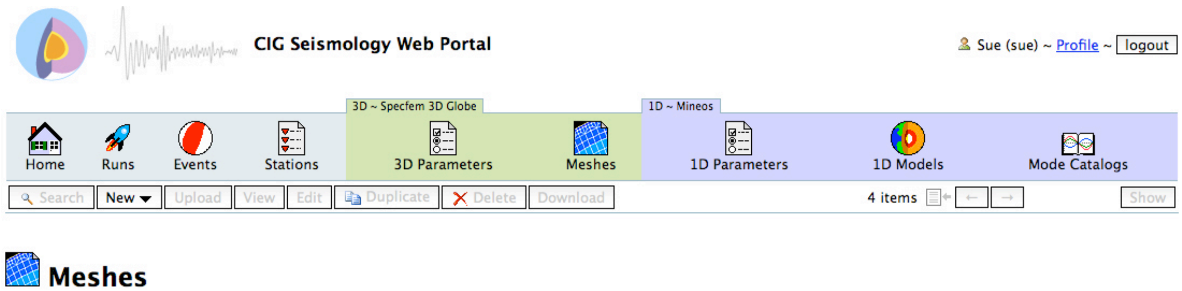
The portal allows users to upload their own custom 3D Earth models for use in SPECFEM3D GLOBE simulations. A user creates a 3D Earth model by implementing a handful of routines in Fortran or C, and then packaging the code together with any required data files. Example Earth model implementations, including S20RTS and S362ANI, are available for download.

Among the Earth model examples is an interesting new code package that converts the output of the CitcomS mantle convection code into an isotropic SPECFEM3D GLOBE velocity model. This enables users to simulate seismic wave propagation through an Earth model generated by CitcomS.

In addition, the portal runs the 1D Mineos code in parallel, resulting in a short turnaround time for 1D synthetics.

The CIG Seismology Web Portal is located at https://crust.geodynamics.org/portals/seismo/





name	nchunks	nproc		nex		angular width		center		γ rotation azimuth	shortest period (s)
		η	ξ	η	ξ	η	ξ	latitude	longitude		
Global 18s Nex=240	6	6	6	240	240	n/a	n/a	n/a	n/a	n/a	18
Global 19s Nex=224	6	7	7	224	224	n/a	n/a	n/a	n/a	n/a	19
Global 23s Nex=192	6	8	8	192	192	n/a	n/a	n/a	n/a	n/a	23
Global 27s Nex=160	6	5	5	160	160	n/a	n/a	n/a	n/a	n/a	27

CIG Seismology Portal Account Holders

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Tim Ahern
Michael Aivazis
Laura Alisic
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Richard Aster
Jerry Ballard
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Robert Barsch
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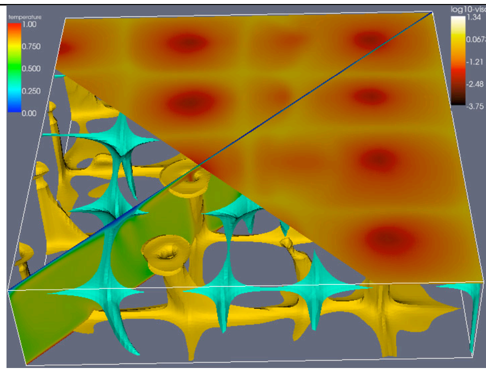
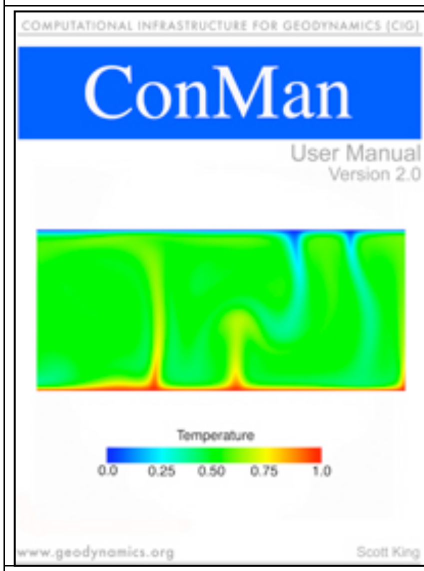
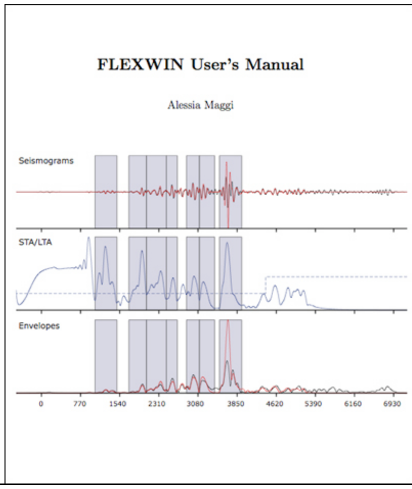
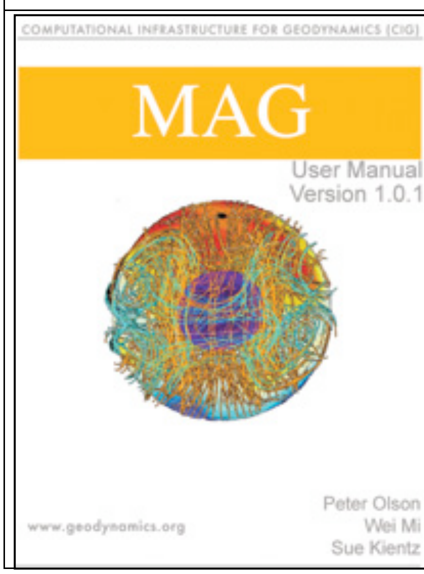
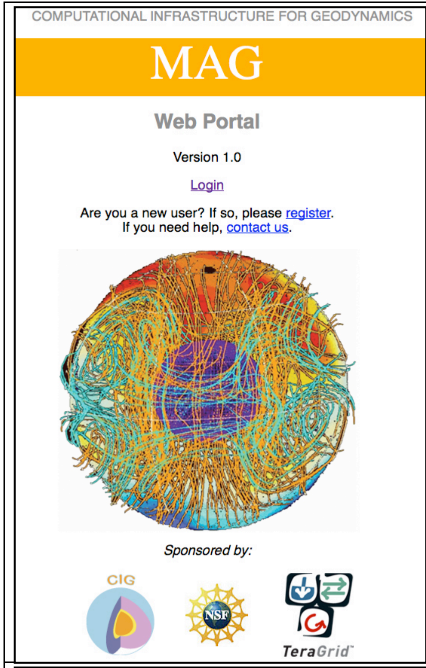
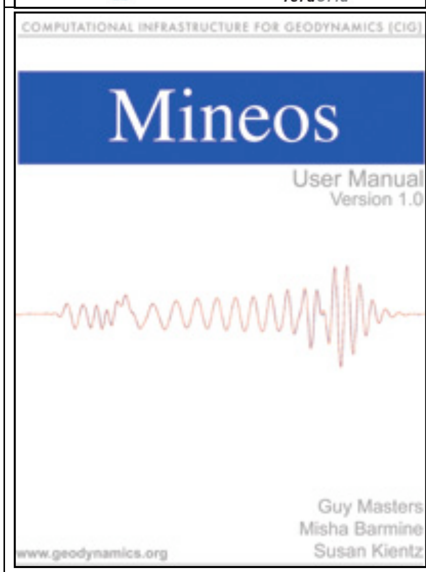
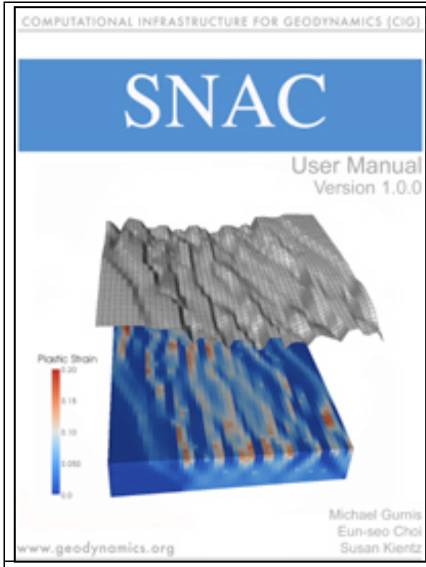
Shaji Nair
John Naliboff
Tarje Nissen-Meyer
Giovanni Occhipinti
John Orcutt
Silke Overkott-Brown
Gary Pavlis
Daniel Peter
Steve Quenette
Adam Ringler
Jeroen Ritsema
Michael Ritzwoller
Luis Rivera
Arthur Rodgers
Brian Savage
Jeff Shragge
Anne Sieminski
Teh-Ru Song
Tehru Song
Marc Spiegelman
Laurent Stehly
Jeffry Stevens
Leif Strand
Marco Stupazzini
William Symes
Eh Tan
Carl Tape
KiranKumar
Thingbaijam
Bf Tian
Jeannot Trampert
Jeroen Tromp
Victor Tsai
Tai-Lin Tseng
Emily Van Ark
Elizabeth Vanacore
Miguel Angel Vidal
Arango
Yun Wang
John Woodhouse
Francis Wu
Michael Wysession
Heming Xu
Hongfeng Yang
Yingjie Yang
Zhaohui Yang
Huajian Yao
Mohammad Youssof
Chunpeng Zhao
Zuihong Zou

Other Software Maintained by CIG

	CitcomCU is a finite element parallel code capable of modeling thermochemical convection in a three dimensional domain appropriate for convection within the Earth's mantle. Based on the original CitCom code developed by Louis Moresi, CitcomCU was developed by Shijie Zhong at the University of Colorado at Boulder and implements many new extensions, such as support for both regional Cartesian and regional spherical geometries, thermochemical convection with particles, and extended Boussinesq approximations.
	ConMan is a finite element program for the solution of the equations of incompressible, infinite-Prandtl number convection in two dimensions, originally written by Scott King, Arthur Raefsky, and Brad Hager.
Ellipsis3d	Ellipsis3d is a three-dimensional version of the particle-in-cell finite element code Ellipsis, a solid modeling code for visco-elastoplastic materials. The particle-in-cell method combines the strengths of the Lagrangian and Eulerian formulations of mechanics while bypassing their limitations. Ellipsis3d originated from CIItcom (CitCom version II), a multigrid mantle convection code developed by Louis Moresi. Subsequently, Chris Wijns contributed user-functionality and miscellaneous back end improvements. Later extensions to include the Cosserat continuum theory were introduced by Frederic Dufour. The two-dimensional version of ellipsis was extended into three dimensions by Richard Albert and Craig O'Neill.

	The Flexwin software package automates the time-window selection problem for seismologists. It operates on pairs of observed and synthetic single component seismograms, defining windows that cover as much of a given seismogram as possible, while avoiding portions of the waveform that are dominated by noise.
HC	HC is a global mantle circulation solver following Hager & O'Connell (1981) that can compute velocities, tractions, and geoid for simple density distributions and plate velocities. This particular implementation illustrates one possible way to combine the HC solver routines. Based on code by Brad Hager, Richard O'Connell, and Bernhard Steinberger, this version is by Thorsten Becker and Craig O'Neill.
LithoMop	LithoMop is a finite element code for the solution of visco-elastic/plastic deformation that was designed for lithospheric modeling problems.
	MAG is a serial version of a rotating spherical convection/magnetoconvection/dynamo code, developed by Gary Glatzmaier and modified by Uli Christensen and Peter Olson.

<table>
<tr><td>
</td><td>The MAG Portal allows you to run the geodynamo code MAG without compiling it locally. Create and submit a MAG job to a selected TeraGrid site, monitor its progress and, when complete, download a tar-ball with the job results to further analyze locally or visualize with IDL software. You can queue up a long serial run rather than tie up your local machine. MAG is a serial version of a rotating spherical convection/magneto-convection/dynamo code that solves the non-dimensional Boussinesq equations for time-dependent thermal convection in a rotating spherical shell filled with an electrically conducting fluid.</td></tr>
<tr><td>
</td><td>The Mineos package is a 1D code used to simulate synthetic seismograms in the spherical symmetric non-rotated Earth by normal mode summation.</td></tr>
<tr><td>Plasti</td><td>Plasti is a 2D ALE (Arbitrary Lagrangian Eulerian) code donated to CIG by Sean Willett and Chris Fuller of the University of Washington. The code originated at Dalhousie University in Canada.</td></tr>
<tr><td>SEISMIC CPML</td><td>SEISMIC CPML is a set of six Fortran90 programs that solve the 2D or 3D isotropic or anisotropic elastic wave equation using a finite-difference method with Convolutional Perfectly Matched Layer (C-PML) conditions, developed by Dimitri Komatitsch and Roland Martin from University of Pau, France.</td></tr>
</table>

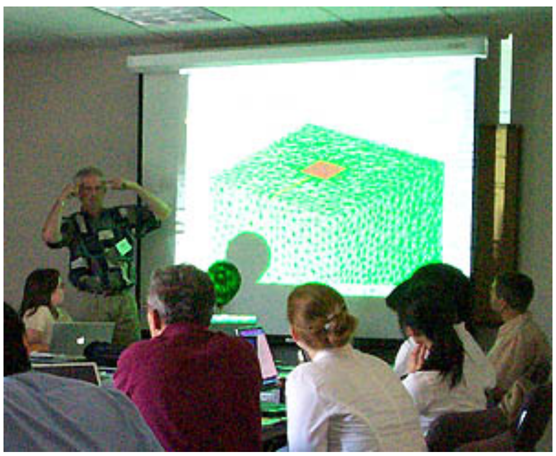
	SNAC (StGermaiN Analysis of Continua) is an updated Lagrangian explicit finite difference code for modeling a finitely deforming elasto-visco-plastic solid in 3D, released under the GNU General Public License.
SPECFEM1D	SPECFEM1D simulates seismic wave propagation in a one-dimensional heterogeneous medium. It is a small code that allows users to learn how a spectral-element program is written.
SPECFEM2D	SPECFEM2D simulates seismic wave propagation in two-dimensional anisotropic viscoelastic or coupled viscoelastic-acoustic media.

Part C:
CIG Workshops

CIG Workshops

CIG sponsors and/or co-sponsors several workshops and training sessions each year. At these events, members of the geodynamics community are exposed to the latest versions of CIG software. Both novices and expert users benefit not just from the training, but also from the added opportunity of being able to personally pose questions and concerns to CIG developers. This contact also enables CIG developers to learn what kind of features users require for their research.

Tinker time at Community Finite Element Models (CFEM) Workshop, Golden, CO (2006)



Presentation at CFEM Workshop in Golden, CO, June 2006

Participants in Oct 2006 Workshop on Challenges and Opportunities at the Interfaces of Scientific Computing and Computational Geodynamics and Computational Science Roundtable held at University of Texas at Austin.

CIG Workshop Dates, Sponsors, and Attendance

Table S1. Location and attendance details of CIG Workshops and Training Sessions

Workshop	Date/Location	Other Sponsors	Students/ Total
Comp. Seismology	6/8/2005, Stevenson, WA	IRIS	4/28
Tectonic Modeling	6/9–12/2005, Breckenridge, CO	NSF Tectonics	8/26
Mantle Convection	6/19–23/2005, Boulder, CO	–	33/67
Short-Term Tectonics	7/11–14/2005, Los Alamos, NM	SCEC/LANL/NSF/ NASA	14/43
Compressible Mantle Convection	3/27–28/2006, W. Lafayette, IN	–	2/13
Short–Term Tectonics	6/26–30/2006, Golden, CO	SCEC/NASA	31/60
Magma Migration	8/18–19/2006, New York, NY	–	20/44
Interface of Scientific Computing and Geodynamics	10/16–18/2006, Austin, TX	–	15/64
Comp. Seismology	10/31–11/2/2006, St. Louis, MO	EarthScope	46/73
Gale, Citcom Training	3/27/2007, Monterey, CA	EarthScope	13/24
Short-Term Tectonics	6/25-29/2007, Golden, CO	SCEC/NASA/ EarthScope	36/63
Comp. Seismology	10/9-11/2007, Jackson, NH	SPICE/IRIS	18/52
Adaptive Mesh Refinement	10/24-27/2007, Boulder, CO	–	6/25
Short-Term Tectonics	6/23–27/2008, Golden, CO	SCEC/NASA/ EarthScope	23/57
Mantle Convection and Lithospheric Dynamics	7/9–11/2008, Davis, CA	NSF Geophysics	50/90
Training	7/22/2008, Santa Barbara, CA	CIDER	10/34
Mathematical and Computational Issues in the Solid Earth Sciences	9/15–17/2008, Santa Fe, NM	NSF CMG, NSF OCI	18/30
Opportunities and Challenges in Comput. Geophysics	3/30–31/2009, Pasadena, CA	–	21/81
Training	5/12/2009, Boise, ID	EarthScope	9/17
Short-Term Tectonics	6/22–26/2009, Golden, CO	NSF/SCEC	18/39

CIG Workshop Summaries

Table S2. Details of CIG Workshops and Training Sessions

Geodynamic Modeling of Tectonic Processes 2005 Workshop, June 10-12, 2005, in Breckenridge, Colorado. This workshop examined the scientific and computational issues that challenge geodynamic modeling of tectonic problems in the coming decade, and focused primarily on tectonic processes that affect continental lithosphere over timescales longer than the earthquake cycle. Attended by 26 individuals, 8 of whom were students. Final report, presentations, and other details are online at http://geodynamics.org/cig/workinggroups/long/workshops/breckenridge05/
Boulder Mantle Convection Workshop, June 19- 23, 2005, Boulder, CO. About 26 graduate students and 39 geodynamicists and computational scientists attended the workshop. The morning sessions consisted of review and research talks, while afternoon sessions were for tutorials, demos, and practices. Also discussed were community software needs and goals that may require help from CIG. The workshop agenda, presentations, and final report are online at http://geodynamics.org/cig/workinggroups/mc/workshops/2005presentations/
Community Finite Element Models for Fault Systems and Tectonic Modeling workshop, July 11-14, 2005, Los Alamos, NM. SCEC, LANL IGPP, NASA, and CIG jointly provided funding for the workshop. We had 42 participants, many of whom were new to the computational crustal deformation modeling community. The underlying goal of this workshop was to have all participants leave with a working FEM code on their home machine to get them over the start-up hurdle. This goal was reasonably successful. In addition, this workshop focused on defining the tools necessary for end-to-end modeling from concept, through structural models, meshes, and finally to solvers and visualization. Presentations are online at http://geodynamics.org/cig/workinggroups/short/workshops/cfem2005presentations/
2006 Purdue Workshop for Compressible Mantle Convection, March 27-28, 2006, Purdue University, Lafayette, IN. Attended by 12 geophysicists (4 of them graduate students) including geodynamicists and mineral physicists and 2 CIG staff members. At the meeting, we clarified the set of governing equations to be solved (Anelastic liquid approximation or ALA and truncated anelastic liquid approximation or TALA); identified the areas for more studies including the effects of different reference states and different formulation; identified a number of algorithms (e.g., GMRES, BiCGstab) that can be potentially used in the CIG's 3D compressible convection code; and defined benchmark problems for compressible mantle convection. The summary report, agenda, and presentations are available online at http://geodynamics.org/cig/workinggroups/mc/workshops/workshop2006/

Fault Systems and Tectonic Modeling, June 26-30, 2006, Golden, Colorado on the campus of the Colorado School of Mines. Co-sponsored by SCEC, NASA, NSF and CIG. The focus was on the science associated with simulating pre- and post-seismic crustal deformation and training researchers in the use and customization of PyLith and GeoFEST, a JPL code for crustal deformation. Workshop presentations are available online at http://geodynamics.org/cig/workinggroups/short/workshops/2006talks/
Computational Magma Dynamics Workshop, August 18-19, 2006, Columbia University, New York. The purpose of this meeting was to discuss current progress and future goals for understanding and modeling magmatic processes in the Earth. In particular, discussion centered on opportunities for new software development afforded by CIG that would enable researchers to explore new science and better integrate theory with observations. Workshop announcement, presentations, agenda, and final report are available online at http://geodynamics.org/cig/workinggroups/magma/workshops/2006-magma-workshop
CIG Workshop on Challenges and Opportunities at the Interfaces of Scientific Computing and Computational Geodynamics, October 16-17, 2006, Austin, Texas. The workshop, designed to bring together mathematicians, computational scientists and geoscientists, addressed meshing, solvers, graphics, and other common issues in computational geophysics. The workshop agenda, presentations, and a summary of the roundtable discussion are at http://geodynamics.org/cig/workinggroups/cs/workshops/austin06-workshop/
Earthscope Imaging Science/CIG Seismology Joint Workshop on Computational Seismology, October 31-November 2, 2006, St. Louis, MO. Topics included aspects of forward modeling and imaging with teleseismic data. The workshop agenda, photos, and presentations are available at http://epsc.wustl.edu/seismology/michael/CIG/workshop06/
CIG Training Session, EarthScope, March 27, 2007, in Monterey, CA. CIG conducted a training session during EarthScope 2007 in the use of the Gale and CitcomS software packages. Presentations from this and other sessions are at http://geodynamics.org/cig/proc/material/
Community Finite Element Models for Fault Systems and Tectonic Studies 2007 Workshop, June 25-29, 2007, Colorado School of Mines, Golden, CO. Attended by over 60 participants, the majority of which were students and postdocs. This workshop included the tutorial and software introduction sessions of previous years, but had many more science application presentations. In the previous workshop, we began befriending the FARM community with talks on laboratory friction laws and on dynamic slip modeling. This represents a concerted effort by the community to merge the modeling codes to hand time scales of seconds to thousands of years – truly a daunting task, but an important one if we want to make progress in understanding the impact of 3D variations in crustal stress. The agenda, lectures, posters, and final report are at http://geodynamics.org/cig/workinggroups/short/workshops/cfem-07/

Joint CIG/SPICE/IRIS Computational Seismology Workshop, October 9-11, 2007, in Jackson, NH. A joint workshop between SPICE (Seismic wave Propagation and Imaging in Complex media: a European network), IRIS (Incorporated Research Institutions for Seismology), and the CIG Seismology Working Group. It was a joint meeting between European and American Seismologists to discuss current "hot topics": algorithm development, imaging developments, and the future goals of a united American-European scientific community. Participants examined the current and future possibilities for computational seismology. The agenda, presentations, posters, and discussion points are available online at http://geodynamics.org/cig/workinggroups/seismo/workshops/spice07/
AMR Tutorial Workshop 2007, October 24 to 27 in Boulder, Colorado. The invited talks and tutorials allowed participants to see the potential benefits of AMR and the feasibility of building the software. Discussion centered on how to implement AMR in codes that are not easily extended to incorporate AMR capabilities. The workshop report, agenda, presentations, and the tutorial are online at http://geodynamics.org/cig/workinggroups/cs/workshops/amr07/
2008 Workshop on Numerical Modeling of Crustal Deformation and Earthquake Faulting, June 23-27, 2008, Colorado School of Mines, Golden, CO. The focus of this gathering was on computational models addressing the seismic cycle across single and multiple events. The workshop blended science talks on case studies from particular faulting environments and on key rheological behavior with discussions of current obstacles to crustal deformation modeling. The first four days (Monday-Thursday) were a mixture of science talks, discussion, and hands-on tutorials. The fifth day (Friday) was dedicated to informal tutorials and collaboration. The workshop agenda, presentations, posters, and final report are available online at http://geodynamics.org/cig/workinggroups/short/workshops/cfem-08/
Workshop for Advancing Numerical Modeling of Mantle Convection and Lithospheric Dynamics, July 9-11, 2008, UC Davis, Davis, CA. This workshop built on the success of the 2005 Boulder workshop on Mantle Convection, but was broader in terms of audience than the Boulder workshop by bringing together both the mantle convection and lithospheric dynamics communities. Discussions were on scientific advances and, importantly, technical and scientific issues related to the quantitative modeling of the origin and evolution of the mantle-lithosphere system. The workshop announcement and presentations are available online at http://geodynamics.org/cig/workinggroups/mc/workshops/litho2008/
CIG Workshop on Mathematical and Computational Issues in the Solid Earth Geosciences, Sept. 15-17, 2008, Santa Fe, NM. This CIG workshop brought together solid-earth geoscientists, mathematicians, computational and computer scientists to focus on specific issues arising from a range of solid-Earth dynamics problems that have proven both difficult and critical for progress in studying and modeling the dynamics of the planet. The agenda, presentations, and posters are available at http://geodynamics.org/cig/workinggroups/cs/workshops/geomath08/

Opportunities and Challenges in Computational Geophysics, March 30-31, 2009, California Institute of Technology, Pasadena, CA. The workshop addressed scientific activities involving state-of-the art software such as that being supported by CIG, innovations and opportunities in computational geophysics, and ways to support and grow computational geoscience through community education programs. An important objective was to obtain community input on the future of the CIG initiative. The overall format combined invited talks, discussion sessions and posters. Participants in all areas of our science attended, including experts in computational science and in geophysics. The agenda, presentations, and posters are available at http://geodynamics.org/cig/workinggroups/cs/workshops/future-of-cig09/
Training Sessions on Tectonic Models and Large-Scale Earth Models at EarthScope 2009, May 12, 2009, Boise Centre on the Grove, Boise, ID. During EarthScope, CIG conducted two separate training sessions: one in the use of the Gale and PyLith software packages for Tectonic Models, and the other in Large-Scale Earth Models using SPECFEM3D/CitcomS software. Presentations from these and other sessions are at http://geodynamics.org/cig/proc/material/
2009 Workshop on Numerical Modeling of Crustal Deformation and Earthquake Faulting, June 22-26, 2009, Golden, CO. The focus of this gathering is on computational models addressing crustal deformation with an emphasis on the seismic cycle across single and multiple events. The workshop will blend science talks on case studies from particular faulting environments and on key rheological behavior with discussions of current obstacles to crustal deformation modeling. The announcement for this workshop is available at http://geodynamics.org/cig/workinggroups/short/workshops/nmcdef-09

Part D: Governance

List of Members

CIG Institutional Members

Argonne National Laboratory (MSC)
Brown University
California Institute of Technology
Colorado School of Mines
Colorado State University
Columbia University
Cornell University
Georgia Institute of Technology
Harvard University
Johns Hopkins University
Lawrence Livermore National Laboratory
Los Alamos National Laboratory (ES)
Massachusetts Institute of Technology
Oregon State University
Pennsylvania State University
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rice University
State University of New York at Buffalo
State University of New York at Stony Brook
U.S. Geological Survey (Menlo Park)
University of Arizona
University of California, Berkeley
University of California, Davis
University of California, Los Angeles
University of California San Diego
University of Colorado
University of Hawaii
University of Maine
University of Maryland
University of Michigan
University of Minnesota
University of Missouri-Columbia
University of Nevada, Reno
University of Oregon
University of Southern California
University of Texas at Austin
University of Washington
Virginia Polytechnic Institute and State University
Washington University
Woods Hole Oceanographic Institution

CIG Foreign Affiliates

Australian National University
Geological Survey of Norway (NGU)
GNS Science
Monash University
Munich University LMU
University College London
University of Science and Technology of China
University of Sydney
Victorian Partnership for Advanced Computing

CIG By-Laws

As approved by the Electorate, February 28, 2005
As amended by the Electorate, December 12, 2006

PREAMBLE

The By-Laws of the Computational Infrastructure for Geodynamics (CIG) are adopted by the Member Institutions for the purpose of conducting CIG business in a collegial manner. They should not be construed as overriding the standard responsibilities and prerogatives of Principal Investigators or their respective institutions. However, situations and issues may arise from time to time for which resolution through standard procedures cannot be achieved. Consequently, should the Director and the Executive Committee not be able to reach agreement on any given issue, the Director, as Principal Investigator on the core CIG grants/contracts, will ultimately retain full authority to make and implement decisions on core CIG programs and policies.

Article I   Name

Section 1. Name: The name of the Organization is Computational Infrastructure for Geodynamics (abbreviated as CIG).

Article II   Member Institutions

Section 1. Membership: Institutions that are both educational and not-for-profit, chartered in the United States, with a major commitment to research in Earth Science with a particular emphasis on geodynamics and computational geophysics, and related fields, including single or multiple campuses of multi-campus university systems, may become Members of the Organization. Governmental research laboratories with a close link to the academic research community in geodynamics and computational geophysics are also eligible for Membership. The current list of member institutions shall be maintained by the Director.

Section 2. Election: An institution applying for membership must be qualified as an educational and not-for-profit institution according to criteria adopted by the Electorate. Qualified institutions may be elected as members by the affirmative vote of two-thirds of the members of the entire Electorate, or by unanimous vote of the Executive Committee of CIG. The rights and privileges of Members with respect to participation in the scientific activities of CIG will be according to policies established by the Electorate.

Section 3. Foreign Affiliation: Institutions not chartered in the United States may be elected as Foreign Affiliates for an indefinite term by the affirmative vote of two- thirds of the members of the entire Electorate or by a unanimous vote of the Executive Committee of the Electorate. A Foreign Affiliate will be entitled to designate a nonvoting representative to the Electorate, and will be able to participate in all activities in the governance of CIG other than voting at business meetings as a regular CIG Member or serving in a position specifically restricted to Electors. The rights and privileges of Foreign Affiliates with respect to participation in the scientific activities of CIG will be according to policies established by the Electorate.

Section 4. Resignation or Removal: Any Member or Affiliate may resign at any time by giving written notice to the Chairperson of the Executive Committee or the Director of the Organization. Such resignation shall take effect at the time of receipt of be removed by the affirmative vote of two-thirds of the Members of the entire Electorate.

Article III   Electorate

Section 1. Powers: So long as they do not conflict with the responsibilities of Principal Investigators, power in the management of the affairs of the Organization is vested in the Electorate. To this end and without limitation of the foregoing or of its powers expressly conferred by these By-Laws, the Electorate shall have power to authorize such action on behalf of the Organization, make such rules or regulations for its management, create such additional offices or special committees and select, employ or remove such of its officers, agents or employees as it shall deem best. The Electorate shall have the power to fill vacancies in, and change the membership of, such committees as are constituted by it.

Section 2. Power of Appointment: The term "Executive Officer" referred to in Sections 3-6 shall mean a Senior Officer of a Member institution above or at the level of Department Head.

Section 3. Composition: The Electorate shall be composed of one person from each of the Member institutions. An Executive Officer of each such Member institution shall designate one Elector, who shall be the holder of an academic appointment, with major responsibilities for instruction and/or research in the earth sciences, in a department, program or other organizational unit of such member institution.

Section 4. Term of Office: Each Elector shall continue in office until a successor is chosen and qualifies or until he or she dies, resigns or is removed by an Executive Officer of the member institution.

Section 5. Resignation: Any Elector may resign at any time giving written notice to the Chairperson of the Executive Committee or the Director of CIG. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein.

Section 6. Alternate Electors: An Executive Officer of each Member institution may appoint from within the Member institution an alternate Elector to serve for the term specified by such appointment. In the absence of an Elector from any meeting of the Electorate, his or her alternate may, upon written notice to the Director of the Organization from the Elector or from a duly authorized representative of the Member institution of the Electorate, attend such meeting and exercise all the rights, powers and privileges of the absent Elector.

Article IV Meetings of the Electorate

Section 1. Annual Meeting: A meeting of the Electorate for the election of officers and for the transaction of such other business as may properly come before it shall be held once per year.

Section 2. Special Meetings: Special meetings of the Electorate may be called by the Chairperson of the Executive Committee or by the Director upon written request of at least four Electors or one-fifth (1/5) of the membership of the Electorate, whichever is greater.

Section 3. Place of Meetings: The Chairperson of the Executive Committee or the Director shall designate the place of the annual meeting or any special meeting and which shall be specified in the notice of meeting or waiver of notice thereof.

Section 4. Notice of Meetings: Notice of such meeting of the Electorate shall be given to each Elector by the Director, or by an officer directed by the Chairperson of the Executive Committee or the Director to give such notice, by delivering to him or her personally, by electronic means, or by first-class mail, postage prepaid, addressed to him or her at the address of his or her Member institution, a written or printed notice not less than thirty nor more than sixty days before the date fixed for the meeting. Notice of any meeting need not be given to any Elector, however, who submits a signed waiver of notice, whether before or after the meeting. The attendance of any Elector at a meeting without protesting prior to the conclusion of the meeting the lack of notice thereof shall constitute a waiver of notice by him or her. When a meeting is adjourned to another place or time, it shall not be necessary to give any notice of the adjourned meeting if the time and place to which the meeting is adjourned are announced at the meeting at which the adjournment is taken.

Section 5. Quorum: Except as may be otherwise expressly required by law or these By-Laws, at all meetings of the Electorate forty percent (40%) of the Electors then serving shall constitute a quorum. At all meetings of any committee of the Electorate a majority of the members of that committee shall constitute a quorum. For the purposes of election of Officers and Executive Committee members, a quorum shall be determined in accordance with Article VIII. If a quorum is not present, a majority of the Electors present may adjourn the meeting without notice other than by announcement at said meeting, until a quorum is present. At any duly adjourned meeting at which a quorum is present, any business may be transacted which might have been transacted at the meeting as originally called.

Section 6. Voting: Each Elector shall be entitled to one vote. Except as otherwise expressly required by law or these By-Laws, all matters shall be decided by the affirmative vote of a majority of the Electors present at the time of the vote, if a quorum is then present.

Section 7. Action without a Meeting: Any action required or permitted to be taken by the Electorate, or the Executive Committee, may be taken without a meeting if all Electors or the Executive Committee consent in writing to the adoption of a resolution authorizing the action. The resolution and the written consents thereto shall be filed with the minutes of the proceedings of the Electorate or the Executive Committee.

Section 8. Participation by Conference Telephone or Video Conference: In any meeting of the Electorate or any committee thereof, any one or more Electors or members of any such committee may participate by means of a conference telephone or similar communications equipment allowing all persons participating in the meeting to hear each other at the same time. Participation by such means shall constitute presence in person at a meeting.

Article V Officers

Section 1. Officers and Qualifications: The officers of the Organization shall consist of a Chairperson and a Vice Chairperson of the Executive Committee, a Chief Software Architect, and a Director and such other officers as the Electorate may from time to time establish and appoint. Unless otherwise specified by Electorate action, officers need not be Electors.

Section 2. Chairperson: The Chairperson of the Executive Committee shall, when present, preside at all meetings of the Electorate and shall perform such other duties and exercise such other powers as shall from time to time be assigned by the Electorate. The Chairperson of the Executive Committee shall be an ex officio member of all CIG committees.

Section 3. Vice Chairperson: The Vice Chairperson of the Executive Committee shall preside, in the absence of the Chairperson, at all meetings of the Electorate and shall perform such other duties and exercise such other powers as shall from time to time be assigned by the Electorate.

Section 5. Chief Software Architect: The Chief Software Architect will act as the chief advisor to the Director and Executive Committee on matters of software development and integration. The Chief Software Architect shall be a non-voting member of the Executive Committee.

Section 4. Director: Except as otherwise provided by the Electorate, the Director shall be the Chief Executive Officer of the Organization, and unless authority is given by the Electorate to other officers or agents to do so, he or she shall execute all contracts and agreements on behalf of the Organization. The Director shall be the Principal Investigator on proposals which fund the core CIG facility. It shall be his or her duty, insofar as the facilities and funds furnished to him or her by the Organization permit, to see that the orders and votes of the Electorate and the purposes of the Organization are carried out. In the absence of the Chairperson or the Vice Chairperson of the Executive Committee, the Director shall preside at meetings of the Electorate. The Director shall be a non-voting member of the Executive Committee.

Section 5. Election and Term of Office: The Chairperson and Vice Chairperson of the Executive Committee shall each be elected by the Electorate for a term not to exceed three years or until his or her successor is chosen and qualifies. The Chairperson of the Executive Committee shall not be eligible for reelection until another person shall have served an intervening term, or a portion of a term of more than one year, as Chairperson. All other officers of the Organization, with the exception of the Director, shall be elected by the Electorate for terms not to exceed three years or until their successors are chosen and qualify, and they shall be eligible for reelection. The Director and the Chief Software Architect shall be appointed by the Executive Committee.

Section 6. Resignation: Any officer may resign at any time by giving written notice to the Chairperson, the Vice Chairperson or the Director of the Organization. Such resignation shall take effect at the time of receipt of the notice, or at any later time specified therein.

Section 7. Vacancies: Any vacancy in any office may be filled for the unexpired portion of the term of such office by a vote of the Electorate.

Section 8. Removal: Any officer may be removed at any time either with or without cause by vote of the Electorate.

Article VI Executive and Other Committees

Section 1. Executive Committee of CIG: There shall be established an Executive Committee of CIG comprised of five voting members (the Chairperson, the Vice Chairperson, and three additional members elected by the Electorate) and three non-voting members (the Director, the Chief Software Architect and the Chairperson of the Science Steering Committee). The elected members of the Executive Committee shall have terms not to exceed three years or until his or her successor is chosen and qualified. Members of the Executive Committee may not simultaneously serve on of the Science Steering Committee.

Section 2. Powers of the Executive Committee of CIG: Unless otherwise provided by resolution adopted by the affirmative vote of a majority of the entire Electorate, the Executive Committee may have and may exercise all the powers of the Electorate, except that it shall not have authority as to the following matters:

(a) the amendment or repeal of the By-Laws, or the adoption of new By-Laws;
(b) the amendment or repeal of any resolution of the Electorate, which by its terms shall not be so amendable or repealable; and
(c) the levying or assessment of fees and dues.

The responsibilities of the Executive Committee include coordination of activities, meetings, and workshops. The Executive Committee shall establish the priorities for software development undertaken by CIG. In establishing these priorities, the Executive Committee will consider input obtained from the Electorate directly and from recommendations made by the Science Steering Committee.

At all meetings of the Executive Committee, the presence of a simple majority of its members then in office shall constitute a quorum for the transaction of business.

Section 3. Special Committees: The Electorate may create such special committees as may be deemed desirable, the members of which shall be appointed by the Chairperson of the Executive Committee from among the Electors, with the approval of the Executive Committee. Each such committee shall have only the lawful powers specifically delegated to it by the Electorate.

Section 4. Science Steering Committee: There will be standing committees as defined in Article VII for overseeing the major scientific and research programs to which the Organization provides scientific counsel and advice or management direction and fiscal recommendations.

Section 5. Other Committees: The Executive Committee may create committees other than Standing or Special committees to be Committees of the Organization. Such committees shall be appointed in such a manner as may be determined by the Executive Committee and shall have such lawful duties as may be specified by the Executive Committee. An individual or an institution may be a member of any such committee whether or not they are an Elector or officer of the Organization.

Article VII Science Steering Committee

In order to carry out and oversee CIG operations, a Science Steering Committee (SSC) shall be established. The members will be selected by the Electors and will serve terms up to three years duration. A committee will be formed according to Article VI, section 4 to determine and prioritize software development from the perspective of the Earth science and Computational science disciplines represented by the Electorate. This committee will evaluate the utility of software developed and delivered to the community by CIG. This committee will consider the community's needs and recommend changes in the levels of support of CIG development resources. The committee will formulate policies for evaluation of user proposals for CIG software development. At least twice per year, the committee shall report in writing to the Executive Committee priorities for software development and resource allocation.

Article VIII Elections

Section 1. Officers, Executive Committee, and Standing Committees: Officers, Executive Committee members, and Science Steering Committee members may be elected by the Electorate at the Annual Meeting or by an E-mail Election, in accordance with the procedures established in this Article.

Section 2. Nominating Committee: No less than 90 days before the Annual Meeting or the E-mail Election, the Executive Committee shall appoint a Nominating Committee, which shall prepare a slate of one or more nominees for each position to be filled. The Nominating Committee shall solicit the Electors for the names of suggested nominees. Any candidate shall be placed on the slate by the Committee upon receipt of written nomination signed by three Electors at least 40 days before the Annual Meeting.

Section 3. Mailed notice of election and ballot: If the election is to be held at the Annual Meeting, the ballot prepared by the Nominating Committee shall be included in the Notice of Meeting. If the election is to be held by E-mail, then a copy of the ballot shall be mail to the Electorate not less than thirty nor more than sixty days before the date fixed for the E-mail Election.

Section 4. Election: If the election shall take place at the Annual Meeting, it shall include the opportunity for nominations to be made from the floor. Election shall be by written ballot, which may be cast in person by an Elector at the meeting, or may be submitted by mail, email, or facsimile, if received by the Vice-Chairman before the meeting. If the Election is by E-mail, then the ballot shall be sent to the Electorate ten (10) days before the date of the Election. Election shall be valid if ballots are received from one-half of the membership of the entire Electorate in accordance with this Article, even if a quorum is not present for the purpose of conducting other business.

Section 5. Method of Voting: In the election of officers, a valid ballot shall contain at most one vote for each office; election shall be decided in favor of the nominee receiving a plurality of votes. In the election of Executive and Science Steering Committee members, a valid ballot shall contain no more votes than vacancies being filled; election to each vacancy shall be determined in sequence in favor of those qualified nominees with the most votes.

Section 6. Counting of ballots: Ballots shall be counted by the Vice-Chairman and the Chair of the Nominating Committee.

Article IX Compensation

Section 1. Compensation: The Electorate shall have the power to fix the compensation and fees payable to officers and employees for services rendered to the Organization; provided, however, that these fees and compensation are consistent with the policies of the host Institution that oversees the employment of said person or persons, and that no Elector shall be paid any compensation for serving as Elector. All Electors may be reimbursed for the actual expenses incurred in performing duties assigned to them by the Electorate.

Section 2. Dividends: The Organization shall not pay dividends or distribute any part of its income or profit to its members, Electors or officers.

Article X Amendments to the By-Laws

Section 1. Amendments: All By-Laws of the Organization shall be subject to amendment or repeal and new By-Laws may be made by the affirmative vote of two-thirds of the entire Electorate at any annual or special meeting, the notice or waiver of notice of which shall have specified or summarized the proposed amendment, repeal or new By-Laws.

Part E:
Publications and Abstracts Resulting from CIG

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