Discovery & Innovation via High-End Computational Resources

Russ Miller

Cyberinfrastructure Lab, SUNY-Buffalo

Hauptman-Woodward Med Res Inst

NSF, NIH, DOE, NIMA, NYS, Dell

www.cse.buffalo.edu/faculty/miller/CI/

Academia in the 21st Century

- **Empower students to compete in knowledge-based economy**
- **Embrace digital data-driven society**
- **Accelerate discovery and comprehension**
- **Enhance virtual organizations**
- **Provide increased education, outreach, and training**
- **Enhance and expand relationships between academia and the corporate world**

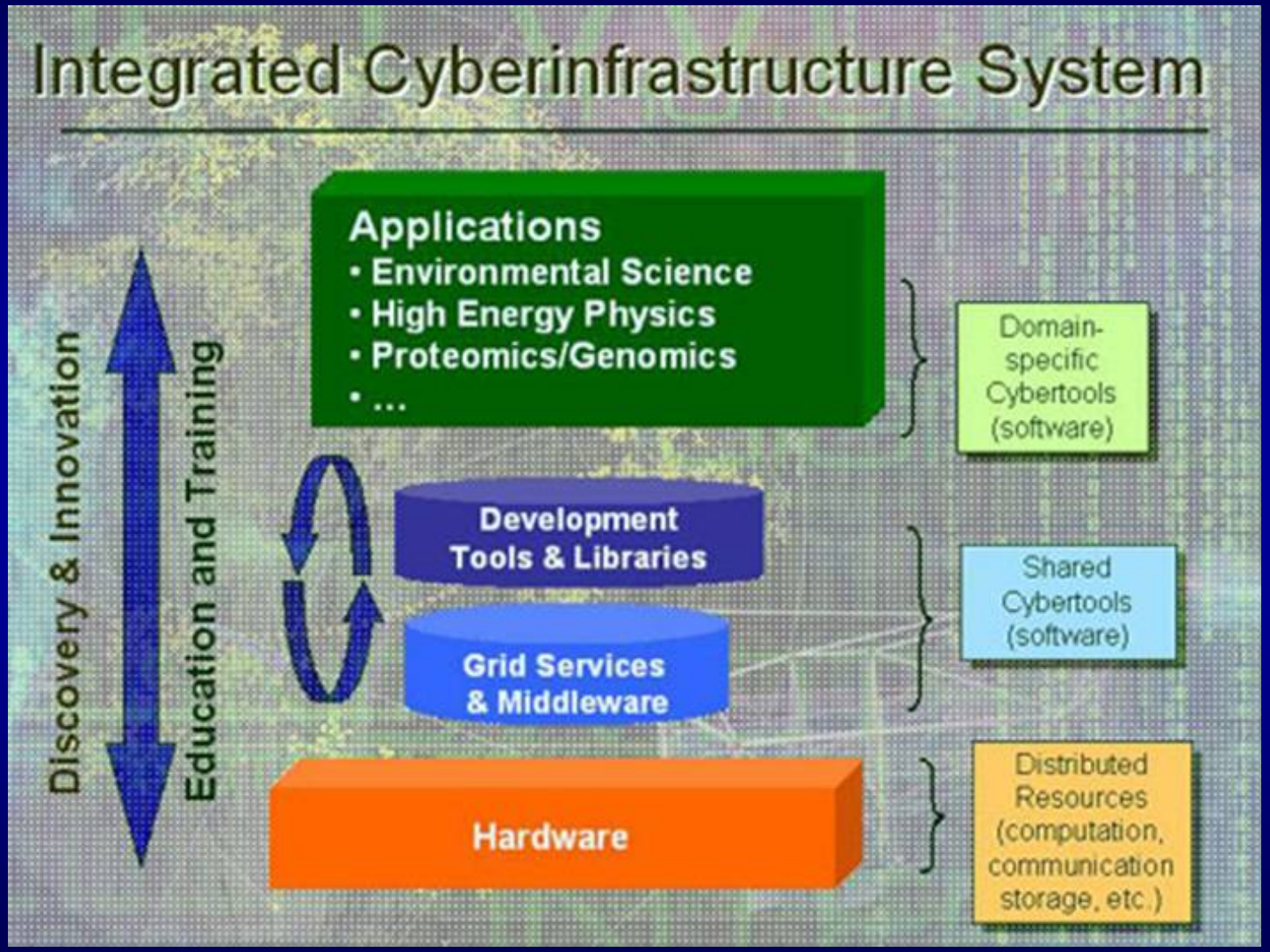
Academia in the 21st Century: Implementation

- **Support HPC infrastructure, research, and applications**
- **Deliver high-end cyberinfrastructure to enable efficient**
  - **Collection of data**
  - **Management/Organization of data**
  - **Distribution of data**
  - **Analysis of data**
  - **Visualization of data**
- **Create links between enabling technologists and disciplinary users**
- **Improve efficiency of knowledge-driven applications in myriad disciplines**
  - **New Techniques**
  - **New Algorithms**
  - **New Interactions (people & systems)**

Cyberinfrastructure

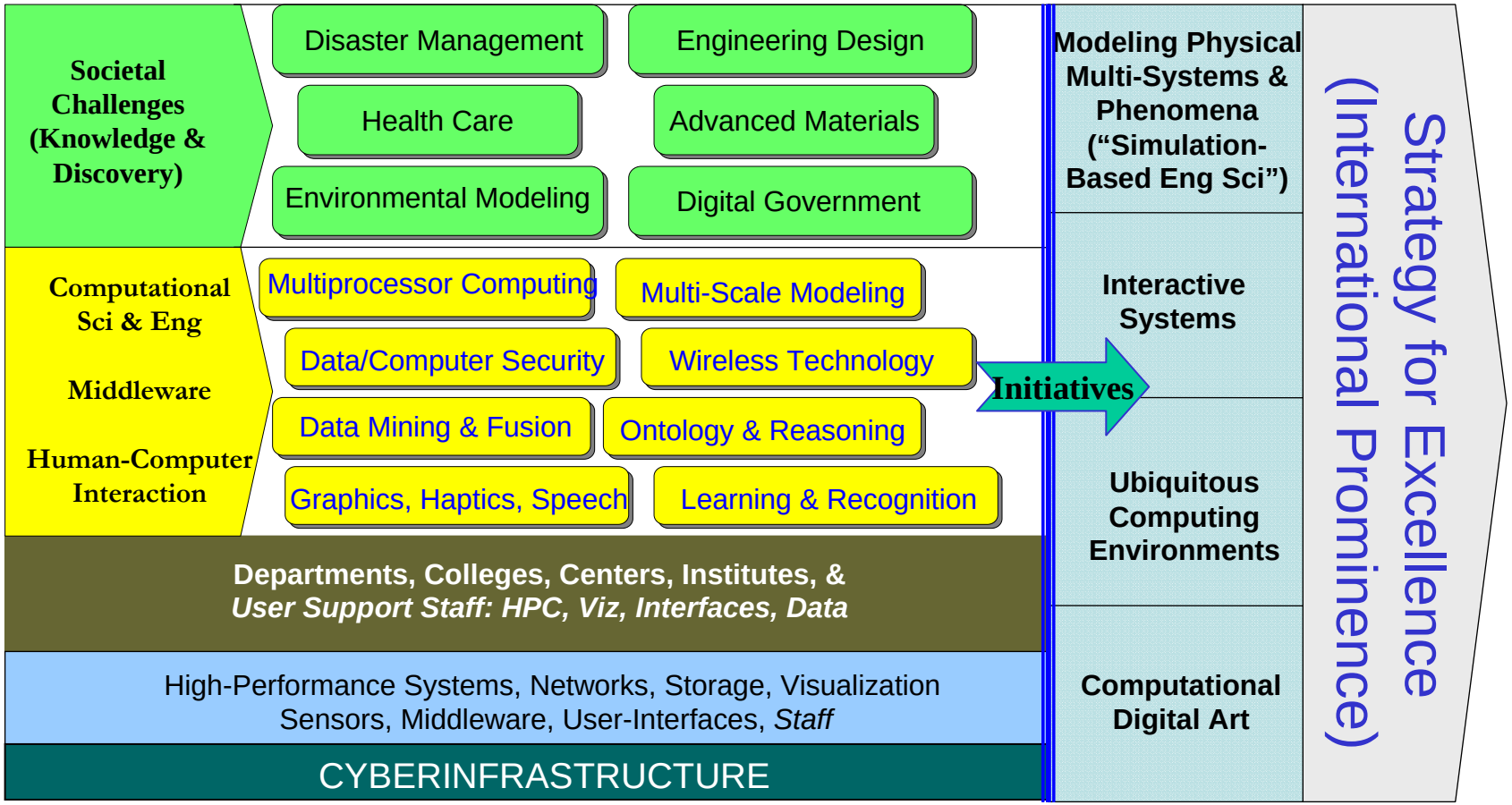
- **NSF: "comprehensive phenomenon that involves creation, dissemination, preservation, and application of knowledge"**
- **Generic: transparent and ubiquitous application of technologies central to contemporary engineering and science**
- **Foster & Kesselman: "a domain-independent computational infrastructure designed to support science."**
- **NSF Cyberinfrastructure (OCI)**
  - **HPC Hardware and Software**
  - **Data Collections**
  - **Science Gateways/Virtual Organizations**
  - **Support of Next Generation Observing Systems**

NSF Integrated Cyberinfrastructure



NSF Director Arden L. Bement: "leadership in cyberinfrastructure may determine America's continued ability to innovate – and thus our ability to compete successfully in the global arena."

Academic Computing Initiative: Inverted Umbrella (Sample)

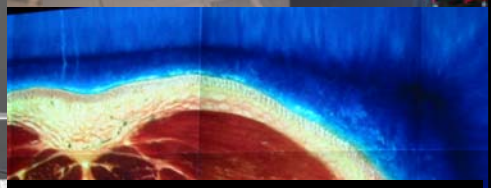


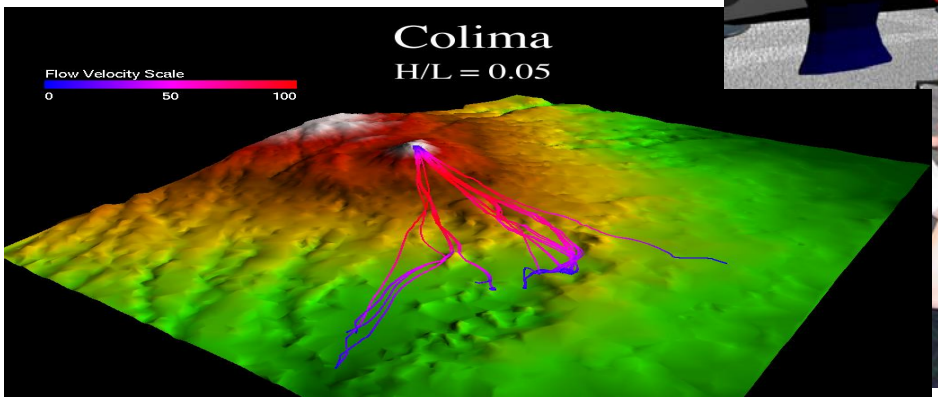
Academic HPC Initiative

- Must be Pervasive Across the Entire University
- Must Remove Barriers
- Groups Must Interact
  - Research Groups
  - Support Staff
  - Students
  - Departments
  - Colleges
- Issues
  - Tenure & Promotion
  - University vs Colleges vs Departments vs Faculty vs Centers/Institutes vs Degrees vs Courses
- Details are University Dependent

Center for Computational Research (CCR): 1998-2006

- **Founding Director**
- **Facts & Figures**
  - **Top Academic HPC Center in World**
  - **~25 TF of HPC**
  - **~600 TB of High-End Storage**
  - **Significant Visualization**
  - **Special-Purpose Systems**
  - **~30 FTEs Staff**
  - **140 Projects Annually**
- **EOT**



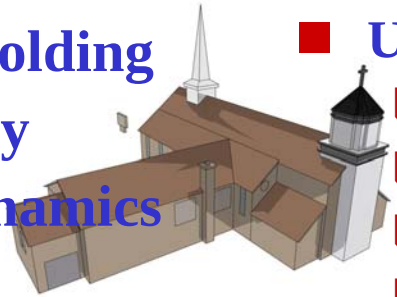


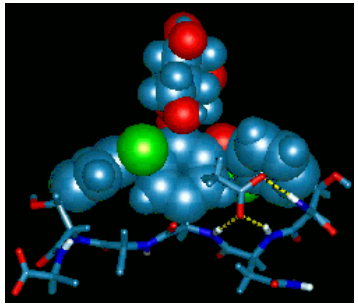
CCR Highlights (1998-2006)

- Provide HE-Comp
- Provide HE-Vis + AGN
- Special Purpose Systems
  - Bioinformatics
  - Data Warehouse / Mining
- Support Local/National Efforts – Industry + Acad
- Create jobs in WNY
- Certificate Program
- Workshops + Tours
  - Campus, Industry
  - High-School
- Urban Planning & Design
- MTV Videos
- Peace Bridge, Med Campus
- Olmsted Parks, Thruway
- NYS Agencies
- Elected Officials
- Magnet on Campus
- Significant Funds
- Numerous Awards
- Significant Publicity

CCR Research & Projects

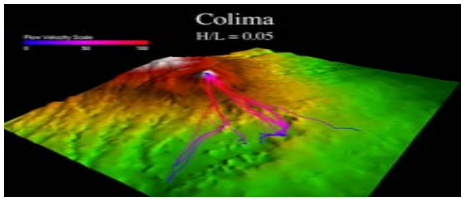
- Archaeology
- Bioinformatics/Protein Folding
- Computational Chemistry
- Computational Fluid Dynamics
- Data Mining/Database
- Earthquake Engineering
- Environ Modeling & Simulation
- Grid Computing
- Molecular Structure Determination
- Physics

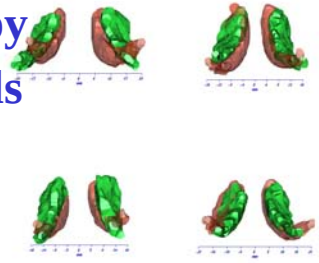




- Videos: MTV
- Urban Simulation and Viz
  - StreetScenes
  - I-90 Toll Barrier
  - Medical Campus
  - Peace Bridge

- Accident Reconstruction
- Scientific Viz
  - Dental
  - Surgery
  - MRI/CT Scan
  - Confocal Microscopy
  - Crystallization Wells
  - Collaboratories





CCR Funding (1998-2006)

- **CCR-Enabled to SUNY-Buffalo**
  - **$170M External Funds**
  - **$140M In-Kind Contributions**
- **CCR-Enabled to WNY**
  - **$200M External Funds**
- **Federal Appropriations**
- **New York State Appropriations**
- **Local WNY Foundations**
- **In-Kind Contributions (Dell, SGI, Sun, etc.)**
- **Grants (NSF, NIH, DOE, etc.)**
- **Projects with Local Companies**
- **Government Projects**
- **SUNY-Buffalo: staff and space**


Sen. Clinton


Sen. Schumer


Rep. Reynolds


Gov. Pataki


M. Capellas


Michael Dell

Real-Time Visualization

StreetScenes: Real-Time 3D Traffic Simulation

- Accurate local landmarks: Bridges, Street Signs, Business, Homes
- Can be viewed from driver's perspective
- Real-Time Navigation
- Works with
  - Corsim
  - Synchro
- Generate AVI & MOV
- Multiple Simultaneous
  - Traffic Loads
  - Simulation
  - Varying POV

Animation & Simulation

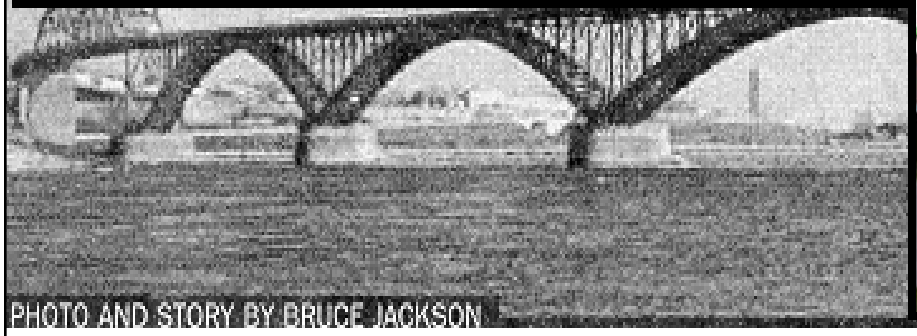
Rendered Scenes

Williamsville Toll Barrier Improvement Project

Initial Photo Match incorporating real and computer-generated components

Peace Bridge Visualization: Animation & Simulation

- **Proposed Options**
  - **Relocate US plaza**
  - **Build a 3-lane companion span**



MTV

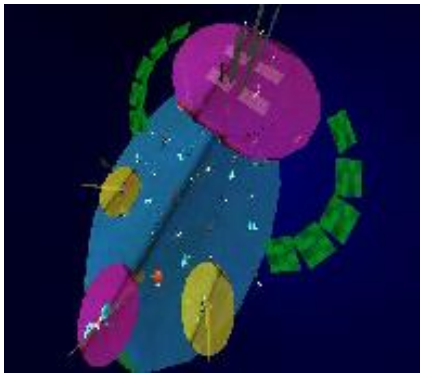
IBC Digital & CCR

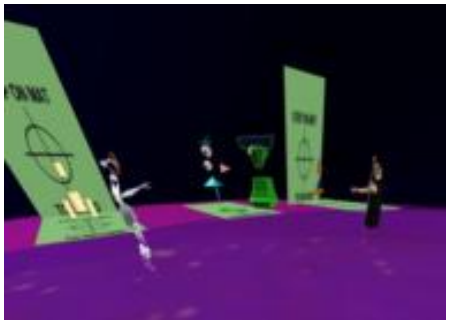
Song: I'm OK (I Promise)
Band: Chemical Romance
Gaming Environment: Death Jr.

Virtual Reality

Alive on the Grid: PAAPAB

- Networked art application for CAVE
  - Users from around the world
  - First performance 2001
- Dance-floor environment
  - Inhabited by life-size puppets
  - Dance with each other
  - Synchro
- Recording Booth
  - User enters booth
  - User dances
  - System records dance from tracking on head and hands
  - Dance mapped to Avatar

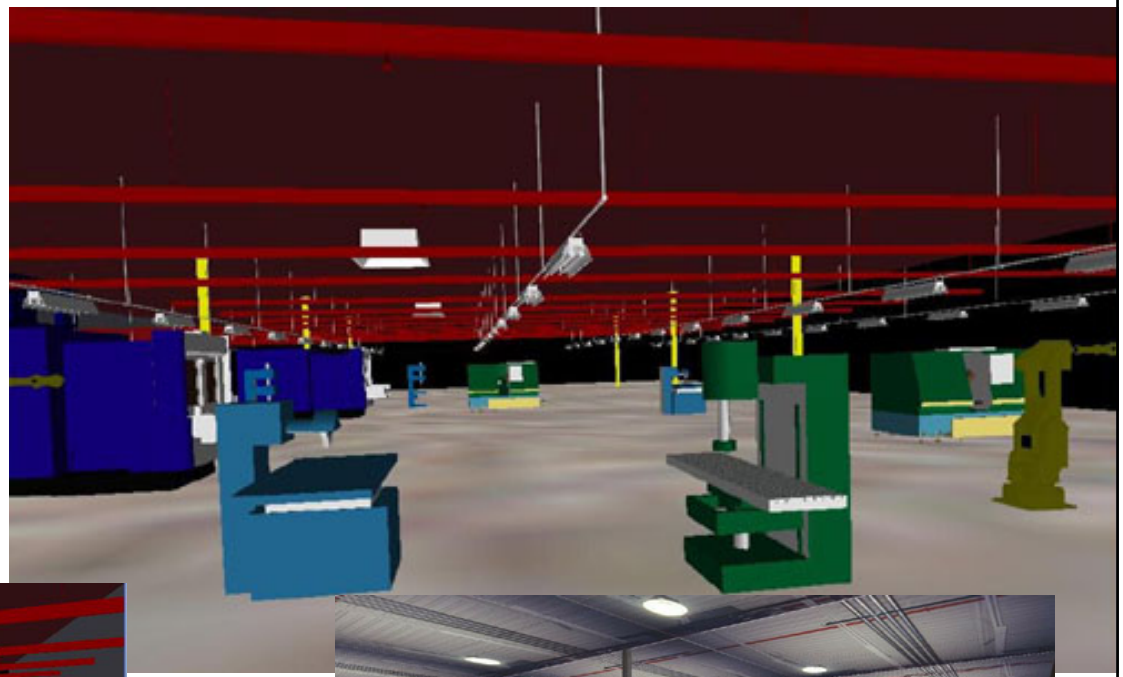


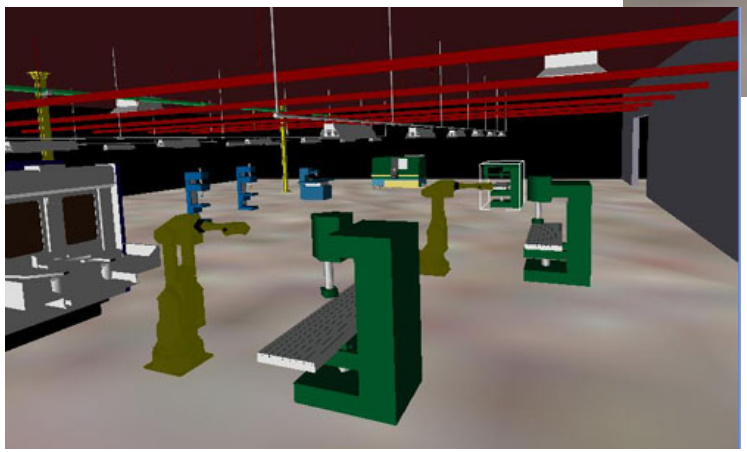


J. Anstey

VR-Fact!

- Interactive virtual factory
- Creates digital mock-up of factory
- Drag & place modular machines
- Mathematical algorithms for consistency checks





Kesh

Collaborative Visualization Environments

- Enable distributed collaboration via software developed at CCR
- Enable visualization and interaction with data across a geographically disparate network topology
- Integrate multiple data sources:
  - Scientific
  - Multimedia
- Research Topics
  - Distributed databases
  - OpenGL 3D programming
  - 3D Modeling
  - Character animation
  - User interaction
  - Virtual Reality

A. Ghadersohi, R. Miller, M. Green

Western New York

Some Facts

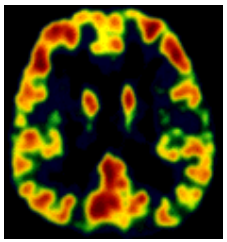
Buffalo, New York

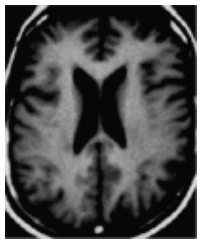
- The Queen City: 2nd Largest City in NYS
- City of Lights
  - First U.S. city to have electric street lights
  - Pan American Exposition (1901)
    - Pres. McKinley Shot

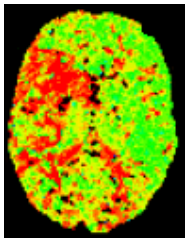
- Architecture
  - Frederick Law Olmsted
  - Frank Lloyd Wright
- Underground Railroad
  - Slaves escaped to freedom in Canada
- Four straight Super Bowl appearances
- Culinary Delights
  - Beef on Weck, Pizza, Fish Fries
  - (Buffalo) Wings: Anchor Bar, 1964
- Health Problems
  - Heart Disease/Stroke
  - Multiple Sclerosis

Recent Biomedical Advances (Buffalo, NY)

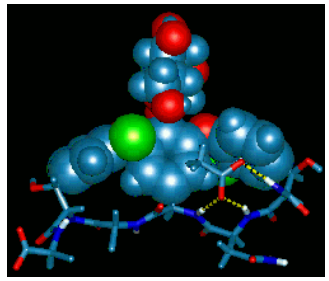
- PSA Test (screen for Prostate Cancer)
- Avonex: Interferon Treatment for Multiple Sclerosis
- Artificial Blood
- Nicorette Gum
- Fetal Viability Test
- Edible Vaccine for Hepatitis C
- Timed-Release Insulin Therapy
- Anti-Arrythmia Therapy
  - Tarantula venom







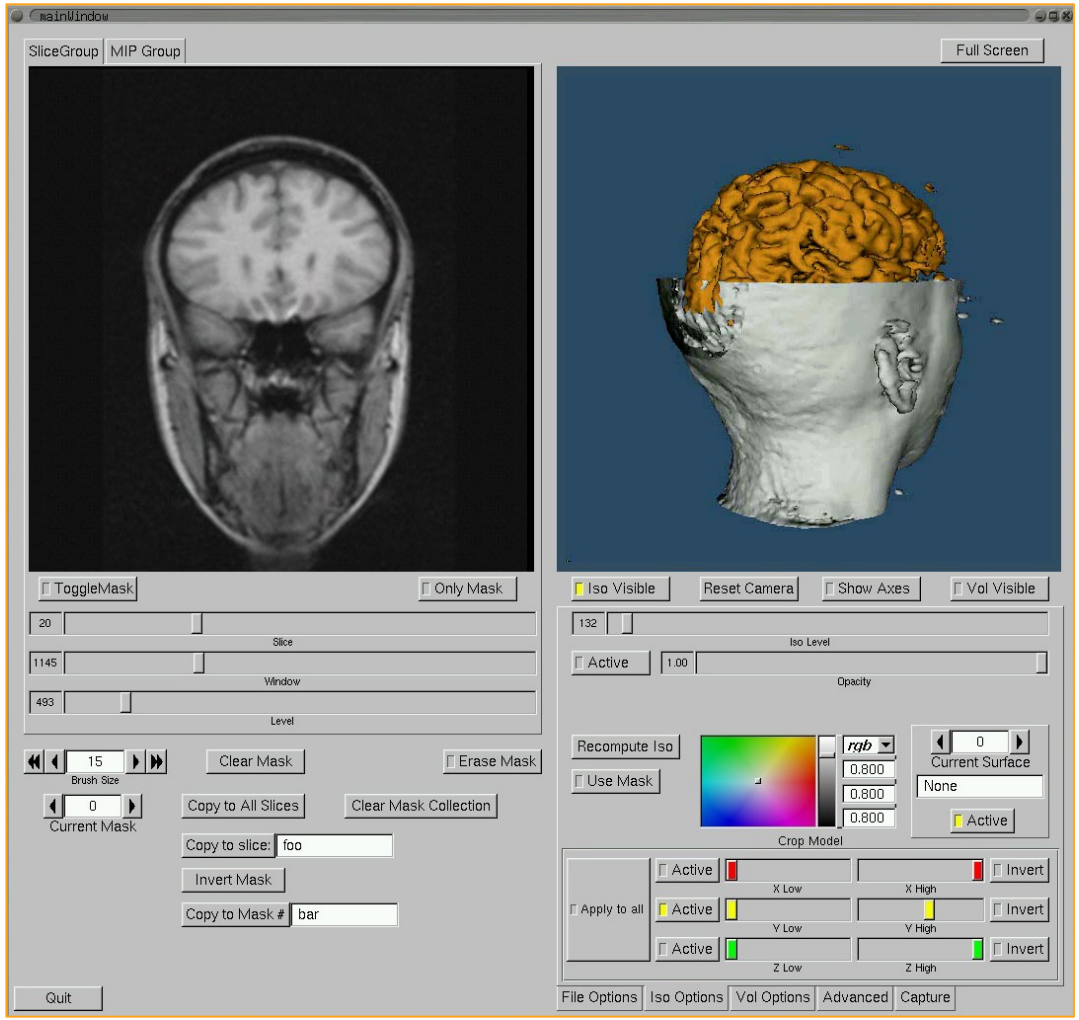
- Direct Methods Structure Determination
  - Listed on "Top Ten Algorithms of the 20th Century"
- Vancomycin
- Gramacidin A
- High Throughput Crystallization Method: Patented
- NIH National Genomics Center: Northeast Consortium
- Howard Hughes Medical Institute: Center for Genomics & Proteomics



Scientific Visualization

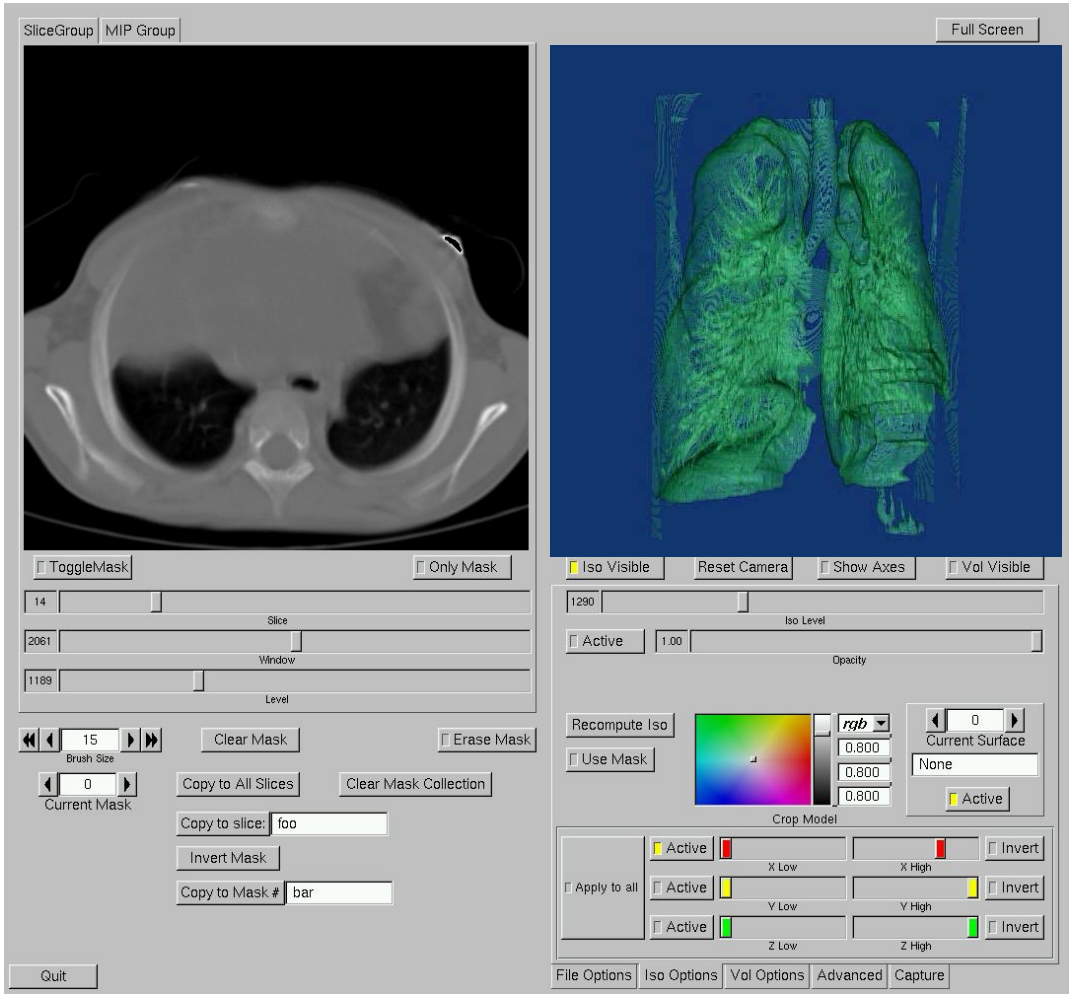
Multiple Sclerosis Project

- **Collaboration with Buffalo Neuroimaging Analysis Center (BNAC)**
  - **Developers of Avonex, drug of choice for treatment of MS**
- **MS Project examines patients and compares scans to healthy volunteers**



3D Medical Visualization

- Reads data output from a CT or MRI Scan
- Collaboration with Children's Hospital
- Visualize multiple surfaces and volumes
- Export images, movies or CAD file
- Pre-surgical planning
- Runs on a PC



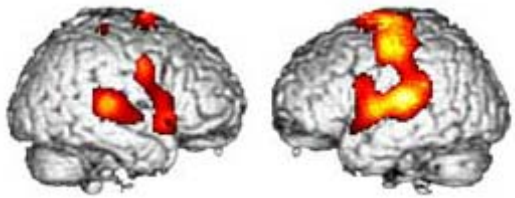
M. Innus

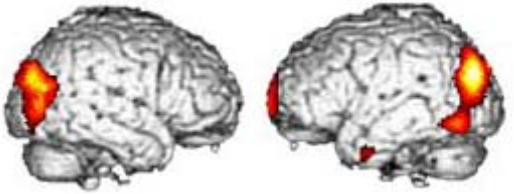
Mapping Brain Activity

Positron emission tomography (PET), shows sites activated and deactivated as subjects decide whether a sound is a target or not.

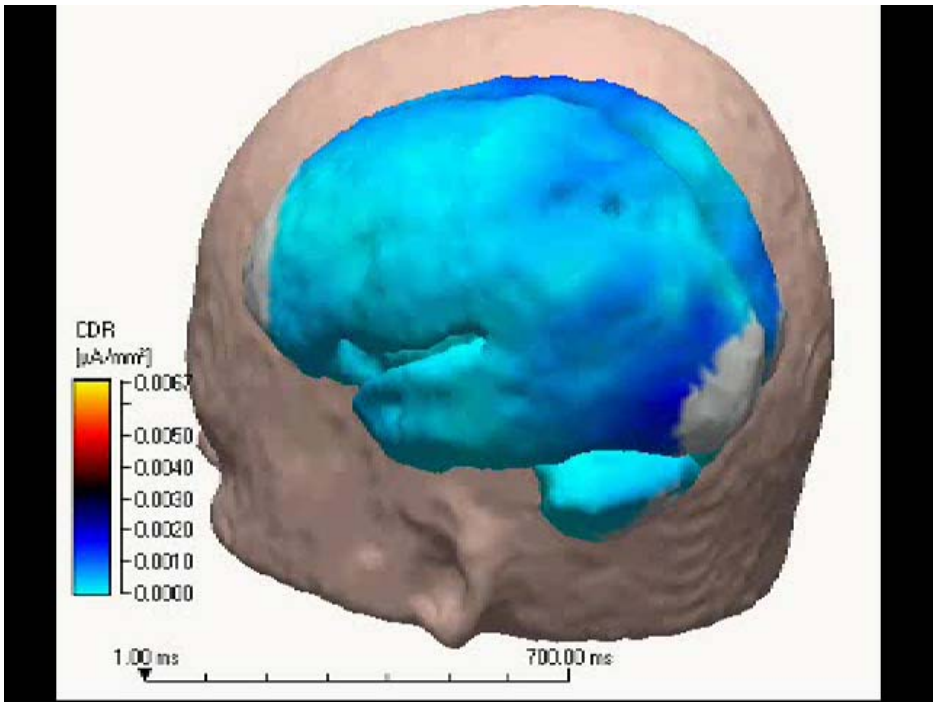
Sites Activated

Sites Deactivated





Current density maps of brain surface (1–700 ms after target) show dynamic pattern of brain activity during decision-making process.



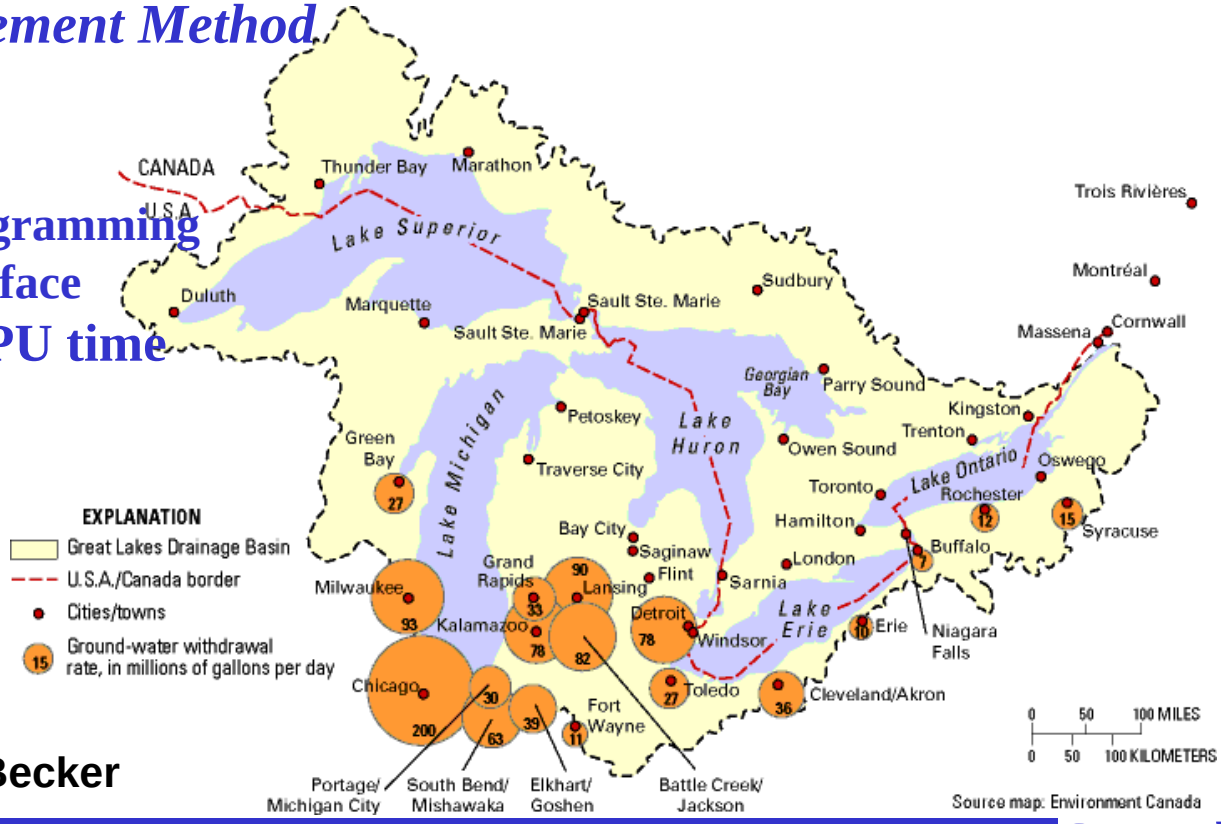
A. Lockwood

Science & Engineering

Small Subset of Projects

Groundwater Flow Modeling

- **Regional scale modeling of groundwater flow and contaminant transport (Great Lakes)**
- **Ability to include all hydrogeologic features as independent objects**
- **Based on *Analytic Element Method***
- **Key features:**
  - **Highly parallel**
  - **Object-oriented programming**
  - **Intelligent user interface**
- **Utilized 42 years of CPU time on CCR computers in 1 calendar year**

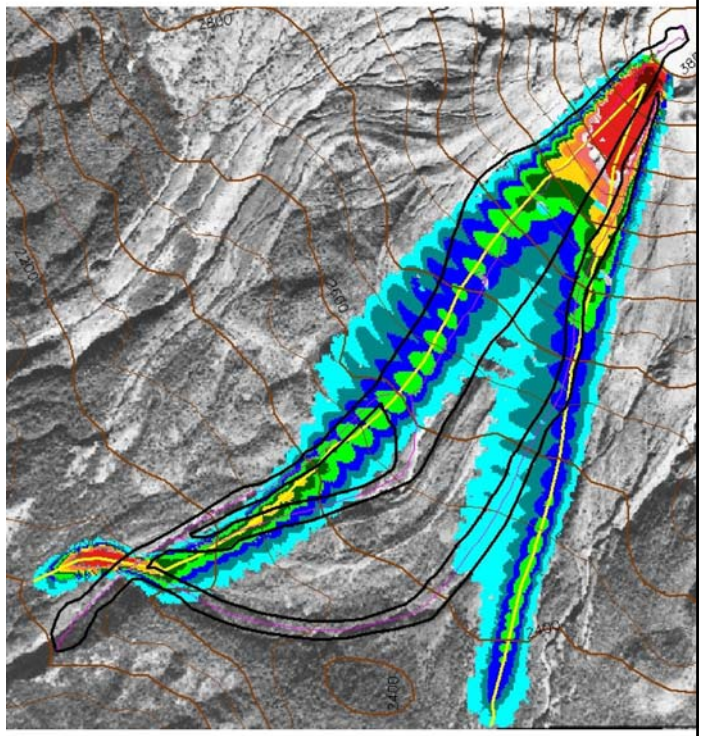


A. Rabideau, I. Jankovic, M. Becker

Avalanches, Volcanic and Mud Flows

Geology, Engineering

- **Modeling of Volcanic Flows, Mud flows (flash flooding), and avalanches**
- **Integrate information from several sources**
  - **Simulation results**
  - **Remote sensing**
  - **GIS data**
- **Present information to decision makers using custom visualization tools local & remote**
- **GRID enabled for remote access**
- **Key Features**
  - **Parallel Adaptive Computation**
  - **Integrated with GIS System for flows on natural terrain**



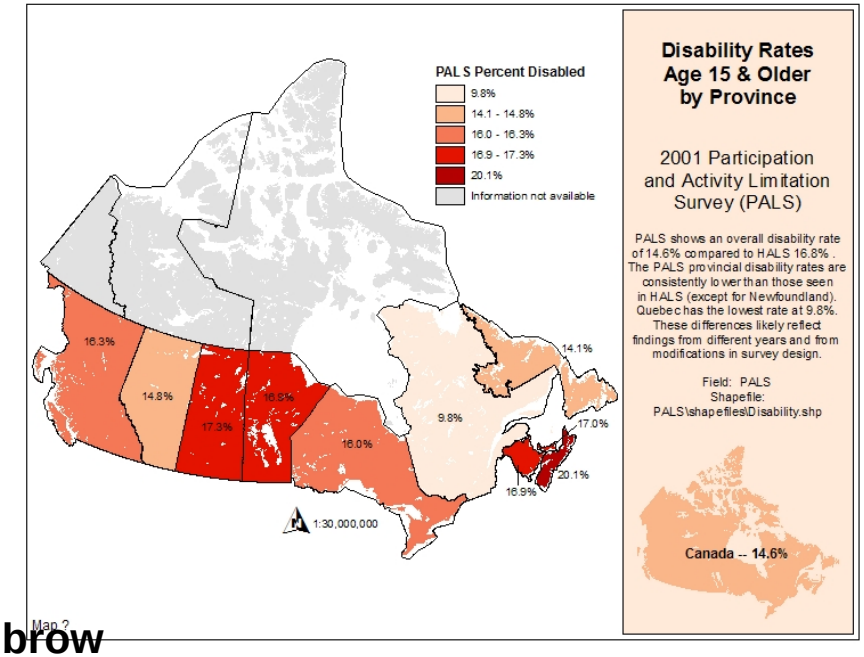
Flow models of Colima volcano
In Mexico – courtesy Rupp et. al.'06

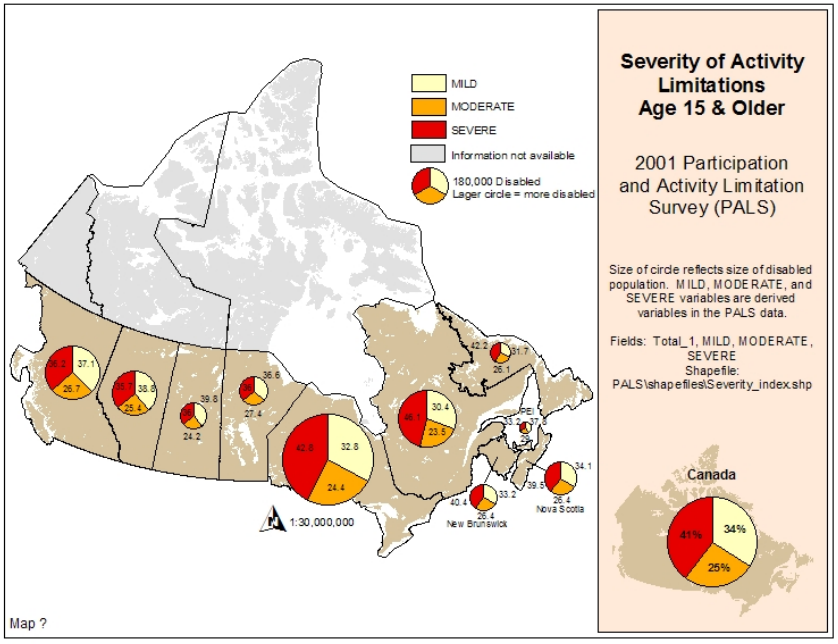
A. Patra, B. Pitman, M. Sheridan, M. Jones

Anthropology

Literacy & Disability in Canada

- Exploring the relationship between illiteracy & disability across the Canadian landscape
- Social Systems GIS Lab in the Dept. of Anthropology is working with researchers from York University & the Canadian Abilities Foundation.
- Sponsored by The Adult Learning & Literacy Directorate of the Ministry of Human Resources & Social Development Canada.

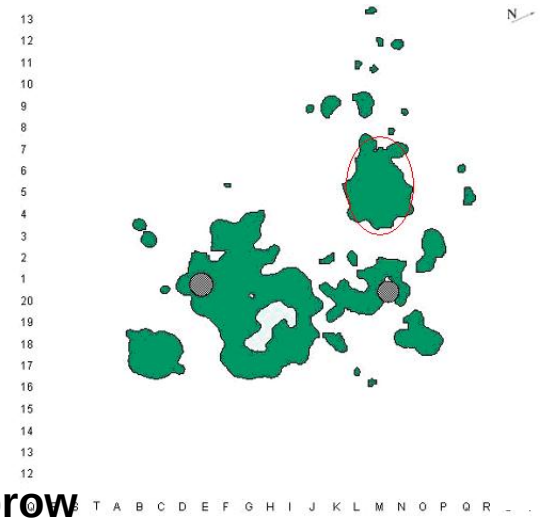


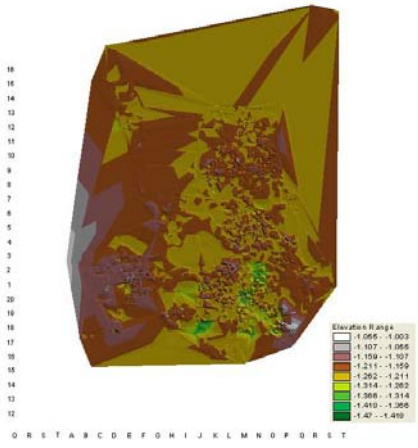


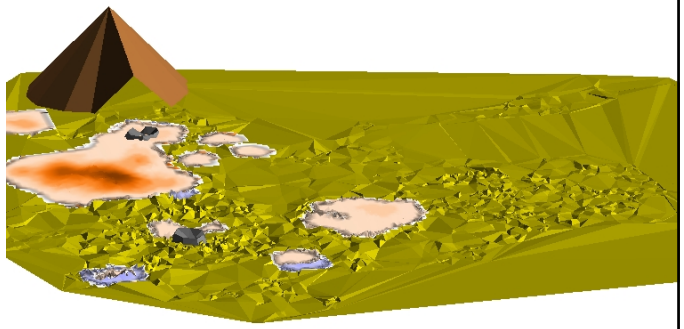
E. Zubrow

Verberie Paleolithic Site in France

- **Intrasite spatial analysis and 3D modeling of the a Late Upper Paleolithic archaeological site in the Paris Basin of France**
- **Social Systems GIS Lab in the Dept. of Anthropology is working with researchers from the CNRS in Paris**
- **Sponsored by the National Science Foundation**



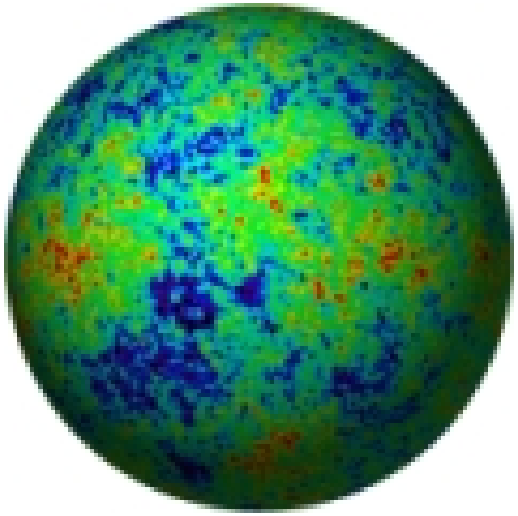


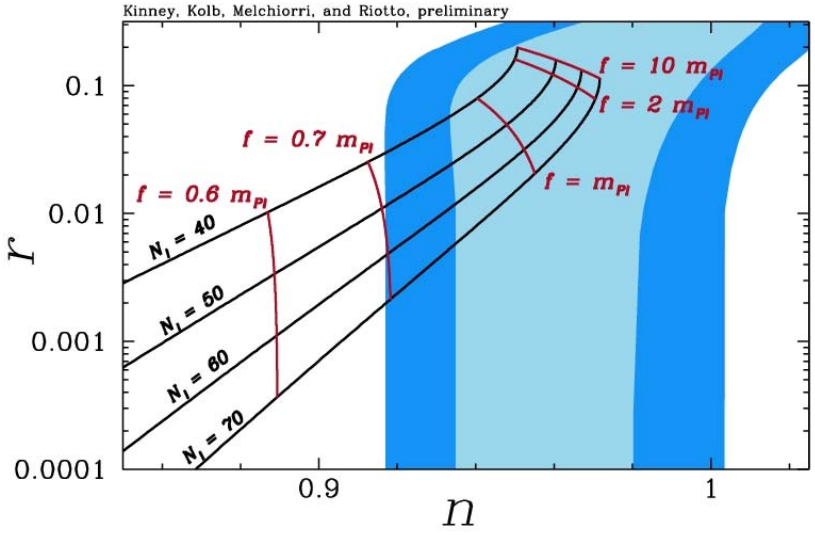


E. Zubrow

Cosmological Parameter Estimation

- **Wealth of new precision cosmological data**
- **WMAP Cosmic Microwave Background Measurement**
- **Sloan Digital Sky Survey: 3-D map of a million galaxies**
- **Interpret implications of data for models of the first trillionth of a second of the universe: *inflation***
- ***Monte Carlo Markov Chain data analysis: stochastic exploration of many-dimensional parameter spaces***



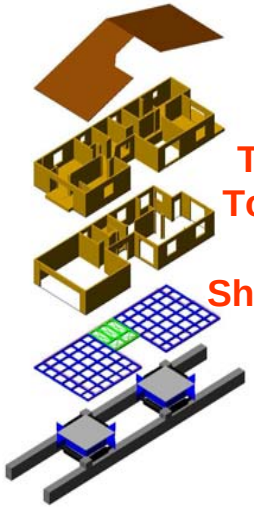


W. Kinney

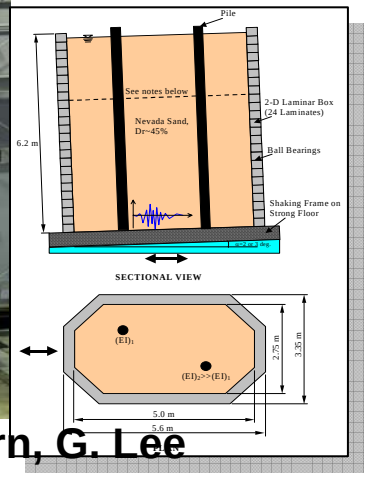
UB's Structural Engineering and Earthquake Simulation Laboratory (SEESL)

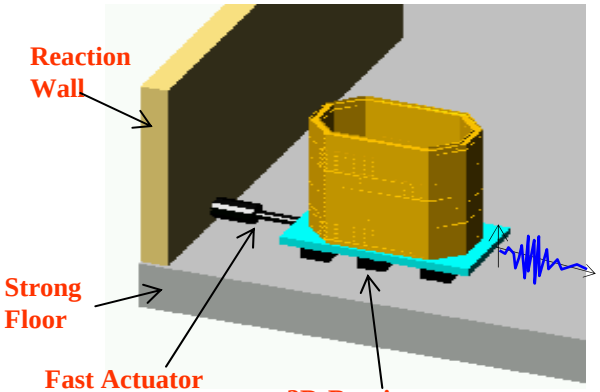
Structural Engineering

NEESWood: Development of a Performance-Based Seismic Design for Woodframe Construction:



Two-story Townhouse on Twin Shake Tables



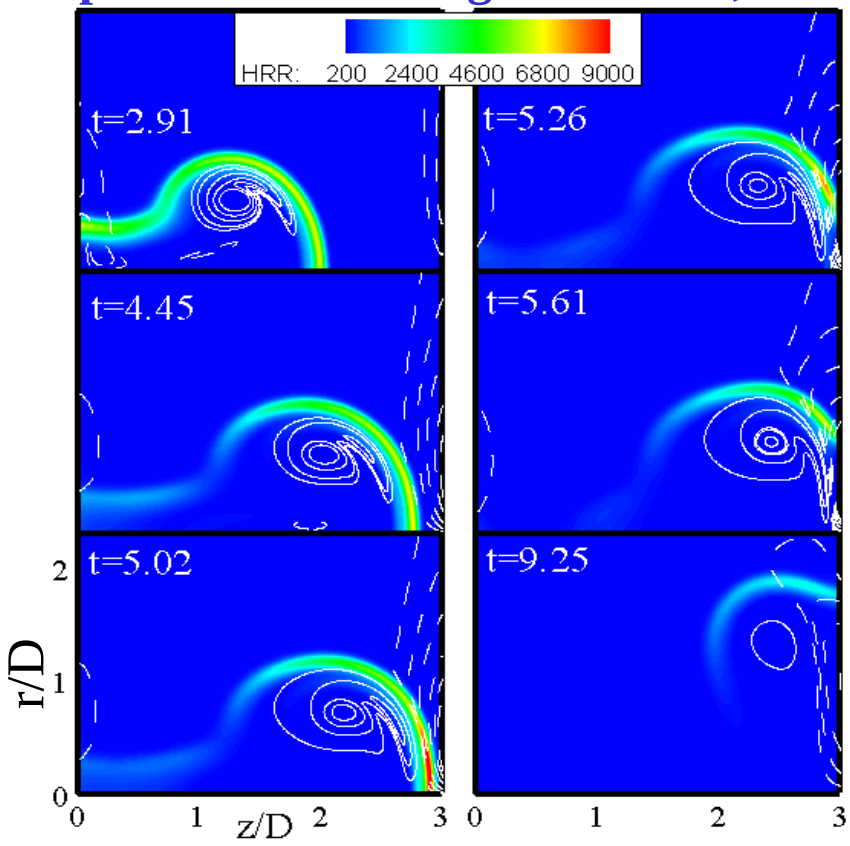


2-D Geotechnical Laminar Box Tests of Pile Foundations Subjected to Soil Liquefaction

M. Bruneau, A. Reinhorn, G. Lee

Understanding Combustion

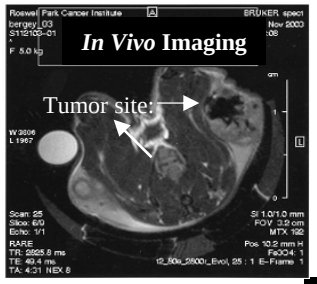
- Flame-wall interaction modeling for a non-premixed flame propelled by a vortex ring.
- In this figure different time instants are shown during the interaction. White line contours and color contours represent vortex ring and flame, respectively.
- Key Features:
  - Modeling of Detailed GRI3. Mechanism for Methane Combustion
  - Parallel algorithm using mpi
  - 85-90% Parallel efficiency for up to 64 processors
- FWI study is important to determine
  - Engine Design
  - Quenching Distances
  - Flame Structure
  - Unburned hydrocarbon
  - Maximum Wall heat fluxes



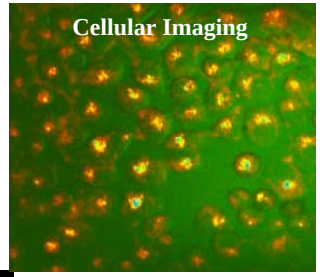
Institute for Lasers, Photonics, and Biophotonics

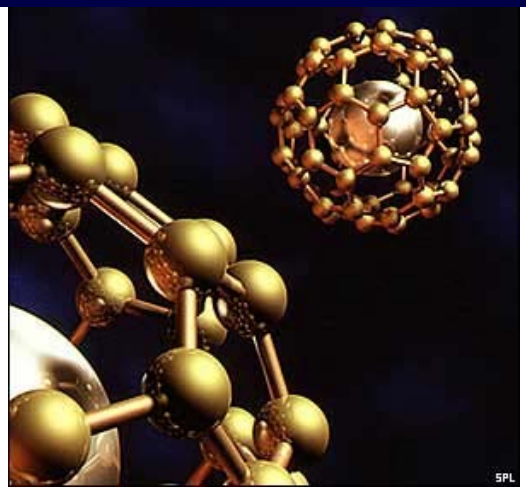
Nanomedicine Program

World class Research Program Melding Nanotechnology with Biomedical Sciences



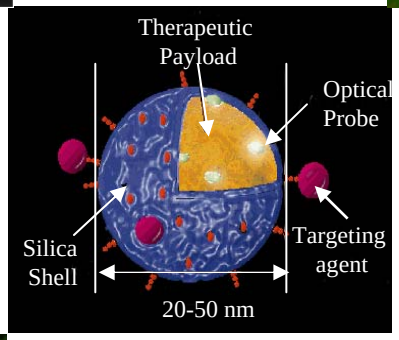
Multi-Modal Imaging



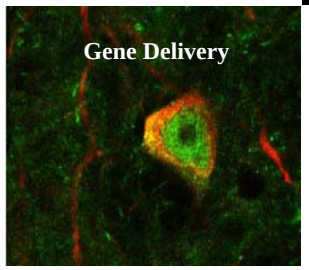


Building from the Bottom Up

BioCompatibility/ Distribution



In Vivo Sensing



Targeted Therapy

State of the Art Molecular Imaging and Nanocharacterization Facilities

- Multiphoton Laser Scanning System
- Confocal Imaging including FRET, FLIM & FRAP analysis
- Coherent Anti-Stokes Raman Imaging
- Optical Trapping/Dissection
- Advanced Laser Systems

P. Prasad

www.biophotonics.buffalo.edu

"Leading the Way to Technology through Innovation"

Miller's Cyberinfrastructure Laboratory (MCIL)

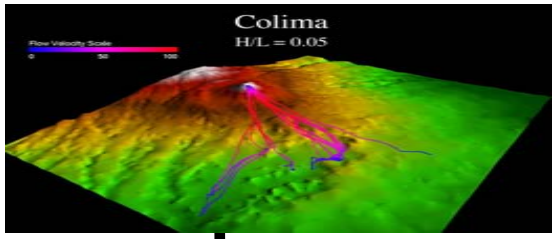
MCIL Overview

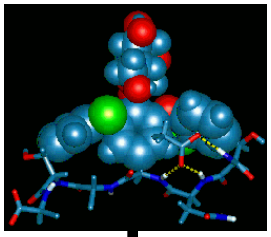
- **Working Philosophy**
  - **CI sits at core of modern simulation & modeling**
  - **CI allows for new methods of investigation to address previously unsolvable problems**
- **Focus of MCIL is on development of *algorithms, portals, interfaces, middleware***
- **Goal of MCIL is to free end-users to do disciplinary work**
- **Funding (2001-pres)**
  - **NSF: ITR, CRI, MRI**
  - **NYS appropriations**
  - **Federal appropriations**

MCIL Equipment (50+ TF)

- **Experimental Equipment (57.5 TF; 22TB; 156 Traditional Cores; 15 nVidia Tesla GPGPUs)**
  - **Clusters**
    - **Head Nodes: Dell 1950 (Intel)**
    - **Workers: Intel 8×2 ×4, Intel 8×1 ×2, & AMD 8×2×2**
    - **13 nVidia S1070s & 2 nVidia S870s**
  - **Virtual Memory Machines (2 × Intel 4×4)**
  - **Dell GigE Managed Switches**
  - **InfiniBand**
  - **22 TB Dell Storage (2)**
  - **Condor Flock (35 Intel/AMD)**
- **Production Equipment**
  - **Dell Workstations; Dell 15 TB Storage**
  - **Access to CCR equipment (13TF Dell/Intel clusters)**

Grid Computing Tutorial



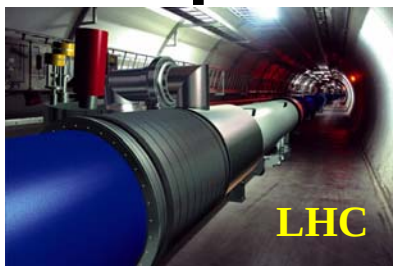


Data Acquisition

Advanced Visualization

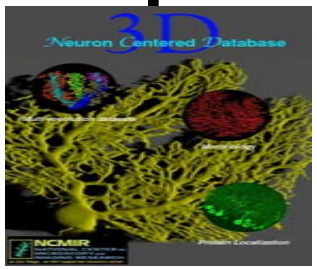
Analysis

Imaging Instruments



LHC

Computational Resources



Large-Scale Databases

- Coordinate Computing Resources, People, Instruments in Dynamic Geographically-Distributed Multi-Institutional Environment
- Treat Computing Resources like Commodities
  - Compute cycles, data storage, instruments
  - Human communication environments
- No Central Control; No Trust

Major Grid Initiatives

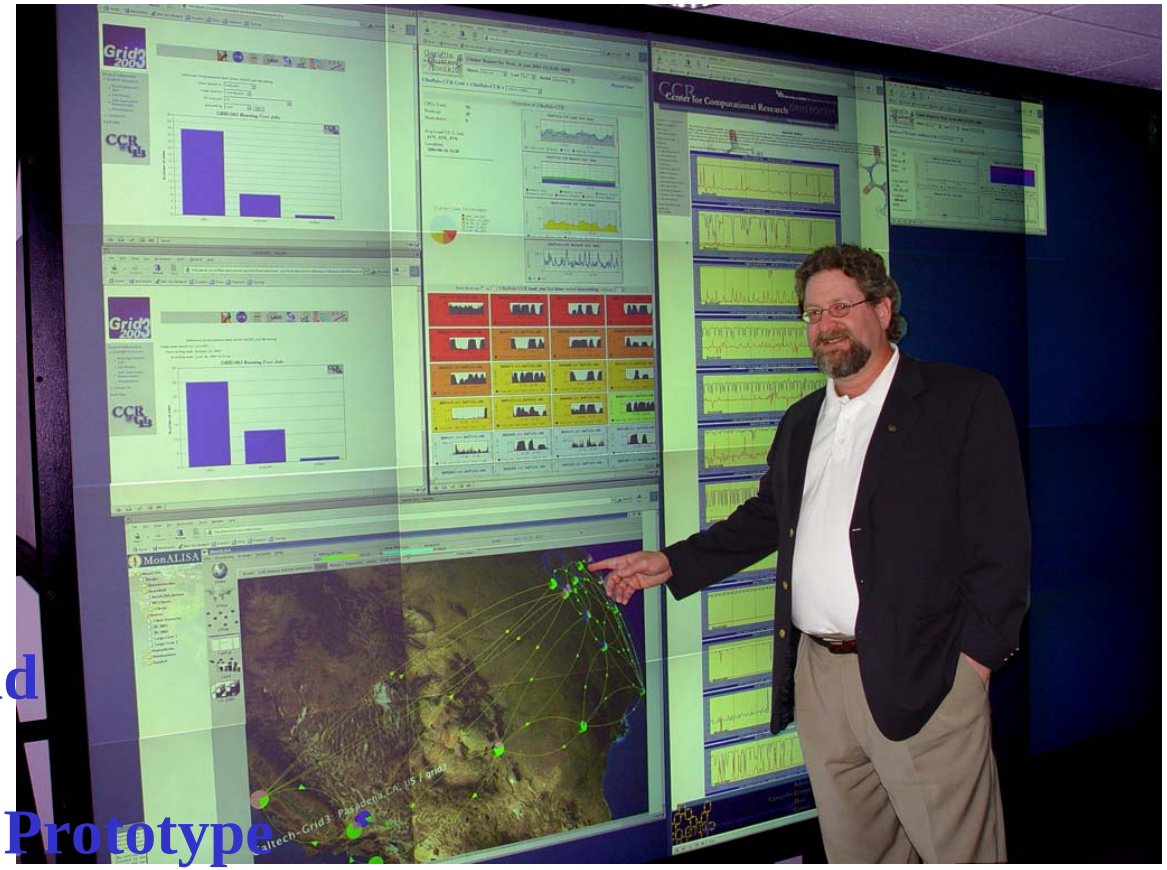
- TeraGrid (NSF)
  - Integrates High-End Resources
  - High-Performance (Dedicated) Networks
  - 11 Sites; 1.2PF, 4PB Disk, 30PB Tape
  - 100+ Databases Available
- OSG (DOE, NSF)
  - High-Throughput Distributed Facility
  - Open & Heterogeneous
  - Biology, Computer Science, Astrophysics, LHC
  - 57 Compute Sites; 11 Storage Sites;
  - 10K CPUS; 6PB
- EGEE: Enabling Grids for E-SciencE (European Commision)
  - Initial Focus on CERN (5PB of Data/Year)
    - High-Energy Physics and Life Sciences
  - Expanded Focus Includes Virtually All Scientific Domains
  - 200 Institutions; 40 Countries
  - 20K+ CPUs; 5PB; 25,000 jobs per day!

Evolution of MCIL Lab Projects

- **Buffalo-Based Grid**
  - **Experimental Grid: Globus & Condor**
  - **Integrate Data & Compute, Monitor, Portal, Node Swapping, Predictive Scheduling/Resource Management**
  - **GRASE VO: Structural Biology, Groundwater Modeling, Earthquake Eng, Comp Chemistry, GIS/BioHazards**
  - **Buffalo, Buffalo State, Canisius, Hauptman-Woodward**
- **Western New York Grid**
  - **Heterogeneous System: Hardware, Networking, Utilization**
  - **Buffalo, Geneseo, Hauptman-Woodward, Niagara**
- **New York State Grid**
  - **Extension to Hardened Production-Level System State-Wide**
  - **Albany, Binghamton, Buffalo, Geneseo, Canisius, Columbia, HWI, Niagara, [Cornell, NYU, RIT, Rochester, Syracuse, Marist], {Stony Brook, RPI, Iona}**

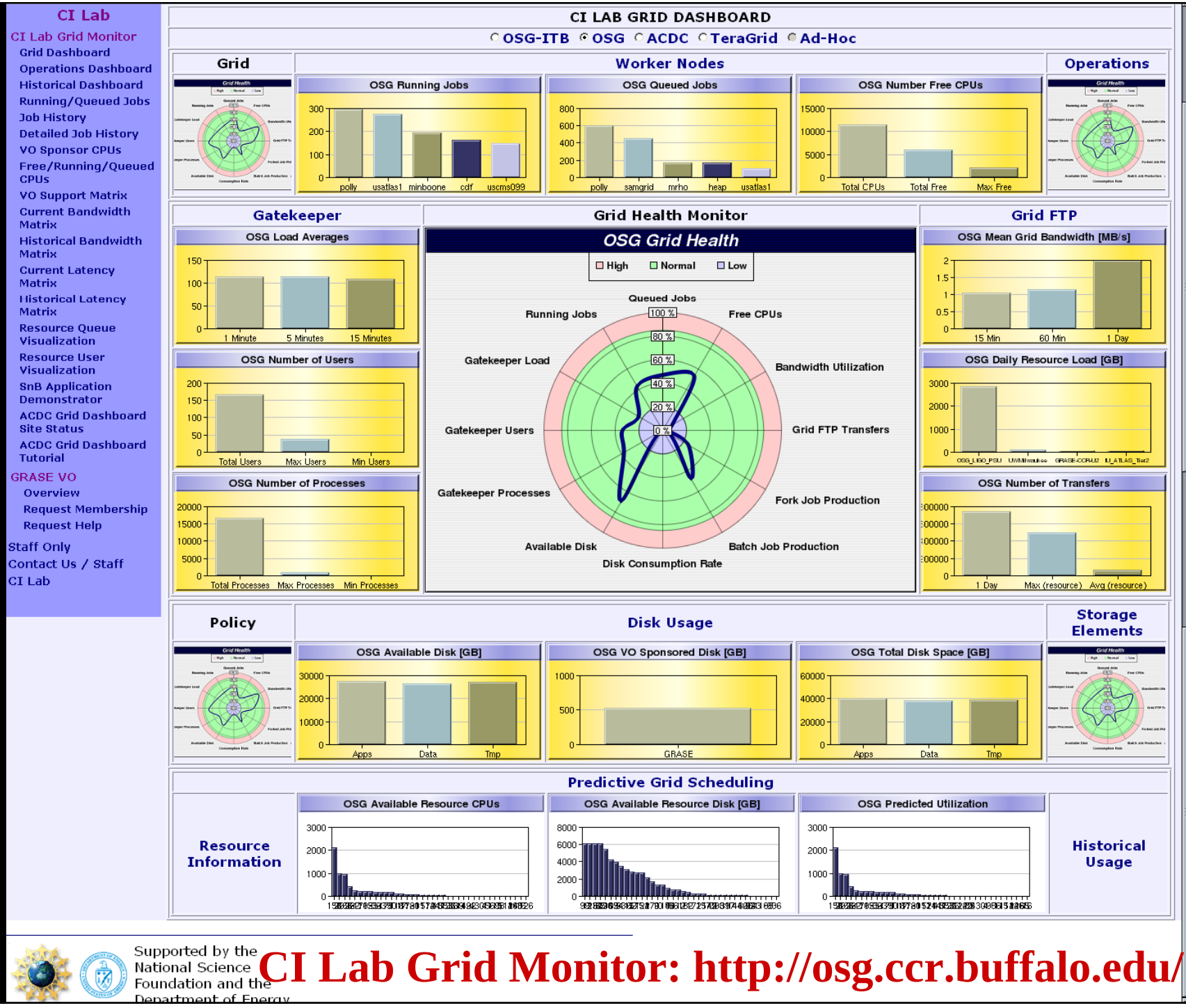
MCIL Lab Collaborations

- High-Performance Networking Infrastructure
- Grid3+ Collaboration
- iVDGL Member
  - Only External Member
- Open Science Grid
  - GRASE VO
- NYS CI Initiative
  - Executive Director
  - Various WGs
- Grid-Lite: Campus Grid
  - HP Labs Collaboration
- Innovative Laboratory Prototype
  - Dell Collaboration



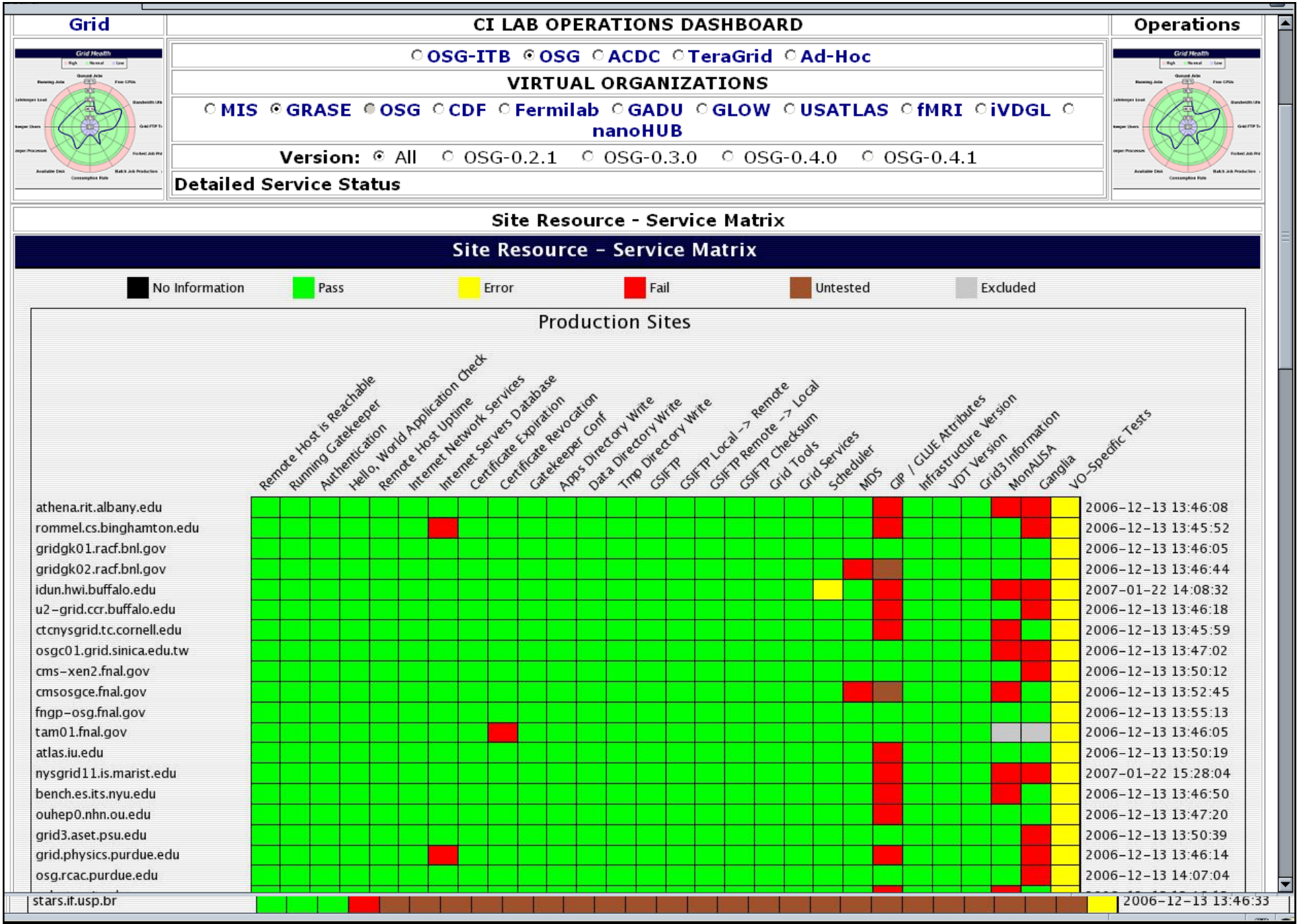
MCIL Lab Projects

- **Lightweight Grid Monitor (Dashboard)**
- **Predictive Scheduler**
  - **Define quality of service estimates of job completion, by better estimating job runtimes by profiling users.**
- **Dynamic Resource Allocation**
  - **Develop automated procedures for dynamic computational resource allocation.**
- **High-Performance Grid-Enabled Data Repositories**
  - **Develop automated procedures for dynamic data repository creation and deletion.**
- **Integrated Data Grid**
  - **Automated Data File Migration based on profiling users.**
- **Grid Portal**



Supported by the National Science Foundation and the Department of Energy

CI Lab Grid Monitor: http://osg.ccr.buffalo.edu/

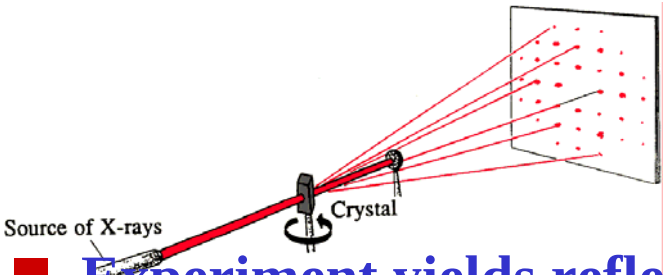


CI Lab Operations Dashboard

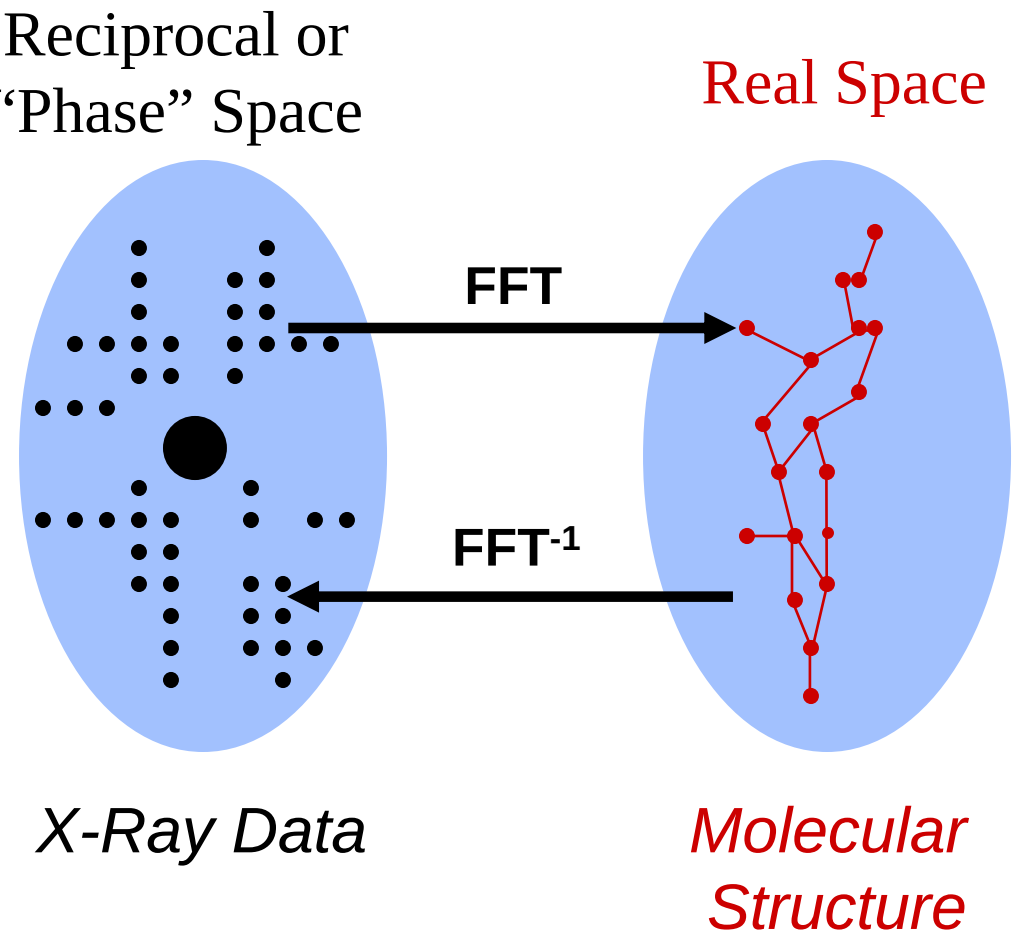
Grid-Enabling Application Templates (GATs)

- **Structural Biology**
  - ***SnB* and *BnP* for Molecular Structure Determination/Phasing**
- **Groundwater Modeling**
  - ***Ostrich*: Optimization and Parameter Estimation Tool**
  - ***POMGL*: Princeton Ocean Model Great Lakes for Hydrodynamic Circulation**
  - ***Split*: Modeling Groundwater Flow with Analytic Element Method**
- **Earthquake Engineering**
  - ***EADR*: Evolutionary Aseismic Design and Retrofit; Passive Energy Dissipation System for Designing Earthquake Resilient Structures**
- **Computational Chemistry**
  - ***Q-Chem*: Quantum Chemistry Package**
- **Geographic Information Systems & BioHazards**
  - ***Titan*: Computational Modeling of Hazardous Geophysical Mass Flows**

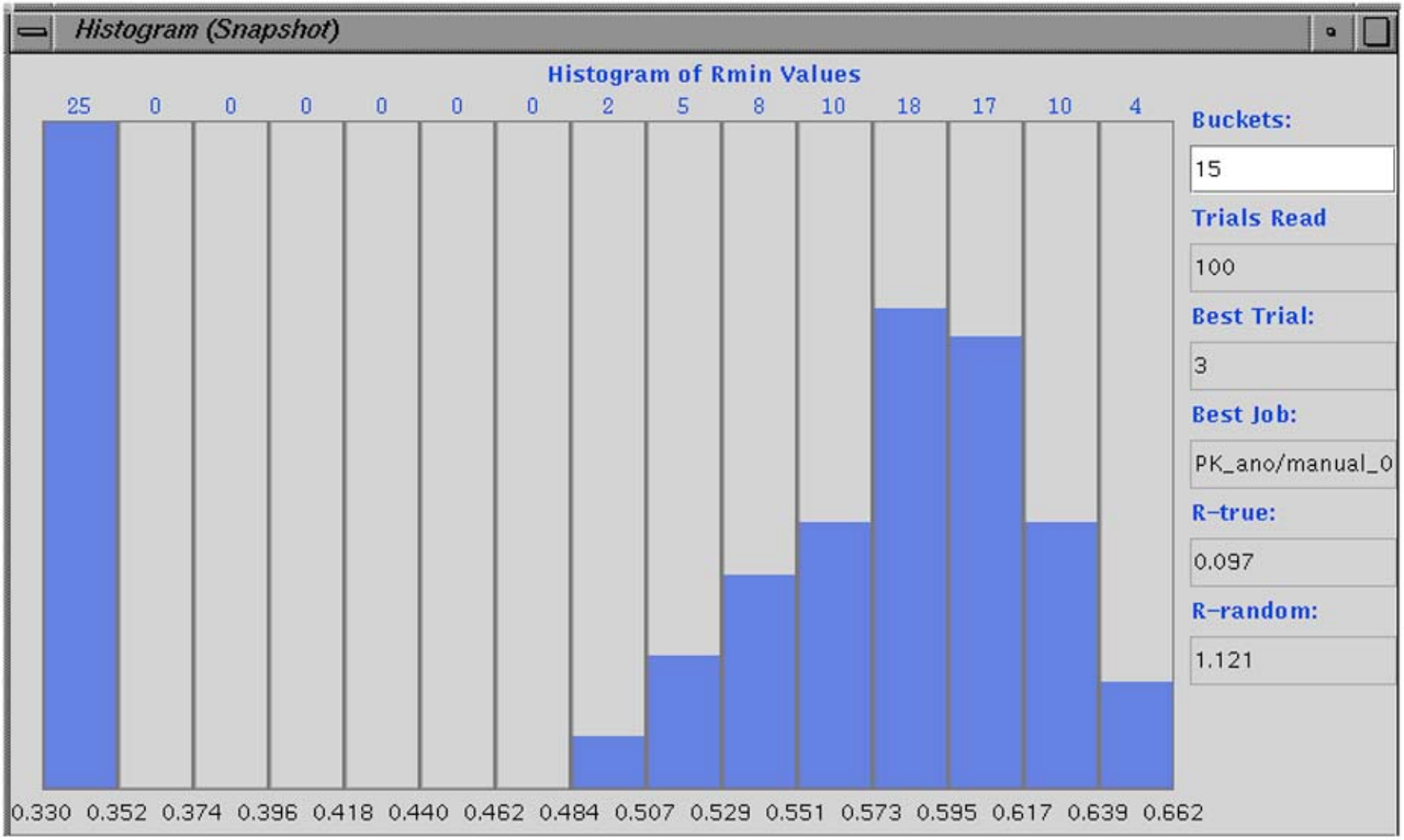
X-Ray Data & Corresponding Molecular Structure



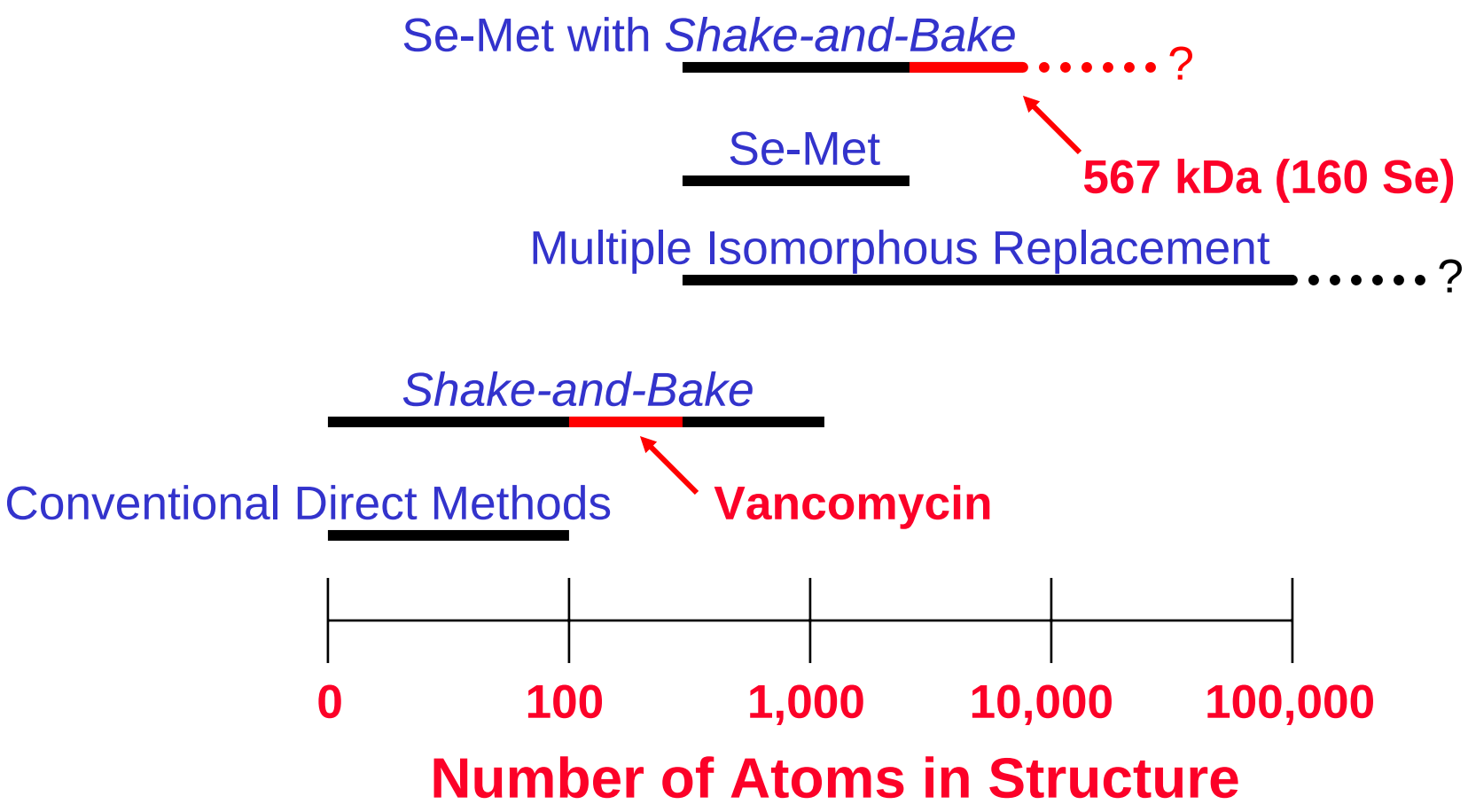
- **Experiment yields reflections and associated intensities.**
- **Underlying atomic arrangement is related to the reflections by a 3-D Fourier transform.**
- ***Phase angles are lost in experiment.***
- ***Phase Problem*: Determine the set of phases corresponding to the reflections.**



Ph8755: *SnB* Histogram



Phasing and Structure Size

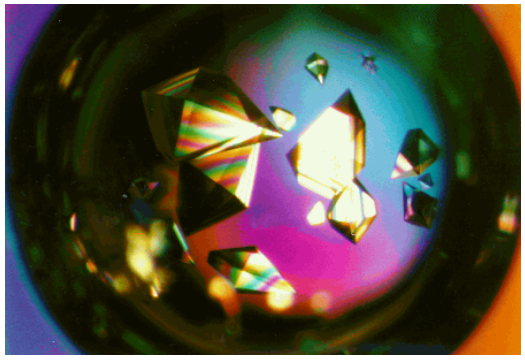


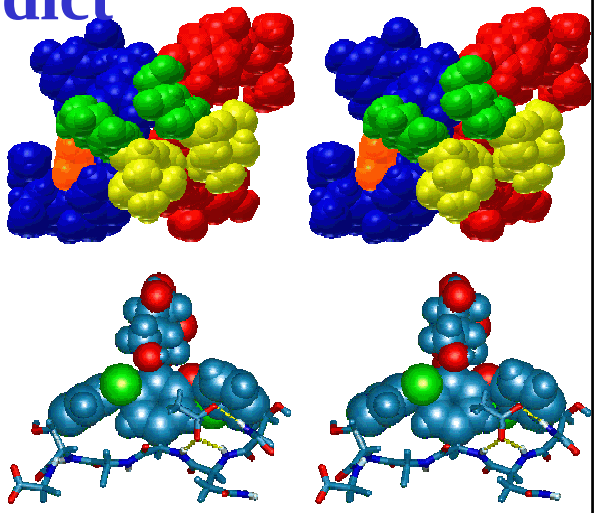
Shake-and-Bake Applications: Structure Size and Data Resolution

- **Basic Data (Full Structure)**
  - ~750 unique non-H atoms (equal)
  - ~2000 such atoms including 8 Fe's
  - 1.1-1.2Å data (equal atom)
  - 1.3-1.4Å data (unequal atoms, sometimes)
- **SAS or SIR Difference Data (substructures)**
  - 160 Se (567 kDa / ASU)
  - 3-4Å data
  - 5Å truncated data have also worked

Vancomycin

- **Interferes with formation of bacterial walls**
- ***Last line of defense* against deadly**
  - **streptococcal and staphylococcal bacteria strains**
- **Vancomycin resistance exists (Michigan)**
- **Can't just synthesize variants and test**
- **Need structure-based approach to predict**
- **Solution with *SnB* (*Shake-and-Bake*)**
  - **Pat Loll**
  - **George Sheldrick**





Grid Enabled *SnB*

- **Required Layered Grid Services**
  - **Grid-enabled Application Layer**
    - ***Shake – and – Bake* application**
    - **Apache web server**
    - **MySQL database**
  - **High-level Service Layer**
    - **Globus, NWS, PHP, Fortran, and C**
  - **Core Service Layer**
    - **Metacomputing Directory Service, Globus Security Interface, GRAM, GASS**
  - **Local Service Layer**
    - **Condor, MPI, PBS, Maui, WINNT, IRIX, Solaris, RedHat Linux**

https://grid.ccr.buffalo.edu/

Mail Home Netscape

New Tab | CCR Grid Computing Services:

Cyberinfrastructure Laboratory

Grid Portal

Dr. Russ Miller
UB Distinguished Professor of Computer Science & Engineering

Welcome to the Cyberinfrastructure Laboratory Grid Portal

The **Cyberinfrastructure Laboratory**, in conjunction with the **Center for Computational Research**, has created an integrated Data and Computational Grid. This site is devoted to a Grid Portal that provides access to applications that can be run on a variety of grids. A related site contains a **Grid Monitoring System** designed by the Cyberinfrastructure Laboratory.

Applications may be run on the Cyberinfrastructure Laboratory's **ACDC Grid**, **Western New York Grid**, and **New York State Grid**, which includes computational and data storage systems from dozens of institutions throughout the State of New York.

The applications available to the users cover a variety of disciplines, including Bioinformatics, Computational Chemistry, Crystallography and Medical Imaging, to name a few.

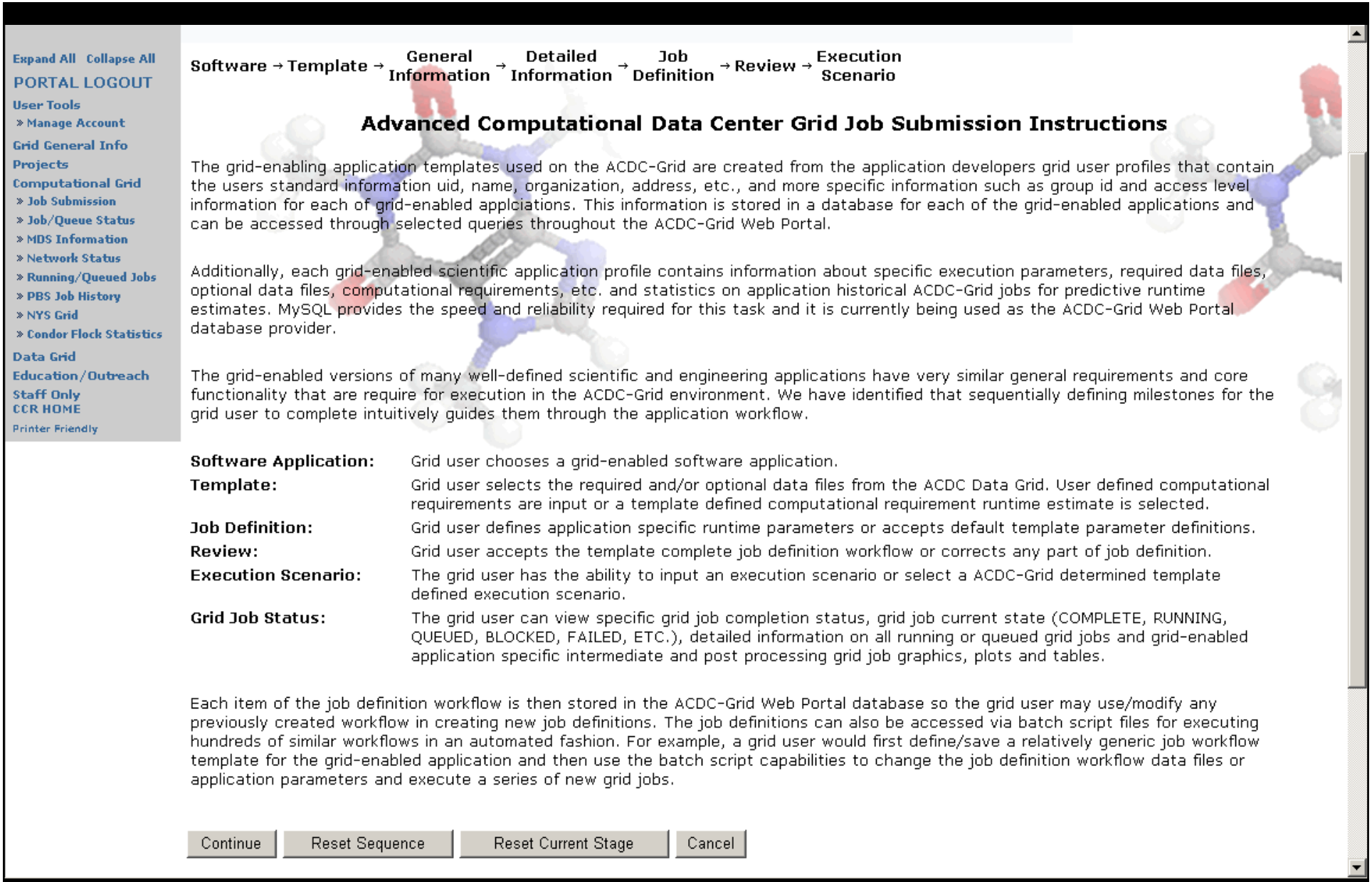
The grids developed by the CI Lab support teaching and research activities, as well as providing infrastructure that includes high-end data, computing, imaging, grid-enabled software, all of which relies on the New York State Research Network (**NYSERNet**).

This work is funded by the National Science Foundation (ITR, MRI, CRI), three program projects from The National Institutes of Health, and the Department of Energy.

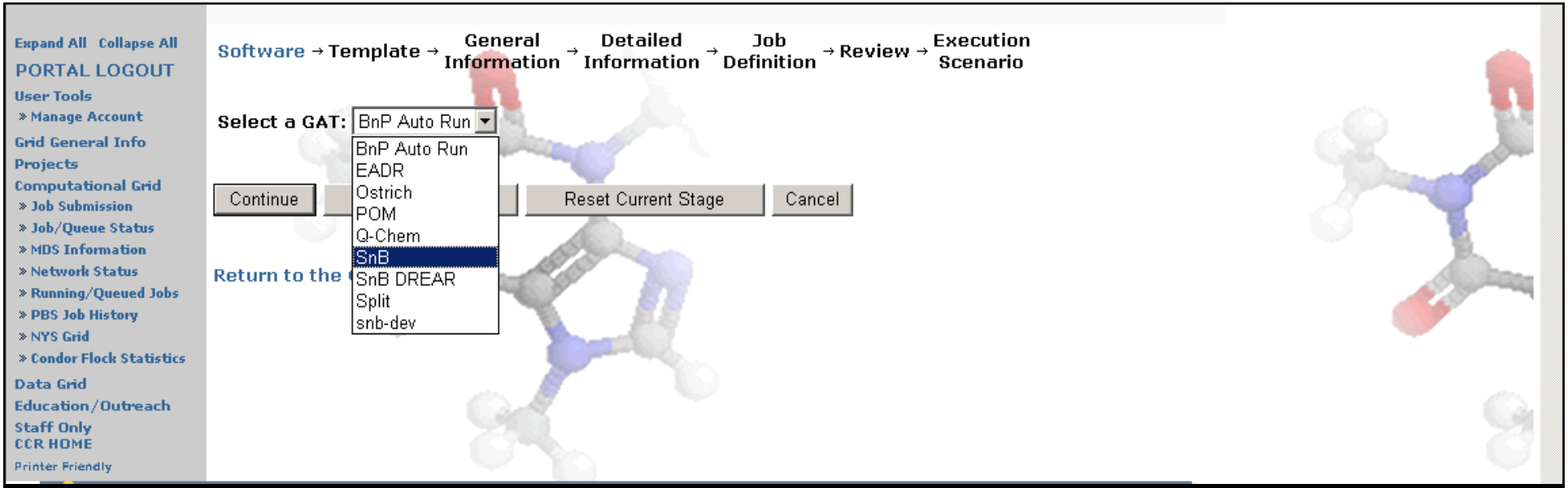
BnP

Software : BnP
Field : Protein crystal structure determination

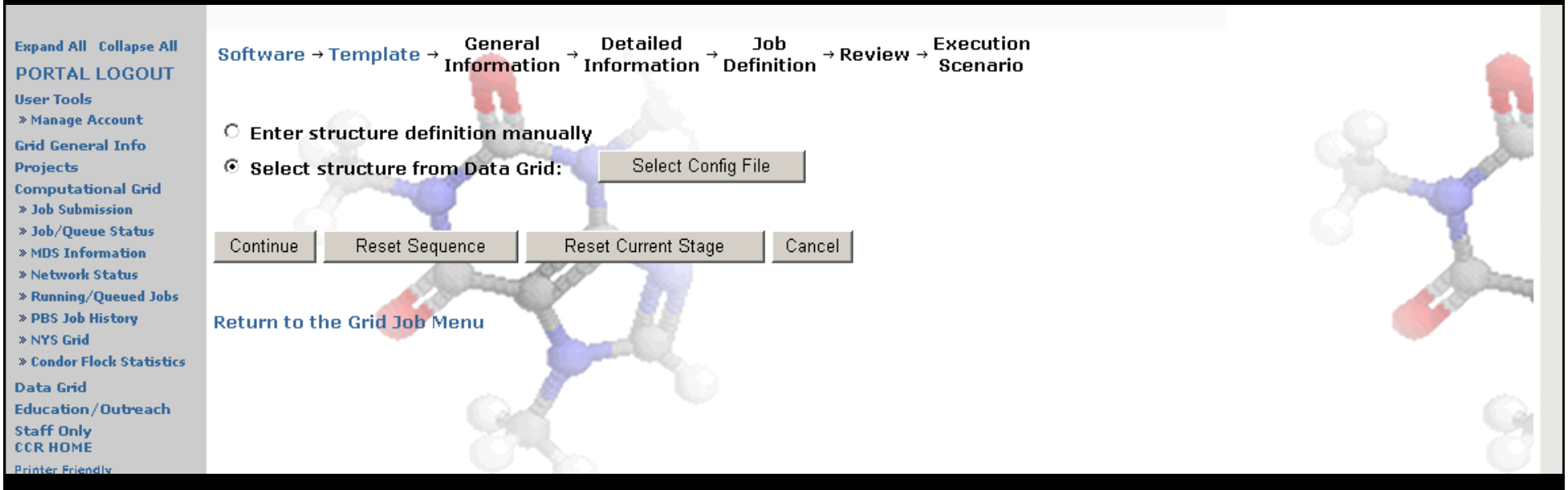
Startup Screen for CI Lab Grid Job Submission



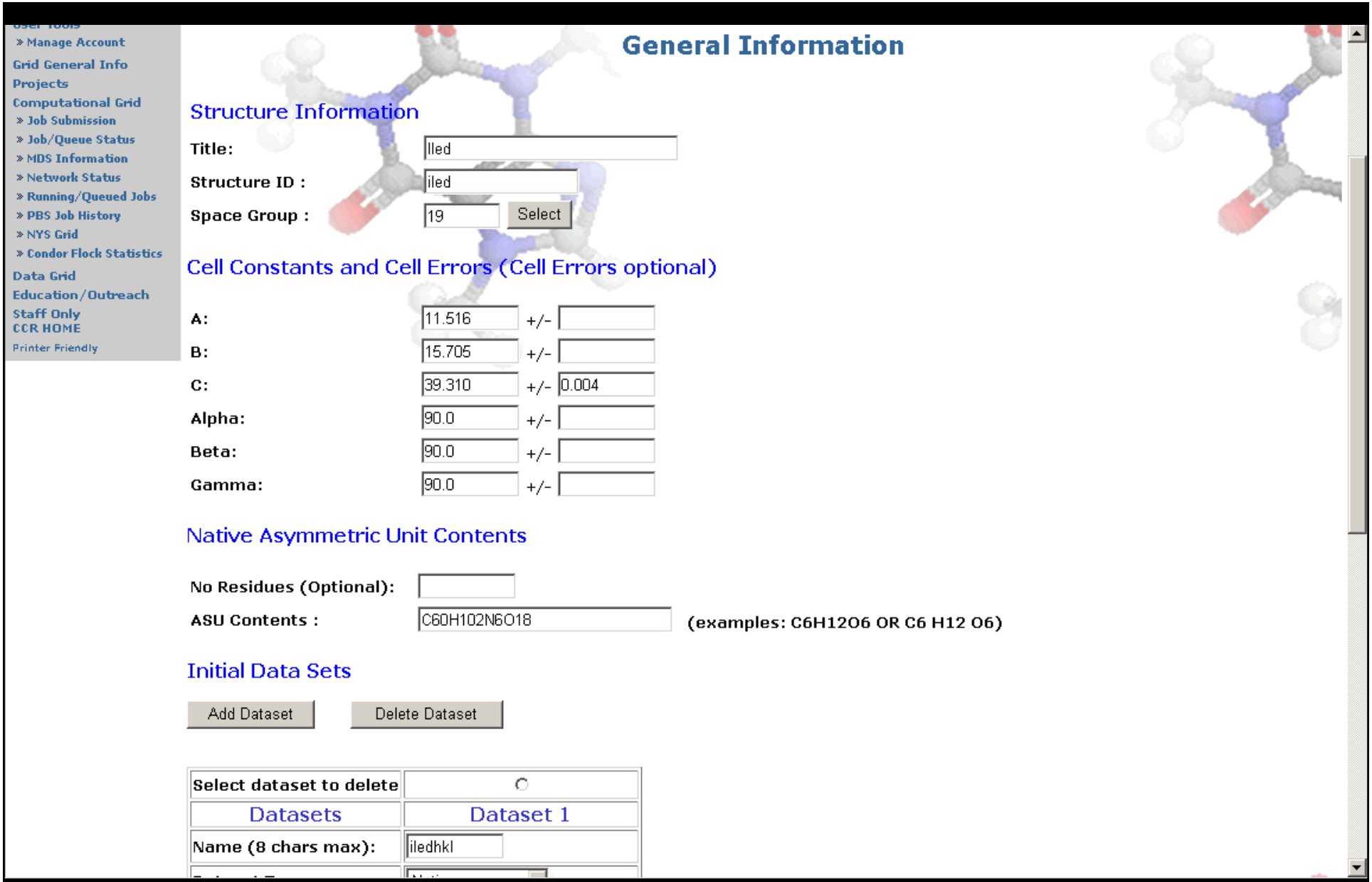
Instructions and Description for Running a Job on ACDC-Grid



Software Package Selection



Full Structure / Substructure Template Selection

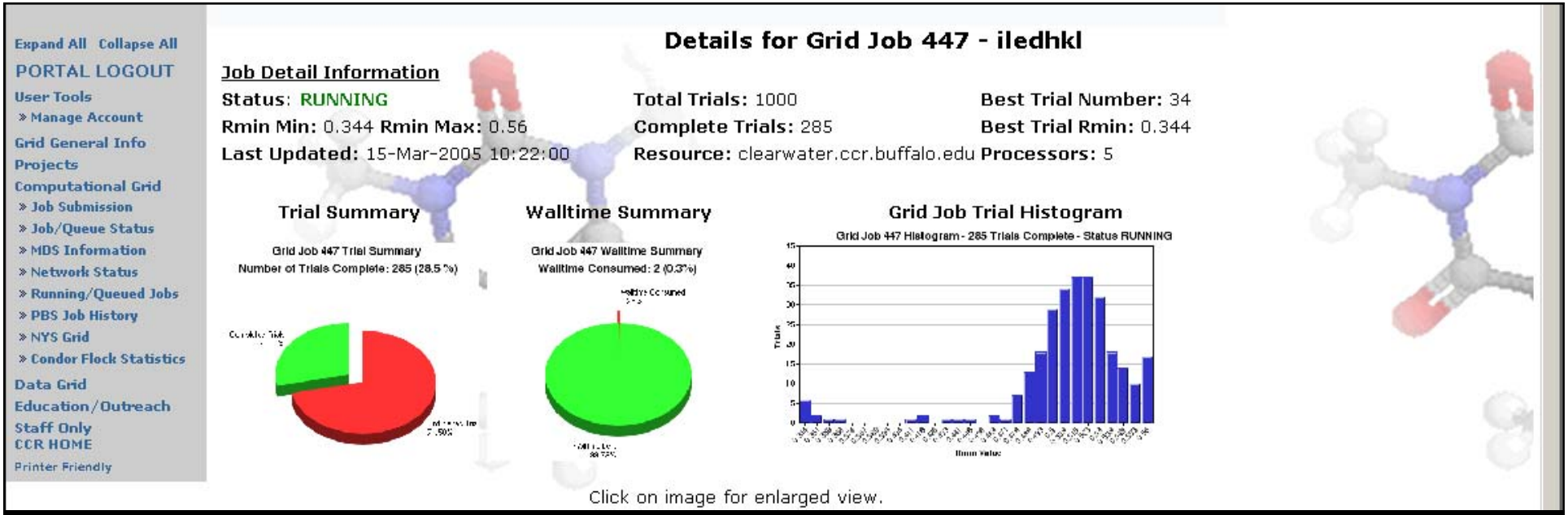


Default Parameters Based on Template

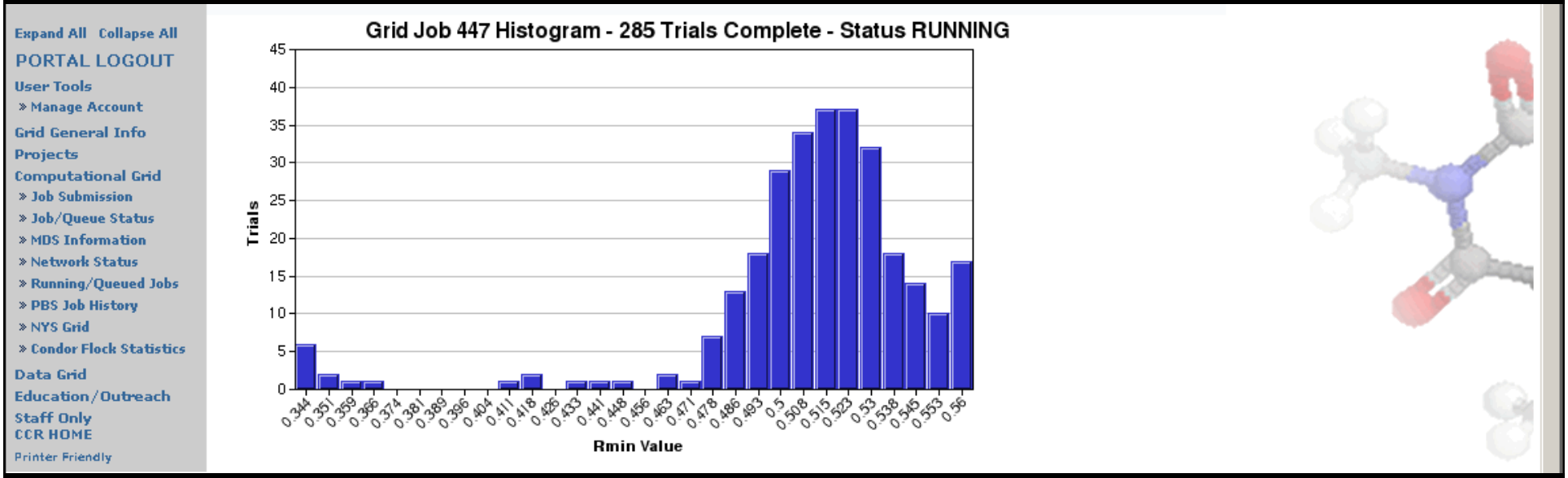
SnB Job Review

Grid Job ID:	447
Selected resource:	clearwater.ccr.buffalo.edu
Number of processors:	5
Wallclock time requested:	720
Number of triplet invariant to use:	8400
Start Phases From:	Random Atoms
Random seed (prime):	11909
Number of trials:	1000
Starting Trial:	1
Input Phase File:	Unused
Input Atom File:	Unused
Keep complete (every trial) peak file? :	Yes
Number of Shake-and-bake cycles:	20
Keep complete (every cycle) trace file? :	No
Terminate trials failing the R-Ratio test? :	No
R-Ratio cutoff:	Unused
Phase Refinement Method:	Parameter Shift(Fast)
Number of passes through phase set:	3
Phase shift:	90.0
Number of shifts:	2
Number of peaks to select:	84
Minimum interpeak distance:	3
Minimum distance between symmetry-related peaks:	3.0
Number of special position peaks to keep:	0
Fourier grid size:	0.31
Perform extra cycles with more peaks? :	No
Number of extra cycles:	Unused
Number of peaks:	Unused
Trials for E-Fourier filtering (fourier refinement)? :	None
Number of cycles:	Unused
Number of peaks:	Unused
Minimum |E|:	Unused

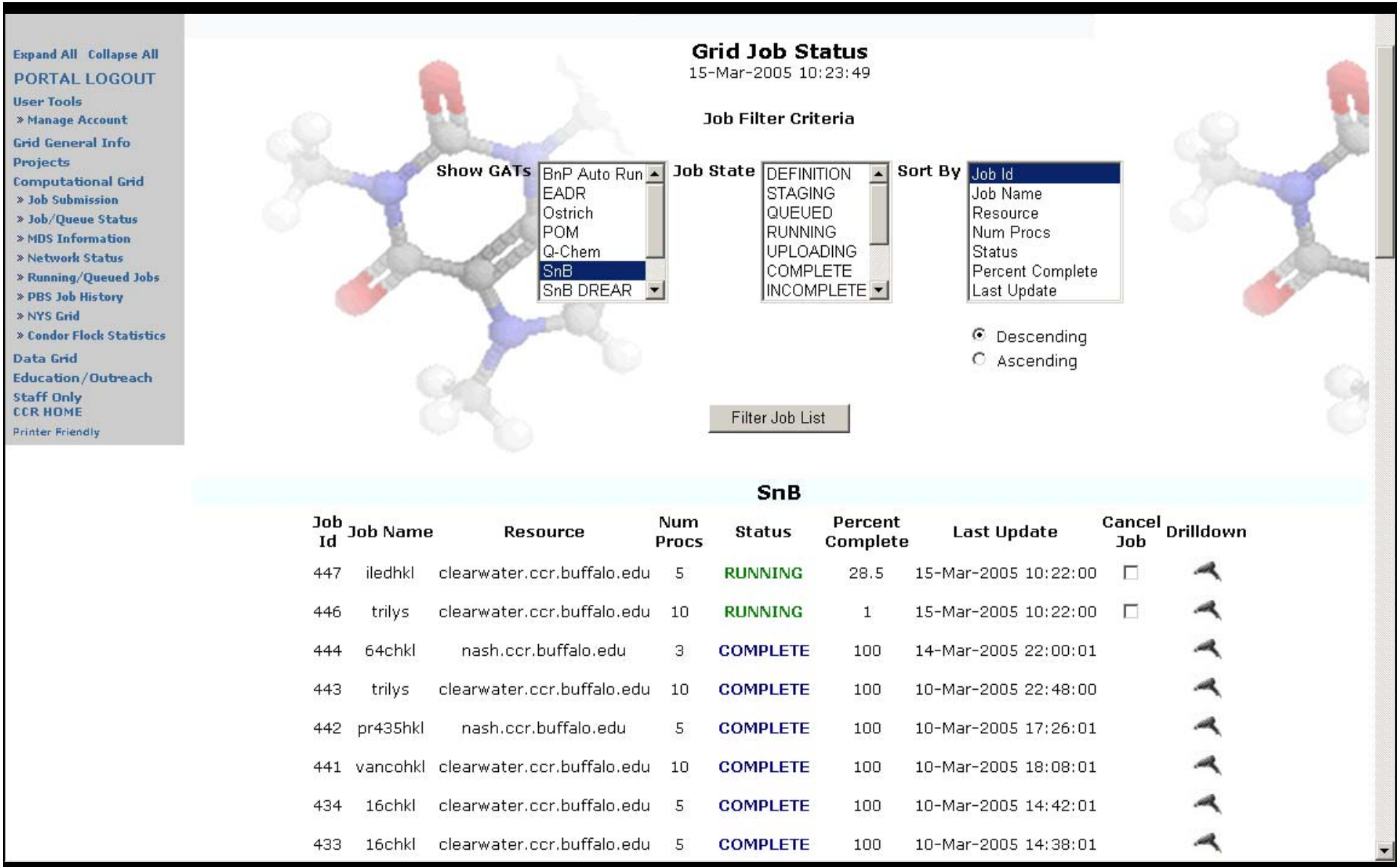
SnB Review (Grid job ID: 447)



Graphical Representation of Intermediate Job Status

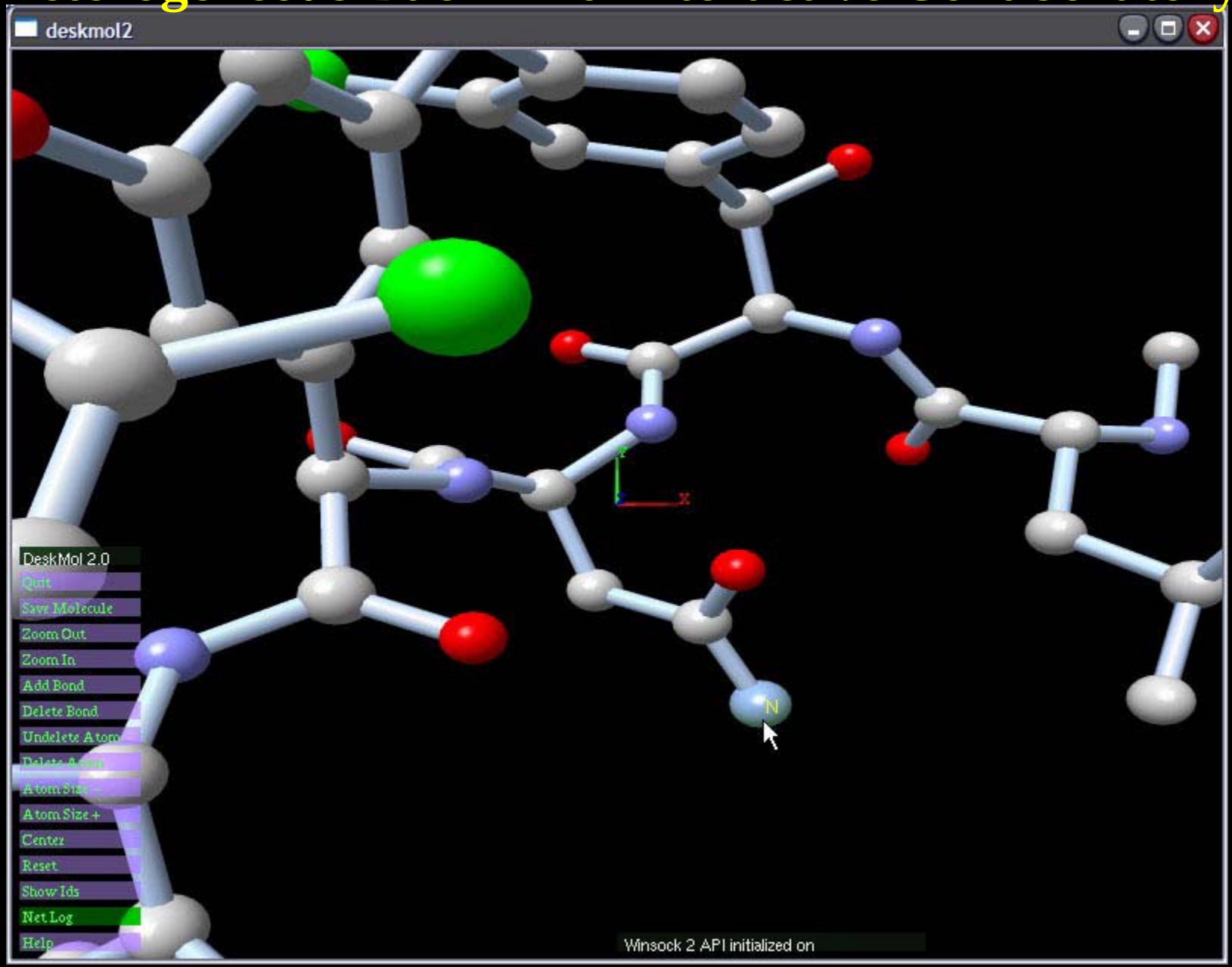


Histogram of Completed Trial Structures

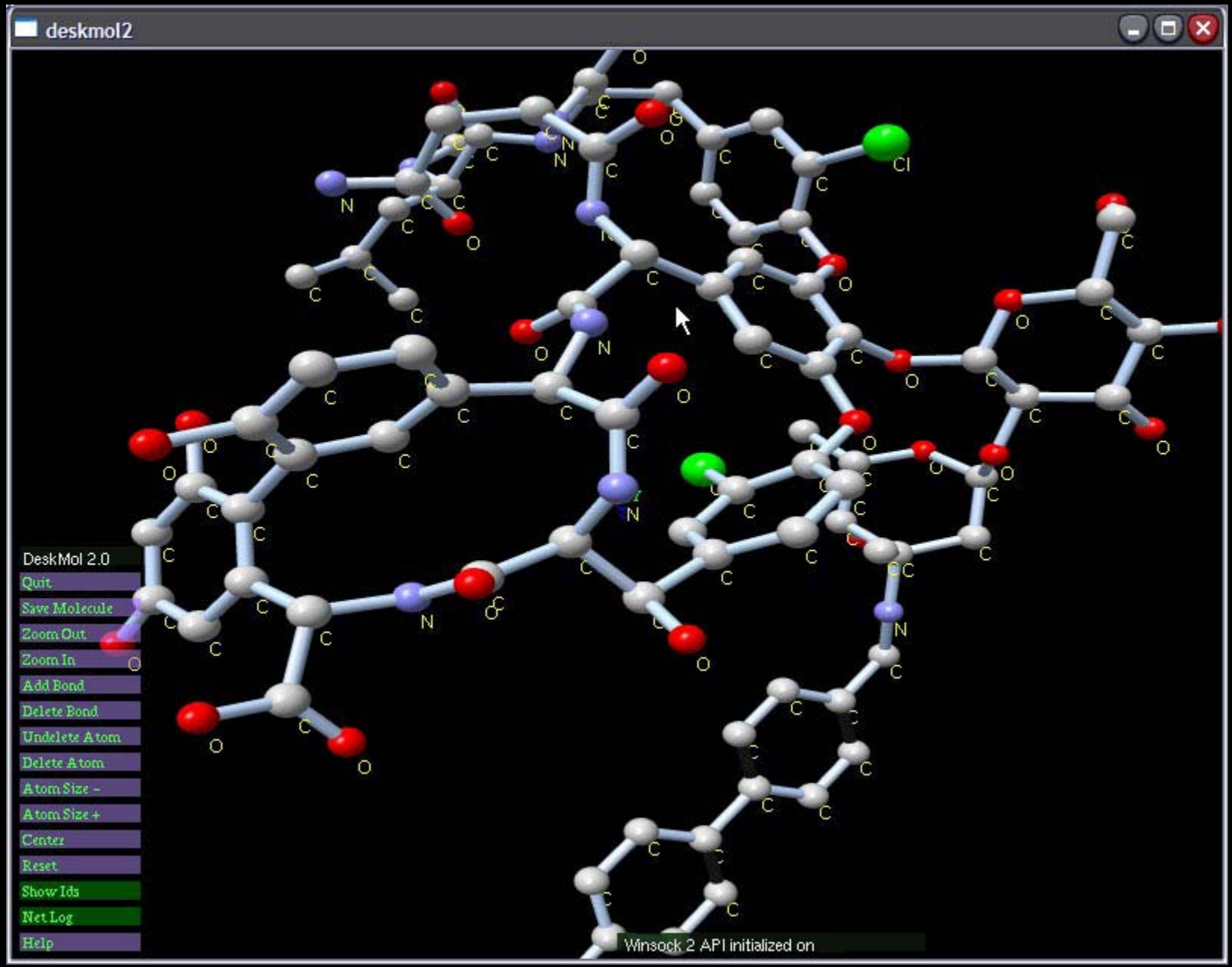


Status of Jobs

Heterogeneous Back-End Interactive Collaboratory



User starts up – default image of structure.



Molecule scaled, rotated, and labeled.

New York State Grass Roots Cyberinfrastructure Initiative

- **Miller's NYS Grid used as fundamental infrastructure.**
- **Currently an initiative of NYSERNet.**
- **Open to academic and research institutions.**
- **Mission Statement: To create and advance collaborative technological infrastructure that supports and enhances the research and educational missions of institutions in NYS.**
- **Enable Research, Scholarship, and Economic Development in NYS.**
- **Currently, no significant utilization.**

TRUN: Transborder Research University Network

- **Ontario: York, Toronto, Western Ontario, McMaster, Queen's, Waterloo, Guelph**
- **NYS: Buffalo, Rochester, Syracuse, Cornell, Albany, RIT**
- **Mission Statement: Expand and support cooperation among research universities in the border region of Province of Ontario and NYS:**
  - **Collaborative/consortial research**
  - **Joint applications for external funding**
  - **Cooperative academic programs**
  - **Faculty and student exchanges**
  - **Shared facilities**
  - **Joint conferences, symposia, workshops**

www.trun.ca

TRUN: Transborder Research University Network

- **Current Focus**
  - Great Lakes Sustainable Energy
  - IT-Supported Disciplinary Research
  - High Performance Computing
  - Canada-U.S. Policy and Standardization of Binational Data

www.trun.ca

- **General Issues**
  - Public Policy Issues, Regional Governance
  - Border Security and Mobility
  - Economic and Worforce Development
  - University Partnerships with Government and Industry
  - Health Care and Policy
  - Basic Research and Technology Transfer

Acknowledgments

- Mark Green
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- Jon Bednasz
- Sam Guercio
- Martins Innus
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- George DeTitta
- Herb Hauptman
- Charles Weeks
- Steve Potter

- Alan Rabideau
- Igor Janckovic
- Michael Sheridan
- Abani Patra
- Matt Jones

- NSF ITR
- NSF CRI
- NSF MRI
- NYS
- CCR


www.cse.buffalo.edu/faculty/miller
CCR
CCR