NMI Integration Testbed

Case Study Series

Georgia State University: NMI Grid Middleware Enhances Georgia State's Cosmic Ray Muon Project

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NSF Middleware Initiative (NMI) Integration Testbed Case Study Series

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The NMI Integration Testbed Program provided practical evaluation of NMI components within the context of real projects and application scenarios from June 2002 through November 2004. During that time, NMI Testbed sites collectively submitted over 170 evaluation reports to middleware component developers as direct feedback into the NMI development cycle. Site representatives also actively inspired, promoted and facilitated the integration of middleware throughout their institutions.

The NMI Integration Testbed Case Study Series documents the most significant influences and outcomes of NMI Testbed sites' middleware integration efforts, highlighting intersections with established projects, application contexts and influences, drivers for innovation, decision points and challenges. Through this documentation, the work of these pioneering institutions is captured to provide a breadth of insight and approaches for others to use towards successful middleware development and deployment.

This NMI Integration Testbed Case Study Series is sponsored by the National Science Foundation Middleware Initiative-Enterprise and Desktop Integration Technologies (NMI-EDIT) Consortium of EDUCAUSE, Internet2, and SURA. Additional support was provided by the National Science Foundation Cooperative Agreement NSF 02-028, ANI-0123937.

Executive Summary

The Georgia State University nuclear physics group, and the middle and high school students they are working with, will use a distributed muon detector array to collect data on muon showers in the Cosmic Ray Muon Measurement project. The tracking and measurement of muon showers is important because of their potential effect on our environment, weather, electronics, and our health. One of the goals of the Cosmic Ray Muon Measurement project is to gather more information about the levels of radiation from cosmic rays in our biosystems so that biologists can make use of it. Furthermore, project results may also have profound implications on the fundamental theory of nuclear and particle physics, and on astrophysics.

In the Cosmic Ray Muon Measurement project, a network of distributed detectors will be set up to collect experimental and simulation data. Physicists will mentor high school teachers, while middle and high school students learn fundamental physics by analyzing study data. This Cosmic Ray Muon Measurement project has been significantly enhanced by grid technology.

Georgia State's Art Vandenberg led two initiatives that were critical to getting the muon detector project "on the grid" - Georgia State's participation in the National Science Foundation (NSF) funded NSF Middleware Initiative (NMI) Integration Testbed Program, and the GRID Group @ GSU. The Testbed program provided Vandenberg's team with real life experience in using NMI components, while the discussions between GRID Group and Georgia State's physicists helped illuminate the potential benefits the grid could have for the muon detector project (including remote access, management and control of the detectors in a secure and coordinated manner).

Fully deploying the distributed muon detector array is a complex and long-term undertaking. As part of Vandenberg's team, two Georgia State's NSF-funded Research Experiences for Undergraduates (REU) students have played key roles in deploying the muon detector array. Deployment is continuing, and it's expected that nearly 100 schools in all in the state of Georgia will have permanently installed muon detectors that make up the muon detector array. Without being grid-enabled, the logistics of coordinating muon measurements at such a large number of schools would likely be overwhelming.

Along with the foresight of leaders like Art Vandenberg and Dr. He, the hard work and collaborative efforts of Vandenberg's team, the REU students, the physics staff at Georgia State, and the numerous educators from the project's participating middle and high schools is producing a significant distributed, grid resource for Georgia's research and educational institutions. The Cosmic Ray Muon Measurement project's muon detector array will benefit research, enable improved scientific results, provide students with experiences in leading edge science, and form the basis of a more secure and managed information technology infrastructure.

For more information about Georgia State's NMI grid integration or the Cosmic Ray Muon Project, contact:
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NMI Components Highlighted in this Case Study

The NMI components discussed in this case study series encompass NMI Releases 1 through 4. Information about NMI Releases can be found at **http://nsf-middleware.org/**.

Condor-G

The GRIDS Center's Condor-G is a computation management agent for the grid. Condor-G is the marriage of technologies from the Condor project and the Globus project (see below).
Home site: http://www.cs.wisc.edu/condor/; Globus (see below).

Globus

The GRIDS Center's Globus Toolkit is an open-source collection of modular technologies that simplifies collaboration across dynamic, multi-institutional virtual organizations. It includes tools for authentication, scheduling, file transfer and resource description.
Home site: http://www-unix.globus.org/toolkit/

GridPort

The GRIDS Center's GridPort enables the development of portals and applications on top of underlying distributed and grid computing infrastructure to facilitate computational science.
Home site: http://gridport.net/index.cgi

Network Weather Service

The GRIDS Center's Network Weather Service (NWS) is a distributed system that periodically monitors and dynamically forecasts the performance various network and computational resources can deliver over a given time interval.
Home site: http://nws.cs.ucsb.edu/

Georgia State University: NMI GRID Middleware Enhances Georgia State's Cosmic Ray Muon Project

Middle and high school students in the state of Georgia are participating in important physics research, facilitated in large part by dedicated faculty and staff at Georgia State University, using cutting-edge grid technology. The Georgia State University nuclear physics group, and the students they are working with, will use a distributed muon detector array to collect data on muon showers. These fortunate students are benefiting from the work of a number of visionary, dedicated people and the organizations they represent. On the local level, the project is facilitated by the commitment and vision of physics staff at Georgia State University, Dr. Xiaochun He and his associates, and of Art Vandenberg, Georgia State's Director of Advanced Campus Services.

These local leaders are helping to implement the broader goals of the National Committee on Science Education (NCSE) Standards and Assessment in the area of K-12 science education, and of the National Science Foundation (NSF) in enabling research scientists and educators to "accomplish scientific collaboration and information sharing with great efficiency". To help meet this latter goal, the NSF has funded the NSF Middleware Initiative (NMI) Integration Testbed Program[1]. In addition to furthering the NCSE's and NSF's goals and educating students involved, the Cosmic Ray Muon Project is contributing to important scientific research. The tracking and measurement of muon showers is important because of their potential effect on our environment, weather, electronics, and our health. On an even broader level, the results from the muons measured in this project may have profound implications on the fundamental theory of nuclear and particle physics, and on astrophysics.

The cosmic ray muon research project that the students and Georgia State faculty are engaged in serves as a valuable example of the results of strong organizational commitment, successful outreach on the part of IT professionals, and the foresight of faculty to experiment not only within their field of expertise, but with cutting-edge technologies such as grids. This article will explain how this convergence occurred. It will describe how the specific programs and

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[1] As part of its overall effort to develop and disseminate software that lets scientists and educators share resources across the Internet, NMI deployed a practical deployment and evaluation effort called the NMI Integration Testbed. Managed by the Southeastern Universities Research Association (SURA) on behalf of the NMI-EDIT Consortium (NSF Middleware Initiative-Enterprise and Desktop Integration Technologies; see http://www.nmi-edit.org/), the Testbed consisted of eight universities that participated in a closely coordinated effort to deploy and evaluate NMI technologies: http://www1.sura.org/3000/NMI-Testbed.html

goals of various organizations came together, and how specific NMI Grid components are being used to enhance the work of Georgia State physics faculty and Georgia middle and high school students as they search for cosmic ray muon particles.

Georgia State's Middleware Initiative

Georgia State Background in Middleware

Georgia State University computing services staff began working to implement a middleware infrastructure in September 1999. In February 2000, the Associate Provost/CIO formalized Georgia State's organizational commitment to enhancing its middleware infrastructure by the creation of the Advanced Campus Services (ACS) unit. The CIO charged ACS with deploying middleware architecture consistent with the national middleware initiatives of Internet2 and EDUCAUSE. A robust middleware infrastructure will facilitate Georgia State's transformation to an "eUniversity". eUniversities are the electronic, next-generation institution of higher education" (similar to the commercial sector's growth into eCommerce) (1).

As part of ACS's strategy to bring middleware to their campus, Georgia State became a participant in the NSF-funded NMI Integration Testbed Program. The ACS was aware of applications on campus, like the cosmic ray muon project, that could benefit from Georgia State's participation in the Testbed. This program provides Georgia State with the ability to participate in "real life" evaluation and feedback on NMI middleware software, specifications, and services to enhance the work of their faculty and researcher applications. At the same time, participation in the Testbed allows Georgia State to further its goals in the middleware area through collaboration with other institutions working within the Testbed.

Georgia State's GRID Group @ GSU

Another element helping to bring the search for muons to the grid is Georgia State's GRID Group @ GSU. As a result of Georgia State's testing and evaluation of grid components in the first year of the NMI Integration Testbed Program, the GRID Group @ GSU was formed to engage faculty, students and staff in discussions of a potential grid infrastructure. Art Vandenberg initiated the GRID Group @ GSU in Spring 2003, after several of his discussions with various faculty and staff (including Dr. He) made clear that there were potential grid applications on campus.

Hoping to fully answer the question, "What grid research or potential grid applications are there at Georgia State?" and to track these applications, Vandenberg put two NSF Research Experiences for Undergraduates (REU) Program students to work on populating the "Catalog of Grid Applications". The students began their survey by documenting Dr. He's Cosmic Ray Muon Project and, as part of the ongoing outreach of the GRID Group @ GSU, they are continuing to compile information on other potential grid applications. Georgia State's Grid Group continues to meet, sharing information and providing a valuable forum for education and outreach.

Georgia State's Cosmic Ray Muon Project

The Cosmic Ray Muon Measurement project is one of three experiments the Nuclear Physics Group at Georgia State University is conducting. Dr. Xiaochun He, Associate Professor in the Georgia State Physics Department, is the principal investigator for this project. Dr. He and his associates are developing an array of distributed muon detectors in collaboration with local area Georgia middle and high schools. In this project Georgia State is providing unique, leading edge opportunities for the students who will be our next generation of physicists and astronomers (and grid technology researchers!) In addition to contributing to real physics research, Georgia State's muon detector program represents Georgia State's commitment to furthering the NCSE's science teaching standards. These standards promote advanced science research activities in middle and high schools in Georgia in order to inspire students to seek higher science education. In the cosmic ray muon detector project, a network of distributed detectors will be set up to collect experimental and simulation data. Georgia State physicists will mentor high school teachers, while students learn fundamental physics by analyzing study data.

Georgia State's Cosmic Ray Muon Project is similar to the QuarkNet project in education outreach at Fermi National Accelerator Laboratory (Fermilab). Georgia State University, an early QuarkNet participant, was one of the universities and national labs participating in QuarkNet in 2003. QuarkNet centers are connected via the Internet to high-energy physics experiments operating at CERN, Fermilab and others. The QuarkNet At Work website notes that a distributed array detector will allow students to use a virtual data portal, enabling them to upload their particle data and associated analysis code to the web so that it can be shared with students at other schools (regardless of whether those schools have their own cosmic ray detectors). The QuarkNet project is supported in part by the National Science Foundation and the Division of High Energy Physics, Office of Science, U.S. Department of Energy.

Today, Georgia State has expanded its Cosmic Ray Muon Project to middle schools as well as high schools. Georgia State's Cosmic Ray Muon project has also supported the work of middle school teacher, Dr. Candy English from Griffin Middle School in Smyrna, Georgia, to assist with the muon detector construction at Georgia State. Carola Butler has recently begun working with science educator Dr. John Wilson, Kennesaw State University. Dr. Wilson used to be the Astronomy Lab

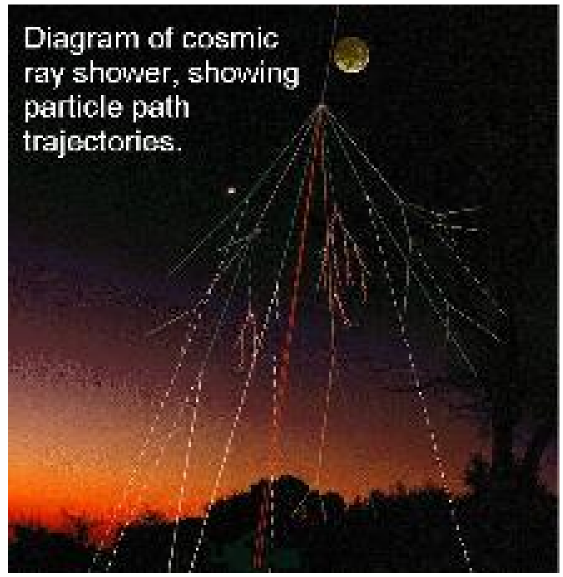
Coordinator at Georgia State and recently received his Ph.D. in science education from Georgia State. Carola and John are working together to include the muon detector project in curriculum for Kennesaw State junior and seniors preparing as high school physics teachers. Plans for establishing a muon detector grid node at Kennesaw are being investigated.

How Does The Grid Help Find Muons?

First, a Muon Primer

While the nucleus of an atom is made of protons and neutrons, physicists have discovered that protons and neutrons themselves are comprised of a more fundamental "set" of universal building blocks – quarks and leptons. In the physicist's standard model of the particle world, there are six quarks and six leptons that are considered to be "structureless" and thus comprise the universe's set of fundamental building blocks. The protons and neutrons that make up the nucleus of an atom are made of three quarks (i.e., no leptons in them). Electrons orbit the nucleus and complete the structural model of an atom. Electrons and muons are two of the six known types of leptons.

A muon decays to form an electron or positron. Most muons observed at the surface of the Earth are produced by primary cosmic rays in the upper atmosphere. When these primary cosmic rays hit our atmosphere, the impacts produce pions. Pions decay into a muon and muon neutrino, and these particles rain down upon the surface of the earth. Many muons decay on the way down, but there are still enough to be detected fairly easily. In fact, about 200 muons reach each square meter of the Earth every second, leaving us in the midst of a virtual, invisible cosmic rain shower.



The cosmic ray muon particles that survive their journey through the Earth's atmosphere enter the Earth's biosystems and decay into energetic electrons. These electrons deposit energy into our biosystems. The typical electrons "orbiting" an atom's nucleus carry energies measured in "electro-volts". Even at their average energy rating, muon particles have strong penetrating capabilities. Not only can they penetrate things such as steel and concrete, they can easily go through living cells. This penetrating energy can potentially have significant effects on plants and animals. For instance, muon showers contribute about 5% of the natural radiation dose humans are exposed to. The specific damage muon showers cause to people is not yet clear, but we do know what damage the photons of an atom cause when people are exposed to sunlight- anyone who has ever had a suntan or sunburn has actually experienced skin damage from photons. Thus, one of the goals of Dr. He's team is to gather more information about the levels of radiation from cosmic rays in our biosystems so that biologists can make use of it.

The Search for Muons Meets the Grid

As grid technology can provide services for sharing computer power and data storage across the Internet (essentially enabling a network of computers to work as a single resource), the muon detector array seemed a natural candidate for grid middleware, affording a means for securely managed infrastructure. Through their GRID Group @GSU work during 2003, the Georgia State University Testbed team discussed with Dr. He how grid technology might be used to enable remote access and management of cosmic ray detector nodes, facilitate collection and analysis of data, and enhance simulation capabilities. Dr. He gave examples of what he saw as the potential capabilities available to a user of a grid-based muon detector, including 1) the ability to collect data from remote nodes and process it on a more powerful, central host computer, 2) the ability of individual nodes to collect data from other nodes and run simulations locally and, 3) the ability to change detector positions at site nodes and coordinate for specific events. Meeting Dr. He's requirements for the distributed detectors presented interesting problems that made the muon detector project ideal for implementation within the NMI Integration Testbed Project. Specific grid deployment issues for the project include how the detectors are to be accessed, managed and controlled while providing a secure, coordination operations.

In addition to enhancing the muon detector project with grid technology, the on-going, cross-disciplinary discussion between the GRID Group @ GSU, Georgia Tech faculty in computer science and visualization, and with Georgia State faculty in computer science and computer information systems have increased the potential utility of the muon detector grid. During these meetings, several ideas to improve on the detector's instrumentation were brought to light, including the idea to include Global Positioning System (GPS) sensors at each node to exactly record the muon's location, as well as weather stations to record climate conditions that impact muon showers, and geomagnetic sensors. These sensors would nicely integrate with overall muon detection. GPS would provide the exact locations of detected events, while weather stations would inform the researcher of weather conditions that may impact muon events, and geomagnetic sensors would help correlate muon events with geomagnetic variations. Such a layered grid could improve the results of the muon detection and might provide other purposes – improved weather tracking, for instance.

The Building Begins

Through their collaborative efforts, Georgia State's staff are creating a classic scientific grid in that they will collect data across grid nodes, transfer and process the results, then share the results via the grid-enriched environment. A prototype grid-based system for controlling detector nodes, collecting muon data, running simulations and sharing muon data should be up running in Fall 2004. Muon monitoring equipment will be installed at selected public schools in the metro Atlanta area, and a central monitoring station will be installed at Georgia State University. To date five Georgia high schools, and a middle school, have "experienced" the muon detector through presentations and on-site demonstrations of the detector's apparatus and operation. Carola Butler, Dr. He's Lab Coordinator, is responsible for coordinating these on-site activities. During the two-week period the detector was at each school, Dr. He and his team guided the school's teachers and students, step-by-step, in making a muon flux measurement. This testing of the detector was a "standalone measurement" in that it didn't use grid tools. The next step in this project is to grid-enable the detectors and verify their functionality in the lab. This step will be followed by building a detector for each school and permanently installing it at the schools. Each detector will have grid-enabled control computers and GPS capability.

A Geant4 based cosmic muon simulation program has been set up for studying muon flux distributions. Geant4 is a C++ software program that allows researchers to simulate the passage of particles through matter (including atmospheric or "air" matter). It not only helps in optimizing the muon detector design, but also plays an inseparable role in analyzing the experimental data. Georgia State graduate student, Christopher Cleven, has used the program to simulate a set of atmospheric layers, with realistic air densities within each layer. A non-uniform geomagnetic field has been installed in the simulation program in order to correctly simulate the trajectories of charged particles created from cosmic showers. To further enhance the simulation data, GPS capability will be built into each detector, the data recorded at each site will be time-stamped with a given detector orientation that provides the detector's angle and position at the time of the muon particle event.

Grid Component Use in the Muon Detector

Several NMI components are planned for use in this project, including the GRIDS Center's Globus Toolkit™[2], Network Weather Service[3] (NWS), and Condor-G[4] are being evaluated within this context. The Globus Toolkit has already been installed and is providing the fundamental enabling technology for the "grid" functions. It brings the nodes together into a single, unified

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[2]Globus Toolkit information: http://www-unix.globus.org/toolkit/
[3] Network Weather Service information: http://nws.cs.ucsb.edu/
[4]Condor-G information: http://www.cs.wisc.edu/condor/

whole and provides services for discovering, monitoring and managing network resources, while ensuring security and effective file management. NWS provides the capability to have sensors located on grid nodes within the array that will allow the researcher to understand trends in how the grid performs while muon detection is being done. Condor-G provides students and physics faculty using the muon detectors with the workload management capabilities. These capabilities allow the user to submit a job, monitor it, and have it completed in a way that makes the most of the resources available on the grid. In late 2003, the project team began looking for a grid portal solution, initially working with the GRIDS Center's GridPort[5]. The Open Grid Computing Environment (OGCE) (2) Portal is being added to the set of grid tools used in this project, and will provide an effective way to supply users with easy access to the muon detector grid via web browser technology.

In December 2003, two of Georgia State's NSF-funded REU students began installation of the first grid component to be put to work in the search for muons. In April 2004 the Globus component implementation was verified for the successful installation of the Globus Toolkit, as well as file transfer and job submission capabilities. Reaching these milestones successfully was no small task for Georgia State ACS staff member Victor Bolet who was tasked with coaching two undergraduates, Nicole Geiger, Physics, and Anish Shindore, Computer Information Systems, in R4 Globus. Their work through August 2004 included building ten PCs by assembling them from the parts of forty other surplus units. In all, they spent nearly 630 hours on the project (406 of which were spent focusing on learning about, installing and configuring Globus components), while graduate students Imran Faridi (Computer Science) and Alan Tang (Master Business Administration) spent another 320 hours on the portal part of the project (see Appendix for more details on timeline). The NSF REU students are currently deploying additional Grid nodes for the muon detector, resolving security issues related to PKI (public key infrastructure) certificates, and reviewing the application aspects of the muon detector grid, including data collection and simulation. All this hard work resulted in not only the successful implementation of the grid components into the muon detector project, but a great learning experience for the REU students, graduate students, (and their management team!)

Looking Forward- The Project Continues

At present, Dr. He and his team have built two prototype detectors and are building parts for more. It's expected that nearly 100 schools in all will have permanently installed muon detectors that make up the distributed detector array. Without being grid-enabled, the logistics of coordinating muon measurements at such a large number of

[5] GridPort information: http://gridport.net/index.cgi

schools would likely be overwhelming. At the least, the processes of collecting and sharing study data would be so manually laborious that a project of this scope would not have been feasible without the grid.

The ACS team, lead by Art Vandenberg, Dr. He and his team, and the educators at participating schools have made a great deal of progress in this project. Fully deploying a distributed, grid-based series of muon detectors within Georgia State's Cosmic Ray Muon Measurement Project is complex and long-term undertaking. Grid technology is ever advancing and maturing, and the ACS group is working to bring current developments in the grid computing field to the muon detector project. Students and Art Vandenberg meet weekly with Dr. He to review the project's status.

While taking measurement data with these grid-enabled computers was the initial goal of the muon detector grid, the potential of enabling a computational grid (using collective nodes for simulation processing) or data grid (storing collected data across grid nodes) is now also being discussed.

Through much hard work, collaboration, and foresight, the concept for a stand-alone detector that collected data about a local muon event, is being transformed into a plan for a distributed resource benefiting research, enabling improved scientific results, providing students with experiences in leading edge science, and forming the basis of a more secure and managed information technology infrastructure.

More Information

For more information about Georgia State's NMI grid integration or the Cosmic Ray Muon Project, contact:

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or
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References

(1) Georgia State University: Building an Identity Management Infrastructure for the eUniversity. *NMI-EDIT*

(2) OGCE-The OGCE produces free, open source software for building Grid Computing Portals. http://www.collab-ogce.org/nmi/portal/user/anon/js_pane/P-fc75d05650-10001

Links of Interest

Catalog of Grid Applications http://art12.gsu.edu:8080/grid_cat/index5.jsp

Cosmic Ray Measurement, Department of Physics and Astronomy, Georgia State University http://phynp6.phy-astr.gsu.edu/~cosmic/

Fermilab http://www.fnal.gov/

Georgia State University http://www.gsu.edu

GRID Group @ GSU http://www.gsu.edu/~wwwacs/GRID_Group/Index.htm

GRIDS Center http://www.grids-center.org/

Grid technology http://www.globus.org/research/papers.html

Griffin Middle School http://www.cobb.k12.ga.us/~griffin/

Kennesaw State University http://www.kennesaw.edu/

Middleware infrastructure http://middleware.internet2.edu/

Muons http://www.lbl.gov/abc/cosmic/SKliewer/Index.htm and http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Muons.htm

Nuclear Physics Group, Georgia State University http://phynp6.phy-astr.gsu.edu/~phenix/new/home.html

NMI-EDIT http://www.nmi-edit.org/

NMI Integration Testbed Program http://www1.sura.org/3000/NMI-Testbed.html

NSF Middleware Initiative http://www.nsf-middleware.org/

NSF Research Experiences for undergraduates (REU) Program http://www.nsf.gov/home/crssprgm/reu/start.htm

QuarkNet http://quarknet.fnal.gov/

QuarkNet At Work http://quarknet.fnal.gov/quarknet_work.html