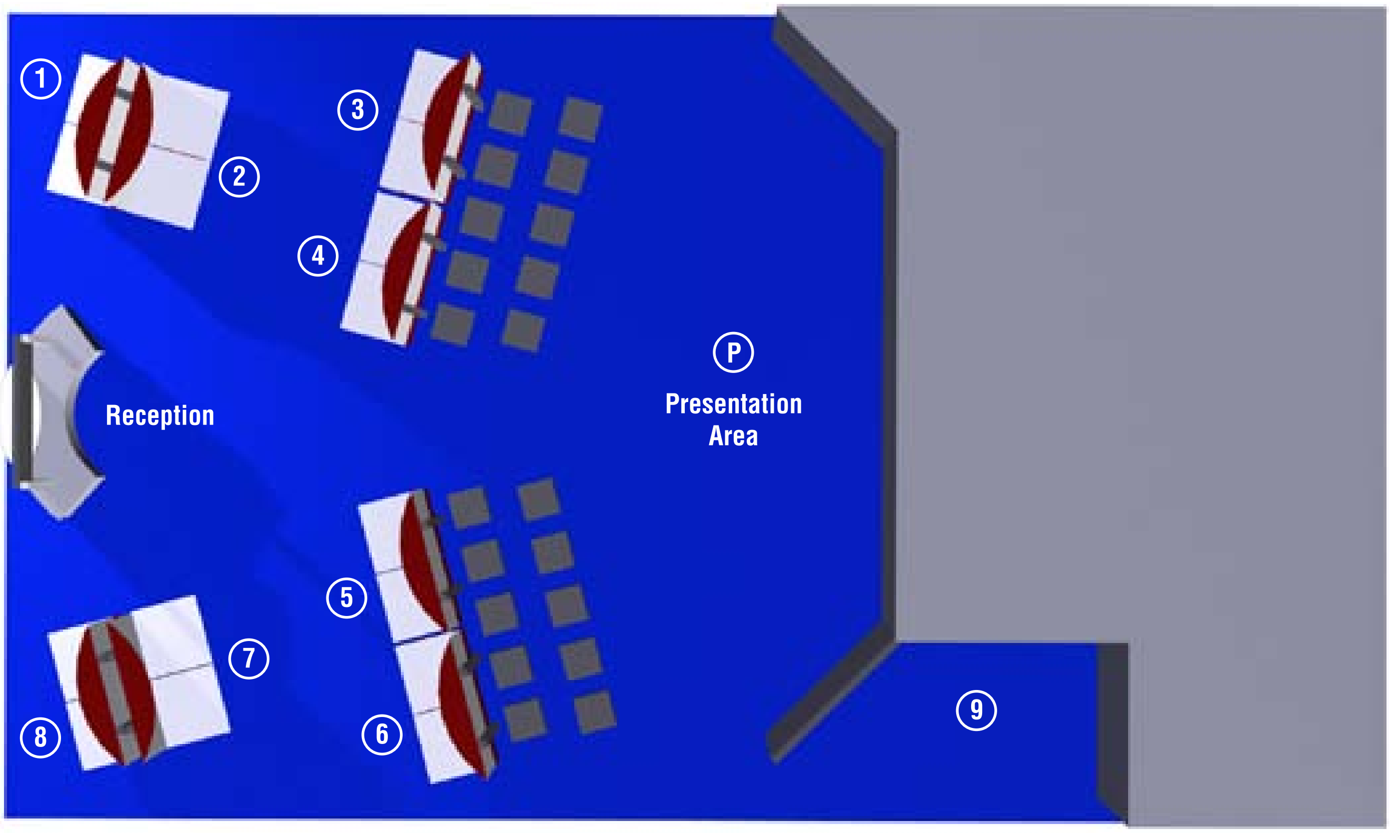
National Aeronautics and Space Administration

NASA @ SC12

November 10–16, 2012 • Salt Lake City, Utah • Booth #831

SC12
Salt Lake City, Utah

NASA BOOTH #831 DIRECTORY



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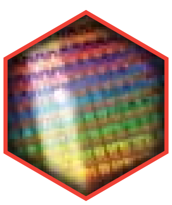
SPACE EXPLORATION

SUPERCOMPUTING



THE UNIVERSE

For more information on any of NASA's SC12 demos, you can either talk to a researcher, scan the QR code (at left), or visit http://www.nas.nasa.gov/SC12/demonstrations.html

FEATURED DEMO

Designing Curiosity's Perfect Landing on Mars

On August 5th, 2012, millions of people around the world watched as the Curiosity rover gently touched down on the floor of Gale Crater. Five hundred thousand lines of sophisticated, interplanetary, autonomous code brought the spacecraft down from a speed of 13,000 kilometers per hour (km/h) at the top of the Martian atmosphere to a complete stop on the planet's surface in just seven minutes. Engineers at NASA's Jet Propulsion Laboratory (JPL) combined their unique entry, descent and landing (EDL) knowledge with thousands of processor hours on several Beowulf clusters to orchestrate the sequence of events that successfully placed this 2,000-pound rover onto the surface of Mars.

The biggest robotic exploration rover yet, Curiosity carries 10 times more payload in scientific instruments than the Mars Exploration Rovers, making it the most comprehensive Martian geologist ever to rove the Red Planet. It powers its 17 different cameras, 4 spectrometers, 2 radiation detectors, environment sensor, and atmospheric sensor with a radioisotope thermoelectric generator that produces 110 watts.

Artist's conception of the moment that NASA's Curiosity rover touched down on Mars, suspended on a bridle beneath the spacecraft's descent stage.

After a nine-month journey across 350 million miles, the spacecraft was designed to steer itself using a series of S-curves for a guided entry through the atmosphere. Three minutes from touchdown, the spacecraft parachute decelerated to about 200 mph in an atmosphere that is 100 times thinner than that of Earth. Finally, retrorockets and a sky crane were used to complete the precision landing sequence, touching down inside the smallest Martian landing ellipse ever attempted.

Curiosity's primary science objective is to evaluate whether Mars has ever had, or still has, the necessary environmental conditions to support life. Scientists believe that the alluvial fan on the floor of Gale Crater may have been created by water-carried sediments and may hold the key to answering this question. Mount Sharp's layered formation, rising nearly 6 km above the center of the crater, may contain minerals formed in water that are the building blocks of life. Curiosity has a long journey of discovery ahead, but it has already captivated millions of hearts through its revolutionary achievements in science and technology.

Sixteen months ago, JPL's EDL team began working with the center's supercomputing team to create the fully customized supercomputing environment necessary to run the complex guided-entry simulations. Innovative version-control and automated-build techniques allowed the teams to re-create any version of the customized environment.

A Monte Carlo simulation ran a series of high-fidelity trajectory integrations that used a unique set of inputs for each embarrassingly parallel simulation. Precision landing with guided entry required that each simulation have 8,001 separate trajectory integrations and 90 minutes of runtime. JPL's supercomputing capabilities allowed the EDL team to dramatically reduce the risk in landing at Gale Crater.

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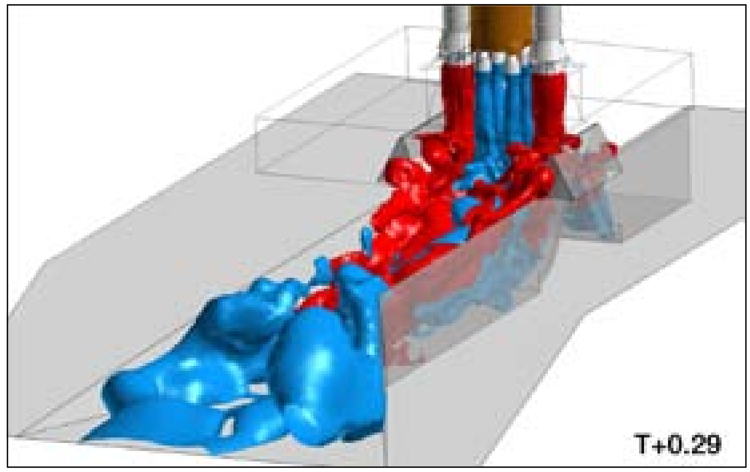
FEATURED DEMO

Simulating Rocket Ignition and Launch Environments for NASA's Space Launch System

At liftoff, the Space Launch System's (SLS) solid rocket boosters (SRBs) will send large amplitude pressure waves into the confined space of the launch structure. These ignition overpressure (IOP) waves, which radiate throughout the launch environment, can cause damage to the launch structure, the vehicle, and the payload, and therefore must be well understood during the design process.

Simulating both the rapid ignition process within the SRBs and the IOP phenomenon in the external launch environment is a highly complex and computationally expensive endeavor. Therefore, we decomposed the full-scale analysis into component problems that could be simulated and validated independently and then used to inform simulations of the full-scale integrated vehicle. We developed robust models using the Loci/CHEM computational fluid dynamics (CFD) software and ultimately, supported by these models, simulations of the entire vehicle were used to augment existing analysis tools and aid the SLS vehicle design process.



Isosurfaces of core stage engine combustion gas (blue) and solid rocket booster effluent (red) show the evolution and mixing of the plumes during Space Launch System ignition.

The first component problem examined the propagation of acoustic waves through the launch environment and established the accuracy of the simulation methods by validating them against real-world test data gained from the Ares I Scale Model Acoustics Test. The simulations tracked the propagation of acoustic waves in both dry launch pad conditions and in conditions with water-based sound suppression systems activated. Dry simulations showed excellent correlation to real-world results and provided NASA with the confidence to move forward with full-scale simulations, while wet simulations provided a new capability for sound suppression to be tailored to a specific vehicle.

For the second component problem, we performed time-accurate, fully 3D simulations of the SRB ignition transient to determine the internal dynamics of the rocket during ignition. We used a Loci/CHEM ignition module to determine the ignition conditions from the chemical kinetics of the propellant and the local heat flux at the propellant surface. When ignited, the simulated propellant "burned" using an empirical boundary condition based on propellant formulation and local pressure. Simulation results were validated through comparisons to data from motor static test firings, which showed excellent correlation. Once validated, the results were used to create a time-dependent, 3D CFD profile that can be used as an input boundary condition to further simulations for SLS launch-induced environments.

Finally, using the results of the sub-scale and SRB simulations, we performed full-scale simulations of the SLS launch environment with the goal of resolving multiple uncertainties in existing IOP analysis tools developed for the space shuttle that could not account for differences in the SLS vehicle configuration. Several simulations indicated that the biggest difference in IOP for the SLS was due to the interaction of the plumes from the SRBs and the core stage engines. These and other findings were used to improve the IOP analysis provided to the SLS vehicle designers by removing unnecessary levels of conservatism, which could lead to increased program costs.

The use of NASA's supercomputing resources was vital to completing this work. Our simulations used thousands of processors over periods of weeks and were typically run in groups of two or more to test model permutations. In addition, each simulation required multiple terabytes of storage, with regular processing of hundreds of individual gigabyte-scale files for visualization, postprocessing, and data analysis.

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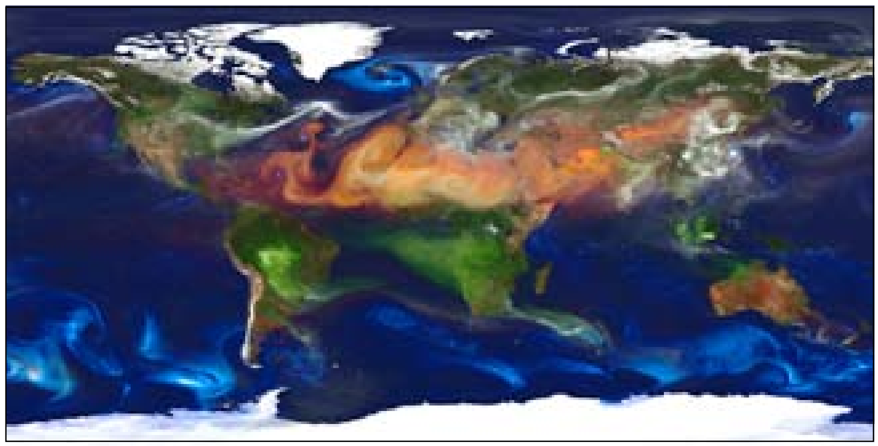
FEATURED DEMO

Recent Advances in High-Resolution Global Atmospheric Modeling

High-resolution global atmospheric modeling provides a unique tool to study the role of weather within Earth's climate system. The Goddard Earth Observing System Model, Version 5 (GEOS-5) is capable of simulating worldwide weather at resolutions of 10 to 3.5 kilometers (km). These mesoscale simulations produced with GEOS-5 represent multiple scales of atmospheric phenomena—from clusters of deep convection, to hurricanes, to large mid-latitude storm systems—within a unified simulation of the global circulation.

The GEOS-5 global mesoscale simulations produce a realistic representation of our atmosphere at resolutions comparable to many satellite observations. This advancement provides an opportunity to perform comprehensive process studies on the formation of regional weather events and their impact on seasonal climate, improve the integration of existing observations into our data assimilation systems, and explore the potential of new observations through carrying out observing system simulation experiments.



The atmospheric winds near the surface (white) and at mid- to upper-levels (colored) that transport and disperse global aerosols within the GEOS-5 atmospheric model.

GEOS-5 uses the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model within these simulations to include the global transport and direct radiative impacts of aerosols. These aerosols include dust particles lifted from the Earth's surface by strong winds and deep convection, sea salt blown from the ocean surface, plumes of sulfates from volcanic eruptions and fossil fuel emissions, and organic and black carbon within smoke from wildfires and human-initiated burning. These tiny particles can be transported long distances from their sources as they get caught up in the strong winds of the atmospheric circulation, and they can have a significant impact on air quality, visibility, and human health.

A two-year global mesoscale simulation at 10-km resolution with GEOS-5 provides our first look at the potential of high-resolution simulations integrating global weather phenomena within the variability of seasonal climate change. The 10-km simulation captured the dynamic variability of North Atlantic tropical cyclone activity for the very active 2005 season and the more typical 2006 season. While resolution does improve the simulated variability of tropical cyclone formation, it is also a key element in improving the intensity of tropical cyclones that form within the model. At 10-km resolution, the GEOS-5 simulations begin to represent the strongest hurricanes with near-surface winds in excess of 160 miles per hour.

The two-year, 10-km GEOS-5 global mesoscale simulation ran on 3,750 processors of the Discover supercomputer at the NASA Center for Climate Simulation for several weeks and produced over 400 terabytes of data. Experimental versions of GEOS-5 at 3.5-km resolution represent the future of global atmospheric modeling including non-hydrostatic dynamics, cloud microphysics, and interactive aerosols—known collectively within the community as global cloud-resolving models. This class of models requires more than 20 times the computational capability of the Discover supercomputer in order to complete a five-day forecast within the three-hour window required for the operational data assimilation system.

William Putman, NASA Goddard Space Flight Center
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FEATURED DEMO

The Search Continues: Kepler's Quest for Habitable Earth-Sized Planets

NASA's Kepler mission has captivated science enthusiasts and astronomers from around the world in its quest to find Earth-sized and smaller planets around other stars. In the three and-a-half years since its launch in March 2009, the Kepler spacecraft has been continuously measuring dips in the brightness of more than 150,000 stars to search for transiting planets.

Ever since Kepler's 95-megapixel photometer began collecting science data, the Kepler team has been performing semi-weekly health checks of the spacecraft and downloading science data once per month. Pixels of interest are transferred to the Kepler Science Operations Center (SOC) at NASA Ames Research Center, where the pixels are calibrated, combined to form light curves, corrected for systematic errors introduced by the instrument, then searched for the signatures of transiting planets.

Data is automatically copied between the Kepler SOC and the Pleiades supercomputer at Ames' NASA Advanced Supercomputing (NAS) facility, with the most computationally intensive portions of the SOC data processing pipeline (the pre-search data conditioning, transiting planet search, and data validation modules) running on Pleiades, and the less-intensive parts on SOC computers. Recently added features and improvements to the SOC pipeline software that correct systematic errors and improve search sensitivities have been mirrored on Pleiades.

As of February 2012, the Kepler team has found 2,321 planet candidates circling 1,790 host stars, with 77 confirmed planets—an 88 percent increase over the previous year. Some of these systems also involve planetary candidates orbiting binary star systems (circumbinary planets). Among the important discoveries enabled by Kepler over the last year: A planet orbiting a double star that, in turn, is orbited by a second distant pair of stars; a circumbinary system with more than one transiting planet, one of which is in the habitable zone of its parent binary star system; and the first exoplanet system with regularly aligned orbits similar to those in our own solar system.

Artist's conception of Kepler-47, the first transiting circumbinary system—multiple planets orbiting two stars—discovered by NASA's Kepler space telescope.

The Pleiades supercomputer enables the enormous planetary transit searches to be completed in less than a day, as opposed to more than a month on the Kepler SOC systems. This year, computer scientists at the NAS facility significantly improved the accuracy and effectiveness of the pipeline software, and completed all the computational runs on Pleiades. The combination of supercomputing power and coding expertise enables the rapid turnaround of analyses of planet candidates. This will benefit the general public, as well—beginning in December, both the pipeline results and all data will be available for analysis with no proprietary period—allowing much greater community participation as we continue into Kepler's extended mission through 2016.

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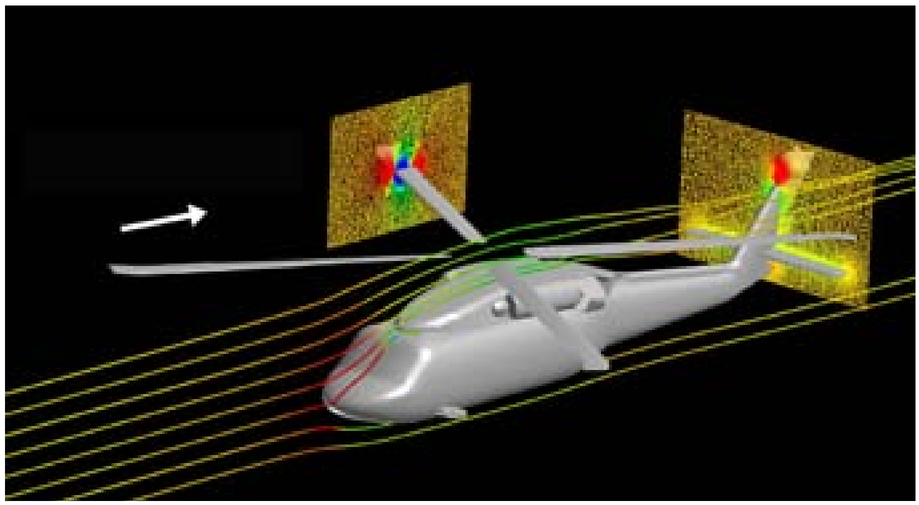
FEATURED DEMO

Adjoint-Based Design for Complex Aerospace Configurations

Aerospace engineers face enormous challenges when designing new aircraft and space vehicles to meet modern safety and efficiency standards. To enable formal, constrained design optimization of complex aerospace configurations, we have developed adjoint-based methods that are implemented in the NASA FUN3D computational fluid dynamics (CFD) code. A single simulation for configurations experiencing unsteady turbulent flows and requiring dynamic/deforming geometries and high-fidelity physical models may require millions of compute hours, so highly efficient strategies are needed to compute accurate sensitivities for many thousands of design parameters.

Our adjoint-based methods, implemented on massively parallel computers, allow design engineers to formally tackle a broad array of complex optimization problems across the speed range. Without these powerful supercomputers, it would be nearly impossible to address these computational problems.



Downstream propagation of flow solution for a UH-60 Black Hawk helicopter in forward flight.

In a typical CFD problem, the governing equations are integrated forward in physical time to determine aerodynamic quantities of interest, such as heat transfer, pressure, and forces. To efficiently compute numerical sensitivities of these quantities with respect to thousands of input parameters, the adjoint approach solves the linearized governing equations in reverse physical time. In this manner, the adjoint solution marches backward in time to determine the sensitivities of output functions due to any input parameters required for the simulation.

We have taken a discrete adjoint approach, in which the discretized governing equations are linearized exactly with respect to the flowfield and mesh variables. Our implementation supports steady and unsteady flows based on compressible and incompressible forms of the Reynolds-averaged Navier-Stokes equations. Computational meshes may include general element types belonging to single-block or overset grid topologies. Furthermore, these grids may be rigidly moving, deforming, or any combination thereof. General parent-child body motion relationships are also accommodated.

The effort required to develop and mature this general capability has taken two decades of sustained research and software development. Our approach has been successfully demonstrated on a broad range of realistic design problems including rotorcraft geometries, fighter jets, biologically inspired micro-air vehicle configurations, active flow control systems, and wind energy devices. The adjoint-based methodology also provides a rigorous foundation, valuable insight, and an effective tool for estimating error, adapting meshes, and quantifying uncertainties for such problems.

A relatively simple, single-point design optimization case typically requires the equivalent of O(30) flow simulations. Since a single simulation may require millions of compute hours, efficient use of the world's most powerful supercomputers is essential. In addition, a customized asynchronous parallel I/O strategy enables the terabytes of data generated to be transferred and stored efficiently.

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NASA ELSEWHERE AT SC12

Science on a Sphere: NASA Climate Supercomputing

Monday: November 12, 2012 at 8:30-9:00 pm

Tuesday: November, 13, 2012 at 12:45-1:15 pm

Wednesday: November 14, 2012 at 11:15-11:45 pm

Thursday: November 15, 2012 at 11:15-11:45 am

Internet2 Booth #1042

High-resolution global simulations are realistically representing our atmosphere at resolutions approaching those of many satellite observations and providing a unique tool to study the role of weather within Earth's climate system.

***Presenter:** Phillip Webster – NASA Goddard Space Flight Center*

Meeting NASA's High-End Computing Goals Through Innovation

Tuesday: November 13, 10:30 a.m. – 11:00 a.m.

Wednesday: November 14, 10:30 a.m. – 11:00 a.m.

SGI Booth #2631

NASA's High End Computing Capability (HECC) project provides scientists and engineers with a world-class computing environment and a full range of support services to facilitate advances in areas across all NASA technical mission organizations. Through strong relationships with the vendor community and a strong technical team, HECC's unique environment was expanded over the last year, and several key innovations were put in place, including the addition of Fourteen Data Rate InfiniBand (IB) into the world's largest IB fabric (65-plus miles of cable) and increasing the hypercube to a twelfth dimension.

***Presenter:** William Thigpen – NASA Ames Research Center*

Monday, November 12, 2012

Ultrascale Climate Data Visualization and Analysis

Climate Knowledge Discovery Workshop
9:00 a.m. – 5:30 p.m.
Room 250-DE

The fourth in a series of planned workshops to discuss the design and development of methods and tools for knowledge discovery in climate science, featuring contributions from researchers in a broad range of domains working on the development and application of large-scale graph analytics, semantic technologies, and knowledge discovery algorithms in climate science.

***Presenter:** Thomas Maxwell – NASA Goddard Space Flight Center*

Tuesday, November 13, 2012

A Dynamic Portrait of Global Aerosols

Scientific Visualization Showcase
5:15 p.m. – 7:00 p.m.
North Foyer

Through numerical experiments that simulate our current knowledge of the dynamical and physical processes that govern weather and climate variability of Earth's atmosphere, models create a dynamic portrait of our planet. The simulation visualized in this presentation captures how winds lift up aerosols from the Earth's surface and transport them around the globe. Such simulations allow scientists to identify the source and pathway of these tiny particles that influence weather and climate.

Author: *William Putman – NASA Goddard Space Flight Center*

The Apache Software Foundation, Cyberinfrastructure, and Scientific Software: Beyond Open Source

Birds of a Feather
5:30 p.m. – 7:00 p.m.
Room 251-A

In this Birds of a Feather session, we examine the Apache Software Foundation as a governance model for open source scientific software communities. The BOF will discuss both general and specific governance requirements for research software communities through interactive discussions motivated by case study presentations. The outcome will be a summary white paper co-authored by BOF volunteers.

Session Leaders: *Marlon Pierce (Primary Session Leader) - Indiana University; Suresh Marru (Secondary Session Leader) - Indiana University;* ***Chris Mattmann (Secondary Session Leader) - NASA Jet Propulsion Laboratory***

Managing Big Data: Best Practices from Industry and Academia

Birds of a Feather
5:30 p.m. – 7:00 p.m.
Room 255-BC

We will explore the challenges faced by companies and scientific researchers managing "big data" in increasingly diverse IT environments including local clusters, grids, clouds, and supercomputers, and present architectural and technology options for solving these challenges, informed by use cases from commercial organizations and academic research institutions. Participants will discuss key questions related to data management, and identify innovative technologies and best practices that researchers should consider adopting. Organizations including Ebay/Paypal, NASA, SGI and IDC will present commercial use cases; the University of Chicago and Argonne National Laboratory will discuss examples from bioinformatics, imaging based science, and climate change research.

Wednesday, November 14, 2012

Student Job/Opportunity Fair

Broader Engagement
10:00 a.m. – 3:00 p.m.
Room 251-ABCDEF

Students interested in graduate fellowships, internships, summer job, graduate school assistant positions or permanent employment will be able to meet with potential employers. Also, pre-registered organizations will interact with the students in computer science, information systems, scientific computing and high performance computing related fields. At the 2011 Student Job/Opportunity Fair, employers from research labs, academic institutions, recruiting agencies and private industry met with students to discuss about research, employment, internship and co-op opportunities. This face-to-face event is open to all students participating in the SC12 conference.

Presenter: *Harper Pryor – NASA Ames Research Center*

Thursday, November 15, 2012

Cosmology Application Session

***Chair:** Subhash Saini – NASA Ames Research Center*

Paper: ***First-Ever Full Observable Universe Simulation***
10:30 a.m. – 11:00 a.m.
Room 255-EF

We performed a massive N-body simulation of the full observable universe. This has evolved 550 billion particles on an Adaptive Mesh Refinement grid with more than two trillion computing points along the entire evolutionary history of the universe, and across 6 orders of magnitudes length scales, from the size of the Milky Way to the whole observable universe. To date, this is the largest and most advanced cosmological simulation ever run. It will have a major scientific impact and provide an exceptional support to future observational programs dedicated to mapping the distribution of matter and galaxies in the universe.

Paper: ***Optimizing the Computation of N-Point Correlations on Large-Scale Astronomical Data***
11:00 a.m. – 11:30 a.m.
Room 255-EF

The n-point correlation functions (npcf) are powerful statistics that are widely used for data analyses in astronomy and other fields. These statistics have played a crucial role in fundamental physical breakthroughs, including the discovery of dark energy. To meet these computational demands, we present a highly-tuned npcf computation code that show an order-of-magnitude speedup over current state-of-the-art.

Paper: ***Hierarchical Task Mapping of Cell-Based AMR Cosmology Simulations***
11:30 a.m. – 12:00 p.m.
Room 255-EF

Cosmology simulations are highly communication-intensive, thus it is critical to exploit topology-aware task mapping techniques for performance optimization. To exploit the architectural properties of multiprocessor clusters (the performance gap between inter-node and intra-node communication as well as the gap between inter-socket and intra-socket communication), we design and develop a hierarchical task mapping scheme for cell-based AMR (Adaptive Mesh Refinement) cosmology simulations, in particular, the ART application.

Big Data and Data Integrity – How Do We Handle Reliability, Reproducibility, and Accessibility

Panel
3:30 p.m. – 5:00 p.m.
Room 355-BC

As HPC data becomes larger and more complex, so does our need to maintain its integrity. Threats to our data's integrity come at different levels. The HPC community has experience these already in transfers of large data over the wide area, reproduction of data from large complex systems, silent corruption of data in our compute and file systems, and the requirements and expectations the community expects from HPC compute and storage clouds. This panel of experts will discuss their organizations views on the various issues and explain potential solutions to these pressing issues.

***Moderators/Panelists:** Tracey D. Wilson (Moderator) - Computer Sciences Corporation; Ron Bewtra – NOAA; **Daniel Duffy – NASA Goddard Space Flight Center**; James Rogers - Oak Ridge National Laboratory; Lee Ward - Sandia National Laboratories; Keith Michaels – Boeing*


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