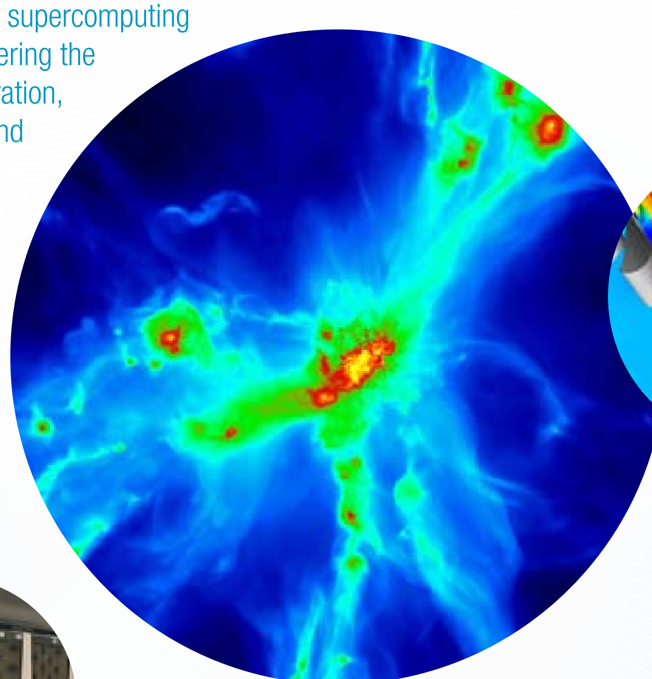
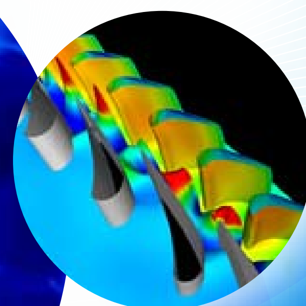
National Aeronautics and Space Administration

NASA @ SC08

Inspiration, Innovation, Discovery

Visit NASA researchers at booth 1343 to hear about the role of supercomputing technologies in pioneering the future in space exploration, scientific discovery, and aeronautics research





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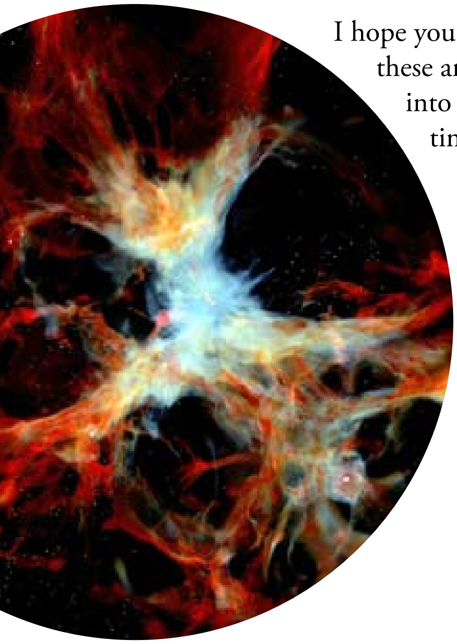
Welcome fellow participants:

On the occasion of the SC08 conference, NASA is pleased to note that throughout our fifty year history, the space agency has depended on high-end computing technologies to extend our Nation's exploration reach throughout the solar system, to advance fundamental scientific knowledge, and to improve the performance of aircraft and space vehicles.

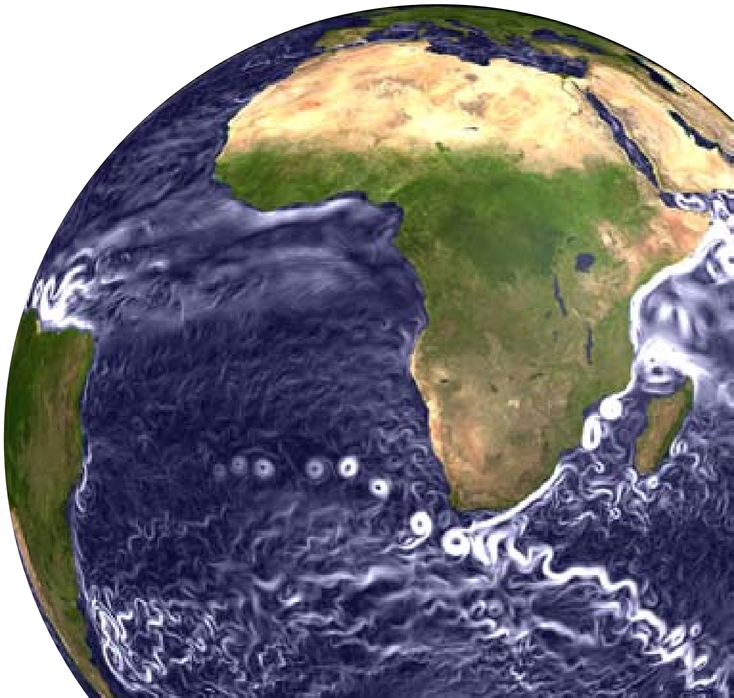
Michael D. Griffin, NASA Administrator

At SC08, representatives of six NASA Centers will demonstrate the use of our supercomputing capabilities for the Agency's aeronautics, exploration systems, science, and space operations missions. Visitors to our exhibit will be able to see how NASA's Fundamental Aeronautics Program is using computing power to explore innovative ways to reduce jet engine noise. They also will learn about how NASA scientists use aerothermal computational fluid dynamics to help design the thermal protection system for America's next generation spacecraft, the Orion crew exploration vehicle. Finally, NASA will also showcase its Multi-scale Modeling System, which is advancing our ability to predict tropical storms by using computational modeling.



I hope you have an opportunity to learn about these and other impressive supercomputing applications that are enabling NASA, as we move into our second half-century, to expand our commitment to technical excellence and to continue pioneering the space frontier on behalf of the American public.

Michael D. Griffin
NASA Administrator



AERONAUTICS RESEARCH MISSION DIRECTORATE

The Aeronautics Research Mission Directorate's efforts are directed toward the transformation of our nation's air transportation system, and developing the knowledge, tools, and technologies to support future air and space vehicles. Our focus is on cutting-edge, fundamental research in traditional aeronautical disciplines. We are investing in research for the long term in areas appropriate to NASA's unique capabilities and meeting our charter of addressing national needs. We are advancing the science of aeronautics as a resource for our nation, as well as advancing technologies, tools, and system concepts that can be drawn upon by civilian and military communities, and other government agencies. For more information, visit: http://www.aeronautics.nasa.gov

Advances in USM3D for Supporting Large, Unstructured CFD Simulations

This past year has seen dramatic improvements in the capability of USM3D to perform extensive simulations of large problems in aero and space vehicle design on the latest NASA computing platforms. The principal areas of improvement are:

- Reduced memory requirements—the code now supports problems as large as 100M cells on the new reduced-memory XEON-based Pleiades system
- Improved performance—problems execute at or above previous Altix speeds on the new system, and 5x over what was possible just two years ago
- Imbedded visualization—a new imbedded graphics system has been introduced that allows users to visualize the flowfields on the their desktop computers in near-real-time as the calculation proceeds
- Parameter study support—a graphical user interface-based job submission system has been constructed to simplify the input/output "bookkeeping" needed in large parameter studies involving many runs

All of these features are discussed in the technical presentation, which will also include a demonstration of the new imbedded visualization system.

POC at SC08: James Taft, NASA Ames

Computational Fluid Dynamics Simulation of the V-22 Isolated Rotor

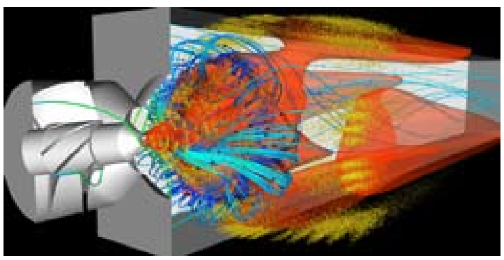
V-22 Osprey transitioning from helicopter to airplane mode. *NASA Ames*

Helicopters and tiltrotor aircraft provide many crucial services including emergency medical and rescue evacuation, security patrols, offshore oil platform access, heavy-lift capability, and military operations. Some of the phenomena associated with rotorcraft flight include aerodynamic performance and noise, vortex wakes generated from the rotating blades, and rotor blade flexibility and vibration. Many of these phenomena are poorly understood and difficult to accurately predict. One of the goals of the Subsonic Rotary Wing project, part of NASA's Fundamental Aeronautics Program, is to develop improved physics-based computational tools to address these issues.

NASA scientists are developing more accurate computational fluid dynamics (CFD) and computational structural dynamics (CSD) flow simulation tools for coupling the CFD, CSD, and rotor control system into a unified framework. Computational efficiency is addressed through numerical algorithms that require less memory with improved accuracy, and that scale well with large parallel computer platforms such as those housed at the NASA Advanced Supercomputing (NAS) facility at Ames. A new NAS concurrent visualization paradigm is also used to "see" what the flow is doing by coupling visualization software directly into the CFD/CSD computer codes. This provides improved visual acuity and reduces disk space requirements by orders-of-magnitude over traditional post-processing methods.

POC at SC08: Neal Chaderjian, NASA Ames

Emissions Calculations of a Lean Direct Injection Combustor



Overview of the LDI process. Air flows through the swirler (shown as streamtubes, colored by velocity magnitude), producing a toroidal recirculation zone. Fuel is injected at the center of the venturi (liquid spray particles, sized by droplet diameter). The hot combustion zone (red isosurface) is shaped by the recirculation zone, which is critical to combustion stability, but also produces NOx. *Anthony C. Iannetti, NASA Glenn*

Reducing harmful combustion emissions like carbon monoxide (CO), and smog-producing nitrogen oxides (NOx) is an important goal of the NASA Fundamental Aeronautics Program. The National Combustion Code (NCC), a state-of-the-art computational fluid dynamics (CFD) code, recently completed a phase-one validation against an experimental Lean Direct Injection (LDI) combustor. Using two NASA supercomputers—Columbia, an SGI Altix and RTJones, an SGI ICE system—each numerical experiment took approximately four days to complete using 96 processors. The operating pressure of the LDI combustor was at atmospheric pressure, and Jet-A fuel was injected into the combustor as a liquid spray at a fuel-lean mixture equivalence ratio of 0.75 (more air available than fuel). We compared important features such as airflow (velocity vectors), temperature, and emissions (CO and NOx). Results indicated most of the fuel and air mixing occurred at the fuel injector tip, but also showed weaknesses in combustion modeling assumptions. With these results, NASA is improving the NCC, planning for future gas turbine combustor experiments, and helping select future supercomputers to meet the Agency's growing computational requirements.

POC at SC08: Anthony Iannetti, NASA Glenn

Jet Engine Turbine Noise Generation

Contemporary commercial jet engines are much quieter than their 1970s vintage predecessors. However, with the increasing number of flights and greater population density near airports, noise produced by today's aircraft is still objectionable. NASA is continually searching for innovative ways to reduce the noise from aircraft turbofan engines. To make future engines quieter, noise from components deep inside the engine core must be reduced.

Jet engines are being designed with increasingly higher bypass ratios. This means the fan on the front of the engine moves a greater quantity of air (compared to the amount going through the engine core) without changing the velocity of the air as much as previous designs. As a result, the engine produces the same thrust but in a more efficient and quieter way. However, while noise produced by the fan and jet exhaust of these high-bypass engines has been reduced, other sources of engine noise such as the compressor, combustor, and turbine have become more significant. Numerical simulations of the engine core, generated by the NASA TURBO code, are being used to identify the sources of this noise, as the first step in finding ways to mitigate noise from the engine core and enable the next generation of quiet engines.

POC at SC08: Richard Rinehart, NASA Glenn

Simulating Radiation Transport and Chemistry in Reentry Flows

Calculations based on rigorous theoretical foundations are being used to simulate radiative transport under hypersonic reentry conditions. Such simulations are necessary for large, high-speed reentry bodies such as the crew exploration vehicle (CEV) and High Mass Mars Entry Systems (HMMES) because the radiative and convective heat loads may become comparable. These simulations of convective and radiative heating are needed to determine size requirements for high-speed reentry vehicle heat shields.

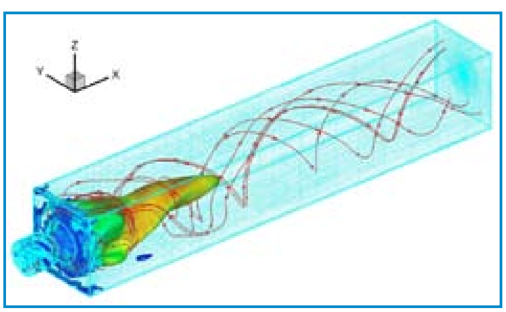
Because coupling of radiation with fluid flow is expensive (due to three extra dimensions—two angular directions plus frequency), most flow field simulations of high-speed reentry heating do not couple the radiation transport to the fluid flow; instead, they compute the fluid flow first and then add radiation parameters.

Computation of radiative coefficients involves understanding the detailed chemistry in the flow field. These coefficients and chemical reaction rate parameters are determined from first principles quantum chemistry and scattering calculations.

Calculations were carried out on the Columbia supercomputer at NASA Ames using both internally developed software and the commercial quantum chemistry packages GAMESS, GAUSSIAN2003, and MOLPRO.

POC at SC08: Richard Jaffe, NASA Ames

Very Large Eddy Simulation of Combustor Flows



Snapshot of the vortex breakdown bubble and streamlines in a single-element lean direct injection combustor. *Tsan-Hsing Shih, Ohio Aerospace Institute; Nan-Suey Liu, NASA Glenn Research Center*

Flows in combustors are three-dimensional and intrinsically unsteady due to massive flow separation and strong swirling. These flows contain large-scale, coherent structures which play an important role in determining efficiency, robustness, and emissions of the combustion. Traditional engineering tools cannot provide any information on these coherent structures, but existing, more scientific-oriented approaches are often too costly for practical engineering applications. There is a need for approaches capable of capturing these dynamically important large-scale flow structures in the simulation, but at a reasonable computational cost.

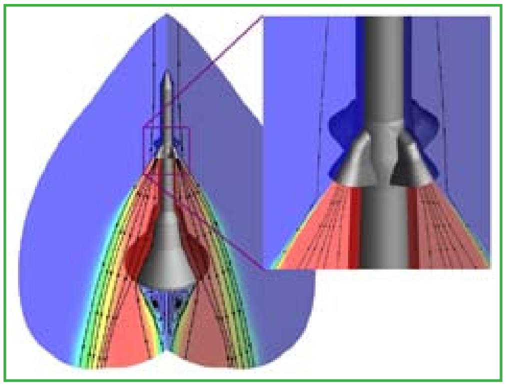
Under the Subsonic Fixed Wing and Supersonic projects (both part of NASA's Fundamental Aeronautics Program), NASA researchers are addressing this need by developing an approach called partially resolved numerical simulation (PRNS). PRNS has the characteristics of a very large eddy simulation and can effectively bridge the modeling fidelity and computing resource gaps between traditional engineering and the more scientific-oriented approaches. This tool should be of particular interest to researchers and designers working in an engineering environment.

POC at SC08: Anthony Iannetti, NASA Glenn

EXPLORATION SYSTEMS MISSION DIRECTORATE

The Exploration Systems Mission Directorate is developing a constellation of new capabilities, supporting technologies, and foundational research that enables sustained and affordable human and robotic exploration of the moon, and later, Mars. Key research areas include: development of Orion, the new crew exploration vehicle for astronaut travel in space; health and safety assurance of crews on long-duration space missions; development of Ares I, the launch vehicle that will carry Orion and its astronaut crew into space; and Ares V, the heavy-lift cargo launch vehicle that will carry the equipment astronauts need to explore the moon and beyond. For more information, visit: http://exploration.nasa.gov

Aerothermal Computational Fluid Dynamics for CEV Aerosciences Project



Streamlines and engine plume gas concentration for Orion launch abort system. *Ryan McDaniel, NASA Ames*

NASA's Constellation Program is designing a new space exploration system capable of carrying crew or cargo to the International Space Station (ISS) or the Moon. The Data Parallel Line Relaxation (DPLR) computational fluid dynamics (CFD) flow solver, combined with the computing power offered by NASA's Columbia supercluster, has enabled high-fidelity computational solutions to complex aerothermal design challenges posed by the crew exploration vehicle (CEV). In the event of a launch failure, the launch abort vehicle (LAV) will transport the crew away from the rocket booster.

CFD is being used to answer key aerothermal design questions such as: what heating on the vehicle is due to abort motor exhaust plumes; how does the heating footprint change during ascent due to interactions between plume and freestream flow; and what thermal protection system (TPS) design requirements will maintain a safe environment for the crew within the CEV.

The CEV crew and service modules are physically attached by a system of compression pads. Some aerothermal design questions posed by the compression pads include: what is the heating footprint on the heatshield downstream from the compression pads; how does the heatshield shape change due to the heating augmentation; and what is the optimal design for the compression pads (e.g., protruding vs. recessed, straight vs. beveled walls, round corners vs. ramp).

POC at SC08: Michael Olsen, NASA Ames

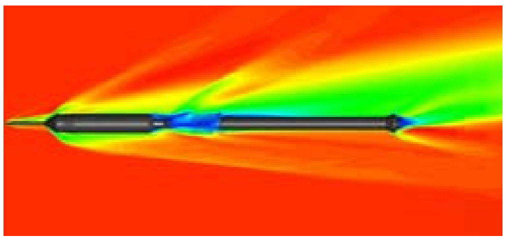
Ares I Ascent Aerodynamic Analysis using USM3D and OVERFLOW

The full-stack configuration of the Ares I crew launch vehicle consists of the launch abort system, crew capsule, service module, upper stage, frustum, first stage, and aft-skirt. Numerous detailed protuberances on the vehicle also add to the complexity of computational fluid dynamics (CFD) and wind tunnel model geometries. CFD analyses are performed to assess the aerodynamic performance of evolving Ares I designs at flow conditions representative of the launch trajectory ascent phase. These analyses complement broader wind tunnel data to refine Ares ascent aerodynamic databases. CFD provides computed line loads for structural design, which represent section-by-section integrated aerodynamic load distributions on the vehicle. CFD is also the primary tool used for flow diagnostics and determining estimates for critical tunnel-to-flight Reynolds number scaling effects.

In addition, CFD was used for exploratory parametric studies prior to any wind tunnel testing within the program, enabling quick assessments of design changes and revealing possible improvements for better aerodynamic performance. Early access to advanced CFD analyses led to better wind tunnel model design, more efficient use of instrumentation, and improved overall test matrix development.

POC at SC08: Khaled S. Abdol-Hamid, NASA Langley

Ares I Stage Separation Aerodynamics

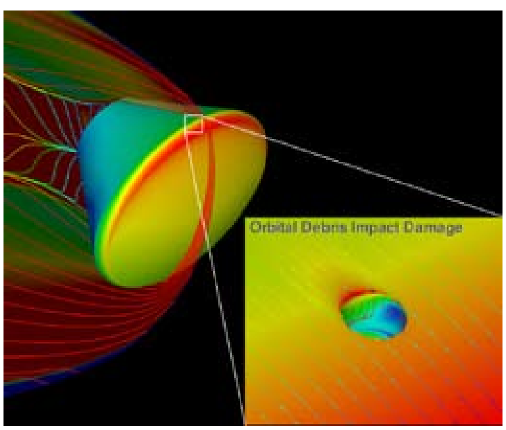


Flowfield around the CLV during stage separation. *Jeff Onufer, NASA Ames*

To support development of the new Ares I crew launch vehicle (CLV), NASA's Exploration Systems Mission Directorate is using modeling and simulation capabilities to predict various aspects of the launch process and assess viability of the new rocket design. The Ares I launch vehicle employs a solid rocket booster (SRB) for lift-off from the launch pad. Once the fuel in the SRB is consumed, the SRB is discarded from the launch vehicle. This stage separation maneuver is studied using computational fluid dynamics (CFD) simulations to analyze aerodynamic interference between the two bodies. The forces and moments on the vehicle body are computed for each separation position and the resulting patterns are analyzed to quantify aerodynamic interference.

POC at SC08: Shishir Pandya, NASA Ames

CEV Thermal Protection System CFD Simulations

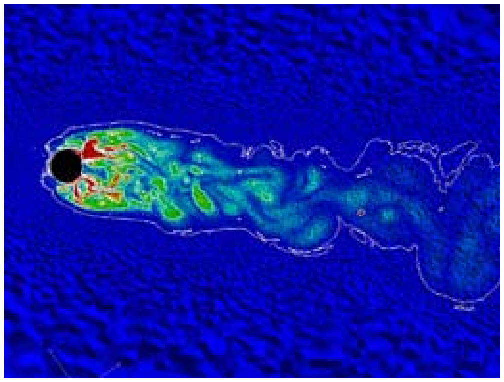


Simulation of the full CEV with small-scale damage to the shoulder region. *Dinesh K. Prabhu, Todd R. White, and Andrew J. Hyatt, NASA Ames*

A thermal protection system (TPS) will protect NASA's crew exploration vehicle (CEV) as it returns from space at over 23,000 mph, generating enormous amounts of heat. To understand the environments the TPS must withstand, NASA engineers use aerothermal computational fluid dynamics (CFD) to simulate on-the-ground arc jet tests and effects of in-orbit debris damage. Arc jets are powerful, high-energy facilities used for testing TPS materials in environments similar to those of atmospheric entry. CFD simulations of ground tests are combined with measurement data to determine important flow quantities that cannot be found from experiment alone. These simulations are vital to understanding how materials perform in intense, chemically reacting flows and to help drive material selection and heatshield design. The potential effects of critical damage due to in-space debris impacts are simulated using CFD and material response codes. The CFD code provides aerothermal surface conditions, such as heat flux, pressure, and shear, and the material response model then indicates how the TPS would react to such a flow. These combined simulations are used to design more resilient heatshields and protective covers.

POC at SC08: Todd White, ELORET Corporation, NASA Ames

FUN3D CAE Simulations of Ares Crew Launch Vehicle Flexible Response



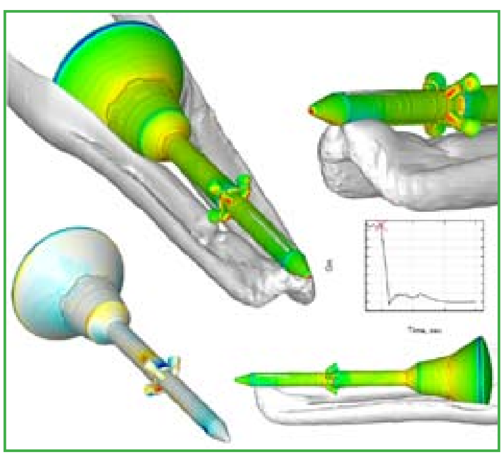
Cross-section of FUN3D grid and contours of vorticity due to ground wind behind the Ares crew launch vehicle. *Ray Mineck, NASA Langley*

The Navier-Stokes computational fluid dynamics (CFD) code FUN3D is being used to simulate the static and dynamic flexible vehicle responses to ascent aerodynamics and ground wind-induced oscillations. FUN3D is an unstructured, finite volume-based CFD code developed at NASA Langley Research Center. It is capable of performing distributed parallel computations of turbulent and laminar, steady and unsteady flowfields that include both static and dynamic fluid-structure interaction (FSI). It allows direct coupling between the flow solver and an external finite element structural solver for generating static solutions, and also allows FSI computing with structural mode shapes for dynamic solutions.

The Ares Program is performing computational aeroelastic (CAE) flutter analyses of crew launch vehicle (CLV) ascent using FUN3D, combined with an efficient reduced-order modeling (ROM) method. This approach allows computation of the dynamic aeroelastic responses of the vehicle at many different flight conditions, enabling assessment of any potential aeroelastic instabilities throughout the ascent trajectory. This work represents the first large-scale use of CFD to perform launch vehicle aeroelastic stability analyses for the purpose of flutter clearance. The Ares Program is also performing CAE analysis of ground wind-induced oscillation of the vehicle on the launch pad using FUN3D Detached Eddy Simulation (DES). The purpose of this analysis is to assess potential coupling between vortex shedding and vehicle structural modes. Because the vortex shedding of a full-scale vehicle occurs in a critical Reynolds number range, analysis reveals a chaotic shedding pattern.

POC at SC08: Robert Bartels, NASA Langley

OVERFLOW Time-Accurate Analyses for Orion Launch Abort Control Motors



Simulation snapshot of thrust allocation change from south-firing jets to null-firing jets.
Stuart Rogers, NASA Ames

The Orion launch abort vehicle (LAV) consists of a tower-mounted tractor rocket tasked with carrying the crew module safely away from the launch vehicle in the unlikely event of a catastrophic failure during ascent. The Orion system relies primarily on eight attitude control motors (ACMs) for pitch control during much of the abort trajectory in many of the likely abort scenarios. In this work, the OVERFLOW computational fluid dynamics (CFD) code was used to compute the flow about the LAV in a time-accurate fashion as the ACMs were firing and the thrust allocation was changing. The goal of these simulations was to assess the time lag of the vehicle aerodynamic response relative to the time it takes the ACM jets to change from one thrust allocation to another. Understanding the effects of the ACM jets on vehicle aerodynamics is critical to predicting LAV performance and mitigating risks associated with the ACM system.

POC at SC08: Andrea Nelson, NASA Ames

Physically-Based Global Illumination Simulation for the Hubble Space Telescope

STS-125—the Hubble Space Telescope Servicing Mission 4—will include a sensor package for advanced autonomous relative navigation (RNS). To support RNS algorithm development and testing, images of the shuttle's approach to Hubble were rendered on the Discover cluster using a NASA Goddard-developed ray tracing application with attention to physically-based, unbiased simulation of orbital lighting, RNS detector technology, and spacecraft materials properties. *NASA*

The Relative Navigation Sensor (RNS) experiment will be carried in the shuttle bay onboard STS-125, the Hubble Space Telescope Servicing Mission 4, in early 2009. A portion of that experiment utilizes CMOS-based video cameras and the Goddard Natural Feature Image Recognition (GNFIR) machine vision algorithm to perform a "pose" estimation experiment during the shuttle's approach and rendezvous with Hubble. Ultimately, elements of the RNS experiment will be used as part of a complete autonomous navigation system.

To facilitate testing and feature training of the GNFIR algorithm, an image synthesis application was developed to simulate the three RNS camera views. This image synthesis is achieved using unbiased, physically-based Monte Carlo path (ray) tracing techniques to simulate the global illumination of Hubble and the detector/lens system. As with all Monte Carlo methods, variance in light sampling appears as noise in the generated image. The edge-detection processing of the GNFIR algorithm was sensitive to this variance and required a large number of rays/pixel (100,000) to generate "clean" images for pose estimation processing.

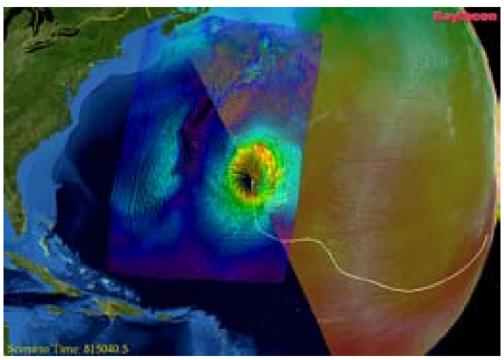
Images were generated using 1,024 processor cores on NASA Goddard's Discover cluster, with parallel execution of the path tracing code. This work was done in minutes instead of days, making it possible to complete algorithm testing on schedule.

POC at SC08: Jim McElvaney, NASA Goddard

SCIENCE MISSION DIRECTORATE

NASA's Science Mission Directorate conducts scientific exploration that is enabled by access to space. We project humankind's vantage point into space with observatories in Earth's orbit and deep space, satellites visiting our moon, Mars, and other planetary bodies, and robotic landers, rovers, and sample return missions. From space, in space, and about space, NASA's science vision encompasses questions as practical as next week's weather, as enticing as lunar resources, and as profound as the nature of the universe. The Science Mission Directorate organizes its work into four broad scientific pursuits: Earth Science, Planetary Science, Heliophysics, and Astrophysics. For more information, visit: http://nasascience.nasa.gov/

3-D Hurricane Visualization and Analysis Tool



QuikSCAT versus WRF model wind for Hurricane Helene. *Raytheon Information Solutions; JPL Hurricane Research Group; JPL PO.DAAC*

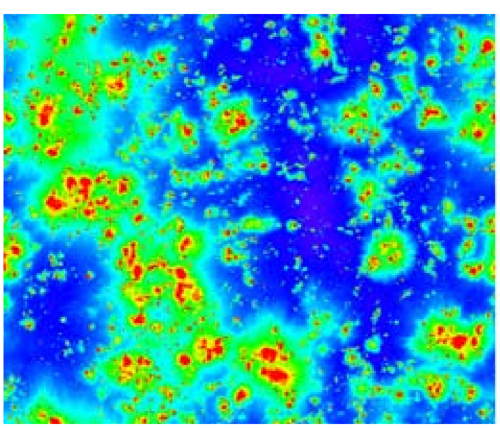
A 3-D visualization system, VIS, based on Raytheon's Enterprise Modeling and Simulation System (EMS), was developed through a joint collaboration between NASA's Jet Propulsion Laboratory (JPL) and Raytheon to visualize and compare 3-D observational data and model output for hurricane studies.

For this demonstration, we will display datasets of the 2006 category 4 hurricane, Helene: a 5-kilometer resolution sea-surface temperature (SST) for the North Atlantic Ocean, the QuikSCAT Wind vectors sub-sampled in a 2,000km x 2,000km region around the hurricane center, the Tropical Rainfall Measuring Mission (TRMM) water vapor profiles, and the Weather Research & Forecasting (WRF) hurricane model output co-located with the observations.

We can animate the formation of Hurricane Helene using available observational data along the hurricane track. We can also compare the model and observational data side-by-side, and slice through the rain profile across track, along track, or vertically. The three-level moving domain WRF model for Hurricane Helene was run on an SGI Altix supercomputer at JPL.

POC at SC08: Heidi Lorenz-Wirzba, Jet Propulsion Laboratory

3-D Radiative Transfer Hydrodynamic Cosmological Reionization Simulations



We have carried out the world's largest 3-D radiative transfer hydrodynamic simulations of cosmological reionization. Our simulations resolve ionizing photon-producing galaxies in a 100-megaparsec (Mpc) box with 26 billion particles. Our simulations concurrently treat hydrodynamics of the cosmic gas with a total variation diminishing hydrocode and a 3-D ray tracing code to accurately follow propagation of cosmological reionization fronts.

POC at SC08: Renyue Cen, Princeton University

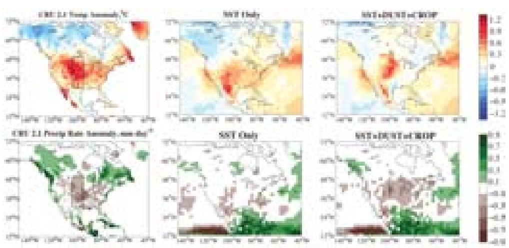
Images of a 100Mpc^2 slice with a thickness of two hydro cells (130 kiloparsec/h) from the late reionization model, showing the redshifts of reionization of individual cells. *Hy Trac, Renyue Cen, Princeton University; Avi Loeb, Harvard University*

Accelerating Earth and Space Applications With IBM Cell Technology

To accommodate ever-increasing model resolutions and physical processes, Earth and space science applications must rely on multi- and many-core processors now dominating high-end computing systems. One attractive option is IBM's Cell Broadband Engine System, which offers order-of-magnitude peak performance increases over conventional processors. NASA Goddard Space Flight Center's Software Integration and Visualization Office (SIVO) is supporting the NASA High-End Computing Program by evaluating the impact of the Cell processor and developing solutions to mitigate risks in porting applications to it. Small local memory in the Cell's Synergistic Processing Element (SPE), and a low-level communication mechanism make the Cell a challenging programming environment for running full science applications. SIVO focused on one of the most computationally intensive parts of NASA's Goddard Earth Observing System Model, Version 5 (GEOS-5)—the solar radiation component. The group converted the baseline component code (single-precision, Fortran) to C and ported it to the Cell-based IBM BladeCenter QS20 system at the University of Maryland, Baltimore County's Multicore Computational Center. Latest results show the Cell ran the code 8.8, 11.6, and 12.8 times faster than a core on Intel's Woodcrest, Dempsey, and Itanium2 processors, respectively. Researchers are currently utilizing new Cell Fortran compilers with a hybrid Fortran/C code. More information: http://sivo.gsfc.nasa.gov

POC at SC08: Shujia Zhou, NASA Goddard

Amplification of the Dust Bowl Drought Through Human Land Degradation



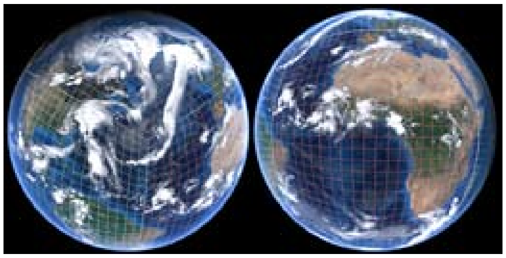
Temperature and precipitation anomalies for the 1932–39 Dust Bowl drought from a climate dataset and two model experiments: SST-ONLY (SST forcing only) and SST+DUST+CROP (full land degradation in the form of a Great Plains dust aerosol source and crop removal). *Benjamin Cook, National Oceanic and Atmospheric Administration; Ron Miller, NASA; Richard Seager, Lamont-Doherty Earth Observatory*

The Dust Bowl drought of the 1930s was highly unusual for North America, with maximum drying in the central and northern Plains, warm temperature anomalies across nearly the entire continent, and widespread dust storms. General circulation models (GCMs), forced by sea-surface temperatures (SSTs) from the 1930s, produce a serious drought—but one centered in the southwest and without warming in middle North America. Simulations using the NASA Goddard Institute for Space Studies' ModelE GCM show that to reproduce the anomalous features of the Dust Bowl drought, it is necessary to include forcing from human land degradation. In the GCM, degradation over the Great Plains is represented as a reduction in vegetation cover (crop failure) and the addition of a soil dust aerosol source. As a result of land surface feedbacks, the drought simulation is much improved when including these conditions. Notably, precipitation and temperature anomalies are of similar magnitude and in a similar location compared to the observations. We conclude that human land degradation not only led to the 1930s dust storms, but also amplified the drought. Together, they turned a typical SST-forced drought into one of the worst environmental disasters in U.S. history. More information: http://pubs.giss.nasa.gov/abstracts/2008/Cook_etal.html

POC at SC08: Thomas Clune, NASA Goddard

The Cubed-Sphere Goddard Earth Observing Model

The NASA Goddard Earth Observing System (GEOS) model integrates multiple models using the Earth System Modeling Framework (ESMF) such that components may be interchanged or augmented under a common computational framework. GEOS has been extended to the cubed-sphere grid configuration with the inclusion of a cubed-sphere finite-volume dynamical core component. The inclusion of this component



The cubed-sphere grid, overlaid on the Earth with satellite observations of clouds, provides a quasi-uniform mapping of grid cells on the sphere for solving the equations of motion, thermodynamics, and moist physics within the atmosphere. *William Putman, NASA Goddard*

has poised GEOS to efficiently address high-resolution climate, weather, and data-assimilation problems on petascale computing platforms.

Over the last four decades, increased computing capacity and enhanced scientific capability have joined to produce remarkable advances in the science of earth system modeling. Global atmospheric modeling has benefited from increased computing power, allowing more accurate and efficient solution of the equations of motion, more advanced representation of physical processes, and increased spatial resolution of the representative motions.

The cubed-sphere GEOS modeling system is being developed to address all scales of global modeling challenges. These challenges include the computing capacity problem of climate change, the computing capability arena of weather prediction and data assimilation, and the grand-challenge problems of high-resolution meso- to micro-scale non-hydrostatic weather prediction and extreme event modeling, which require hundreds to hundreds of thousands of computational processors.
More information: http://sivo.gsfc.nasa.gov/cubedsphere.html

POC at SC08: Thomas Clune, NASA Goddard

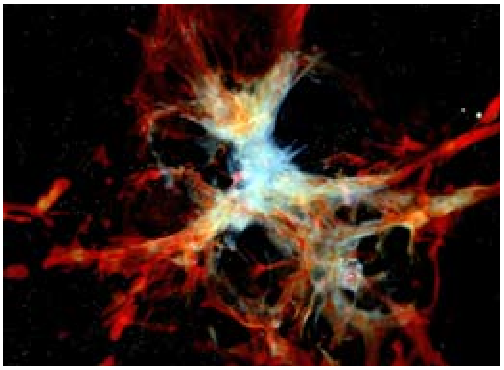
ECCO2: High-Resolution Global Ocean and Sea-Ice Data Synthesis

Surface currents on September 9, 2005 in a partially constrained ECCO2 computational solution. The luminance and opacity of the streak lines is modulated by the surface current speed, with saturation level at 0.5 meters per second. Background is from NASA MODIS imagery. *Chris Henze, NASA Ames*

To increase understanding and predictive capability of the ocean's role in future climate change scenarios, the NASA Modeling, Analysis, and Prediction (MAP) Program is funding a project called Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2): High-Resolution Global-Ocean and Sea-Ice Data Synthesis. ECCO2 aims to produce increasingly accurate syntheses of all available global-scale ocean and sea-ice data at resolutions that start to resolve ocean eddies and other narrow current systems, which transport heat, carbon, and other properties within the ocean. ECCO2 data syntheses are obtained by least squares fit of a global full-depth-ocean and sea-ice configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) to the available satellite and in-situ data. ECCO2 data syntheses are being used to quantify the role of the oceans in the global carbon cycle, to understand the recent evolution of the polar oceans, to monitor time-evolving term balances within and between different components of the Earth system, and for many other science applications. More information: http://ecco2.org/

POC at SC08: Constantinos Evangelinos, Massachusetts Institute of Technology

The First Stars and Galaxies in the Universe

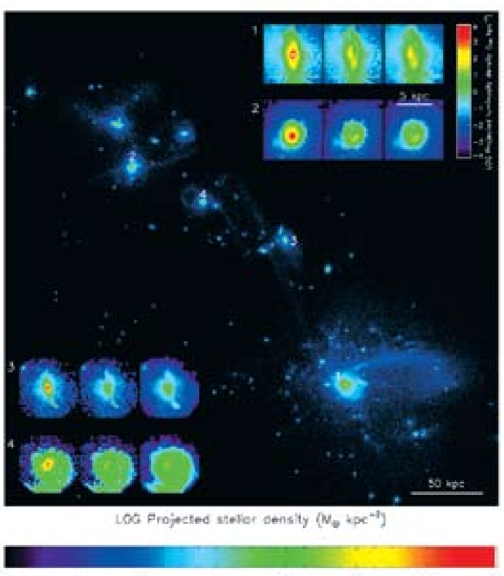


Cosmic web surrounding the heated dwarf galaxy, showing cold gas in red, and warm in blue. This volume rendering was computed with photo-realistic ray tracing, accelerated on a graphics processing unit. *Ralf Kaehler, Zuse Institute Berlin*

We follow assembly of the first galaxies, which will be observed with the upcoming James Webb Space Telescope, using an adaptive mesh refinement code, Enzo. We simulate these earliest galaxies "one star at a time," starting with the first generation of stars approximately 80 million years after the Big Bang and studying effects from stellar radiation on the environment of these nascent galaxies. The Enzo code calculates gravity, hydrodynamics, non-equilibrium chemical systems, and radiation transport. The chemistry module tracks evolution of nine species of atomic hydrogen, helium, and molecular hydrogen, which are the important ingredients of primordial gas before any stars were born. The radiation transport module computes the evolution of irradiated volumes around stars. These regions are approximately 30,000 kelvin and are completely ionized. We use ray tracing to transport the radiation on the adaptive mesh. These calculations were done using 16 to 128 processors on an SGI Altix 3700 Bx2 at Stanford University and on the Discover system at Goddard's NASA Center for Computational Sciences.

POC at SC08: John Wise, NASA Goddard

Galaxy and Star Formation Simulations



We have carried out unprecedented cosmological simulations of galaxy formation with an adaptive mesh refinement hydrocode. These simulations have a sufficiently large cosmological volume to provide a representative sample of galaxies and to facilitate the essential dynamics of galaxy formation—including complex interactions between galaxies and their surroundings. At the same time, they provide sufficiently high resolutions to resolve the galaxies. We show how spiral galaxies are born naturally in the cosmological context, through complex mergers and accretion, how elliptical galaxies are created through major mergers, and how stars are grouped according to their age. More information: http://people.nas.nasa.gov/~bgreen/renyue/AMR_GalaxyFormation.mov

POC at SC08: Renyue Cen, Princeton University

The main image displays the projected stellar mass density of a region of commoving size 1x1 Mpc2 with a depth of 2Mpc at $z=3$. The insets zoom in on the four most massive galaxies and show their projected luminosity density distributions. *Hy Trac, Renyue Cen, Princeton University*

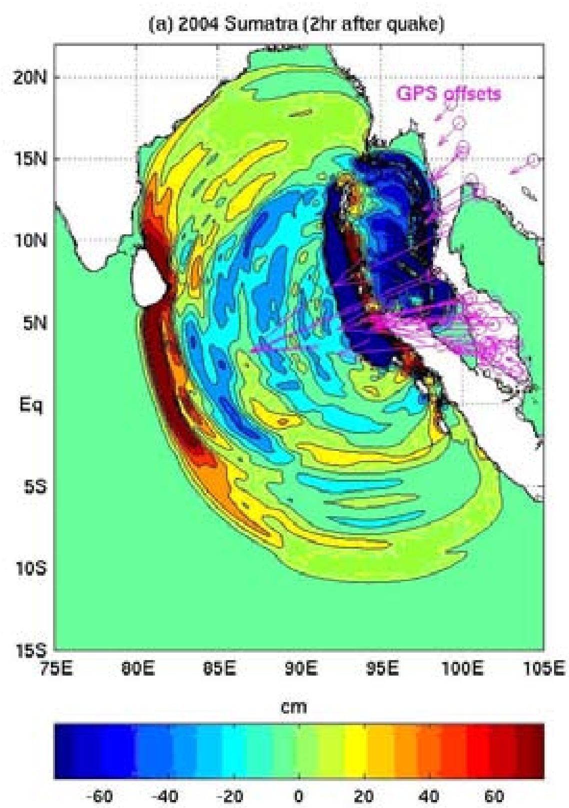
GFDL's Coupled Data Assimilation System on NASA High-End Computers

Climate changes occur in a coupled Earth system that includes the atmosphere, ocean, land, and sea-ice components. Due to incomplete understanding of the dynamical and physical processes, modeling is always uncertain, and generated simulations drift away from real-world scenarios. Climate modeling includes predicting future changes as well as assessing historical variations. The necessary estimates of climate states and initial conditions come from data assimilation—blending observational data with coupled models. Assimilation requires massive computational resources.

With computational support from the NASA Advanced Supercomputing Division, the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL) has developed a coupled data assimilation system consisting of an ensemble filter applied to GFDL's fully coupled global climate model. Within the coupled framework, the assimilation provides a self-consistent, temporally continuous estimate of the model state and its uncertainty, in the form of discrete ensemble members that can be used to directly initialize probabilistic climate forecasts with minimal initial coupling shocks.

POC at SC08: Zhi Liang, National Oceanic and Atmospheric Administration

GPS-Guided Simulation of the 2004 Indian Ocean Tsunami



Scientists have long believed tsunamis form from vertical deformation of the sea floor during undersea earthquakes. However, seismographic and global positioning system (GPS) data from the 2004 Indian Ocean earthquake show that such deformation was too small to generate the powerful tsunami that ensued. We have developed a GPS-guided simulation method which shows that horizontal forces were responsible for two-thirds of this tsunami's height, as observed by three satellites (NASA's Jason, the U.S. Navy's Geosat Follow-On, and the European Space Agency's environmental satellite, Envisat), and that these forces generated five times more energy than the earthquake's vertical displacements. The horizontal forces also best explain the way the tsunami spread out across the Indian Ocean. The same mechanism was also found to explain the data observed from Sumatra's 2005 Nias earthquake and tsunami.

How the method works: An earthquake's epicenter is located using seismometer data. GPS displacement data from stations near the epicenter are then gathered to derive sea floor motions. Based on these datasets, local topography data, and new theoretical developments, a new "tsunami scale" measurement from 1 to 10 is generated, much like the Richter Scale used for earthquakes.

POC at SC08: Heidi Lorenz-Wirzba, NASA JPL

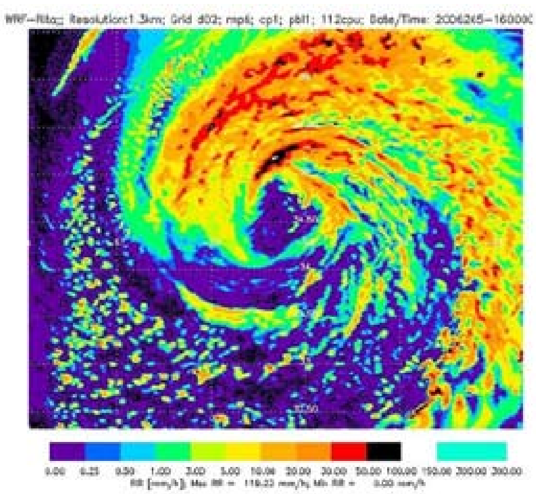
Using GPS data (purple arrows) to measure ground displacements, scientists replicated the December 2004 Indian Ocean tsunami, whose crests and troughs are shown here in reds and blues, respectively. The research showed GPS data can be used to reliably estimate a tsunami's destructive potential within minutes. *NASA Jet Propulsion Laboratory*

High-Impact Tropical Weather Prediction with the NASA Multi-scale Modeling System

The accurate representation of atmospheric thermodynamic fields, and their interaction with radiation and aerosols in numerical weather prediction (NWP) models, is among the most significant challenges for improving our understanding and prediction of high-impact tropical weather, including meso-scale hurricanes and planetary-scale Madden-Julian Oscillations (MJOs). Better prediction of these events is urgently needed to save lives and mitigate economic damage caused by extreme weather events, such as Hurricane Katrina (2005) and Tropical Cyclone (TC) Nargis (2008). Recent advances in NASA's global multiscale modeling and supercomputing capabilities show great potential for achieving this goal. The ultra-high resolution finite-volume general circulation model (fvGCM) was deployed and used to generate remarkable forecasts of intense hurricanes in 2004 and 2005. Now, an innovative approach, called the multiscale modeling framework (MMF), applies a massive number of cloud-resolving models (the Goddard Cloud Ensemble model) to the fvGCM to overcome the cumulus parameterization deadlock in traditional global NWP models. These advanced global modeling systems produce remarkable genesis predictions for TC Nargis (2008) and 15- to 30-day simulations of MJOs that occurred in 2002 and 2006.

POC at SC08: Bo-Wen Shen, NASA Goddard

Hurricane Observing System Experiment



Comparison of surface rain rate: WRF simulations of Helene 2006 versus TRMM retrievals. *Simone Tanelli, Svetla Hristova-Veleva, Peggy Li, NASA JPL*

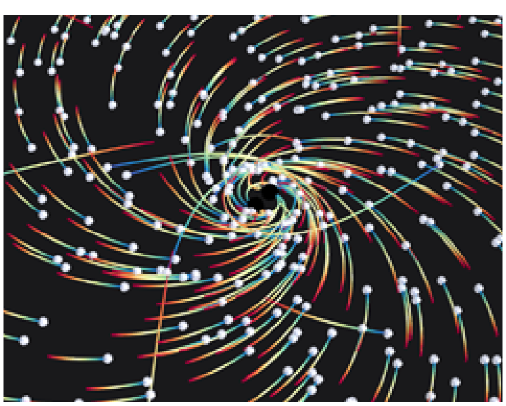
This study uses the nested-grid Weather Research Forecasting (WRF) model to generate 3-D representations of hurricanes and other storms at a horizontal resolution of less than 2 kilometers (km). Mass content of the atmospheric constituents, pressure, temperature, and wind vector fields are produced over domains of approximately 500 km by 500 km.

Such 3-D fields are then used as input to a 3-D Doppler radar simulator to obtain realistic reflectivity and Doppler measurements, used in configuration studies for the Aerosol/Clouds/Ecosystem mission.

Products are being included in the Jet Propulsion Laboratory's Tropical Cyclone Information System, together with imagery and data from observations.

POC at SC08: Heidi Lorenz-Wirzba, NASA JPL

Modeling of Binary Black Holes and Gravitational Radiation

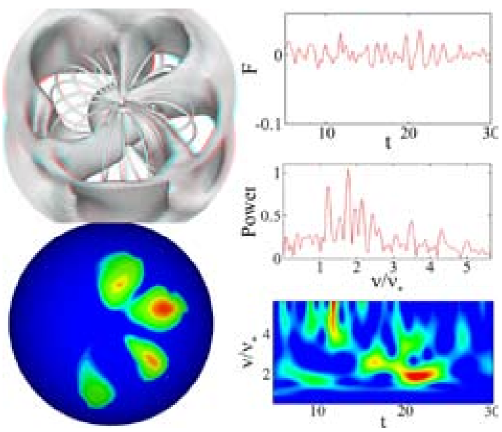


Five hundred randomly selected particles from a thin accretion disk around a binary black hole, which are about to merge. Notice several particles are flung out of the accretion disk and will escape from the system. *John Wise, NASA Goddard*

Coalescing massive black hole binaries are produced by the merger of galaxies. Final stages of black hole coalescence produce strong gravitational radiation that can be detected by the space-borne Laser Interferometer Space Antenna (LISA). For cases in which the black hole merger takes place in the presence of gas and magnetic fields, various types of electromagnetic signals may also be produced, which could assist in localizing the event and increase our knowledge of the surrounding environment. Modeling such electromagnetic counterparts of the final merger requires evolving the behavior of both gas and fields in the strong field regions around the black holes. We have taken a first step toward this problem by mapping the flow of pressureless matter in the dynamic, 3-D general relativistic space-time around merging black holes. We report on the results of these initial simulations and discuss their likely importance for future hydrodynamical simulations. These simulations were run on the Discover system at the NASA Center for Computational Sciences at Goddard Space Flight Center.

POC at SC08: John Wise, NASA Goddard

Modeling the Variability of Accreting Neutron Stars



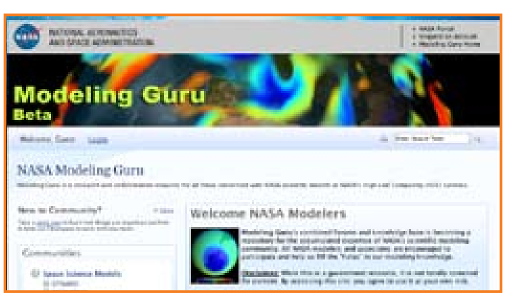
Left column: Accretion flow and hot spots in the unstable accretion case. Right column: Lightcurve, Fourier, and wavelet spectra. (Red-blue glasses needed for top left image.) *Akshay Kulkarni, Cornell University*

Stars several times heavier than the sun end their lives as neutron stars, made of neutrons packed into a sphere of only about 10 km in radius, but weighing nearly as much as the sun and having magnetic fields billions of times stronger than Earth's. These incredibly dense, magnetized objects provide a unique opportunity to study physics under extreme conditions unattainable in any laboratory. Like most stars, many neutron stars are part of two-star (binary) systems. In some of these systems, the neutron star can gravitationally pull gas from its companion star onto itself, a process called accretion.

A significant number of accreting neutron stars have been discovered using NASA's Rossi X-Ray Timing Explorer, which reveals periodic changes in the stars' X-ray brightness. Numerical modeling of the accretion process gives insight into the nature of these changes, and ultimately into the structure of the stars. We present results of such modeling, performed using NASA high-performance computing facilities. We solve the equations of magnetohydrodynamics on a cubed-sphere grid and have found that, in addition to the standard picture of accretion flow around the magnetosphere, a new regime of accretion through instabilities exists, in which the accreting matter penetrates the neutron star's magnetosphere, completely altering the observational properties of the star.

POC at SC08: Akshay Kulkarni, Cornell University

NASA Modeling Guru

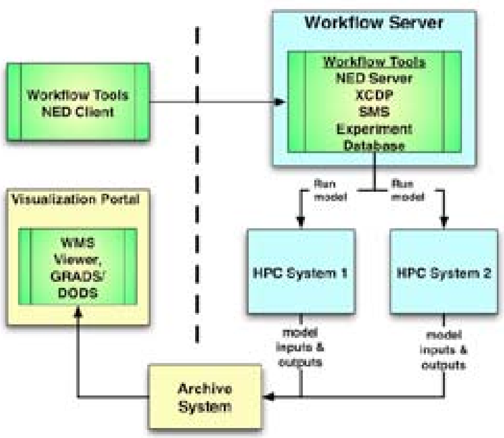


The Modeling Guru home page is the entry point to accessing this online NASA science modeling community. *Software Integration and Visualization Office*

NASA's Modeling Guru (MG) is a research and collaboration resource for all those concerned with NASA scientific models or the Agency's high-end computing (HEC) systems. Its combined forums and knowledge base are becoming a repository for the accumulated expertise of NASA's scientific modeling community. The website invites all NASA modelers and associates to peruse topics of interest and contribute their own knowledge to further enrich this community resource. MG is available at: https://modelingguru.nasa.gov

POC at SC08: Amidu Oloso, NASA Goddard

The NASA Workflow Tool: Advancing Scientific Computing Through Modern Tools



The Workflow Tool interface provides end-to-end user support and can be customized for a specific environment. *NASA Goddard*

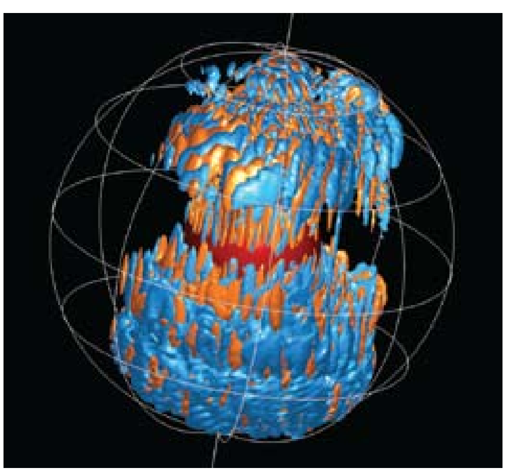
While many advances in scientific computing have been made, researchers often still use decades-old user-interface technology. To help users concentrate on scientific results rather than system environments, NASA Goddard has developed the Workflow Tool.

The Workflow Tool is a system of integrated applications that enable end-to-end support—from configuring experiments to visualizing the results. Users configure, run, monitor, manage, and visualize complex models through an easy-to-use graphical user interface rather than changing scripts and executing applications—all from a single location. The "dirty work" of running a science experiment is hidden under the hood of the tool. The Workflow Tool takes care of scheduling individual tasks that make up the experiment, such as checking out source code, building and running the model, and visualizing output. In addition, configurations can be saved and shared among users.

Since the tool is generic, it can be customized for many systems and models. It is currently being employed on several NASA projects, and plans are underway to apply it to Northrop Grumman projects.

POC at SC08: Robert Burns, NASA Goddard

Numerical Simulations on Termination of Martian Dynamo

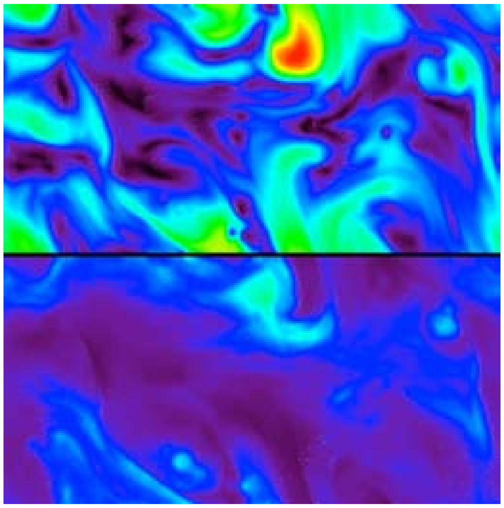


Snapshot of the dynamo region. The orange-colored region produces the magnetic field, while blue represents dissipation. *Tianyuan Wang, Chinese Academy of Science*

Measuring crustal magnetism using the NASA Mars Global Surveyor requires that, in its early history, Mars had to have possessed a strong internal field generated by a core dynamo. Using NASA's Columbia supercomputer, we apply the NASA-developed MoSST (Modular, Scalable, Self-consistent and Three-dimensional) core dynamics model to simulate early Martian dynamo, focusing primarily on the minimum energy needed to sustain an established dynamo. Our numerical simulation results show that the Martian dynamo could reverse frequently near its end, and could be sub-critical, with the energy required to sustain it being significantly less than that needed to excite it. Lower sub-critical maintenance energy could allow for longer dynamo life, but also indicates that the dynamo could be terminated suddenly by a very small perturbation and could not be reactivated without substantial increase of the buoyancy force in the Martian core.

POC at SC08: Weiyuan Jiang, University of Maryland, Baltimore County

Particle Acceleration and Jet Instabilities Around Kerr Black Holes



Contour plot of turbulent magnetic field (top) and electron density (bottom) in the plane of cosmic ray drift. *Gamma-Ray Astronomy Space Science Research Center MSFC/NSSTC*

We are investigating astrophysical jets using 3-D General Relativistic Particle-in-Cell (GRPIC), RPIC, and 3-D General Relativistic Magnetohydrodynamics (GRMHD) codes. GRPIC simulations allow self-consistent electromagnetic field and particle dynamics. Simulations generated by GRPIC show strong particle acceleration near the event horizon of Kerr black holes. However, preliminary studies indicate that the jet launching mechanisms for GRPIC and GRMHD simulations are different. The inclusion of radiation transfer and collisional dynamics will clarify the specific jet mechanisms which drive the system. The RPIC simulations are used to investigate particle acceleration and magnetic field generation in collisionless jets.

The National Space Science and Technology Center is a collaboration between NASA Marshall Space Flight Center and the State of Alabama.

POC at SC08: Michael Watson, NASA Marshall

Sensitivity of Sea-Ice Export Through Fram Strait

NASA's Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project aims to produce a best-possible, time-evolving synthesis of most available ocean and sea-ice data at a resolution that permits ocean eddies. ECCO2 syntheses are obtained via least squares fit of a global, full-depth-ocean, and sea-ice configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) to the available satellite and in-situ data.

A major milestone was reached recently with the completion of an adjoint model of the full-fledged dynamic/thermodynamic MITgcm sea-ice component. The dominant pattern reflects the advective pathways of sea-ice through the Arctic. In general terms, points furthest away from the Fram Strait are connected to it by faster advective time scales.

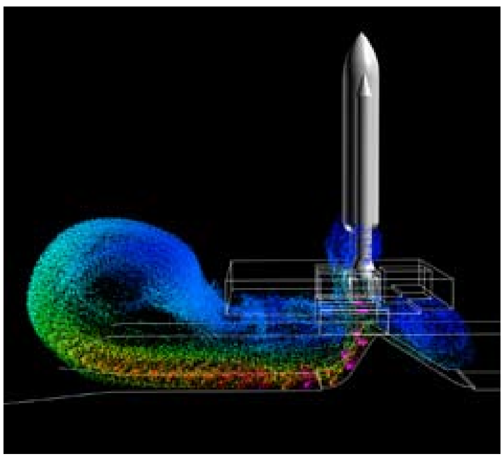
The computational demands of rigorous ocean state estimation are enormous. Depending on the method and approximations used, the computational cost of state estimation is several dozen to several thousand times more expensive than integrating a model without state estimation, which itself is a huge computation when carried out globally at eddy resolving resolutions. ECCO2 is sponsored by the NASA Modeling, Analysis, and Prediction (MAP) Program.

POC at SC08: Heidi Lorenz-Wirzba, Jet Propulsion Laboratory

SPACE OPERATIONS MISSION DIRECTORATE

The Space Operations Mission Directorate provides Agency leadership and management, including top-level requirements development, policy, and programmatic oversight of NASA space operations related to human exploration in and beyond low-Earth orbit. Current exploration activities in low-Earth orbit are the Space Shuttle and International Space Station Programs. The directorate is similarly responsible for Agency leadership and management of NASA space operations related to launch services, space transportation, and space communications in support of both human and robotic exploration programs. For more information, visit: http://www.hq.nasa.gov/osf/

CFD Support for NASA Kennedy Launch Pad Environment

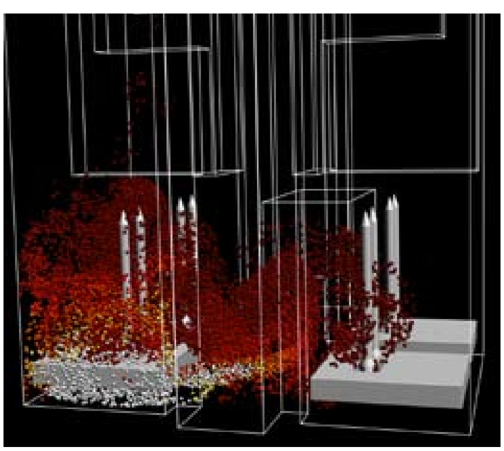


Visualization of shuttle flame trench CFD simulation showing instantaneous particle traces colored by Mach number. *David Ellsworth, NASA Ames*

NASA Advanced Supercomputing (NAS) Division modeling and simulation experts are supporting ground operations at NASA Kennedy Space Center (KSC) by conducting time-accurate simulations of the launch pad and shuttle configuration during ignition. Using the NASA-developed OVERFLOW code, along with other computational fluid dynamics (CFD) codes, NAS is analyzing the effects of ignition exhaust plumes on the flame trench below the vehicle. NAS CFD experts have developed a modeling framework for launch pad applications in which they can generate simulations and validate them with measured flight data collected during earlier shuttle missions. Recently, time-accurate simulations of the flame trench have been performed to identify the root cause of damage to its wall sustained during the launch of shuttle mission STS-124. The computed pressure data were compared with data from a previous flight (STS-4) and good correlation was observed. The resulting loads on the damaged wall were provided to KSC to assist in the critical repair effort. Additionally, these simulations are being used to help determine whether the existing trench and deflector system used to launch the shuttles can withstand flow from NASA's next-generation Ares launch vehicles.

POC at SC08: Cetin Kiris, NASA Ames

CFD Support for VAB Quantity-Distance Analysis



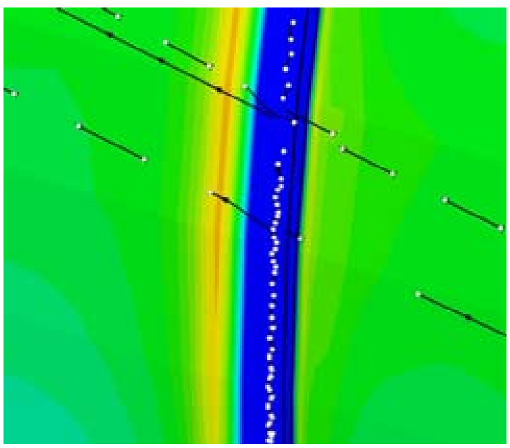
To support upcoming space exploration missions, NASA modeling and simulation experts are providing a computational framework for analyzing ground operations of future launch vehicles at NASA Kennedy Space Flight Center (KSC). Part of this effort is determining whether the Vehicle Assembly Building (VAB) at KSC, used for the Space Shuttle, can safely handle storage of the significantly greater amounts of fuel required for the Agency's next-generation space vehicles. Experts are implementing high-fidelity computational fluid dynamics (CFD) tools to simulate and predict the effects of various VAB fire scenarios.

Instantaneous particle traces from CFD simulation of a VAB fire scenario, colored by temperature. *David Ellsworth, NASA Ames*

The objectives of these modeling efforts are to: help determine the probability that a fire in one solid rocket booster (SRB) bay will ignite any of the other three bays in the VAB; to identify the maximum worst-case-scenario heat flux generated; and to assess the resulting effects on other nearby structures. The CFD simulations generate time-dependent temperature, heat flux, and plume concentration data for radiative heat transfer modeling, which will then be used to determine quantity-distance safety criteria between the VAB and surrounding buildings. The unique, extremely complex nature of this problem underscores the importance of high-end computing resources such as NASA's Columbia supercomputer. Current fire scenarios, running for several minutes of "real time" with a conservative level of detail, require more than 100 million grid points and 6 to 8 weeks of runtime on 128 processors of Columbia.

POC at SC08: Cetin Kiris, NASA Ames

Computational Investigation of Shuttle Leading Edge Defects



Flowfield structure of gap region between the orbiter's wing leading edge Reinforced Carbon-Carbon panel and seal. *Stephen Alter, NASA Langley*

An investigation into possible flow ingestion at the wing leading edge of the Space Shuttle Orbiter was conducted to assess possible causes of material defects. Investigations of the orbiter systems have been ongoing since the Shuttle Columbia disaster in 2002. The current investigation focuses on assessing aggravated thermal environments at the peak temperature region of the wing leading edge. Previous investigations found degraded Reinforced Carbon-Carbon (RCC) laminates used in the construction of this region. High-resolution computations of the smallest details of the leading edge RCC region were performed on the Columbia supercomputer at the NASA Advanced Supercomputing (NAS) facility, to assess flowfield and thermodynamic effects at key segments of the leading edge. These segments, including the RCC panels extending along the leading edge with seals inserted between the panels, have a small, thin gap that permits pressurization of the leading edge during reentry. The computations have identified that flow is not ingested into the wing leading edge, as surmised, but stagnates near the peak temperature region. Together with other investigations, this work provides more information about the physical phenomenon along the orbiter's wing leading edge to determine the root cause of RCC defects.

POC at SC08: Stephen Alter, NASA Langley

Cross-Flow Cavity Engineering Model Development

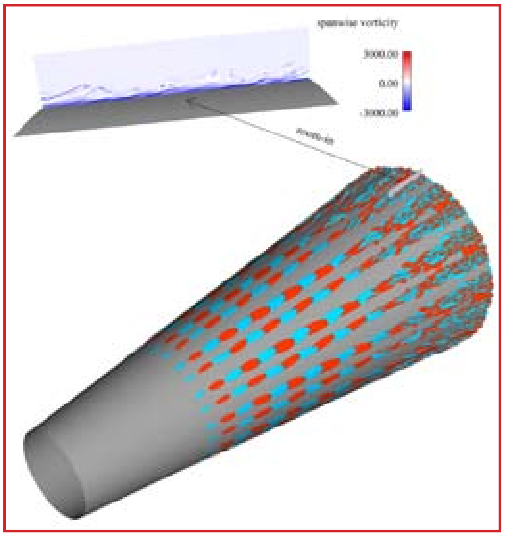
The Space Shuttle Damage Assessment Team (DAT) has developed a series of engineering models to disposition damage sustained to the thermal protection system (TPS) during ascent, before re-entry. One of these tools, the Cavity Heating Tool (CHT), is used to determine the local surface heating augmentation as a result of the change in geometry associated with a cavity in the shuttle tile. As part of ongoing development of the CHT, a series of high-fidelity computational fluid dynamics (CFD) solutions were run to evaluate the effect of varying cavity orientation with local flow direction.

POC at SC08: Andrew Hyatt, NASA Ames

NATIONAL LEADERSHIP COMPUTING SYSTEM INITIATIVE

NASA's National Leadership Computing System (NLCS) initiative provides selected non-NASA researchers with access to the Agency's largest supercomputers to conduct cutting-edge, computationally intensive science and engineering work of national interest. NLCS demonstrates the Agency's support for important national priorities, and its commitment to continued U.S. leadership in high-end scientific and technical computing, and computational modeling. By inviting industry and academia participation, NASA can help advance U.S. technology and education, and assist U.S. competitiveness. In return for NLCS awards, much of the resulting knowledge will be made publicly available.

Transition in High-Speed Boundary Layers: Numerical Investigations Using DNS



Transition to turbulence initiated by "oblique breakdown" for supersonic flow over a sharp cone (7 deg). Ma=3.5, T=90.116 K, Re=9.45E6 1/m, f=45.2 kHz, forcing location x=0.021 m. (Isosurfaces of streamwise vorticity, blue: -50, red: 50.) *AIAA-2008-4397*

Vehicles, cruising at speeds higher than the speed of sound, experience high surface heating rates. In a high-density environment, these aerothermal loads are even further increased due to the transition process of a laminar, high-speed boundary layer becoming turbulent. Therefore, boundary layer transition has important design implications for any thermal protection system (TPS) developed by NASA.

In the past, engineers used a rather conservative approach for the design of a TPS, wherein the turbulent boundary layer was assumed to be present over the entire TPS. For the design of future high-speed vehicles, however, design margins will need to be reduced to enhance payload capabilities. To reach this goal, the transition process of a high-speed boundary layer has to be better understood to provide the design community with accurate physical models for prediction of the transition point.

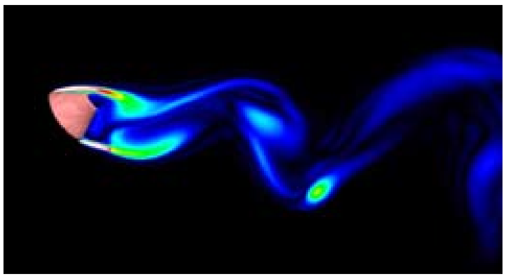
In this work, the transition process of a high-speed boundary layer is studied using direct numerical simulations (DNS). With this approach, equations governing the flow are solved directly using very efficient, accurate numerical methods that scale well on large parallel computers such as NASA's Columbia supercomputer.

POC at SC08: Christian Mayer, University of Arizona

HIGH-END COMPUTING

NASA's aeronautics, exploration, science, and space operations communities rely heavily on the Agency's world-class, high-performance computational resources to facilitate the rapid development and application of advanced knowledge and technology for mission success. For more information, visit http://www.hec.nasa.gov/

Application Performance and Productivity: Benchmarking for NASA HEC Resources



Computational fluid dynamics simulation of the Orion crew exploration vehicle, showing vorticity of airflow around the crew module. *Visualization Team, NASA Advanced Supercomputing Division*

The Application Performance and Productivity Group supporting NASA's High-End Computing Capabilities (HECC) project has three key activities: enhancing performance of high-end computing application codes of interest to NASA, leveraging software technologies to improve user productivity, and characterizing performance of current and future architectures.

In this talk, we describe our benchmarking efforts focused on characterizing the effects of recent architectural trends (such as multi-core chips) that introduce significant challenges that need to be addressed to effectively utilize impending petascale systems. We have evaluated performance of several systems recently installed at NASA Ames Research Center including two SGI Altix ICE clusters based on Intel Xeon quad-core processors, and the new hyperwall-2 visualization system, which uses AMD Opteron quad-cores. For this study, we utilized synthetic benchmark suites (NAS Parallel Benchmarks and the HPC Challenge benchmarks) and four full, NASA-relevant applications (OVERFLOW, CART3D, USM3D, and ECCO) from the computational fluid dynamics and climate modeling disciplines.

POC at SC08: Piyush Mehrotra, NASA Ames

Discover—NASA Center for Computational Sciences Scalable Cluster

The NASA Center for Computational Sciences (NCCS) recently expanded its Discover supercomputer by integrating a 4,096-core IBM iDataPlex cluster, for a combined performance of 67 teraflops. NCCS plans to at least double the iDataPlex processor count during 2009. *Jarrett Cohen, NASA Goddard*

The NASA Center for Computational Sciences (NCCS) at Goddard Space Flight Center selected an IBM iDataPlex cluster supercomputer with a peak computing capability of over 60 teraflops to augment their cluster environment. The newest addition to NCCS' cluster computing environment harnesses 1,536 Intel Xeon Harpertown quad-core processors in a new IBM design that dramatically improves energy efficiency and cooling requirements (http://www-03.ibm.com/press/us/en/pressrelease/25187.wss). This system will support computational projects to make projections of Earth's 21st century climate, a reanalysis of global weather observations taken since the satellite era began in 1979, modeling of solar activity, and complex simulations of relativistic astrophysics. NCCS integrated the new IBM system into its existing cluster environment, resulting in a peak computing capability of over 80 teraflops. This presentation will review the architecture of the NCCS cluster environment, including performance comparisons between the dual- and quad-core Intel Xeon processors. It will also address challenges faced in integration of a multi-vendor solution into an Open Fabrics

InfiniBand cluster, in addition to providing a look ahead at future evolution of the NCCS cluster environment. More information: http://www.nccs.nasa.gov

POC at SC08: Daniel Duffy, NASA Goddard

hyperwall-2: High-Resolution Scientific Visualization and Data Exploration for NASA Missions

The 128-screen hyperwall-2 system is used to view, analyze, and communicate results from NASA's high-fidelity modeling and simulation projects, leading to new discoveries. *NASA*

The hyperwall-2, installed in April 2008 at the NASA Advanced Supercomputing (NAS) facility at Ames Research Center, is one of the highest resolution scientific visualization and data exploration environments in existence. The 23-ft. by 10-ft., 128-screen liquid crystal display is capable of rendering one quarter billion pixel graphics, allowing NASA scientists and engineers to determine trends across an array of related simulation results, or to view a single, large image or animation.

Wired directly to the Pleiades and Columbia supercomputers at NAS via high-speed interconnects, hyperwall-2 offers users a truly supercomputer-scale environment. The system is integrated with the NAS Visualization team's extensive suite of software tools, including a sophisticated concurrent visualization framework that allows users to view and explore in real time, their high-fidelity modeling and simulation data, and then analyze and communicate their results. Research projects cover topics such as the safety of new space exploration vehicle designs, atmospheric re-entry analysis for the Shuttle, earthquakes, climate change, global weather, and collision of black holes.

The hyperwall-2 also provides detailed information on how NAS supercomputers are operating to quickly and precisely diagnose problems or inefficiencies with the systems or software. The system was designed and developed by the NAS Visualization team in partnership with Colfax International.

POC at SC08: Chris Henze, NASA Ames

NASA Advanced Supercomputing Facility: A Year of Growth and Opportunity

The Pleiades supercomputer, with 47,104 quad-core processors, was recently installed at the NAS facility at NASA Ames. *Marco Librero, NASA Ames*

This year marks the 25th anniversary of NASA's premier supercomputing organization, the NASA Advanced Supercomputing (NAS) Division at Ames Research Center. 2008 has also been a year of growth and opportunity for NAS, whose mission is to lead the country in the development and delivery of integrated, revolutionary high-end computing services and technologies to facilitate NASA mission success. This comprehensive integrated services approach encompasses high-end computing (HEC), high-speed networking, mass data storage, code performance optimization, scientific visualization, user support, and modeling and simulation. In 2004, NAS installed the 10,240-processor Columbia supercluster—which provided a ten-fold increase increase in the

Agency's HEC capability. In September 2007, NAS began a rigorous, formal evaluation of next-generation HEC architectures to address the Agency's future demand for production supercomputing cycles and to provide HEC capabilities for NASA's unique, time-critical computations. Just one year later—with the installation of the new Pleiades system, an upgrade to Columbia, and installation of two other systems to augment the Agency's mission computing needs—the facility has increased its computational capability from 62 teraflops in 2004 to a total of 699 teraflops. Going forward, NAS is planning another significant expansion over the next few years—again increasing peak performance by more than a factor of 10 over the current HEC capability.

POC at SC08: William Thigpen, NASA Ames

A Systems Perspective on the Pleiades Cluster

The NASA Advanced Supercomputing Division's newest supercomputer, Pleiades, has a peak floating point performance of over 600 teraflops, making it the fastest general-purpose, open system design in the world. Pleiades employs a dual-plane InfiniBand fabric to interconnect the system's 6,400 nodes in a partially populated 10-D hypercube topology. By node-count, this represents the largest InfiniBand fabric ever built, requiring over 20 miles of double data rate InfiniBand cabling, 1,536 24-port InfiniBand switches, and 12,800 host ports. The high radix-vertices of the 24-port InfiniBand switches result in reduced message latency, fabric complexity, and cost. An architectural challenge of this system was to combine message and data traffic on the same subnet switch fabric.

With an aggregate I/O rate of nearly 40 GB per second, Pleiades provides a good balance of sustained data throughput and I/O transactions-per-second capability. The fully connected hypercube system effectively supports workloads of either multiple applications or single, large applications. InfiniBand is also deployed as the primary LAN backbone to merge computing, storage, and visualization systems, and to facilitate cross-system data file access. This enables visualization and data analysis to be performed concurrently as applications run, providing very high temporal fidelity results for enormous datasets.

POC at SC08: Robert Ciotti, NASA Ames

NASA SC08 CONFERENCE ACTIVITIES

Tuesday, 11:30 a.m. – 12:00 p.m.
Paper Session, Ballroom F

"Scientific Application-based Performance Comparison of SGI Altix 4700, IBM POWER5+, and SGI Altix ICE 8200 Supercomputers," ***Subhash Saini, Dale Talcott, Dennis Jespersen, Jahed Djomehri, Haoqiang Jin, Rupak Biswas, NASA Ames***

The suitability of next-generation high-performance computing systems for petascale simulations will depend on various performance factors attributable to processor, memory, local and global networks, and input/output characteristics. In this paper, we evaluate performance of new dual-core SGI Altix 4700, quad-core SGI Altix ICE 8200, and dual-core IBM POWER5+ systems. To measure performance, we used microbenchmarks from the High Performance Computing Challenge, NAS Parallel Benchmarks (NPB), and four real-world applications—three from computational fluid dynamics and one from climate modeling. We used the microbenchmarks to develop a controlled understanding of individual system components, then analyzed and interpreted performance of the NPBs and applications. We also explored the hybrid programming model (MPI+OpenMP) using multi-zone NPBs and the CFD application OVERFLOW-2. Achievable application performance is compared across the systems. For the ICE platform, we also investigated the effect of memory bandwidth on performance by testing 1, 2, 4, and 8 cores per node.

Tuesday, 12:15 p.m. – 1:15 p.m.
Birds-of-a-Feather Session, Room: 11A/11B
Format: 5-10 minute presentations by multiple HEC-IWG members, with Q&A

Opportunities in Federal NITRD High End Computing Interagency Working Group (HEC-IWG) Agencies "HEC Community Partnership Opportunities with NASA," ***Bryan Biegel, NASA Ames***

High-fidelity modeling and simulation is a critical tool in helping NASA to pursue some of the greatest science and engineering challenges of our time—from increasing the safety of spaceflight and designing new aerospace vehicles to advancing understanding of our planet and our universe. To enable and accelerate these missions, NASA operates some of the largest supercomputing facilities in the world, and constantly seeks opportunities to enhance user productivity through hardware, software, service, and user environment improvements. NASA's approach to enhancing user productivity strongly leverages partnerships with the high-end computing community, such as with industry on major procurements and new technology evaluation; other agencies to support architecture advancements; academia in collaborative research; and small businesses through the SBIR program. This talk will cover these partnership opportunities.

Tuesday, 5:00 p.m. – 7:00 p.m.
Poster Session, Rotunda Lobby

"Predicting the formation of tropical cyclone Nargis (2008) with the NASA high-resolution global model and supercomputers," ***Bo-Wen Shen and Wei-Kuo Tao, NASA Goddard***

Wednesday, 5:30 p.m. –7:00 p.m.
Birds-of-a-Feather Session, Room 11A/11B

User Experiences with Large SGI Altix ICE
Presenter: ***Bob Ciotti, NASA Ames Research Center***

With several SGI ICE systems on the TOP500 list, the SGI User Group sees the need to have a BOF to discuss user experience on SGI's newest platform. In this BOF, several sites running a large SGI Altix ICE 8200 configuration will share their experiences with installing and operating the Altix ICE. Discussions will include system tuning, application performance, and system management. Speakers will include Henri Calandra (TOTAL Exploration Production Head of Seismic processing RD), Stephane Requena (GENCI, Technical Manager), Francis Daumas (CINES General Manager), Bob Ciotti (NASA Ames Research Center, Terascale Applications Lead), Lorie Liebrock (New Mexico Computing Applications Center, Interim Education Director), Dr. Thomas Steinke (Konrad-Zuse-Zentrum fr Informationstechnik Berlin (ZIB), HPC Research & Consulting).

Secondary Session Leaders: Davin Chan, NASA Ames; Gary Jensen, SGI User Group

Friday, 8:30 a.m. – 10:30 a.m.
Panel Session, Ballroom F

"SC: The Conference," ***Ron Bailey, NASA Ames panel member***

Started as the Supercomputing Conference, it has evolved to The Conference on High Performance Computing, Networking, Data and Analysis. The panel will examine the first 20 years of SC; discuss its impact on our community, then speculate about impacts in the next 20 years. Has it had an impact on the industry? Science? Society? Education? What is the future of the Conference? What should it be? It could be stated that the Conference itself has been a catalyst in advancing the state of the art of HPC. But, has the Conference succeeded in making a dent in the "broadening participation" of underrepresented groups? Has the Education Program added to the population of people seeking to use HPC in advancing science? Attendees in the audience are invited to share their memories, thoughts, and ideas.

Cover captions from left to right:

The Pleiades supercomputer, with 47,104 quad-core processors, was recently installed at the NAS facility at NASA Ames. *NASA Ames*

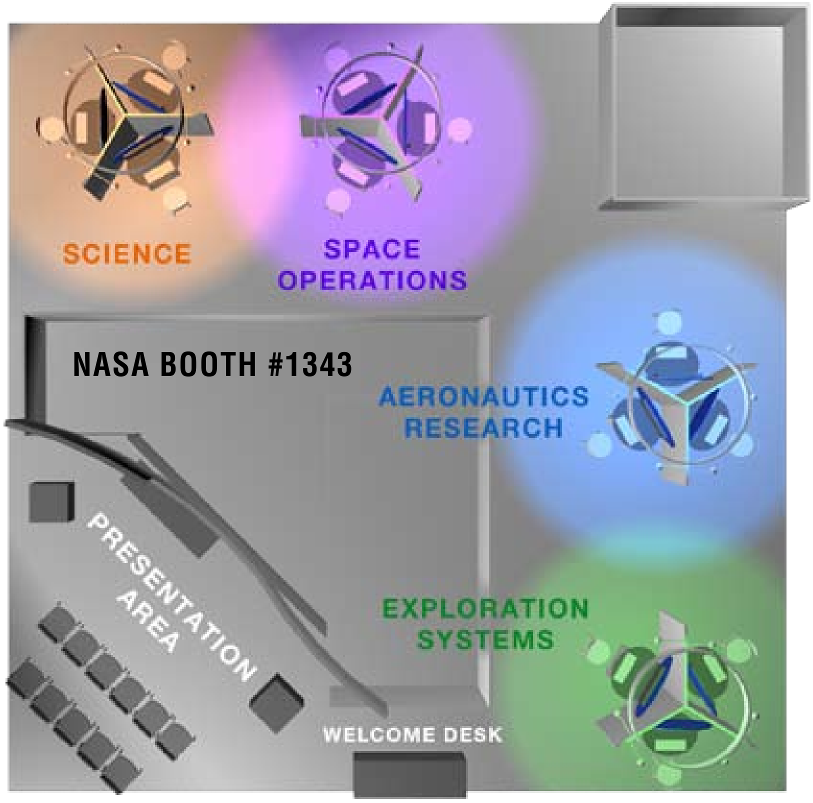
Projection of gas density of the surrounding 24,000 light years around the dwarf galaxy. Colors correspond to increasing densities. Notice the fine density structures of the dwarf galaxy. *John Wise, NASA Goddard*

Pressure waves are created as the rotor cuts through the wake of the vane.
Dale Van Zante and Jay Horowitz, NASA Glenn

Inside front cover captions from left to right:

Cosmic web surrounding the heated dwarf galaxy, showing cold gas in red, and warm in blue. This volume rendering was computed with photo-realistic ray tracing, accelerated on a graphics processing unit. *Ralf Kaehler, Zuse Institute Berlin*

Surface currents on September 9, 2005 in a partially constrained ECCO2 computational solution. The luminance and opacity of the streak lines is modulated by the surface current speed, with saturation level at 0.5 meters per second. Background is from NASA MODIS imagery. *Chris Henze, NASA Ames*



AERONAUTICS RESEARCH

- Advances in USM3D for Supporting Large, Unstructured CFD Simulations
- Computational Fluid Dynamics Simulation of the V-22 Isolated Rotor
- Emissions Calculations of a Lean Direct Injection Combustor
- Jet Engine Turbine Noise Generation
- Simulating Radiation Transport and Chemistry in Reentry Flows
- Very Large Eddy Simulation of Combustor Flows

EXPLORATION SYSTEMS

- Aerothermal Computational Fluid Dynamics for CEV Aerosciences Project
- Ares I Ascent Aerodynamic Analysis using USM3D and OVERFLOW
- Ares I Stage Separation Aerodynamics
- CEV Thermal Protection System CFD Simulations
- FUN3D CAE Simulations of Ares Crew Launch Vehicle Flexible Response
- OVERFLOW Time-Accurate Analyses for Orion Launch Abort Control Motors
- Physically-Based Global Illumination Simulation for the Hubble Space Telescope

SCIENCE

- 3-D Hurricane Visualization and Analysis Tool
- 3-D Radiative Transfer Hydrodynamic Cosmological Reionization Simulations
- Accelerating Earth and Space Applications With IBM Cell Technology
- Amplification of the Dust Bowl Drought Through Human Land Degradation
- The Cubed-Sphere Goddard Earth Observing Model
- ECCO2: High Resolution Global Ocean and Sea Ice Data Synthesis
- The First Stars and Galaxies in the Universe
- Galaxy and Star Formation Simulations
- GFDL's Coupled Data Assimilation System on NASA High-End Computers
- GPS-Guided Simulation of the 2004 Indian Ocean Tsunami
- High-Impact Tropical Weather Prediction with the NASA Multi-scale Modeling System
- Hurricane Observing System Experiment
- Modeling of Binary Black Holes and Gravitational Radiation
- Modeling the Variability of Accreting Neutron Stars
- NASA Modeling Guru
- The NASA Workflow Tool: Advancing Scientific Computing Through Modern Tools
- Numerical Simulations on Termination of Martian Dynamo
- Particle Acceleration and Jet Instabilities Around Kerr Black Holes
- Sensitivity of Sea-Ice Export Through Fram Strait

SPACE OPERATIONS

- CFD Support for NASA Kennedy Launch Pad Environment
- CFD Support for VAB Quantity-Distance Analysis
- Computational Investigation of Shuttle Leading Edge Defects
- Cross-Flow Cavity Engineering Model Development

NATIONAL LEADERSHIP COMPUTING SYSTEM (NLCS) INITIATIVE

- Transition in High-Speed Boundary Layers: Numerical Investigations Using DNS

HIGH-END COMPUTING

- Application Performance and Productivity: Benchmarking for the NASA HEC Resources
- Discover—NASA Center for Computational Sciences Scalable Cluster
- hyperwall-2: High-Resolution Scientific Visualization and Data Exploration for NASA Missions
- NASA Advanced Supercomputing Facility: A Year of Growth and Opportunity
- A Systems Perspective on the Pleiades Cluster