INFUSION

Innovations from the NASA CICT Program

CICT

Computing, Information, and Communications Technology Program

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Accelerating the Design of Space Vehicles

- **AeroDB automates and dramatically speeds CFD simulations on the NASA Grid**
- **Takes advantage of distributed NASA computing resources**

One of NASA's key goals is to increase the safety and reduce the cost of space transportation. Thus, a key element of NASA's Exploration Systems Enterprise is to develop new propulsion, structures, and operations for future generations of space exploration vehicles.

As part of this effort to develop new space exploration vehicles, the CICT Program's Computing, Networking, and Information Systems (CNIS) Project is developing and demonstrating collaborative software technologies that use the collective power of the NASA Grid to accelerate spacecraft design. One of these technologies, called AeroDB, automates the execution and monitoring of computational fluid dynamics (CFD) parameter studies on the NASA Grid.

About the NASA Grid

The NASA Grid, or Information Power Grid, is being developed to leverage the distributed resources of NASA's many computers, instruments, simulators, and data storage systems. The goal is to use these combined resources to solve difficult NASA challenges, such as simulating the entire flight of a space vehicle from ascent to descent.

To realize the vision of the NASA Grid, the CNIS Project is developing the software framework and protocols for building domain-specific environments and interfaces, new Grid services based on emerging industry standards, and advanced networking and computing testbeds to support new Grid-based applications such as AeroDB.

AeroDB automates CFD studies

Goetz Klopfer, manager of CNIS's Grand Challenge Applications subproject, says, "The AeroDB system automates the process for submitting, monitoring, and executing hundreds to thousands of CFD simulations on the NASA Grid."

AeroDB is an object-oriented system that includes Perl scripts to automate pre- and post-processing, a database to store information about each job, and a Web portal to provide information to users about the status of each job. AeroDB also includes custom modules for the execution of NASA's Cart3D and OVERFLOW flow solvers.

Stuart Rogers, NASA aerospace engineer and task lead for AeroDB, says, "We wanted

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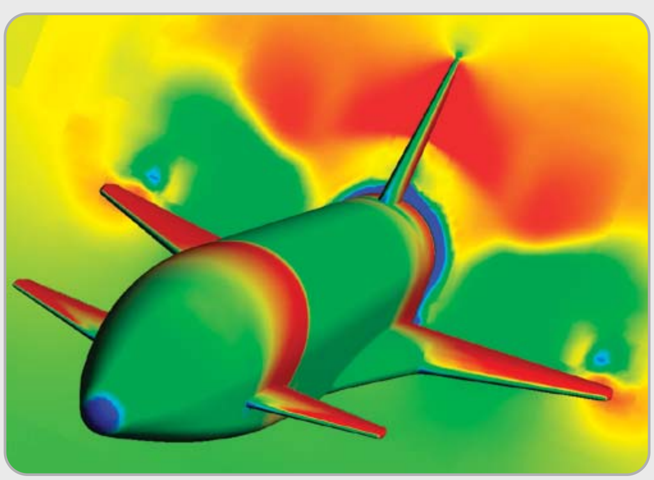

At left is a CFD simulation of a configuration of a liquid-glide-back booster (LGBB), showing velocity magnitude.

Technology Spotlight

Technology

AeroDB

Function

Automates CFD simulations on the NASA Grid

Relevant Missions

- Exploration Systems Enterprise—design of future space exploration vehicles
- Earth Science Enterprise—study of wind dynamics and vegetation

Features

- Perl scripts that interact with Grid services
- Database that stores job information and status
- Web portal that provides easy remote access and progress reports

Benefits

- Simplifies process of executing many CFD simulations
- Saves time by using distributed computing resources

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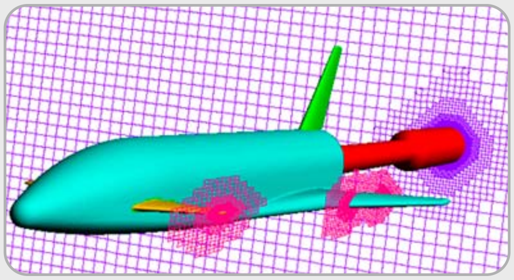
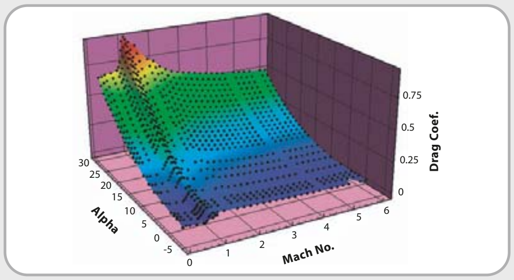


This Cartesian unstructured mesh was generated by the Cart3D flow solver for a configuration of an LGBB.



This graph shows the relations of different parameters for the Cart3D LGBB cases run with no sideslip flow: drag coefficient (C_D), Mach number, and angle of attack. Each dot represents the C_D from one case.

to design a tool that automates the process of running and monitoring our CFD tools—Cart3D and OVERFLOW. This idea fused with our goal of bringing these applications onto the Grid and demonstrating their usability."

Surpassing a Grand Challenge milestone

To meet its CNIS Grand Challenge milestone, Rogers' team used AeroDB scripts to execute and monitor cases for a large CFD parameter study on a configuration of a liquid-glide-back booster (LGBB). The goal was to execute over 1,000 simulations of the CART3D inviscid flow solver and at least 100 simulations of the OVERFLOW viscous flow solver in less than a week. They were to use at least ten different computing resources located in at least four different locations.

A typical Cart3D case takes from 2-10 CPU hours to solve for the LGBB, whereas an OVERFLOW case takes about 100-200 CPU hours. OVERFLOW takes longer because it simulates the effect of fluid viscosity. Cart3D, which does not solve for viscosity, models flow more quickly, but with lower fidelity.

Within 72 hours, AeroDB completed more than 1,000 Cart3D and 100 OVERFLOW simulations, and, after seven days, completed just over 3,000. The trial used 13 different computing resources at four different locations in California, Ohio, and Illinois.

"In achieving this milestone," says Rogers, "we demonstrated the functionality of automatically running jobs at distributed computing centers. The standardized security and user authentication services greatly simplified this process."

Serving Earth Science

The AeroDB framework was also used to assist the Earth Science Enterprise in simulating the impact of high-velocity winds on vegetation disturbance and recovery in Alaska. The study was conducted by Marc Kramer and associates at the Earth Science Division's Ecosystem Science and Technology Branch at NASA Ames Research Center, in collaboration with Neal Chaderjian and Ed Tejnil of the AeroDB team at Ames and others at NASA Glenn Research Center, NASA Langley Research Center, and NASA Jet Propulsion Laboratory (JPL). The study used over eight compute nodes at five Grid-enabled sites: two at Ames, and one each at Langley, Glenn, and JPL.

The study used data from three remote Earth-sensing instruments in combination with a nonlinear 3D CFD model to compare observed vs. predicted areas of wind impact. Prior to this Grid-based application, a linear 2D airflow model had been used. The three sensing instruments were the Shuttle Radar Topography Mission (SRTM), Light Detection and Ranging (LiDAR), and the Landsat 7 Thematic Mapper ETM+ (TM). Topographic data of the land surface from SRTM was used to generate the surface grid for the CFD model. LiDAR was used to detect forests recovering from catastrophic wind disturbance. Information about landcover types (forest, bog, woodland) was derived from TM spectral data using statistical clustering algorithms.

This application enabled the CNIS Grand Challenge Applications subproject to demonstrate that the NASA Grid can dramatically reduce the processing time for an Earth Science application that requires access to large data volumes in secondary and tertiary storage systems, as well as CPU-intensive model runs.

The future of AeroDB

Rogers and his team are now working on further enhancements to AeroDB, including scripts for error checking and monitoring, methods for automatic error recovery, and use of the NASA Grid Common Services job manager. Rogers also wants to explore machine learning as a way to populate the AeroDB database with fewer flow-solver runs. AeroDB has meanwhile served as a successful prototype for automating large CFD parameter studies on the NASA Grid.

–Larry Laufenberg

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CICT is part of the NASA Exploration Systems Enterprise's Human and Robotic Technology Theme which represents NASA's commitment to investing in the technologies and capabilities that will make an ambitious and sustainable 21st century space exploration program possible.

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