1 NAS Overview

In the mid-1970s, a group of Ames aerospace researchers began to study a highly innovative concept: NASA could transform U.S. aerospace R&D from the costly and time-consuming wind tunnel-based process to simulation-centric design and engineering by executing emerging computational fluid dynamics (CFD) models on supercomputers at least 1,000 times more powerful than those commercially available at the time. In 1976, Ames Center Director Dr. Hans Mark tasked a group led by Dr. F. Ronald Bailey to explore this concept, leading to formation of the Numerical Aerodynamic Simulator (NAS) Projects Office in 1979.

At the same time, a user interface group was formed consisting of CFD leaders from industry, government, and academia to help guide requirements for the NAS concept and provide feedback on evolving computer feasibility studies. At the conclusion of these activities in 1982, NASA management changed the NAS approach from a focus on purchasing a specially developed supercomputer to an ongoing Numerical Aerodynamic Simulation Program to provide leading-edge computational capabilities based on an innovative network-centric environment. The NAS Program plan for implementing this new approach was signed on February 8, 1983.

As the NAS Program got underway, its first supercomputers were installed in Ames’ Central Computing Facility, starting with a Cray X-MP-12 in 1984. However, a key component of the Program plan was to create the NAS facility: a state-of-the-art supercomputing center as well as a multi-disciplinary innovation environment, bringing together CFD experts, computer scientists, visualization specialists, and network and storage engineers under one roof. Groundbreaking for the NAS facility took place on March 14, 1985. In 1986, NAS transitioned from a projects office to a full-fledged division at Ames. In January 1987, NAS staff and equipment were relocated to the new facility, which was dedicated on March 9, 1987. At the grand opening, excitement levels were high about what had been accomplished so far, and about what was yet to come.

Grand Opening

Pioneering Achievements

From its earliest years, NAS has achieved many firsts in computing and in enabling NASA’s challenging science and engineering missions, including deployment of...
NAS Overview (continued)

the first Cray-2 in 1985, which attained unprecedented performance on real CFD codes. NAS was also the first facility to put the UNIX operating system on supercomputers, and the first to implement TCP/IP networking in a supercomputing environment, linking to users across the country. In 1984, NAS became the first organization to connect supercomputers and workstations together to distribute computation and visualization (what is now known as the client-server model). In another innovation, NAS developed the first UNIX-based hierarchical mass storage system, NASstore. NAS was the first customer for Silicon Graphics Inc. (SGI), beginning an enduring partnership that remains important today, and that led to the successful NASA-SGI-Intel collaboration on the Columbia supercomputer in 2004.

NAS has also been a leader in visualization, benchmarking standards, and job management. The graphics tools, PLOT3D and FAST, both have vast user bases and won major software awards from NASA. The NAS Parallel Benchmarks (NPB), which became the industry standard for objective evaluation of parallel computing architectures, are still widely used today. And since its first release in 1994, the Portable Batch System (PBS) has been commercialized and adopted broadly in the supercomputing community.

Throughout its history, NAS has also been a pioneer and committed partner in both high-fidelity modeling tool development and applications. Redesign of the Shuttle main engine, failure of the Challenger O-ring, wing stall and aerodynamic loads for lighter airplanes, thrust loss in vertical take-off jets—all demonstrated the potential of CFD supported by faster supercomputing to help lives and millions of dollars. Many of the award-winning codes that supported these analyses were also developed at NAS, including INSID, OVERFLOW, and CorID. These codes have continued to evolve through the years, and remain workhorses for NASA missions today.

New Directions

With a wealth of information technology expertise and a visionary spirit, NAS helped pioneer new technologies, including computational nanotechnology and grid computing, starting in the mid-1990s. NAS even set up one of the earliest websites in the world in 1993. In the late 1990s, NAS's Shuttle flights began to seem routine, and aeronautics research and modeling lost momentum in the Agency, leading to diminished investment in supercomputing capabilities and CFD research. Nevertheless, NAS managed to sustain its international leadership in single-system image supercomputing with funding from an information technology R&D project and NASA's Earth Science Enterprise. In 1999, NAS changed its name to the Numerical Aerospace Simulation Division, and in 2001, NAS became the NASA Advanced Supercomputing Division—the name it retains today.

Rediscovering the Mission

Starting in 2001, NASA conducted a series of major engineering studies, including the X-37 vehicle atmospheric reentry and the Shuttle's hydrogen fuel line flowliner cracking, each of which required the use of NAS computational resources for three to six months, significantly delaying other important simulations. Following the Columbia tragedy in February 2003, the Agency again turned to NAS CFD experts for foam debris transport analysis, further straining NAS computational resources in an effort to determine the physical cause of the accident. The Earth Science Enterprise stepped in once more to support the purchase of Kalpana, NAS first SGI Altix system, which enabled the even larger computational modeling effort required to improve the Shuttle design for a successful Return to Flight.

By June 2004, the importance of supercomputing-enabled high-fidelity modeling and simulation for aerospace and other missions was clear. Purchase of the Columbia supercomputer was approved by NASA and Congress in record time, and the system returned supercomputing leadership to the U.S. after two and a half years with the Japanese Earth Observation Laboratory having the highest computational performance. More importantly, NASA was able to pursue its new Space Exploration mission and simultaneously conduct leadership research in Earth science, astrophysics, and aerospace modeling. In October 2005, NASA's long-term commitment to supercomputing at NAS was assured with the formation of the High End Computing Columbia project as the first asset in the Strategic Capabilities Assets Program (SCAP). NAS remains widely recognized as the premier supercomputing facility for the Agency, and vital to each of NASA's mission directorates. In 2007, the Aeronautics Research and Exploration Systems Mission Directorates procured additional resources and placed them at NAS to augment their SCAP allocations. NAS facilities and staff are playing key roles in Shuttle operations, designing the Ares and Orion space exploration vehicles, advancing Earth and space science understanding, and conducting aeronautical research in all flight regimes.

Future

While reflecting on NAS' 25-year legacy is inspiring, current NAS and Agency leadership is carrying on the tradition of the visionaries of a quarter century ago. The newly-installed Hyperviz-2 graphics and data analysis system—currently the world's highest resolution display at a quarter-billion pixels—will allow supercomputer users to view and explore their computational results in unprecedented detail and speed. Visualization will become more tightly integrated into the traditional environment of computing, storage, and networks to provide a more powerful tool to scientists and engineers. The NAS facility is being significantly upgraded and expanded in preparation for installation of new generations of leadership-class supercomputers over the coming months and years to address NASA's increasingly challenging modeling and simulation requirements. Emerging innovative architectures and systems will be strategically leveraged to provide the most effective supercomputing platforms and environments. Advanced algorithms and applications will be developed in kokkos to exploit these petascale systems. Partnerships with other NASA centers, government laboratories, the computer industry, and academia are being aggressively developed to continue Ames and the NAS facility's proud reputation of being the “go-to” place for supercomputing and advanced simulations. Discussions are underway regarding bleeding-edge concepts such as 10-petaflop systems and 1-exabyte data archives at NAS, connected to the science and engineering community via 1-terabit-per-second links, enabling near-real-time aerospace design and deeper understanding of our planet and the universe.

At NAS, we honor our past most sincerely by continually pursuing more impressive achievements in the future. And as these triumphs attract a new generation of innovators and leaders to NAS, soon enough their aspirations and achievements will exceed our own.
A visionary team of managers, engineers, and CFD researchers develops the NAS Program plan, which leads to the beginning of a NASA New Start Program in October. One of the primary goals included in the plan is to provide a national computational capability as a necessary element in ensuring continued leadership in CFD and related disciplines.

NAS purchases its first hardware—two DEC VAX 11/750s named Orville and Wilbur, linked by Ethernet and hyperchannel networks. Engineers design a network-centric environment with a UNIX operating system and TCP/IP protocol.

In collaboration with Rocketdyne, and supported by NASA Marshall’s Development Engine Project Office, researchers generate CFD solutions for the Space Shuttle Main Engine (SSME) hot gas manifold flow, using newly developed INS3D software. This first known application of CFD to rocket propulsion systems development led to replacement of the original three-duct hot gas manifold design. The more reliable, better performing two-duct design made its first flight on Shuttle Discovery’s 20th mission (STS-70) in July 1995.

NAS cooperates with Rockwell on CFD calculations for the F-16 aircraft, and over the high-vortex flows over the wing surface distributions both inside the SSME, vortex flows over the wing surface of F-16 aircraft, and over the high-speed National Aerospace Plane.

First 4-processor Cray-2 system, Navier (1.95 Gflops peak) is delivered, which later helps NASA achieve its initial performance goal of a sustained 250 Mflops rate—the world’s most powerful supercomputer to date.

Researchers run CFD calculations on the Cray-2s to investigate V/STOL (vertical and short take-off and landing) flows and characteristics as Navier).

A second Cray-2, Stokes arrives, doubling NAS computing capacity.

Inexpensive Disks) project, RAID (Redundant Array of Inexpensive Disks) project, which was completed in 1992, resulting in the RAID storage technology standard in use today.

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A single-processor Cray X-MP-12 (210.5 Mflops peak performance) arrives at building 233a at NASA Ames (where NAS computer hardware was housed prior to construction of the NAS facility). This is the first customer installation of a UNIX-based Cray supercomputer, and the first to provide client-server interface with UNIX workstations.

NASnet, a high-speed, long-haul communications subsystem using TCP/IP, connects users across the U.S. to supercomputing resources at NAS. This is the first instance of a supercomputer being connected to a TCP/IP network without using a front-end system.

NAS Langley researchers use NAS systems to understand and analyze events in the Shuttle Challenger disaster, and in particular, failure of the O-ring; this work results in the largest 3D structural simulation in the world to date.

The Remote Interactive Particle-tracer (RIP) application is developed—a unique program to combine capabilities of SGI IRIS graphics workstations and the Cray-2 to reduce demands on computational resources. The workstations perform excellent 3D graphics but lack the Cray-2’s memory and speed to process large datasets—RIP exploits the strengths of both systems.

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Installation of NAS-developed AEROnet is underway, the first high-speed wide-area network (WAN) connecting supercomputing resources to remote customer sites. This new network provides increased bandwidth to remote users, keeping NAS on the forefront of networking technology while implementing open systems standards.

Original NAS Parallel Benchmarks (NPB) are developed in response to the program’s increasing involvement with massively parallel architectures. The synthetic application benchmarks mimic computation and data movement of large-scale CFD applications, providing objective evaluation of parallel computing architectures. NPBs become an industry standard and are still widely used today.

Research scientists successfully run incompressible Navier-Stokes simulations of isotropic turbulence—the first application code to demonstrate the effectiveness of Lagrange, the highly parallel Intel iPSC/860 system (128 processors, 7.68 Gflops peak) for very large CFD simulations—the largest having a mesh size of about 16 million grid points.

NAS makes extensive modifications to GRIDGEN, including the addition of four new modules. The multi-program software package, originally developed by Wright Patterson Air Force Base and General Dynamics, is used at NAS for modeling complex-structured aerodynamic grid configurations.

NAS supports the U.S. Navy and McDonnell Aircraft Company in demonstrating the effectiveness of applied CFD in meeting immediate engineering design objectives—to reduce the number of expensive, time-consuming wind tunnel tests required. This effort focuses on developing methods and demonstrating the ability of CFD to predict aerodynamic loads on the F/A-18 vehicle.
**TIMELINE (1993-1998)**

1993

- A 16-processor Cray C90 (15.36 Gflops peak) arrives at the NAS facility, just hours after removal of the Cray-2. This new system, named von Neumann, allows NAS to run many more multitasking jobs around the clock, some as large as 7,200 MB.

- A 160-processor IBM SP2 configuration called Babbage is installed at the NAS facility and starts off with a user base of approximately 300. This system has a peak of 42.56 Gflops.

- The INS3D code, designed to solve incompressible Navier-Stokes equations in 3D for both steady-state and time-varying flows, wins NASA Software of the Year Award.

- The PLOT3D team is awarded NASA Software of the Year Award for their work on the earlier PLOT3D program.

- Ames computational molecular nanotechnology group is created, securing $1 million for the first-ever nanotechnology program at a federally funded laboratory.

- The Flow Analysis Software Toolkit (FAST) team wins NASA Software of the Year Award for their work on the highly modular software environment for visualizing and analyzing CFD scalar and vector data. FAST builds on the earlier PLOT3D program.

- A 64-processor SGI Origin 2000 testbed system named Turing—the first of its kind to be run as a single system—is installed. This joint purchase by the Ames Information Technology Program and NASA's Data Assimilation Office is part of a collaborative plan for systems software development and code optimization.

- NASA embarks on the ambitious Information Power Grid (IPG) project to seamlessly integrate computing systems, data storage, networks, and analysis software across the Agency. Among the IPG's primary goals is enabling researchers to spend less time dealing with computing resources and more time conducting research and analysis software across the Agency.

- NASA researchers are developing CAPO, an automated tool that helps speed up and simplify the tedious process of parallelizing NASA's large serial codes for distributed-memory machines. Among the success stories, NASA Goddard uses CAPO to parallelize one of their codes, enabling them to run larger cloud simulations much faster than before.

- NASA Ames computational molecular nanotechnology group wins the Richard P. Feynman Prize in Nanotechnology for Theoretical Work.

- NAS and the National Energy Research Supercomputer Center (NERSC) of Lawrence Livermore National Laboratory release the first phase (alpha test release) of the Portable Batch System (PBS), providing improved batch job scheduling and resource management for massively parallel computers, clustered workstations, and traditional supercomputers. PBS is later commercialized in 1998.

- NAS networking group successfully connects the internal NASA AEROnet wide-area network and DARWINnet, a secure focal-area network at Ames, to facilitate remote access to wind tunnel and other aircraft design tests across the Agency.

- To prepare for a January 2000 test flight over the Pacific, NASA Langley researchers use a NASA Cray system to simulate the scramjet-powered Hyper-X vehicle's unprecedented horizontal separation from its Pegasus booster rocket—a risky Mach-7 maneuver never before attempted.

- Theoretical Work.

- NASA Langley researchers are exploring the potential of using nanotubes for tiny electromechanical sensors and semiconductor devices.

- NASA and the National Center for Supercomputing Applications, NAS researchers are exploring the potential of using nanotubes for tiny electromechanical sensors and semiconductor devices.

- A 1992 NAS-produced video covering the Division’s services and projects wins a nationally recognized Silver Telly Award—the highest honor in the video industry for non-network and cable films.

- The PLOT3D team is awarded the fourth largest prize ever given by the NASA Space Act Program for development of their software program, which has revolutionized scientific visualization and analysis of 3D CFD solutions.

1994

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**TIMELINE (1999-2002)**

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**1999**
- Multi-Level Parallelism (MLP), a new method for application parallelisation, is developed by NAS computer scientists to take advantage of shared-memory, multiprocessor computing architectures such as the SGI Origin 2000 housed at NAS.

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**2000**
- Computational chemistry is being used to calculate the global warming potential of industrial compounds being released into Earth’s atmosphere—exploring phenomena impossible to capture in laboratory experiments due to the instability of crucial compounds at Earth’s surface.

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**2001**
- Version 1.0 of the NASA-developed Chimera Grid Tools (CGT) software package is released under a beta testing agreement, and used in a wide variety of disciplines including aerospace, marine, automotive, environmental, and sports. This comprehensive tool for overset grid generation has since been licensed to more than 500 user organizations at different NASA centers, government labs, industries, and universities.

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**2002**
- NAS visualization scientists develop two new algorithms, GEL and Batchvis, to help discern unsteady flow features not readily distinguishable or reproducible with traditional software packages. These algorithms are being applied to the YAV-8B Harrier jet to visualize the vehicle’s exhaust flows and resulting ground vortices during vertical take-offs—phenomena that can lead to rapid loss of engine thrust and flight failure.

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NAS visualization experts develop an innovative visualization system called the Hyperwall, including a graphics cluster and LCD panel wall, which enables scientists to view complex datasets and series of computational results across a dynamic, linked array of 49 displays.

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NAS aerospace engineers develop the AeroDB software system to automate CFD processes. With its database-centric approach, AeroDB provides users with a convenient central warehouse for investigating simulation results in real time. Since its launch in September, it has been used during several Shuttle missions to conduct rapid-turnaround engineering analyses.

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The Cart3D team wins the 2002 NASA Software of the Year Award. The software package, developed by researchers from Ames and the Courant Institute at New York University, streamlines the design and analysis process for complex configurations such as aerospace vehicles.

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The life-saving DeBakey Ventricular Assist Device (VAD), a collaborative effort between researchers at NASA Ames, NASA Johnson, and MicroMed Technology, Inc., is named NASA’s Commercial Invention of the Year. By this date, the device—improved using SSME technology and CFD, coupled with NAS-HEC resources—has been implanted in 115 heart patients in Europe with no reported failures.

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Using NAS’ SGI Origin 2800, Lomax, NASA Langley researchers run CFD simulations of the NASA Boeing X-37 experimental launch vehicle—which flies at speeds over Mach 20—to analyze thermodynamic conditions of the vehicle’s reentry through the atmosphere.

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The NASA Research and Education Network (NREN) continues to serve as a global leader in deploying new multicast routing and forwarding protocols used for sending information across the Internet.

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A 1,024-processor SGI Origin 3800, Chapman (819.2 Gflops peak), is installed.

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Since the Shuttle Columbia accident in February 2003, NASA resources have largely been dedicated to analysis of the accident’s cause. These time-critical analyses underscore the Agency’s requirement for expanded supercomputing power to complete human spaceflight analyses much more quickly, while still providing sufficient resources to continue NASA’s broad modeling and simulation activities.

The High End Computing Revitalization Task Force (HERTF) is established in March to fuel improvements in U.S. NEC capacity, capability, and accessibility. NAS is heavily involved, looking for ways to help the U.S. gain a competitive, cost-effective edge over Japan’s HEC capacity, capability, and accessibility. NAS is heavily involved, looking for ways to help the U.S. gain a competitive, cost-effective edge over Japan’s HEC capacity, capability, and accessibility.

The first SGI Altix system, a S12-processor single-system image supercomputer, is installed. The system, named Kalpana after astronaut and former NAS colleague Kalpana Chawla, is being used for a joint effort between NASA Headquarters, the Jet Propulsion Laboratory, Ames, and Goddard to deliver high-resolution ocean analyses for the ECCO (Estimating the Circulation and Climate of the Ocean) model. The work dramatically accelerates development of highly accurate analyses of global ocean circulation and sea-ice dynamics.

The first two SGI Altix 512-processor systems of the Columbia supercomputer (63 Tflops peak) are installed, with all 10,240 processors operational by October.

NAS scientists are extensively involved in the Agency’s Return to Flight (RTF) activities, employing state-of-the-art CFD codes to simulate steady and unsteady flow fields around the Shuttle during ascent. NAS findings help make crucial design changes to the Shuttle for future flights.

NAS CFD experts are performing high-fidelity computations on Columbia to analyze the Shuttle orbiter’s liquid hydrogen feedline flowlines. Several computational models are being used to characterize unsteady flow features, which have been identified as major contributors to cyclic loading that damages the flowliner over time.

The finite-volume General Circulation Model (IGCM) runs on Columbia throughout the 2004 hurricane season, validating its real-time, numerical weather prediction capabilities to improve hurricane tracking and intensity forecasts.

The MAP’05 team (under the auspices of the Modeling, Analysis, and Prediction Program), implements two high-resolution versions of the Goddard Earth Observing System (GEOS), a global atmospheric model that enables “real-time” prediction of Atlantic tropical cyclones and other meteorological events. These models run 4 times daily for over 6 months on one of Columbia’s S12-processor nodes to produce hurricane forecasts for immediate integration into the national ensemble forecast.

The Simulation-Assisted Risk Assessment (SARA) team gets into full swing with Constellation-related work, incorporating CFD analyses performed on Columbia into a probabilistic risk assessment model for Ares I crew launch vehicle (CLU) ascent. Ares I will launch Orion, the crew exploration vehicle (CEV) that will take over NASA human spaceflight missions after the Space Shuttle is retired in 2010.

The Integrated Modeling and Simulation project’s Entry Descent and Landing team greatly streamlines efficiency of vehicle design work for the Agency’s new Constellation Program, created in May 2004. By coupling engineering methods with high-fidelity aerodynamic and aerothermal simulations run on Columbia, engineers are able to analyze six potential design shapes for the Orion crew exploration vehicle within a three-month period—saving years of design work and demonstrating the value of using high-fidelity simulations early in the design cycle.

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Aerospace engineers from NASA Johnson and Ames are relying heavily on Columbia to support redesign efforts for the Shuttle’s external tank, consuming more than 600,000 processor-hours on the task by the end of FY09.

The Army Research Laboratory selects the NAS facility as its new operations base for the Army High Performance Computing Research Center (AHPCRC). NAS now houses a Cray X1E and a Cray XT3, plus other supporting equipment. NASA Ames, Stanford University, High Performance Technologies, Inc., and several minority university partners serve as the consortium for AHPCRC.

In support of NASA Kennedy ground operations, NAS simulation and modeling experts are conducting time-accurate simulations of the launch pad with double- and single-solid rocket booster configurations (to mimic the design of the Ares I-X) to analyze effects of ignition over-pressurization on the vehicle.

Two new systems arrive as part of the NTR effort—Schirra, a 640-core IBM POWER5+ (4.8 Tflops peak) and a 2,048-core SGI Altix 4700 (13 Tflops peak, Columbia node 22), which is the largest SGI computer to date. NAS staff members are evaluating the two architectures to determine their potential to help meet the Agency’s future computing needs.

The Division releases the NAS Technology Refresh (NTR) request for information in September, initiating the process of enhancing NASAs high-end computing capacity to keep pace with the Agency’s growing HEC requirements. NAS’ ultimate goal is to increase total computing capacity at least four-fold over Columbia’s existing size by the end of FY09.

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To meet increasing computational demands, the Agency’s Aeronautics Research and Exploration Systems Mission Directorates fund the purchase of additional computing resources at NAS. The ESMD systems are two 1,024-core SGI Altix 4700s with the latest Montvale Itanium 2 processors, which become nodes 23 and 24 of Columbia (now 88.9 Tflops). The ARMD system is a 4,096-core SGI Altix ICE cluster (43.5 Tflops peak) with Xeon quad core processors.

NAS visualization, applications, and facilities teams work together to complete construction of Hyperwall-2, a follow-on version of the Hyperwall visualization system that enables scientists to display high-fidelity simulation results in a single view. This new version comprises 128 state-of-the-art graphics processing units and 1,024 cores, providing 74 teraflops peak processing power and a total of 245 million pixels—the highest resolution display in the world today.

NAS visualization team members enhance their concurrent visualization framework to extract complicated vortex core isosurfaces directly on Columbia, shedding new light on phenomena associated with V-22 tiltrotor flight. Without concurrent data extraction, storing and interactively exploring the full data from every simulation timestep (43 terabytes total) would not be possible.

NAS modeling and simulation experts are using Columbia to determine whether the Vehicle Assembly Building (VAB) at NASA Kennedy, designed for the Shuttle Program, is properly equipped to safely handle storage of the significantly greater number of solid rocket booster segments required for next-generation launch vehicles.

The CEV Aerosciences Project (CAP) Aerodynamics team begins using NASAs Cart3D and OVERFLOW codes on Columbia to generate aerodynamic performance databases for each major design iteration of the Orion launch abort vehicle (LAV). These results enable the team to examine critical performance factors such as stability, control, and separation dynamics for the vehicle, and to recommend specific modifications to the design.

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After months of performance testing and analysis, NAS announces the outcome of its large technology refresh effort to carry the Agency through the next several years of high-end computing—a 20,480-core SGI ICE cluster system with a peak performance of 245 Tflops. The system will be installed in summer 2008, initially augmenting and eventually replacing Columbia.

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NAS visualization experts assist NASA Goddard researchers in modeling the spectacular merger of two black holes. The Goddard simulation represents one of the largest single calculations ever run on Columbia.
Among the large cast of important players deserving applause for their contributions to the reputation and success of NAS over the past quarter-century, these 25 individuals are spotlighted for their vision, guidance, and influence on the organization’s achievements in supercomputing and computational science for NASA and the nation.

**David Bailey**
Senior Scientist 1984–1996: Expert in high-performance scientific computing who led development of the NAS Parallel Benchmark suite that is still widely used to evaluate sustained performance of highly parallel supercomputers.

**Ron Bailey**
Founding NAS Division Chief 1982–1990: Computational fluid dynamics (CFD) pioneer and leader of the team that developed the NAS concept and laid its technical foundation. Anticipated and promoted the transition from vector to parallel computing, and remains an important contributor to NAS’ vision today.

**Bill Ballhaus**
Ames Center Director 1984–1989: Among the researchers who created the field of CFD at NASA Ames. Earlier, as Director of Aeros- nautics when the NAS Program plan was approved, strongly supported the NAS vision.

**Bob Bishop**
SGI CEO 2004–2007: Key partner in NASA-industry collaboration to build Columbia. Enabled radical alteration of SGI production to turn out 5–10 times more Altix systems to meet the aggressive Columbia schedule. Contributed intellectual and fiscal support to create this powerful national resource.

**Bruce Blackburn**
NAS Chief Engineer 1994–1999: Important early contributor to shaping of NAS Program. Earlier, as NAS Systems Development Branch Chief, provided clear vision and staff support for software development, and introduced rigorous design methodologies, tools, and environments.

**Dean Chapman**
Ames Director of Aeroscience 1974–1980: Visionary who established the first research group at Ames to develop and combine CFD with supercomputers. With Chapman to champion and support early NAS technical studies and program planning.

**Loren Bright**
Director of Ames Research Support 1969–1976: Early advocate of supercomput- ing at Ames who led the ILLIAC IV project. Teamed with Chapman to champion and support early NAS technical studies and program planning.

**Dave Cooper**
NAS Division Chief 1991–1995: NAS advocate extraordinaire who tirelessly campaigned for NAS recognition and funding. Influenced the transition from vector to parallel computing, and contributed significantly to the advancement of U.S. supercomputing.

**Bill Feilerseisen**
NAS Division Chief 1998–2002: Gave NAS its start in single-system image (SSI) architectures, increasing NAS computing capability ten-fold, and was a key player in Ames’ entry into grid technolo- gies. Previously, Program Manager for NASA’s HPCC Program.

**Randy Graves**
Graves NASA Director of Aeroscience 1984–1989: As the first Headquarters Program Manager for NAS, understood and promoted its importance as part of the U.S. supercomputing effort. Helped shape national HPC policies and was influential in starting the HPCC Program of the 1990s.

**Tom Lasinski**
NAS Deputy Division Chief (acting) 1995–1999: Established and led NAS Applied Research Branch and fostered development of key technology projects. Collaborated with aeronautics scientists at Ames to create the NAS program that shifted NAS’ focus to highly integrated workstations with supercomputers.

**Harry McDonald**
Ames Center Director 1984–1999: Supported pioneering work in SGI architectures, known internationally for his work in computer applications. Responsible for defining and executing Ames’ role as a Center of Excellence for Infor- mation Technologies.

**Dave Parry**
SGI Senior Vice President and Chief Executive Officer 2002–2007: Champion of hardware engineer- ing of SGI Altix servers that enabled Columbia’s implementa- tion. His vision and leadership moved the Altix to Open Linux and provided scaling to 512 and 2,048 processors, enabling Columbia’s growth.

**Sy Syvertson**
Ames Center Director 1979–1984: Signatory on the NASA Program plan, who led aerodynamics and wind tunnels at Ames into the super- sonic and hypersonic regimes. His early research on lifting bodies helped define the basic shape of the Apollo capsules, and the Space Shuttle orbiter.

**Paul Kuter**
Ames Applied Computational Aeroscience Research 1980–1984: CFD research scientist and manager who developed and promoted creation of aerospace-related software to run supercom- puters. Dedicated much of his NASA career to advocacy, planning, and utilization of NAS capabilities.

**Paul Ottolini**
Intel President and Chief Executive Officer 2001–2005: Pioneered the partnership between NAS and SGI to deliver the Intel Itanium 2 processor-based Columbia supercomputer to accelerate NAS’ design and engineering research.

**Vic Peterson**
Ames Deputy Director 1989–1994: Earlier, as Chief, Therm- o- and Gas- Dynamics Division and then Director of Aerodynamics, an origi- nator (with Bailey, Chapman, and Marks) of initiative to develop the NAS capability. Devoted much time to advocating the importance of supercomputing to maintain U.S. leadership in aerospace.

**Steven Wheel**
Intel Senior Director of HPC Platforms 1996–present: Innovator of Intel’s flagship supercom- putting project, who worked directly with NAS management to develop the initial framework, key objectives, and parameters for Columbia.

**Randy Graves**
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Special appreciation goes to our stakeholders—the many managers and leaders throughout NASA and up through the halls of Congress, whose sponsorship, commitment, and financial support have allowed NAS’ successful 25-year run.
The NAS concept was a revolutionary idea for its time: A balanced supercomputing capability consisting of processors, networks, storage, and visualization tools, all speaking the same language. Over the last quarter-century, NAS has continued to evolve as a leader in high-end computing (HEC). Our supercomputers are still integrated with high-speed networks and mass data storage systems, but are now augmented by customizable support in user services, software performance optimization, high-fidelity modeling and simulation, and scientific visualization. Together, they provide our users with unparalleled support throughout the entire life-cycle of their projects.

Production Supercomputing
Our expert HEC team manages all aspects of the NAS production supercomputing environment to ensure users get the secure, reliable resources they expect. The current environment includes three supercomputers, as well as two secure front-end systems requiring two-factor authentication, and two secure unattended proxy systems for remote operations. The Columbia supercomputer—recently upgraded to 14,336 cores and 88.9 Tflops of peak processing power—continues to enable striking advances in addressing NASA’s real-world science and engineering challenges. In addition, NAS houses two smaller but still very powerful tested systems, RTJones (43.5 Tflops) and Schirra (4.8 Tflops).

Networking Technologies
NAS high-speed networking technologies and services are essential to the performance of the HEC systems and their high impact for our customers. Using high-capacity network connections and our local and wide-area network expertise, scientists’ massive data transfers (some exceeding 1 terabyte per hour) travel seamlessly between local and remote systems. Our network engineers have also implemented innovative transfer strategies and protocols to vastly reduce time-to-solution for users.

Scientific Visualization
The NAS visualization team develops and applies tools and techniques customized for NASA science and engineering problems. Our tools help users view and interact with their results—right from their desktops—to quickly pinpoint important details in complex datasets. Working closely with NASA users, our visualization experts capture, parallelize, and render the enormous amounts of data needed to produce high-resolution, 3D visualizations and videos. NAS’ new Hyperwall-2 visualization system—the highest known resolution display in the world at a quarter-billion pixels—is designed to provide users with a way to visualize massive datasets directly from the supercomputing systems.

User Services
Our user services team works 24x7 to assure users can make effective, productive use of the NAS HEC systems. This team’s experience in anticipating and heading off problems and quickly solving challenges as they arise is greatly appreciated by users. During Space Shuttle missions, the team marshals all HEC components and NAS staff to ensure essential support is in place for vital analysis tasks. This enables engineers to rapidly provide mission managers with critical data to clear Shuttles for landing. User services staff monitor all systems, networks, job scheduling, and resource allocations to ensure a stable, seamless computing environment.

High-Fidelity Modeling and Simulation
Many of NASA’s missions present unique aerospace design challenges that no off-the-shelf software can address. NAS scientists specializing in physics-based modeling and simulation have years of experience in developing world-class CFD software packages, custom tools, and methods. Our CFD experts provide critical services to NASA teams—often dramatically reducing time-to-solution and substantially increasing model resolution. Recently, the team has been involved in simulations to assess design risks for proposed crew exploration and launch vehicles.

Performance Optimization
The NAS application optimization team specializes in enhancing performance of NASA’s complex codes so researchers can do more science and engineering in less time by utilizing our HEC systems more effectively. Optimization services range from answering basic questions to partnering with users for in-depth code performance optimization. The team also evaluates tools and technologies best suited for the NAS environment and gives feedback to outside tool developers.

Data Storage
Our HEC customers often require vast amounts of data storage. With about 25 petabytes (PB) of tertiary storage and over 2 PB of disk storage on the floor, NAS’ mass storage system allows users to archive and retrieve important results quickly, reliably, and securely. Our storage specialists create custom filesystems to temporarily store large amounts of data for special user projects, and provide individual training to help users efficiently manage and move such large amounts of data.

For more details on NAS systems and services, please visit http://www.nasa.gov/Resources/resources.html on the web.
Theoretical peak performance of NAS’ first supercomputer, the Cray X-MP (1984), in Teraflops: 0.00021
Minimum number of Apple Mac Mini computers it would take to exceed performance of the Cray X-MP: 1
Theoretical peak performance of Columbia (2008), in Teraflops: 88.9
Number of Mac Minis it would take to equal peak performance of Columbia: 329,185
Estimated total number of people who have ever lived on Earth, as of 2002: 168 billion
Amount of time, in seconds, it would take the Cray X-MP to add all their heights together: 505
Amount of time, in seconds, it would take Columbia to add all their heights together: 0.0012
Amount of time in years it would take a person to complete 1 hour of Columbia calculations, if they performed 1 calculation per second for 8 hours per day for 365 days per year: 30 billion
Approximate number of books housed in the U.S. Library of Congress collection: 32 million
Number of complete copies of the U.S. Library of Congress collection that would fit on NAS’ current mass storage system: 1,000+
Current amount of unique data, in Petabytes, stored on NAS mass storage systems: 3.2
Approximate number of trees it would take to make the paper needed to print all of this data: 168 million
Total amount of memory (RAM), in Gigabytes, available on the Cray X-MP supercomputer: 0.016
Number of iPod songs that could be stored in the Cray X-MP’s memory: 4
Total amount of memory (RAM), in Gigabytes, currently available on the Columbia supercomputer: 28,672
Number of iPod songs that could be stored in Columbia’s memory: 6,880,320
Speed of network connections, in bits per second, to some of NAS’ remote users in 1983: 300
Number of years it would take to download a feature-length movie using the original network connection: 3.97
Speed of NAS’ current high-bandwidth wide-area network, in Gigabits per second: 10
Number of seconds it would take to download a feature length movie now: 3.76
Number of Microsoft Xbox game consoles required to equal this graphics capability: 589

*The numbers in this chart represent the aggregate theoretical peak of the supercomputers operational at NAS on each date. For the purposes of this presentation, 1 Gflops = 1 mph