Case Study.

Bringing the Universe Down to Earth with High Performance Computing

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Design: Soulellis Studio

This work was supported by The National Science Foundation under grant award #0456129.

Printed in the United States of America

Bringing the Universe Down to Earth with High Performance Computing

To conduct leading edge astrophysical research, educate the public, and create its spectacular and highly popular shows based on real science, the American Museum of Natural History's Hayden Planetarium augments its own computing with the extensive supercomputer capabilities available through the National Science Foundation high performance computing Centers, such as the San Diego Supercomputer Center.

The audience leaned back in their chairs and watched the Milky Way unfold above them in exquisite detail. The voice of actor Tom Hanks invited them to take a trip far beyond planet Earth – a trip to the outer reaches of the universe. Within moments, they were speeding through the solar system and into the depths of space, heading straight for the Orion Nebula some 800 light years away.

Passport to the Universe was the stunning first show at the totally rebuilt American Museum of Natural History's (AMNH) Hayden Planetarium when it reopened on February 17, 2000. Located in New York City as part of the museum's new Rose Center for Earth and Space, the revitalized planetarium is unique. The top half of the Hayden Sphere houses the Space Theater, the most technologically advanced theater in existence, which uses state-of-the-art visual technology to create shows of unparalleled sophistication, realism and excitement in a completely immersive dome environment. With this high-definition system, the Hayden Planetarium has become the largest and most powerful virtual reality simulator in the world. As Hanks told the *Passport* audience, "To explore the universe in three dimensions, we will use a powerful computer, loaded with real astronomical data from the great observatories on Earth and in space."

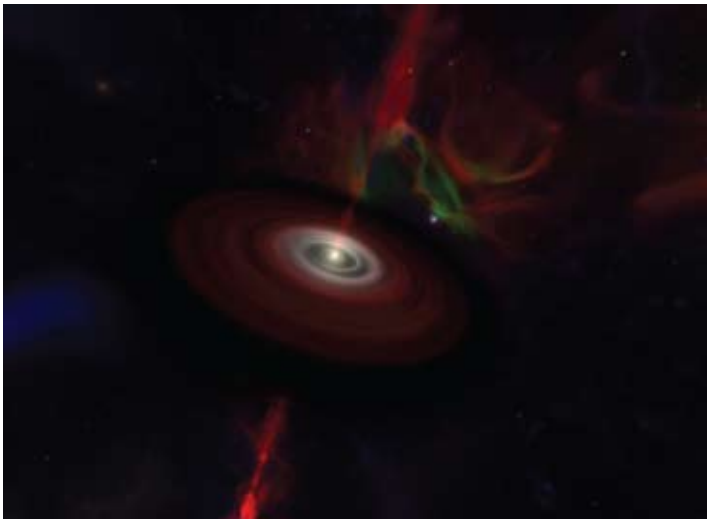
Since the facility's reopening, two other shows have been produced: *The Search for Life: Are We Alone* and *Cosmic Collisions.*

Educating the Public in an Entertainment-Driven Society

More than the Space Theater or a building, the Hayden Planetarium enjoys a proud legacy that has blended scientific scholarship with innovative public outreach for much of the past century. Since 1935, the Hayden Planetarium has served as the premier conduit between the frontier of cosmic discovery and the public's appreciation of it. Its mission is education – to bring the latest discoveries of astrophysics to the public via exhibits, books, public programs and online resources. The museum's newest research department, astrophysics, also located at the Rose Center, provides the scientific underpinnings for planetarium programs from its world-class astronomy and astrophysics research, and supports the museum's broader educational offerings.

As part of its charter to educate the public, the Hayden Planetarium, along with the Department of Astrophysics, must produce informative shows that are not only scientifically accurate, but highly popular as well. This is a major challenge in an entertainment-rich world, with everything from thrill rides to MP3 players to the latest generation of interactive video entertainment systems and the seemingly inexhaustible resources of the Internet competing for people's time and attention.

"The reality is that we are competing in a national and international market, not just for planetarium shows, but also for visitors attending location-based tourist attractions as well," says Mordecai-Mark Mac Low, curator of



the AMNH Department of Astrophysics. "This includes not only venues like the Adler Planetarium in Chicago and the Cité des Sciences in Paris, but also Disneyland and Six Flags…We have to provide an experience to the public that is frankly going to get them to spend their leisure time with us, hopefully learning something, instead of on a roller coaster."

For Mac Low and the other AMNH scientists, this means using their cutting-edge scientific data to collaborate with Carter Emmart, director of astrovisualization, and the Rose Center visualization team in creating exciting and entertaining educational productions that draw large audiences. Accomplishing this requires advanced computing capabilities – the kind that only supercomputers can provide.

Number Crunching the Cosmos

The process of computationally transforming mathematical data into realistic, 3-D images is called visualization. This is the process used to create the hugely popular animated movies enjoyed around the world. At the Hayden Planetarium, the same process is used to transform enormous volumes of actual scientific data from observations and physics-based computer models (also called simulations) into visualizations of the real universe. Processing this amount of data in a realistic time frame is impossible without high performance computing (HPC).

To create its three planetarium shows, the AMNH team used its own HPC resources – currently a powerful cluster of 100 off-the-shelf microprocessors. But for the really huge number crunching needed to render the most difficult and complex scenes, they turned to the HPC capabilities available through the National Science Foundation (NSF) Supercomputer Centers – a partnership between NSF and some of the nation's top universities. Harnessing the thousands of processors available at these HPC facilities has enabled a level of scientific simulation and visualization that was not otherwise possible.

For example, sequences in *Passport* made extensive use of the HPC capabilities and expertise available at the San Diego Supercomputer Center, one of the NSF partners. This included rendering the Orion Nebula sequence.

Rendering is the process of following or tracing the light rays to create an accurate image for the visualization. This process is similar in concept to a camera recording a picture when light bounces off an image and strikes the camera lens. Rendering the Orion Nebula was an HPC-sized challenge because millions of light rays had to be traced from the stars through the gas to create an accurate and authentic visualization.

AMNH researchers also turned to the San Diego Center's HPC systems to tackle the rendering challenges for scenes in *The Search for Life.* For this show, a series of complex computations detailed the sequence of events that led to the formation of the solar system and the earth. The AMNH researchers took the distribution of gas density, pressure, temperature, velocity and other extremely detailed parameters and produced a 3-D visualization of the gas flow as the solar system began to coalesce. This was not an artist's conception of what might have happened – all the sequences were created from simulations or actual observations, meeting the museum's dual goals of creating shows that not only convey the greatest possible educational value, but also are highly appealing to the public.

"Classical planetarium shows have been centered on a terrestrial view of the two-dimensional night sky," Mac

These images show the Orion Nebula. SDSC created an unprecedented, multi-scale, volumetric rendering method to depict this combination of ground and space-based data. SDSC and AMNH won the highest honors in the field of computer graphics at the time for this work (equivalent to the Oscars in the graphics field) at the annual, international computer graphics expo, SIGGRAPH. Image courtesy of American Museum of Natural History.

Low says. "Such a perspective neither captures our vastly expanded scientific understanding of the cosmos, nor is it competitive with other location-based leisure activities. At the Hayden Planetarium, high-performance computing coupled to high-resolution video projection enables travel in the third dimension, off the Earth and out into the observable universe. These advanced capabilities have allowed us to bring the latest scientific research to audiences numbering in the millions."

HPC Competitive Impact: Freeing the Imagination — Educating the Public

Passport to the Universe, The Search for Life: Are We Alone? and the Hayden's newest project, *Cosmic Collisions,* have helped to make the planetarium one of the most respected and visited in the world. And these shows would not have been possible without HPC, Mac Low says. "The power of supercomputers allows us to let our imagination and scientific understanding drive the show process, rather than the limitations of technology. As a result, our shows have become the current state-of-the-art for planetarium shows both nationally and internationally and draw audiences in the millions. In addition, access to these supercomputers helps us meet our educational goals, bringing frontier astrophysical research into the museum's programs and activities," he adds.

Their success is in the numbers. Approximately one million people a year see a show at the Hayden. In addition, AMNH has issued 47 licenses to show one of the three shows at other venues in the United States, Europe, Japan, China and Australia. Even vacationers on the Cunard's *Queen Mary 2* luxury liner can view one. As a result of these licenses, AMNH reaches more than another two million people with its educational visualizations about the origins of our earth and universe. And these licenses provide an additional source of revenue for the museum that helps support its research and the creation of new shows.

"High performance computing capabilities, especially those available to us through San Diego and the other NSF Centers, are invaluable – we wouldn't be occupying the leadership position we hold today without them," Mac Low explained. "The result is a new generation of highly appealing educational programs that allows us to include the latest discoveries in astrophysics in the learning process."

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>
> **Mordecai-Mark Mac Low,** curator, The American Museum of Natural History Department of Astrophysics

In Brief

Key Challenges

- Support the American Museum of Natural History's Hayden Planetarium's mission of bringing the frontier of astrophysics to the public via planetarium shows, exhibits, books, public programs and online resources
- Create popular, well-attended shows based on real astrophysical data and physics-based simulations to both educate and entertain the general public
- Provide education, training and professional development for both students and teachers, as well as to professionals specializing in astrophysics
- Compete in the national and international marketplace against other planetariums and location-based tourist attractions

Web Sites

- amnh.org/rose/spaceshow/cosmic/?src=e_h
- www.amnh.org/rose/searchforlife.html
- www.amnh.org/rose/passport.html
- haydenplanetarium.org/index.php

Solutions

- Couple high performance computing to high-resolution video projection to create and present detailed, science-based and visually exciting 3-D shows that range from the planet Earth to the observable universe
- Make those shows available not only to Hayden Planetarium visitors but also to other planetariums and venues world wide

Key HPC Benefits

- Enables the creation of planetarium shows that are both informative and entertaining
- Planetarium shows educate millions of people with a compelling view of our solar system, galaxy and the cosmos based on actual frontier astrophysics research
- Allows the Hayden Planetarium to compete more effectively in the national and international marketplace, and generate additional revenue to continue driving the research and education process

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