

**Advanced Visualization Laboratory (AVL) at the
National Center for Supercomputing Applications (NCSA) University of Illinois**

***Hubble 3D* Fact Sheet**

Donna Cox, Director of AVL, acted as NCSA's visualization producer/designer for *Hubble 3D* astrophysical scientific visualization, contributing two dramatic voyages comprising nearly 10 minutes of the 43-minute film. NCSA's scenes were based on a host of scientific data, including model and Hubble image data provided by the Space Telescope Science Institute (STScI), animation elements provided by the Spitzer Science Center, and simulation data provided by Princeton University's Department of Astrophysical Science.

AVL has a long history of producing astronomy and astrophysics scientific visualizations for planetarium digital domes and broadcast television, in addition to two prior IMAX® documentary shorts. AVL has worked with virtual reality, 3D rendering, and display technology for many years. Partnering with IMAX and STScI on the production of the astrophysical scientific visualizations for *Hubble 3D* was a wonderful opportunity to share ultra-high-resolution renderings of the cosmos with the public in the immersive IMAX® 3D format.

The IMAX team—Toni Myers (Producer/Director), Judy Carroll (Associate Producer), and Hugh Murray (Stereography Consultant)—visited NCSA on several occasions, along with Frank Summers from STScI, to develop the concept and treatment for NCSA's contribution to the film. The team worked with AVL's state-of-the-art ultra-high-resolution 3D display to interactively design the scenes and get a sense of what they would look like when transferred to the IMAX screen.

The first scene AVL created flies to the Orion Nebula and through its “star nursery.” The second leaves our Milky Way galaxy and flies to the Virgo Cluster, through the Hubble Ultra Deep Field of galaxies, and embeds them in a supercomputer numerical model of the Cosmic Web.

Working with Toni Myers and the team, Robert Patterson created two seamless camera moves that take the audience across millions of light years in a matter of minutes. This was achieved with AVL's Virtual Director software, which allowed the team to work interactively in an immersive 3D “virtual cosmic set” based on scientific models and data. Stuart Levy used his Partiview application to interactively preview the galaxy models and Alex Betts used an interactive Maya scene file renderer for previewing the Orion nebula. Patterson and Myers were then able to make immediate, finely-tuned changes to the audience's journey and preview these scenes in 3D.

Matthew Hall, a primary developer of Virtual Director, added new navigation and 3D capabilities to the software, which enabled the multi-scale flight paths to be created in real time. Using a spaceball controller, Patterson could navigate, record, and edit flight paths through the cosmic content. Once the camera paths were designed, the AVL team

could start the elaborate visualization rendering process.

To create the voyage to the Orion Nebula, AVL collaborated with Frank Summers and the STScI team, who provided the Orion base geometric model and Hubble image textures along with star nursery data. AVL used this data as a starting point and developed methods for creating the elaborate realistic renderings of the nebula.

Alex Betts developed new volume modeling capability by adding a “voxelizer” to AVL’s Maya data visualization plug-in. The voxelizer uses the Orion polygonal model and textures as source input along with a host of other parameters to create a three-dimensional volume model that, when rendered, creates the elaborate and realistic nebula imagery. Betts and Patterson worked together to create layers of volume-rendered elements for the scene.

Levy and Betts worked on a method of rendering stars that could suggest the millionfold range of star brightness through the Orion scene. Stars are shown with glare artifacts such as the human eye might see when looking at brilliant points of light. The brightest stars have fine radial lines, as if from light scattered by fibers within the eye’s lens, and diffraction related speckle patterns.

AJ Christensen and Betts created the rendering treatments of Orion's veil, proplyds and bowshocks based on the STScI model. Christensen created numerous veil elements that the camera passes through and refined the look of the proplyds and their internal disks and jets to match the Hubble imagery.

At the end of the Orion shot, we see a close-up of an elaborate proto-planetary disk, which was rendered by Robert Hurt of the Spitzer Space Telescope Group and composited at NCSA. There were 52 separate layers of imagery rendered and layered together over the course of the Orion shot for both the left and right eye.

To create the voyage from the Milky Way to the Virgo Cluster of galaxies, AVL used their model of the Milky Way and created new 3D particle models for the Andromeda and M87 galaxies. These galaxy models were properly positioned in a larger galaxy catalog from Brent Tully, University of Hawaii, which contains approximately 30,000 galaxy positions and types. Levy worked on the rendering of this larger collection of galaxies, using imagery from Hubble and from ground-based telescopes.

After the voyage from our Milky Way to the Virgo cluster the scene transitions to the Hubble Ultra Deep Field (HUDF) collection of galaxies, prepared by Summers and his team at STScI. Christensen, Levy, and Cox created the camera move for the pullback from the HUDF and choreographed a seamless transition to a visualization of a supercomputer simulation of the large-scale structure of the universe: the cosmic web, developed by Jeremiah Ostriker and Paul Bode of Princeton University. The visualization of the cosmic web provides the context for a dramatic ending to the film.

NCSA shared test animations with the IMAX team and STScI for review, and IMAX’s

Murray provided important feedback on the 3D stereo treatment. NCSA created over 2.4 terabytes of final composited images at 5616x4096 pixel resolution that were shipped to David Keighley Productions in Los Angeles for IMAX film recording.

Facts on supercomputing the scenes

AVL used Linux cluster supercomputers to develop and render the two scenes. The supercomputers are 64 bit Linux system machines with 8 cores and 16 gigs of memory per system.

Below, we provide a comparison of supercomputing to computing one hour on a typical fast personal computer (PC machine-hour) in order to develop and render the scenes for the *Hubble 3D* project:

- 28,000 PC machine-hours (3 years around the clock) or 20 fast PC computers working for 8 weeks around the clock

Computation for the two Final scenes only (not counting pre-processing data and tests):

- 6500 PC machine-hours total = 9 months = 20 computers running for 2 weeks around the clock
- 5000 PC machine-hours for the Voyage to the Orion Nebula
- 1500 PC machine-hours for Milky Way to the Cosmic Web scene

Facts on final image data

The two scenes of astrophysical visualizations, totaling 9 min. 18 sec. of animation, more than 20% of the film:

- Journey to Orion Nebula shot: 6417 frames, 4 min. 27 sec.
- Flight from Milky Way to Cosmic Web shot: 6987 frames, 4 mins 51 sec
- Total 13,404 stereo image pairs at 5616x4096 resolution
- 6.9 trillion bytes (6.28 terabytes, 135030 stereo pairs) of image segments and layers, assembled into 2.47 trillion bytes (2.24 terabytes) of final images
- 64 stereo computer graphics layers (12 for Milky Way to Cosmic Web and 52 for Journey to the Orion Nebula)

NCSA University of Illinois Credits

Donna Cox	Visualization Producer / Designer
Robert Patterson	Visualization Designer / Camera
Stuart Levy	Visualization Programmer
Alex Betts	Visualization Programmer
AJ Christensen	Visualization Programmer
Matthew Hall	Visualization Programmer