PHSColograms™

Science in Depth

A **PHSCologram** (pronounced *skol·o·gram*) is a new kind of picture. The images in *Science in Depth* represent collaborations by scientists and artists who want to communicate their love of the often complex mathematical beauty of nature.

To make a PHSCologram, (Art)^n and EVL slice a number of slightly different views of one subject into very thin vertical columns less than 1/400 of an inch wide. Thousands of vertical columns from all these views are lined up to make a single, slightly fuzzy-looking image. (Art)^n refers to this process as "interleaving."

This fuzzy image is then laminated onto the back of a piece of Plexiglas™. A black film with thin clear vertical lines called a "barrier screen" is then laminated onto the front of the plexiglas. The tiny slits in the barrier screen allow only one image at a time to be seen from a particular angle. Each eye sees a slightly different view of one subject, and the brain condenses these two views into a three-dimensional image.

A PHSCologram can be made of a real object or of a simulated one existing only as information in a computer program. Photographs of real objects are entered into the computer with a scanner, a machine which converts shapes and colors into numbers. Computer simulations are either photographed from the computer screen and scanned in, or transferred from the computer of the scientists who did the mathematical work to the computer which helps make the PHSCologram.

The four different types of PHSCologram in this show are described in more detail on panels near the respective PHSColgrams: the Early Camera Technique; the Computer/Camera Technique; the Stealth Negative Technique; and the Enlarged Stealth Negative Technique.

The Enlarged Stealth Negative Technique

A new method currently under development at (Art)^n and EVL is the Enlarged Stealth Negative technique. Until recently, all Stealth Negative PHSColograms™ were produced on a Crosfield™ scanner at I.P.P. Lithocolor with 400 dots per inch resolution. In collaboration with Ross-Ehlert photo labs, (Art)^n and EVL are now experimenting with a Kodak LVT (Light Valve Technology) scanner. This device produces negatives with a resolution of 1,000 dots per inch, a 250% increase in resolution, which means the final image can be greatly enlarged without loss of detail.

1. Volume Visualization of a Quaternion Julia Set *(formerly Fourplay)*

1990/40"x48" Enlarged Stealth Negative PHSCologram
(Art)^n Artists: Stephan Meyers, Ellen Sandor
In collaboration with: John Hart, University of Illinois at Chicago

A three-dimensional quaternion Julia set is shown in front of a section of the Mandelbrot set and the complex subset Julia set.

The Stealth Negative Technique

PHSCologram negatives are now interleaved with the aid of a computer. Once the images are in the EVL computer, they are interleaved and stored on magnetic tape. This tape is called a *stealth negative™*, since the visual information is present, but invisible.

The stealth negative is output on a *high-resolution pre-press scanner* at I.P.P. Lithocolor. This scanner produces four black and white images, each of which is used to expose a piece of transparent photographic film in one of the four colors used to create color pictures. These transparencies are then placed directly onto cibachrome film and a contact print is made.

The scanner also prints the barrier screen. Since the same scanner that makes the image also makes the barrier screen, very close alignment is possible between the interleaved images and the lines in the barrier screen. The barrier screen and the contact print film are laminated onto the opposite sides of the plexiglas, and, as with the previous techniques, each of the viewer's eyes sees a slightly different image which the brain condenses into a three-dimensional image.

2. O'Keeffe III

1990/20"x 24" Stealth Negative PHSCologram
(Art)^n Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Clifford Pickover, IBM
A visualization of the formula: $z = \frac{5xy^2}{x^2+y^4} + \cos(6 \pi x \sqrt{x^2+y^2} \arctan(\frac{y}{x}))$
combined with the black-and-white imagery of Georgia O'Keeffe

3. Strange Attractor

1989/20"x24" Stealth Negative PHSCologram
(Art)^n Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
Rendered at the Electronic Visualization Lab at the University of Illinois at Chicago

A strange attractor, a mathematical description of chaotic motion, rendered with a trigonometrically-based recursive mathematical formula.

4. Stacked Julia Set II

1990/20"x24" Stealth Negative PHSCologram
(Art)^n Artists: Dan Sandin, Stephan Meyers, Ellen Sandor
Rendered at the Electronic Visualization Lab at the University of Illinois at Chicago

A progression of two-dimensional fractals are stacked on top of one another to form a three dimensional fractal. A view from the top looking west.

5. Stacked Julia Set

1989/20"x24" Stealth Negative PHSCologram
(Art)^n Artists: Dan Sandin, Stephen Meyers, Ellen Sandor
Rendered at the Electronic Visualization Lab at the University of Illinois at Chicago

A progression of two-dimensional fractals are stacked on top of one another to form a three dimensional fractal. This view shows the entire fractal, looking down.

6. Radar Thunderstorm

1990/20"x24" Stealth Negative PHSCologram
(Art)^n Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Erik Pepke, Ken Johnson, Peter Ray, Steven Lang Supercomputer Computations Research Institute, Florida State University

Radar data of a thunderstorm in the Magdalena Mountains near Socorro, New Mexico. A transparent white surface shows heavier precipitation toward the center. Red surfaces show updrafts within the storm. Brown surfaces represent the terrain below.

7. **Messiah**

1987/60"x96"(5'wide by 8' tall) sculpture with 6 PHSCologram panels
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi,
Stephan Meyers

*In the background of each panel is a CATSCAN of a person named Messiah
who died from complications brought on by the AIDS virus.*
Special thanks to: Dr. Roberta Glick.
*Note: All panels in Messiah were produced using the early camera technique,
except for the AIDS Virus image, which uses a Stealth Negative.*

A. Hope

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi

B. Chance

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi

C. AIDS Virus, Third Edition

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
Special thanks to: Kevin Maginnis

*A visualization of the AIDS virus, based on scientific data available in 1987.
Most of the structure portrayed is still accurate by 1990 standards.*

D. Chance

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi

E. Death

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi

F. Hope

1987/20"x24" PHSCologram
(Art)ⁿ Artists: Randy Johnson, Dan Sandin, Ellen Sandor, Jim Zanzi

8. **Benzene passing through a Faujasite Ring**

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Aileen Alvarado-Swaisgood, Keith Baumruck,
Don Hopkins, Christopher Marshall, Don Washecheck, April
Swanson, Amoco Corporation; Mike Krogh, Jeffrey Thingvold, NCSA

*Faujasite is used as a diffusion filter for benzene during the processing
of petroleum products. The electron density field for the benzene does
not overlap that of the faujasite, showing that there is no chemical
reaction between them, and proving that faujasite is a suitable filter.*

9. **Chromium Chloride Density Difference Contours**

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Aileen Alvarado-Swaisgood, Keith Baumruck,
Don Washecheck, Amoco Corporation; Jeffrey Tilson, James Harrison,
Michigan State University; Mike Krogh, Jeffrey Thingvold, Harrell
Sellers, NCSA

*The surfaces show changes in the electron density field surrounding
chromium chloride (CrCl+) as it forms. Blue denotes electron loss, red
shows a gain of electrons, and green indicates no change.*

10. **Ion Sulfur Cluster**

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Arthur Olsen and David Goodsell, The Scripps
Clinic and Research Foundation

*The ion sulfur cluster is very important to the function of a number of
proteins. This visualization uses the results of complex quantum
mechanical calculations performed by Lou Noodleman.*
©1990 David Goodsell and Arthur Olsen

The Early Camera Technique

These early PHSColograms are based on photographs of physical objects, sculptures or scenes set up in front of a room-sized camera. A large sheet of blank, unexposed film is placed on a vacuum table which uses air pressure to hold the film smooth and in place. A barrier screen is placed on top of the film. Multiple exposures (usually nine) are then taken of the subject. Between each exposure, the camera and the subject are moved so each image will pass through the barrier screen at a different angle onto the film. This means the film is exposed in strips corresponding to the lines on the barrier screen. Each exposure takes 45 minutes, and a whole PHSCologram can take almost 7 hours to photograph. The film is then developed and laminated onto the back of a piece of plexiglas, with a barrier screen on the front which allows each eye to see only one of the original nine images at a time. The brain interprets this stereo image as three-dimensional.

11. O'Keeffe II

1986/30"x40" PHSCologram
(Art)^n Artists: Randy Johnson, Ellen Sandor

12. O'Keeffe I

1983/32"x48" PHSCologram
(Art)^n Artists: Randy Johnson, Mark Resch, Ellen Sandor, Gina Uhlmann and Jim Zanzi

13. Man Ray 1983

1983/32"x48" PHSCologram
(Art)^n Artists: Randy Johnson, Mark Resch, Ellen Sandor, Gina Uhlmann, and Jim Zanzi

14. Keeping Time With Fashion

1983/32"x48" PHSCologram
(Art)^a Artists: Randy Johnson, Mark Resch, Ellen Sandor, Gina Uhlmann, and Jim Zanzi

15. Battle to the Death at the Ice Palace

1983/32"x48" PHSCologram
(Art)^n Artists: Randy Johnson, Mark Resch, Ellen Sandor, Gina Uhlmann and Jim Zanzi

Computer/Camera Technique

The first computer-generated PHSColograms were produced using the same camera mount used to photograph objects. Instead of photographing a real-life scene, however, (Art)^n and EVL photographed images displayed on a computer monitor. Between each of the nine exposures, the camera and the monitor were moved, and the image on the screen changed, to simulate a change in viewing angle and perspective. Because the only light entering the camera was the soft glow of a computer monitor, a special low-light film was provided under a special grant from Kodak.

16. Sadie Elmo

1988/20"x24" Computer PHSCologram
(Art)^n Artists: Donna Cox, Dan Sandin, Ellen Sandor, Tom DeFanti
In collaboration with: George Francis, Ray Idaszak, NCSA

The image juxtaposes the Transparent Venus (a projection of the Rhomboy Homotopy) with a bump-mapped mammogram of a breast cancer victim. This PHSCologram was done in memory of Donna Cox's grandmother, who died of breast cancer.

17. Lotus

1987/20"x24" Computer PHSCologram
(Art)^n Artists: Donna Cox, Dan Sandin, Ellen Sandor, Tom DeFanti
In collaboration with: George Francis, Ray Idaszak, NCSA

A three-dimensional projection of the Rhomboy Homotopy, a four-dimensional object.

18. Transparent Venus

1987/20"x24" Computer PHSCologram
(Art)^a Artists: Donna Cox, Dan Sandin, Ellen Sandor, Tom DeFanti
In collaboration with: George Francis, Ray Idaszak, NCSA

A three-dimensional projection of the Rhomboy Homotopy, a four-dimensional object.

19. Apollo At Sunset

1987/20"x24" Computer PHSCologram
(Art)^n Artists: Donna Cox, Dan Sandin, Ellen Sandor, Tom DeFanti
In collaboration with: George Francis, Ray Idaszak, NCSA

The Rhomboy Homotopy, a four-dimensional object, juxtaposed with a video image from nature.

20. Transparent Lotus

1987/20"x24" Computer PHSCologram
(Art)ⁿ Artists: Donna Cox, Dan Sandin, Ellen Sandor, Tom DeFanti
In collaboration with: George Francis, Ray Idaszak, NCSA

A three-dimensional projection of the Rhomboy Homotopy, a four-dimensional object.

The Stealth Negative Technique *(continued)*

21. A. Hypersonic Vehicle

1989/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
In collaboration with: Workstation Applications Office, NASA Ames
Research Center/Sterling Software

A simulation of a hypersonic vehicle traveling at Mach 12.4, showing pressure on the surface of the vehicle and on a cross-section of the shockwave. Magenta is the highest pressure, blue is the lowest.

B. Mars

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: The Viking Project Office, NASA/JPL, and USGS

The surface of the planet Mars, showing Mount Olympus and Valles Marinaris (Valley of the Mariners), compiled from surface data supplied by space probes.

C. Space Shuttle

1989/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
In collaboration with: Workstation Applications Office, NASA Ames
Research Center/Sterling Software

The colors indicate pressure distribution over this computer model of the space shuttle. White is the highest, green is the static, and blue the lowest pressure. The left side is computational data and the right is wind tunnel data, allowing comparison between the theoretical and the real world.

22. A. F-18

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Workstation Applications Office, NASA Ames
Research Center/Sterling Software

Flow field around the F-18 aircraft at Mach .243, 30 degree angle of attack. The red traces represent the simulated oil flow on the nose, wing, and deflected leading edge flap and show the lines of primary and secondary separation. The forebody and leading edge extension vortices are shown using helicity density contours which appear as spiral shapes. The particle traces, shown in magenta, show the development and burst of the leading edge vortex.

B. V/STOL

1989/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
In collaboration with: Workstation Applications Office, NASA Ames
Research Center/Sterling Software

Pressure and windflow around a Vertical/Short TakeOff and Landing aircraft. The ground plate is colored according to pressure density, whereas the particle traces are colored by height above the ground: red is ground level, blue is above the delta wing.

C. F-16

1989/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Dan Sandin, Ellen Sandor
In collaboration with: Workstation Applications Office, NASA Ames
Research Center/Sterling Software

Windflow, colored to indicate height above the horizontal plane through the center of the airplane wing. Red is closest to, and blue is furthest above, this plane. The interaction between the vortex shed off the strake and the vortex shed off the wing is clearly visible.

23. Spacetime Visualization

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Ping-Kang Hsiumg, Carnegie-Mellon University

The relativistic effects of zooming into a cubic lattice at 99% of the speed of light (roughly 660 million miles per hour).

24. Papilloma Virus, Third Edition

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Donna Cox, Stephan Meyers, Dan Sandin, Ellen Sandor

A sexually transmitted disease virus. When left untreated, this virus can lead to cervical cancer. The background is a mammogram of a woman who died of breast cancer, with the cancer visible to the lower right.

25. Herpes Virus

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Dr. Bernard Roizman, University of Chicago;
Dr. Patricia Spear, Northwestern University

The general structure of the herpes virus, summarizing information gained by microscopic analysis and other experimentation.

26. MRI Brain III

1989/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Dr. David Levin, M.D., Ph.D., and Robert Grzeszcuk of the Department of Radiology, University of Chicago Hospital, Chicago, IL.

A Magnetic Resonance Image of a woman with a brain tumor. Clearly shown are the skin surface, the brain surface, and the tumor.

27. Polio II

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Arthur Olsen, The Scripps Clinic and
Research Foundation

The capsid of the polio virus, with the front two pentamers removed to show the interior. The three-dimensional structure was determined by X-ray crystallography to a 2.9 angstrom resolution by Jim Hogle and co-workers.
©1990 Arthur J. Olsen

28. Adenovirus

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: David Goodsell and Arthur Olsen, The Scripps Clinic and Research Foundation

The protein coat of the virus is shown in blue and a red icosahedron highlights the icosahedral nature of the coat. The putative genetic material is shown in cyan, inside the protein coat. This visualization was calculated from electron microscope data collected by Roger Burnett and Phoebe Stewart Hexem of the Wistar Institute.
©1990 David Goodsell and Arthur Olsen, Scripps Clinic

29. Roundup™ Herbicide

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Robert Otto, Monsanto Corporation

Visualization of EPSP synthase, a molecule involved in plant growth, being blocked by glyphosate, the active component of the Roundup™ herbicide.
©1990 Monsanto Corporation

30. Glycogen Phosphorylase

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: Dr. Robert J. Fletterick,
University of California, San Francisco

Visualization of a molecule found in the human liver, it is involved in the consumption of starch.

31. Extensions to the Twin Dragon

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: John Hart, University of Chicago at Chicago
Rendered at the Electronic Visualization Lab at the University
of Illinois at Chicago.

An extension of the two-dimensional twin dragon shape into 3-D. This is a linear fractal, constructed from an iterated function system of four affine transformations. The wood tiles on the floor illustrate the twin dragon shape.

32. Performance!

1990/20"x24" Stealth Negative PHSCologram
(Art)ⁿ Artists: Stephan Meyers, Ellen Sandor
In collaboration with: R.G. Belie, D. Vaske, K. Scholz, S. Singer, S.Reaser, R. Hayes, Lockheed Aeronautical Systems Company

Computational fluid dynamic data of F-22 Stealth Fighter airplane flight characteristics.

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