
Fermilab's 2016 Artist-in-Residence
Ellen Sandor and (art)ⁿ present
NEUTRINOS in a New Light
Including Select Works of Art and Science
December 2, 2016 - March 17, 2017
Fermilab
Fermilab Art Gallery
Kirk Rd. and Pine St. Batavia, IL 60510

Catalog Design by Chris Kemp

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Georgia Schwender, Kurt Riesselmann,
and Fermi National Accelerator Laboratory

Special Thanks:

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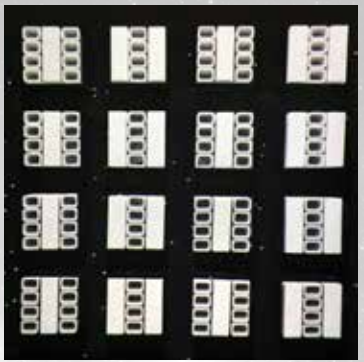

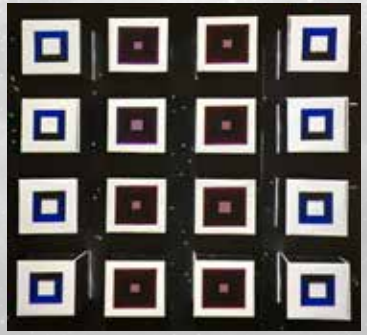
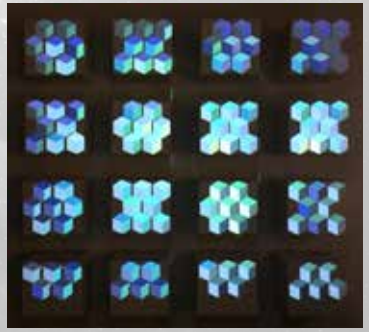

Neutrinos and NOvA: A Vasarely Variation, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Jennifer Raaf, Sam Zeller, Thomas Junk and
Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
Projection Mapping Installation

OUR VIRTUAL WORLD

NEUTRINOS IN A NEW LIGHT

December 2, 2016 - March 17, 2017

Fermilab's 2016 Artist in Residence

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The Art and Science of $(art)^n$ and Fermilab

Creativity is a common thread essential to artists and scientists. Reflected in drawings on blackboards or renderings in sketchbooks, the visualization of information is important to reach scientific and artistic goals.

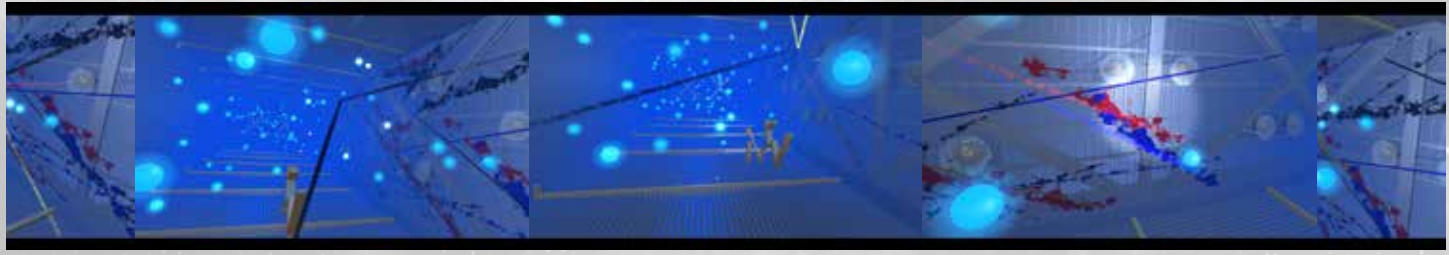
At Fermilab, this connection between art and science runs deep. Robert R. Wilson, the laboratory's founding director, was an innovator, physicist and artist. His vision of combining arts and science is evident by the sculptures, architecture and the design of the Fermilab site. The 8-foot Mobius strip perched on top of Ramsey Auditorium and the decorative Feynman diagrams displayed at the ground floor entrances to Wilson Hall are beautiful examples of art and design representing scientific principles.

In 2014, Fermilab established an Artist in Residence program to stimulate communication and interactions among scientists, artists and the public. The goal is for the artist to interact with scientists at the laboratory, learn about their research, see how it connects to society, and then use this information to create a body of work. In addition, the program opens the door to presentations in the local community and leads to the exhibition of artwork in the Fermilab Art Gallery and other places. Most important, the program aims to promote conversations between two worlds that have much in common and form collaborations that generate discoveries.

It is a great honor to have Ellen Sandor, a Chicago new media artist and director of $(art)^n$, as the 2016 Fermilab artist-in-residence. Her energy, enthusiasm and curiosity are rooted in her ability to combine art and science using state-of-the-art technologies. She values the alliance between artist and scientist and

finds discovery to be at the forefront of the digital age. Her ability to visualize the invisible—from viruses to subatomic particles—made her the perfect candidate, and her innovative artwork speaks for itself.

- Georgia Schwender,
  Founder of the Artist-in-Residence
  program at Fermilab



The Magnificent MicroBooNE: Science Through the Art of Jackson Pollock and David Smith, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Code by William Robertson, Co-Founder/CTO Digital Museum of Digital Art
Jennifer Raaf, Sam Zeller, Thomas Junk and Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
Virtual Reality Installation with Unity and Oculus Rift

Neutrinos in a New Light

Throughout 2016, Ellen Sandor and (art)^n collaborated with Fermilab scientists, translating their neutrinos research into multidimensional and interactive works of art and science that visualize the invisible. Neutrinos are strange elementary particles that travel near the speed of light and rarely interact with matter and other particles. They are produced by many different sources, including the Sun, the Earth's atmosphere, the decay of radioactive elements, and the death of some types of stars. Such properties make these particles mysterious and exciting subject matter for researchers and artists alike. It was (art)^n's role to reimagine such intricacies into visual art forms that speak to scientists and artists, while connecting with the society in which we all live.

During the 1930s, Enrico Fermi coined the term neutrino, and used it during a conference held in Paris in July 1932 and at the Solvay Conference held in October 1933. In parallel, Alberto Giacometti was experimenting with Cubism and Surrealism, and became an important Surrealist sculptor. His contemporary, Victor Vasarely was also experimenting with new ideas and innovated the Op-Art movement, in which abstract artworks gave viewers impressions of movement, hidden imagery, and vibrating patterns. By the 1960's, the abstract expressionist sculptor David Smith created his *Cubi* series, featuring large, abstract geometric forms made out of steel. The intersecting histories of these avant-garde artists created precursory works of art that reveal an inquiry into the scientific realm of invisible ideas, which are explored in this exhibition.

A large portfolio of collaborative works with scientists from NASA, JPL, Scripps Research Institute and others has been created by Sandor and (art)^n since the mid-1980s, which included a groundbreaking exhibition with the help of Martyl Lansgdorf that was featured at Fermilab in 1987. Martyl was one of the first women artists to work with scientists that resulted in her iconic design of the *Doomsday Clock*. (art)^n's first exhibition at Fermilab included 'Rhomboy Homotopy' images–four-dimensional mathematical fractals from scientific data visualized at the National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign. Additional PHSCologrames shown included

tributes to artists and an early computer generated portrait of the AIDS Virus based on available scientific data in 1987.

I have spoken against tradition, but only the tradition of others who would hold art from moving forward. Tradition holding us to the perfection of others. In this context tradition can only say what art was, not what art is.

- David Smith




From left to right:
Giacometti, 1963, by Henri Cartier-Bresson, 14” x 9 3/8” Modern gelatin silver print, from the Richard and Ellen Sandor Family Collection. Digital photo © Art Institute of Chicago. Photography by Jamie Stukenberg, Professional Graphics, Inc.
Alberto Giacometti and His Sculptures, Paris, France, 1951, by Gordon Parks, 11” x 14” Vintage gelatin silver print, from the Richard and Ellen Sandor Family Collection.
Cubi XVIII, 1965, David Smith, 10”x8” Vintage gelatin silver print, from the Richard and Ellen Sandor Family Collection. Digital photo by James Prinz Photography.
Cubi XXVI,1965, David Smith, 9 15/16”x8” Vintage gelatin silver print, from the Richard and Ellen Sandor Family Collection. Digital photo by James Prinz Photography.

Bubble Chamber Beginnings: Revisiting the Vintage, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Jennifer Raaf, Sam Zeller, Thomas Junk and Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
12”x42”x72” Digital PHSCologram Sculpture

Bubble Chamber Beginnings: Revisiting the Vintage

The bubble chamber PHSCologram sculpture was created as a reference to neutrino detectors of the past. A bubble chamber is filled with super-heated liquid, and charged particles traveling through the liquid leave trails of microscopic bubbles. The bubbles are expanded by changing the pressure of the chamber until they are large enough to be photographed.

Neutrinos cannot be seen directly; only the “aftermath” of their occasional collisions can be seen, and the neutrino type and energy must be inferred from the types and energies of the other particles that are created in the collision. The bubble trails of these other particles are photographed by cameras mounted at various locations on the chamber walls, and the trails curve in the images because of the magnetic field inside the chamber. The radius of curvature is proportional to the mass of the particle and its velocity.

Data from these chambers is vintage, and scientists have far better ways of detecting neutrino interactions these days. However the bubble chamber subject matter was chosen by $(art)^n$ because the data images produced from these detectors are truly beautiful artworks that still resonate.

Particle Physics as Art

Particle physics is art. It is most obvious in images of data from various types of particle detectors over the past decades, where each type of detector has its own personalized way to show what information it has collected. Each image is beautiful and intriguing, possibly hiding within itself the resolution to long-unanswered questions.The art lies both in the visualization of the raw data itself, and in the analysis of the data to probe the underlying science hidden within those beautiful images. The art and the science are inextricably linked.

As an “art-sympathetic scientist,” I appreciate opportunity to share with “science-sympathetic artists” my excitement over bits of color or light distributed in distinct patterns in my detectors. It’s not the color or the pattern itself that excites me (although sometimes they do), but the meaning of the color and the pattern. The fact that I can use the simple constructs of color and pattern as tools to help reach deep into not-yet-fully-understood physics is astounding to me. In return, the artists teach me how much more closely the art and the science are related than I knew.

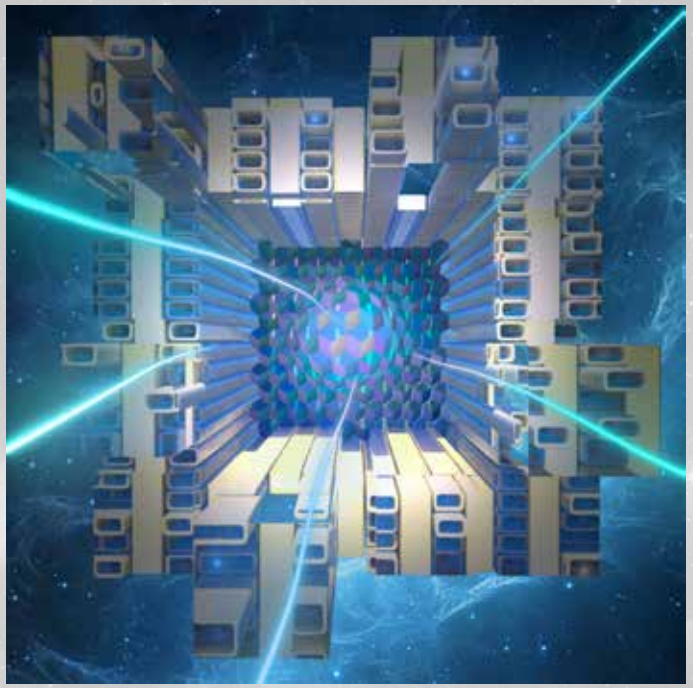
Scientific visualization would not be where it is today without the help of artists. Scientists must consider aesthetics when choosing how to best represent their data. We must express the essence of the science by showing the abstract representation of the data that best conveys the point. Artists create new ways to see the data; they help us to better communicate the message hidden within the data. Aesthetic consideration and a bstraction are the fundamental constructs that bridge the gap

of human understanding and perception of our mysterious universe, and this partnership of art and science makes it possible.

Neutrinos are a simple and yet abstract example of the scientific-artistic alliance. A neutrino itself cannot be seen, but the art and science together make the invisible visible, recording evidence of the truly occasional occurrences of neutrinos interacting, where they leave tiny traces like DNA at the scene of a crime. The art lies in every part of the science, and there is science in the art: in designing and building machines that are sensitive to miniscule deposits of energy in the form of light or charge, in taking these collected data from their raw format to something visually appealing and understandable, in gathering the evidence and synthesizing it, reaching toward the new and the unknown, and aiming for clarity and refinement. Perhaps we will never reach full understanding of our entire universe, but it is certain that we would not be where we are today without both the art and the science.

- Dr. Jennifer Raaf
  Scientist, Neutrino Division
  Fermi National Accelerator Laboratory

Dr. Jennifer Raaf has been a staff scientist at the Fermi National Accelerator Laboratory (Fermilab) since 2011. Her interest in neutrinos began in graduate school, and she has since worked on several neutrino experiments in the U.S. and Japan, studying the properties of these particles that may hold the key to unanswered questions about our universe. Dr. Raaf received an Early Career Award in 2016 from the U.S. Department of Energy Office of Science, and is a joint awardee of the 2016 Breakthrough Prize in Fundamental Physics.



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Special Thanks to Janine Fron
30”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

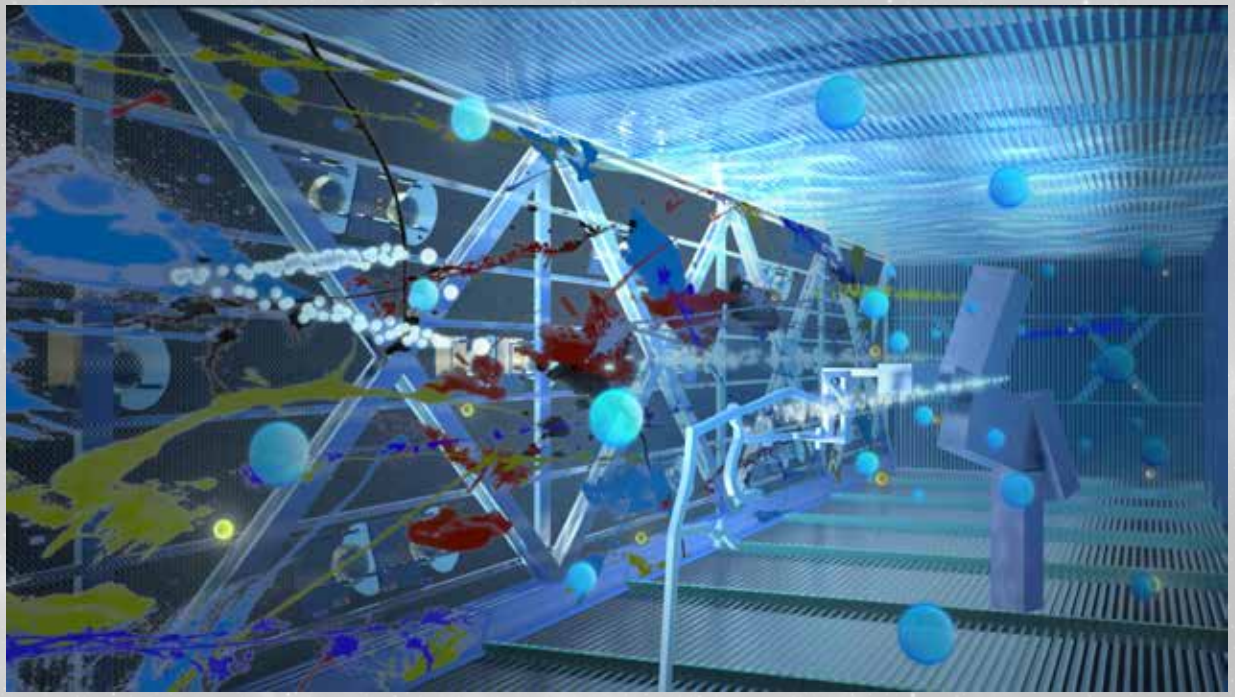
Neutrinos and NOvA: A Vasarely Variation

NOvA is a large above-ground neutrino detector made mostly out of plastic PVC pipes filled with mineral oil, which is the material with which the neutrinos interact. Neutrinos are constantly being fired into the NOvA detector, and on the rare occasion that a neutrino interacts with the mineral oil, the collision releases protons, neutrons, and other types of particles. As these outgoing particles travel through the oil, they leave energy in the form of a very tiny bit of light. Photosensitive optical fibers that are installed inside the PVC pipes detect the tiny amounts of light, marking the locations of the particles' paths as they travel through the oil. Because the precision of the location of each particle path is limited by the size of the PVC pipes, the path can only be pinpointed to that extent within the full grid of pipes.

$(art)^n$ depicts this through both projection mapping and a PHSCologram work, using the grid-like design to transcend the data into a Victor Vasarely inspired artwork. Vasarely's work tends to use repeating shapes and different colors, and was an obvious fit for an artful analogy.

Victor Vasarely was a Hungarian born artist widely considered the "grandfather of Op-Art art." With training as a graphic designer, Vasarely believed the correct use of color geometric shapes could lead to enhanced ways of perceiving space, matter, and energy in art. This form of geometric abstraction became known as Op-Art.

$(art)^n$ uses Vasarely's Op-Art geometric abstraction to artistically demonstrate the both the inner workings and produced data of the NOvA detector. The geometric layout of the PVC piping inside the NOvA detector can create geometric data graphs with color indicating places of neutrino collision. $(art)^n$ expands on this and elevates it to Vasarely's colorful and energized Op-Art level.



The Magnificent MicroBooNE: Science Through the Art of Jackson Pollock and David Smith, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Jennifer Raaf, Sam Zeller, Thomas Junk and Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
40”x24” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

The Magnificent MicroBooNE: Science Through the Art of Jackson Pollock and David Smith

The MicroBooNE particle detector resides inside a closed chamber (about the size of a school bus) filled entirely with liquid argon. Neutrinos are constantly being shot though the chamber and on occasion they will collide with an argon nucleus. The collision sometimes causes the argon nucleus to break up and at other times the nucleus remains intact, but in both cases the aftermath of the collision results in protons, neutrons, and other particles being expelled, sending them flying out from the collision point. The exiting particles leave trails of charge behind them as they pass through the detector, and these trails of charge are the way that scientists identify what type of interaction the neutrino had with the argon nucleus. A strong electric field is used to push the charged streams toward one side of the detector, which is instrumented with delicate wires arranged in a grid-like pattern that can sense the charge. Light is also created as the exiting particles travel through the liquid, and it is recorded by light-sensitive detectors situated behind the charge-sensing planes of wires.

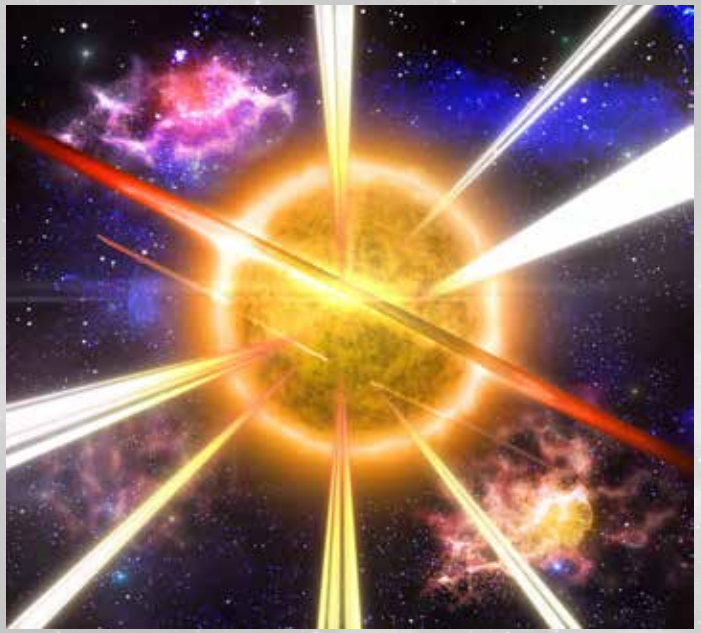
Both the light and the charge are important in understanding the details of the neutrino interactions. Data from the charge-sensing wires are displayed as a two-dimensional graph showing the path and the activity of particles exiting the neutrino interaction. Multiple views of the two-dimensional plane allow scientists to create three-dimensional graphs that are used to interpret the data. These graphs are color-coded and can be quite beautiful and reminiscent of abstract art.

With the $(art)^n$ MicroBooNE VR, the recorded charge of the outgoing particles is replaced with colorful drawn lines and painted strokes in a Jackson Pollock style, as well as constructed sculpture in the style of David Smith's Giacometti-inspired work. Both the Pollock painted brush strokes and the Smith sculptures are built up in relation to the course of the particles, illustrating their paths both two-dimen-

sionally and three-dimensionally, while elaborating on the artful presentation of the scientific data and honoring the style of these influential presences in art history.

Jackson Pollock was an American born painter renown for his role as one of the premier artists of the Abstract Expressionist movement of the 1940s. He is best known for his wild and resonate drip paintings, which Pollock created by dripping, pouring, and splattering resin-based paints onto large floor-lying canvasses in a process called action painting. This method of painting was just as much about the physical act of painting a work as it was about the final image. $(art)^n$ uses Jackson Pollock's unique drip painting style to artistically demonstrate the 2-dimensional graphs Fermilab researchers acquire from the charge-sensing wires inside MicroBooNE. In the same way Pollock's paint drips record his own movements of his action painting process, MicroBooNE data graphs illustrate the paths and the activities of the charged particles exiting the neutrino interaction.

Like Pollock, David Smith was also an American born artist who worked primarily in seclusion while expressing emotions in his work through strictly abstract ways. Combining influences of European Modernism including Cubism, Surrealism, and Constructivism, Smith is noted for essentially translating the painterly concerns of the Abstract Expressionist movement into sculpture. Traditional metal sculpture and casts required premeditation and design but Smith built his sculpture in the moment, welding metal pieces together in whatever form he currently desired. Smith considered himself more a painter than sculptor, considering his method of work. Later Smith began exploring stainless steel sculpture with burnished textures added through sanding and his work evolved into much more minimalistic art. In the end he was known along with his fellow artist of the times Alberto Giacometti, as one of the greatest sculptors of the era. $(art)^n$ uses an evolution of David Smith's various sculpture work to artistically demonstrate the three-dimensional data graphs Fermilab researchers gain from analyzing multiple views of the two-dimensional planes. In the same way Smith's sculptures became more minimal over time, the three-dimensional data is interpreted from the existing two-dimensional so it's less detailed than its Jackson Pollock implied predecessor.



The Supernova Spectacle, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Jennifer Raaf, Sam Zeller, Thomas Junk the Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
30”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

The Supernova Spectacle

When a massive star dies, it becomes a supernova, making the most powerful explosion known to occur in the universe. As the star runs out of nuclear fuel, the forces that support the star’s core weaken, and the core cannot withstand its own gravitational force. It collapses, creating a massive number of neutrinos that carry off the enormous amount of energy released by the collapse. Matter flows to the center of the core, and eventually the conditions within the collapsed core become so hot and dense that the star explodes into a very bright supernova.

The neutrinos escape from the exploding star hours or days before the light does, and these neutrinos can be detected and studied by neutrino experiments on earth to give information about the very early stages of core collapse. This allows scientists to better understand the life cycle of stars through a path that is inaccessible to optical astronomy.

Neutrinos as Forces of Nature

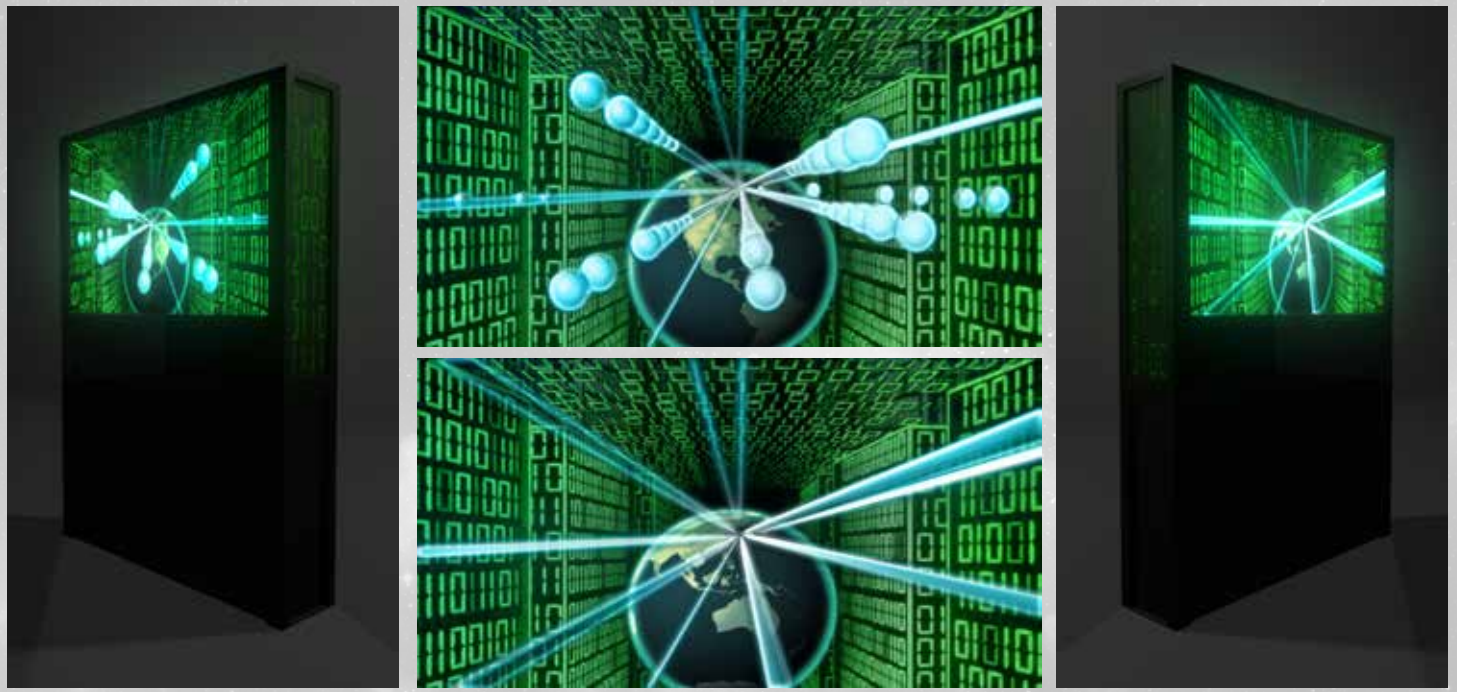
Neutrinos are the most abundant massive particles in the universe and as a result, they influence an enormous range of physics. Neutrinos allow us to search for new forces of nature, they measure the composition of the earth's crust, they tell us how the sun works, and they allow us to peer into the inner workings of a supernova explosion. Despite all that we have learned from these special particles, there remains a surprising amount of information we still do not know about neutrinos themselves. I have spent the large part of two decades studying these important yet elusive particles, using sources of both low-energy and high-energy neutrinos produced by the particle accelerators at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. The newest of these experiments is called MicroBooNE, a collaboration of over 150 scientists who are using a 170-ton liquid-argon neutrino detector to examine neutrinos in greater detail to better understand their often baffling behavior. MicroBooNE is part of a new short-baseline neutrino program at Fermilab that has the capability to tell us if new types of neutrinos exist. Finding a new type of neutrino would be a ground-breaking discovery, but one that requires careful cross-checks and scientific scrutiny. While searching for new types of neutrinos, I am also involved with planning next steps to use liquid-argon neutrino detectors on a much grander scale to study the phenomenon of neutrino oscillations across large distances. In this case, we plan to send very intense beams of neutrinos to a 70,000-ton liquid-argon detector sited a mile underground in a mine in South Dakota. This project is called the Deep Underground Neutrino Experiment (DUNE). Over 900 scientists from around the world are eagerly planning this bold new neutrino experiment that will soon be driving game-changing science. It is a fantastic time to be a

neutrino physicist. The coming years are full of promise and excitement as we move in new directions to better understand these unique subatomic particles and their connections to the world we live in.

The yearlong process of collaborating with Ellen Sandor and $(art)^n$ has been profoundly exciting and inspiring. Just as we are doing with our neutrino science at Fermilab, this team is pushing boundaries. They are challenging us to think differently about the neutrino physics we are doing and how this fits into the larger world around us. Through painstakingly accurate visualizations, we find ourselves immersed in the middle of a neutrino detector, wondering how the story will end and what neutrinos will tell us. Through this epic exhibit, I am proud to have been a part of this innovative and thought-provoking work.

- Dr. Sam Zeller
  Scientist, Neutrino Division
  Fermi National Accelerator Laboratory

Dr. Sam Zeller is a scientist at Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. She received a Ph.D. in particle physics from Northwestern University in 2002. Her dissertation, a measurement of the weak mixing angle in neutrino deep inelastic scattering, earned a Mitsuyoshi Tanaka Dissertation award in 2003 and has been cited over 600 times. She worked at both Columbia University and Los Alamos National Laboratory prior to joining the staff at Fermilab in 2009. She has participated in seven different experiments studying the properties of neutrinos over the course of her career, including NuTeV, MiniBooNE, SciBooNE, MicroBooNE, ArgoNeuT, SBND, and DUNE. In 2012, she received a U.S. Department of Energy (DOE) Office of Science Early Career award to further the study of neutrino interactions using liquid-argon detectors and is currently co-spokesperson of the MicroBooNE experiment. Dr. Zeller is currently a member of the U.S. DOE High Energy Physics Advisory Panel (HEPAP) and is Deputy Head of the Fermilab Neutrino Division. Her current research focuses on neutrino-nucleus interactions and neutrino oscillations.



Binary Bypass: Neutrinos for Data Communication, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Jennifer Raaf, Sam Zeller, Thomas Junk the Fermi National Accelerator Laboratory
Special Thanks to Janine Fron
12”x42”x72” Digital PHSCologram Sculpture

Binary Bypass: Neutrinos for Data Communication

Although still off in the not too distant future, scientists believe it is theoretically possible that eventually we will be able to send neutrinos through the entire earth in a binary code pattern to be deciphered on the other side. Neutrinos can pass through matter including the Earth. Scientists have already sent neutrinos through the earth in binary code and detected them after they traveled a short distance. If they can figure out a way of doing this on a larger scale, they could send neutrinos of a certain signature through the planet to be picked up with detectors on the other side, where the binary data would be analyzed to decipher the message. This would be a much more secure form of data transfer as opposed to beaming data around the Earth via satellites.

These innovative ideas are represented in a two-sided PHSCologram sculpture with 3D-printed digital ones and zeros attached to the sculpture's sides to add a further element of three-dimensionality.

Allies for Antineutrinos

Nuclear reactors are one of the most abundant sources of antineutrinos on earth and thus they're an excellent way of monitoring countries' nuclear programs. The International Atomic Energy Agency was established in the 1970s to be a watchdog to countries all around the world using nuclear energy. When a nuclear reactor contains uranium, more antineutrinos are emitted, however when a nuclear reactor contains more plutonium (which can be weaponized), fewer antineutrinos are emitted.

Scientists, governments, and members of the IAEA hope that at some point in the near future, governments will allow other countries to use antineutrino detectors near their nuclear reactors to prove that they are using these reactors for safe uranium nuclear power and not weaponized plutonium.

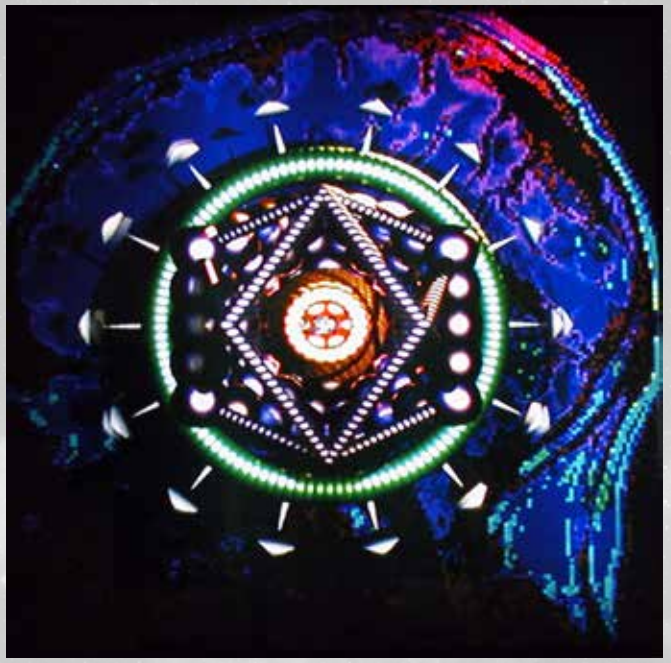
$(art)^n$ takes more of a metaphorical approach to this idea with a PHSCologram of the world created by two hands (partnering nations) with many antineutrinos being released ensuring safe use of uranium nuclear power is taking place and not weaponized plutonium.

Allies for Antineutrinos, 2016
Ellen Sandor, Chris Kemp, Diana Torres, and $(art)^n$
Jennifer Raaf, Sam Zeller, Thomas Junk and
Fermi National Accelerator Laboratory
Adam Bernstein and Lawrence Livermore National Laboratory
Special Thanks to Janine Fron
30"x30" Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Solar Dynamo / Solar Interior, 2016
Visualization by AVL, NCSA, University of Illinois
Donna Cox, Robert Patterson, Stuart Levy, Kalina Borkiewicz, AJ Christensen, Jeff Carpenter; Scientific Simulation by Juri Toomre, University of Colorado, Boulder; Mark Miesch, NCAR; Nicholas Nelson, LANL; Allan Sacha BRUN, UMR AIM Paris-Saclay; Benjamin Brown, University of Wisconsin-Madison
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
40” x 24” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Magneto-Convection Emerging Flux, 2016
Visualization by AVL, NCSA, University of Illinois, Donna Cox, Robert Patterson, Stuart Levy, Kalina Borkiewicz, AJ Christensen, Jeff Carpenter; Scientific Simulation by Robert Stein, Michigan State University; Åke Nordlund, Copenhagen University; Pat Moran, NASA Ames
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
40” x 30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Double Coronal Mass Ejection, 2016
Visualization by AVL, NCSA, University of Illinois, Donna Cox, Robert Patterson, Stuart Levy, Kalina Borkiewicz, AJ Christensen, Jeff Carpenter; Scientific Simulation by Yuhong Fan, NCAR
Ellen Sandor, Chris Kemp, Diana Torres, and $(art)^n$
40” x 30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas



AIDS Virus, Third Edition, 1989
Ellen Sandor, Stephan Meyers, and (art)^{n}
Dan Sandin and Tom DeFanti, Electronic Visualization Lab, School of Art and Design, University of Illinois at Chicago
Special thanks to Kevin Maginnis
30”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Ebola Virus, 2014
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Dr. Lukas Tamm, Center for Membrane Biology, University of Virginia
30”x30” PHSCologram, Duratrans, Kodalith, and Plexiglas

Ellen Sandor

Founding Artist and Director, (art)^{n}

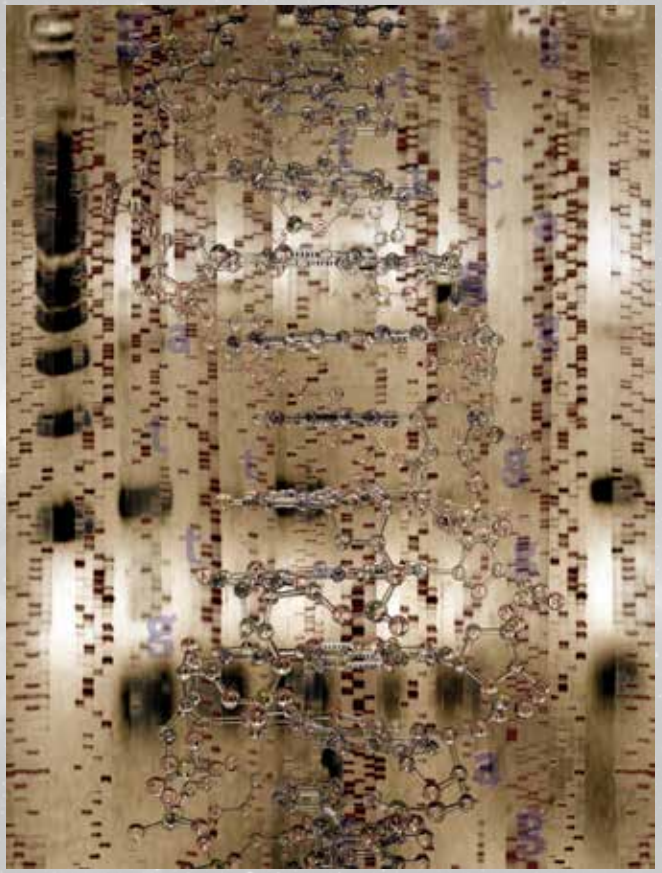
Ellen Sandor is a new media artist, and Founder/Director of the collaborative artists' group, (art)^{n}. She believes in the transformative role of Artist as Producer and Director. In 1975, Sandor received an MFA in Sculpture from The School of the Art Institute of Chicago. Her time at SAIC led her to be inspired by photography, sculpture, and video, and intrigued by the spiritual nature of Outsider Art. In the early 1980s, Sandor had the vision to integrate these things with other art forms including computer graphics that resulted in a new medium she called PHSCologrames–the photography of Virtual Reality and Computer Graphics that can be viewed reflectively or backlit as multidimensional photographs and sculptural installations.

Because PHSCologrames are a collaborative endeavor, Sandor has had the good fortune to work with an incredible group of gifted artists, scientists, technologists, and thinkers. These collaborators hail from distinguished institutions and universities including: The Scripps Research Institute, NASA Ames, Langley and Lewis Research Centers, JPL, EVL and NCSA at the University of Illinois, and the School of the Art Institute of Chicago. Some acclaimed artists Ellen and (art)^{n} have worked with include: Ed Paschke, Karl Wirsum, Roger Brown, Mr. Imagination, Robert Losutter, Christopher Landreth, Martyl, Claudia Hart and Carla Gannis. All these collaborators have shared her enthusiasm for utilizing technology to push conceptual and technical boundaries within the arts.

The works of (art)^{n} are in the permanent collection of The Art Institute of Chicago, Santa Barbara Museum of Art, International Center of Photography, The University of Oklahoma, The Smithsonian Institution and others. Commissions include The City of Chicago Public Art Program, The State of Illinois Art-in-Architecture Program, and SmithBucklin Corporation.

Sandor co-authored U.S. and international patents awarded to her for the PHSCologram process. She also co-authored papers that have been published in Computers & Graphics, IEEE, and SPIE. She is an Affiliate of eDream and a Visiting Scholar of Culture and Society, NCSA, University of Illinois, Urbana-Champaign. She is

Chair of the Advisory Board of the Gene Siskel Film Center of the School of the Art Institute of Chicago. She is on the Board of Governors for the School of the Art Institute of Chicago, Life Trustee of The Art Institute of Chicago and Secretary, Board of Directors, Eyebeam, New York. In 2012, she received the Thomas R. Leavens Award for Distinguished Service to the Arts through Lawyers for the Creative Arts. In 2013, she received the Gene Siskel Film Center Outstanding Leadership Award and in 2014, she was awarded an Honorary Doctorate of Fine Arts from the School of the Art Institute of Chicago. In 2016, she was honored as Fermilab's Artist in Residence. She is also co-founder of the Richard and Ellen Sandor Family Collection.



Cryptobiology: Reconstructing Identity, 2001
Ellen Sandor, Keith Miller, Fernando Orellana, Janine Fron, and $(art)^n$
Kathleen Helm-Bychowski, DePaul University
Special Thanks to Stephan Meyers
30"x40" Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

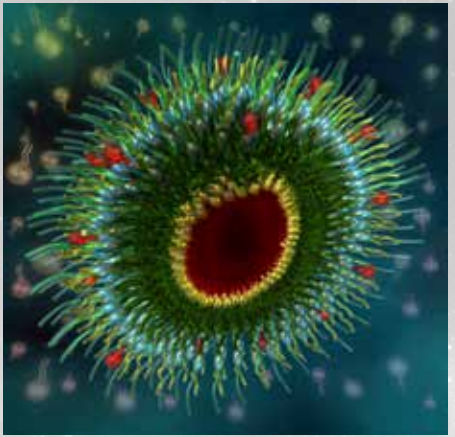
(art)^n Collaborators

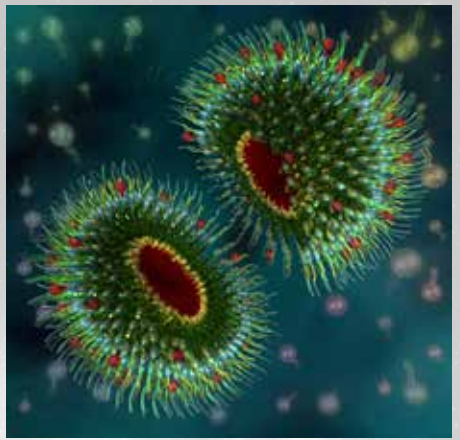
Chris Kemp is a long-standing collaborator with (art)^n since 2006 and current studio director of the collective. Along with new media PHSColograms and virtual reality, he's a devoted painter, photographer, and digital designer who has exhibited his work throughout the United States as well as Europe and Central America.

Diana Torres started working with (art)^n as a 3D artist in 2011 while getting her MFA at The School of the Art Institute of Chicago. She is an interdisciplinary artist from Colombia whose work includes animations, illustrations, paintings, drawings and sound. She has exhibited and screened her work in Europe, Australia, USA and South America.

Janine Fron has been a member of (art)^n since the early 1990s, and has collaborated on works that are in the permanent collection of The Art Institute of Chicago, Smithsonian Institution, International Center of Photography, and Santa Barbara Museum of Art, among others. She believes in the transformative nature of the arts to heal the human spirit.

Have a Nice Day, 2002
Martyl, Ellen Sandor, Keith Miller, Pete Latrofa, Janine Fron, and (art)^n
40"x30" Digital PHSCologram, Duratrans, Kodalith, and Plexiglas



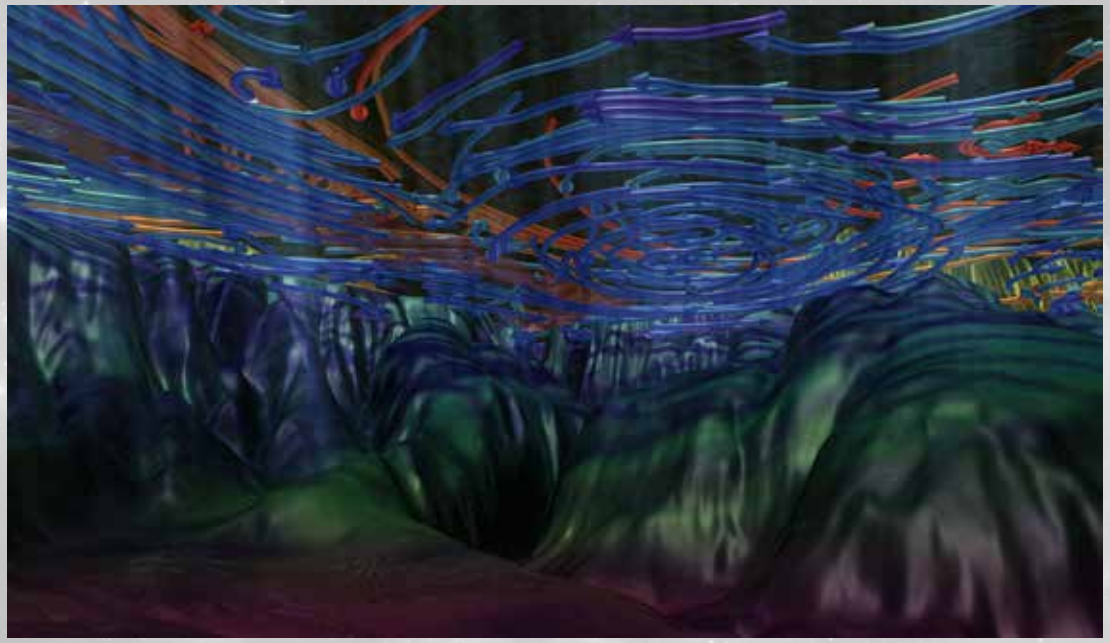


The Magnificent Micelle, 2013
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
Matthew Tirrell, Pritzker Director of the Institute for Molecular Engineering (IME), University of Chicago
Peter Allen, Scientific Visualization Director, University of California-Santa Barbara
30”x30”x63” Digital PHSCologram Sculpture

(art)^{n} PHSCologramsPHSCologram (pronounced skol-o-gram) is a new media acronym for photography, holography, sculpture and computer graphics. A number of rendered views of a virtual scene are digitally interleaved, in which the first line of every image is combined with the corresponding first line, and so forth until a recombined single image is made. This blurring of images into a single piece is attached to a line screen–a black piece of film with corresponding clear lines that is afixed to a piece of plexiglas, and allows a viewer to interpret the digital photograph as a three-dimensional sculptural object when backlit. The PHSCologram process is patented and was licensed by Picker International and 3M.

Commissioned projects include works in The Smithsonian Insitution, Museum of Contemporary Art Chicago, Santa Barbara Museum of Art, Museum of Jewish Heritage, International Center for Photography, City of Chicago Department of Cultural Affairs Public Art Program and State of Illinois Art-in-Architecture Program.

Museum collections include The Art Institute of Chicago; Roger Brown Study Collection, School of the Art Institute of Chicago; Fred Jones Jr. Museum of Art, University of Oklahoma; Brauer Museum of Art, Valparaiso University; Chazen Museum of Art, University of Wisconsin-Madison; Union League Club of Chicago; Museum of World Culture; Buckminster Fuller Institute; National Academy of Sciences; and Musée Carnavalet Paris.



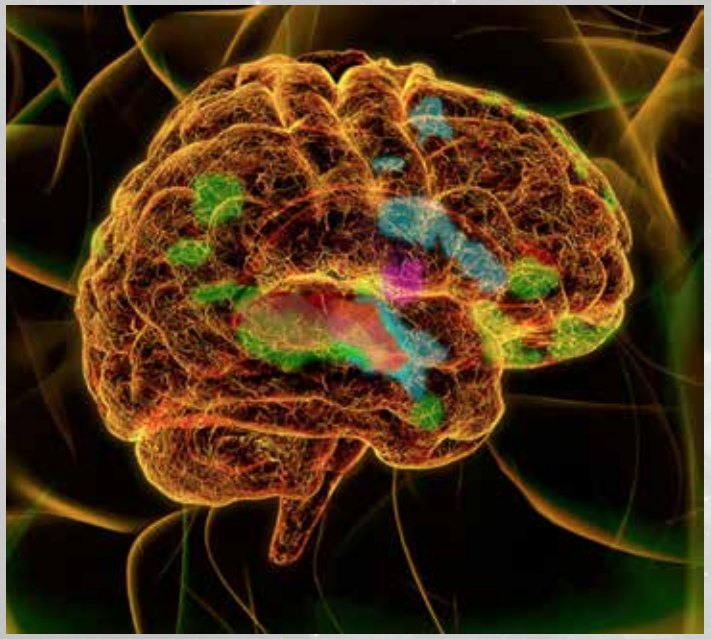
Oceans of Change, 2007
Donna Cox, Robert Patterson, Stuart Levy, Matt Hall, Alex Betts, and Lorne Leonard, National Center for Supercomputing Applications, University of Illinois, Urbana-Champaign; Yi Chao, Jet Propulsion Laboratory, California Institute of Technology; James Bellingham, Monterey Bay Aquariium Research Institute
Ellen Sandor, Chris Kemp, Janine Fron, and (art)^{n}
40”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

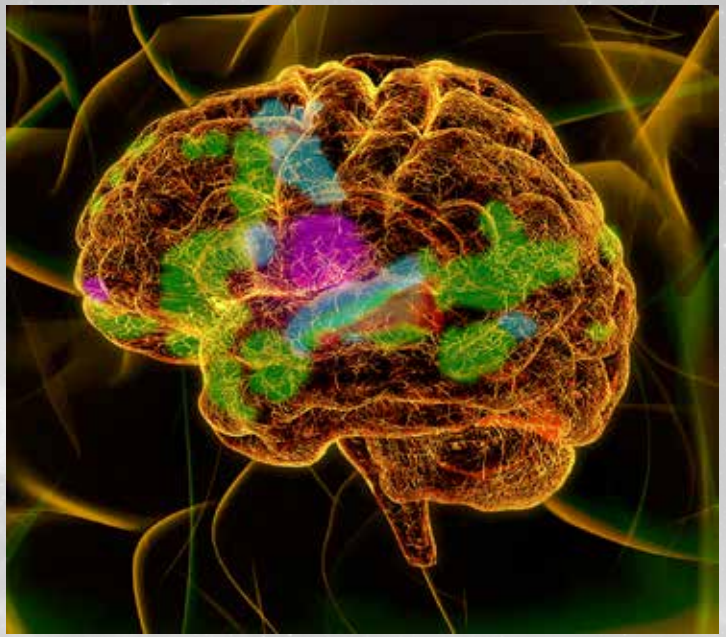
(art)^{n} Virtual Reality

(art)^{n}'s virtual worlds are created with Autodesk Maya ®: a three-dimensional computer graphics software that has been used by the collaborative for 25 years. It is a powerful engine where complex modeling and rendering tools help create creative three-dimensional images and animations.

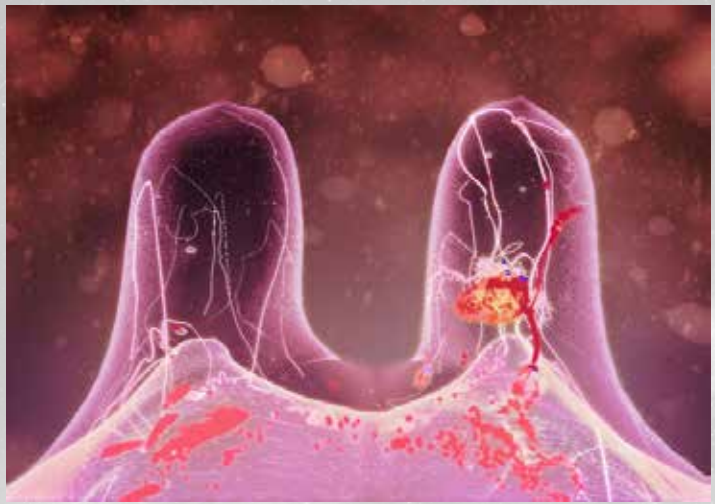
The development of the virtual environments and programming are created with Unity 5: a development platform primarily known for creating games. This software provides a rich ecosystem that allows the artist to weave together nearly every form of digital asset – images, three-dimensional models, audio, and more – with a powerful object-oriented scripting language allowing for boundless creativity.

The virtual worlds created with these two engines allow players to interact and navigate with them by using the Oculus Rift. These immerse simulations of three-dimensional environments are controlled by the movement of the body.





(Brain + Love) Right and Left, 2008
Raun K. Kaufman, Autism Treatment Center of America: The Son-Rise Program
Cynthia K. Thompson, Sladjana Lukic, Bharath Chandrasekaran, Joan Chiao, and Patrick Wong, Northwestern University
Ellen Sandor, Chris Kemp, Michael Cone, Janine Fron, and $(art)^n$
Special thanks to Penya Sandor and Eric Taub
30”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas



Making a Difference: Breast Cancer Revisited, 2011
Michelle Lee M.D. Department of Breast Imaging, Northwestern Lake Forest Hospital
Ellen Sandor, Chris Kemp, Michael Cone, and (art)^{n}
40”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

PET Study II: Man Ray/Picabia Imitating Balzac, 2003
Jim Strommer, Digital Media Group, Department of Molecular and Medical Pharmacology, UCLA School of Medicine
Ellen Sandor, Keith Miller, Janine Fron, Jack Ludden, and (art)^{n}
40”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Water, Research, Water, Rebirth, 2014
Penny Feuerstein
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
40”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Complications of a Heart Attack, 2011
Richard Lee, Division of Cardiac and Thoracic Surgery, Northwestern University Feinberg School of Medicine
Ellen Sandor, Chris Kemp, Diana Torres, and (art)^{n}
40”x30” Digital PHSCologram, Duratrans, Kodalith, and Plexiglas

Contributing Artists 1983 - 2016

Ben Carney
Michael Cone
Chris Day
Miguel Delgado
Janine Fron
Nick Gaul
Randy Johnson
Gary Justis
Chris Kemp
Pete Latrofa
Jack Ludden
Todd Margolis
Nichole Maury
TJ McLeish
Thomas Meeker
Stephan Meyers
Keith Miller
Fernando Orellana
Sabrina Raaf
Mark Resch
William Robertson
Mike Siegel
Dan Sandin
Diana Torres
Dien Truong
Gina Uhlmann
Jim Zanzi

Gallery Affiliations

Maya Polsky Gallery
Chicago, IL, 1997 - 2015

Galería Arteconsult
Panama City, Panama, 2010 - 2012

Kasia Kay Art Projects
Chicago, IL, 2007 - 2009

Jean Albano Gallery
Chicago, IL, 2000 - 2006

Oskar Friedl Gallery
Chicago, IL, 1995 - 2006

Rhona Hoffman Gallery
Chicago, IL, 1993 - 1994

Feature Inc.
New York, NY, 1985 - 1993

Major Institutional and Corporate Collaborators

SmithBucklin Corporation
Murphy/Jahn Architects
Howard Ecker + Company
Cornell University
Genentech, Inc.
Iowa State University
Jet Propulsion Laboratory
California Institute of Technology
Johnson & Johnson Pharmaceutical
Research & Development, L.L.C.
Lawrence Berkeley Lab
Monsanto Corporation
NASA Ames, Langley, and Lewis
Research Centers
San Diego Supercomputing Center
The Scripps Research Institute
UCLA School of Medicine
USAE Waterways Experiment Station
University of Illinois
Yale University
Fermi National Accelerator Laboratory

Major Individual Collaborators

Stephanie Barish
Geoffrey Baum
BINO & COOL
Steve Boyer
Benjamin Chang
Donna Cox
Carolina Cruz-Neira
Charles Csuri
Tom DeFanti
Margaret Dolinsky
Michael Dunbar
Andre Ferella
Barry Flanary
George Francis
Phillipe Paul Froesch
Carla Gannis
David Goodsell
Gero Gries
Anton Hand
Claudia Hart
Mr. Imagination
Chris Landreth
Robert Lostutter
Gerhard Mantz
Feng Mengbo
Ron Nielsen
TJ O'Donnell
Arthur Olson
Ed Paschke
Bob Patterson
Dana Plepys
Maggie Rawlings
Miroslaw Rogala
Cynthia Beth Rubin
Dan Sandin
Larry Smarr
Lisa Stone
Margaret Watson
Karl Wirsum
Zhou Brothers

Collections

The Art Institute of Chicago

Buckminster Fuller Institute

Fred Jones Jr. Museum of Art, The University of Oklahoma

Smithsonian National Museum of Natural History

Howard Ecker + Company

International Center of Photography

Musée Carnavalet, Paris

Museum of Contemporary Art, Chicago

Murphy/Jahn, Inc. Architects

Museum of Jewish Heritage - A Living Memorial to the Holocaust

Northwestern University

University of Chicago

Ed Paschke Art Center

Keck Center Gallery, National Academies

LUMA- Loyola University Museum of Art

Victoria and Albert Museum

Santa Barbara Museum of Art

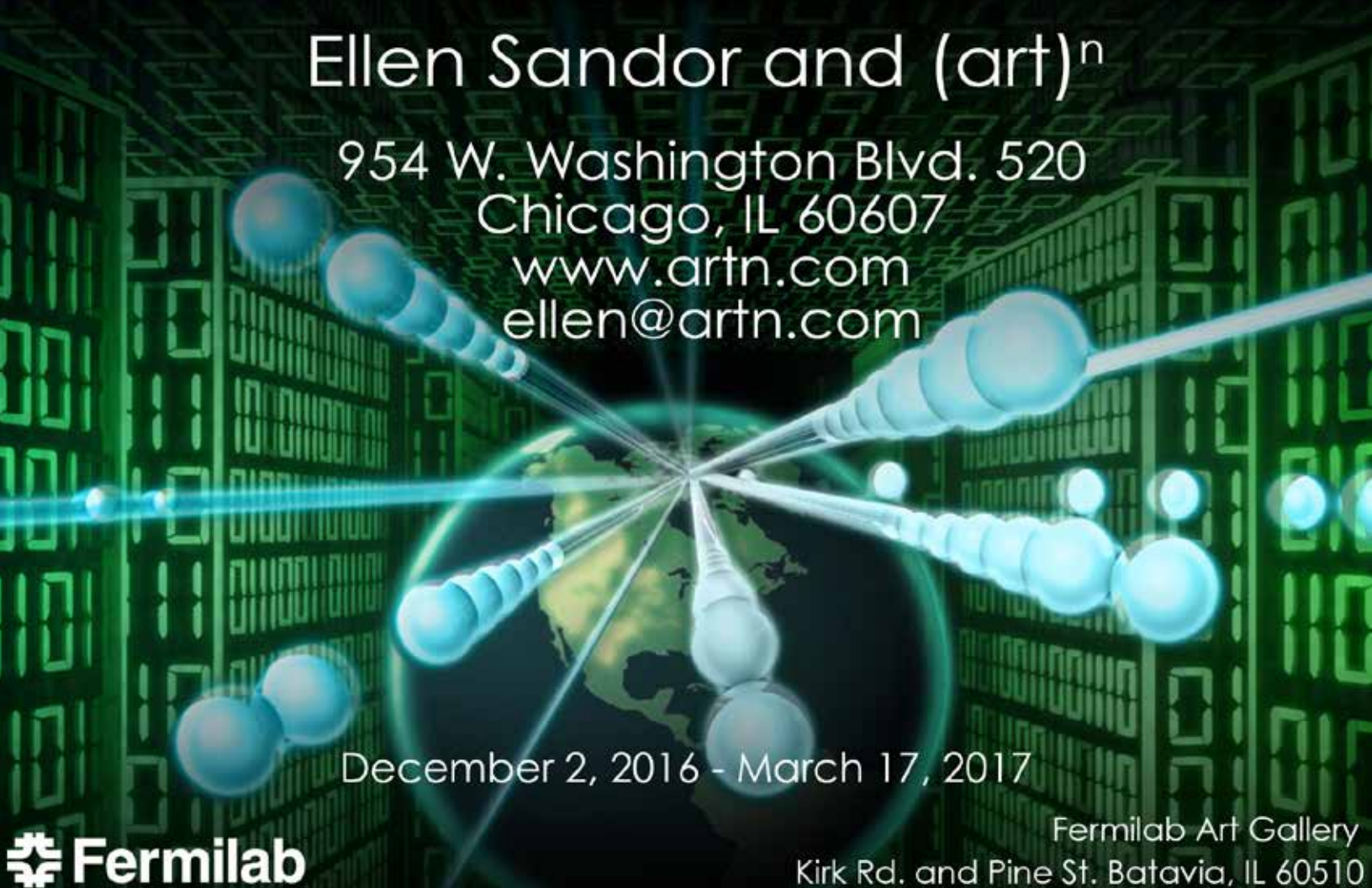
Union League Club of Chicago

Chazen Museum of Art, University of Wisconsin-Madison

Brauer Museum of Art, Valparaiso University

Centre of Contemporary Art, Warsaw

Roger Brown Study Collection, School of the Art Institute of Chicago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ellen@artn.com
December 2, 2016 - March 17, 2017
Fermilab
Fermilab Art Gallery
Kirk Rd. and Pine St. Batavia, IL 60510