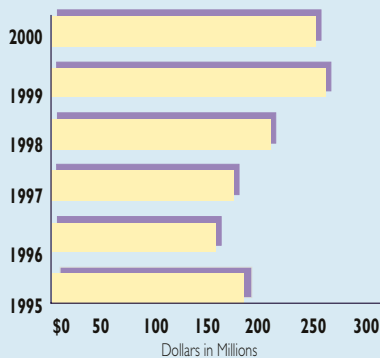




IN BRIEF

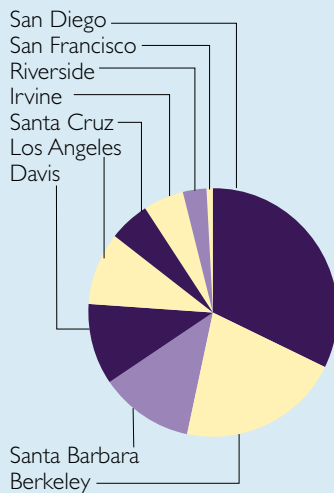
- UC received \$244 million in NSF awards in FY2000, more than any other university system.
- Five UC campuses in FY2000 were among the top 25 universities in NSF funding.
- UC San Diego earned more NSF awards in FY2000 than any other university.

NSF funding to UC



source: UCOP grants database

Share of FY2000 NSF funding



source: UCOP grants database

UC expands NSF's research portfolio

The National Science Foundation awarded the University of California \$244 million in FY2000 to conduct research in a wide variety of disciplines, from astrophysics and nanotechnology to psychology and ecology.

Created in 1950, NSF is an independent U.S. government agency responsible for advancing science and engineering. Operating no laboratories itself, NSF carries out its mission primarily by making merit-based grants to researchers in universities and other research institutions.

NSF invests in the best ideas from the most capable people, determined by competitive merit review. NSF selects about 10,000 new awards each year from about 30,000 proposals submitted by scientists and engineers.

In FY2000, UC was awarded over 30 grants from NSF worth one million dollars or more. Although down slightly from its 1999 peak, NSF funding to UC has grown strongly in recent years. Among UC campuses, San Diego earned the largest amount of research funding from NSF in FY2000, \$78 million, or 32 percent of UC's NSF research awards.

Berkeley received \$51 million, or 21 percent of UC's total NSF awards. Santa Barbara captured \$30 million, while Davis earned \$26 million and Los Angeles \$22 million. Santa Cruz

and Irvine each earned \$13 million, while Riverside earned \$8 million.

As UC's only campus devoted solely to health sciences, UCSF receives the vast majority of its federal research funding from the National Institutes of Health.

In FY1999, the most recent year for which comparable statistics are available, NSF distributed over \$2.15 billion for research at U. S. colleges and universities, up from \$1.91 billion in FY1998. This amount is second only to the National Institutes of Health (\$8.19 billion) and it is greater than that of the Department of Defense (\$1.37 billion).

The National Science Foundation invests in the best ideas from the most capable people, determined by competitive merit review.

NSF is taking the lead in the multi-agency National Nanotechnology Initiative (see p. 5 for more information). Many academic research disciplines are highly dependent upon NSF funding. Roughly two-thirds of all federal funding for mathematics, earth sciences and oceanography, and chemical engineering are provided by NSF. In the social sciences, NSF is even more dominant – virtually all federal awards in political science and anthropology are provided by NSF.

In Washington, D.C., the prospects for increased funding for NSF are mixed. For now, other demands are taking priority over significant NSF budget increases, but support remains strong for doubling NSF's budget over the next five years.

Native meadow remnants

Preserving California's biodiversity

California has not always been the golden state. The familiar summer color of the hillsides is due to the non-native grasses that have been invading the state for two centuries. Unlike the annual grasses that arrived along with European immigrants of both the human and hoofed variety, the native perennial grasses once kept the hills verdant well into summer.

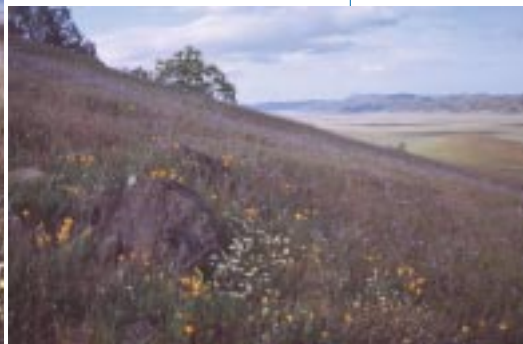
What is left of the native grasses and how can we protect their remaining habitat? Is the invasion over, or do native grasslands continue to shrink? With help from the National Science Foundation, UC Davis professor Susan Harrison and Ph.D. student Jonathan Gelbard are finding answers to these questions.

Using a combination of old-fashioned painstaking field research, and computerized statistical and geographic techniques, Harrison and Gelbard are analyzing the abundance of native grasslands over an area of 500 square miles in the Blue Ridge area of Napa, Lake and Colusa counties. Their research will lead to better under-



A serpentine native grassland in Lake County, featuring Goldfields and Bird's Eyes. Inset: Biologist Susan Harrison

farming or other soil disturbance. The results showed that sites located more than 1000 meters from roads contained a substantially greater percentage, variety and coverage of native species than sites closer to roads. Yellow starthistle, a particularly noxious



A Bear Valley panorama in Colusa County features native California Poppies, Ithuriel's Spear, Woodland Tips and California Melic.



standing of how to preserve biodiversity, and how to help reduce invasive weed species that cost farmers and ranchers millions of dollars to control.

Harrison and Gelbard have discovered that one of the main culprits encouraging the spread of invasive species is roads. Grazing has varying impacts, depending upon its timing, the extent of grazing, and the nature of the soil.

The researchers chose 92 sampling sites and classified them by soils (serpentine and non-serpentine), by slopes (cool, warm, and neutral) and by isolation (10 meters, 100 meters, and greater than 1,000 meters from roads). They also measured and analyzed a large set of environmental factors related to soil quality, and any history of grazing,

invader, was significantly less abundant in isolated sites than in roadside grasslands.

According to Harrison, "Our results indicate that spatial isolation does indeed provide a significant refuge for California's native grassland species. Unfortunately, our results also imply that exotic species are still continuing to spread and that natives are continuing to lose ground."

Since cows and hikers both prefer native grasses to yellow starthistle and barbed goatgrass, there is the possibility of consensus among ranchers and environmentalists to maintain roadless spaces. Adds Gelbard, "We need a landscape composed of a mosaic of grazed and ungrazed areas to conserve the full suite of California's native grass and wildflower species."

Dark matter

MACHOs fade, but will WIMPs prevail?

Like many spiral galaxies, the Whirlpool Galaxy pictured here has presented astronomers with a perplexing problem. When they first developed techniques to measure the speed of the stars in the spiral arms, astronomers were astonished that the stars there were moving far faster than predicted – so fast that the spiral galaxies should be flying apart.

Researchers have concluded the visible stars don't have enough mass to hold the galaxies together. There must be some source of gravitation – some invisible dark matter – that keeps galaxies from breaking up.

Astronomers now estimate that over 90 percent of the matter in the universe is dark matter. Early candidates included clouds of helium or hydrogen gas in deep space, and massive condensed halo objects (MACHOs) like black holes and dwarf stars. Although researchers have located such objects, MACHOs and gas clouds don't come close to explaining the total amount of dark matter in the universe.

Yet another possibility is a new subatomic particle, one outside the physicist's standard model. These weakly interactive massive particles (WIMPs) could account for the dark matter in the universe. But how to find them? The fact that they don't interact is precisely what makes them so hard to detect.

Under the leadership of Bernard Sadoulet of the UC Berkeley Institute for Particle Astrophysics and with help from a large award from the National Science Foundation, researchers from the institute, UC Santa Barbara and collaborators from several other universities have devised an ingenious way to determine if WIMPs really exist.



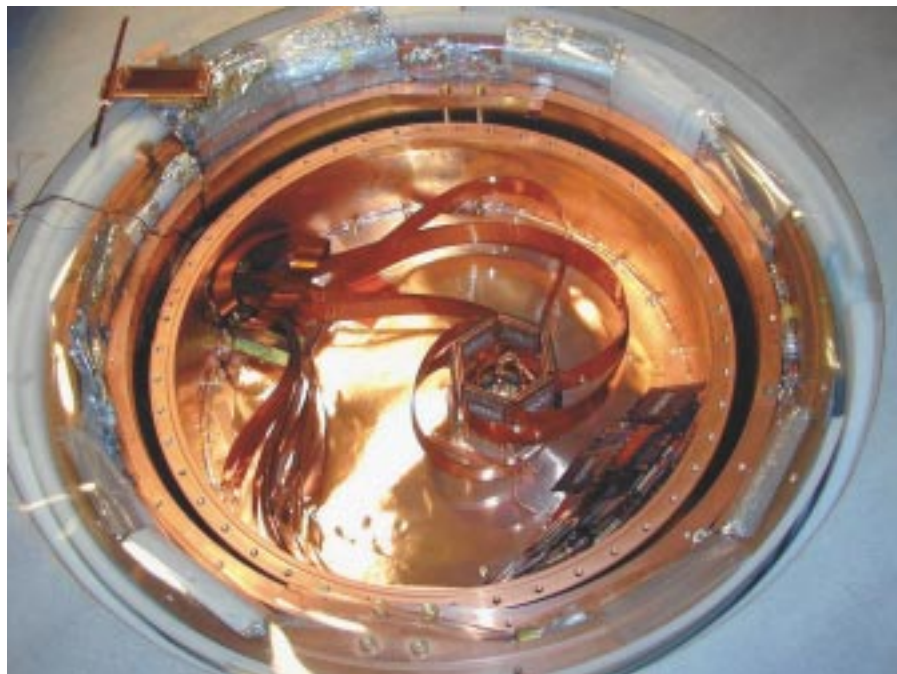
The Whirlpool Galaxy in visible and infrared light. *Image courtesy of NASA.*

The NSF-funded detector has been built from radiopure copper, with shielding provided by lead removed from the ballast of an 18th-century French sailing ship. The

detector will be installed roughly 2,000 feet below ground level in the abandoned Soudan mine in northern Minnesota. Few errant subatomic particles will be able to penetrate the earth and lead shielding, and the age of the lead and the purity of the copper ensure that the device itself emits no radiation.

The detector will be cooled to less than one degree above absolute zero. Almost completely free of heat vibration at this temperature, the detector will be extremely sensitive to the impact of any WIMPs.

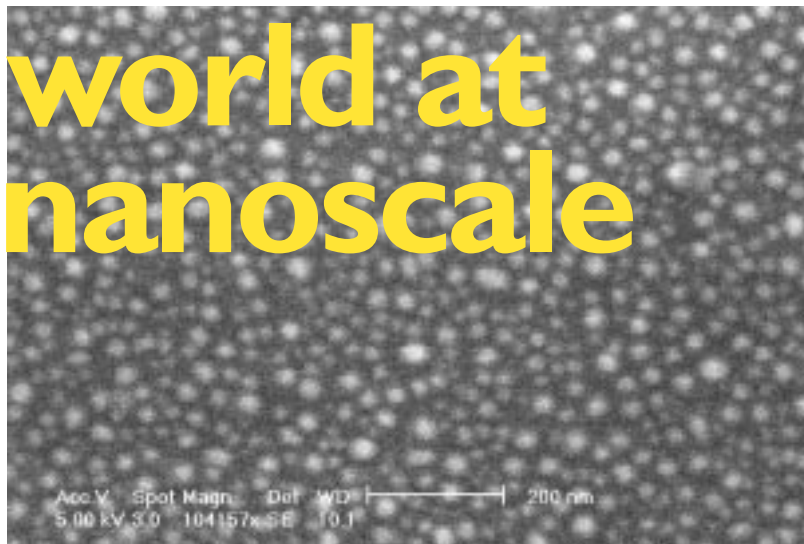
Working with a detector in an Alpine mountain tunnel, Italian and Chinese scientists may have detected WIMPs, but results from the NSF-funded prototype at Stanford University contradict this finding. The jury is out for now, although detectors have become sensitive enough that the question of the existence of WIMPs should be resolved in the next few years.



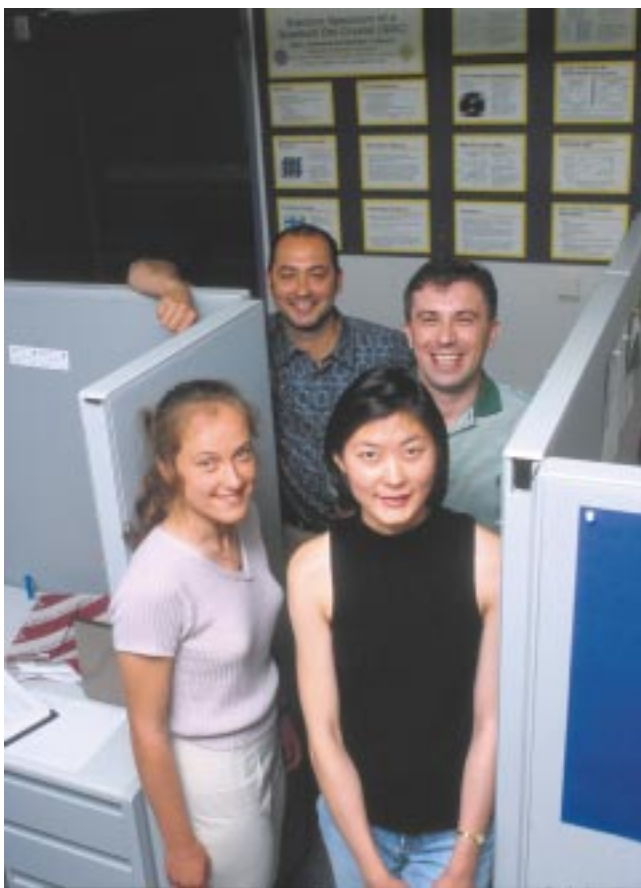
A close-up of the cryostat with a detector assembly installed. The six cables fanning out from the assembly carry the detector signals out to room temperature. *Image courtesy of UC Berkeley Institute for Particle Astrophysics.*

Exploring the world at nanoscale

At UC Riverside, a group of young researchers is gaining recognition for its pioneering work in nanotechnology.



Above: Image of germanium quantum dots on silicon, obtained by the UCR researchers using scanning electron microscopy. Right: An atomic force microscope image of the surface of germanium dots on silicon showing a nanometer scale height variation.



The Balandin research group (clockwise from front right): Jie Zou, Olga Lazarenkova, Alexander Balandin, Dmitrii Kochetkov.

At the meeting of the Materials Research Society last April, two presentations stood out among several from top-ten U. S. universities. These award-winning presentations were given by two UC Riverside colleagues – post-doctoral researcher Olga Lazarenkova, and Ph.D. student Jie Zou. Both researchers work with electrical engineering professor Alexander Balandin, himself a recent recipient of a National Science Foundation Young Investigator award. “I’m pleased our group did so well, especially against such stiff competition,” says Balandin.

Balandin and his colleagues study the electrical and thermal properties of nanostructures and nanoscale

semiconductor devices. These devices are so small that they are measured in nanometers, or billionths of a meter. In a computer chip, silicon atoms are spaced just a few to the nanometer, so nanoscale devices involve interactions between a handful of atoms. In the diagram above, the 200 nanometer line spans only about 700 silicon atoms.

The realm of nanotechnology exists on a scale in between the subatomic realm of elemental particles and the macroscopic world of electronic devices and circuits. “To understand nanotechnology,” says Balandin, “you have to realize that as you reduce the scale, at some point quantitative changes become qualitative changes.” This is an Alice-in-wonderland world that plays by its own rules – rules researchers have yet to understand fully.

Imagine a transportation planner flying over a busy freeway. She can make very good predictions about traffic flow rates and about how many cars leave each freeway exit every hour. But this same traffic planner knows very little about how to predict the movements of one car in particular – where it entered the freeway and where it will exit, or how it will interact with the cars around it.

Nanotechnologists have a similar problem. They must understand not how millions of electrons move through a copper wire thousands of atoms thick, but how far fewer electrons move through a nanowire just dozens of atoms thick. At nanoscale, quantum effects – due to the wave nature of the electrons at this scale – begin to influence the characteristics of electronic devices.

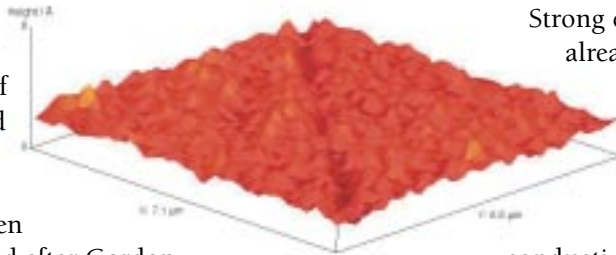
Balandin oversees the Nanoelectronic Materials and Device Laboratory (NOMAD) in conjunction with professors Roger Lake and Alexander Korotkov, also of the UC Riverside electrical engineering department. At NOMAD, Balandin’s group focuses both on deriving theoretical models for the behavior of nanomaterials and on testing them.

Early radios and computers used vacuum tubes to control and amplify electrons. By the 1950s, a standard five-tube radio was small enough to sit on a bedside table, although crude computers occupied whole labs. By the 1960s, transistor radios were small enough to sit in the palm of a hand, and mainframe computers began to shrink in size and grow in power.

With the development of the integrated circuit, at first thousands, and then millions, of semiconductor transistors could be embedded in a substrate of silicon. Over the last four decades this progression has been described by Moore's Law, named after Gordon E. Moore, a co-founder of Intel and UC Berkeley alumnus. Moore predicted the number of transistors that could be placed on a silicon chip would double every 18 months.

Engineers now can put 100 million transistors on a silicon wafer only a few square centimeters wide. Some features of these computer chips measure only 180 nanometers. Within a few decades, this size may be reduced to close to 100 nanometers, a tricky descent into the nanoscale world where the rules begin to change.

The award-winning paper that Zou presented at the materials conference addresses one of the problems of nanoscale circuits – heat conduction in nanowires and ultra-thin films. The phonon, the smallest unit or *quantum* of heat energy, is confined in nanoscale devices in a way that may make it difficult to cool future generations of computer chips.



“Part of what we are trying to accomplish is to keep Moore's Law alive by better understanding the problems of nanoscale devices,” says Balandin. “But ultimately, the more useful approach will be to learn enough about the characteristics of the nanoworld so that we can take advantage of its special properties to design new types of devices.”

Strong contenders for these new devices already exist in quantum dot crystals, three-dimensional regimented arrays of small blocks of semiconductor materials embedded in silicon or other host materials. The electrical conductivity of these quantum dot crystals manifests a variety of intriguing properties that can be used in the design of novel devices. Lazarenkova's award-winning presentation for the materials conference describes just such a quantum dot crystal.

Nanoscale devices not only will allow the creation of smaller and more powerful computers, they also will aid in creating a new generation of photodetectors that can help bring fiber-optic communications to households. They may dramatically increase the efficiency of photovoltaic cells, making solar power a more viable alternative to burning fossil fuels.

“Nanotechnology has tremendous potential,” says Balandin, “and we are grateful for NSF's support of our work and for the leading role it has taken in funding nanotechnology research.”

Nanotechnology, UC and the NNI

Nanotechnology is the ability to work at the molecular level to create new molecules and structures. At the level of molecular building blocks, the traditional boundaries between the scientific disciplines dissolve. Nanotechnology embraces physics, chemistry and biology and may lead to breakthroughs in all of these areas. Possibilities include high-strength materials, miniature electronics systems and new drugs and biomedical devices.

In February 2000, the Clinton administration announced the \$495 million National Nanotechnology Initiative (NNI) to coordinate federal efforts to stimulate nanotechnology research. Since then, more than 30 universities have announced plans for nanotechnology research centers.

The Bush administration has requested another \$485 million for nanotechnology research in FY2002. Just as nanotechnology spans several academic disciplines, at the federal level, nanotechnology research will span several

different agencies. The federal government's efforts will be coordinated by the National Science Foundation.

At UC Riverside, chemist Robert Haddon will direct the new Center for Nanoscale Science and Engineering, an interdepartmental effort combining the talents of UC Riverside faculty in several departments.

Haddon's specialty is the formation and application of carbon nanotubes and other nanoscale structures. Nanotubes have several unique properties, including the ability to act like a semiconductor; or to act as the matrix for growing new human neural tissue.

UC also will sponsor the California Nanosystems Institute, a joint project of the Los Angeles and Santa Barbara campuses. With the field still in its infancy, it is too early to tell how the UC centers will specialize. Until then, the campus centers “will both compete and collaborate with each other,” says Haddon. “No one has a monopoly on good ideas.”

Causality *revealing the mind at work*

Most children understand that umbrellas don't cause mud puddles. They know the cause for the appearance of both umbrellas and mud puddles is rain. Although there is a correlation between the two events – if umbrellas appear, mud puddles tend also to appear – one event doesn't cause the other.

Humans share with other higher animals the ability to infer causal relationships from sensory experience. But psychologists still don't understand completely how the mind identifies causal relationships from among the hundreds of events that impinge on our senses every day.

How do we come to understand that the rooster's crow does not cause the sun to rise? This is an old question, one that puzzled philosophers like David Hume and Immanuel Kant. Hume felt that all knowledge of the world was ultimately derived from sensory input. Kant argued that humans had *a priori* knowledge, or some innate understanding of the world.

UC Los Angeles psychologist Patricia Cheng is using a grant from the National Science Foundation to help understand causal reasoning. She has found that existing formal models of this fundamental human capability are weak. She also has discovered that many standard statistical tests of causation lead to erroneous results when two or more possible causes interact.

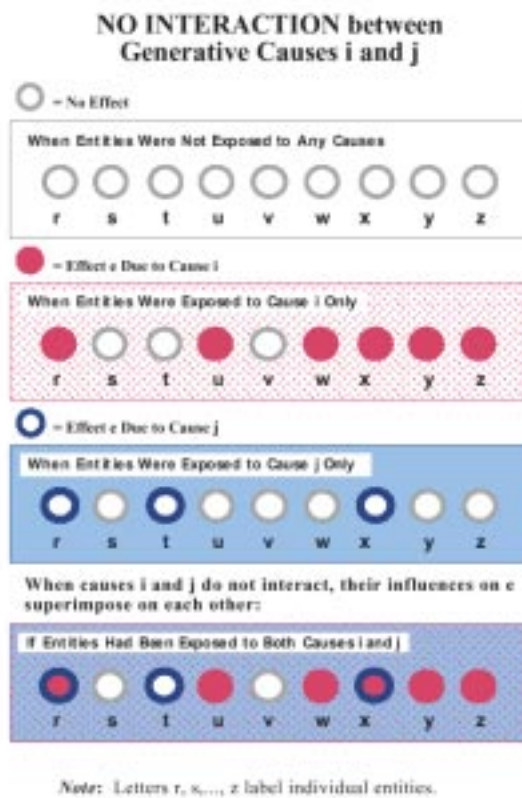
Cheng's earlier work drew on the strengths of both the covariational approach that harks back to Hume and the causal power approach that relies on the Kantian tradition. She previously had combined these two approaches and now has extended her model to joint causality, or events that require two or more causes acting together. Cancer, for example, is caused both by exposure to a carcinogen like cigarette smoke and a genetic predisposition.

Developed with coauthor Laura Novick of Vanderbilt University, the model is a complex series of probability statements, yet their experimental tests with human subjects show that it describes innate causal reasoning well. Both the Cheng-Novick model and the "untutored reasoners" that they studied were able to unravel correctly the influence of joint causes, while standard statistical tests found interdependence when there was none.

Faulty decisions based on conceptual errors can lead to bad policies. Returning to the first example, if mud puddles in the streets are a social problem, one possible response is to pass a law banning umbrellas. Such a policy would result from a common (and in this case obvious) fallacy – the confusion of correlation and causality. In many other cases, such as determining the causes of cancer, the fallacy is not so obvious.

These results not only may influence the development of better statistical tests, they also may help computer scientists improve algorithms to allow computers to infer causality from patterns of probabilities. One area where these ideas have been applied is in medical diagnosis. A computer program is fed medical data and test results and it helps doctors infer the cause of illness based on the probabilities that different underlying conditions cause different symptoms.

"Our results stand in contrast to the genre of psychological research that looks to mainstream formal analyses for a definition of rationality and measures how untutored reasoning falls short of this standard," says Cheng. "If anything, formal models in statistics could benefit from a better understanding of untutored human causal reasoning."

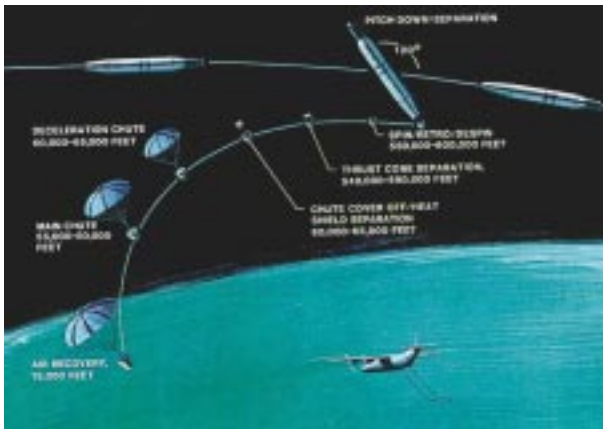


A diagram from Cheng's experiment of her joint causality model. Although most people who view this diagram correctly reason that causes i and j are independent, many formal statistical tests find interdependence. Graphic courtesy of Deborah Clifford, UCLA.

Mapping the Corona project

In 1995 cartographer Keith Clarke, then teaching in New York, was invited to a conference in Washington, D.C. The topic was the declassification of the CIA's super-secret Corona project. "I sat for two days with my mouth hanging open in astonishment," says Clarke.

What was revealed that day was a satellite photography project whose technological advances had laid the foundation for many modern mapping techniques.



A diagram of the reentry and recovery sequence.

Over 40 years ago, the first Corona satellites were launched from Vandenberg Air Force Base, on the coast of Santa Barbara County. In 1996, Clarke joined the faculty at UC Santa Barbara, just 35 miles away from the Corona launch site. Visiting the site, Clarke was struck by the need to document the technologies spawned by Corona.

With National Science Foundation support, Clarke has interviewed the aging participants in the program and has attempted to preserve the program's instruments, many of which served as models for advances in civilian cartography.

The Corona project was the U. S.'s first satellite surveillance effort. Corona featured an evolving series of marvelously sophisticated cameras

that used a special polyester film base designed for the program –now known as mylar.

After the cameras photographed the world from a polar orbit, the exposed film was jettisoned back to earth near Hawaii, in a capsule fitted with a parachute designed to be snagged by special planes.

The program started with a series of one-day missions and a single camera taking photos with limited resolution of 25 to 40 feet. The first successful Corona flight, on August 18, 1960, covered more than 1.65 million square miles of Soviet territory and produced 3,000 feet of film.

By the mid 1960s, Corona cameras could make stereo photographs, which allowed cartographers to derive the relief of terrain below the satellite. Missions eventually were extended to as long as 19 days with multiple cameras and images with resolution of six feet.

The systems worked so well that the CIA, with classified assistance from the U. S. Geological Survey and other federal agencies, used Corona to map the world and to revise maps of the U. S.



Corona image of Santa Rosa Island, Channel Islands National Park, near Santa Barbara.



Post-doc John Cloud, professor Keith Clarke, and Vandenberg AFB Museum curator Jay Prichard standing at Corona's launch site.

The Corona program continued until 1972 when it was replaced by more advanced systems, such as Big Bird, which use digital imagery to monitor the globe.

During its lifetime, Corona produced over 800,000 images and 2.1 million feet of film, delivered in 39,000 cans. All of the Corona images are now declassified and copies can be ordered through the U.S. Geological Survey.

"Corona is a prime example of a technology developed for military purposes that has had tremendous spin-offs for the civilian sector," says Clarke. "I often use the images in my own studies of changing patterns of urbanization."

Clarke also has led anthropologists to Corona images that reveal details of Amazonia 40 years ago, before contact first was made with indigenous tribes. The images also have been useful in tracing changes in forest coverage during the last several decades, helping climatologists calibrate global climate models.

NSF helps K-12 students develop math and science skills

The National Science Foundation has awarded \$30 million in 25 new grants, enabling 300 talented graduate and advanced undergraduate students to serve as teaching fellows in K-12 schools. The grants, from NSF's Graduate Teaching Fellows in K-12 Education (GK-12) program, will go to colleges and universities in 19 states from Maine to California, as well as to Puerto Rico.

“Researchers need to bring their expertise and enthusiasm out of the laboratory and into the classroom,” says Rita Colwell, NSF director. “The GK-12 program creates partnerships across the academic community that benefit research and education at every level.”

At the University of California, NSF has funded several grants to help researchers improve math and science education. Robert Calfee, UC Riverside's dean of the graduate school of education, is leading the *Reading and Writing About Science Project*. This NSF-funded project addresses the teaching and learning of science by fostering students' reading and writing skills in the context of science instruction.

It takes place in elementary and middle public schools within the counties of Riverside and San Bernardino, California, focusing on science instruction in selected classrooms, grades four through eight. Classrooms are selected in part on the basis of student diversity – students participating in this project come from varied cultural and socio-economic backgrounds.

At UC Los Angeles's school of education, Yasmin Kafai's research on the design of learning technologies is supported by NSF. Her research focuses on young children as designers of simulations and builders of digital archives for science learning. She studies how young students share their technological expertise, develop collaborative planning tools and integrate science learning.

NSF underwrites UC Santa Cruz education professor Judith Moschkovich's research on math education in bilingual settings. NSF also funds educational research at others UC campuses. With support from NSF and others, UC continues to improve the quality of K-12 education in California.



For more information about research funding at the University of California, please contact:

Allison Rosenberg
Director, Research Policy and Development
Office of Research
UC Office of the President
1111 Franklin St., 11th Floor
Oakland, CA 94607-5200
voice: (510) 987-9474
fax: (510) 987-9456

In Washington, D.C. please contact:

UC Office of Federal Government Relations
1523 New Hampshire Ave. NW
Washington, DC 20036
voice: (202) 588-0002
fax: (202) 785-2669

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writing: Michael Barnes
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