San Francisco's "Big One" Turns 100

Two images from the exhibit: San Francisco's city hall was demolished, and a statue of Harvard paleontologist and glaciologist Louis Agassiz got no respect, being tossed from its niche above the arches around the Stanford Quad. Both photographs are from the earthquake commission's report.

April 18 is the centennial of the great San Francisco earthquake, and the Caltech Archives is marking the occasion with *Documenting Earthquakes: A Virtual Exhibit in Six Parts* (http://archives.caltech.edu/exhibits/earthquake/index.html). Compiled from the Archives' own collections, the six parts will be presented serially over the next six months.

Part One, "Documenting the 1906 Quake," offers an in-depth look at the earthquake's social, political, scientific, and economic repercussions. Included are excerpts from the State Earthquake Investigation Commission's report, comprising two volumes and an atlas, which introduced a significant feature of the local landscape that, up to that time, had largely escaped notice: the "San Andreas Rift." Next, photographs graphically depict the devastation, followed by a sampling of what senior archivist Shelley Erwin calls the "sensationalist literature" chronicling the "San Francisco horror" in which, among other outrages, soldiers compelled even the "fashionably attired to assist in cleaning streets." The section ends with a recap of the post-quake "spin" that transformed "The Great San Francisco Earthquake" into "The Great San Francisco Fire," allaying the fears of residents and tourists alike by turning a calamity of unknown origin that might possibly recur into an every-day disaster.

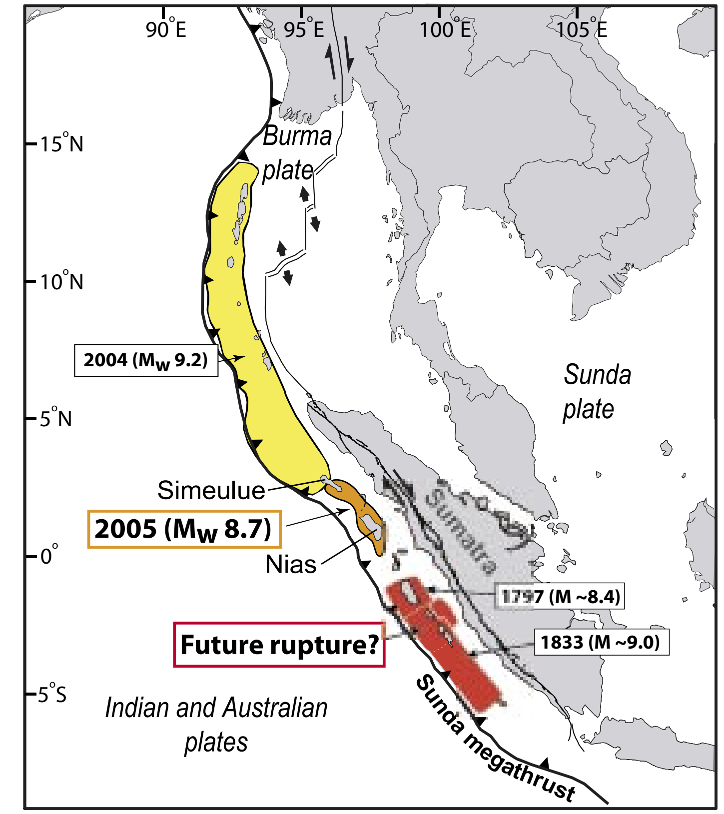
The next two segments will go live later this spring. "The Beginnings of Seismology at Caltech" and "Charles Richter and the Earthquake Magnitude Scale" feature Caltech's contributions to a budding science.

Components four and five showcase rare earthquake-related books and artwork donated by George Housner (PhD '41), the Braun Professor of Engineering, Emeritus, and the father of modern earthquake engineering. The Housner collection includes one of the earliest printed books on earthquakes, published in Germany in 1531, and woodblock prints of the 1855 Tokyo earthquake that recount the Japanese folk belief that the wriggling of a giant catfish was responsible.

The final section includes images from Sir William Hamilton's *Campi Phlegraei*, prepared in the 1770s as a report to the Royal Society in London on earthquakes, volcanoes, and other geologic hazards.

Documenting Earthquakes is curated by Erwin, in collaboration with archivists Judith Goodstein, Kevin Knox, and Elisa Piccio, and was designed and produced by Wayne Waller and Leslie Maxfield of Caltech's Digital Media Services. □—*DW-H*

The rupture zone of the December 2004 megaquake is shown in yellow and that of the March 2005 quake in orange. The region shown in red appears poised to go next.



More Earthquakes to Worry About

Follow-up work on the great Sumatran quake of December 26, 2004, and its March 28, 2005, aftershock (itself the seventh largest quake ever recorded; the main shock comes in at number three) shows that there may be one more big one coming in the near future. Postdoc Richard Briggs and a host of coworkers at Caltech's Tectonics Observatory, the Indonesian Institute of Sciences, and the Scripps Institution of Oceanography have found that another fault segment farther south is showing the same signs of decades-long subsidence that the region around Nias Island did before it let go last March. Parts of this segment, which runs for some 600 kilometers, last broke in 1797 (estimated magnitude 8.4) and 1833 (estimated magnitude 9.0). Either or both of those zones could slip this time, so it's going to be a punisher, and could quite possibly set off a tsunami. Says Kerry Sieh, the Sharp Professor of Geology and a coauthor of the paper, "It could happen tomorrow, or it could happen 30 years from now, but I'd be very surprised if it were delayed much beyond that."

The paper appears in the March 31 issue of *Science*. □—*RT*

Darkness and Light

Every few days, a telescope peering into the night sky over Mauna Kea, Hawaii, detects an enormous firecracker going off—somewhere deep in space, a star detonates. This cosmic catastrophe is a supernova. "Supernovas are so intense," says Richard Ellis, Caltech's Steele Family Professor of Astronomy, "that for many weeks, they outshine the entire galaxy in which they lie."

There are two types of supernovas: in the first, a single star runs out of fuel, collapses due to gravity, becomes unstable, and explodes; in the second, a parasitic star sucks in material from another star, becomes unstable, and similarly explodes. The latter is the focus of Ellis and the international research team called the Supernova Legacy Survey (SNLS), because this parasitic star—called a white dwarf—can slurp up only so much matter before getting sick. When the dwarf hits the Chandrasekhar limit, 1.4 times the mass of our sun, it bursts to create a supernova that emits the same amount of light every time. Astronomers call such supernovas "standard candles."

Most galaxies have a supernova eruption every few decades, and when this happens even those in very distant galaxies become visible. In the same way that the loudness and change in pitch of a passing police siren reveal how far away the car is and how fast it is going, a supernova's brightness and the shift in the frequency peaks of its spectrum reveal its distance and velocity. Light from a supernova can take billions of years to reach us, so that our telescopes literally allow us to see history unfold.

In January 2003, when SNLS's camera was ready for use, it was the world's largest digital imager. Appropriately named MegaCam, this 340,000,000-pixel camera can fit four full moons in an image, spanning a full square degree of the sky. The camera is attached to the 3.6-meter Canada-France-Hawaii telescope, and every month it detects about 40 supernovas. Once a supernova of the correct type (about one in four) is detected, larger telescopes like the 10-meter Keck and the 8-meter Gemini are used to verify its type and record its spectrum. Because of this unprecedented combination of a large camera that looks at just one spot in the sky and the extensive time available on many telescopes, postdoc Mark Sullivan of the University of Toronto says that "the data we collect is a huge improvement over previous studies."

To understand why this data is crucial to resolving cosmological mysteries, we need to delve into the history of the field. A century ago, everyone assumed the universe was static. However, in 1916, Albert Einstein was working on his theory of relativity and found that when he applied it to the universe, it predicted that the universe could not exist! A static universe was impossible; it would collapse inward. So a baffled Einstein was forced to add a new number, which he called the "cosmological constant," into his equations to balance gravity.

Einstein decided that the cosmological constant was an embarrassing mistake when, in 1921, Edwin Hubble found that the farther away a galaxy is, the faster it is moving away from us. This finding is now called Hubble's law. The inescapable conclusion was that the universe is not static, but expanding. To return to the police car analogy, this does not just mean that the cars are moving away from us, but that the road is being stretched, dragging the cars along with it.

In 1998, two groups using supernovas to verify Hubble's law found an anomaly: the most distant celestial objects are not just moving away, they are *accelerating* away from us. In other words, the farther away the galaxy is, the faster the rate of expansion of the universe increases—meaning that the universe was expanding more slowly in the distant past. No known force can explain this.

Since then, there has been feverish activity: astronomers trying to obtain precise data, and theorists trying to explain the findings. Many of these theories resurrect the cosmological constant—this time using it to *cause* the acceleration. The most popular postulate is that some kind of mysterious energy is pushing the universe apart. Perhaps reflecting a Hollywood influence, it's been given the peculiar name of "dark energy."

Data from the SNLS survey can sort out this tangle of possibilities by putting constraints on the possible theories. For instance, some theories predict that the dark energy's strength should change with time. However, Ellis says, "SNLS data show, to within 10 percent error, that the acceleration has been constant for half the age of the universe." This puts theories involving a cosmological constant on firmer experimental ground. Ellis expects the error will be reduced by more than half when all the data are in. □—*SV*

The Brain Trust

The workings of the human brain are being probed by several Caltech research groups through collaborations with various hospitals and medical schools. Some of these studies use Caltech's fMRI facility, in which volunteers literally have their heads examined, allowing the experimenters to see what parts of the brain "light up" when different things are being done. (Functional Magnetic Resonance Imaging, or fMRI, is closely related to the MRI scans you may have had if you've ever torn a ligament.)

If all numbers look alike to you, you may have "dyscalculia," which is the digital equivalent of dyslexia. Caltech postdoc Fulvia Castelli and Daniel Glaser and Brian Butterworth at the Institute of Cognitive Neuroscience at University College London have found that an area of the brain known as the intraparietal sulcus, located toward the top and back of the brain and across both lobes and known to be the seat of numerical knowledge, determines *how many* things are perceived, as opposed to *how much*.

To appreciate the difference, consider the checkout lines at your local Trader Joe's. "How do you really pick the shortest checkout line?" says Castelli. "You could count the number of shoppers in each line, in which case you'd be thinking discretely in terms of numerosity. But if you're a hurried shopper, you probably take a quick glance at each line and pick the one that seems the shortest. In this case you're thinking in terms of continuous quantity."

The two modes of thinking are so similar that it's very hard to isolate the specific networks within the intraparietal sulcus that are responsible for each. So Castelli and her colleagues devised a test in which subjects were shown either a series of flashing blue or green lights or a chessboard with blue and green rectangles and were asked to estimate whether they saw more green or more blue.

The results show that when subjects see separate colors, sequentially or in an in-focus chessboard, the brain automatically counts the objects. But when presented with either a continuous blue and green light or a blurry chessboard, the brain instead estimates *how much* blue and green is visible.

The article was published in the March 13 issue of the *Proceedings of the National Academy of Sciences*.

Another fMRI study by researchers at Caltech and the University of Iowa College of Medicine explains why you might have second thoughts when ordering a strange-sounding dish at an exotic restaurant. This fear of getting fricasseed eye of newt—or something even worse—comes from certain neurons saying that the reward potential for this risk is unknown.

Colin Camerer, the Axline Professor of Business Economics, Ralph Adolphs, the Bren Professor of Psychology and Neuroscience, grad students Ming Hsu and Meghana Bhatt, and Daniel Tranel of the University of Iowa College of Medicine ran a series of betting experiments on Caltech student volunteers and patients with specific types of brain damage at the University of Iowa.

The results show that the brain behaves differently when there is a degree of ambiguity to the risk. In simple wagers, where the chances of getting a payoff are clearly known, the dorsal striatum tends to light up. But in a nearly identical game in which the chances of winning are unknown, the more emotional parts of the brain known as the amygdala and orbitofrontal cortex (OFC) are involved.

According to Camerer, "The amygdala has been hypothesized as a generalized vigilance module in the brain. We know, for example, that anyone with damage to the amygdala cannot pick up certain facial cues that normally allow humans to know whether they should trust someone else." Problems with the amygdala are also known to be associated with autism, a brain disorder that causes sufferers to have trouble recognizing emotions in other people's faces. (See page 13.) And the OFC is associated with the integration of emotional and cognitive input. So the two regions presumably work together in facing the unknown—the amygdala sends a "caution" message that the OFC processes.

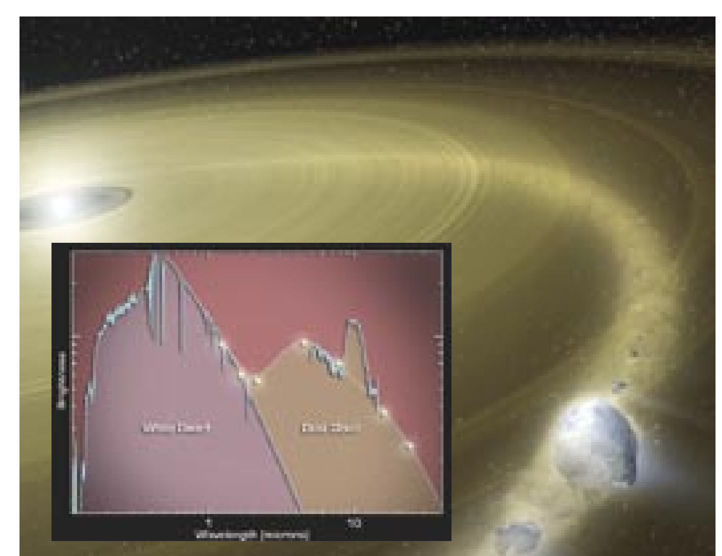
In the "risk" games, subjects chose a card that could be either red or blue. Red cards paid cash, blue cards paid nothing, and the subjects knew that the chance of drawing a red card from the 20-card deck was 50 percent. In the "ambiguity" games, subjects were told that the deck contained 20 cards, but not how many were red or blue. In either case, subjects made a series of 24 choices, with different sums of money at risk and the option of drawing different numbers of cards.

Caltech students drew more cards in the risk game than in the ambiguity game, because people dislike betting when they do not know the odds. But the medical school patients, who had lesions to the OFC, played entirely differently. On average, they were much more tolerant of risk and ambiguity. Caltech students also showed more intense activity in the amygdala and OFC when the chance of winning was ambiguous. (The Iowa patients were not scanned.)

On a societal level, Camerer says that fear of the economic unknown creates a strong preference for the familiar. Thus investors often hold too many stocks they are familiar with, for example, and do not diversify sufficiently. A sort of opposite response may be driving entrepreneurs, who often thrive under uncertainty. "It could be that aversion to ambiguity is like a primitive freezing response that we've had for millions of years," he says. "In this case, it would be an economic freezing response."

The study appeared in the December 9 issue of *Science*.

And studies of epileptic patients awaiting brain surgery have located single neurons that help recognize whether a stimulus is brand-new or has been seen just once before. The patients, who suffer from drug-resistant epileptic seizures, have had electrodes implanted in their medial temporal lobes. Inserting small additional wires inside these electrodes allows researchers to observe the



Billions of years from now, our dying sun will become a red giant. In its final throes, it will engulf Earth before shrinking to a white dwarf. Life on Mars won't be much fun either, but if it's any consolation, the outer gas giants and the comets should survive. Now the Spitzer Space Telescope has found the first traces of such a comet in a ring of dust around a white dwarf named G29-38. It's hypothesized that the comet strayed too close to G29-38 and was ripped apart, as shown in the rendering—the actual data (inset) shows the excess infrared emissions that betray the dust cloud; the 10-micron peak is the signature of silicate grains like those seen in comet Hale-Bopp. The telescope was built by Lockheed Martin and is managed by JPL; the Spitzer Science Center, which programs the observations and processes the data, is located on the Caltech campus.

firing of individual brain cells. These cells are located in the amygdala and the hippocampus, both of which are known to be important for learning and memory.

Says grad student Ueli Rutishauser, this “shows that single-trial learning is observable at the single-cell level. We’ve suspected it for a long time, but it has proven difficult to conduct these experiments with laboratory animals because you can’t ask the animal whether it has seen something only once—500 times, yes, but not once.” Rutishauser is in Caltech’s computation and neural systems program, working with Erin Schuman, professor of biology and an investigator with the Howard Hughes Medical Institute.

The six patients were shown 12 different visual images. Then, 30 minutes or 24 hours later, each subject was shown some of the same images plus new ones and asked whether each image was new or old. The subjects correctly recognized nearly 90 percent of the images they had already seen. Meanwhile, certain neurons increased their firing rate only if the image was being seen for the first time and certain others only if it was the second time, but neither fired for both.

The second type, the “familiarity detectors,” went off even when the subject mistakenly reported that the stimulus was new. This could account for subconscious recollections—“even if the patients think they haven’t seen the stimulus, their neurons still indicate that they have,” Rutishauser says. “These neurons seem to have better memories than we do.”

The third author of the paper, which ran in the March 16 issue of the journal *Neuron*, is Adam Mamelak, a neurosurgeon at the Huntington Memorial Hospital and the Maxine Dunitz Neurosurgical Institute at Cedars-Sinai Medical Center. □—*RT*

PICTURE CREDITS: 3 — Richard Briggs; 5 — NASA/JPL, NASA/JPL/GSFC; 6 — Joanna Tong; 13 — Bob Paz

We’ve Been Punked!

Left: The Fleming cannon, adorned with an MIT class ring, sits in front of Building 54, which last spring was “painted” with a laser that spelled out CALTECH.
Above: The “brass rat.”

The Fleming cannon, displaced from its usual spot on Caltech’s Olive Walk by the rehabbing of the South Houses, vanished altogether on the morning of March 28. On April 6, pranksters from That Other Institute of Technology revealed that it had been relocated from sunny, palmy Pasadena to the gritty urban confines of Cambridge.

The stunt, a year in the planning, was in retaliation for a series of pranks at MIT’s pre-frosh weekend last spring that culminated in the distribution of hundreds of shrink-wrapped t-shirts that read “MIT” on the front, and when unfolded, “Because not everyone can go to Caltech” on the back.

The well-prepared perps struck around 5:00 in the morning, loading the cannon on a flatbed trailer pulled by a pickup truck bearing a construction company’s logo. When intercepted by campus security near the 210 freeway, they produced bogus work orders supporting their cover story that they were moving the cannon to a parking lot across campus so that a proper concrete slab could be poured at its temporary home. They even had a map, with the route to the parking lot marked with a highlighter, and explained that they had gotten lost. Security obligingly led them to their putative destination, but once the coast was clear the cannon was on the road again.

But the pranksters’ crowning touch was the class ring, known in MIT parlance as a “brass rat,” machined for the cannon’s barrel at the cost of some 1,000 man-hours.

Suspicion was originally directed at Harvey Mudd College. Besides being a more plausible 25 miles east of Caltech, Mudders stole the cannon 20 years ago in a very similar manner—right down to the fake work orders.

The cannon is on its way back home at this writing, although the denizens of Fleming House who retrieved it left behind a miniature version under glass. Says Caltech security chief Gregg Henderson, who takes these things in stride, “Ditch Day is tomorrow, and we’re going to need it.” □—*DS*