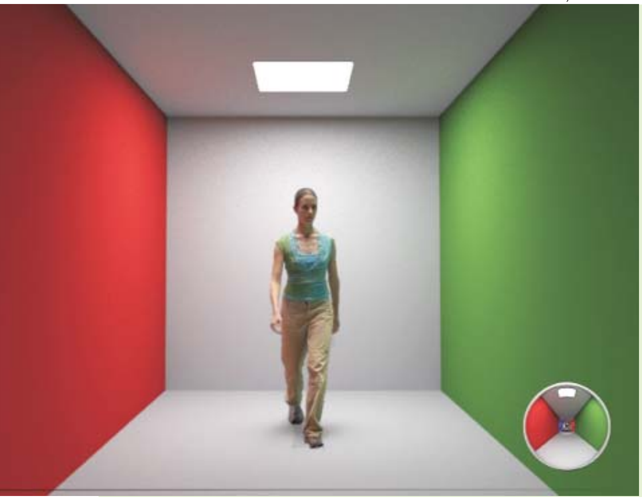
PAUL DEBEVEC, USC ICT



Digital doubles: This simulated image was created from measurements of the light reflected from the actual woman as she stood on a rotating stage with light shining on her from 6666 LEDs dotting a geodesic dome (see cover). The subject's position and lighting can be matched to a new digital environment. The technique is used to create digital doubles for stunt scenes in live-action films.

prerecorded sound, but, especially for fluids, there is a long way to go to get the same degree of realism that people in computer graphics get for visuals."

Digital characters

"One of the coolest things you see in a movie is when there is some sort of otherworldly beast or digital character that is sitting in the scene, roaming around, and it looks like it was really there," says Debevec. "The only way you can do that is by understanding the physics of light transport, respecting how light works in the real world, and then using computers to try to make up the difference from what was really shot."

For example, he says, in *Narnia* "they filmed a lot of it with the children dressed up in their knight costumes and left an empty space for the lion." Then, to get the digital lion just right, "Rhythm and Hues Studios used radiometrically calibrated cameras to measure the color and intensity of illumination from every direction in the scene." The measurements, he adds, "are fed into algorithms that were originally developed in the physics community and have been adapted by the computer graphics community as a realistic way to simulate the way light bounces around in the scene. They also use the measurements to change the illumination in the scene that was really shot, so that shadows will appear where the character is blocking light."

Similar methods are used for creating digital doubles—virtual stunt characters that fill in for live actors. For that, says Debevec, "film studios sometimes bring actors here to our institute, where we've built devices to measure how a person or object, or whatever you stick in [the device], reflects light coming from every possible direction" (see cover photo). The resulting data set, he says, can be used to simulate a virtual version of the person. "There are about 40 shots of a digital Alfred Molina playing Dr. Otto Octavius in *Spider-Man 2*. It looks like him, but it's an animated character. The reflection from the skin looks realistic, with its texture, translucency, and shine, since it's all based on measurements of the real actor."

A tradition of cheating

"We rarely simulate more than two indirect bounces of illumination, whereas in reality light just keeps bouncing around," continues Debevec. "With no bounces, things look way too spartan and the shadows are too sharp. One bounce fills in perhaps three-quarters of the missing light, and with two bounces you're usually past 95%. That's good enough." Another shortcut, he adds, is to focus just on the light rays that will end up at the eye. "We try to figure out the cheats you can make that give you images that look right."

"There is a long tradition of cheating as much as possible," says Marschner, "because setting up an exact simulation is either not possible or too expensive." For example, he adds, to get illumination to look right, a light source might be placed in some nonphysical position, like inside a character's head. Adds Kass, "You can run a simulation backwards if you know how it should end up. Or you can add semi-invisible forces—pins or virtual glue to change the coefficient of friction locally. Animated characters don't object when you stick pins in them."

We use physics to get realism, says Trojansky. "But I am a physics cheater. I use it as a base, but I am interested in the visual effect." For fluid simulations, cheating might mean ignoring the compressibility or surface tension of the fluid, computing only surface behavior, or setting unrealistic boundary conditions to get the desired visual effect. Trojansky adds, "The Navier–Stokes equations are basic. They describe motion in our world, and there is no way to get around them. The question is how to solve and convert them into code that can create photorealistic results. If BMW does a crash-test simulation, they want an accurate simulation that gives real behavior, for safety. In films, we want to satisfy the director. So we write code that only fulfills the visual aspects and looks believable."

Toni Feder

CERN's fix-it man

As director general of CERN, Robert Aymar has perhaps the most visible job in particle physics today.

In 2004, when Robert Aymar was appointed to run CERN, he was seen as a troubleshooter brought in to get the Large Hadron Collider (LHC) up and running.

Born in 1936, Aymar studied at the École Polytechnique in Paris and then entered the Corps des Poudres, a former French government agency for basic and applied research. In 1959 he was transferred to the Atomic Energy Commission (CEA) in Saclay, where he focused on fundamental research in plasma physics and applications in controlled thermonuclear fusion. In 1977 Aymar was appointed director of the Tore Supra tokamak in Cadarache. "When I first pushed superfluid technology for the Tore Supra large magnets, I was called a fool," he says. After the success of Tore Supra, the same technology was proposed for cooling the LHC magnets. In 1990 Aymar became director of fundamental research at the CEA's natural sciences division. He was chairman of the 1993 external review committee that approved the technical specifications for the LHC. "In some ways that makes me the LHC's godfather," he says. In December 2001, while he was director of ITER, an international prototype energy fusion reactor, the CERN council appointed Aymar chair of a committee mandated to review and evaluate programs and management at CERN. From there, he took the lab's reins.

By the time Aymar's tenure as CERN director general draws to a close at the end of 2008, the LHC should have begun producing results—despite the revelation last month of a new slip in its start-up schedule (see also PHYSICS TODAY, September 2007, page 32). This December CERN will announce Aymar's successor. Many of Aymar's colleagues at CERN suggest he is a leading candidate to head ITER again. But Aymar wouldn't comment on that when he sat down this summer with PHYSICS TODAY.

PT: Did you make any major changes when you first joined CERN? Why did you become director general?

AYMAR: A few years earlier, in 2001, was a crazy time at CERN. The cost [of the LHC] was much higher than expected, and the start date was unknown—it seemed like every month the delay increased by a month. I was asked to chair a committee to look at the problems at CERN. Following our deliberations, I proposed a series of recommendations to the CERN council, and the joke was that instead of putting it on paper, I should come here and make it happen. That's why I came. I found the situation much worse than I expected. We had to regain the confidence of the member states or we would be in trouble. We also needed to try and change the attitude here, as there was too much a culture of individual perfection, and of inaction. First, the system has to work as one, not hundreds of smaller systems working without a common goal. Second, I tried to make sure that everyone is concerned with the common goals of the laboratory, not just the affairs of their own department.


MAXIMILIEN BRICE, CERN

Aymar

The third change was to make everyone, as much as possible, cost conscious because we did not have the money to build [the LHC]. We had to borrow a huge amount [1.5 billion Swiss francs ($1.3 billion)]. We had to squeeze as much efficiency out of our budget as possible, which came as a huge shock to some, who were used to a lot of money at CERN.

PT: How long will it take to pay back the money borrowed for the LHC's construction? And what is next for CERN?

AYMAR: This year we will start to pay back the loans, finishing in 2011. Currently all our budget is tied up with the LHC. . . . That is why in 2006 I made a plea to the different member states to increase their [combined] contributions by 240 million Swiss francs ($203 million) over four years. It is looking successful since the last council meeting, mostly because of the good will of the two host states, France and Switzerland, who are providing half of the total additional contributions. This money would allow CERN to prepare R&D for the new injection line and other cost-effective ways of improving the LHC's performance and reliability over the coming years. Otherwise we've done nothing on the state of our buildings since we started LHC construction, and some of them are falling apart.

PT: Will more countries become member states of CERN?

AYMAR: Romania is preparing its case, and Israel is looking ahead. Russia is certainly active in asking itself what it should do, and my guess is that sometime in the future it will become a member.

PT: What will CERN's involvement be with the International Linear Collider?

AYMAR: We have participated reasonably in the reference design of the ILC, but if construction is decided before 2016, I don't think CERN will be able to participate, as Europe won't have the money.

The decision will also depend on what results the LHC will provide. CERN is now developing a novel technology for a linear collider, CLIC [Compact Linear Collider, a proposed 3- to 5-TeV electron–positron collider generally considered to be further in the future than the ILC]. The cost would be similar for ILC and CLIC. I suspect that by 2010 we will have an answer as to which technologies and research direction are the most appropriate. The high-energy-physics community will probably only be able to afford one of these projects.

PT: There seems to be a push in particle physics for open-access publishing of scientific papers. Why do you think that is?

AYMAR: The number of journals that publish particle-physics papers is very small. This community of authors and publishers is small and as such all their papers can be made freely accessible for a few million euros.

Why is open access happening now? The price of subscriptions is increasing, the number of people buying journals is decreasing, and at some point [the journals] will disappear. And what we should make clear is what is important—independent peer review. Editors are necessary, publishers are necessary, but the idea that by editing a piece the journal gets the copyright is strange. Instead publishers should be paid for coordinating peer review, improving readability, and publishing papers with open access on the Web. We [at CERN] think this is the way scientific articles should be published.

PT: And what will you do next?

AYMAR: I don't quite know. I may retire permanently this time.

Paul Guinnessy

Sandia heads up new nanoengineering institute

Preparing students to work in teams that cut across disciplines and research sectors is a key aim of Sandia's latest educational program.

"Engineering is changing incredibly rapidly, and engineering education must change in major ways in response," says Paul Peercy, dean of engineering at the University of Wisconsin–Madison. "The boundaries between science and engineering are fading. Thirty or forty years ago, people worked alone and in small teams. If you think about the next generation of solutions to complex problems, they're going to be obtained by large interdisciplinary teams."

Forging the mindset and connections to nurture large interdisciplinary teams is the aim of the National Institute for Nano-Engineering, a partnership among industry, government, and university researchers that is getting started with the Department of Energy's (DOE's) Sandia National Laboratories in New Mexico as its base. Besides Sandia, 12 universities and 7 companies make up NINE's founding members, but the partnership is open to expansion, and researchers from any university can participate, says Duane Dimos, Sandia's director of materials science and engineering. NINE's main focus is on undergraduate and graduate students, including developing curricula in nanoscience and nanoengineering that will be both used within NINE and shared openly with academic institutions. "NINE will impedance match to broker internships with industry and collaborations with Sandia," says Paul Fleury, Yale University's dean of engineering.

Hundreds of students

Dimos points to institutes in Europe, Singapore, and South Korea as models for NINE, singling out the 23-year-old IMEC—the Interuniversity MicroElectronics Center in Belgium. In microelectronics and nanoelectronics, he says, "IMEC has become a strong player throughout Europe, and it has a large industrial component. By combining what they do at the center with what they do at their home universities, students are getting a really interesting education. We are emulating that, although we will add our own twist in that universities might be more active in driving the program [at NINE]."

SANDIA NATIONAL LABORATORIES

Students learned to synthesize nanoparticles this past summer at the kickoff workshop of the National Institute for Nano-Engineering at Sandia National Laboratories.

Many practical matters are still being worked out, says Dimos. "We anticipate having a central facility in Albuquerque next to the Sandia campus." Participating researchers would work at both Sandia and partner institutions, and they would have access to equipment at Sandia, such as the Microsystems and Engineering Sciences Applications facility (see PHYSICS TODAY, October 1999, page 65).

The institute kicked off this past July with a two-week workshop at Sandia attended by three dozen undergraduate and graduate students. Some 13 projects are under way in topics such as nanowire electronics, flow and rheology of nanomaterials, catalytic function of nanomaterials, and manipulation of nanowires, Dimos says. The goal, he adds, is to eventually involve a couple hundred undergrads and a similar number of graduate students.

Industrial guidance

"There is a strong belief at Corning that education is falling short of expectations," says Daniel Ricoult, the company's director of technology assessment. "That's why when we heard about the concept of NINE, we were intrigued. It's a nice way to build bridges between industry and academia."

Sharon Smith, who leads Lockheed Martin Corp's efforts in nanotechnology, agrees: "We have to have a really good pipeline of talented scientists and engineers, and we see NINE as an exciting program that will benefit us in the future." Her company, she adds, hires 5% of new engineering bachelor's recipients in the US each year.

"We see nanotechnology as a key area," Smith says, "because it's going to impact virtually every aspect of our business." New materials are lighter and stronger and have new capabilities, she adds, citing as applications multifunctional materials, embedded sensors, and energy. "We have no lack of problems to be solved."

NINE's industrial partners will provide guidance on the technical directions of research, Smith adds. "We will be looking for areas of research that will benefit our industry as a whole, and we will be looking to provide a unique experience for students to learn how what they do in the NINE program could benefit industry." As part of the collaboration, she adds, NINE partners are