BusinessWeek

EUROSCAN February 8, 2007, 11:00AM EST

A Big Bang... of Innovation

At the site of the world's most powerful accelerator, physicists aim to recreate the Big Bang. Innovation is an unexpected—but welcome—by-product

by Bruno Giussani

While subatomic particles such as electrons and protons are very small, the devices used to study them are rather large. Consider ATLAS: the particle detector, still mid-construction, is about 45 meters long, more than 25 meters high, and weights about 7,000 tons. It was first imagined in 1994, and some 2,000 scientists and engineers from three dozen countries have been building it since January, 2003. Starting this November, ATLAS will observe and measure the collisions of minuscule beams of protons traveling at nearly the speed of light inside a new particle accelerator, the Large Hadron Collider (LHC). The collider is under construction at CERN, the largest particle-physics lab in the world, located near Geneva, Switzerland.

The work of thousands of physicists at CERN, which is operated by the European Organization for Nuclear Research, may be highly specific and somewhat obscure to most. However, the technologies they have developed over the years and their approach to complex problems have led to breakthrough innovations with relevant applications in many sectors of business and life. Just to mention the best-known: The World Wide Web was invented at CERN, originally to solve the problem of connecting large amounts of information and making it accessible to physicists worldwide. While the physicists themselves study the Big Bang that created the universe, you might say that the physicists' work methods catalyzed a big bang of innovation.

To see for myself how CERN's network of scientists works together in the name of Big Science, and to ogle at these incredible machines, I recently visited the LHC construction site, accompanied by three CERN scientists—Brian Cox, Torsten Wengler, and Albert de Roeck. What I got first was a lesson in physics. No doubt it's one of the most complex and ambitious scientific experiments ever. When it becomes fully operational next year, the nearly €6 billion (or $8 billion) LHC will be the world's most powerful particle accelerator.

HYPOTHETICAL NEEDLE IN A HAYSTACK

The LHC is installed in a circular tunnel some 100 meters beneath the ground and measuring 27 km in diameter (the loop actually crosses the Swiss-French border). Inside, beams of protons will travel in opposite directions inside two pipes surrounded by magnets (cooled to near absolute zero—minus 273 Celsius—by liquid helium) and other machinery and wiring. The protons will be accelerated until they reach 99.99% of the speed of light (which is 299,792 km per second).

"Basically, we will start with a bottle of hydrogen gas, open it up, and start accelerating," says Cox. The hydrogen nucleus consists of only a single proton, and "accelerating" in a physicist's terminology means increasing the particle's energy levels. At full speed, the energy stored in a beam of protons "will be close to that of a train traveling at 500 kilometers per hour (about 311 miles per hour),", adds Wengler.

Along the 27-km ring the scientists are building five detectors: ATLAS, the more compact CMS, and three smaller, more specialized devices. When the speeding protons travel through them, powerful magnets create the collisions (40 million per second) by slightly deflecting their trajectory. As a result, thousands of particles will be sprayed in every direction. The detectors are designed to "see" and measure the post-collision particles, and to look for one in particular: the minuscule, elusive, hypothetical Higgs boson, whose existence is supposed to explain why there's mass in the universe—a seemingly basic question that physicists can't yet explain.

BASIC QUESTIONS

A bit more background: Modern particle physics is based on a "standard model" that explains the interaction between the building blocks of matter. All the particles in this model have been discovered, except for the Higgs, which is why it's target No. 1 of the LHC. Scientists hope that by re-creating the conditions of those first fractions of a second after the Big Bang (when it is supposed everything in the universe was weightless), they will then be able to observe the first appearance of mass—in the form of the Higgs, if the hypothesis is correct.

Hence, if successful the LHC experiment will reveal the origins of mass. And it may uncover more. For example: Why is the force of gravity so weak that we can lift an apple off a plate even if the whole Earth is pulling in the opposite direction?

So what happens if, after all this effort, they don't find the Higgs? Would that qualify as a failure? "Not really. We would still learn a lot," says Wengler, and the first lesson would be that some of today's physics theories would need serious reconsideration, for the Higgs is the glue that keeps the whole theoretical construct together. (The only scenario that Wengler would call "catastrophic" is that of a beam of protons going out of control, and spinning out of the tunnel. However, he's quick to say that it would likely travel a couple hundred meters at most and end up punching a hole in a rock, the energy dissipating into the ground. "There would be no risk for people," he adds, but "it would wreck our machine.")

After visiting the control room, we descend 100 meters underground to a vast chamber—a physics cathedral with concrete walls three meters thick—where the ATLAS is being assembled. The logistics, organization, and project management involved in designing and constructing this device are on an industrial scale. Nearly 6,000 scientists from CERN and hundreds of institutions around the world are working on the LHC and its detectors.

WHY SO HUGE?

The challenges are enormous, as well as extremely subtle. For example, the underground chamber that hosts the ATLAS is affected by ground temperature, by the pressure of the rocks around it, by the phases of the moon, and by how much water there is in nearby Lake Geneva. These may cause millimetric movements, but the beams are sensitive to sub-millimetric shifts. "We can't prevent the machine from moving," explains Wengler, "so we try to know the movements in advance and adjust" through a series of alignment systems (such as lasers) built into the detector.

Why does it need to be so big? "It's driven by the energy of the particles and the size of the magnets needed to bend the beams of protons," Cox explains. Paradoxically, despite the extreme scale of the device the actual collisions will happen within a 20-centimeter portion at the core of ATLAS and the other detectors.

After exiting the ATLAS complex, we drive for about 20 minutes—another indication of the size of the LHC—to reach the CMS detector. The two are, in a way, competing experiments. Their aim is the same—find the Higgs, and more—but they're built following two different strategies for observing the particles, approaching the proton beams from different angles. The CMS is about one-quarter of the size of the ATLAS but much heavier (12,500 tons). The complexity of the two devices is not to be underestimated: Their technical specs fill more than 5,000 pages—each.

GLOBAL COMPUTER EFFORT

The pipes and the machines are only part of the LHC story, however. A sizable part of the effort has to do with software, which high-energy physics has traditionally treated as an add-on. While the construction of the hardware is still the main focus—mainly owing to the fact that a hardware mistake would be more difficult to fix—the software-development process is at least as complex, because the Higgs really cannot be "seen." It will have to be modeled by computers tracking the electrical impulses generated by the collisions.

And because the amount of data that the collisions will produce is staggering, less than 0.1% of the data generated by the 40 million collisions per second will be saved and analyzed. Even that adds up to some 300 megabytes of data per second, or 15 million gigabytes per year, that must be stored and analyzed in search of the tiny anomalies that would indicate the Higgs.

To manage this unprecedented quantity of data, CERN has been working for years on developing a global network of computers, linked by high-speed connections, called the LHC Grid. Grid computing, in its simplest form, involves splitting data into chunks and sending them to hundreds of thousands of computers to be analyzed. Computers around the world will contribute to the effort in the coming years.

That the LHC team would be employing so many of the methods of innovation we see today—collaboration, an open-source approach to sharing information, distributed computing—should come as no surprise. It was physicists at CERN who, nearly 20 years ago, built the Web to solve their data-sharing problem. With the Grid they may revolutionize yet again the way we use computers. And that's just a byproduct of their search for answers to some (as yet) unanswered fundamental questions.

Giussani is a Swiss writer, tech entrepreneur, conference host, and the author of Roam: Making Sense of the Wireless Internet. He blogs at www.LunchOverIP.com.