Looking deep into the architecture of existence (FT)

Written by Marie Neptune
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Still referred to as CERN, for Conseil Européen pour la Recherche Nucléaire (European Council for Nuclear Research), as it was called when it was founded in 1952, this famous scientific laboratory's official name is now Organisation Européenne pour la Recherche Nucléaire (European Organization for Nuclear Research). -- CERN is where W and Z bosons were discovered, and, it is hoped, where the Higgs boson, widely presumed to exist but never observed, will be found in the not-so-distant future; **it is also the place where the World Wide Web began as a project initiated by Tim Berners-Lee and Robert Cailliau in 1989.** -- CERN was profiled in Saturday's *Financial Times* of London.[1] -- Its most important machine — known as "the Machine" — is the Large Hadron Collider, or LHC, which "20 European member states agreed in 1994 to build . . . after the U.S. government cancelled an even more powerful atom-smasher, the Superconducting Super Collider in Texas, $2bn into construction, because its costs were running far ahead of budget," Clive Cookson recalled. -- Thanks to the cancellation of the Super Collider, the LHC is "a de facto global instrument." -- "CERN was founded close to Geneva because the city symbolized internationalism and political neutrality. The footprint of the lab was originally entirely within Switzerland but today several of its buildings are in France and the collider's ring crosses the Swiss-French border six times. In keeping with the relaxed atmosphere, I never encountered any passport control or security checks when I drove across the frontier on the public road." -- The U.S. government has contributed some $530m to building it. -- "Many components for the accelerator and detectors were made in the U.S., and almost 1,000 of the 9,000 scientists expected to use the LHC will be American," Cookson noted. --
But the **LHC's director is a Welshman named Lyn Evans**, who has spent his entire professional life at CERN. -- In a coda to Cookson's article, Edwin Heathcote called the Large Hadron Collider "perhaps the most complex, most technologically advanced, and most philosophically challenging thing ever to be constructed." -- But humanity hardly knows how the building it housing it should look. Heathcote observed: "As post-Einstein physics pulls away from our broader culture, introducing ideas of supersymmetry, strings, and multiple extra dimensions, we, as a culture, have become resigned to our incomprehension. -- The medieval master masons were at the forefront of engineering expertise. Sir Christopher Wren built London's St. Paul's while actively involved in mathematics, optics, and science; Sir Robert Hooke built London's Monument as a scientific observatory. Now we have entirely lost our faith in architecture's ability to express anything about our culture, particularly about our science." ...

THE APPLIANCE OF SCIENCE
By Clive Cookson

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The world's greatest shrine to pure scientific curiosity hides its glories from the casual visitor. On the surface CERN, the European center for particle physics, is built in the apologetic drab-lab style typical of a public research laboratory anxious to reassure taxpayers that no money has been wasted on ostentatious display. My first reaction is that the scenery of the Swiss-French borders, from the Jura foothills to Alpine peaks, deserves something better -- and so does CERN's quest to understand the secrets of the universe.

When I drop 100m beneath the surface in a high-speed lift, however, a spectacularly colorful new world opens up. Giant magnets in red and yellow, green and blue stand ready to guide two beams of protons -- hydrogen nuclei -- round a 27km underground race track. At four "collision points," where the protons will smash together at almost the speed of light, huge multicolored flowers seem to blossom on the beam lines. These are 25m-high "detectors," designed to make sense of the myriad subatomic particles that will fly off in all directions when the protons annihilate one another. CERN scientists hope fervently that the flight patterns will reveal the existence of previously unknown particles and forces, maybe even dimensions.

This vast underground apparatus makes up CERN's latest atom-smasher, the $8bn Large Hadron Collider. Later this summer, if all goes well, the LHC will be switched on and will start to produce a cornucopia of data to feed theoretical physicists seeking to understand the ultimate laws of nature. They have been starved of experimental results since CERN's previous accelerator, the Large Electron-Positron (LEP) collider, was closed in 2000 so that the new machine could be built within its circular tunnel.

At the very least, the scientists at CERN aim to find the final missing element of the so-called Standard Model of the universe that physicists have built up during the past 40 years. This particle, known as the Higgs boson, would at last explain how matter acquires mass, its most basic property. But the CERN team have ambitions far beyond the Higgs particle and the Standard Model. They aim to take science into speculative new pastures such as "supersymmetry" and "string theory."

Governments have long been willing to fund physics experiments for the sake of pure intellectual curiosity -- science as culture -- to help us understand the past, present, and future of the universe. There are two complementary ways of gaining the necessary evidence: one is to observe the universe through telescopes and other astronomical instruments; the other is to experiment on Earth. This has meant building more and more powerful colliders, to bring us closer to the intense energy of the newborn universe immediately after the Big Bang 14 billion years ago.

CERN's 20 European member states agreed in 1994 to build the LHC after the U.S. government cancelled an even more powerful atom-smasher, the Superconducting Super Collider in Texas, $2bn into construction, because its costs were running far ahead of budget. **Forty years earlier, in 1954, CERN had been established as the focus for Europe's peaceful research in atomic physics after the devastation of the Second World War.** Its acronym comes from the French Conseil Européen pour la Recherche Nucléaire.

A genial Welshman called Lyn Evans has led the LHC project from the start, through financial and technical crises, to the brink of what he hopes will be its triumphant inauguration. "If I knew back in 1994 what I know now, I wonder whether I'd have taken it on. But I'm glad I did," he says. "The collider is an inanimate object at the moment but it will come alive when we first put a beam [of protons] into it."

Although his voice still holds the cadences of the Welsh valleys, 63-year-old Evans has spent almost two-thirds of his life at CERN, just outside Geneva. He arrived in 1969 as a visitor for three months, after completing his Ph.D. at the University of Wales in Swansea. He never left.

The cancellation of the Superconducting Super Collider in 1993 left the field clear for CERN's machine to become a de facto global instrument, and the U.S. government has contributed $530m to its construction. Many components for the accelerator and detectors were made in the U.S., and almost 1,000 of the 9,000 scientists expected to use the LHC will be American.

One of the joys of touring the site is to see contributions from so many different countries, many of them outside CERN's West European core membership. The vast 12,500-ton Compact Muon

Solenoid or CMS detector rests on eight steel feet made in Pakistan. India has supplied 7,000 jacks (adjustable supports) for the collider's magnets. Russian components and technicians making last-minute adjustments appear everywhere. The smart brass plating for CMS comes from "several thousand redundant naval shells melted down by the Russian Navy," says Austin Ball, the detector's technical co-ordinator. In the main tunnel, Evans points out an array of red magnets made in Novosibirsk.

CERN was founded close to Geneva because the city symbolized internationalism and political neutrality. The footprint of the lab was originally entirely within Switzerland but today several of its buildings are in France and the collider's ring crosses the Swiss-French border six times. In keeping with the relaxed atmosphere, I never encountered any passport control or security checks when I drove across the frontier on the public road.

Indeed, the whole CERN site seems refreshingly free of intrusive security. When Dan Brown wrote about CERN in 2000 in his thriller *Angels and Demons*, the plot depended on the use of biometric iris scanners to control access to sensitive areas. Eye scanners were not in fact being used at CERN then, but they are being installed now on all access gates to the machine. And yes, CERN security has indeed checked that a villain could not copy Brown's plot of killing an authorized scientist, ripping out his eye and using it to fool the system.

Computing is perhaps the field where CERN's international credentials are best displayed. The experiments will produce a staggering amount of data from particle collisions. Even after internal electronic "filters" at each detector have weeded out the least interesting 99 per cent of primary data, there will still be 15 million gigabytes a year to process -- enough to fill 100,000 DVDs.

That is too much for CERN to handle on its own, so 80 per cent will be distributed to 200 computing centers around the world, using a special "grid" infrastructure set up for the purpose. CERN is proud of its title as the birthplace of the World Wide Web, which Tim Berners-Lee created in 1989 to enable scientists to share information from the previous LEP collider.

When CERN scientists are asked to justify their spending, they often feel compelled to identify practical spin-offs, such as the web and grid, or the new generation of electronic devices and superconducting magnets developed with industry. "The politically correct answer is that we provide a training ground for industry to innovate," says Jos Engelen, CERN's Dutch chief scientist and deputy director. "Of course, the real answer is to satisfy intellectual curiosity. If you talk to young people, they want to know about quarks and black holes."

But if you take an ultra-long view, what looks now like pure intellectual curiosity may pay off eventually in ways that we cannot comprehend. For example, the 19th-century experiments that led to the discovery of electromagnetism and the electron paved the way to modern electronics. Just possibly, in the 22nd century, our descendants may cruise the galaxy in spacecraft powered by a force whose discovery dates back to the LHC.

By now I have emerged from the tunnel to enjoy a fine lunch with Engelen and Robert Aymar, CERN's French director-general, in the staff restaurant. They seem to be the only men in suits on the site; most CERN scientists favour a jeans-and-jumper look. Both are evidently preoccupied with the practicalities of running CERN and commissioning the collider, but as we eat our duck breast salad, lightly lubricated with Swiss wine, I get them to speculate about pure science. It is something the pair rarely find time to discuss together, they admit sadly.

The project's first aim is to confirm the existence of the Higgs boson, a particle first proposed in the 1960s by Peter Higgs of Edinburgh University to explain how matter acquires mass. His idea, incorporated into the Standard Model of physics, is that a "Higgs field" pervades the universe; the more an object interacts with the field, the more mass it has. Any force field must have an accompanying particle -- in this case, the Higgs boson. Leon Lederman, the American Nobel laureate, famously called it the "God particle," but CERN scientists understandably cringe when people repeat his phrase.

These concepts are so hard to grasp that in 1993 William Waldegrave, then U.K. science minister, issued an imaginative challenge to physicists: come up with a simple explanation of the Higgs effect. The winner, David Miller of University College London, produced an analogy that CERN staff still use today. Here's my adapted version.

The Higgs field pervades the universe. Imagine it as a gigantic political reception in which party workers are evenly distributed throughout the room. Then a big celebrity (Margaret Thatcher in the original version) walks across the space, attracting clusters of admirers who slow her progress. This resistance to movement is analogous to the mass given to a particle by the Higgs field. A political lightweight attracts less clustering and resistance -- equivalent to having a lower mass.

Now comes the more difficult bit. Replace the famous guest with a juicy rumor (for example, that the prime minister is about to resign). As the rumor crosses the room, it creates a clustering effect, just as a real celebrity does. This is the Higgs boson -- a particle that inevitably arises from the Higgs field. Just as it takes a powerful rumor to produce clustering at a political gathering, physicists need extremely high energies to make Higgs bosons -- and the LHC is the first machine powerful enough to do so.

For Engelen, proving the existence and measuring the properties of the Higgs particle is sufficient justification for the project. "It is true that confirmation of Higgs' existence would seem like old news, but if we did not build the collider we would never know -- and that's unacceptable," he says.

"There are much larger and more speculative explanations [of the universe] accessible to the machine," Engelen adds. He is particularly keen for evidence to help enable physicists to construct a grand theory, uniting gravity with the three fundamental forces covered by the Standard Model: electromagnetism and the strong and weak nuclear forces.

Energies trillions of times greater than even the LHC can produce would be required to study gravity in our four familiar dimensions -- length, width, depth, and time. But Engelen's dream is that quantum particles associated with gravity may show up at much lower energies, if the collider can reveal "hidden" dimensions. According to the currently popular string theory, at least six more dimensions are somehow curled up tightly in our familiar space-time.

Aymar is keener on supersymmetry, the theory that every conventional subatomic particle has a far heavier partner, a "superparticle." Mathematicians say this could simplify the universe by bringing out new links between forces and particles. If supersymmetry is correct, CERN stands a reasonable chance of producing and detecting the lightest predicted superparticle, the neuralino. Its discovery would delight those cosmologists who believe superparticles make up the mysterious "dark matter," which accounts for a quarter of the universe but is not observable because it does not interact with light.

Engelen, however, is not impressed. "Supersymmetry is not symmetry at all," he observes enigmatically. "It might explain dark matter, but it is not elegant." And inelegance is a serious insult in the world of theoretical physics.

Miniature black holes are another possible product of the project. Although most of the collisions will be between protons -- hydrogen nuclei -- the machine will also smash together the far heavier nuclei of lead atoms. "Rather than the point-like interactions of proton-proton collisions, we get a miniature fireball at a temperature of **10 billion degrees -- a million times**

hotter than the center of the sun," says David Evans, senior scientist at the detector called Alice (which stands for A Large Ion Collider Experiment) which is focusing on lead-lead collisions. **"We are recreating a tiny volume of matter that is very similar to the universe one-millionth of a second after the Big Bang,"** Evans says. **"We are more likely to find black holes than in the proton-proton collisions."**

Talk of this sort has alarmed some people. CERN scientists say any microscopic black holes produced would be unstable and disappear almost instantaneously in a burst of radiation. But what if they grow and swallow up the Earth? Or if the collider makes "strangelets," hypothetical particles that could theoretically also trigger a cataclysm? Opponents have even filed a lawsuit against CERN and its U.S. partners in a federal court in Hawaii, seeking to prevent the LHC from opening on safety grounds.

CERN's safety assessments insist that the project presents no such risk. Though the collider will produce the most intense energies ever created by mankind, far more energetic processes take place in natural phenomena, such as supernovae, sending out cosmic rays that have been bombarding the Earth and solar system for billions of years without mishap.

The LHC is scheduled to run for 20 years, with an upgrade planned for 2016. But the lead times for big science projects are so long that the world's physicists are already planning another multibillion-dollar atom-smasher, the International Linear Collider, to follow on.

The proportion of public expenditure devoted to high-energy physics has been declining for decades, as governments spend more on the biomedical sciences and on research with more immediate applications. "CERN's budget has been flat in real terms for 30 years," says Evans. Recently both the U.S. and U.K. have cut spending on particle physics.

If the world's decision-makers are to build a successor machine devoted to understanding the nature of the universe, the LHC will need to produce some spectacular scientific surprises -- which can be sold imaginatively to the public as needing more answers. Without, of course, bringing the world to an end.

--Clive Cookson is the FT's science editor.

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GLOSSARY

Particle physics studies the fundamental particles and forces that make up the universe. "High-energy physics" is an equivalent term, because many particles appear only in the extreme conditions produced at labs such as CERN.

Protons are the positively charged building blocks of atomic nuclei. Hydrogen has a single proton. Each proton is made from three smaller units called quarks.

The Standard Model of the universe, built up since the 1960s, provides a coherent explanation for three of the fundamental forces -- lectromagnetism and the weak and strong nuclear forces -- but does not yet cover gravity.

Supersymmetry is the theory that every conventional subatomic particle has a far heavier partner, a "superparticle" or "sparticle." This would clear up several theoretical loose ends in particle physics.

String theory regards the basic units of matter and energy as minuscule vibrating loops or strings, no more than a millionth of a billionth of a billionth of a billionth of a centimeter long. It proposes a universe with 11 dimensions of space and time.

Black holes are regions of space so dense that their gravity prevents light -- and anything else -- escaping. Black holes at the centers of galaxies are star-gobbling monsters, but any microscopic black holes produced by the Large Hadron Collider would be unstable and quickly disappear in a puff of subatomic particles.

--Clive Cookson

THE AESTHETICS OF THE MACHINE
By Edwin Heathcote

The Machine. That's how they refer to the Large Hadron Collider at Cern. "Have you seen the Machine?" That's what everybody asks. It sounds vaguely sinister, but intriguing. Which is what the whole strange CERN site is like.

Somehow, you expect the Machine -- perhaps the most complex, most technologically advanced, and most philosophically challenging thing ever to be constructed -- to be housed in a kind of temple, a cathedral to physics. Instead, it is buried beneath a series of semi-agricultural crinkly-tin sheds and a tatty complex of grey institutional buildings which could house a large college in any provincial town in Europe.

The big warehouses within which the detectors themselves were assembled have been partly dismantled. The vast, turbine-like machines have been lowered into the ground and the sheds will be reduced in height to appease the neighbors who had been worried about their views across the Alpine landscape.

In a way, these buildings are the perfect metaphor; a 27km tunnel around which are distributed these astonishing detectors, with nothing of any interest showing above ground. Scientists can account for only 4 per cent of the mass and energy in our universe; this almost behemoth is the manifestation of the search for the missing stuff, dark matter, dark energy. If the Gothic cathedrals were the medieval monuments to the mysteries of existence, this underground orbit is ours, the physical manifestation of an age in which aesthetics has been entirely separated out from science.

Greek or Roman, Gothic or baroque, medieval or enlightenment, each age invested its buildings of existential or scientific inquiry with the prevailing architectural language. In their columns, naves, spires, and domes, each culture attempted to define itself against the sky. Our age is different. Our achievement is not aesthetics but machines, the computers that control every single aspect of first-world lives. Our technology, the cheap chips in all those devices we own, depends on quantum physics -- which most of us can't even begin to comprehend. As post-Einstein physics pulls away from our broader culture, introducing ideas of supersymmetry, strings, and multiple extra dimensions, we, as a culture, have become resigned to our incomprehension.

The medieval master masons were at the forefront of engineering expertise. Sir Christopher Wren built London's St. Paul's while actively involved in mathematics, optics, and science; Sir Robert Hooke built London's Monument as a scientific observatory. Now we have entirely lost our faith in architecture's ability to express anything about our culture, particularly about our science. The result is the LHC.

Yet this is a thing by no means void of beauty. There are vast caverns hewn from the earth and reinforced with massive concrete shells. There are vertiginous shafts below which are visible gantries and infinitely complex machinery. There are the astonishing, beguiling colors of the veins exposed on the surface of the detectors; the shimmering copper conduits bent and folded into organic arteries feeding the skin, cooling the contents orbiting around at 11,000 times a second. There are the copper-clad surfaces, artificial suns to detect the most astonishing minute sub-atomic collisions. And there is the unselfconscious beauty of endless cables in the brightest colors.

In this beauty we can see emerging the hope that the Machine will begin to confirm the symmetrical elegance of the Standard Model -- that this idea, built up through prediction rather than observation, so frustrating to an empirical world of physics, will turn out to be true. The building of the Machine, in the engineering and technical achievement of constructing something using parts and expertise from every continent, reveals a confidence in a vision, an idea of how the world should work.

This is what it looks like when we look deep into the architecture of existence. To find the architecture of everything, the particles which give us mass, which give us energy, which were there in the first fractions of a second of the beginning of time and yet which we cannot see or feel or even prove, we construct a subterranean wonder with no more than a recycled expo pavilion above ground.

The architecture of everything, it transpires, needs no architecture beyond the elegance of the perfectly functioning machine -- the dream of technocratic modernism. In CERN, reductivist modernism has found its ultimate muse, an existential machine which needs no expression other than its own engineering.

--Edwin Heathcote is the FT's architecture critic.