Mysteries of the Universe

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A visit to CERN's laboratories near Geneva exposes Dan Brown's Angels and Demons for the fairy tale it is. Here the giant particle accelerator (the Large Hadron Collider) smashes protons with unimaginable forces in experiments designed to demonstrate or prove theories about the sub-components of atoms or the properties of anti-matter. In their investigations CERN's scientists and engineers go to the heart of the nature of the creation of the universe. Their efforts have helped to push the boundaries of medical science in the treatment of cancers; they have led the way in the development of computer networks and data interchange. In its international make-up the team working at CERN is a model example of cooperation between different nationalities in the search for knowledge.

A Polemical Science Report

Compared with the daily grind at the European Organization for Nuclear Research, Dan Brown's mystery bestseller *Angels and Demons* makes science seem like a breeze. Had he known even a little about CERN (the research centre's French acronym for the Conseil Européen pour la Recherche Nucléaire), he would have bowled you over with the lengths to which fantasy can go. They don't spin fantasy at CERN, though. They just slog away at things they routinely call the integration of science and engineering. The only place in the world you can see this in action is in Geneva on the border between Switzerland and France.

The World Begins with Matter

CERN's matchbox laboratories present a strange sight as you bank before landing at Geneva's Cointrin airport. Where else could you land for a visit to CERN? The world-famous research centre has no helipad nor even a helicopter of its own, let alone a hypersonic airliner, like the marvel in Dan Brown's *The Da Vinci Code* that could whisk you from America to Lake Geneva in 120 minutes. That apart, CERN seems to possess everything the prolific American writer thought of committing to paper.

A cheerful, gruff 'Hi' breaks in on my thoughts. It comes from an ageing hippy. If I believed in reincarnation I would take him for the young Karl Marx. Sporting faded jeans and a T-shirt with a lizard struggling out of a football, he reclines in a basic plastic chair turned towards the sun, splaying his bare toes to get a tan. Several more CERN boffins are relaxing nearby, sipping coffee, and smoking. Their ages? I would put them anywhere between 30 and 70. Listening in, I hear a jumble

of languages: English, French, Russian and a sprinkling of Italian. It must be pleasant working here, within sight of the snow-capped summit of Mont Blanc.

'CERN is the second greatest marvel on Earth after the Tower of Babel', opines British scientist John Ellis (Karl Marx with the lizard on his chest). 'The biblical Tower crumbled when God made the builders speak different languages and they could no longer communicate with one another. But CERN is still standing amidst its babel of tongues. Where else will you see an Arab and an Israeli, a Russian and an American, mainland Chinese and Taiwanese, Serb and Croat working side by side in one research laboratory? No one country could cope with the tasks we take on. For instance, we have 130 different institutes involved in staging a single experiment. With the largest body of like-minded people on earth, over half the world's nuclear scientists, CERN can take on the seemingly impossible. We are entering a new age in our knowledge of the Universe. H-hour has arrived.'

Bringing together the victors and vanquished after the Second World War in 1954, CERN became Europe's first joint research project and demonstrated an amazing example of international cooperation. Straddling the border between France and Switzerland, in the Jura foothills, the centre developed into a test site for elementary particle experiments now involving 7,000 researchers from 80 countries. All of them are dwarfed by the Large Hadron Collider (LHC), or giant particle accelerator.

I looked down through the safety grille and began to feel giddy. I was born with acrophobia – fear of heights, or in this case depth. I was looking into a concrete shaft, the end of which was lost, it appeared, deep down in the inferno, near the centre of the Earth.

'A hundred and twenty metres deep. Fancy a walk down there?'

Vitaly Kaftanov, a Russian professor, volunteered to guide me through Geneva's underworld. He's daring me, I thought. With a sinking heart, I nodded, realizing in the back of my mind I was in for an adventure no journalist would want to miss.

'Put a helmet on then', my guide told me. 'Pull the straps tight to secure it on your head. For safety. What shoes are you wearing? Laced boots with thick soles are the standard here. I guess your moccasins will have to do, though.'

I expected to see a clanking cage, the sort that terrified me years ago when I used to go down coal mines to do interviews. This time, however, I was reassured as we descended a broad stainless steel staircase and entered a fast well-lit elevator. In this Jurassic purgatory it all seemed as safe and efficient as everything else in Switzerland.

The tunnel down the shaft reminded me of the Moscow subway but cleaner and better lit. I had a feeling I was only steps away from some great mystery.

'Can you conjure up an enormous metal tube 27 kilometres long and weighing 4,000 tonnes? Add to that image two accelerating proton beams rushing toward

one another in the tube heated to 300 degrees centigrade below room temperature? At the end of their run, right where we're standing now, they will smash into one another and spark off swarms of particles each 14 times as heavy as its parent proton. This is a world no one has yet seen'. Prof. Kaftanov sounds enigmatic. 'The beams will be constricted to increase the probability of collision as they converge at a point inside this machine. To make sure they don't stray, they are tamed by magnets. The one you see here is the world's biggest. Superconducting, with a flux density of four tesla. It weighs 50 tonnes, and measures 12.5 metres long by 6.5 metres across. At minus 270 degrees centigrade, it is fed with electric current at 20,000 amperes. Every single one of 50 million collisions it generates every second is unfailingly registered and entered into the database. We certainly don't need that much, and we only select specific events that help us understand how our world came into being.

'All our hopes rest on the LHC, which we expect to come on stream in 2007. Once we have an accelerator developing previously unknown energies, we will be able to start unravelling otherwise unassailable physical problems. Such as where do particles get their energy from?'

Peter Higgs, a luminary in physics, theorized that elementary particles are given their mass by a kind of boson, which is now known as 'Higgs boson.' This is little more than a hypothesis, though. So far, no one has staged an experiment to observe these bosons. The new collider is expected to clear up the puzzle – either we will track down the Higgs boson, or humanity will have to review its ideas about the Universe.

How little I knew of the wonders that were yet to be revealed to me.

Elephant Hunt

'Dan Brown, did you say? Couldn't be worse. A delusion for the uninformed.'

Michael Doser didn't mince words.

The tanned Austrian with a Van Dyck beard and the air of a Castilian hidalgo looked completely out of place in this physics laboratory. This man, I thought to myself, could afford to be forthright in his judgments, having been the first researcher at CERN to trap antimatter.

'It's simple to trap antimatter', says Michael, a replica of St Michael the Archangel, except that he wields a cigarette rather than a sword in his hand. 'The accelerator we have here at CERN is a large industrial plant churning out antimatter round the clock. You only have to convert one kind of energy into another, and transform moving protons into particles and antiparticles. To do that, we shoot protons at a tungsten cube. We track a million collisions between microscopic particles to catch a single antiproton. The rest is a matter of skill and technology.'

The Big Bang must have produced equal quantities of matter and antimatter. We live in a world made up entirely of matter. Where has antimatter gone? Dan Brown was correct in his *Angels and Demons*, when he wrote that antimatter explodes when it comes in contact with matter, which may be anything: air, for example. But then he came up with the notion of portable traps to catch positrons.

'That's crazy', fumes the antiproton tamer. 'To collect as little as a gram of antimatter, as Dan Brown suggested, we at CERN would have to be slaving away, night and day, for ten billion years. Yes, we have been harvesting antimatter for a long time already. But to what purpose? Our crop isn't enough to warm a glass of water by just one degree. Dan Brown's tales of secret laboratories rolling out anything, right up to new generation nuclear bombs, are just empty visions.'

Michael Doser saunters along the antimatter accelerator, familiarly known as the pressure cooker. He steps over a group of devices connected to the tube, without a glance at the grim warning, 'Caution Radiation', and rambles on about things that would turn the master storyteller green with envy.

'We generate ten million antiprotons a second. In another two minutes we freeze them solid, slow them down, and send them to the experimenters. We chase them down with magnetic fields, but only one in a thousand is trapped. The rest escape. They live forever in a vacuum and freezing cold conditions, so we can catch up to a million of them in the course of a day. That is the limit of what humans can do for now.'

Like a loving master with his pedigree dog, Michael Doser now strokes a solid-looking machine swaddled in a blue jacket.

'This is a decelerator, an antiparticle brake. Have you ever seen a surfer gliding on an ocean wave? Much the same happens in here. The antiparticles we want to slow down follow in the wake of the wave, radio waves, in our case. As they catch up with the wave, they ease off, without losing any of their properties. Over here we have another trap operating on a different principle. Similar to the action of a bowling ball as it plunges into a sea of table tennis balls, scattering them in all directions and losing some of its speed in the process. We use an antiparticle for a bowling ball and electrons for table tennis balls. It only remains to tell particles from antiparticles. We have the finest measuring equipment in the world. To illustrate how fine, I'll give you another example. If you smuggled a grain of sand up to the top of Mont Blanc, our detectors would sense the difference in weight. Don't ask me how we catch atoms. The same way wild elephants are lured with bait. Elephants have a passion for nuts. You offer a nut to the beast, and you can persuade him into a cage. In our case, we use electrons to draw antiparticles.'

CERN operates a large plant to convert protons into particles and antiparticles. About three decades ago, it developed a technique to embed protons into cancer cells. Now they are fine-tuning operations by using antiprotons and positrons, which kill four times as many cancer cells as protons do. Furthermore, these particles collide with electrons and both are annihilated, producing photons that have no diffculty in escaping from the patient's body. As they exit, they can be captured

and analysed to yield information about the effectiveness of the cure. This process is a kind of silent dialogue with the patient's organism. Antiparticles can be put to work selectively at any depth. This is a tool that can be used against tumours in delicate organs such as the brain or the eyes. Surgeons can put aside their scalpels and pick up guns that fire hadrons, or particles subject to strong nuclear interaction, without any effect on their quantum numbers. A sick cell resistant to traditional cure techniques is bombarded with antiparticles that enter it and explode it from inside, killing the disease. Hadrons can be shot with the precise level of energy needed to fly as far as is required.

The idea was not lost on many governments who have started building hadron therapy centres. In Germany, the government is subsidizing construction of a hospital in Heidelberg to offer hadron treatment. A similar hospital is to be put up in Darmstadt. The French government is not far behind, with a specialized clinic under construction from public funds in Lyons. The governments in Austria, Italy and the Czech Republic are also investing considerable funds in 'antiparticle medicine'.

'Several international and national laboratories have approached CERN with requests for assistance in their own research, and we gladly oblige', says Manjit Dosanjh, UK coordinator of the Centre's biomedical programme. 'Aside from anything else, CERN gives them unrestricted access to new technologies. We work in partnership with non-Europeans as well. Americans, for one, have gone far ahead in hadron therapy, with the Japanese close on their heels. The cancer centre in Chiba, near Tokyo, Japan, has taken in around three thousand patients who receive this treatment. The Japanese are planning to open another five hadron hospitals across the country. All these programmes are coordinated by CERN.'

Hadron Soup

Charts show the accelerator as a circle or ellipse. In fact it is not exactly either. The LHC is a polygon, with softly rounded corners between straight stretches, where particles are accelerated to their highest speeds. As I said, they plan to unveil it in 2007. For now, some of its completed units are being put through their paces in laboratories at ground level. Once all the tests are complete, the units will be assembled underground into magnets, detectors, vacuum chambers, you name it.

Errors are suicidal here, as they are in outer space. Every part must be trouble free for at least ten years. You can't operate the accelerator if any of its components breaks down in the tunnel. The obsession that drives CERN physicists to new discoveries reminds me of the enthusiasm – on the ground and in outer space – that fired astronauts in the days, now regrettably almost forgotten, of legendary space exploration pioneers like Gagarin.

'We are neither angels nor demons, we are here just out of curiosity', says Prof. Yves Schutz, France, who is engaged in an experiment with a romantic name – Alice. 'We are preparing the LHC for three experiments we shall be running to look for

new particles that were out of scientists' reach with old accelerators. These particles are the missing links in one theory of the Universe. If we find them it would be the proof that makes that theory sustainable. Unlike anything that has come before, Alice is designed to produce new matter. Exactly the matter that was flying around after the Big Bang.'

There are no secrets at CERN. Everything is on view. Nor are there any secret laboratories underground. This is not surprising given that CERN is for all the people on Earth, whatever their political affiliations or religious beliefs. It is a common concern. In a way, researchers at the underground centre between Switzerland and France are working to solve our common mysteries: mysteries of the Universe. Including the mystery of 'dark energy.' A CERN wit dubbed it 'the Lord's Lever' – a metaphor that pleases me immensely.

Dark energy is the energy of vacuum. Vacuum concentrations, we now know, breed Universes. Our own Universe arose from a very rare concentration of vacuum that had pulled a colossal amount of energy together in one place, or rather one tiny spot. It was packed so tightly that it snapped and exploded. Researchers at CERN hope to learn about the nature of dark energy concentration. So far, no one has succeeded in obtaining dark energy. It was previously believed that nothing existed beyond the fringes of our Universe and that space evolved together with the expanding Universe. Now, space mavens realize they were wrong. The bigger the Universe, the larger the vacuum energy. It turns out that our Universe is hemmed in by more vacuum, with more Universes living side by side with our own. Do they obey our physical laws? Why not? Physical laws should apply equally everywhere and at all times.

There we have it. Dan Brown was still far from crediting the Illuminati with the Big Bang. More's the pity, I think. Here at CERN, they have come the closest to cracking the biggest mystery of the Universe – the Creation. It was an article of faith with scientists that during the first ten microseconds after the Big Bang, just after the Universe was born, matter was in a different state from the way it is now. Quarks and gluons, which are locked up inside protons and neutrons in today's 'cold' Universe, were too hot to fuse at that time. To put it differently, they were in a state that the CERN crowd, and everyone else, calls the quark–gluon soup. It is assumed that matter survives in this state at the centre of neutron stars, which are so dense that a speck of their matter the size of a pinhead weighs as much as a thousand jumbo jets.

To try to glimpse how the Universe looked at birth, the CERN wizards aim to recreate the quark–gluon soup in an experiment in the underground tunnel. To produce a Big Bang on a greatly reduced scale, nuclei will be made to collide at temperatures 100,000 times those generated at the centre of the Sun.

'The LHC is our time machine', says Yves Schutz. 'If we put the age of the Universe at ten years, dinosaurs would have arrived when the Universe was seven years old. The solar system would have emerged when the Universe was six. Atoms were first created when the Universe, if we keep to our timescale, had just turned two hours. We hope to reconstruct the conditions that existed a millionth of a second after

the Big Bang. What we are doing with Alice is not a Wonderland dream – it's totally real. Science today has created a minute timeline to illustrate the first three minutes following the Big Bang when everything clicked into place at the atomic level. After those three minutes, another 300,000 years elapsed during which atoms were created and put together to make the Universe. At that point, nuclear physics ceased to play the lead role in fashioning the Universe; gravity took over – moulding atoms into stars, gathering stars into galaxies, and so on. The laws of physics are not enough to explain what happened at the start. Who is behind the Big Bang? God? Where does He come from? If He came about by himself, why couldn't the Universe come into being in the same way? An eternal question.

To the average person whose knowledge of science comes mainly from television serials or from reading science fiction, CERN and the ripples it sends all around is in the realms of the wildest fantasy, or even a mad delusion. Facts are too hard to ignore, though. Recent geological findings undeniably support nuclear physicists' theories. The latest expedition undertaken by an international team of American, Australian and French scientists has dug up evidence that the Earth was created almost simultaneously (on a geological timescale) exactly as we know it today. With continents and oceans, and seas, too.

These findings fly in the face of the traditional idea that, for some time after birth, the Earth looked like a lunar desert or was almost completely covered with water. Add to this the recent evidence that complex living organisms made up of many cells can survive completely unprotected in outer space for a considerable time, at least several weeks, without coming to any visible harm, and you can see that the new discovery could result in a major overhaul of our old ideas about the time when life originated on Earth.

Scientists reached this conclusion after they found a rare earth element known as hafnium, in the rocks of Jack Hills, a massif in Western Australia. The hills are thought to be among the oldest rocks on the planet. Hafnium was discovered together with zirconium crystals in rocks dating back nearly 4.4 billion years. Radioactive dating of rocks from Jack Hills gave scientists reason for claiming that continents took their final shape of Earth in the first 500 million years of the planet's existence.

'All this leads us to suggest that the planet had continents within the first 100 million years from birth', says Prof. Steven Maugice of the University of Colorado. 'It looks as though the Earth was created in an instant.'

In 2001, Prof. Maugice and his colleagues from the University of Colorado published the findings of another study suggesting that bodies of water existed on Earth around 4.3 billion years ago. Quite a humiliating finding for those who never suspected there might have been life on Earth earlier than previously thought.

'The crust, oceans, and the atmosphere made their appearance on our planet almost instantaneously', Steven Maugice believes, 'and a life-friendly environment arose almost immediately, as if by a wave of the magic wand …'.

Poor Mr Brown. He clearly ran out of his mystic mission to demonise antimatter. Amongst scores of other designs left by modern rock painters, you can read graffiti claimed in Geneva to have been made by Brown himself to testify to his visit to the tunnel. This is in fact a hoax. CERN officials assured me the American celebrity had never turned up there.

Whether they be porters or security staff, you can trust the Swiss 110 per cent: no country in the world monitors a person's movements as closely as Switzerland.

It's a pity he's never been here. Had he materialized at CERN, he would certainly have turned to far cooler subjects than antimatter annihilation. As, for example, the origins of 'dark matter' that physicists are hoping to discover during their Atlas experiment. This is, in fact, the greatest enigma of modern astrophysics. It is hard to believe but the experiment may help them to detect very light supersymmetric particles that could be another layer of our Universe. A question popped up in my mind – could there be worlds made up of those particles? The experiment could open a chink in the door to another space, unaware of the surprises it could spring on us. It could well be a small cubicle, or an unfathomable world. What, indeed, could it be?

Enough Data to Go Around …

As I queued for a bowl of pumpkin (not quark–gluon) soup at the local canteen, I found myself breathing down the neck of a Nobel laureate, none other than Jack Steinberger. CERN has quite a stock of Nobel prizewinners, few as famous, perhaps, as the Englishman, Tim Berners-Lee. He now works in America. Back in 1989, he kicked off the World Wide Web (WWW or Web). He can't have escaped Dan Brown's attention, but the writer omits to say a word about CERN's new global project, Grid, a worldwide data processing network.

'Our experiments require the integration of computer resources on a scale the world has not yet seen. Our studies are unprecedented for unique data interchange – scientific data is expected to grow by many petabytes (millions of gigabytes) a year', says François Grey, a Canadian scientist responsible for the coordination of CERN's computer program. 'Nowhere else in the world is information processed and transmitted at rates even remotely comparable with CERN's. Tomorrow they will be higher still. CERN was the first place to make the Internet a staple communication tool which scientists tackling physical problems around the world had been yearning for. Everybody liked the new plaything, and it caught on, first with the military and soon, with everybody else. Very soon the bulk, or more precisely, 80 per cent, of the information whizzing around the world was travelling through our channels. Now, our share has dropped to 20 per cent but CERN continues to lease out its capacities to various telecommunications and commercial companies, and also to providers. For example, the World Trade Organization operates on our resources. Recently, we hit on a new idea, the Grid, which provides us with a new understanding of computer networking capabilities. It is a global integration of information and computational resources. While the web gives us access to infor-

mation and offers us a search engine, Grid offers an entirely different level of service - fulfilling tasks and accessing processed information available from data stores and archives around the world.'

'Silo' reads a sign on the computer room wall. In reality, the web is set to become a data silo, to be drawn on to make mind-boggling computations and process medical and geophysical data, a storehouse of facts for oil companies and space exploration. In medicine, it will become a fount of knowledge for cancer diagnostics, particularly breast cancer in women and prostate cancer in men. Initially, Grid services will be provided free, and will only be offered to a limited community of scientists. Having received no return from the web, CERN wants to develop its new project for profit.

To begin with, the Grid will only be available to organized groups of scientists, but CERN officials are still uncertain about what will follow. Rigid controls will be enforced. People allowed to tap into the Grid will have to hold a certificate of authorization. It is better to err on the side of caution than risk allowing the unique database to fall into the hands of organized crime or terrorists.

CERN's integrated system connects 3,000 computers today, and it will have over 5,000 within two years. Quantity, however impressive, is not all though. What is more important is that thousands of computers around the world will be hooked up to a shared system. Linked by optic fibres, they will process their share of data from the LHC experiment and carry out tasks requiring computer application, not just in the physics of elementary particles. We are, indeed, witnessing the birth of another effective tool for planet-wide communication.

Energy Integration

The main challenge facing the physics of high energies is studying the interaction between elementary particles at high energies. The energy they carry can be transformed into mass. Energy, Einstein said, was mass multiplied by the speed of light squared. The first cyclotron was built at Berkeley, California, in 1934. The Americans used the opposite beam flux developed by Academician Butker in the USSR – the more energy released, the heavier the particles that can be generated.

In the CMS experiment, to be initiated in the tunnel equipped with magnets and vacuum chambers, two accelerated proton beams will be set on a collision course. As previously stated, this will generate particles 14 times as heavy as the proton. They will come from a world no humans have ventured into as yet.

The CMS experiment will use a magnet yoke to generate a circular magnetic field. Charged particles are deflected in the magnetic field, and the extent of deflection serves as a measure of momentum or energy. The equipment weighs half as much again as the Eiffel Tower. Its magnet laminations – a total of 120 – were manufactured in Russia, and their bolting was made in the Czech Republic. The yoke supports were fabricated in Pakistan, the central part of the locks in China, and the

end parts, in Japan. Germans from Bavaria assemble the different components. This is CERN's practical approach to internationalization. We doubt if a broader economic integration exists anywhere in the world.

Core equipment has already been installed in all the shafts. Much of the installation process is handled by Russian workers. Atlas, for example, employs 30 workhands from Russia, and another 100 will soon come here in rotation from research institutes in Moscow, Protvino, Gatchina and Troitsk among other science towns. Even though the Russian Federation officially holds only observer status at CERN, Russian engineers and workers make up at least 15 per cent of the Centre's work force. CERN has given the nod to the Russians, even though its employment policy goes against the grain with pampered French and Swiss trade unions.

CERN engineers feel more comfortable with Russians. Unlike French, German or Czech workers who are prone to ship equipment back to the suppliers for repair if it fails to meet strict engineering standards (not a rare thing in Switzerland these days), Russians will attempt to correct deficiencies on site themselves. With nothing more sophisticated than screwdriver and hammer, Russians have wowed CERN old-timers on many occasions by screwing and hammering faulty equipment into good shape and winning precious time for experimenters. In addition, Russians leave few, if any, holes in CERN's tight budget, in stark contrast to the French, for example. Russia can't afford to pay fortunes for its participation in CERN experiments, and Russian workers' wages are set off against their country's financial account. Not quite what you would call a civilized way to follow equal-pay standards. On the other hand, CERN receives full value for its money. The West seems to be quite happy to have such smart and cooperative workers from a country where memories of sharashkas – white-collar Gulag labour compounds that helped to launch their country first on the road into outer space – are still remarkably fresh.

Back in 1996, the Russian Ministry of Science and Technological Policy signed a protocol with CERN on Russia's participation in the LHC project. Russia has since delivered equipment worth 200 million Swiss francs under the protocol alone. They have also filled 36 million Swiss francs worth of orders CERN placed directly with Russian manufacturers. Another 23 million Swiss francs was paid to Russia under the defence conversion programme. Originally conceived as an exclusive West European affair, CERN helped many Russian enterprises and institutions to stay afloat through the lean years of Yeltsin's post-perestroika in the 1990s. In the process it also saved itself considerable time and money.

However Dan Brown and his Illuminati have shown not the slightest interest in this and probably never will.

Geneva