OutPost on the Endless Frontier©

EPRI e-News on Recent Key Developments in Energy Science and Technology
By Paul M. Grant

No. 13, 31 December 1999

Nearer, My God, to Thee

The release of the 1997 epic film, Titanic, brought rushing back a public wave of nostalgia and remembrance of that most tragic example of man's overconfidence in his technology. Perhaps the most poignant scene is of the ship's small band bravely playing, as the end neared, that old Anglo-American hymn whose title we have borrowed as our theme for this issue of OutPost[1], and also most appropriate as I sit writing this piece while the hour of possible biblical[2] and technological[3] apocalypse approaches.

Today great progress has been made in the wiser management of both technology itself and those responsible for its operation and safety. Moreover, advances in technology have indeed been turned to achieve a deeper understanding of how Creation was formed, heavenly and within life itself, thus singing the more hopeful aspirations of mankind expressed by that hymn rather than the desperation that must have been in the minds of the victims of the Titanic. Maybe.[4]

Let's examine just one coming development sure to spring from the passion of this century's scientists to "get a little closer to God," and what it might mean to mankind's energy future.

It might be called today's equivalent of the medieval gothic cathedral, the huge machines called hadron colliders, mostly constructed within the second half of the 20th century in an atmosphere of communal competition mimicking that of the 11th through the 14th. Perhaps we can say the present Winchester and Cologne exist in Batavia , Illinois and on the French/Swiss border near Geneva. They are the Tevatron at Fermilab and the Large Hadron Collider at CERN. With these tools, we have parsed the proton down to its constituent quarks held together by the gluon field (the electroweak and strong forces)[5], currently the most "fundamental" of the fundamental particles, and established what has become the "standard model" of matter as we now understand it.

The latest of these scientific monuments…perhaps analogous to Ulm…is the Relativistic Heavy Ion Collider (RHIC, or "ric") at Brookhaven[6], designed to probe the "quark-gluon plasma" that existed for a few microseconds after the "Big Bang." If you'd been following the newspapers this past fall, you might have noticed some concern that we may now be getting more "near to God" than might prove comfortable![7]

But what's next? Where and when will be built the Chartres[8] of microscopes which will allow us to peer ever more deeply into the nature of Creation?

Several teams of physicists at Fermilab have been studying possible concepts which could in principle be realized in the next quarter century. The essential problem is that to achieve ever higher collision energies, if one is to build on the basis of the present Tevatron and LHC designs, whose ancestry lies in Ernest Lawrence's cyclotron, greater and greater magnetic fields have to be created to confine the particle beams in circular rotation. There is essentially a cost trade-off between ring diameter and magnetic field strength and, in addition, with increasing "bending radius," more and more energy will be lost to "synchrotron radiation" and not put into the desired collision event.

What's to be done?

Well, suppose you could somehow vastly increase the circumference of the next supercollider, thus requiring much lower magnetic fields (and therefore cheaper magnets)? Such an approach[9] has generally never been taken seriously given that the perceived expense of constructing lengthy tunnels has been considered prohibitive. For example, if one used iron magnets whose saturation field is 2 tesla, to confine a 100 TeV (trillion electron volts) beam of protons, the circumference of the ring would have to be some 1000 km![10] On the other hand, the size and costs of the magnets themselves would be orders of magnitude less than the huge superconducting magnets approaching 20 tesla employed in today's "conventional" designs. There would still be a superconducting component, a dc cable carrying 75,000 amps running through the center of the array of cylindrical iron magnets, but its cost would again be much smaller than that of superconducting magnets and their attendant refrigeration.

A small group of visionaries at Fermilab, under the leadership of Bill Foster,[11] has been investigating current and future trends in tunneling technology (we might call them "tunnel visionaries")[12], which could be the "containment vessel" for this Chartres of supercolliders. They believe, given the advances being made in deep guided tunnel boring currently under consideration for infrastructure renewal in Eastern Europe, an eventual cost of $500/meter for a tunnel two meters in diameter at a depth of 100 to 150 meters should be achievable within the next ten years. This figure is competitive with present urban trenching and burial costs, and what is even better, at the depths the Fermilab guys are looking at, there's no other infrastructure in the way.

Naturally, there are many problems, technical and otherwise…geologic and seismic stability and legal access to right-of-way among them. But what if Fermilab can bring this off? Think of the implications for energy delivery, a new national grid, if you will.

Imagine a network of tunnels between cities separated by anywhere from 100 to 1000 miles. The eastern United States comes readily to mind. A two meter diameter tunnel, 100 meters deep, could carry:

- 10 GW of electric power over superconducting dc cables.
- Deliver the liquid hydrogen, used for refrigerant, as consumable energy (now, if we could only get a practical 150 K high temperature superconductor, we could use liquid methane!).

- LPG and LNG, of course.
- As much wide bandwidth communication capacity as would ever be required.
- A small-parcel intercity delivery system using supersonic, magnetically levitated "packages," (by superconductivity, naturally) further enhancing the benefits of e-commerce (buy Amazon.com, sell UPS).

And all of this via an infrastructure that's as hardened against weather, climate and political terrorism as you're ever likely to get. And would fit a large variety of energy production scenarios from distributed generation (you still need a geographically extensive grid for "storage" and marketing) to a comeback of the nukes (no other way around CO_2-driven global climate change).

Anyway, something to think about in the New Year…if there is a new year. We might all get sucked into a Black Hole emanating out of Upton, Long Island…certainly a lot more dramatic than Leonardo DiCaprio slowly sinking into the North Atlantic! And then there's the question whether there will even be enough light for you to read this OutPost by the time you're back to work next week and the Internet's still up. That's why I thought I'd better send it off today just in case you'll be having an otherwise boring New Year's Eve.

73

[1]"Nearer, My God, to Thee," has an interesting and controversial history. The original verse, inspired by Jacob's Dream (Genesis 28: 10-22), and music were written by two English sisters of the Unitarian persuasion, Sarah and Elizabeth Adams, sometime around the 1830s. Much later the prolific American hymnodist, Lowell Mason, set their words to a different melody, that which one hears today, and the piece ironically became a staple of Christian worship thereafter. There is absolutely no evidence that "Nearer, My God, to Thee" was the last work to be performed by Titanic's White Star Line Orchestra. The story seems to have arisen largely from a stated wish by the group's conductor, Wallace Hartley, to have it played at his funeral (which indeed it was some months later). However, in view of the events at hand that night of 14 April 1912, perhaps this is one of those rare instances where truth is better served by legend than historical fact!

[2]Leaders of all spiritual beliefs have always fiddled with the calendar. A synod during the Middle Ages agreed that Jesus of Nazareth was most likely born in the summer of 4 BC, which would mean the second millennium arrived in 1997 since there was no "year zero" (did I get that right?). A big problem for the ancients was the incommensurability of the lunar and solar cycles with each other, as well as with the earth's rotation. Some early civilizations, the Aztecs in particular, reasoned the year had to be 360 days, and that the extra 5-odd were what the gods required to decide whether time would continue. The Aztecs just hunkered down for these five days awakening to the pleasant surprise on the sixth that the world still existed. Interestingly, this is exactly the attitude held by many today toward Y2K! Oh, incidentally, the Mayans were somewhat less concerned…they had figured out the solar system was heliocentric, about a century in advance of Europe.

[3]Speaking of Y2K, wouldn't life be simpler (and arithmetic easier) had the primates evolved with eight fingers instead of five? Tomorrow would then begin the year 7D0…no problems!

[4]Nonetheless, Titanic teaches us humility. Every bite we continue to take out of the apple from the Tree of Knowledge can have its dark side, a subject for a future OutPost.

[5]Visit www.fnal.gov for many excellent tutorials on high energy physics and the Standard Model. For those of you who live near Washington, DC, I recommend gong to see the Imax film, Cosmic Journey, continuously showing at the National Air and Space Museum. If you're a physicist, it will bring tears to your eyes.

[6] http://www.bnl.gov/rhic.

[7]A letter to Scientific American and the London Times this past summer speculated that the RHIC experiments could generate a "mini-Black Hole" which could lead to the end of this region of the universe. I was somewhat reminded about the concern created by Teller's speculation that the Trinity device would trigger the fusion of global nitrogen. Fortunately, the possibilities of both are vanishingly small. RHIC-type events, at even much higher energy, occur all around us as cosmic rays.

[8]The perceptive reader will have noticed by now that I have blatantly disregarded historical precedence in my analogy between existing particle colliders and cathedrals. I admit to having ranked my individual perception of beauty and majesty alone of these medieval marvels over time of construction, Chartres, to me, being the culmination. Oh, by the way. in "pushing the envelope of construction technique," several of these middle age projects collapsed under their own weight. Our present day equivalent can be seen in the cave in Waxahachie, Texas, meant to house the Superconducting Supercollider (SSC)!

[9]This design, called in the trade the "superferric low field collider," was first suggested by Bob Wilson, a pioneer of experimental American high energy physics and the first director of Fermilab. Wilson proposed using iron magnets saturated by the field from a superconducting cable.

[10]By comparison, the SSC energy was to be 20 TeV center-of-mass (10 Tev for each colliding beam), in a tunnel some 20 miles in circumference and, if I remember right, some 100 feet in diameter. Wilson's concept, including all supporting infrastructure, could fit in a tunnel three feet in diameter.

[11] *http://www-ap.fnal.gov/VLHC/*. Foster doesn't seem to have an office. When I've been at Fermilab, he's always been in someone else's carrying a clipboard and a whiteboard marker.

[12]At EPRI we have Tom Rodenbaugh. Contact Tom at trodenba@epri.com for the latest EPRI studies on tunneling.