NASA DRYDEN FLIGHT RESEARCH CENTER

Test flights with Gulfstream Aerospace Corp's "quiet spike" were completed in February.

should be revised," says Burleson. "The most important thing right now is developing a metric to judge whether the booms are acceptable or not. We hope to have a metric in 2008."

Tests of human sound perception include using sonic boom simulators, in which people compare recorded and simulated booms; having people listen to sonic booms outside; and rigging a house with microphones and accelerometers during sonic booms. "We don't know all the fundamental physics of boom interactions with structures," says Kevin Shepherd, head of structural acoustics at NASA's Langley Research Center in Hampton, Virginia. "But we have reason to believe that how people react indoors and outdoors is quite different. Inside you hear objects rattle and walls creak. This will influence people's perceptions." The time of day, frequency of sonic booms, and ambient noise also play a role.

But computations, wind-tunnel tests, and noise and rattle measurements only go so far. "If we are going to argue to change the rule, someone is going to have to build an actual aircraft to demonstrate, as there [are] likely to be considerable community concerns," Burleson says. That someone, he adds, will have to come from industry. No one has stepped forward yet. "There is no way we as an industry are going to invest a whole pile of money into developing airplanes until we know that the regulatory groups are going to move off of ground zero. There has to be some kind of agreement," says an industry engineer who insisted on anonymity.

"There are so many challenges," says NASA's Shepherd, "and a lot of places where [a revival of supersonic flight] could fall down—the sonic boom is not the only problem you can imagine. There is fuel efficiency, global warming, airport noise. . . . If there was enormous pressure on oil consumption, then producing a new supersonic aircraft would probably be poor timing. It would look crazy." Although some industrial researchers claim they can make engines for supersonic jets that do not pollute more per mile than subsonic planes, those data are not open to the public, and most researchers believe the opposite is true.

A more detailed look at the repercussions of flying at 50 000 feet is needed, Burleson says. But, he adds, "aviation is a relatively small contributor to greenhouse gas emissions, 2 to 3%. If you have 12 000 to 14 000 aircraft flying around the world, adding a couple hundred more"—the projected number of supersonic jets is 400 to 500—"is probably not going to add a huge [emissions] inventory burden."

As for when supersonic flight overland might become a reality, predictions start at about six years from now. Besides the uncertainties of setting a metric and building and testing a prototype plane, says Burleson, "once you get into the rule-making process, it's anyone's guess." **Toni Feder**

International Linear Collider gets reference design and cost estimate

But DOE warns that the design team's hope for completion of the 31-kilometer-long machine by 2019 may be too optimistic.

For more than five years now, a linear electron–positron collider big enough to explore the so-called terascale (collision energies of order 10^{12} electron volts or 1 TeV) has topped the wish list of the international community of particle physicists (see Physics Today, September 2004, page 49). Given the present state of accelerator technology, the collider's two face-to-face linacs would need a combined length of about 30 km to achieve a first-phase collision energy of 0.5 TeV. The cost of such a gargantuan facility dictates that the undertaking—from R&D and design, to construction, to operation—be thoroughly international from the start. Appropriately, the project carries the name International Linear Collider. The ILC is regarded as an essential complement to the Large Hadron Collider (LHC) ring at CERN, which should begin providing 14-TeV proton–proton collisions next year.

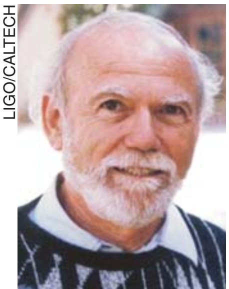
Now the ILC has its first estimated price tag, based on a reference design prepared over the past two years by the Global Design Effort, a 60-member team headed by Barry Barish of Caltech. GDE's report of its design and cost estimate (http://media.linearcollider.org/rdr_draft_v1.pdf) was released at the February meeting in Beijing of the International Committee for Future Accelerators, GDE's parent organization. Although the report doesn't give the estimated total cost as a straightforward sum, it comes to roughly $7.5 billion in 2007 US dollars.

Sample sites

Because it will be several years before a site is chosen for the ILC, the reference design and cost estimate are not site-specific. But civil-engineering cost estimates are included for three sample sites: in the mountains west of Tokyo, near CERN on the Swiss–French border, and near Fermilab in Illinois. Despite the obvious geological contrasts, it turns out that the tunneling and other civil-engineering costs for the underground machine, about $1.8 billion, are much the same for the three sites. That's because each site has different difficulties and compensating advantages. The problems posed by the mountainous terrain of Honshu, for example, are balanced against the virtues of horizontal access and a granite substrate that, unlike the Illinois prairie or the Rhone valley, requires no concrete lining of tunnel walls.

A possible site near the DESY laboratory in Hamburg was much discussed in previous years when DESY pioneered the superconducting RF acceleration technology that was selected in 2004 for the ILC. But Hamburg was not included among the sample sites because a machine there could not sit nearly as deep as at the other three sites. That would require significant changes in the reference design. Furthermore, if the collision point were at DESY itself, the Elbe river would obstruct the ILC's eventual extension to 50 km for 1-TeV collisions in a later upgrade foreseen in the reference design.

What about the cost of acquiring and installing the machine's high-tech components? Because different governments have different accounting systems for costing the creation of a major facility, the GDE report separates the cost of acquiring the injectors, RF structures, focusing magnets, and other high-tech components from the labor required to install and test them. The latter, including administration and other personnel support, is estimated in the GDE report to be 13 000 person-years over the seven years of the construction phase.


LIGO/CALTECH

Barish

The report estimates the cost of acquiring the high-tech accelerator components (excluding the detectors) through worldwide competitive bidding to be $4.9 billion. If one then adds a rough dollar estimate for the unspecified labor cost, the machine's total $7.5 billion price tag is not unlike those of comparable international megaprojects like ITER and the LHC. The latter comparison works only if one adds the civil-engineering cost of the LHC's preexisting 27-km-circumference tunnel, left over from the earlier LEP electron–positron collider ring.

Modifications for thrift

Just last July, GDE's preliminary estimate of the sum of the civil-engineering and high-tech-acquisition costs, now quoted as $6.7 billion, was roughly $9 billion. "So we spent the next six months," says Barish, "scrutinizing the design to find modifications that would yield significant savings without hurting the physics." And the team did indeed identify 10 such modifications and incorporate them into the reference design.

The modifications yielded a gratifying 25% reduction in the ILC's estimated cost. Two were particularly significant: Instead of separate 7-km-circumference tunnels at opposite ends of the ILC for the electron and positron beam-damping rings, the reference design calls for a single tunnel near the center to house both damping rings. Also, the design now calls for a single beam-collision point—into and out of which the ILC's two large detector complexes will be moved alternately at intervals of a few weeks.

The preliminary design had called for a Y junction in each beam so that the beams could be directed alternately at two collision points, one at the center of each permanently situated detector. The expectation is that moving the detectors is not significantly slower than redirecting and refocusing the beams. But it is certainly cheaper than providing bending and focusing magnets for two collision points.

The reference design and its cost estimate are meant to set the stage for the next phases of the project. Over the next three years, R&D will proceed at various laboratories worldwide in tandem with the preparation of a detailed engineering design. An important R&D goal, for example, will be optimization of design and fabrication details for the machine's 16 000 superconducting niobium RF acceleration cavities. "Without such optimization of high-tech components," says Barish, "we'd be handing the eventual mass production off to industry with too many risky question marks."

What about site-specific details? If negotiations haven't begun to converge on a specific site by the time the engineering design is due in 2010, "then the design will be incomplete," says Barish. "We could design to several sites, but that's wasteful." Even if a site is provisionally selected by 2010 and incorporated into the engineering design, further international negotiations would be required to tie down funding commitments.

Sharing the cost

It is expected that the host country would bear the civil-engineering cost, which represents about a quarter of the total. The remaining three-quarters would be divided equally among the three participating regions: Europe, Asia, and the Americas. Because Europe includes many countries with big particle-physics programs, a European host could expect to bear not much more than 30% of the ILC's total cost. But the US or Japan as host would bear closer to half the total. It's generally felt, however, that no one country's share should exceed 50%. "People don't want a majority stockholder," explains Barish.

By the time the engineering design is ready, theorists expect, the LHC will already have given convincing evidence of the much-sought-after Higgs boson, with a mass somewhere between 100 and 200 GeV. There's also much anticipation of possible supersymmetric particles accessible at terascale energies. Pinning down the mass of the Higgs boson at the LHC would reassure physicists and funders of the adequacy of the ILC's 500-GeV first-phase collision energy. And discovering supersymmetric particles or additional Higgs states at the LHC with masses near or above 500 GeV would argue the urgency of proceeding to the linear collider's 1-TeV upgrade. "But there's little chance of getting approval for the ILC before the LHC has seen something interesting," says the University of Chicago's Melvyn Shochet, chair of the High Energy Physics Advisory Panel (HEPAP) to DOE and NSF.

Schedule realities

If all goes well, including adequate and timely funding, the GDE report concludes that ILC construction could begin in 2012 and be completed by 2019. But at a HEPAP meeting in Washington, DC, just one week after the report's release, DOE Undersecretary for Science Raymond Orbach urged a more realistic view of the schedule and worried aloud about its consequences.

"Negotiating an international structure, selecting a site, obtaining firm financial commitments, and building the machine," Orbach warned, "could take us well into the mid-2020s, if not later." Fermilab's Tevatron and SLAC's B factory are scheduled for shutdown by 2010. So Orbach's prognosis would leave the US particle-physics community without a collider for at least 15 years. In that light, he urged the community to come up with a productive program of lesser initatives to fill the uncomfortably long gap.

Barish looks at Orbach's protracted schedule as a "useful kick in the pants." He responds that "finishing the ILC before the end of the next decade will require, in parallel with the engineering design work, a major effort to organize the international collaboration, divide up responsibilities, and get commitments from governments."

Bertram Schwarzschild

Industry supplants academia as career of choice

From the 1940s through the 1980s, most physicists entering the job market snapped up positions in academia, shunning industrial posts, but that trend reversed itself by the early 1990s.

The days when a newly minted physicist automatically sought his or her first job at a college or university, expecting to conduct academic research, publish papers, teach, or do all three, are over. Today that physicist is far more likely to find work in industry, where his or her job is tightly linked to developing commercial products.

That's one of the findings that has surfaced from 134 interviews with physicists working at 14 large corporate labs across the US. Conducted by the American Institute of Physics's Center for History of Physics, the History of Physicists in Industry (HOPI) project, which concludes this December, sought to determine the nature and extent of physics-related record-keeping at domestic corporations and institutions, but the project expanded to include questions on physicists' career paths and the infrastructure of industrial R&D, among other issues. This summer the HOPI staff plans to publish preliminary findings and recommendations on how individual and corporate labs can preserve records that document physicists' contribution to innovation.

Physicists interviewed—who ranged in age from mid-30s to early 80s—said that through the 1970s, academia was considered the career of choice for physicists entering the job market. Those who chose industrial work over pursuing a job in a university setting typically had either a personal tie to the company that hired them or an offer to work at one of the few industrial labs in the US where academic-style research was then encouraged.

Trained for academia

Jim Hollenhorst, senior director of intellectual property strategy at Agilent Technologies Inc in Santa Clara, California, earned his PhD in physics in 1979 from Stanford University, where he learned he would be expected to look for work in academia after completing his degree and postdoc.

"There were two places in industry where you could hold your head up high: Bell Labs and IBM," Hollenhorst said. "They were OK because they were enough like academia. Any other job would have been frowned upon."

Hollenhorst later accepted an offer from Bell largely because of its research-oriented culture, but also because of a better salary and the fact he would be working on products that might be helpful to many. "I could have my cake and eat it too," he said.

Through most of the 1980s, HOPI staff found, academia remained the career of choice. Still, an increasing number of physicists entering the job market chose to seek work in industry, citing higher salaries as an important factor. By the 1990s, things had changed: More physicists wanted to and did work in industry than in academia. That trend continues today.

The HOPI findings agree with a 2001 NSF report (http://www.nsf.gov/statistics/issuebrf/nsf01332/sib01332.pdf). According to the NSF document, more than one-third (36%) of physicists who received PhDs from 1946 through 1965 were working in industry in 2001, while almost half (49%) had jobs in academe. For physicists entering the job market in the late 1990s, the numbers invert. Of those who earned PhDs between 1996 and 2000, more than half (57%) were working in industry in 2001, while less than one-third (31%) had academic positions.

Charlie Duke, retired vice president of Xerox Corp and a research professor of physics at the University of Rochester in New York, said an erosion in federal funding for both academic research and instruction in the physical sciences has been a driver of the shift in physicists' career choices. Those dollars, he said, are now being directed toward research on treatment of illness and disease.

"Fifty years ago when I started off, Russia had just tested the thermonuclear bomb and launched the first space satellite, so physics was hot. Everybody was pouring money into physics because it was important for defense," explained Duke, who was interviewed as part of the HOPI project. "It was a time when physics was clearly vital to the economic and defense future of this country. That's still true, but it's not so well appreciated. The situation has evolved—today biotechnology and information technology are the superstars."

Research product

But like Hollenhorst, many others interviewed for the HOPI project also cited their wish to be involved in developing commercial products—tools, appliances, devices—that could help people or simplify their lives in some way. Doug Allan, a senior research associate in the glass research department at Corning Inc in Corning, New York, said that going into academic research, where the principal product is a published paper with little influence outside of the academic realm, would not be as satisfying.

"I became disillusioned and frustrated with the lack of interest in the results of theoretical work. I felt the calculations my colleagues and I were