encoding its loop-forming ends located in different places on the chromosome.

Liu and his colleagues at Dalhousie University in Halifax, Nova Scotia, made their discovery while "mining" the complete genome of a cyanobacterium called *Synechocystis*. They found that the genetic code for a key protein called DnaE, which helps to replicate DNA, was split between two genes separated by a very long stretch of other DNA. They also found telltale signatures of intein ends in the DNA in both genes.

Two other groups independently found the same signatures, but Liu's group is the first to report biochemical evidence that the intein works. The enzyme is too rare to be detected in *Synechocystis*, so the team inserted copies of the two genes, intein signatures included, into *Escherichia coli* bacteria and forced the bacteria to overexpress these genes. Three proteins were produced in quantity: the products of the two individual genes and a third, larger protein the same size as the other two spliced together, minus the intein fragments. The team examined parts of this large protein's amino acid sequence, including the suspected splicing site, and found that it was identical to the predicted DnaE protein, similar to those found in other bacteria. Thus they concluded that the split intein is active in cells.

Researchers hope that additional work on the split intein, which lacks a DNA-cutting sequence seen in most inteins, may eventually help solve the mystery of how inteins arose in the first place. Researchers have argued whether the original inteins had the DNA-cutting function—which is suspected of helping inteins spread from one genome to another—or were simply ancient protein manipulators, sewing together protein fragments to make new and improved enzymes. Liu's team is studying DnaE genes from closely related species, seeking clues to what this intein looked like before the splitting event.

The find may also help protein engineers find better ways to manipulate and produce proteins. Some therapeutic proteins, such as human growth hormone, are toxic in high amounts to the organisms enlisted to manufacture them. With a split intein, researchers could make the protein in two pieces in different organisms and assemble them later, Paulus says. Based on studies of regular inteins, at least two teams have already had some success at producing artificial split inteins. But Paulus says that perhaps nature does it better: "The fact that it can occur in [nature] means it's potentially a very efficient process."

—GRETCHEN VOGEL

PHYSICS

Accelerator Gets Set to Explore Cosmic Bias

An understanding of why the universe is biased in favor of matter may have come a step closer with a burst of collisions in a particle accelerator that has a bias of its own. Called the Asymmetric B Factory and based at the Stanford Linear Accelerator Center (SLAC), the machine collides a beam of electrons, accelerated in a ring 2200 meters around, with positrons, their antimatter partners, accelerated to lower energies in a second ring of the same size. The collisions spawn B mesons, particles containing heavy bottom quarks, and the energy mismatch flings the B's off to one side for study. On 23 July, just days after the positron ring was completed, the two rings collided particles for the first time—a critical step in the long process of getting this novel facility up and running, which should be completed early next year.

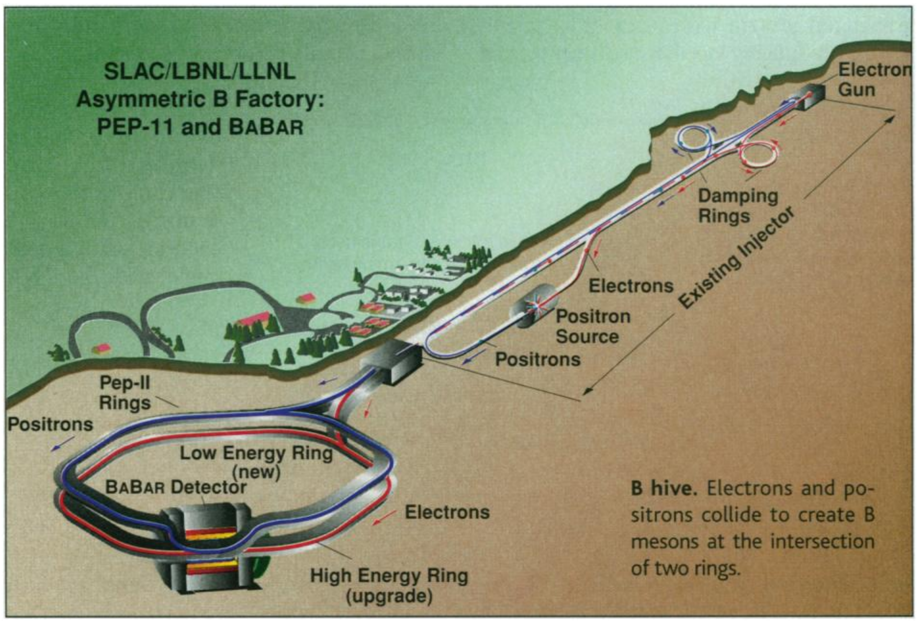
"We're very excited about what we have managed to do," says project leader Jonathan Dorfan. "It's definitely a milestone," agrees George Brandenburg of a competing facility, CESR, the Cornell Electron-Positron Storage Ring. The B mesons made in the Stanford machine, CESR, and other colliders around the world should enable physicists to probe a phenomenon called CP violation, a subtle effect that distinguishes matter from antimatter and could explain why we live in a matter-dominated universe. The asymmetric Stanford machine could offer an especially sharp view of the phenomenon, because it boosts the short-lived B mesons to a large fraction of the speed of light, extending their lifetime through the time dilation predicted by Einstein's theory of relativity.

The new machine, built on time and on budget at a cost of $177 million, uses electron and positron beams from the existing SLAC linear accelerator. It stores the 9.0-billion-electron-volt (GeV) electrons in the old, rebuilt PEP ring, while a new ring stores the lower energy, 3.1-GeV positron beam. The two superbright beams are brought into collision at a single crossing point, where the BaBar detector, now nearing completion, will watch for the creation and subsequent decay of about 100 million B mesons per year.

"The asymmetric energies make the design of the interaction region very complicated," says SLAC's John Seeman. The challenge, Dorfan explains, was designing a set of magnetic optics that can handle two beams of different energies simultaneously. The payoff, he believes, will be a better understanding of the symmetry between matter and antimatter, and why it breaks down.

In almost all particle interactions, matter and antimatter show a basic equivalence, CP symmetry. CP symmetry holds that the behavior of a set of particles and that of the matching antiparticles look identical—one system is a mirror-image of the other, with all the particle spins reversed. But, mysteriously, some exotic particle systems violate CP symmetry. "CP violation is one of the remaining enigmas of the standard model of particle physics," says Andreas Schwarz at the DESY accelerator center in Germany. It "can be linked to the very fact that matter dominates over antimatter in the universe."

B mesons, containing either a bottom quark or its antiparticle, are thought to show especially strong CP violation when they decay, making them ideal for probing this gray area in particle physics. That has spurred a worldwide surge of interest in accelerators that can mass-produce B mesons. Cornell,



B hive. Electrons and positrons collide to create B mesons at the intersection of two rings.

TERRY ANDERSON/SLAC

which lost out to SLAC 5 years ago in a competition for government funding for an asymmetric collider, will upgrade both the CESR accelerator and its CLEO detector in the middle of next year. DESY has a B meson project of its own, says Schwarz. And across the Pacific the sun is rising on the world's other asymmetric B factory, under construction at KEK, the Japanese high-energy physics lab near Tokyo, which is likely to produce its first collisions by the end of the year.

For now, Dorfan and his team are still coaxing their new machine to its full brightness and learning how to operate it efficiently. "We're not about to start physics next week," says Dorfan. At about the end of the year, the 1000-ton BaBar detector will be slotted into place, and by next spring the machine will begin exploring the universe's fundamental bias. **–ANDREW WATSON**

Andrew Watson is a science writer in Norwich, U.K.

SPACE

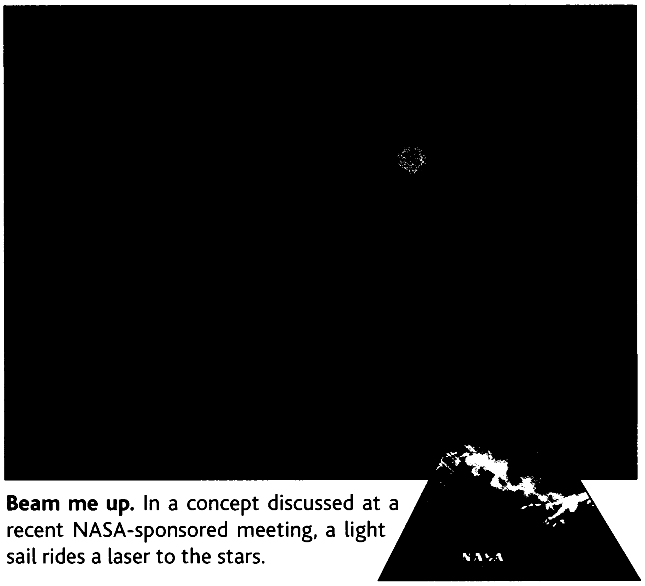
Engineers Dream of Practical Star Flight

Why settle for poking through the clutter of the solar system when you can break out into interstellar space? That was the mood last week at a workshop on Robotic Interstellar Exploration in the Next Century, held at the California Institute of Technology in Pasadena and sponsored by NASA's Jet Propulsion Laboratory (JPL). Engineers took the opportunity to engage in some uninhibited thinking about practical—or, at least, plausible—ways to propel, control, and communicate with an interstellar probe.

One enthusiast is NASA Administrator Daniel S. Goldin, who has directed NASA's Office of Space Science to investigate the possibilities for interstellar flight. The notion is also getting a boost from the recent discovery of planets around other stars. Although the first interstellar probes would probably aim for nearby interstellar space, the ultimate goal would be to reach other planets within, say, 40 light-years of Earth. "If you can find them and image them, maybe you should think about visiting them," says JPL deputy director Larry Dumas.

That idea, says Dumas, "is so audacious that it stimulates and confounds at the same time"—which is exactly the point, say researchers. The requirements of a journey thousands of times longer than any spacecraft has ever taken are so daunting that some people find them laughable. But even skeptics say that some of the novel propulsion, robotics, and communications concepts discussed at the meeting could pay off for travel within the solar system, if not to the stars. "I think it is enormously valuable and stimulating," says Louis Friedman of the Planetary Society in Pasadena. "I would just caution that the reality of interstellar flight is far off."

The scientific interest is already there, says Richard Mewaldt, a physicist at Caltech who spoke at the workshop. The solar system sits inside the heliosphere, a bubble blown into the ionized gases of the interstellar medium (ISM) by a wind of particles from the sun. The ISM reflects the makeup of the galaxy billions of years ago, before the solar system formed, and researchers would like to probe its composition and magnetic fields. They would also like to sample cosmic rays in the ISM, because many of them can't penetrate the heliosphere, and survey two distant reserves of comets: the Kuiper Belt just outside the orbit of Pluto and the Oort Cloud in nearby interstellar space. A spacecraft at the right location in the ISM could even use the sun as a colossal gravitational lens to bend light rays from objects in the far reaches of the universe, magnifying them. "There's science to be done all the way," says JPL's Sam Gulkis.



NASA/JPL

Beam me up. In a concept discussed at a recent NASA-sponsored meeting, a light sail rides a laser to the stars.

But just to reach the heliosphere's edge, perhaps 100 Earth-sun distances (100 AU) from the sun, in a reasonable time, a craft would need a propulsion mechanism that is thousands of times more powerful than conventional, chemical rockets yet doesn't require carrying large amounts of fuel. (Today's spacecraft would take at least 30 years to make the journey.) Three approaches have emerged as contenders, says Henry Harris, the JPL researcher who organized the workshop: thrusters or sails driven by Earth-based lasers, matter-antimatter annihilation, and nuclear power.

In the first concept, a laser fired from the ground is reflected off a mirror and focused into a chamber at the back of the spacecraft, heating gases that then rush out of a rocket to generate thrust. The concept "is very efficient, because you're leaving your engine on the ground," says Harris. Before the craft leaves Earth's atmosphere, ambient air could serve as the propellant. At the workshop, Leik Myrabo of Rensselaer Polytechnic Institute in Troy, New York, described actual flight tests in which he fired a 10,000-watt laser into a Coke-can-sized facsimile of a spacecraft and lifted it about 30 meters off the ground, says Harris. He says that million-watt lasers, which already exist, could fling objects into orbit, at a calculated cost of about $500 per kilogram for the electricity.

Outside the atmosphere, such a probe would need to carry its own supply of propellant, which could be bulky. A better strategy for harnessing laser power might be to equip a craft with a large, reflective sail that would catch and deflect the beam from a laser—or even plain old sunlight—and accelerate under the bombardment of photons. Harris, who leads a program involving several NASA labs, the Army, the Air Force, and the Department of Defense to develop space sails, calculates that a ground-based, 46-billion-watt laser firing at a craft that has a 50-meter sail could send 10 kilograms to Mars in 10 days. A billion watts "is a lot," allows Harris, with more than a touch of understatement—it's roughly the output of an average electric power station.

Another propulsion concept, based on the annihilation of matter with antimatter, faces even bigger scientific hurdles. But it too would require only small masses of fuel to power a craft into deep space—assuming sufficient quantities of antimatter could be produced and stored. Still more futuristic engines would scoop hydrogen right out of interstellar space and use it as fusion fuel.

"These three technologies may have the capability of getting us to the nearest stars in a reasonable time—10 to 100 years," says Gulkis. Once a probe gets into interstellar space, communications delays of hours, weeks, or years rule out controlling the spacecraft from the ground. So other talks at the workshop dealt with ways to get an interstellar probe to operate autonomously during its long, lonely voyage. Another challenge comes at the journey's end: sending back data across a distance of light-years. Laser beams aimed at Earth might be the answer, some participants suggested. Because the lasers could be more tightly focused than radio beams, they could in prin-