bursters. Construction on those projects could begin in about four years.

For the CTA, says Spiering, "the technology is watertight. It's a matter of making it cheaper and making it global—making it converge with the [proposed] American project AGIS [Advanced Gamma-ray Imaging System]." The CTA and KM3NeT are both on the European Strategy Forum on Research Infrastructures road map, which looks across all science fields.

A third high-energy project endorsed by the ASPERA road map is the US-led cosmic-ray observatory Auger North. The road map suggests that Europe contribute about €45 million, roughly half the project's total cost.

A second wave of projects will come from "a blooming of interesting and competing technologies on neutrino mass and dark matter," says Stavros Katsanevas, ASPERA coordinator and a deputy director of IN2P3/CNRS, France's national institute for nuclear and particle physics. Ton-scale detectors in those areas will cost €50 million–200 million, he adds. At present, notes Spiering, "this is a divergent field, with about 25 dark-matter experiments worldwide. They are now on the level of 10 kg; some are increasing to 100 kg. To increase the sensitivity, you have to increase the mass. We have to wait for the experiments that are presently starting before defining which method works best. We will define in 2010 or so which experiment should go first."

A decision on the approach for a megaton detector to search for proton decay is expected in around four years. Rounding out the seven top priorities is an underground gravitational antenna. That would cost €300 million–500 million, says Katsanevas, and construction would start "only after [existing gravitational wave observatories] have seen a few sources—maybe in 2016 or 2017."

The road map also recommends the creation of a European astroparticle physics theory center, possibly to be hosted by CERN. "Astroparticle experiments are widely spread all over the globe, often in rather inhospitable locales," says Oxford University theorist Subir Sarkar, who served on the road-map committee. Theorists generally have interests broader than a given experiment, he adds, and "it is essential for us to interact face-to-face."

Finally, the road map says that about a quarter of Europe's astroparticle physics budget should go to existing smaller national projects, such as Europe's participation in the US-led Large Synoptic Survey Telescope, the Gran Sasso National Laboratory in Italy, and Virgo, a gravitational-wave observatory.

Spreading the cost

"If we sum the astroparticle parts of the budgets" from all the relevant agencies, says Katsanevas, "we get €700 million over 10 years." Projects on the ASPERA road map come to around €1 billion. "We showed this projection to the [funding] agencies, and we got a good reception. They looked with a good eye."

"The other part in our strategy to keep all the road-map projects alive is by global coordination," Katsanevas says. Through the Organisation for Economic Co-operation and Development, he adds, "we want to start a global discussion on world collaboration." The OECD could take a census of existing strategies in different geographical regions and, says Katsanevas, "if we all agree, and I think we will, we will move to a concrete plan to collaborate."

Dennis Kovar, the US Department of Energy's associate director of high-energy physics, says, "The meeting [at which the road map was unveiled] was interesting because all of us see that the next generation of tools will require a lot of funding. You cannot duplicate capabilities. We need to regionally develop programs that complement programs elsewhere." **Toni Feder**

Are organic LEDs ready for the big screen?

This year the first commercial organic LED TV hit the US market, some 20 years after the invention of a fluorescent diode by Eastman Kodak Co's Ching Tang. Yet while the 3-mm-thin, 28-cm-diagonal TV from Sony Corp approaches the OLED promise of low-power, flexible products, other TV manufacturers have been slow to follow. Priced at $2500, Sony's OLED TV—which, unlike LCDs, requires no backlight or filters—costs five to six times as much as a similarly sized LCD TV.

Most commercial OLED displays found in cell phones, other small consumer products, and Sony's new TV are made by vacuum evaporation of small organic molecules. That process, however, is tricky to scale up. A competing process uses more scalable ink-jet printing to make polymer OLEDs, but they lag behind the efficiencies of small-molecule diodes. To get both advantages and compete with the cost of LCDs and large-screen plasma TVs, some OLED manufacturers are exploring ways to make small molecules printable.

The spin on efficiency

Commercialization of OLED displays took off about 10 years ago after phosphorescent small-molecule OLEDs were invented by Stephen Forrest, a physicist now at the University of Michigan, and Mark Thompson, a chemist at the University of Southern California. As with inorganic LEDs, electrons and holes combine to form excitons, which emit light when they decay. For every four electron–hole pairs, one singlet and three triplet spin-state excitons are formed. In a fluorescent small-molecule system, the basis of Tang's 1987 diode, only singlets emit light, which limits the quantum efficiency to 25%. However, in the technique advanced by Forrest and Thompson, triplets phosphoresce in addition to singlets fluorescing, and that raises the theoretical quantum efficiency to 100%.

An alternative OLED device that uses fluorescent polymers was invented in 1989 in the lab of University of Cambridge physicist Richard Friend. Researchers associated with Friend and Cambridge Display Technology Ltd, the company he founded, dismiss the claim that engineered polymer materials are constrained by a 25% theoretical ceiling. "We and others have done experiments that suggest that the singlet/triplet ratio is much higher in some of our materials than it is for a small molecule," says CDT chief technology officer Jeremy Burroughes. "There certainly is potential for driving the singlet efficiency higher." CDT's new parent company is now building a process-development line to accelerate the mass production of polymer OLED TVs. "Polymer OLEDs will have advantages in screen size and cost" over small-molecule OLEDs if they can overcome efficiency, color-reproduction, and lifetime issues, says Sony communications officer Masayo Endo.

Printed picture

Besides quantum efficiency, manufacturers of OLED products are most concerned with the high cost of making large displays. The vacuum thermal evaporation process that patterns the red, blue, and green pixels for small-molecule OLEDs loses precision when scaled up. For small panels, "You can

CAMBRIDGE DISPLAY TECHNOLOGY LTD

Inkjet printing is used to make polymer organic LED display prototypes at a Cambridge Display Technology Ltd pilot plant and is being explored by other manufacturers for small-molecule OLEDs.

get away with less uniformity in the organic layers and less capable current-driving circuitry, but patterning colors is very difficult to do in larger sizes with current masking equipment," says Columbia University electrical engineer Ioannis Kymissis.

Light-emitting polymers can be scaled up more easily, through spin-coating or ink-jet printing. In 2004 Seiko Epson Corp developed a 102-cm-diagonal polymer OLED TV prototype that used CDT's technology. Now, the printer manufacturer is also collaborating with Universal Display Corp, holder of the original phosphorescent small-molecule patents, on a process that puts small molecules into solution for printing. Universal Display's vice president of technology commercialization, Janice Mahon, says that direct printing is an exciting area, but she adds that vacuum evaporation processes can become cost-effective and commercially viable for large-area OLEDs. DuPont Displays Inc. has already developed a small-molecule printing process, says William Feehery, director of the company's OLED business. "We are banking on [printing] as the future of OLED technology."

Other factors play into the cost and performance of OLED displays. Manufacturers must reduce the cost of the thin-film transistor backplane needed to drive current through large-screen OLEDs, says Optoelectronics Industry Development Association president Michael Lebby. The lifetime of OLED emission has also been an issue, but researchers say the blue-light lifetime has now improved to around 20 000 hours, or six years of average TV use. Many OLED manufacturers, including Universal Display and CDT, have also improved the efficiency of OLED lighting, but with large commercial TVs now in sight, the immediate focus is on displays. "There's been a lot of excitement in this field" since Sony's TV was released, says Forrest, "but we still have more work to do."

Jermey N. A. Matthews

DOE officials detail security concerns at labs

The Department of Energy's top counterintelligence official dismissed assertions by the former counterintelligence chief at Lawrence Livermore National Laboratory (LLNL) that a 2007 restructuring of DOE's security programs has left the nuclear weapons complex more vulnerable to spying. But he and other DOE officials testifying at a recent House hearing warned of a growing risk to DOE's labs and other weapons assets from cyberattacks, which are increasing in number and sophistication. Directors of the weapons laboratories conceded that further protections should be made to their computer networks.

Stanley Borgia, the highest ranking of 21 Federal Bureau of Investigation agents who are detailed to counterintelligence posts in the DOE complex, told the House Committee on Energy and Commerce that former LLNL