| Ministry of Science and Technology goals to reach by Brazil's 2022 bicentennial |
|---|
| ▶ Increase investments in R&D to 2% of gross domestic product, with more than half from private enterprise |
| ▶ Double to 340 000 the number of scholarships awarded annually by the ministries of Science and Technology and Education |
| ▶ Grow the research community to 450 000, or 2 researchers per 1000 inhabitants, up from the current 8 per 10 000 |
| ▶ Generate 5% of the world's production of scientific papers |
| ▶ Triple the percentage of higher-education graduates in engineering to 15% |
| ▶ Master the technologies of microelectronics, pharmaceutical production, nanotechnology, biotechnology, and a host of green technologies |
| ▶ Increase by 10-fold the number of innovative companies, from 3% of industrial companies to 30% |
| ▶ Increase by a factor of 10 or more the number of patents a year, to at least 4000 |
| ▶ Ensure independence in the production of nuclear fuel and reactor technologies |
| ▶ Master the manufacturing technologies of satellites and launch vehicles |

doctoral thesis can be written in English if the candidate's committee includes a non-Brazilian. "There is an emphasis on increasing collaborations with the whole world, and particularly with our neighbors in Latin America," says the UFRJ's Koiller.

To free up scientists' time for science, FAPESP, for example, has extended grants from four to five years. And, Brito Cruz notes, FAPESP awards money to individual researchers, not to their institutions. "This was important when universities began," he says, because they "were very hierarchical, and older professors controlled everything. But they were not the best, so FAPESP created some subversion by funding the best people directly."

In the past couple of years, the country has invested about $400 million to create 130 National Institutes of Science and Technology around the country. About half of those virtual institutes focus on physics-related research, including 10 in nanotechnology. "The idea," says Mota, "is to stimulate new ways to produce science." Traditionally in Brazil, he says, people worked on their own or in small groups. "Today's problems are more complex. They can hardly be approached by just one line of research. We need teams."

Another boon for research, says Koiller, has been the electronic access to journals that was negotiated in 2000 for all universities. More than 15 000 journals are available in more than 300 institutions, she says. "That has had a big impact." The emphasis in research has shifted from quantity of papers to "a trend to enhance the quality." Right now, says former S&T minister Rezende, "because of Brazil's economic expansion, industry and academia are attracting people from other places." It is key, he adds, for people "to become more ambitious scientifically, and not be afraid to enter challenging fields."

## Transforming science for society

Even with increased scientific activity in Brazil, the number of patents remains low, at about 400 a year. In São Paulo, the percentage of researchers working in companies is 60%, but nationwide it fell from 35% in 2006 to 26% last year; for PhD researchers it's less than 5%, according to Rezende. Industry tends to import technologies from other countries rather than create and develop its own, he and others say.

A 2005 law opened the way for the government to provide fiscal incentives for industry—including large companies—to engage in R&D. In addition, a funding line modeled on the Small Business Innovation Research program in the US has been created. Some R$2 billion–R$3 billion is available annually in low-interest loans to stimulate industry. The federal government will pay part of the salary when a company hires a PhD researcher. And researchers can take extended leaves from their university jobs to work in industry. Vanderlei Bagnato, who works in atomic physics at USP, currently heads his university's agency for innovation. He says, "We always had the idea that science should be transformed to benefits for society. But there have always been some missing elements. That's changing."

Under Brazilian law, universities get money from companies for research related to offshore drilling, biofuels, and other areas in which Brazilian industry has been successful. The government is introducing many incentives for innovation, says Nussenzveig, "but by far the biggest challenge is a lack of entrepreneurial mentality. All of science has the problem that there are not enough spinoffs." Alberto Guimarães of the Brazilian Center for Physics Research in Rio de Janeiro agrees: "We have learned how to do science, but we have not learned how to transform science into products."

Brain drain is low, and the country is becoming increasingly attractive to foreign researchers. To those considering coming to Brazil, Guimarães says, "The overall trend is positive. If you come here, you will not be frustrated. Your work would be visible, you could make a difference. If you need large facilities, you can collaborate with other countries. Here, there is a general expectation that things will be better next year."

**Toni Feder**

# Will industry save academic research?

**Partnerships with universities could bolster the competitiveness of US corporations.**

**As funding** from their state governments plummets, and with little or no growth likely in the federal R&D programs that pay for most of the research they perform, US research universities are looking to industry for support. University officials are hopeful that US corporations, which perform little basic research of their own and are mostly flush with profits, can be wooed into research partnerships that will benefit both.

Public research universities nationwide have been squeezed hard; appropriations from state governments have plunged an average of 20% in inflation-adjusted terms from 1989 through 2009, according to the Association of Public and Land-grant Universities. Nearly a third of that decline occurred in 2008 and 2009. The University of California's 10 campuses have lost more than one-quarter of their state funding during the past four years. The federal funding picture is little better; the appropriations process to date for the fiscal year beginning 1 October 2011 has R&D budgets that stay even with the current fiscal year, which in turn were essentially the same as FY 2010. That's a far cry from the doubling of funding that


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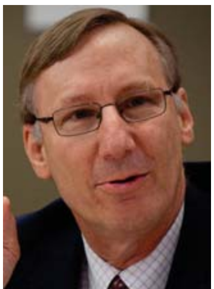
EUGENE SALAZAR
Forrest

President Obama at the start of his term had promised for the Department of Energy, NSF, and NIST programs that fund most basic research in the physical sciences.

Industry is still a largely untapped resource. US companies supplied $2.9 billion, or about 6%, of the $52 billion of R&D funds that academic institutions received in 2008, according to NSF figures. That compares with the 20% that universities themselves provided for their research programs. A survey released early this year by the Industrial Research Institute, whose 200-plus corporate members perform or finance roughly half of the privately funded R&D in the US, showed that 39% of respondents planned to increase their spending on university research and 32% also would step up participation in research consortia that involve universities. More than half of the remaining respondents planned to maintain 2010 levels of sponsorship for research partnerships and consortia.

## Focusing on the practical

Bank of America chairman Chad Holliday heads a National Academies committee on the future of research universities. Its report, expected to be released late this year, will likely urge more widespread R&D partnering between business and academia, Holliday told a meeting of the President's Council of Advisors on Science and Technology (PCAST) in July. "It looks to us like the supply chain [of partnerships] happens more at random rather than in a planned way," he said. "Is there a way to put those partnerships together without destroying academic freedom?" he asked.

Holliday, formerly chairman of DuPont, said that corporate leaders are rapidly realizing that they must spend significant capital on university research to keep up with competitors in China, Japan, and other countries where academic partnerships are widespread. He added that he expects US industry to also partner with foreign universities.

Harvard University professor Venkatesh Narayanamurti told PCAST that academia must adapt to the new funding climate by refocusing physical sciences research on real-world problems "using fundamental science for a purpose and practical problems as a stimulus to curiosity." Narayanamurti cochairs an American Academy of Arts and Sciences committee on the impacts of federal and industry funding on universities.

At a discussion with reporters in July, A. J. Stewart Smith, dean of research at Princeton University, said that industry support for academic research has evolved over the past quarter century from philanthropy, to licensing of inventions, to relationships motivated mostly by the opportunity for industrial partners to shape the training of students who will become employees. "What large companies want is a relationship that involves student transfer as much as anything else," echoed Leslie Tolbert, vice president for research at the University of Arizona. "They want interns to come in as undergraduate and graduate students; they want access to them as new hires." At North Carolina State University, industry is helping to develop the curriculum for a new "professional science master's" degree, added Terri Lomax, vice chancellor for research and graduate studies. The new degree is aimed at some of the 85% of graduate students who don't remain in academia; it will prepare them for careers in business. Students take business and management courses and are placed in internships; they do not have to write theses.

## Collaborations and one-on-ones

Some industry–academia partnerships are collaborations seeded with federal funds. Two have been unveiled this summer. In June Obama announced a federal manufacturing initiative that will target up to $500 million for cooperative research on new and more efficient manufacturing processes, with the goal of improving US competitiveness (see PHYSICS TODAY, August 2011, page 27). A few weeks later, NSF unveiled a new program to attract individuals from industry and venture capital firms to serve as mentors to NSF grantees in commercializing technologies developed at universities. Private foundations also are contributing to the NSF Innovation Corps program, dubbed I-Corps.

But many companies have developed long-term one-on-one relationships with one or more universities. John Deere has partnered with universities for two decades, says Jerry Duncan, the company's manager of university R&D relations. As Deere began getting into research on how people interact with machines, Duncan realized it would be less expensive and take less time to use capabilities already available at Georgia Tech. Deere later joined a University of Pennsylvania research project that was developing a digital human model with Department of Defense support. The company now uses that model, known as Jack, in the design of new products and in harvester-operator training simulators. Today, Deere has ongoing partnerships with Iowa State University, Carnegie Mellon University, the University of Illinois at Urbana-Champaign, and Georgia Tech. A dozen ISU graduates have gone to work at Deere, and the company has hired students from the other schools. "It's not just the training and education and knowledge that they have at the moment, it's the potential that they have over a long period of time," Duncan says. He notes that partnerships give companies a far better opportunity to spot talent than they get through job interviews.

In May, Brown University and General Motors signed an agreement in which the automaker is to provide $2 million over five years to Brown's Collaborative Research Laboratory on Computational Materials Science. The center, supported by GM for the past 10 years, develops simulations that predict the mechanical properties of materials used in automotive applications, such as the behavior of aluminum during the forming and evolution of aluminum–silicon alloys.

### Irreplaceable funding

Industry should be careful not to regard universities as a source of short-term applied research, cautions Clyde Briant, vice president for research at Brown. Briant says that academic institutions, unlike corporations such as General Electric, where he worked for 18 years, are not set up to do applied work. To develop a product in industry, he says, "You really need a whole support team. You have to have people who deeply know the problem, and you've got to quickly judge if you've got a solution, and understand the economic impacts." Those aren't skills that are readily available on campus.

Academic research administrators warn that industrial support will never be sufficient to supplant federal funding. "There is simply no substitute for the type, the quality, and the scale of federal funding. It's the key to the innovative engine of this country," says Stephen Forrest, vice president for research at the University of Michigan. Despite 10 years of effort to attract more industry funding, the fraction of UM's $1.3 billion research portfolio paid for by industry has been stuck at 5%, he laments, the same as a decade ago. Adds Mel Bernstein, vice provost for research at Northeastern University, "We understand the clear pressures on the federal budget. But there really is no substitute for the kind of support the federal government provides."

**David Kramer**

## US narrows fusion research focus, joins German stellarator

**Tight money leads to increased emphasis on tokamak plasma physics and the shuttering of some exploratory experiments.**

**Joining** the Wendelstein 7-X (W7-X) stellarator project in Greifswald, Germany, affords the US the opportunity to participate in a premier fusion facility. The project aims to prove that a stellarator could perform as a reactor and generate energy.

The move also fits with the US Department of Energy's redirection of fusion plasma research to science relevant to ITER, the international fusion test reactor under construction in France. Accordingly, DOE has canceled some small, non-tokamak experiments. Edmund Synakowski, DOE's Office of Science associate director for fusion energy sciences, describes the shift as going away from "exploring such alternative configurations for their own sake" to research that "can contribute to our understanding and optimizing the tokamak configuration and configurations closely related to it."

### Superconducting stellarator

Slated to start experiments in 2015, the W7-X will operate in a steady-state mode, confining a fusion plasma for 30 minutes at a stretch. Stellarators, like tokamaks, rely on magnetic fields to confine plasmas. But a stellarator's donut shape does not have a symmetrical cross section. That makes it harder to design but gives it advantages for attaining steady-state operation because, unlike in a tokamak, the plasma in a stellarator does not carry a strong current.

Modern simulation techniques were used to design the W7-X. Its heat diverters, 70 superconducting coils, and other features are optimized to confine the plasma, prevent the escape of helium nuclei that result from fusion reactions, prevent particle impurities from entering the plasma, and create a stable magnetic field with minimal toroidal current. The stellarator is designed to confine plasmas of up to 100 million K. "This machine is going to go into uncharted territory," says W7-X scientific director Thomas Klinger. "[The plasma] will be hotter and denser than other plasmas generated in a stellarator device. We want to demonstrate that optimized stellarators can perform as well as a tokamak of the same size." The only stellarator of comparable size is the Large Helical Device in Japan.

Part of the US contribution to the W7-X consists of trim coils for fine-tuning the plasma edges, which are sensitive to small perturbations in the magnetic field. The trim coils will be made by the Princeton Plasma Physics Laboratory (PPPL) and Oak Ridge National Laboratory. Los Alamos National Laboratory is also part of the W7-X collaboration, for which US partners are also working on R&D and code development to analyze results. The trim coils "were a very much wanted missing item. We discovered that this instrument was utterly needed and was not in the budget," Klinger says.

The US commitment is about $8.8 million over three years, or annually around 1% of the US fusion budget. The total cost of building the machine and diagnostics instruments is €346 million ($493 million); the full construction cost, counting salaries, buildings, and everything else, is in the €1 billion range. Germany is footing most of that, with contributions from the local host government and the European Union.

Poland is the other key partner in the construction process. In addition to cash and in-kind contributions worth more than €5 million, Poland has sent a team—transferred from the Large Hadron Collider at CERN—to work on assembling the W7-X.