Despite such strains, everyone agrees that Canadian physics is better off now than it was a few years ago. Word of the improvement has reached the public, says Pat Kalyniak, a theoretical particle physicist at Carleton University in Ottawa, Ontario. "I think the perception of physics has changed. People still may not know what physicists do, but they understand it's a profession—that there are jobs. This didn't use to be the case." Students are more optimistic these days, Grütter adds. "They are talking about having competitive research careers in Canada. That's very different from five years ago. I hope we can deliver on it." **Toni Feder**

Pentagon Revamps Nuclear Doctrine

The US government's plan to overturn a ban on designing new nuclear weapons is generating controversy.

The Department of Defense has asked Congress to abolish the Spratt–Furse provision, a nine-year-old ban on developing new nuclear weapons below 5-kiloton yields. Meanwhile, the Air Force has made a bid for more funding for a separate, new high-yield nuclear weapon to destroy deeply buried, hardened bunkers. The requests are part of the Bush administration's 2004 budget proposal (see the story on page 30). The development of tactical nuclear weapons—high- or low-yield—and the recent mandate that the US Strategic Command take charge of the full range of warfare options for combating foreign weapons of mass destruction increase the likelihood that nuclear weapons will be used, say critics.

The US has not manufactured a new nuclear weapon since 1990. Lifting the ban is supported by the majority of Republicans in Congress, who say they want flexibility in guaranteeing US security. Most of the Democrats oppose the ban, fearing it will lead to an end of the US moratorium on nuclear testing and launch a new arms race.

Richard Garwin, senior fellow at the Council on Foreign Relations in New York, favors US ratification of the Comprehensive Test Ban Treaty (see PHYSICS TODAY, March 1998, page 24, and December 2000, page 44) and says, "it would be unwise in the extreme to manufacture and place such [new] weapons into the stockpile without nuclear tests. There is no need for additional types of weapons at this time."

The repeal of the ban and need for the new air force weapon were hinted at in the Bush administration's unclassified version of the 2002 Nuclear Posture Review. The NPR implies that nuclear weapons could be used in retaliation for attacks involving nuclear, biological, or chemical weapons; against targets able to withstand a nonnuclear attack; or "in the event of surprising military developments."

The NPR strategy was further refined by the public version of National Security Presidential Directive 17, signed by President Bush last year. The directive implies that the US should be prepared to launch a preemptive strike, using all military options to destroy stocks of weapons of mass destruction. Both the NPR and NSPD17 imply that the US might consider breaking international law by using nuclear weapons against a nonnuclear state; such action would violate the 1970 Nuclear Nonproliferation Treaty.

Chilling effect?

The budget request states that the research ban has had a "chilling effect" on weapons research "by impeding the ability of our scientists and engineers to explore the full range of technical options. . . . It is prudent national security policy not to foreclose exploration of technical options that could strengthen our ability to deter, or respond to, new or emerging threats."

Garwin strongly disagrees with this statement. The money would be better spent, he says, on a detailed and objective analysis of the effects following a nuclear weapon's destruction of a bunker full of chemical or biological agents.

Repeal of research restrictions is not the real worry of many scientists in the arms control community; they are more concerned about future implications described in the NPR. "Generally I am not in favor of inhibitions on R&D," says Michael May, a former director of Lawrence Livermore National Laboratory. "We don't know ahead of time what that R&D will lead to, and we also don't know ahead of time what weapons will be needed." But, he adds, "bringing the possible use of tactical nuclear weapons back into the picture is a big shift in US strategy, in my opinion, especially when coupled with a strategy of preemption." Adds Michael Levi of the Federation of American Scientists, "Developing low-yield nuclear weapons contributes little to deterrence and could only be conceived for warfighting."

"There is little debate," Levi continues, "that developing our own nuclear weapons weakens our hand in diplomatic efforts to combat proliferation. The real debate is over how much it weakens us and whether the military benefits are worth the sacrifice. I don't think they are."

New or adapted weapons

Some 70 countries and more than 1000 known or suspected strategic bunkers are mentioned in the NPR as targets for nuclear weapons. The B61-11—currently the only nuclear weapon in the US arsenal capable of destroying hardened bunkers—has a yield between 0.3 and 340 kilotons and explodes 6 meters underground. The Robust Nuclear Earth Penetrator (RNEP) that the air force hopes to develop would penetrate 30 meters before exploding, causing shock waves that would reach bunkers more than 300 meters beneath the surface. The RNEP would be based on the B61-11, and the air force wants the yield of the new weapon to be similarly variable: An RNEP yield below 5 kilotons would allow troops to move through an area after an explosion and receive minimum radiation poisoning. Research into the RNEP low-yield option is one reason the air force has asked that the Spratt–Furse provision be repealed.

In principle, assuming the RNEP

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A more powerful device could eventually replace the B61-11 bunker buster.

explodes in a bunker containing biological or chemical weapons, it would generate temperatures exceeding 1000°C and neutralize the agents. But independent research on nuclear bunker busters suggests otherwise. "They are not reliably effective in that use," says May. Robert Nelson, a theoretical physicist at Princeton University who works in technical arms control and nonproliferation, says that highly radioactive fallout would be spread over several kilometers by irradiated dirt and debris thrown up from the underground explosion or that a near miss might spread the very chemical or biological weapons meant for destruction. Although the RNEP has been discussed since the early 1990s, Congress only recently approved legislation. President Bush signed that bill into law on 20 February.

Workforce issues

Of the $21 million allotted in the proposed 2004 budget for research on new nuclear weapons, $15 million will go to the RNEP. The rest of the allottment, according to the budget request, will help revitalize an essential "nuclear weapons advanced concepts effort" that is required in order to "train the next generation of nuclear weapons scientists and engineers." The funds will also "restore a nuclear weapons enterprise able to respond rapidly and decisively to changes in the international security environment or unforeseen technical problems in the stockpile."

Levi doesn't buy it. "The argument relating weapons development to lab employment changes so often it's hard to take seriously," he says. He points out that officials from the national laboratories stress retaining skilled employees, rather than recruiting new ones.

In his testimony at a 6 March House Armed Services Committee hearing, Everet Beckner, deputy administrator of defense programs with the National Nuclear Security Administration, stated that it is not necessary to end the Spratt–Furse provision this year "in order for us to conduct the program that we have outlined in fiscal year '04," but it would be prudent to do so eventually. Beckner reminded the committee that, even if the ban were lifted, Congress would still have to approve the production and deployment of any weapon developed from the research efforts. He added that RNEP research might expand beyond theoretical design work and may include a combination of component and subassembly tests and simulations that would lead to an integral flight or laboratory test or to "a subsequent decision to proceed with further development activities." The RNEP research is scheduled to be completed by 2006.

"This new [budget] legislation does not, as I read it, mandate or urge development or production of a new low-yield nuclear weapon," says Garwin. "But it is highly probable that it will be so interpreted by supporters of such work." **Paul Guinnessy**

Three Millimeter Arrays Converge in Inyo Mountains

After announcing in 2000 that two California telescope arrays would be united at a fresh site in the state's Inyo mountains, the project's university partners finally have the formal agreement and most of the money to go ahead with the merger (see PHYSICS TODAY, January 2001, page 27). But before the Combined Array for Research in Millimeter-wave Astronomy is formed, a piggyback array of smaller telescopes will begin using the Sunyaev-Zel'dovich effect (SZE) to survey galaxy clusters.

Located at CARMA's center, the subgroup of telescopes that make up the Sunyaev-Zel'dovich Array (SZA) will use the SZE to spot galaxy clusters by the distortions they cause in the cosmic microwave background. "Most of the scattering is from the intracluster medium—the soup between the galaxies," says the University of Chicago's John Carlstrom, SZA project leader. "It turns out [that the SZE] has this amazing property, that how well you can measure the effect is independent of how far away the cluster of galaxies is." In combination with x-ray and optical data, he adds, "you can solve for distances to galaxy clusters. And if you get the distance, you can get the Hubble constant. You can put together a history of cluster formation." The SZE was postulated more than 30 years ago and has been observed. The trouble, says Carlstrom, is that data collection is very slow. Starting with the new survey, he predicts that "the SZE will become mainstream."

After a year or two of dedicated cluster searching, the SZA's eight 3.5-meter telescopes are expected to be linked to the main CARMA—nine 6.1-meter telescopes from the Berkeley Illinois Maryland Association (BIMA) array, which will be moved from Hat Creek in northern California, and six 10.4-meter telescopes from Caltech's nearby Owens Valley Millimeter Array. Spread out over four square kilometers, CARMA will have a flexible configuration and observe mostly at wavelengths of 1.3 mm and 3 mm; with the SZA, it would gain sensitivity in the 8–11 mm range.

CARMA "will be a nonhomogeneous array, so we will be able to do studies of wide fields of view at high resolution. For example, we can learn about the origin of galaxies, stars, and planets, and look at comets, which tell us about the origins of material in the Solar System," says Anneila Sargent, director of the Owens Valley Radio Observatory. CARMA will be at an altitude of roughly 2400 meters, more than twice that of either BIMA or the OVRO array, and it will have an angular resolution of about 0.2 arcseconds and be sensitive to temperature differences of a fraction of a kelvin—better than its parent arrays. The same sorts of problems will be tackled very efficiently by the larger Atacama Large Millimeter Array under construction in Chile, Sargent adds. "But we will have five years before ALMA comes on line, and CARMA will observe the northern skies. This university-based array will be the place to train scientists and technicians and build equipment."

Caltech and the BIMA group—the University of California, Berkeley; the University of Illinois at Urbana-Champaign; and the University of Maryland, College Park—have pledged $10 million to CARMA; NSF has contributed $2 million and the project still needs about $3 million. If the environmental impact studies currently under way go well, the SZA, an independent project priced at $7–8 million, will start collecting data next spring, and CARMA could be fully operational in mid 2005. **Toni Feder**

Bahcall Awarded Dan David Prize

John Bahcall has won $1 million. A theorist at the Institute for Advanced Study in Princeton, New Jersey, Bahcall is being honored with a Dan David prize for his wide-ranging contributions to astrophysics, from the interpretation of quasar absorption lines, to the first detection of a neutron star companion, to his calculations on solar neutrinos, which predicted a flux roughly three times greater than that observed on Earth. The shortfall in solar neutrinos is now thought to be caused by neutrino oscillations (see PHYSICS TODAY, December 2002, page 16).

"This prize is really a recognition of