That figure would rise to $80 million to $100 million annually through 2010, he estimates, followed by a couple of billion dollars for a next-generation NIF.

Even if NIF reaches its goal of igniting a fusion target, no one argues that the approach could lead directly to a commercial fusion power plant. NIF's glass lasers, for example, are acceptable for defense purposes but impractical for a power plant because of their cost and low efficiency. While NIF would demonstrate controlled ignition, another technology, heavy-ion drivers, could take the place of the lasers in a future machine. These particle accelerators, which could prove far more efficient and flexible than lasers, are under development at Lawrence Berkeley National Laboratory in California as part of the department's civilian fusion effort. The funding, however, is modest—about $7 million a year.

Meanwhile, pulsed-power advocates at Sandia hope to advance their own long-term plan in light of recent breakthroughs in that technology. The method, whose energy applications are just starting to be explored, would crush fuel pellets with x-rays emitted from a plasma imploding after an array of wires is vaporized by a jolt of current. Although the concept has received much less study and funding than Livermore's approach, Sandia officials say pulsed power could prove far cheaper than lasers or ions, and they want to build a $400 million facility called the X-1 to prove it. "We have a reasonable prospect to produce real energy gain," says Yonas.

But Campbell and Yonas will have trouble squeezing additional money out of the stockpile stewardship program, despite its massive $4-billion-a-year budget. Vic Reis, who heads DOE's defense programs, warns that any fusion efforts funded by his office must also help to keep the nuclear stockpile safe: "We can't do science for science's sake." Adds David Crandall, who heads DOE's inertial confinement program: "The budget process over here is at least as fierce as it is on the [civilian] fusion energy side. Finding a few million dollars more over here is no easier."

Some magnetic fusion researchers worry that behind the congressional request for a review is a move to shift money into inertial confinement programs at their expense. And civilian fusion program officials are quick to note that there's no money to spare in magnetic fusion. Given her tight budget, says Anne Davies, head of DOE's civilian fusion program, "they don't *want* to be over here." Congressional aides deny such an intent. The idea, says one, is "to keep doing basic research on each technology until we are confident enough to choose one direction." And inertial confinement researchers insist that greater cooperation among the various technologies would benefit all sides. "My goal is not to erode the program—it already has been eroded—but to build it up," says Campbell. Adds Yonas: "You don't compete to kill each other, but for the better idea."

DOE officials are now making plans for the review, which likely would be conducted by a panel of researchers from within and outside the fusion community. They hope to have it ready by December, in time to offer guidance to Congress as it considers the 2000 budget. "I'm not going to prejudge where we will come down," says outgoing DOE Secretary Federico Peña. But one outcome could be a single fusion office, speculate some congressional aides and researchers, adding that such a change would not be easy given the long-standing separation between fusion researchers.

What seems certain is that the very process of a review will force all the players in the fusion drama—laser, pulsed-power, ion-driver, and magnetic researchers alike—to interact more closely. Both Davies and Crandall say there has been progress in building bridges between the cultures. But a great deal more blood may be shed before the fusion communities can become one. **–ANDREW LAWLER AND JAMES GLANZ**

BIOLOGICAL WEAPONS

Arms Control Enters the Biology Lab

An enforcement protocol of the bioweapons convention, now under negotiation, could affect some biotech firms and academic microbiologists

Some biotechnology companies and academic biology labs could soon find themselves caught in the highly charged world of arms control. Facilities and labs that handle potentially worrisome types of biological agents could be required to file reports detailing the materials they possess and submit to regular inspections. The reason: Negotiations that resumed last week in Geneva may finally put some teeth into the Biological and Toxin Weapons Convention (BTWC), an arms control agreement that is currently based entirely on trust; it has no mechanism to check whether signatories are complying.

"The [convention] needs enforcement teeth if we are to have confidence it is being respected."
—Madeleine Albright

BRAD MARKEL / GAMMA LIAISON

Although the convention was negotiated in 1972, verification was not considered a high priority until recently, largely because few military experts considered biological weapons to be a major threat. But revelations about the extent of the former Soviet Union's biological weapons program, and recent discoveries by United Nations inspectors of Iraq's widespread efforts, have injected a sense of urgency into the discussions. Both the European Union and the Clinton Administration are now pushing for a compliance protocol to be negotiated for the BTWC by the end of this year. And, in a speech last month, U.S. Secretary of State Madeleine Albright underlined the message: "The [biological weapons convention] needs enforcement teeth if we are to have confidence it is being respected around the world." Tibor Toth, the Hungarian ambassador chairing the talks in Geneva, told a meeting of industrialists, diplomats, and academics in Vienna in May, "It is not now a question of whether but of when and how."

That prospect has come as a wake-up call to biotech industry and microbiology researchers worldwide. Industry trade organizations, particularly in the United States, have long been aware of the issue, but individual companies and institutions are only now realizing they soon may become involved. "Until recently," says Brad Roberts from the Institute of Defense Analysis in Washington, D.C., "the U.S. [biotech and pharmaceutical] industry hoped this issue would just go away."

The negotiations that reopened last week in Geneva will determine how extensive and intrusive the verification provisions are likely to be. Some of the 158 countries that have

signed the treaty are proposing that facilities judged to fall under the treaty should declare what potential biological warfare agents they possess, be subject to site visits to check the declaration, and be given a thorough inspection if a violation of the convention is suspected. "The idea is to force those countries running a biological weapons program to lie," says Patrick Lamb, of the U.K.'s Foreign and Commonwealth Office. Once a country is forced to lie, he says, discrepancies are likely to show up between its declarations and intelligence reports, giving the United Nations grounds to act.

The critical issue is which facilities would have to make these declarations. Because many of the pathogens and toxins that could be used as weapons, as well as the equipment to manufacture them, also have civilian uses, hundreds of facilities in any country could potentially fall under the scope of the treaty. And, unlike the manufacture of nerve gases—which are prohibited by the chemical weapons convention—only small quantities of a biological agent are needed to produce an offensive weapon that multiplies in its host organism.

At the Vienna meeting, many diplomats and arms control specialists were talking of devising a combination of "triggers" that would bring no more than a few tens of facilities per country under the convention. These will probably include any facility that has worked on offensive or defensive biological weapons, any facility currently working on biological defense measures, and any facility working with the most stringent biocontainment standards of biosafety level 4. If such activities were used as stand-alone triggers, most signatory countries would only have a handful of facilities that needed to make declarations, and some may have none.

Other triggers under discussion include biosafety level 3, work with listed pathogens or toxins, expertise in genetic manipulation or creating aerosols of pathogens, and production microbiology. As stand-alone triggers these would in many countries force declarations from as many as several hundred facilities, many of which would be of no interest to the convention, says Graham Pearson, former head of the U.K. Chemical and Biological Defence Establishment at Porton Down. However, Pearson says, combinations of, say, biosafety level 3 and other triggers would be more discriminating and could be tailored to require no more than 10 or so facilities per nation. "The aim," says Tony Phillips, who is providing technical advice to the British government, "is to catch the facilities most relevant to the treaty."

Industry's response to these efforts to minimize the number of facilities affected by the treaty may come as a surprise to the diplomats, however. Gillian Woollett of the regulatory department of the U.S. Pharmaceutical Research and Manufacturers Association (PhRMA) says that if just a few companies are singled out to make declarations, their reputations could be tarnished. PhRMA, says Woollett, would prefer that a broad range of companies be required to make a declaration under the convention, but that these declarations be kept as short as possible.

PhRMA is, however, far more leery about opening up industrial labs to routine inspections to verify the declarations because of problems of commercial confidentiality. "By looking at the way equipment is linked, an expert can learn about our whole production process, or work out how easily prototype equipment could be scaled up. One bug casually wiped from a surface could tell you everything about the protein product produced, its promoters, and the environment in which it thrives," says Woollett.

That sentiment seems to be widely shared in industry. Helmut Bachmayer, head of corporate biosafety at the Swiss drug giant Novartis International in Basel, for example, fears that the already heavily regulated pharmaceutical and biotech industries will run the risk of industrial espionage without making the world a safer place. "You cannot stop the bad guys if they intend to make biological weapons," says Bachmayer. And following a May meeting held by the European Union in Brussels to try to get the biotech industry on board, Roger Wils from Janssen Pharmaceutica in Belgium said, "There were a lot of nice beautiful words, but I'm not sure anyone can guarantee confidentiality." Wils says he left the meeting with the sense that the protocol would lay open his company's entire research program.

Although reluctant to submit to routine inspections, American and European industry accept the need for investigations when a treaty violation is suspected. Such "challenge inspections" could be politically damaging both for the accuser and the accused, and much discussion is currently focused on what circumstances would require challenge inspections to be instigated.

Concerns over confidentiality also worry those few academic researchers aware that their labs might fall under the scope of the protocol. It is still unclear how many labs will be affected, but it is almost certain that the activities of some academic institutions will trigger the need for a declaration. According to Otto Doblhoff of the Institute of Applied Microbiology at the University of Agricultural Sciences in Vienna, the large number of concurrent activities in a modern biology lab will also make visits and inspections more difficult for academic institutions than for production facilities. And in a research world of tight budgets and limited resources, completing the paperwork for a bioweapons compliance declaration could be an onerous burden on researchers. Nevertheless, Doblhoff believes a compliance protocol for the BTWC is essential and could be made workable.

Industry in the United States and Europe is beginning to accept the inevitability of the impending compliance protocol, however, and is becoming engaged in the negotiations on technical issues. Both PhRMA and the European Federation of Pharmaceutical Industry Associations are completing position papers. Lynn Klotz, a biotechnology and biobusiness specialist with the Federation of American Scientists, says the PhRMA paper is much less combative than its earlier statements. Klotz attributes this softened position to a series of White House–sponsored meetings where government and industry exchanged views. "At the first of these, there were maybe three industrialists and 30 White House staffers. That balance has now changed," says Klotz.

Moreover, says Malcolm Dando of the Department of Peace Studies at the University of Bradford in the U.K., industry knows that their governments are not going to fit them into an arms control straitjacket: "The diplomats know that biobusiness is a growth area for the 21st century and that they must protect the intellectual property of their national industries." —HELEN GAVAGHAN

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HOW MANY FACILITIES WOULD FALL UNDER THE BIOWEAPONS TREATY?

Trigger	Canada	U.K.	Italy	Nordic countries
Military microbiology facility	20	not reported (NR)	1	NR
High-containment facility	NR	hundreds*	43†	37‡
Use of listed agents and toxins	750	90	44	49
Production microbiology facility	30	>170	55	40
Aerobiology/aerosols	NR	17	1	NR
Genetic manipulation	600–700	170	21	NR

* Biosafety level 3 & 4 † Biosafety level 2, 3, & 4 ‡ OECD containment category 2 & 3

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