equipment and other overhead costs. In the end, though, US access to Japanese markets will depend not only on the Japanese government but on American producers.

Dire analysis. In two papers prepared for his PhD thesis, the most recent issued on 29 August, Charles H. Ferguson of MIT's Center for Technology, Policy and Industrial Development, discusses the decline of US microelectronics. He argues that the US industry is "substantially inferior to Japan's in most product and process technologies" and has failed to restructure itself along the lines of the vertically integrated Japanese industry to meet the new global competition. Instead, he writes, US microelectronics remains "highly vulnerable, fragmented and poorly suited to intense competition." Protectionist measures will not help, Ferguson warns, unless these are accompanied by a strategy similar to Japan's, which includes government support, industrial coordination and corporate restructuring. Ferguson's brave new world operates on Darwinian laws: Only the strongest, most stable and dynamic firms, with the best research, would survive. His candidates include IBM, Digital Equipment, General Electric, Hewlett–Packard, Xerox, Motorola, Intel and Boeing.

Ferguson's assessment was recently confirmed and complemented in a more technical analysis by a panel of the National Research Council's National Materials Advisory Board. In one of its state-of-the-art reviews, entitled *Advanced Processing of Electronic Materials in the US and Japan*, the group, headed by Walter Bauer of Sandia Livermore Labs, concludes that the "vigorous" commitment by at least ten major Japanese firms gives them a leading edge in technologies critical to microelectronic advances. Japan is out front in seven technologies the report calls "the key to future electronic and optical device development." These are microwave plasma processing, lithographic sources, laser-assisted processing, electron and ion microbeams, compound-semiconductor processing, optoelectronic integrated circuits and three-dimensional stacked structures. The report says the US still holds the edge in three technologies: ion implantation, thin-film epitaxy and film deposition, and rf reactive-ion etching. But, the report adds, "the Japanese have mounted strong programs in all three areas and the balance could easily shift in the next few years." Indeed, the report goes on, within the past year, the US has lost control of optical lithography to the Japanese.

While "overall competitiveness of the US in electronics has worsened dramatically relative to Japan in the past five years," the Bauer panel asserts, the situation can still be reversed. At least six US universities, which are not named by the panel, possess strong academic and research programs directly pertinent to the industry's needs, and a similar number of consortia, such as the Microelectronics and Computer Technology Corp, Semiconductor Research Corp and the National Science Foundation's new engineering research centers are important to wresting the technological lead from Japan.

The Bauer panel also urges government laboratories to provide "substantial support" to the US microelectronics industry, but rightly observes that "this would require a change of emphasis from current policy." Without such efforts in response to the technological challenge, warns the panel, the current trend toward Japan's dominance of the electronics revolution is likely to continue.

—Irwin Goodwin

Bardon's reputation in NSF physics precedes him to NATO

Patrons of physics don't always have the reputations they deserve and many are not necessarily best placed to bestow funds on those most deserving. Not so in the case of Marcel Bardon, who has been awarding research grants in physics to academics for nearly 15 years at the National Science Foundation. He earned "enormous respect," says Princeton University's Val Fitch, a Nobel laureate who was chairman of NSF's Physics Advisory Committee in the early 1980s, "for his acute judgment and his willingness to take risks."

Aptly put, but Bardon himself prefers to credit the hundreds of physicists who serve NSF as peer reviewers and science advisers for the decisions the agency makes about research projects and facilities. Bardon claims he has little power over awards to individual scientists who submit new proposals or seek to renew ongoing research and even less over the baronial fiefdoms that develop around such research centers as the Cornell Electron Storage Ring and the Michigan State University superconducting heavy-ion cyclotrons. Yet, as one of a relatively small number of scientists in government with authority to bestow money on research, he is capable of influencing the physics research agenda at many universities.

Bardon bashing. It is precisely because of this that Bardon is known as "Mr. Physics" to some academic physicists. The appellation isn't always applied with affection. There are some who bash Bardon for wielding too much power over university physics. In the late 1970s he was criticized for advocating a special institute for the study of theoretical physics over objections from many universities and theorists who argued against concentrating NSF money and key thinkers in one place. More recently, he was reproached for advising NSF to sponsor such unusually large projects as supercomputer centers and authorizing the killing of the University of Wisconsin's chronically feeble Aladdin synchrotron light source. Five supercomputing centers were organized at a cost of about $200 million to be spread over five years, despite complaints these would be at the expense of individual researchers. In the other case, Bardon watched skeptically as Wisconsin's Synchrotron Radiation Center was saved by the ingenuity of its operators, who brought the machine up to more than 150 milliamps at 800 MeV—a sixfold increase in stored electron-beam currents in one year's time—with virtually no financial help from NSF.

Many agree with Fitch that "Marcel accepts the responsibility of his job very seriously." William A. Fowler of Caltech, another Nobelist who sat on NSF's Physics Advisory Committee a few years ago, says, "Marcel has a good ear for what is going on and a good nose for making sure we aren't getting tired old wine in new bottles."

Fitch and Fowler count themselves among the physicists saddened by Bardon's departure from NSF at the end of August to take up the post of deputy assistant secretary-general for scientific and environmental affairs at the North Atlantic Treaty Organization in Brussels. As such he is responsible for managing 46 nonmilitary cooperative research agreements among the 16 NATO countries, running workshops, conferences and summer studies, handling more than 1000 fellowships and administering an annual budget of $25 million, supplemented by almost half again as much money from member countries.

"As it's described to me," said Bardon in a recent interview, "the job is not very different from the one I held at NSF." There are major differences, of course. "At NATO we are trying to improve relations between countries where there might be some tensions and political problems. Science is particularly useful in dealing with such situations, and scientific activities have a lot of potential for communication and interaction in those cases where otherwise it might be difficult to get people together."

New dimension. NATO promises Bardon a wholly new, more complicated dimension beyond NSF: dealing with science ministers and organizations in the member countries. Affable, approachable and articulate, Bardon, by all accounts of his career and personality, is capable of dealing with the situation.

"He served under a half dozen different directors at NSF—a remarkable feat in itself," says Fowler. "It's true, he turned off some people. He has a quick, sometimes sardonic wit. We frequently teased each other. He also could be tough, as I found out several times when he came with a visiting committee to review the work at Kellogg Lab [at Caltech]. Though he was tough, I always found him fair. I'm greatly indebted to Marcel for his support of Kellogg against some strong opposition among physicists to our study of nuclear astrophysics. Marcel insisted we were really doing nuclear physics, with applications for astrophysics. He spoke up for Kellogg as a good investment. When members of the National Science Board opposed supporting Kellogg, he convinced them with details on Gamow–Teller strengths in nuclear resonances, beta decay in nucleosynthesis effects within massive stars and electron capture in neutron-star models. I think we lived up to his confidence in us."

Boyce McDaniel of Cornell tells of Bardon's enthusiasm for CESR, the Indiana University cyclotron, the Michigan State heavy-ion accelerator and gravitational-wave studies. It was Bardon, more than anyone, who persuaded the Science Board that gravitational-wave astronomy is likely to open a window on the universe even more exciting than the window opened by radioastronomy in the 1950s. McDaniel recalls how Bardon led the battle for CESR after the Government Accounting Office, Congress's watchdog over spending by executive agencies, reported that the Department of Energy's High Energy Physics Advisory Panel had opposed building the facility and that, anyway, NSF had not listed the storage ring in its budget.

Bardon counterattacked, pointing out that HEPAP had indeed approved of CESR, but only after the construction of PEP, the positron–electron collider at SLAC, and that NSF had not identified it as a new start because it was considered a conversion of the Cornell synchrotron project at that stage.

Practicing triage. All the while, Bardon kept a tight rein on physics. Given successive years of budget crunches, he

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was constantly confronted with critical choices: He could starve all the academic research facilities or turn to the practice called triage, eliminating those with marginal chances of survival while nourishing the others.

The choice was clear. NSF decided in the 1970s, when basic research was a casualty of government displeasure with academic opposition to the Vietnam War, that it could protect individual research by reducing its support of campus facilities. Accordingly, it cut back on university cyclotrons and Van de Graaff accelerators that had operated on shoestrings for years and outlived their usefulness. Among those were machines at Stanford and the University of Maryland. During the decade NSF also shut down the Space Radiation Effects Laboratory proton accelerator at Newport News, Virginia, which it inherited from NASA. Another fatality was the synchrocyclotron at Columbia University's Nevis Lab, where Bardon had worked from 1963 to 1970, the last four years as deputy to its director, Leon Lederman.

Lederman, who had been Bardon's PhD adviser at Columbia, finds him "methodical and caring" in his work. "Marcel's the only student I've ever heard about who did two PhD theses," Lederman remembers. "He wrote the first on the neutral K meson after his experiments at Brookhaven. But he wasn't satisfied. He said he didn't learn enough. So he wrote his second on muons out of the Nevis machine."

Such persistence and perception are likely to be important at NATO.

NATO science. When NATO was founded in 1949, its purpose was the military defense of Western Europe, though Article 2 of its charter also called for improving the political stability and economic health of the region. Not until 1957 did NATO add science to its program as another way of strengthening relationships and security among the member states. Science was elevated among NATO concerns largely through the efforts of I. I. Rabi of Columbia University, then on President Eisenhower's science advisory panel. Despite NATO's best intentions, efforts to superimpose scientific programs on its defense operations proved exceedingly difficult.

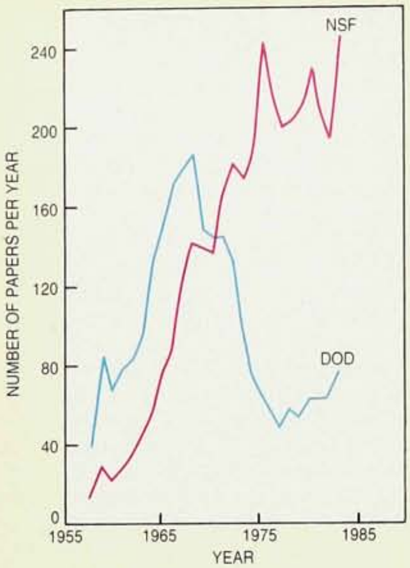
What's more, in 1969, during a period of détente with the Soviet Union, NATO leaders set up a Committee on Challenges to Modern Society, which took up the looming issues of environmental protection. Both scientific and environmental programs have increased over the years, but they have never achieved high visibility. At a recent Committee on Challenges meeting, for instance, experts discussed air pollution as a major source of interference with optical astronomy in Europe.

Bardon is familiar with such problems from his experience as NSF's acting assistant director for mathematical and physical sciences for nearly three years, while the White House pondered a more permanent choice for the post, and as scientific officer of the US delegation to UNESCO in Paris in 1979–81. Born in Paris in 1927, he and his family fled to the US only months before Hitler unleashed his madness in 1939. After graduate and postdoctoral work at Columbia University, Bardon joined Nevis Laboratory and quickly climbed up the management ladder to become deputy director. He left Nevis in 1970 to be an NSF physics program director, a job he thought would be only temporary. Instead, by 1977, he was director of the entire physics division.

Selection factors. With that background and his fluency in French, German and English, Bardon seemed a natural for the NATO position. The US State Department thought so too when it urged him last March to apply for the job. He was chosen from among 20 other candidates from all the NATO nations. He has taken a two-year leave from NSF, but he is likely to stay longer because his NATO boss, Henri Durand, has indicated he will be leaving next year. Meanwhile, at NSF, Harvey Willard, who heads nuclear science, took on Bardon's old job as chief of the physics division on 1 September in addition to his own.

Interviewed the day before he departed for Brussels, in a small office adjacent to the larger corner room he had occupied on the third floor of NSF, Bardon reflected on his years as a benefactor of physics research.

"Physics at NSF was a small operation when I arrived in 1970. Some people will say it's still a small operation, but it's of vital importance now in the university world," he said. The budget for the physics division in fiscal 1970, when Bardon arrived, was around



Physical Review Letters write-ups of research supported by the Defense Department hit a peak in 1968, then dropped precipitously, while NSF-funded papers soared from 1958 through 1983. (Data from *Physics Through the 1990s*, National Academy Press, 1986; intimations of this appeared earlier in PHYSICS TODAY, November 1982, page 9.)

$25 million. It was $112.9 million the past year, which concluded on 30 September. NSF's budget request for fiscal 1987 would underwrite basic physics research at $126.6 million, though the final figure is bound to be closer to last year's after Congress takes its whacks in its efforts to hold down the huge fiscal deficit.

Physics payoffs. Even when economic inflation is taken into account, NSF's physics budget soared by nearly 60% between 1970 to 1977, but from then through fiscal 1981 it plunged nearly 20%. Since the Reagan Administration decided, in 1981, to spend more money on sciences with commercial or military possibilities, physics has benefited. Physics research is generally considered central to revolutionary advances in industrial and defense technologies.

This centrality is emphasized in *Physics Through the 1990s*, the National Research Council's recent examination of the field, often called the Brinkman report, after the survey group's chairman, William F. Brinkman of Sandia Labs (PHYSICS TODAY, April). The report testifies to the contributions of basic physics to microelectronics and optical information technologies, to such new instrumentation as nuclear magnetic imagers, scanning electron microscopes and electronic computers, and to the large variety of lasers (solid state, liquid, gas discharge, chemical, optically pumped, injection, excimer and free electron among them), directed-energy weapons and surveillance systems.

"Despite a fairly flat budget for many years, NSF's physics division has provided a substantial endowment to university teaching and research," boasts Bardon.

Unique role. To his professional colleagues Bardon's reputation rests on his ability to separate the best from the rest. Confirmation of this judgment lies in the research NSF supports and the instruments it builds. Bardon claims his major accomplishment at NSF was in "raising the sensitivity of several directors and several science boards to the needs of basic physics research in universities. The tendency 16 years ago was to support very small enterprises. There were some exceptions, but they were all inherited from ONR [Office of Naval Research]. NSF was not doing anything of the sort. It's very different now. In some fields the NSF role is unique—for instance in ground-based gravitational physics we're essentially the only ones providing support. In atomic and molecular physics, in theory, even in nuclear physics we support as much in universities as the departments of Energy and Defense, sometimes both combined. In particle physics, we underwrite about one-third of university support, with DOE providing the accelerators and national labs. Condensed-matter physics used to be in the physics division and now gets much more NSF funding in materials research, as the foundation increases its applied work" through materials-research labs and groups and in the newly established advanced engineering centers at universities.

What changes has Bardon seen in physics since 1970? "The biggest change is that it costs so much more to do things in physics," he states. "In addition to the inflation factor, there is the complexity factor, which influences almost everything. It's become necessary to do experiments much more accurately. High precision costs money. New kinds of instrumentation. Groups getting larger because experiments are more complicated, needing more equipment and collaborators. This is most obvious in particle physics. In some specialties a conglomerate of physicists is required."

On the "big science vs. little science" issue: "I always react very negatively to those words. Certainly, at Science Board meetings one hears a debate between big science and little science. I don't see it that way at all. There is science and research to be done, and there is some research that requires small instruments in a small room and some that requires very large machines at a large center. Some experiments need a few atoms and some need continuous beams of particles. In other words, the form of the instruments is determined by the function of the research. Unfortunately, there are divisions among physicists over the amount of money available to have the opportunity to do certain types of research. Some opportunities cost more than others. The debate is over opportunities."

On the biggest problem in physics: "It's not in clearing up some mystery in physics. Understanding nature better will happen in time. It's dealing with the high cost of taking any steps forward. We can't just walk in the footsteps of others."

On whether other agencies have lived up to their potential in supporting physics: "You would imagine that the Department of Defense, concerned with the security of the country, would be interested in any major technological advance. As sure as I know the Sun will rise tomorrow I know that significant technological advances will follow advances in physics.... My impression is it doesn't do a fraction of what it could."

The Brinkman report confirms Bardon's judgment: "Corrected for inflation, the 1983 combined US Army, Navy and Air Force funding level for physics research was 30% below the 1969 level." The report also says that as a percentage of gross national product, physics research for defense agencies lagged behind physics funded by NSF. "Moreover, this weakening [of support for physics research related to national security] has been compounded by two other factors: a shift by the defense-research agencies away from long-range research and toward shorter-range research or development and the concomitant widespread abandonment of long-range research programs by US industrial firms, both defense oriented and commercial."

Other evidence of this decoupling of the defense establishment from largely academic physics is cited by the Brinkman committee. After 1968, fewer results of basic physics supported by defense agencies appeared in *Physical Review Letters*, where forefront advances often appear first, while reports of research sponsored by NSF increased impressively (see graph).

By contrast to the Pentagon's underwriting of basic physics, the Department of Energy earns high marks on Bardon's scorecard. "DOE funds a great deal of fundamental work in particle and nuclear research, but it only is interested in backing plasma physics that has some relevance to its fusion-energy program," he points out, "and I think that's shortsighted." As for NASA's support of basic research, Bardon says, "That I don't know much about its contribution to fundamental physics means one of two things: Either I'm not well informed or that it's not doing much."

—IRWIN GOODWIN □