must pass through the same point. They knew that a surface with such a "quadruple point" must have a bending energy of 16 π, expressed in a dimensionless unit. (By comparison, the starting energy of any sphere, regardless of size, is 4 π.) In 1983, Kusner had found a surface with exactly that energy—a surface that looks very much like the halfway surface in Morin's eversion.

Kusner proposed that one could give this surface a little push, as one might push a chair that is precariously balanced on two legs, and let nature take its course. A nudge in one direction, he proposed, would cause it to collapse into a sphere; a nudge in the opposite direction would cause it to collapse into an inside-out sphere. Then, by running one sequence backward and the other forward, one could create a complete eversion, in which the original sphere evolved into Kusner's surface and then into its inside-out alter ego.

But there were doubts. Kusner's surface might not be as unstable as the chair on two legs: Given a small push, it might just return to the balance point. Or it might indeed collapse to a sphere when pushed one way, and to the same sphere (not an inside-out one) when pushed the other way. Finally, in its quest to minimize energy, the surface might pinch off into two separate spheres. The animation by Francis and Sullivan shows, however, that the eversion works according to plan.

To create it, the two researchers enlisted software tools that had not existed when Kusner did his work. Each frame of their video uses between 1000 and 2000 triangles to approximate the elastic surface. Both the number of triangles and the way they are connected change during the animation, making it nearly impossible to describe the intermediate surfaces by standard mathematical techniques. Instead of computing the movement of the surface as a whole, the software had to follow each piece separately.

When Francis and Sullivan ran the computation, they found that their energy-minimizing approach offered a bonus. Not only did it minimize bending, but it turned out to have the smallest possible number of topological events as well. To Banchoff, a member of the jury for the VideoMath section of the International Congress of Mathematicians, the video by Francis and Sullivan "represents a new level of elegance." Now, Sullivan hopes to apply the energy-minimizing approach to other classical topology problems, such as smoothly deforming a torus (an inner-tube shape) so that a stripe painted around the central hole changes places with a perpendicular band, running around a "meridian" of the inner tube.

–DANA MACKENZIE

Dana Mackenzie is a mathematics and science writer in Santa Cruz, California.

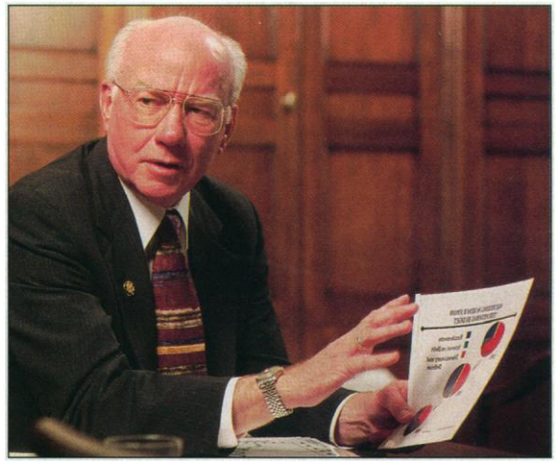
U.S. SCIENCE POLICY

Physicist-Turned-Politician Seeks Middle Ground

Representative Vern Ehlers, a former professor, is completing one of his biggest assignments: setting out a course for U.S. science in the next century

When House Speaker Newt Gingrich (R–GA) called for a sweeping review of science policy last summer, he said it was time for a dramatic new vision for science and technology after the Cold War and on the brink of the millennium. He gave the job of pulling together that vision to Representative Vern Ehlers (R–MI), the number two Republican on the House Science Committee.

Now, on the eve of unveiling his report, Ehlers knows he faces a tough sell. The more detailed the recommendations, the more critics it will attract, including those who may reject it as a partisan document serving the man who requested it. But a failure to take a stand on the important issues facing the community could turn the report into a political bookend, unread and ignored.



SAM KITTNER

"The science community has to develop a new constituency and stop bemoaning the loss of the old one."

—Vern Ehlers

Finding a middle ground is no easy task, even for a man recently named one of the three brainiest U.S. House members by *Washingtonian* magazine. For example, although Ehlers suggests that consolidating research agencies may be a good idea, he hastens to add that there are "many different options." The report, he says, "will not make any recommendations" on the matter or lay out detailed options. "We will simply point out the problem."

Ehlers's background—he calls himself the first research physicist to serve in Congress—may disarm some potential critics. He has a reputation as a moderate Republican and environmentalist. He also holds a Ph.D. in nuclear physics from the University of California, Berkeley, did research at Lawrence Berkeley National Laboratory, and taught for 17 years at his undergraduate alma mater, Calvin College in Grand Rapids, Michigan. And, despite a 23-year career in politics, he retains the serious, self-effacing, and soft-spoken quality of a small-college professor.

"I didn't fit the typical mold," he says, recalling his first try at public office. "Scientists don't generally run. And people who get elected have hair." But the voters didn't seem to mind, electing him as county commissioner, and later state legislator, before sending him to the U.S. House of Representatives in 1995.

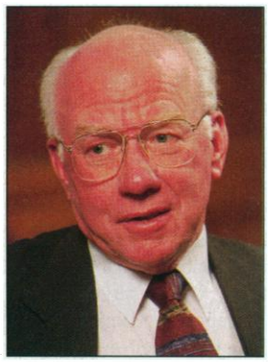
The science policy study is proving to be one of the biggest challenges of his political career. "The most frustrating part is the lack of time to do the kind of job I would like to do," he told *Science*. "I don't want to put the kiss of death on the report, but it was a very complex and time-consuming task, and it comes on top of my regular duties, which take 80 hours a week."

Time is not his only challenge. Neither House Democrats nor the White House has shown much enthusiasm for the review, and a series of hearings held to gather input on a host of science-related issues played to half-empty hearing rooms. But Ehlers, a devout Christian who has rankled some researchers with his opposition to human cloning, is hoping that his scientific colleagues will ultimately embrace his project as a well-intentioned attempt to stir debate on an enormously complicated and important subject. "Nothing would sink it faster than them saying, 'Oh, this is just another study,' " he says.

What follows is an edited transcript of a

21 July *Science* interview with Representative Ehlers in his Capitol Hill office.

On the report's potential impact:
I'm not trying to produce the most comprehensive science policy but one that Congress will take action on in the form of a resolution. We would also like to get some indication of approval from the President's Committee of Advisers on Science and Technology. Even if nothing is ever adopted—and I expect something will be—we've already had a major impact. A lot of things have come together since we started work on the report: a Senate bill [to double R&D spending] and Newt's public statements in support of increased science funding, which in turn led to the president putting substantial increases in his budget. This has all focused a lot of attention on science funding and the need to set priorities.



I'm hoping to finish a draft before the August recess, but it's a very slow process. Once Newt Gingrich and [Science Committee Chair James] Sensenbrenner [R–WI] have vetted it, [the report] will go public. But that is just the first step toward what I hope is a long-term process in which Congress will actively focus on science policy, reviewing it at least every 5 years.

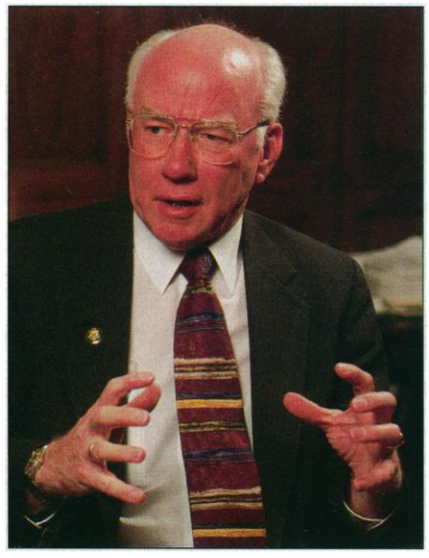
On the need for a new science policy:
First, we're not doing a good job of setting priorities. Second, the Superconducting Super Collider was killed, which indicated [a lack of communication on the need for basic research]. And then there is the space station, which is getting very, very expensive. And look at what's happened with science education—we're not doing well.

So, although there is no catastrophe, there are a lot of indications that science is not in the healthy state it has been for the past half-century. And the time when military competition provided the built-in support for science is over. That constituency has diminished and nearly disappeared. Now, economic competition is at the forefront. The science community has to develop a new constituency and stop bemoaning the loss of the old one.

On oversight of federal R&D programs:
There is a need to consolidate some of the science decision-making in Congress. [Former Energy Secretary] Admiral [James] Watkins loves to point out that when he wanted to get his oceanographic initiative passed a few years ago, he had to work with 43 different subcommittees and committees in the House and Senate. In our report, we don't offer solutions outside the jurisdiction of our committee, but we will point out this issue. I am sure the Rules Committee will work on this next year.

It's just as bad on the Administration end. A Department of Science is not a good political option—there's not enough support for it. A more realistic option would be to consolidate some of the science functions within an existing agency or a new one without Cabinet status. That way, you are more likely to end up with a technically or scientifically oriented person heading it rather than a political person. The question is how you would make all this fit together. Or the president could be encouraged to go the route of a very strong scientific adviser who has considerable say over the operation of the nation's science establishment.

On math and science education:
We need a more coordinated effort. The National Science Foundation (NSF) is doing a better job [than the Education Department], and math and science education certainly should be in NSF's hands. I see no need to have it in both places. We also have to energize the state and local governments, which brings up a whole host of issues. And although we spend $300 billion a year on education, we spend about 0.01%—some $30 million—on education research. Not too many corporations would survive if they spent that percentage on research.



On federal spending:
We need to reform entitlement programs [such as Social Security and Medicare], because they can eat up any surplus we generate. Entitlements were a quarter of the budget in 1962; now, they are half. If we don't get them under control, by 2010 we'll be spending all of our revenue on entitlements and interest. That will leave nothing for defense and domestic discretionary spending [where science programs reside].

PHOTOS: SAM KITTNER

On linking basic and applied research:
We've been shoving our [federal] money more toward basic research, while industry has been driven by international competition and their stockholders to focus on the shorter term payoffs. What has developed is a Valley of Death: As basic research becomes more basic, applied research is shifting more toward product development.

We need to stop talking about the Commerce Department's Advanced Technology Program (ATP), which basically gives money to industry [for applied research] they should be doing anyway, and Cooperative Research and Development Agreements between the federal government and industry. Instead, we should focus on setting up partnerships involving governments, industries, and universities. In the report, we won't get into details of which approach is better, but we'll discuss the elements of good partnerships—which ones work and which ones don't. Why should we tie ourselves to a limited model like ATP? We need to go back to first principles.

Look at Monsanto Corp., which provides direct funding to individuals at Washington University in St. Louis for basic research. Monsanto is not buying researchers and telling them what to do; it is providing grants to faculty in the hope that someday that research will pay off for that company. Perhaps, we need tax credits or tax breaks for any corporation that provides that kind of funding for university research. And states have to play a better role—they are much more into economic development than the federal government.

On large funding increases for the National Institutes of Health (NIH), compared with other agencies:
It's a very dangerous trend. NIH depends very strongly on work done by NSF, the Department of Energy, and also NASA to a certain extent. They are constantly dipping into the well of ideas generated by research in chemistry, physics, and biology. If we continue to give more money to NIH and less to the others, someday that well is going to be dry.

On how well scientists lobby Congress:
Historically, [their grade is] probably a D+. But they are improving tremendously. Particularly in the past couple of years, scientists have become more politically astute and more politically involved.

–ANDREW LAWLER