

Physicists Find Challenges in Building Better Cars

To many people, the car is more than just a mode of transportation. It may be a means of self-expression, an aesthetic statement, a symbol of freedom. Or it may be a highly polluting, environment-destroying menace.

To a physicist like John Larson, who heads the physics department at General Motors Corporation, the car is an intellectual challenge. He's interested in the knowledge that will allow him to increase the car's energy efficiency and decrease its environmental impact, while maintaining interior size and not increasing cost. For decades research at Ford, Chrysler and General Motors—the Big Three automakers—has included study of the physics of automotive aerodynamics, fuel efficiency, new materials and battery design.

In recent years the Big Three have teamed up in joint research efforts of common interest. And in 1994 the Clinton Administration announced a ten-year research initiative, the "Partnership for a New Generation of Vehicles," with various PNGV projects spread throughout the three automakers and the national laboratories. Such efforts are drawing attention to the scientific challenges underlying car design and creating new opportunities for physical scientists in industry, government and academe.

Government and the Big Three

In the 1950s and early 1960s automotive researchers from different companies could talk to each other, but as sensibilities gradually changed, the government came to view such communication as "collusion." Over the last half-decade, however, as the US deficit grew worse and concerns about foreign competition increased, government attitudes relaxed and the automakers began forming consortiums to work on specific areas of research, for example, batteries. In June 1992 the experience gained from building several consortiums led the Big Three to create the aptly acronymed umbrella organization called the United States Council for Automotive Research.

Sixteen months later, the Clinton Administration announced PNGV, which brought USCAR into partnership with many government agencies: the Department of Commerce and its

Because of a Clinton Administration initiative, attention again focuses on designing more efficient automobiles. Opportunities for physicists also lie in longer-term research, beyond any particular program.

National Institute of Standards and Technology; the Department of Defense; the Department of Energy, which funds the national laboratories' work through their Cooperative Research and Development Agreements with USCAR; the Department of Transportation, with the National Highway Traffic Safety Administration as the DOT coordinator; and NASA. In fiscal year 1995 these agencies are budgeting a total of about \$300 million of internal funds toward the PNGV program.

The stated goals of this decade-long program, which reflect both the business orientation of the Federal government and its environmental concerns, are as follows:

- ▷ to significantly improve national competitiveness in manufacturing,
- ▷ to implement commercially viable innovation from ongoing research in conventional vehicles, and
- ▷ to develop a vehicle with up to three times the fuel efficiency of three benchmark vehicles, the 1994 Chrysler Concorde, Ford Taurus and Chevrolet Lumina.

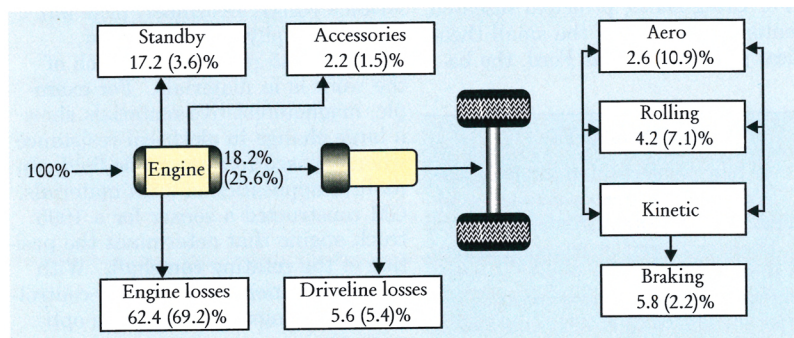
Modernizing the horseless carriage

Scientists at work on these problems focus their efforts on two fronts: re-

ducing the mass of the vehicle and increasing the engine efficiency. To first order, fuel economy goes up as mass goes down, but a 10% mass reduction will yield less than a 10% increase in economy. Incorporating materials such as aluminum, titanium and magnesium can help trim the weight, but all are at least four times as expensive as steel. Polymer composites might be the material of the future, but for now they are costly and difficult to recycle.

The diagram below shows that less than 6% of the energy produced by a car's engine is translated into the kinetic energy of today's midsize (family sedan) vehicle. Three approaches are being taken to improve this situation: developing more efficient engines, reducing overall energy demand (for example, by increasing air conditioning efficiency) and capturing some of the energy lost in braking (for example, with flywheels). Much effort is also going into hybrid vehicles, which combine gas and electric power.

Reducing automobile emissions has been another ongoing area of activity. Larson explained that sensors and controls have developed to the point where mechanisms in the engine exhaust stream measure the composition of the gas and then feed that information back to the engine so it can generate the "right" kind of exhaust, allowing the catalytic converter to do its job—simultaneously oxidizing hydrocarbons and carbon monoxides and reducing nitrous oxide—most efficiently. In recent interviews, both Larson and Alan Brailsford, man-



DISTRIBUTION OF INPUT ENERGY in a midsize (family sedan) vehicle. Numbers outside parentheses are for urban driving; parenthetical numbers, for highway driving. Kinetic energy is completely lost in braking. (Adapted from the PNGV program plan.)

ager of Ford's physics department, noted with obvious pride these "fantastic" (Larson) and "unheralded" (Brailsford) achievements, which have reduced the emissions per vehicle, Brailsford said, by 96% over the last 20 years.

There is generally "a rather long cycle time" in automotive innovations, said Brailsford—from a concept car to a prototype to an actual vehicle. The target date for the PNGV prototype car is now nine years away, and Brailsford said that he had not heard any consideration of developments beyond the prototype. Many knowledgeable people concede that the hoped-for threefold increase in fuel economy, to 80 miles per gallon, is next to impossible in the given timeframe. So PNGV lists as its first two goals the more ambiguous (and therefore reachable) manufacturing and implementation goals.

As one might expect, physics departments do the research with the longest application lead time, which partly explains why PNGV activity is not centered in either Ford's or GM's physics department. (Chrysler has no separate physics department *per se*; instead, interdisciplinary groups are formed for each vehicle.)

One of the longest-running projects in Ford's 25-person physics department has been in applications of chemical sensors. Since modern emission controls require detailed knowledge of the engine exhaust, Ford wants to improve the present zirconia-based electrochemical oxygen sensor so that it can detect different chemical components—hydrocarbons, nitrogen oxides and carbon monoxide—directly.

Ford researchers are also studying electrorheological fluids. These fluids, which are typically composed of highly polarizable particles in insulating oils, have great potential for use in electrically controlled shock absorbers.

For Craig Davis, principal research scientist and leader of the small theoretical physics group at Ford, the ba-

sic goal of improving efficiency has existed throughout his 25 years with the company, but the level of effort "goes in spurts," he said. "There's often some new driver—either government regulations or fuel prices or in this case a new program. We go back and visit these things and see if there's been progress and if we can do things that we couldn't do before."

Davis, who earned a PhD in solid-state physics in 1966, said he came to Ford because of his interest in electron tunneling phenomena. "They had a good group here; the original patents on the SQUID—in 1968 and 1970—were Ford patents." Davis now serves on the American Physical Society's recently launched Forum on Industrial and Applied Physics (see PHYSICS TODAY, December, page 55).

In GM's physics department, which has 45 researchers, much of the work is in materials. For example, magnetoresistive materials show a large change in electrical resistance when exposed to a magnetic field. In its first application of such materials, GM constructed a sensor for a 1995 truck engine that determines the position of the rotating camshaft. With this information the computer-controlled spark plugs can fire at the optimum time.

Another group at GM works on three-dimensional computer modeling of sheet-metal deformation. In the traditional process of making, say, a

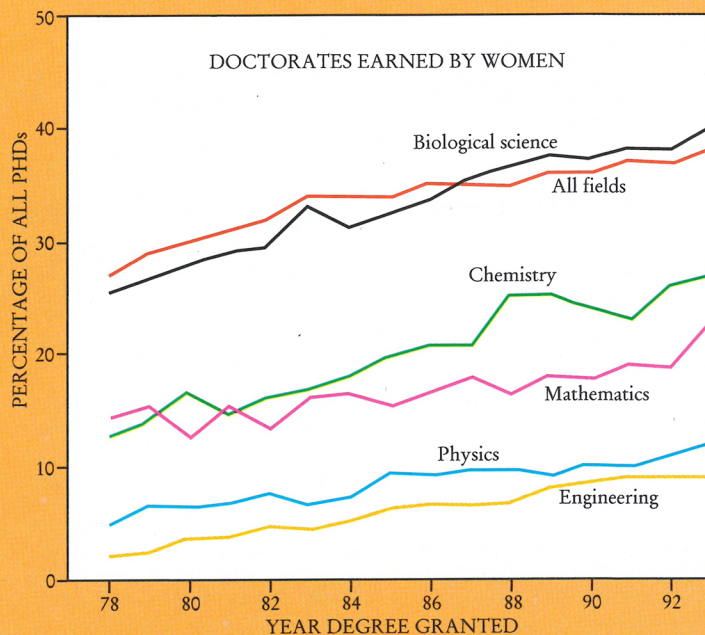
fender, a designed car is modeled in clay, from which engineers produce detailed drawings of the fender. After workers build a die for the fender, it is finally punched onto a piece of flat sheet metal to obtain the desired shape. Often, however, the metal wrinkles or tears. By understanding the physics of the metal and incorporating its properties into the computer codes, GM hopes to predict the outcome and thereby avoid the iterative process now used.

University participation

Peter Eisenberger, professor of physics at Princeton University and director of the Princeton Materials Institute (and coauthor of the Opinion column on page 78 of this issue), feels that basic physics research can contribute to improving future vehicles in many areas, especially on time-scales beyond the ten-year PNGV. However, he thinks that in many cases university faculty are unaware of the underlying science challenges.

To help strengthen a longer-term role for the physical sciences, Eisenberger, with colleagues from national laboratories and the Big Three, organized the first of a continuing series of conferences designed to produce "an integrated perspective on basic research opportunities," as the draft report of the conference puts it. Held in early January in New Orleans, "Basic Research Needs for Vehicles of the Future" was sponsored by NSF and

STAT OF THE MONTH



Source: NRC Summary Report, various years.

CONTACTS

For further information about the upcoming simulation conference, send e-mail to larger@itp.ucsb.edu.

Those interested in receiving copies of the "Basic Research Needs" conference reports or in obtaining information about the upcoming ecology conference should contact afaustr@princeton.edu.

For further information about AIP's Corporate Associates meeting, contact Bo Hammer at bhammer@aip.org.

DOE in "partnership" with Chrysler, Ford and GM. Research and development people at the Big Three had identified six areas in need of basic research, and meeting participants have now drafted reports on the workshops held on those topics: energy storage materials and processes; energy conversion materials and processes; lightweight materials; the impact of emissions on the atmosphere; emission control; and sensors for control, performance and emissions.

The next conference, now being organized by James S. Langer, the director of the Institute for Theoretical Physics at the University of California, Santa Barbara (and Eisenberger's Opinion coauthor), will concentrate on modeling and simulations, and the one following that, again headed by Eisenberger, will be on industrial ecology. October's Corporate Associates meeting of the American Institute of Physics will be hosted by Ford at its Research Laboratory in Dearborn, Michigan. Eisenberger sees these conferences as bringing together "knowledge generators and knowledge users"—or, using the language of mod-

ern management, "owners of problems and owners of expertise."

But would you be seen in it?

Brailsford said that the best part of PNGV and the atmosphere surrounding it is the elimination of the "adversarial relationship" between the government and industry—or rather, he corrected himself, between "the Executive branch" and industry—in trying to achieve common goals. "There is a global fossil fuel economy at stake, and I think it's up to the United States to fully participate, in a responsible way."

Auto manufacturers must look for ways to ply their trade in a global marketplace while responding to the public's increasing desire for a livable environment. According to Eisenberger, with little or no shift in their scientific interests, many physicists could be doing some of the basic research needed for the solution of these longer-term problems. Let us forget the total picture, however, Davis phrased the ultimate PNGV challenge: creating a high-efficiency vehicle that "somebody like you would like to drive."

DENIS F. CIOFFI

New AIP Education Head Will Crank Up SPS to Help Physics Departments

When Dwight E. Neuenschwander sat at his word processor to respond to Kenneth Ford's open challenge to the national council of the Society of Physics Students, "Study Physics to Be a Nonphysicist," he had no idea that a year later, because of the experience he brought to the composition of that response, he would be made the new manager of the education division of the American Institute of Physics. (Neuenschwander later submitted a variation of his original response to former AIP Executive Director Ford as a letter to *PHYSICS TODAY*; see March, page 124.) John Rigden, AIP's director of physics programs, announced the appointment in January, and Neuenschwander, who replaced Donald F. Kirwan, began working part-time on 9 February. As of 1 June, he will be at AIP's offices in College Park, Maryland, full-time. He comes to AIP from Southern Nazarene University, in Bethany, Oklahoma.

Neuenschwander received his BS in physics in 1976 at the University of Southern Colorado. With a theoretical investigation of the contact-interaction approximation in quantum chromodynamics, he earned his PhD in physics from Arizona State University, in Tempe, in 1983. After teach-

Dwight E. Neuenschwander, the new manager of AIP's education division, plans to work with AIP member societies while focusing his initial efforts on the Society of Physics Students.

ing at Arizona State as a visiting assistant professor from 1983 to 1985 and as an assistant professor at Northern Michigan University at Marquette in 1985–86, he went to Southern Nazarene University. In 1988 he was named chairman of the physics department, a post he held for five years. He was the principal author of the "Structures and Interactions" model for the Introductory University Physics Project. (See the article by Rigden, Donald F. Holcomb and Rosanne DiStefano in *PHYSICS TODAY*, April 1993, page 32). He is an associate editor of the *American Journal of Physics* and a coach of the US Physics Olympiad team.

The education division manager of AIP also holds the titles of executive director of Sigma Pi Sigma, the national physics honor society, which granted Neuenschwander membership in 1975, and director of the Society of Physics

Students. Neuenschwander says that in his new position he has two primary objectives: to work with AIP member societies on educational efforts "at any level" and to lead AIP's own education division in revitalizing $\Sigma\Pi\Sigma$ and SPS.

A metric of success

SPS has about 5200 student members in 612 chapters organized in 18 zones throughout the US. Neuenschwander's experience has given him reason to think that SPS can help physics departments "reduce their cross sections" as states shrink education funds and cost-cutting university administrators look for expensive targets to attack.

Based on his seven years as the SPS chapter adviser at Southern Nazarene and on his four years as a zone councilor, Neuenschwander believes that, nationally, SPS has been underutilized. He wants to encourage its use as a tool to help "reenergize the culture of physics departments across the US." He has seen it happen at least once: When low enrollments in Southern Nazarene's physics department caused concern on the part of the university administration, the growth and activity of SPS were essential in lifting the department to safety. (See Neuenschwander's March letter.)

Neuenschwander outlines three major areas by which to measure the success of SPS. First, he says, faculty should see in SPS "a powerful instrument" for recruitment and retention of students: "Faculty have to recruit undergraduate students actively. Faculty have to be involved personally." The concept that "if you don't have students, you're out of business" is an obvious one to Neuenschwander, but given the recent elimination of the physics major at Virginia's James Madison University (see *PHYSICS TODAY*, March, page 81), it bears repeating. Neuenschwander argues that physics teaches many "transferable skills" and that faculty should recruit undergraduates "knowing at the outset that many may choose not to be PhD physicists."

Second, Neuenschwander says SPS should help students see themselves as members of a profession. For example, he gets undergraduates involved in research not merely for publications, but for the contrast with course work (where the answers are known) and to give them "the experience of doing science." Through such participation by students, Neuenschwander says, "SPS should be recognized as an important contributor to the overall health of the physics community."

Third, through outreach programs