Volume 2, No. 1,
Spring 1999

# TransForum

News From Argonne's Transportation Technology R&D Center

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# A Different World

*Argonne scientists are helping to make fuel cell vehicles a reality*

**"If the internal** combustion engine is replaced by fuel cells, the whole automotive supplier and user structure will change," says Argonne's Michael Krumpelt. "It will be a different world."

Ten years ago, that world sounded like science fiction: extremely quiet, ultra-efficient electric cars running on hydrogen. Now, it's looking a lot more real, thanks in part to a decade-long program at Argonne to develop a device to convert gasoline into hydrogen fuel for fuel-cell-powered cars *(TransForum*, Vol. 1, No. 1).

Four Argonne researchers involved in this program were among a team of 15 government and industry scientists who received the Partnership for a New Generation of Vehicles (PNGV) Medal for their work toward making fuel-cell vehicles a reality (see Fastrax, p. 7). Two Argonne managers, Jim Miller and Walter Podolski, were also cited for their excellent leadership in steering the project.

Here, the four medalists – Shabbir Ahmed, Romesh Kumar, Michael Krumpelt, and Robert Sutton – share their views on the program, its history, and the prospects for fuel cell vehicles.

***Beginnings***

The fuel reformer arose out of the convergence of three unrelated events in the late 1980s: (1) the U.S. Department of Energy's (DOE's) program to build a fuel cell bus; (2) an effort at Argonne to explore catalytic conversion ("reforming") of gasoline vapor to hydrogen inside a solid oxide fuel cell; and (3) a realization by automakers that developing a full fuel cell system was going to be very expensive. Robert Sutton, who worked until 1998 in fuel cell research at General Motors, explains that building a fuel cell vehicle "was something that probably was not feasible for the car companies to do at that time; it made more sense to go into partnership with the government."

*Argonne's PNGV Medal Winners: Michael Krumpelt, Romesh Kumar, Robert Sutton, and Shabbir Ahmed.*

In the course of the bus project, Krumpelt suggested to Pandit Patil (then DOE Program Manager for Electric and Hybrid Propulsion Systems) that DOE do some research on fuel processing. Kumar and Ahmed surveyed various reforming technologies and recommended partial oxidation, an approach that promised a faster, lighter, and smaller processor than the one used for conventional steam reforming. As a result, DOE began contracting with industry to develop partial oxidation fuel processors for methanol, ethanol, and, later, gasoline.

Meanwhile, the three Argonne scientists persuaded DOE that the Laboratory should be doing some in-house research taking a slightly different approach than the one used by industry. Krumpelt says, "We decided to find a catalyst to promote the conversion of fuel to hydrogen, allowing the process to occur at a significantly lower temperature. This was much more risky than what industry was doing because finding the right catalyst was an enormous challenge. Eventually we discovered a class of new materials that supported the partial oxidation chemistry for gasoline."

In 1996, the Argonne team demonstrated a device that produced enough hydrogen to generate 5 kW of electricity. It ran on methanol and used a standard industrial catalyst. By mid-1997, using the new catalyst, they developed a bench-scale reformer to produce hydrogen from commercial gasoline and natural gas.

Word got out quickly. Sutton says, "We came in February of 1996 to see what Argonne was doing, and we were very impressed with it." He and his colleagues at GM convinced their management to try Argonne's approach. "We went back and developed a methanol reformer similar to what Argonne had but about 10 times the size." The switch to a catalyst made a big difference. "We could demonstrate pretty rapid startups and the processor was very compact. Our device was about 20 liters [volume needed to generate about 25 kW]; the steam reformer [then being developed at GM] was more like 80 to 100 liters [for 30 kW]." Sutton retired from GM and came to Argonne in 1998, but a colleague is continuing the work.

### *The Road to Washington*

For the Argonne researchers, getting to the medal ceremony in Washington was sometimes a rocky road. Along the way, they became men with a message, first convincing people that putting a fuel cell in a car wasn't crazy, then that partial oxidation reforming was better, then that catalytic partial oxidation was even better than that.

Kumar remembers, "When we first starting talking about a fuel cell bus to the developers, they'd just laugh us out of the house, saying 'Go away, don't bother us with this stuff.' They had fuel cells that occupied about one quarter of a tennis court [for utility power generation]. Their reaction was, 'You want to take that whole thing, shrink it down, and put it on the back end of a bus? You're out of your mind!'" He adds, "Pandit Patil was really instrumental in talking to the fuel cell developers and the car companies. You've got to get all these people on board to say, 'O.K., yeah, we'll work on it,' rather than 'O.K., when you're ready, come back and we'll talk to you.'" Changing people's minds took a while. Ahmed says, "Argonne and the others who were interested in pursuing fuel cell research gave a lot of talks and people eventually came around."

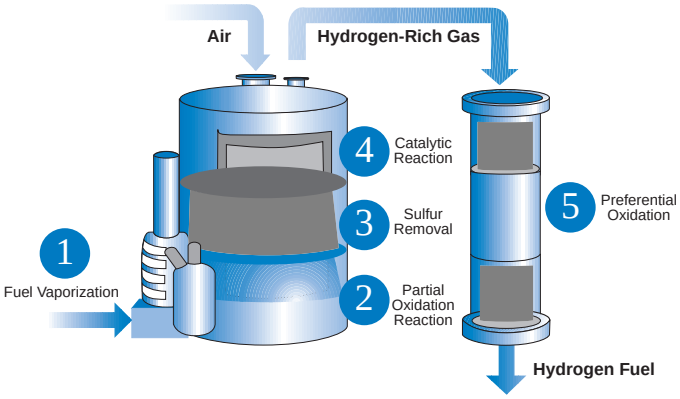
"Because these will be all-electric vehicles, with no mechanical parts, there is no reason you can't have a little refrigerator and microwave – you can drive all day with your cold drink and warm sandwich... It will be a different world."

*– Michael Krumpelt, Fuel Cell Team Leader, Electrochemical Technology, Argonne*

### *The Road Ahead*

So where does the road lead next? For the near- to mid-term, the team is continuing to work on reforming gasoline, as well as diesel and other hydrocarbon-type fuels. Sutton believes auto companies will initially favor methanol in this country. But, he adds, "In the years after 2010, the focus may shift to a fuel processor based on an infrastructure that is readily available here... some type of distillate or gasoline-based fuel. Both DaimlerChrysler and GM have run methanol-fueled [fuel cell] cars and demonstrated them at auto shows. I think the goals that the automobile companies have set for a pre-production prototype by 2004 are reasonable." The principal task at Argonne for the next five years will be finding materials and processes that will make the reformer even smaller, lighter, and faster. The current prototype produces about 2 kW of electricity per liter volume of the processor. Says Krumpelt, "To put it in perspective, when we started with the bus project, the fuel processor with conventional technology was the size of a 55-gallon drum. That wouldn't fit under the hood! Our current fuel processor is about 3-4 liters, or just about a gallon."

Ahmed has set his laboratory team a creative challenge: to rethink every step of the process in search of new solutions. "This is an evolving technology. Nobody's got a monopoly on exactly how it's going to work out." If somebody outside Argonne has a good idea, he wants to hear it. "We'll pursue it, or we'll help them pursue it. We have a lot of support from our management [for this]."




The PNGV award has been great for morale in their lab, Ahmed says. "Industry is recognizing that fuel cell technology is the way to go – this medal tells us we're on the right track."

For these researchers, the PNGV medal adds to a deep sense of satisfaction at having made an impact. Kumar says, "Ten years ago, there was hardly anyone – just DOE, Argonne, and Los Alamos – working on fuel cell transportation research. Now all of the major automakers are investing serious money and serious effort in fuel cell vehicles."

With the success demonstrated by Argonne and the other organizations receiving the award, the advent of fuel cell cars is looking less like *if* and more like *when*. "We worked for 10 years laying the groundwork – that's the role of the national labs," said Krumpelt. "When it looked promising, industry jumped in, and now it's a worldwide activity. It will change the way we live."

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# New Funding Raises Prospects for Maglev

*Proposals sought for high-speed and low-speed systems*

**Energy-efficient, quiet, clean, fast** – magnetic levitation transit systems offer one solution for better transportation within and between cities. After languishing for several years, the prospects for "maglev" technology in the United States got a boost from recent legislation.

The Transportation Equity Act for the 21st Century (TEA-21) could eventually provide over $1 billion for design and construction of the first full size demonstration maglev systems in the United States. Projects can be proposed by private, regional, state, or local organizations for both high-speed intercity and low-speed urban systems.

**Existing Maglev Demonstration Systems**

| | Germany | Japan |
|---|---|---|
| Location | Emsland (open to public) | 43 mi west of Tokyo |
| Track length | 19.6-mi closed loop | 11.4 mi |
| Vehicle configuration | Wraparound | Combination aero-wedge and double cusp shape |
| Maximum speed | 280 mi/h | 342 mi/h |
| Levitation technology | Conventional electromagnets, iron rails | Superconducting magnets on board, motor coils on guideway |
| Principal innovations | Current continuously adjusted, air gap sensors needed | Levitation coils mounted on guideway sidewalls |
| Planned routes | Berlin-Hamburg | Tokyo-Osaka |

Designed to transport passengers and/or freight at speeds of 300 mph, maglev vehicles levitate as a result of magnetic fields created by on-board magnets interacting with a guideway. There is no physical contact between the vehicle and the guideway, and because the vehicles are much lighter, they can accelerate and decelerate much more rapidly than high-speed rail trains. They can be operated as individual cars or multi-car trains to provide very high frequency of service, even in relatively small markets.

"For routes spanning less than 600 miles, maglev vehicles may revolutionize intercity travel," said Don Rote, a physicist at Argonne National Laboratory and a leader in maglev technology development. "They could match gate-to-gate air-travel times and yet consume only one-third of the energy used by commercial aircraft," he added.

"Recently, a number of groups, both foreign and domestic, have been proposing that the United States fund a maglev demonstration," Rote said. "The Germans and Japanese have already built both high-speed maglev systems and lower speed, urban maglev demonstration systems (see sidebar). The idea of a full-size demonstration here has caught on."

The new transportation act, approved in late 1998, provides a total of $55 million for fiscal years 1999 through 2001 for development of maglev transportation systems. The program for high-speed (240 mph) systems is being administered by the Federal Railroad Administration. Up to $15 million has been approved for fiscal year 1999; an additional $950 million is authorized (but not appropriated) under TEA-21 for fiscal years 2000 through 2003 for design and construction of the selected project. A second program, to develop low-speed urban systems, is being administered by the Federal Transit Administration.

Companies wishing to get in on the maglev revival may need a jump start to catch up to Japan and Germany in maglev transportation technology. Argonne has much to contribute to such efforts. According to Rote, "Argonne has significantly advanced the maglev state of the art by developing computer codes and experimental facilities for government and industry use. As the leading national laboratory in maglev research, Argonne has also explored, theoretically and practically, the potential of using such systems for safe, convenient, energy-efficient transportation."

Among Argonne's maglev innovations is the design of a two-mile-long user facility that government or industry could use to evaluate designs and test individual components. Such testing will help ensure that U.S. systems are competitive with existing German and Japanese prototypes.

Argonne scientists have been awarded seven patents for suspension and propulsion system designs. From 1988 to 1995, the Laboratory's maglev team produced more than 70 reports and papers, as well as a number of invention disclosures. Most recently, Argonne assisted NASA in a feasibility study for a new wind tunnel design in which maglev technology would be used to guide and propel the model being tested.

*Argonne is the leading national laboratory in maglev research.*

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# DOE's CARAT Program is No Diamond in the Rough

**In the precious stones market,** a one-carat diamond equals 200 milligrams – that's one valuable rock. The U.S. Department of Energy's (DOE's) CARAT (Cooperative Automotive Research for Advanced Technology) program weighs in with 26 small businesses and universities participating in the first phase of a three-phase program to develop innovative automotive technologies. Everyone, including those involved in the program here at Argonne, expects the investment to pay off.

The CARAT program was conceived out of a desire by Congress to see more involvement by universities and small businesses in the Partnership for a New Generation of Vehicles (PNGV) program. DOE asked Argonne to help develop the concept, and the current program was born. According to Roy Cuenca, a mechanical engineer in Argonne's Center for Transportation Research, Laboratory staff remain active in the CARAT program. "We work with DOE to develop and review technical work statements for the Phase 1 solicitation documents, provide an initial technical review of proposals before their detailed review by an independent panel, and participate as technical advisors in the final review of proposals. There is quite a bit of work involved in managing the 120-140 proposals that come in following each solicitation."

The CARAT program is unique in terms of federally funded programs. Says Donna Lee Ho, Manager, DOE Office of Transportation Technologies, "CARAT takes the most promising ideas from small businesses and universities, funds the development from a bench-scale to an engineering-scale prototype, and then marries the concept with a manufacturer or supplier who has the know-how and resources to take the concept to market."

The program is sponsored by DOE through its Office of Advanced Automotive Technologies (OAAT). All U.S. universities, colleges, and small businesses are eligible to participate. The program funds research projects in areas critical to the advancement of the automotive industry: alternative fuels; compression-ignition, direct-injection diesels; novel batteries; fuel cells; and vehicle systems.

### CARAT a Treasure for Funding Recipients

"It's pretty exciting for us, a new company with fewer than ten employees, to use our technology to work with the major developers of fuel cells on a critical component – a catalyst to convert readily available gasoline into the hydrogen needed for fuel cells. Without CARAT, a small company like ours would never have had the opportunity to be involved in PNGV or to generate interest in our products from the major automakers and their suppliers around the world."

*– Dr. Scott Swartz, NexTech Materials, Ohio*

How will the CARAT program benefit participants and, ultimately, the automotive industry? According to Bob Kirk, Acting Director, OAAT, "We believe that CARAT will channel the creativity and resourcefulness of the small business and academic communities to help remove the technology barriers that prevent our nation's production of increasingly energy efficient and environmentally friendly vehicles."

Applicants for Phase 1, worth more than $3.7 million in cooperative agreements, had to demonstrate a firm technical basis for their technology through test data and/or modeling. After Phase 1 has been completed, DOE will undertake a detailed, comprehensive review of each project. Awardees for Phase 2 will be selected on the basis of the quality of their Phase 1 deliverables and the extent to which their technology is judged to meet the established technical targets.

In Phase 2, participants will have up to 24 months to further develop the component or system, taking it from a bench-scale to a near-vehicle-sized prototype. Cost matching by Phase 2 awardees is at least 25%.

"Those organizations that are accepted for Phase 3," says Lee Ho, "will, with the help of an industry partner, optimize performance, packaging, and manufacturability; install the component or subsystem into a vehicle or system for testing and evaluation; and perform a rigorous manufacturability and cost analysis." Like Phase 2, Phase 3 will last for up to 24 months. Cost matching by Phase 3 awardees is at least 50%.

Where will the program go? Although it's in its first year, expectations are high. Says Kirk, "The success of the CARAT program will ultimately be judged by how these technologies are received by industry. Will the vehicles in which they are installed perform more effectively, more reliably, and less expensively than their conventional counterparts? This will be the final test, but we're expecting some real success stories. Just wait and see."

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# Recycled ABS Passes First Auto Parts Test

*Patented process frees a valuable but hard-to-isolate plastic from appliances headed for landfills*

**More than 2.8 million** tons of home appliances (freezers, refrigerators, and washers and dryers) are scrapped annually in the United States. Although the metals that these appliances contain are typically recovered and recycled, the nonmetallic parts are landfilled, at costs of $10 to $40 per ton. As a result of research sponsored by the U.S. Department of Energy's Office of Industrial Technologies, Argonne has developed a process that allows recycling of these materials – which could reduce appliance solid waste and save about 87 trillion Btu per year in energy. The new process, which can also be used to recover plastics from scrapped automobiles, has just passed its first major test.

A 100% recycled thermoplastic has been successfully used for the first time in the test production of an injection-molded auto part. In December 1998, the Vehicle Recycling Partnership (located in Southfield, Michigan) used recycled acrylonitrile-butadiene-styrene (ABS) to produce headlamp "back-cans."

"The headlamp housing is a complicated component because of its shape," says Dimitrios (Jim) Karvelas, an industrial engineer at Argonne who developed the patented technology for mining valuable thermoplastics such as ABS from discarded appliances. Karvelas reports that "the results of the molding test were very successful." The evaluation phase of the "back-can" test is nearly complete, and tests for other, smaller auto components are under way.

*A headlamp housing "back-can" made of recycled ABS is used in an automobile bumper light assembly.*

According to Karvelas, the two critical criteria for successful injection molding with recycled ABS are high purity and processing consistency. "Once we recover ABS from discarded home appliances, we have to test it for purity," Karvelas emphasizes. The nonmetallic appliance waste (about 25% of the weight of scrapped appliances) is rich in two thermoplastics: ABS and high-impact polystyrene (HIPS). The two are not compatible; if contaminated with HIPS, ABS degrades considerably in quality. So, if either of these two plastics is to be useable, they must be separated from each other. Argonne's process makes this possible.

"Argonne's patented froth flotation plastics separation process is the only technology that has successfully been able to produce recycled ABS with a purity greater than 99.5%," says Ed Daniels of Argonne's Energy Systems Division.

Even at high purity, the recycled material may not be suitable for use in certain applications. But the injection-molding test has confirmed the technical feasibility of using recycled ABS in a complex automotive part. "In general, we expect that this type of recycled ABS will be a viable substitute for virgin materials in applications that use a 'mid-grade' ABS," Daniels adds.

The recycled ABS used in the injection-molding test was recovered in a 1,000-pound-per-hour pilot plant in Minneapolis, Minnesota. Argonne conducted the plant test jointly with the Appliance Recycling Centers of America. Other project partners include the Vehicle Recycling Partnership and the American Plastics Council.

The key to commercialization of ABS recycling is the ability to convert large volumes of discarded materials economically. ABS is used in such products as computers, office equipment, telephones, automobiles, and home appliances.

*Granulated ABS is recovered at 99.5% purity from shredded appliances by means of Argonne's patented froth flotation process.*

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## LOOKING DOWN THE ROAD

**During his visit** last fall to dedicate the Transportation Technology Research and Development Center (TTRDC), Secretary Richardson had the following comment about Argonne's new technology to reduce $NO_x$ and particulate emissions from diesel engines: "This research is an excellent example of government-industry research, and the results are the first of many we expect from this transportation technology center."

We agree. The $NO_x$ breakthrough was a significant achievement, but it was only one of the many contributions we're making here at Argonne toward developing safer, cleaner, more affordable and fuel-efficient transportation technologies. The most recently recognized was a fuel cell reformer that permits the use of gasoline or other currently available fuels, such as methanol, ethanol, and natural gas, in fuel-cell-powered automobiles (see story on page 2). During a ceremony at the White House complex in March, the developers of the reformer – including four members of Argonne's Chemical Technology Division – were awarded the Partnership for a New Generation of Vehicles (PNGV) Medal. Fuel cells, originally developed as part of the nation's space program, hold significant promise as a highly efficient and clean source of power for automobiles. Fuel cells run on hydrogen and, until now, finding a way to refuel them has been a significant barrier to the introduction of fuel-cell-powered vehicles. Argonne's new technology would allow existing gasoline refining and distribution infrastructure to be used to supply fuel for the vehicles.

Argonne is also proud to be involved in an exciting and relatively new program sponsored by DOE's Office of Advanced Automotive Technologies. The purpose of the CARAT program (see page 5) is to help overcome the technology barriers that prevent our nation's production of energy-efficient and environmentally friendly cars and trucks. Phase I of the program, which started last October, is worth more than $3.7 million in cooperative agreements for universities and small businesses.

The magnetic levitation (maglev) program, dormant for several years, is now enjoying a revival thanks to recent legislation (see page 4). Argonne personnel will no doubt be involved in efforts to demonstrate this revolutionary transportation system.

These are just a few of the exciting transportation projects we're working on at Argonne. While we appreciate the awards and the medals, our biggest satisfaction comes from knowing that our innovations will someday save consumers energy and money, help ensure cleaner air, or in some way make all our lives better. Secretary Richardson's words, "the first of many," are both a promise and a challenge – a challenge that we intend to meet.

**Larry R. Johnson**
**Director**

## FASTRAX

**On March 17,** Dr. Neal Lane, Science Advisor to President Clinton, presented the second Partnership for a New Generation of Vehicles (PNGV) Medal to a group of 15 scientists and engineers who developed a breakthrough reformer for use in vehicle fuel cells (see story on page 2). The medals, presented during a ceremony at the White House complex, recognize teamwork and significant technical achievement in the cooperative effort between the federal government and the U.S. auto industry to develop clean, safe, and fuel-efficient cars and trucks. Among the recipients were four researchers from Argonne's Chemical Technology Division: **Shabbir Ahmed, Romesh Kumar, Michael Krumpelt,** and **Robert Sutton**. Their award-winning technology produces hydrogen from commonly available fuels, such as methanol, ethanol, natural gas, and gasoline.

Two papers submitted by members of Argonne's Energy Systems Division to the Society of Automotive Engineers (SAE) in 1998 have been approved by the Engineering Meetings Board of SAE for publication in the 1998 edition of *Transactions*. **Ramesh Poola's** paper on variable air composition control and **Roger Cole's** paper on the Mitsubishi Legnum with a GDI engine have been selected because these papers met the "high standards for the criteria of (1) long-term reference value; (2) technically new, innovative, or constructive review; (3) professional integrity; and (4) clear presentation." Only a small number of the papers submitted each year are selected by SAE for publication in *Transactions.*

Two items published by Argonne's Information and Publishing Division for the Transportation Technology Research and Development Center won awards in the **international** peer competition sponsored by the Society for Technical Communications:

- The CARAT web site (http://www.ipd.anl.gov/carat) received a Distinguished Award (**Renée Nault**/editor and **Tami Sharley**/designer).
- The 1998 FutureCar Results brochure received a Merit Award (**Renée Nault**/editor and **Dann Sarro**/designer).

The TTRDC web site (http://www.transportation.anl.gov) and five other transportation pieces won awards at the national STC competition.

## PARTNERING WITH ARGONNE

Argonne is seeking industrial partners to develop advanced transportation technologies. The following types of working arrangements can be made:

- In a *reimbursable R&D agreement*, Argonne's industrial partner pays the full cost of the research performed. The company generally takes title to any inventions, and proprietary information and research results are kept confidential.

- In a *cost-shared R&D agreement*, Argonne and its industrial partner share the costs of research. The company may obtain rights to intellectual property developed by Argonne. Proprietary information is kept confidential, and research results may be protected from disclosure for up to five years.

- *Licenses* for Argonne inventions and software may be granted to companies that wish to develop them into marketable products or processes. Licenses may also be part of other agreements.

- *Personnel exchanges* and *technical assistance* projects can be arranged with Argonne for short-term or rapid-turnaround work.

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*TransForum* ■ Volume 2, No. 1, Spring 1999

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*TransForum* is published by the Transportation Technology R&D Center, Argonne National Laboratory. Publishing support services are provided by Argonne's Information and Publishing Division. Art direction/design by Lori Hermes.



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