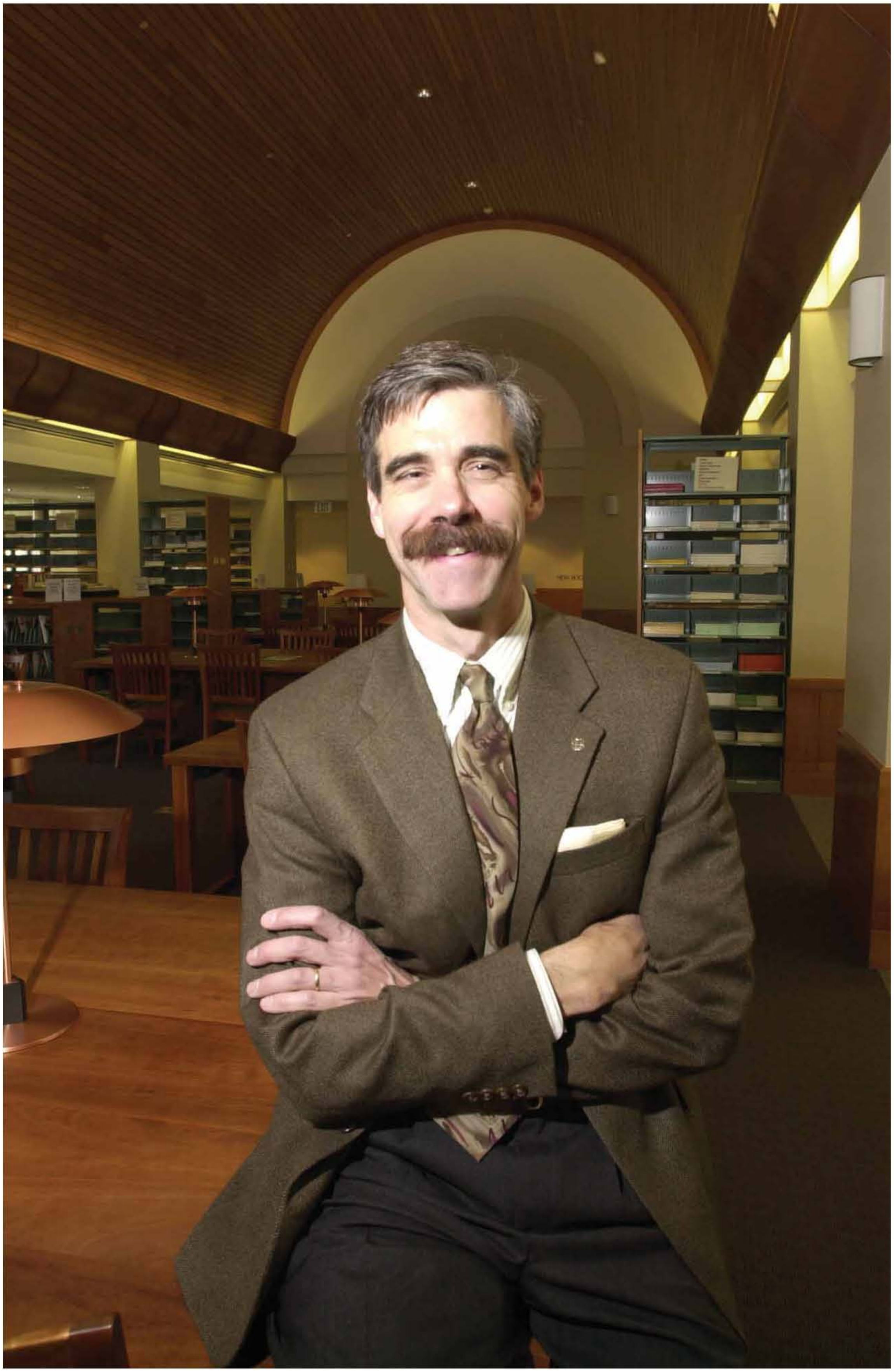


The Chief Technologist's Mechanical Advantage

by Douglas L. Smith

Erik Antonsson, JPL's new chief technologist, in the reading room of the Sherman Fairchild Library of Engineering and Applied Science, which features wireless networking and e-publishing technology.

Erik Antonsson is a builder of bridges. Not literally—he's a mechanical engineer, not a civil one. He's a hands-on, axles-and-wheels kind of guy. His Caltech office has an entire bookshelf devoted to gears, bearings, and mysterious yet intriguing fittings, all within easy reach of the visitor's chair; on the next shelf up, some actual books jockey for position with a dozen electric motors of various sizes, a miniature purple Chrysler Prowler, and a tiny Sojourner rover. Yet his chief research interest is theoretical: engineering design, which is the study of the *process* of designing things, be they bridges, electric shavers, or spacecraft. And now that he's chief technologist at the Jet Propulsion Lab, which Caltech runs for NASA, and which is the home of America's missions to the far corners of the solar system, he builds bridges between really cool but possibly far-out ideas and the funds to incubate them.

Antonsson's father was an aerospace engineer for General Electric. "He tried very hard to keep me from being an engineer," Antonsson recalls, "because he thought that the profession was too uncertain—this was during all the ups and downs in the late '60s and early '70s—but there was no question that I was wired up to be an engineer." Engineers hang from every branch of his family tree: one grandfather and an uncle were mechanical engineers; his other grandfather, who never attended college, was a machinist and a tool-and-die maker. "Had he had the opportunity to get a formal education, he would have undoubtedly pursued engineering. He was tinkering and inventing all the time. And—this tells you what the dinner-table conversations are like when the family gets together—my older sister married a mechanical engineer. It's in the blood, I'm afraid. I recall taking a clock apart once when everyone, including my parents, were utterly convinced that I was way too young to have done so. I remember getting punished for that, which taught me that if I were going to take things apart, which I knew that constitutionally I couldn't resist doing, I had to make sure that I could put them back together." At 14, he spent $25 on a car, fixed it, sold it, and used the proceeds to buy the next, an "affliction" that lingers today; he's also worked as a production machinist, plumber, mason, carpenter, and electrician. "So it's sort of laughable that my father thought he could convince me with mere words that I *shouldn't* be a mechanical engineer."

Not that a convergence of the stars and his genetics set Antonsson on a beeline for Caltech and JPL—far from it. He attended McGill University his freshman and sophomore years. He loved Montreal but McGill wasn't his "cup of tea," and his grades showed it. "So I applied to transfer but, being the headstrong young man that I was, to only one school. I figured that if I couldn't get in where I really wanted to be, I'd go drive a truck." That one school was Cornell, which had interviewed and accepted him two years earlier. He must have made a good impression, as they welcomed him back, and Antonsson remains grateful to this day. "I don't think it's unreasonable to trace my being at Caltech—and the opportunities I've had as a result of that—back to this admissions officer who, for whatever reason, thought there was some merit to readmitting me as a transfer student" despite Antonsson's lackluster transcript.

Cornell turned him around. He took a course in biomechanics—the study of how bones and muscles move, which one might call the pinnacle of mechanical engineering—from Donald Bartel, "who I still maintain an infrequent correspondence with." Bartel was doing pioneering work with artificial hip joints, the first full hip-replacement surgery having been done a few years earlier. "When I came back for my senior year, as I got to the mechanical engineering building, the department secretary stopped me and said, 'Oh, Professor Bartel wants to see you.' And my heart sank. I thought, 'Oh no, he's going to take back that A

Above: Antonsson makes great strides toward his PhD. The round things strapped to his body are plates bearing LEDs, whose travels are recorded by the two infrared cameras on the adjustable rails in the background. (In a real experiment, the LEDs would be facing the cameras.)

Right: The apparatus was also worn by more graceful volunteers, including this member of the Joffrey Ballet.

that he now realizes is a mistake.'" Instead, Bartel offered him a job. "So I got involved in doing biomechanics research with dogs at the vet school, and enjoyed it greatly." Antonsson graduated with a BS in mechanical engineering, with distinction, in 1976, and Bartel "encouraged me to apply to graduate school, which I didn't want to do. There was *nothing* I wanted more than to get *out* of school. But I *really* liked doing research, so I applied to several schools, including MIT. MIT offered me a research assistantship, and how could I say no to that?"

Antonsson earned his MS and PhD degrees with Robert Mann, the founder of MIT's Newman Lab for Biomechanics and Human Rehabilitation, developing a better way to measure human joint motions. The system used two infrared cameras to track some five dozen small LEDs attached to the patient's body in precise clusters in strategic locations. A computer flicked each LED on and off, one by one, some 150 times per second, and calculated its 3-D position to within one millimeter and the orientation of the cluster to within one degree—an "unparalleled" precision at the time. Three LED clusters attached to a limb sufficed to track its motion unambiguously, and the system had enough clusters to scan the whole body. "The original purpose was to measure walking motions with enough speed and precision to be able to calculate the net forces and torques at each joint" for a study of osteoarthritis, says Antonsson. However, because of the system's generality, "it has been used to measure the motions of athletes—luge starts, baseball pitching, golf and tennis swings, etc.—and the pre- and postoperative gaits of children with cerebral palsy. I also spent a very interesting day with several members of the Joffrey Ballet, and at one point we collaborated with a researcher at the Salk Institute investigating hand motion in American Sign Language." After graduating in 1982, he adapted the system for clinical use at Massachusetts General Hospital while a postdoc at Harvard Medical School, working with Dr. Andrew Hodge. "He did all the clinical and hospital-political work; I did the technical work." Hanging out in hospitals had its pluses: while a grad student, he met Barbara Ann Bettick, a pediatric ICU nurse at Children's Hospital, another Harvard teaching affiliate. They married in 1985.

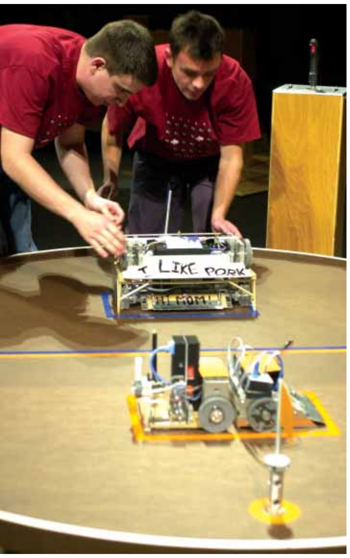
Antonsson started as an assistant professor of mechanical engineering at the University of Utah in January 1983. But first, he shopped around. "I was interviewed by people from several universities, including a conversation with Fred Culick [Caltech's Hayman Professor of Mechanical Engineering and professor of jet propulsion]. And I turned him down flat. I told him I'd never live in Los Angeles, so I didn't need to waste his time or mine with further discussion. I grew up in rural upstate New York, and Los Angeles just seemed too big, too dirty, just all this urban miasma. So I went off to the University of Utah—there's a pattern emerging here, as you'll see—which I shortly discovered also wasn't my cup of tea." Fortunately, Culick wasn't easily put off. In a time-honored tradition dating back to when Robert Millikan was luring Arthur Noyes from That Other Institute of Technology, "Culick made it his business to come to the University of Utah—gave a great seminar on his work on the Wright Flyer—and made a point of meeting with me. He said, 'Look, why don't you come down to Caltech and give a seminar?' And I said, 'Fred, I'd be happy to. I should know more about Caltech. But I'll tell you right now I'll never live in Los Angeles.' So I came out to Caltech for a day or so, and I was absolutely floored by the experience. I got back to Salt Lake, and called Fred up and said, 'You know, I really need to rethink this.'" Antonsson left the University of Utah that December, having been there exactly a year.

He joined Caltech as an assistant professor of mechanical engineering in September 1984, after a nine-month detour at Massachusetts General to put the finishing touches on what is now called the Biomotion Laboratory. Today, nearly 20 years later, it's still going strong. "We are one of the more successful motion-analysis labs around," says Dr. David Krebs, its current director. "We use the same hardware Erik set up, but I suspect even he'd be amazed at the beneficent effect that cheap computers, motivated and smart engineers and scientists—and, yes, doctors!—have had!" They did their best to hang on to him, making him technical director of the lab, an assistant in bioengineering in the hospital's orthopedic surgery department, and an assistant professor of orthopedics at Harvard Medical School.

At Caltech, Antonsson has inspired undergraduates the way Professor Bartel inspired him. He initiated the hugely popular Engineering Design Laboratory, better known as the ME 72 contest, based on a course he'd TA'ed at MIT taught by the legendary Woodie Flowers, another Mann protégé. (The MIT catalog listed it as course 2.70, mechanical engineering being Course 2, so the Caltech course number is an homage.) "I have considerably extended the original; however, the underlying philosophy and broad outline of the course are straight from Woodie." ME 72 students are given a set of specifications and identical "bags of junk" from which to build contraptions to go head-to-head with their classmates' machines in a task that changes each year. Classroom topics include such things as "Gears, Belts, Chains, Clutches, and Brakes," and many long hours are spent in the machine shop on the prototypes that must be submitted at various "milestones." The course is a real-world exercise in designing a device from scratch with limited resources, and building, debugging, and sometimes entirely rethinking it under tight deadlines—useful experience for budding NASA engineers and future toaster designers alike.

The payoff is very public: the first contest, featuring rubber-band-powered scooters that raced down a slotted track to the far end of a 16-foot table and back, drew a crowd of 50. Corporate sponsorship has led to much higher-quality "junk" since then, and at last year's competition 894 onlookers watched pairs of radio-controlled, battery-powered rovers work cooperatively to plant their flag in a socket on the opposing team's side of the arena. ME 72 is now the most popular spectator event on campus—it packs Beckman Auditorium, the glee clubs sing the national anthem beforehand, and local (and occasionally national) television news crews turn out for it. In such a setting, showmanship counts, and Antonsson is fond of reminding his contestants, "If you can't win, lose with style." So does finesse—this isn't *BattleBots*, and devices designed to destroy or maim the opposition are not permitted. Fittingly, ME 72 won Antonsson the Feynman Prize for Excellence in Teaching in 1995.

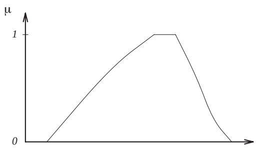
ME 72 students face a fresh design challenge each year, and must choose their strategies before they can plunge into construction. Will knobby wheels or tank treads be better for climbing?



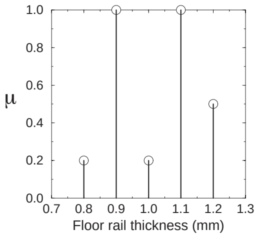
Above: Salomen "Sam" Trujillo (center) of the Invaders is still in the game in the 2002 ME 72 competition, but partner Tyler Kakuda (right) watches helplessly as his device and the team flag are sumo-wrestled out of the ring by Brian Helfinger of the aptly named Atomic Wedgies in the final round. Teaching Assistant (and Antonsson grad student) Fabien Nicaise looks on.

Left: You can stack 'em or park 'em side by side, but everything must fit in your team's starting box and the amount of time you have to set 'em up is strictly limited—a rule that's been in force since the very first competition.

Below: In that first contest back in 1985, Antonsson (far right) watches Chris Schofield (BS '87) claim the championship.



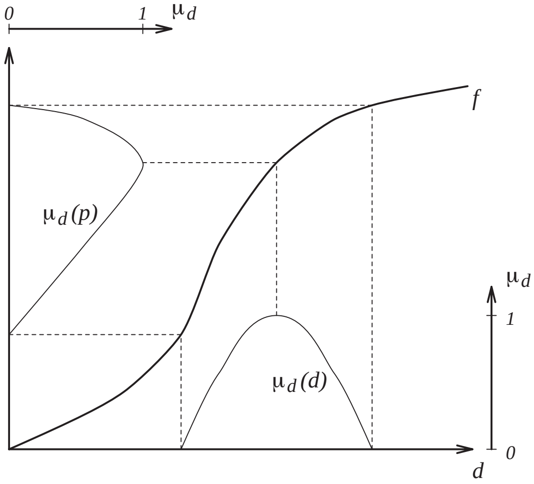
Antonsson, Imprecision in Engineering Design, *Proceedings of IDEA '97*



Scott and Antonsson, *Proceedings of DETC '98* © ASME 1998

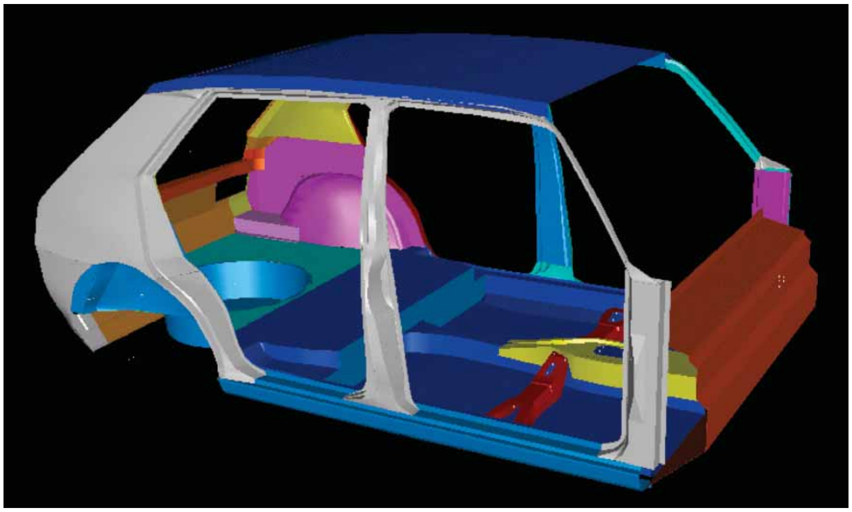
How do you explain "five-ish" to a computer? In the Method of Imprecision, you plot a design variable against your preference (μ) for each of its possible values, as shown at top left. The region where μ = 1 tells the computer, "this is what I want," while any value over zero says, "I can live with this." The variable doesn't need to be continuous, as in the plot of sheet metal thicknesses at bottom left, where μ reflects how easy each thickness is to come by. You find the optimum values by plotting a design preference (*d*) against a performance preference (*p*), at right, using a method proposed in the 1960s by Lotfi Zadeh, who invented fuzzy logic—at least in the mathematical sense. In reality, each *p* usually depends on many *d*s and the curve *f* is a multidimensional surface.

Antonsson, Imprecision in Engineering Design, *Proceedings of IDEA '97*



Should I build a catapult-launched grappler to sail over a competitor, or a wedge-shaped battering ram to flip my opponent's device on its back? It's not obvious what the best approach is, as Antonsson takes pains to create problems with many promising solutions. This ties in with the theme of his own research: developing ways to design things more efficiently. Even if you know what you want to build, you have to make a lot of decisions up front with very little to go on. Yet these decisions are generally the ones with the most expensive consequences if you guess wrong. And you *will* have to guess, because most computer-assisted design and rendering packages require precise inputs: when the system prompts you to input the length of a strut in inches, for example, typing "5-ish" into the dialog box won't fly. But, as Antonsson's group has discovered, relatively small changes in these early choices can have a significant effect on how the design performs. That's because the devil is in the trade-offs: frame thickness vs. stiffness, stiffness versus weight, weight versus fuel consumption, and so on.

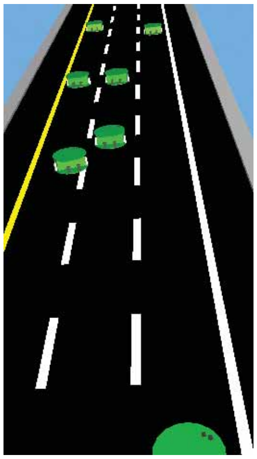
A computer model of the body members of a 1980 Volkwagen Rabbit, made by Michael Scott (MS '94, PhD '99), Zee Khoo (BS '98), and Juan Nuño (BS '99). Scott plugged in various thicknesses for the assorted pillars and panels to see how the body's stiffness changed, and evaluated the results with the Method of Imprecision.

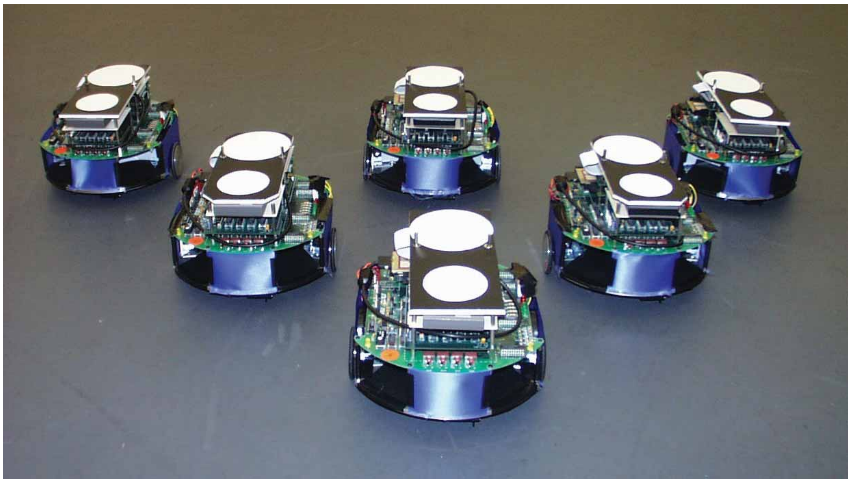


Scott and Antonsson, Preliminary Vehicle Structure Design: An Industrial Application of Imprecision in Engineering Design, *Proceedings of DETC '98* © American Society of Mechanical Engineers 1998

Good engineers develop a "feel" for such things, but quantifying them for a computer is a thorny problem. Things affect one another in ways often not reducible to simple formulas, and there's a horrible mishmash of units—in evaluating a minivan's performance, how do you relate pounds per square inch of tire pressure to miles per gallon of fuel efficiency? Some performance requirements may be graven in stone, such as EPA emission standards; while others may offer more wiggle room—the wheelbase should be 105 inches, give or take a handsbreadth; and let's not even talk about style or color, but looks matter too. Regardless of how well-engineered or cheap to manufacture, the design is a flop if nobody buys it, so purely aesthetic preferences such as sleek, wide windows must be incorporated as well. (Here a variable for the door post's position—the farther aft the post, the wider the window—would serve.) You tell the computer what you want by assigning a preference rating of 1 to the most preferred value of each variable, allowing the machine to compare the relative merits of all possible trade-offs. But if your desired cruising range is 400 miles per tank of gas, say, it's unrealistic to simply program that preference as $r \geq 400$, because 400.01 miles per tank would be perfectly acceptable, generating a preference rating of 1, and 399.99 would be completely unacceptable, scoring 0.

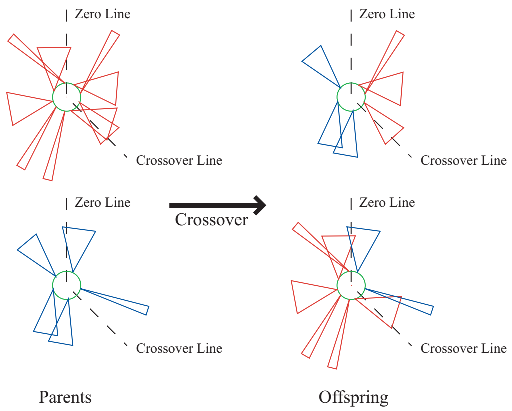
Antonsson and Kristin Wood (MS '86, PhD '90) introduced what they christened the Method of Imprecision, which replaced yes/no calculations with a provision for indicating the designer's and customer's degree of satisfaction with each intermediate performance level. Now the all-or-nothing stairstep became just a special case of a broader class of functions. The trick, of course, was to be sure all the variables were correctly selected and the preferences properly coded—not a trivial task. Then he and Kevin Otto (PhD '92) "formalized," or set up computer-friendly rules, for the process of analyzing trade-offs using the





Grad student Yizhen Zhang's collision-avoiding robots live in a computer, left. If she ever decides to study the real thing, this fleet of Moorebots, right, is available. Housed in the Moore Laboratory of Engineering, they are essentially PCs on wheels.

In the robot-anatomy sketch below, the triangles represent the sensors' fields of view. The "chromosome" for each robot begins at its zero line (facing dead ahead, in other words) and proceeds counterclockwise around its rim. Each sensor is encoded as four variables: position, look angle, range, and width of view. A crossover is tantamount to cutting the robots like wheels of cheese and trading the pieces.



mathematics of "fuzzy" sets. In a nutshell, the system multiplied each preference by a weight factor that reflected how important it was. Then the trade-offs were evaluated under various schemes—either "compensating," pitting headroom against gas mileage, for example, and finding their highest combined rating; or "noncompensating": you make any one bolt in the undercarriage too weak and the axle falls off. And he and William Law (MS '93, PhD '96) developed a system for creating hierarchies or "trees" of trade-offs so that you could, for example, analyze the safety margins of the load-bearing parts in a noncompensating way while independently balancing cost versus weight, and then combine those two results in another noncompensating calculation. Antonsson's group was the first to apply fuzzy math to engineering design; some half-dozen academic labs worldwide and several industrial ones, including at General Motors and Ford, have since taken it up. His own lab has looked at gas turbines; passenger-car bodies; and an aeroshell for a Mars penetrator similar to the two Deep Space 2 probes lost with the Mars Polar Lander, done with Robert Glaser (MS '71, Eng '73), a Member of the Technical Staff at JPL.

Examining every possible combination of potentially thousands of design and performance variables sucks up a lot of computer time, so three of Antonsson's current grad students are exploring evolutionary design, using the various design parameters as "genes." A computer creates random design configurations, each encoded as a sequence of numbers—the genes on the "chromosome"—and puts the designs through a series of simulations. Their performance in these simulations is then evaluated using the Method of Imprecision. The good designs are allowed to breed by "pairing" the chromosomes, cutting them somewhere, and swapping one of the two pieces in what biologists call a crossover. A chromosome may also get zapped by a random point mutation, and genes can even be added or deleted, changing the design's complexity. The offspring get evaluated against one another and against the survivors of previous rounds, ensuring that the population as a whole gets fitter with time.

Third-year grad student Yizhen Zhang (MS '01) is testing evolutionary design on a relatively complex problem by trying to find the optimum arrangement of sensors that will allow a "smart" car to avoid collisions with other vehicles. (Zhang is coadvised by Alcherio Martinoli, a senior research fellow in electrical engineering in Caltech's collective robotics group.) A proximity sensor's cost depends on its range and field of view, so for maximum coverage at minimum cost, is it better to have a few expensive sensors, a bunch of cheap ones, or something in between? Zhang uses a commercially available software package called Webots that models fleets of robots in a computer. Each trial has seven robots driving down a three-lane freeway—no oncoming traffic to worry about, in other words—changing lanes as needed to maintain their randomly assigned preferred cruising speeds, and braking when they have to in order to avoid collisions. One robot carries the sensor array; the rest are just traffic, and the Webot software pilots and tracks all of them from a helicopter, as it were. An invisible "bubble," called the detection region, surrounds the sensor-bearing robot. Whenever another robot penetrates the bubble, the computer determines whether the intruder passes through a sensor's field of view and is detected. When only one type of sensor is permitted, the simulations have evolved vehicles endowed with as many as 20 of them. But when the ranges and fields of view are allowed to vary as well, six to eight sensors suffice to register 99 percent of the vehicles entering the detection region. Zhang hopes to eventually use data from the sensors themselves to steer the vehicles, she says, but "right now the challenge is just to see how well the robot detects things in its environment."

Second-year grad student Fabien Nicaise is expanding on work other researchers originally did in two dimensions, in which the computer "grows" a truss that will support a load with a given margin of safety and a given degree of stiffness—and, eventually, for less than a given cost. (The system currently uses the weight of the beams as a proxy for their price.) The computation begins with a tripod and adds more legs, or changes their thickness, then decides whether the stiffness gained is worth the weight. The goal is to make the truss members smaller and smaller until they blend into a continuous solid, at which point the system would be able to evolve free-form shapes.

Third-year grad student Bingwen Wang (MS '01) hopes to automate the process that creates design genes by borrowing ideas from integrated-circuit design. When you design, say, a new memory chip, you tell the computer, "I want this region of the chip to perform this function to these standards," and the machine does the rest, using a recipe book of procedures called algorithms. Wang is trying to apply this notion of modularity to electromechanical systems. In a minivan, for example, the engine, chassis, and seats would all be modules. And you can have modules within modules—the engine includes the ignition system, the carburetor, and so on, and the ignition system contains spark plugs, which consist of….

Ideally, the computer would figure out the modules and their hierarchy automatically. This means you need a mathematical definition of modularity, which is not as simple as it might seem. "There are some intuitive definitions of modularity," says Wang. "But they do not include information flow." In other words, before you design something in detail, you sketch out how it is supposed to work. You write each function down, draw a box around it, and connect the boxes with arrows representing their interactions. For example, the ignition system has to fire the spark plugs at the correct rate for the engine's speed, which is determined by how hard you tromp on the gas pedal and regulated by a feedback loop that includes a vacuum sensor linked to the intake manifold. "Most definitions of modularity do not consider the attributes of the interactions, and only consider them as links." But the attributes exist—in this example, some of the interactions are electronic, some are mechanical, and some are fluid-mechanical, and this kind of information can be written along the arrows. There are many possible ways that the functions could be grouped into modules, so Wang is developing a set of algorithms that will use the arrows' annotations to find the grouping with the highest modularity.

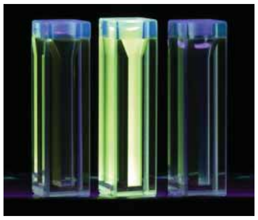
In nonevolutionary work, first-year grad student Tomonori Honda is expanding on Otto's treatment of uncertainties such as manufacturing tolerances (12-gauge steel can vary in thickness by half a millimeter—how does this affect the stiffness?), external factors (is it for use in Miami or the Antarctic?), and even wear and tear on the components. Otto evaluated one variable at a time, and then aggregated the results into an overall score for each design. Honda is aggregating related uncertainties into multidimensional calculations that can then be organized into a hierarchy, vastly reducing the amount of computer time needed. In the process, he's discovered that the methods of correlation chosen, and the order in which they are performed, can significantly affect the outcome.

And first-year grad student Lisa Dang wants to work on rocket engines powered by radioisotope thermoelectric generators, or RTGs. RTGs convert the heat from decaying plutonium into electricity that could run an ion drive, like that on JPL's solar-powered Deep Space 1. They power the instruments on spacecraft that fly too far from the sun to use solar panels, but today's models aren't strong enough to run a thruster. Dang is hoping to parlay Antonsson's JPL contacts into a research position in the RTG part of the Project Prometheus Program, which began funding in fiscal 2003.

Which brings us to the question, What does JPL's chief technologist actually *do?* The press release announcing Antonsson's appointment said he's responsible for "planning, implementing, and leading JPL's technology strategy" and "top-level coordination and assessment of technology work and infusion in flight activity," which translates into an endless string of meetings "driven largely," he says, "by the desire of some large fraction of the 5,000 people that work at the Lab to get a few minutes of my time to talk about something they feel is important for the chief technologist to know about." This takes some flexibility—on a recent morning, his 9:00 meeting started 15 minutes late and had to end 15 minutes early when out-of-town visitors showed up unexpectedly and needed to be worked in before the 10:00 meeting started. But the truncated half-hour meeting wound up taking 40 minutes; the 9:45 visitors became the 9:55 visitors and, when last seen, Antonsson's assistant, Annette Ling, was trying to get the 10:00 meeting postponed to 2:00, and the 2:00 switched to another day. There are administrative meetings, program-strategy sessions, technical discussions, and, in the odd free moment, mountains of reports to read.

The highlight of Antonsson's week is Tuesday afternoon, which he has set aside to play scientific tourist. "I get to actually go out and see the technology that various groups on Lab are devel-

A small sample of JPL's advanced technologies. This "spiderbot" prototype, left, fits in the palm of your hand, and its forelegs can grip and lift twice its body weight. Someday, a squad of sophisticated spiderbots might roam the surface of Mars in search of life. Such 'bots might store energy in ultra-light wafer batteries, below left. And before leaving Earth, they might be checked for sterility by an automated process that generates a fluorescent signal when spores are present, bottom left. Antonssons' bailiwick also includes developing non-hardware technologies, such as swarm intelligence and autonomous systems that can "think" for themselves.



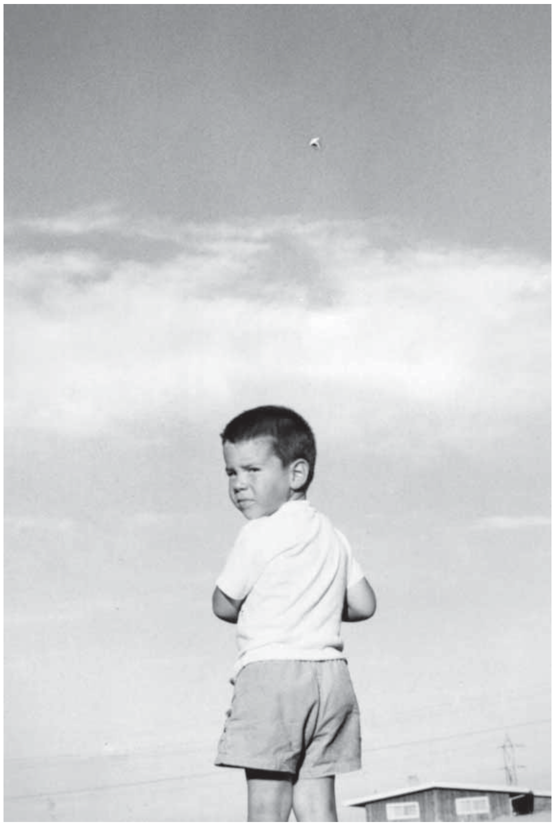
oping. And those are *wonderful*. I love those lab tours because I see dedicated people, excited by the work they're doing, in their native habitat. Right there with the oscilloscopes and vacuum chambers, and all the *stuff*."

The point of all these meetings is to become a technological handicapper, in the racetrack sense of the word. Antonsson and Chief Scientist Tom Prince (a Caltech professor of physics) manage JPL's Research and Technology Development Fund, which amounted to some $10 million in fiscal '03, and which JPL's director, Charles Elachi (MS '69, PhD '71), has pledged to increase to around $50 million over the next several years. It's a drop in the bucket compared to JPL's roughly $1.5 billion budget, but "it's a pivotal fund," Antonsson says. "It's the Lab's venture capital—the fund for speculation, to say, 'Hey, I've got an idea for a totally new sensor. I'd like some money to see whether it will really do what I think it'll do.'" If the idea pans out, it can then be written into the mission profile of a spacecraft on the drawing board, and its development becomes part of that mission. "Job one for me is building a strategic plan for advanced technology: where should the Lab be putting its resources to be most effective in developing the most important—strategically important—technologies for its future? What can be done to best position us to accomplish the missions that, as a group, the Lab feels are most important? I've organized a working group of technologists, and we hope to have a first draft of a plan pretty soon." At the moment, it's more a set of bullet points than a document.

Not all meetings are at JPL. Antonsson is JPL's senior representative for technology research to the rest of NASA, to the White House Office of Science and Technology Policy, and to other techno-agencies. He's been to NASA Headquarters in Washington four times already, and expects that a couple of two- or three-day trips a month—to any of a number of places—will be the norm; as a father of three school-age kids, he's hoping it will be no more than that. Some excursions are more science-touristy, like the day he spent at the Air Force Research Laboratory in Dayton, Ohio. He also plans to drop in on corporate labs. "I got an invitation from Ball Aerospace to help review their internal R&D program, which I had to decline. But I'd be delighted to participate in the future, given more notice, so that the Lab is well-informed about the most advanced technologies that these contracting organizations have available." Another "part of my job is university relations in general, and Caltech and the engineering and applied science division in particular. There are many opportunities for collaboration, but the two institutions have dramatic differences in mission."

Antonsson spends every Thursday on campus. He's disentangled himself from most of his faculty commitments—executive officer for mechanical engineering, director of the Engineering Computing Facility, and memberships on the engineering and applied science division steering committee, the division advisory group, and the Caltech/MIT Voting Technology Project. He is, however, retaining his seat on the faculty board to keep the information pipeline to campus open. And the ME 72 contest will go on, as will the other courses he teaches in various aspects of design and kinematics. He's brought in a "really great" design instructor, Maria Yang from Stanford, along with Karl-Heinrich Grote, a visiting professor from Otto von Guernicke University in Magdeburg, Germany, and visiting associate Curtis Collins from UC Irvine, to teach and to help run his lab. "I've been telling them where all the bones are buried and how things work. So I'm still involved in teaching, and it isn't that I *want* that to go to zero, but I'll have to try to make it as close to zero as I can." He's trying very hard to devote his campus time to keeping his own lab from becoming just another roadside attraction on one of his

From the grad students' point of view, meeting with their advisor just once a week seems to be working out pretty well. "You only have to stress one night a week about your work, rather than every night," says Honda with a grin.



At an early age Antonsson was already prototyping devices for high-altitude research. Or would be, if Dad would just leave him alone...

scientific tours. "The ideal is that I pare back everything except advising my graduate students. My goal is that the research in my group will continue at much the same pace as it had been; I'm enough of a realist to know that it will be imperfect, but it's the best I can do. As I say to people who ask how it's going, I used to have one completely overwhelming 50+ hour a week job as a Caltech faculty member—now I have two."

From the grad students' point of view, meeting with their advisor just once a week seems to be working out pretty well. "You only have to stress one night a week about your work, rather than every night," says Honda with a grin. Says Wang, "A half-hour meeting every week seems to be enough time to get everything done. And this gives me freedom to develop ideas on my own." It might be different if the students were building physical structures, but since all the work is done in simulations, the only thing that can come crashing to the ground is the computer. And if an idea really goes south, Antonsson is only a phone call or an e-mail away.

Antonsson is now roughly a quarter of the way into his two-year leave of absence—time spent mostly in learning how the Lab works and how to speak NASA. In the political world, the first term in office is usually just about enough time to get fully acclimated, so has he given any thought to extending his leave, or going up to JPL permanently? While interviewing for the job, he talked to Ed Stone, Morrisroe Professor of Physics, director of JPL from 1991 to 2001, and project scientist for the Voyager missions [see page 10]. "He was quite influential in convincing me that this was a position that I really should accept. He also said that he thought two years was about right, but probably a little short. I'll be learning and learning and learning, and at the end of that two years, I would be educated sufficiently to be valuable to the Laboratory, and that I would find myself under some pressure to stay. I can only hope that comes true. And he said that I may well want to stay on for a *little* bit longer than two years, but he recommended that I absolutely not stay on longer than three because the rate at which I will be learning new things will decrease. He also said that my position on campus—students knowing me, my position in campus life and politics—would also decay with time, and that if I am away more than three years it would be really detrimental. And I've taken his advice to heart."

Meanwhile, Antonsson's academic specialty has proven a real advantage in his role at JPL, because "engineering design inevitably draws from many technologies in the course of solving the problem at hand. So the people involved in engineering design tend to be conversant in a variety of technologies, in order to be able to know when and how to use them. And that's what the chief technologist does." And his stint at JPL is providing insights he'll be able to use in his own lab. "JPL as an institution designs and builds incredibly complex systems, so I have the opportunity now to see how these design problems are solved in the real world, what strategies work, how performance requirements are integrated, and how different constituencies negotiate trade-offs with one another, and that will help inform the research that I will do going forward." □

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28, 31 – Bob Paz;
30 – Slobodan Tepić;
33 – Yizhen Wang, Adam T. Hayes, Doug Smith;
35 – JPL; 36 – Arvid Antonson