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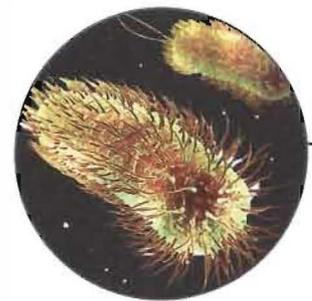
- 'Bot Destruction **David Speidel** 4
A CU-Boulder robot fights its way into Battlebots finals.
- Putting the Engine in Engineering **Marnie Richard** 6
SAE races ahead with its Baja and Formula cars.
- Seeking E.T. **Jackson Lee** 8
Astrobiology explores the possibility of life on other planets.
- The Need for Speed **David Crennen** 10
Students across the world race to complete a car design.
- Engineering Goes Global **Todd Fielder** 14
Engineers Without Borders improve living conditions worldwide.
- Modeling Adventures **Lilly Georgieva** 17
CU-Boulder students devise an airline revenue plan.
- Have you had your MEMS today? **Otto Krauss** 18
Microsystems lead to big innovations.



SAE speeds ahead... P6

o p i n i o n s

- Who's the New Guy? **Joseph Carrafa** 12
Transmeta unveils their groundbreaking Crusoe processor.



Does life exist beyond Earth?... P.10

t h e n o r m

- Editors' Note **Toni Newville and Evan Thomas** 2
- Dean's Corner **Robert Davis** 3
- The Fun Page 21

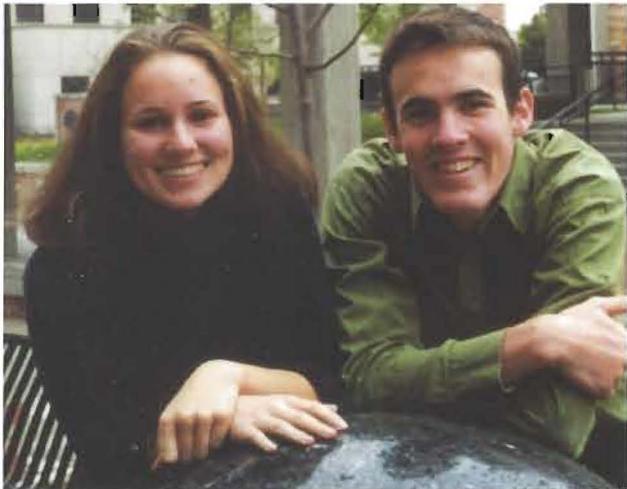


EWB around the globe... P14



Cover: Astrobiologists seek traces of life beyond Earth. Design by Toni Newville and Chris Poyzer.

editors' note



The new millennium is off to a bad start. All over the world, life is being destroyed and civilization seems to be regressing. Rather than coming together in understanding and for exploration, we are pulling ourselves apart and continuing toward war and further suffering.

What can we do about it? As engineers we play a significant role, if we each choose to, in bettering the world around us.

We can build up those disadvantaged communities, educate our young counterparts all over the world, and explore what is beyond our planet. *Engineers Without Borders*, profiled in this issue, stands as an example to engineering organizations by "building a better world, one project at a time." EWB engineering students travel the world aiding developing communities, making a difference.

In the field of astrobiology, scientists and engineers are making headway in finding out what is beyond Earth. In this issue, our readers will discover new and fascinating possibilities for human growth and discovery in the cosmos.

Engineering growth is also progressing on the microscopic scale. Micro Electro-Mechanical Systems, a significant research branch, is finally made accessible to the average engineering student in this issue's article on MEMS.

Industry has applied new machining techniques in part through new processor designs. A contender for state-of-the-art computer processors is Transmeta, profiled in this issue.

The desire for discovery and learning unites engineering students all over the world. Read about the 24 hour-a-day design process for a car that brought together students from Boulder, England and Singapore.

Cars are a popular outlet for engineering endeavors. The campus *Society for Automotive Engineers* chapter has expanded to competing two of their cars, the infamous formula racecar and the newcomer Mini Baja. Both of SAE's competition entries continue to improve their performance and reliability each year.

Engineering students can find their own ways to take out aggression, safely. 'Chummy', a CU-Boulder Battlebot, performed admirably at the televised Battlebots competition in San Francisco this year. On a less dynamic scale, math and engineering students have also applied their education in mathematic modeling, simulating airline overbooking. These adventures are all found in this issue of CEM.

On campus, the *Discovery Learning Center*, having recently opened, will provide engineering students an opportunity to work together for research and learning. Congratulations to the donors, faculty and staff that made the DLC a reality.

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Dean's Corner

This year, 2002-2003, is a remarkable time to be a student in the College of Engineering and Applied Science at CU-Boulder. It is already a year of tremendous accomplishment, and one in which we are laying the foundations for even greater excellence and recognition in the years ahead.

As the new dean of engineering since July, I am pleased to share with you some highlights that you can be proud of — and some that you can participate in — as a student in the college. My goals for our college are that we be widely known for excellence in both education and research and that each student participates in active learning.

As a college, we are nationally renowned for our record of providing active-learning opportunities to students. The faculty and I encourage you to become involved in hands-on design projects, such as those offered through the Integrated Teaching and Learning Laboratory and through the capstone courses in our academic departments, and to seek out opportunities to participate in research as an undergraduate as well.

On Oct. 18, the college celebrated the opening of the Discovery Learning Center, our newest active-learning facility. The DLC offers opportunities for undergraduates to be part of collaborative teams with graduate students, faculty, and industry or government sponsors, working on solutions to current research problems. Eleven top engineering research groups were selected to be initial tenants in the facility, which was designed by the same architectural firm as the ITLL (Klipp Colussy Jenks DuBois) to be a showcase for engineering research and its impact on society.

I encourage you to visit the Discovery Learning Center to see if research is something that interests you. Undergraduates who have been involved in research can attest to the value it adds to their education by allowing them to use what they have learned in the classroom to accomplish a real-world goal.

Other ways that you can participate in active learning include internships and outreach activities where you apply what you have learned in the classroom in a professional environment or through community service. Many of you have enrolled in the college's First Year Engineering Projects course, but your active learning experiences need not end there.

A group of students from the College of Engineering and Applied Science recently teamed with students in the College of Architecture and Planning in the "Solar Decathlon," a national competition to design the most beautiful, most livable, and most energy-efficient solar home. I am pleased to congratulate the team, led by architectural engineering Professor Michael Brandemuehl, for placing first in this national competition. Not only did the team excel in designing the best solar home of all the teams, but it built the home and represented CU-Boulder in Washington, DC, bringing well-deserved recognition to the college and its students.

As you go forth in your own college experience, I encourage you to seek out the faculty during office hours, to take charge of your own education and to pursue excellence through active learning, whether in research, design projects, or summer internships. You and your future employers will be glad you did! I also invite you to stop by the Engineering Center lobby for doughnut holes at 9 a.m. on the first Thursday of each month and to talk with me and with others from the Dean's Office.



Photo courtesy Ken Abbott, University Photographer

Robert H. Davis

Robert H. Davis, Dean
College of Engineering

'BOT DESTRUCTION

David Speidel

Five CU-Boulder students battled their way into BattleBots televised finals with their not so friendly robot, "Chummy."

Technology has come a long way since the *Rock 'Em Sock 'Em* Robots of the '60s. Today we have something much more dangerous and entertaining: BattleBots! Recently, University of Colorado at Boulder students built their own BattleBot, and when they were finished, they had "Chummy" to compete in "BattleBots Season 5.0."

At the beginning of the 2002 spring semester, student Ann Hjelstrom wondered what she could do to make her senior project class more fun and rewarding. After talking with some advisors and faculty, she was allowed to design and build a fighting robot for the BattleBots competition in San Francisco. With the help of Casey Haskell, Eric Kozubal, and Brian Gleeson, team Flip Vibe was born. They began by receiving donations from local companies and university groups in order to pay for the bot and start the design process.

Chummy's outer shell was designed using Solidworks and I-deas software. The layout was conceived to be like an upside-down pie tin, but after some brainstorming, the team decided on an octagonal design. This shape created flat, angled side surfaces for a good geometric yet defensive design. It allowed Chummy to get underneath other bots when attacking,

while inhibiting the opponent from overturning him from all angles. The armor was made of normalized (stress relieved and slightly hardened), 1/16" thick 4130 steel. This combination allowed team Flip Vibe to have a relatively large BattleBot in the weight class.

Unfortunately, budget constraints prevented Chummy from being armored by stronger steel or the desired material, titanium. Furthermore, the large shape of the bot prohibited the team from completely hardening the steel.

The BattleBot's weapon consisted of a 5"-stroke, 2.5"-bore pneumatic cylinder connected to the front panel of Chummy, which acted as a flipping panel. The panel structure (4130 SST) and linkage

(computer machined from 6061-T6 aluminum) was re-enforced to withstand the 750+ lbs of force from the pneumatic system. The air supply was assembled from a number of standard paint-ball accessories.

It was modified to allow for large diameter tubing to stretch from the regulator to the cylinder in order to form an expansion chamber that would overcome the flow rate limitations of the pressure regulator. The pneumatic solenoid was a high flow-rate solenoid with a Cv of 3.0.

The RC receiver was connected to a



Chummy shows off his inner workings, which include a pneumatic cylinder and an RC receiver.



Casey Haskell welds parts of Chummy together. Team Flip Vibe spent many long hours in the ITLL Manufacturing Center machining their BattleBot.

high current RC to DC switch that activated the solenoid. All pneumatic equipment was encased by either the bot armor or 1/4" lexan to protect the integrity of the high pressure system (required by BattleBot regulations). The drive train consisted of 2 NPC wheelchair motors controlled by 2 NPC motor servo drivers. This system was controlled by RC inputs from their RC radio receiver. The receiver chosen was a typical RC car 2 axis steering + 1 extra channel. The car type signal required the use of custom electronics to convert the RC signal (forward/reverse and steer left/right) to left and right motor forward/reverse signals. The BattleBot regulations required that all pneumatic equipment and system shut-offs be accessed within 30 seconds. This brought up some interesting design decisions. The team decided to gain access to



Chummy faces off against Deadblow in the BattleBots arena.

Chummy's components and switches by allowing the top panel to flip open. Less than three months after team Flip Vibe was created, Chummy was finished and on display at the spring 2002 Design Expo.

After hard work at the last minute to prepare the bot for the May competition, the team arrived in California only to find that their pressure regulator had failed and the radio frequency they were using was prohibited by the BattleBots competition. Team Flip Vibe found a new regulator at a nearby paintgun shop, which also had more efficient tubing. The team also found a new radio controller permitted by BattleBot regulations.

Despite having taken a heavy blow in the first round, Chummy won the first two fights by pushing his opponent around the BattleBox arena. The third battle was against "Deadblow," a robot that had

fought its way to second place during Season 3.0. It was a grueling fight, but after the bell had rung without a knockout, Chummy won by decision with two points to spare. The fourth match was televised unlike the previous preliminary rounds; this broadcast meant that the BattleBots' "hazards" were turned on. These hazards include augers, hammers, kill saws, spinners, and pneumatic spikes. Chummy was flipped like a hamburger twice by the infamous kill saws launching him across the arena. The final blow came from the "Pulverizer" hammer bending the frame and popping out a mounting bolt from the gear box. The opponent, Wee Willy Wedgie, was just too much for Chummy, but Team Flip Vibe was proud of all their hard work that resulted in a television appearance and finishing 34 out of 140 initial bots.

There is a new team led by the CU Robotics Club that plans to build a box and wedge design, similar to the one that



Teams ready their robots and make last minute adjustments in the pit area of the BattleBots arena.

defeated Chummy. Its primary weapons will be its high torque, speed, a flipping arm, and... a secret weapon. The team will try to raise money for the project by driving a keg-bot around campus in an attempt to elicit funding.

Chummy is currently being rebuilt and was in good enough shape to present the scissors for the ribbon cutting ceremony at the opening of the new Discovery Learning Center. Team Flip Vibe and the University of Colorado Robotics Club could certainly use support to help keep this young yet exciting sport alive and thriving. ♦



Members of Team FlipVibe pose for a picture with their creation. From left: Eric Kozubal, Casey Haskell, Ann Hjelstrom, and Brian Gleeson.



Putting the **ENGINE** in Engineering

Marnie Richard

In the back of the Durning Lab at the University of Colorado at Boulder's Mechanical Engineering wing, parts of a Formula racecar sit on a table waiting to be assembled. When completed, it will be a small, sleek vehicle that can only hold one person; but its size makes it competitive. It was built to race, reaching speeds of over 110 miles per hour. Nearby is the chassis for another small car—the Mini Baja. The Baja is an off-road vehicle that can climb stairs and maneuver rugged terrain.

The Society of Automotive Engineers' Formula racecar, built by 21 members of SAE, placed 34th out of 125 in SAE's annual Formula car race in Detroit last year. Students from CU-Boulder competed against teams from countries around the world, including Japan, Australia, South America and Canada.

Thirty-fourth is the highest CU-Boulder has placed and the highest that any competing Colorado school has ever placed in the competition. Nonetheless, the designers hope to improve their ranking this year. They are planning to lighten the overall weight of the car by 100 pounds, making their new vehicle weigh less than 500 pounds.

The Formula Racecar uses a 600 cc, 4-cylinder engine. "The car is very fast,"

says SAE president Mark Binsfeld. SAE often brags that it has the same power-to-weight ratio as a Ferrari 550.

The biggest problem in generating power with the Formula car has to do with the air intake. "The intake is restricted;

annual race in Detroit. Once there, each car must "pass tech," and comply with an extensive list of requirements. Before the race begins, professional engineers look over each car thoroughly. "It takes a little while to pass tech because the car may

have one or two things that don't comply with the rules. The team must fix these items before they are permitted to race," said Binsfeld. If a car has even one minor flaw, it may not race.

The four-day competition consists of two major parts. The cars are judged based on their construction cost and the overall designs. The other part of the competition looks at the performance of the vehicle, including acceleration, cornering, and endurance. "Pre-competition testing is paramount to the team's success," said SAE's Brendan Rudack.

Fortunately for the team, last year's yellow car is a good design to use for the upcoming year's vehicle.

The Mini Baja is also a small car, but can handle a severe beating. Unlike the Formula, it does not compete against the clock. Instead, it vies in endurance battles. "The vehicle can take five to seven foot drop-offs easily as long as it lands on



Mechanical engineering student Brendan Rudack prepares to race the Formula car at the annual Society of Automotive Engineers Formula racing competition in Detroit, Michigan.

all air must pass through a 20 millimeter hole which really limits the output horsepower of the engine," said Binsfeld. "We've been reaching 67 horsepower, and I think the maximum is in the high 70s, so we've been doing really well... and every year we've been able to improve that," he added.

After spending months designing the vehicle, the designers are ready for the

its wheels," said this year's Mini Baja team leader, Bradley Dickerson. According to Dickerson, it effortlessly climbs stairwells, and "can fly down them." Its unique chassis makes this possible.

The Mini Baja has a pull-start engine, like a lawn mower. Unlike a lawn mower, however, the Baja's engine is large enough to use unmixed, regular unleaded gasoline and can compete for about three hours between refills. It also uses a ten-horsepower Briggs and Stratton Engine and reaches 20 to 30 miles per hour.

The Baja car is newer to CU-Boulder than the Formula. The design group participates in three competitions each year, including the West Competition in Provo, Utah, and in the Midwest Comp in Troy, Ohio. The competition in Troy is a "grueling endurance race involving hill climb, rock crawl, and acceleration," according to Dickerson. "Last year's car was very competitive in the West Competition until the trailing arm broke on the solid-axle rear suspension design. They were unable to get the car fixed in time to compete in the second competition."

The Baja team is improving its car this year to make it more competitive. This year's vehicle will be built with 4130 Chromoly tubing to make it stronger and lighter. "This is a substantial upgrade from the mild steel used last year," Dickerson said. This adjustment should prevent the trailing arm from breaking

again. They will also be using independent rear suspension to help deal with this problem.

Essentially, the back wheels will no longer be connected by a single axle and will spin independently of each other.

Many things will also remain the same for this year's Baja. Its drive ratio helps it with dynamic events and its continuously variable transmission was an asset to last year's car. The Baja's CVT allows for fast and smooth acceleration without shifting gears, which means that, as the vehicle speed increases, the belt moves out the V-shaped pulleys to give a different drive ratio. While most automobiles have four or five speeds, the Mini Baja has all speeds and continuously shifts.

The Baja is so powerful that it has climbed the large, concrete barricade that guards the Duane Physics parking lot. The key to this feat is to drive at an angle, so that the car doesn't high-center. The Baja team often trains on the business field for off-road experience, but the CU



The chassis of the Formula car sits as it is being constructed in the Durning Lab, where both the Baja and Formula cars are created and designed.

Photos courtesy Brendan Rudack

Police Department does not allow such training, and has ticketed drivers practicing there and on the sidewalks at CU-Boulder.

Five students are contributing to the Baja car this year for their senior projects in Mechanical Engineering. Six members of the Formula team will use the car for their senior project, and underclassmen help both teams. Building and racing with SAE gives students a chance to apply what they have learned about engineering, as well as presents them with problems they may have to face in their professional careers that are not covered in textbooks. "The team is limited mostly by its budget, something not taught in class. Money does not grow on trees and the students must find ways to raise it for the project," said Binsfeld. "The students must learn to design and manufacture components that optimize performance, while staying within a confined budget and time frame, all very challenging lessons that really are not taught in the classroom."

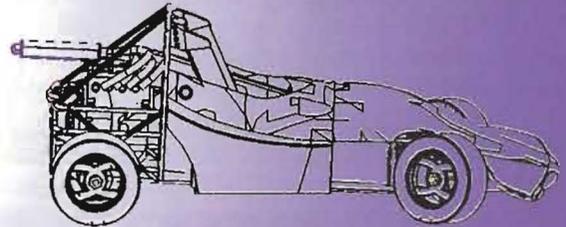
The teams have sponsors to help with the cost of the parts and maintenance fees. The Formula team's biggest sponsor is Ford and this year, they are trying to obtain a sponsorship from Audi of America and General Motors as well. They also receive funds from the Engineering Excellence Fund, the University of Colorado Student Union and the Mechanical Engineering department. Various manufacturers offer discounts on their products as well. The Mini Baja is also involved in fundraising to help with expenses, but has a long way to go this year. With necessary funding they hope to receive, the two design teams hope to continue improving their cars and increase their national rank. ♦



The SAE Formula racecar speeds past its competitors at the 2002 Formula race in Detroit.

THE NEED FOR *Speed*

David Crennen



A CAD drawing of the car designed by the Global Design Initiative team.

We live in a global village. We hear this everyday and we know we are the participants. MTV broadcasts from Britain to Nepal. We mail-order shoes directly from Japan. We can place a long distance call to Saudi Arabia. Yet, despite all this, something is lacking. We say global village and global community, but what we truly have is something much more anonymous.

After all, a village is known for the closeness of its members. In small towns in days of yore, a man could expect his neighbors to throw in a helping hand when a project needed to be done quickly and skillfully. Where is that closeness in our global village?

Heiko Gierhardt, a Ph.D. candidate at the Technical University of Munich, might have the answer. He initiated a plan in the spring of 2000 for a ground-breaking idea, one that draws the world closer to the shape of a true community than ever before. Funded by BMW, Gierhardt approached the university with a proposal to design a variable speed, mass balanced, one-cylinder test-bed engine for

his manufacturer. Time is the great obstacle to all companies. Every inactive hour means one more hour until launch and one more dollar lost.

To this end, BMW formed the "24 hour Around the World Around the Clock" project, a collaboration between the Technical Universities of Munich and Darmstadt in Germany and Clemson

University in South Carolina. The goal was to work a ceaseless day, each group putting in a full eight hours in their time zone, then passing the torch onto the next runner – a marathon of work covering three times as much ground as each group could alone until the final was blueprint resolved.

It was an ambitious project, and the initiators themselves knew it was merely an experiment, one they expected to become bogged down by communication hurdles. Each team consisted of a group of undergraduate seniors, but the similarities ended there. Each group would have to deal with differences in education, geographic position and language itself. Yet,

while the students were expected to achieve a consensus on a solution and give a general description, they in fact produced a detailed layout ready to be taken to the production facility. This resounding success in the face of adversity heralded the inception of something new. It was a birth of a brave new process that promised to revolutionize engineering across the globe and to become the next step in bringing the world closer.

The BMW experiment was only a birth. It takes great engineers to develop an idea, however promising, into an everyday concept. At this point Aston University of Birmingham, England entered the scene and picked up the project where Munich left off. The concept was the same, round the clock engineering, but the execution was a step up. Last spring semester from March 11-15, Chris Evans, Patrick Littlehales and Neil Hardy, all of Aston, began and finished an unprecedented undertaking, the Global Design Initiative. Three teams, spread across the world in England, Temasek Polytechnic in Singapore, and at the University of Colorado at Boulder were to work together for those five days and finish with the completed three dimensional layout for a racecar. The mission statement was simple yet daunting -- create, in 120 hours, the entirely complete design of a functional one person car. Calling the attempt ambitious was an understatement, especially in the light that nothing of this caliber had ever been attempted before, everything that preceded the GDI project paled in comparison. Feelings of anxiety were well-grounded: after all, the Society of Automotive Engineers, who each year hold their racecar construction project, allow a full semester for design. To do such a thing in a single workweek was never contemplated.

Beginning Monday, March 11th, in Singapore at 1:00 AM Greenwich Mean Time the planning began, designing the chassis and body. Seven hours later Temasek entered a videoconference with Aston where the two teams discussed development and planned further

advances. At 10:00 GMT the British team began their work, plotting out the engine and attachments before passing on to CU-Boulder where work commenced on the wheels. As Temasek resumed their labors once more, the flurry of activity first day was officially over. The workdays were arranged so there was an hour overlap on both ends, a time for video conferencing and consulting, done in real time through web cams and microphones.

CU-Boulder's work on the car

“WE WERE DESIGNING A DESIGN PROCESS”

focused chiefly on the steering and suspension systems. Such essential parts as the shocks, uprights, hydraulic steering system, tie rods and even the steering wheel were all the domain of the team.

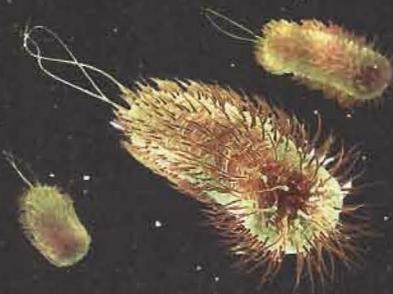
To complete the car in the time limit, the key was portioning it into a number of systems that each group could labor on largely individually. Essentially the car was broken into three sections that were allotted to the different teams depending on the specialization of the students. While CU was doing its part, Aston planned the engine and chassis and Temasek did the bodywork and tended to the small details that did not fall into the dominions of the other universities. All the components were arrayed in a large database program that regulated who could work on a part when, preventing simultaneous development by different teams. However, after three days, the program became too bulky to manage efficiently. To remedy this, the files were moved to a server that the groups could FTP to and from. The

compartmentalized execution of the project did have its share of downfalls. The essentially linear nature of much of the car design, the necessity of one part to be completed before others, caused unavoidable bottlenecks to sporadically occur. Despite the limitations of the technology, the undertaking proceeded largely as planned and as scheduled.

Such a large undertaking requires immense amounts of organization and teamwork. The faculty advisors of the Boulder group were Professors Ken Gall and Larry Carlson, both professors of mechanical engineering, who found the crew that would work at CU. To Gall, the appeal lay in the uniqueness of the task, commenting that, “This is the first time this has ever been done in an educational setting, it gives the students an opportunity to be in on the ground floor of something really innovative.”

The students consisted of twelve engineers, ranging from freshmen to graduate students. The team was co-led by student BSMS Doug Schuler, and doctoral candidate Brian Corff. In fact it was these two students who were the true motivational source behind the Colorado team. What would have been considered gruelingly difficult just decades earlier has been done with ease.

Though hemmed in by fearsome time constraints, the teams pulled through in time, and produced a functional and complete model. What can be said of the GDI experiment in the end? Corff perhaps puts it best when he simply states, “It worked surprisingly well.” Is the car manifestly better than one created by other means? That's not the point. As Corff continues to explain, “We weren't really designing a car, we were designing a design process.” Whether or not this new style becomes widely adopted by companies in the future will remain to be seen, but nevertheless the attempt was a success. A cutting-edge innovation was revealed again as highly efficient, students across the globe grew in their skill and knowledge and gained first-hand, radical experience, and a unified global society materialized a little further. ♦



Seeking E.T.

Jackson Lee

When the Viking probes first landed on Mars, astrobiology belonged closer to the realm of philosophy than science, and leading astrobiologists had more to do with science fiction than with rocket science. Today, however, with the search for the origin of life in the universe as one of its main strategic enterprises, NASA plans to launch a small flotilla of spacecraft from the earth to search for life in the solar system and beyond. Within our lifetimes, astrobiologists, armed with new scientific tools, will be able to determine the origins and distribution of life in our universe.

In September, University of Colorado at Boulder's Center for Astrobiology hosted a public symposium on the subject. A similar symposium held six years ago by CU-Boulder brought various researchers together to help start the Center for Astrobiology, one of fifteen centers currently comprising NASA's Astrobiology Institute. Graduate students from any field related to astrobiology can now obtain a graduate Certificate in Astrobiology, a four-course curriculum formed last year. The center's research spans the entire breadth of astrobiology, from planetary formation to the philosophy of science in astrobiology. According to Dr. Bruce Jakosky, the center's principal investigator, the public is very interested in understanding the possibilities of life in the universe. NASA's studies of these places seek to bracket our understanding of the environmental range and distribution of life in the universe.

Most of the recent planetary exploration missions have gone to the Red Planet. Currently, there are two active probes orbiting Mars: the Mars Global Surveyor, and Mars Odyssey. The Mars Global Surveyor's orbital camera and laser altimeter

have conducted an optical and relief mapping of the planet, while Mars Odyssey will seek to characterize the composition of Martian subsurface minerals and search for the presence of water with gamma ray and neutron detectors.

The reason for this interest is because Mars is one of the few places known outside the Earth that might have once had and might still have the presence of liquid water and a place that also contains the raw materials needed for life. "I feel we are on the verge of finding life on Mars. We know where to look, and we know how to do it," says Jakosky. To that end, the Mars Express mission will launch in 2003 ferrying a small lander called the Beagle 2 that will try to explore past life on Mars. The basis for the instrument is that biological processes on Earth tend to concentrate the carbon-12 isotope in its tissues and consequently in fossils and sediments. If the ratio of the isotopes of carbon-12 to carbon-13 in rocks is similar to terrestrial ratios, it could be an indicator for ancient life on Mars. A robotic arm will take samples of surface and subsurface rock to the lander. There, twelve ovens will gradually heat rock and soil samples in the presence of oxygen. The carbon dioxide generated at each temperature will be delivered to a mass spectrometer which will measure abundance and the ratio of carbon-12 to carbon-13.

However, aside from the Beagle 2, none of these current planned missions look for direct evidence of life simply because no one knows how to definitively detect life. Classical indicators of life

include searching for biomarkers, chemicals released by living

organisms alone. Other methods of life detection revolve around searching for morphological features or evidence of self-replication. However, these processes are difficult to test for or can be duplicated by non-living methods. Moreover, an independent origin of life could have biological processes that are different from earth-based organisms. "The missions today are geared for planetary habitability," says Jakosky. "They show the boundary conditions of life but do not directly support the detection of life. The consensus is that launching a sample return mission targeted at areas of Mars that could have once harbored life and observing those rocks on Earth for an extended duration will be the best bet for finding life."

Future missions still on the drawing board involve imaging the Red Planet at higher resolutions, up to 20-30 cm for the 2005 Mars Reconnaissance Orbiter, and using increasingly sophisticated rovers and microprobes that can do more and cover more ground than current surface probes. Ultimately, a sample return mission will occur sometime in the next fifteen to twenty years and return rocks to earth for study. This mission could be robotic or could involve humans directly collecting the Mars rocks as the Apollo astronauts once did on the moon.

Another branch of astrobiology that has generated interest involves the new field of planet detection. Using large optical telescopes, astronomers have been able to indirectly detect signs that other stars have planets orbiting around them. One method involves measuring the tiny perturbations in starlight that a planet would induce on a star based on Kepler's Laws. A planet rotating around a star induces a gravitational wobble in the star's motion. If the wobble is in the direction of the Sun, it is represented in minute changes in the frequency



Photos courtesy of NASA

of the starlight hitting the Earth, and is thus termed the Doppler spectroscopy detection method.

Another method, called the transit photometry method, involves recording the exact moment a planet eclipses its star when viewed from the Earth. A certain small percentage of stars will have their planetary disks perfectly aligned with the Earth. By observation of the light intensity of many stars over a period of time, astronomers can capture the one star that dips in light intensity when the planet transits in front of it.

With these methods, about one hundred Jupiter-sized extrasolar planets have been discovered, many in orbits around their stars tighter than the orbit of Mercury. By themselves, doppler spectroscopy and transit photometry will not be able to see Earth-sized planets located in the habitable zone. This zone is a region of space where liquid water bearing planets could exist and is a function of stellar mass, orbit radius, and the location of the star in the main sequence of star life. Another method is the idea of microlensing. Under the right conditions, a star with a planet will eclipse another star and bend the starlight due to gravitational effects. A planet orbiting the lensing star will cause a smaller discontinuous spike in the lensing trend of the front star. This effect can be used to judge the mass and orbit of a planet. Unfortunately, microlensing will require constant observation of many stars and will ultimately only provide detection for a few planets. One of the most promising techniques that will allow us to see into this zone is infrared interferometry, which takes advantage of the constructive and destructive wave nature of light. When two displaced telescopes

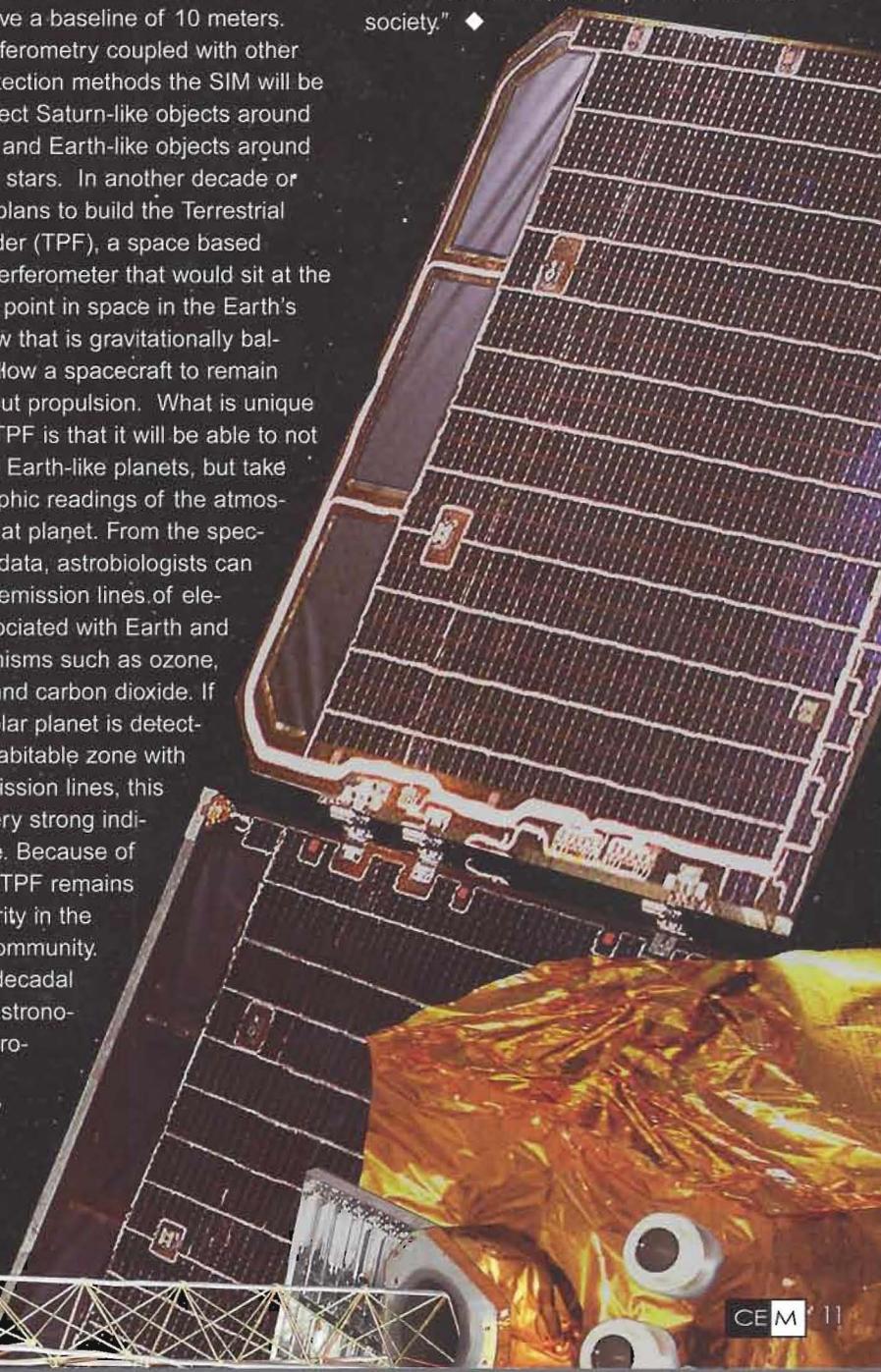


An artist's rendition of the Mars Rover that will soon search the Red Planet for signs of life.

image the same object, the waveforms are out of phase due to the arrival of the signal at collectors located different distances from the star. When the out-of-phase waveforms are combined, interference patterns form bright bands and dark areas called "fringes" that change position according to the position of the telescopes. Dark fringes can be used to block out the starlight of a central star, leaving behind the image of a planet. The phase and intensity of the fringes measured at different distances apart, or baselines, are then used in an inverse Fourier Transform to reconstruct an image source at a higher resolution.

Using this concept, in 2005 NASA hopes to launch the Space Interferometry Mission, a space-based interferometer that will have a baseline of 10 meters. Using interferometry coupled with other indirect detection methods the SIM will be able to detect Saturn-like objects around most stars and Earth-like objects around the closest stars. In another decade or so, NASA plans to build the Terrestrial Planet Finder (TPF), a space based infrared interferometer that would sit at the L2 point, a point in space in the Earth's sun shadow that is gravitationally balanced to allow a spacecraft to remain there without propulsion. What is unique about the TPF is that it will be able to not only detect Earth-like planets, but take spectrographic readings of the atmosphere of that planet. From the spectrographic data, astrobiologists can determine emission lines of elements associated with Earth and living organisms such as ozone, methane, and carbon dioxide. If an extra solar planet is detected in the habitable zone with oxygen emission lines, this will be a very strong indicator of life. Because of this ability, TPF remains a high priority in the scientific community. The 2001 decadal review of astronomy and astrophysics, "Astronomy and

Astrophysics in the New Millennium," prepared by the National Research Council, stated: "The discovery of life on another planet is potentially one of the most important scientific advances of this century, let alone this decade, and it would have enormous philosophical implications," and recommended that the TPF be given equal weight with other planet finding missions. Further, public interest in such projects is high. "People are interested in how we fit in the world around us," says Jakosy. "It makes a difference whether life is common throughout the galaxy and we're just one more example of it or if life is unique. In searching for life elsewhere, we're searching for ourselves and exploring the nature of the human mind and who we are as individuals, as a species, and as a society." ♦



Who's the New Guy? TRANSMETA

Joseph Carrafa



Images courtesy Transmeta

The mobile PC world has not known many processor contenders other than Intel and AMD. Intel is now showcasing its Pentium 4 and AMD – its Athlon. A couple of years ago, a small company Transmeta decided it would give the processor giants a run for their money.

Transmeta debuted its Crusoe processor early in 2000 and has since been pumping their new technology into everything from servers to web pads. They crossed into Intel's terrain when companies such as Sony and Fujitsu featured the Crusoe processor in a new breed of fully functional sub-notebooks. These PDA-notebook hybrids sport a footprint about the size of a piece of paper but still run windows applications. Why the hype? What does Transmeta bring to the table? Here is a technical look inside the Crusoe processor.

A quick overview of processor architecture: data received by a processor is strictly limited to certain instructions that it understands, telling it what to do. This is called the instruction set architecture or the ISA. This is what the buzz-word "x86" refers to. The ISA that runs Windows is x86. ISA design has taught us that the best ISA is the simplest. This is not true of x86. However, if we didn't keep using x86, new applications and old systems, or old applications and new systems, would be incompatible. In order to maintain compatibility, processors translate the x86 code into their own, then execute it. This is a very effective method but is very complex and hence demands a large chip

and a lot of power.

Like other processors, the Crusoe processor has two parts, one to translate instructions, one to execute instructions. However, in the past, hardware has been used to translate instructions; Crusoe uses software.

The only hardware in the Crusoe chip is the VLIW engine. This is the brain that executes all instructions after they are translated. It was designed to be very simple and very fast. A software layer inevitably slows down program execution, so fast underlying hardware is necessary to compensate.

A simple architecture has a single "Function Unit" that does all the operations on a byte. The VLIW engine instead has several units, each of which can perform a different type of operation. This way, while one instruction is using one operation, another instruction can use another operation. Little extra hardware is needed because there is no additional functionality.

In order to utilize this feature, the

instruction set is designed as a hierarchy of molecules and atoms. A molecule holds up to four atoms, each in need of a different operation.

Since the features of the function unit are split up, all atoms in a molecule can be executed at the same time. This way instructions are executed very quickly.

"Code Morphing" software translates x86 instructions into molecules. This task is completed in three passes: In the first pass, each x86 instruction is translated



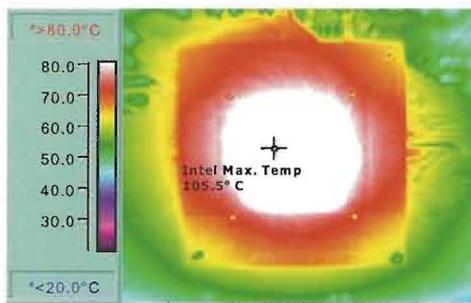
The Fujitsu P-2000, a compact laptop containing the Crusoe processor.

into a sequence of atoms. Some atoms that are created by an instruction can be used by other instructions. The second pass finds these and eliminates the repetitive atoms. In the third pass, the atoms are reordered into molecules for execution by the VLIW engine.

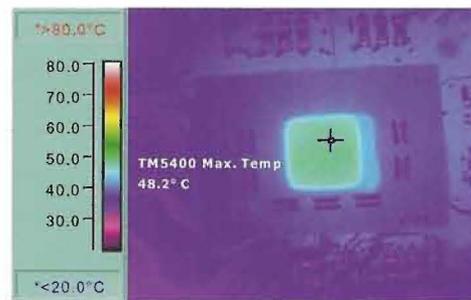
Since the software is doing the work instead of the hardware, the chip can be much smaller and more power efficient. Not all is lost on the performance side of things; soft-



Frontpath Webpad.



A Pentium III processor plays a DVD at 105°C (221°F).



A Crusoe processor model TM5400 plays a DVD at 48°C (118°F).

ware allows for more complex and effective translation algorithms.

By using a cache (short-term memory), the processor remembers recent and repeatedly used translations so that it does not have to do them every time it sees a group of code. The longer a program is running, the more efficiently the processor will run those instructions. In other words, it learns about the program you are using so that it can run it faster.

The point of mobile computing is not solely speed, so the Crusoe processor exchanges speed for power usage. More software means less hardware; less hardware means less power. Also, the tradeoff can be adjusted. Depending on the programming of the software layer, Transmeta can configure its chips to be faster or more power efficient. Different versions of the software can be directed at specific applications. This can be seen by the wide variety of applications that use a

Transmeta Crusoe processor.

Transmeta's new outlook on micro-processor design could revolutionize computer architecture. The idea of using a software layer at such a low level had never previously been attempted, but the benefits are noticeable. A software layer saves power and space and allows for great flexibility. Also a gap is bridged between architectures. If the Crusoe processor needed to be adapted to power an Apple or Macintosh, all that would need to be changed is the software code. Do you own a G4 but want to play your favorite x86 based game? In the future, a software-layer-based architecture may allow you to run programs from either architecture on the same computer.

The flexibility gained can be extended to solve a variety of problems. Research projects sometimes spend millions of dollars to produce a computer system specialized to their area of study.



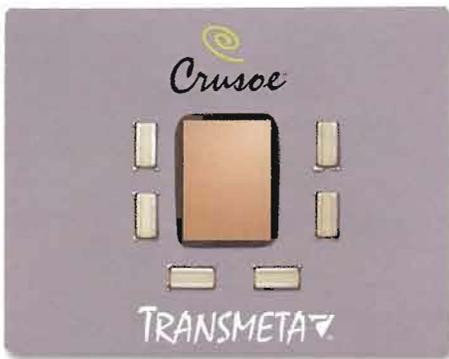
The OQO Ultra-Personal Computer.

With a software layer approach, the same basic hardware could be used (the expensive part) and only the software would need to be reprogrammed. Worlds of opportunity could also be opened for the developer that has been limited for so long by the dreaded x86 architecture.

Backwards compatibility has been a great limiting factor in computer development over the years. Transmeta's new approach at solving this problem gives a new perspective on processor design. In the next ten years or so, we will see if this design approach carries through to the next generation of computers. Perhaps the x86 instruction set will get thrown out completely. We can only hope. ♦



The Crusoe TM5600 microchip.



The Crusoe TM5800 microchip.

Code Corner

Reading this code:

%EAX is a register
(%EAX) is a memory location

```
ADDL %EAX, (%ESP)
ADDL %EBX, (%ESP)
MOVL %ESI, (%EBP)
SUBL %ECX, 5
```

Because of shortcomings in the x86 architecture, the first two instructions actually need to move the value in memory to a temporary register before the calculation is performed. The software would translate this code into simpler instructions.

Translation codes of x86 instructions for the Crusoe processor.

```
LD %R30, [%ESP]
ADD.C %EAX, %EAX, %R30
LD %R31, [%ESP]
ADD.C %EBX, %EBX, %R31
LD %ESI, [%EBP]
SUB.C %ECX, %ECX, 5
```

The %esp register is loaded twice. This is not because of bad programming, but because the x86 instruction set requires that it be loaded each time. Instead, the translator optimizes the code by eliminating the second load and using the same temporary register for the two 'add' instructions.

```
LD %R30, [%ESP] ; SUB.C %ECX, %ECX, 5
LD %ESI, [%EBP] ; ADD %EAX, %EAX, %R30 ; ADD %EBX, %EBX, %R30
```

The original four instructions have been reduced to two.

```
LD %R30, [%ESP]
ADD.C %EAX, %EAX, %R30
ADD.C %EBX, %EBX, %R30
LD %ESI, [%EBP]
SUB.C %ECX, %ECX, 5
```

Now that we have translated the x86 instructions into atoms, the software arranges the atoms into molecules for execution. Molecules are represented with semicolons separating atoms.



ENGINEERING GOES GLOBAL

Todd Fielder

Five years ago, Professor Bernard Amadei of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder, contracted a landscaping company to perform some work on his new Lafayette home, and a few days later three seasonal Mayan landscaping workers arrived at his house. While they were there, the men discussed with Amadei the difficulties they were having in establishing a school in their Mayan community in Belize. Amadei offered to help with the development of the school, and three years later he received an email to take him up on that offer. This request coincided with Amadei's sabbatical leave, and in the spring of 2000, he honored that request.

Once in Belize, Amadei was asked to visit the village of San Pablo to determine the possibility of installing a water delivery system to the village. Amadei returned to Boulder with the goal of designing and installing the system. Amadei has a vision for the role engineers should play in addressing global engineering problems. He believes that there is a need for training a new generation of engineers who could better meet the challenges of the developing world. Consistent with that philosophy, he solicited the help of several civil and environmental engineering students at CU-Boulder, and the team began researching, designing and testing a pump for the village. The actions of this group were to directly lead to the inception of a compassion-driven organization called Engineers Without Borders-USA.

EWB-USA's mission is to improve the quality of life in developing communities while educating engineers to become more culturally and socially aware.

Because EWB-USA exists outside the framework of formal education, students gain valuable skills that are not taught in the engineering curriculum. Amadei claims that, "a key component of EWB-USA is to work with university students," and that the developing world can act as a classroom of the 21st century. The hope is that the students will gain a broader understanding of human interaction with the natural world.

EWB-CU was the first university chapter of EWB-USA and became officially recognized by CU-Boulder at the beginning of the 2002 spring semester. EWB-USA is in direct contact with the EWB-CU chapter to ensure successful development of the chapter and the projects it pursues. Amadei believes it is the responsibility of EWB-USA to keep quality control of many of the on-going proj-



Professor Bernard Amadei uses the local form of transportation to bring materials to a project site in Bir Moghrein, Mauritania.

ects. However, he does want to give the individual chapters autonomy. Potential projects have a protocol that they must follow before the project is implemented.

The first step is for proposals to be reviewed by EWB-USA's Technical Advisory Committee, which is comprised of a wide range of professionals. The TAC reviews and evaluates all projects and rates them based on a predefined set of criteria ranging from feasibility, sustain-



An EWB-USA member examines the piping structure that is used to bring water to the local community in Santa Rita, Peru.

ability, cost, and the overall contribution of the project. Patrick Neidermeyer, co-president of EWB-CU, explains that this final criteria is possibly the most important: "If the project doesn't serve the greater community, then we won't consider it." Several projects have been denied because they addressed the needs of individuals or small groups, instead of the greater community.

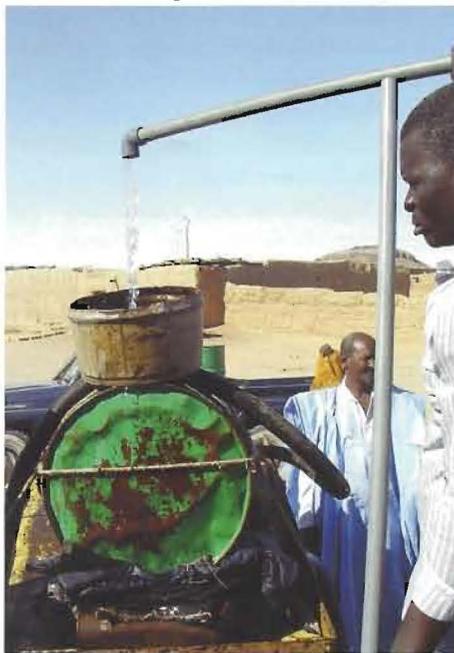
Generally, EWB-USA learns about projects through contact from the communities themselves. They are constantly receiving emails and personal requests for projects from around the world. After contact has been made, the communities are required to fill out a lengthy evaluation form. This helps EWB-USA determine the commitment of the community to the project as well as giving the TAC the information they require to rate the proposal. It also allows the villages to define their hopes and desires for EWB-USA's participation in the area. One of EWB-USA's goals is to develop projects that the community has self-identified. EWB-USA hopes this will encourage ownership in the project and help to increase community involvement.

The next phase of project development requires several members of the team to physically survey the site. This allows them to determine what the engineering needs of the village are and to meet with the community leaders to discuss EWB-USA's involvement in the project. Many times, EWB-USA will request that the local community complete certain tasks before the project can be implemented. For instance, in Mauritania a photovoltaic pump for a well was to be installed, but first the community was responsible for cleaning the well, building a cistern storage structure, and building protective structures around the site.

Another purpose for the preliminary site assessment is to ensure that the requests being made are consistent with the needs of the village. Two EWB-USA members, Seth Friedly and Bill Farr, recently travelled to Santa Rita, Peru, to investigate a request for assistance due to landslides which had allegedly devastated the village. Upon inspection, the team learned that the landslides actually

occurred several hundred yards from the village and caused minimal damage. They did, however, meet with the local nurse and identified several water and sanitation needs of the village, and EWB-USA is continuing work in the area.

After site assessment, substantial research, design and development must take place at the universities before implementation. The projects are designed to use as many locally available resources as possible, allowing the community to have access to the materials should anything need repair. One goal of EWB-USA is to educate the villagers in the technical aspects of the projects so as to limit their dependence on the expertise



Villagers examine the water being pumped from a photovoltaic-powered well installed by EWB-USA in Bir Moghreïn, Mauritania.

of EWB-USA. However, EWB-USA continues to be involved with villages after project completion through written correspondence and future projects.

According to Neidermeyer, continual involvement with the communities is one of the keys to the long-term success of the projects. He claims that while a project may be finished, "the village is adopted by EWB-USA," and EWB-USA assumes an on-going commitment to the village. The process from which initial contact is made to the completion of the project is iterative. As time goes on, the

Current EWB Projects

San Pablo, Belize
A collaboration with the Colorado School of Mines chapter to address energy needs.

Punta Garda, Belize
Developing the Maya Center for Learning designed to enhance cultural and natural resources.

Foutaka Zambougou, Mali
Researching water, sanitation and health needs.

Jalapa Valley, Nicaragua
Addressing water, sanitation, energy and communication needs.

Bir Moghreïn, Mauritania
Completed a project to install a solar-powered water pump.

Santa Rita, Peru
Determining construction needs, including a community building or a water management system.

Bayonnais, Haiti
Providing assistance in basic necessities, like electricity, for a local school.

Santisuk, Thailand
Investigating water and sanitation needs in an over-capacity town.

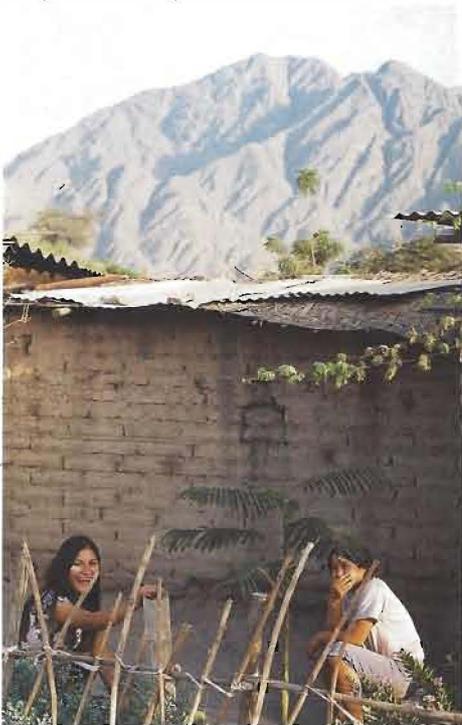
Farza, Afghanistan
Researching water, sanitation and health needs.

Lemraiveg and PK106, Mauritania
Researching water, sanitation and health needs.

Kathmandu, Nepal
Installing PV powered computers with internet in local schools.

goal of EWB-USA is to see that the villages are able to sustain themselves, but EWB-USA will always be available to villages it has adopted. Amadei states that EWB-USA's goal is "to allow them to fulfill their own dreams. We want to give them hope and show them that they have something to offer." He emphasizes that it is not the goal of EWB-USA to simply give supplies to the communities, and the communities do not want to continually rely on charity.

A common theme throughout EWB-USA is the idea of sustainability and empowering the communities to be able to provide for themselves. One ongoing project of EWB-CU in Foutaka Zambougou, Mali is focusing on a sustainable water supply for the village. Several wells are currently available to the villagers, but they have been poorly maintained and as a consequence the water is of very poor quality. The preliminary assessment found that the real problem is not the lack of water, but poor water management. Several recommendations have been made by the TAC including cleaning existing wells, collecting runoff from rooftops, and long-term storage structures. If the vil-



EWB-USA hopes to initiate a cooperative effort with the Peruvian Ecosustainable Research and Understanding group to teach the women of Santa Rita, Peru, techniques of weaving Alpaca sweaters.

lage is able to have a constant supply to sanitary water, it will address the sanitation needs of the village as well as provide water for the irrigation of crops.

There can be no denying the success of EWB-USA. On October 5, 2002, a workshop was held that addressed the necessary steps to create a university chapter. Schools from around the country flew in, along with representatives from industry and national laboratories. Eleven new chapters were added during that workshop. Furthermore, there have been several successfully completed projects by EWB-CU. This current year, EWB-CU has noted substantial growth in members and the number of projects they are taking on. Neidermeyer is excited about the proliferation of EWB-CU, but he claims that such rapid expansion puts stress on the group. Amadei also admits that the rapid growth is a concern to him. However, he notes that there are certain measures in place to be sure that only committed, mature students are involved. These include a small membership fee and the requirement that students have at least junior status to go on trips. While these are not overwhelming obstacles, they do help ensure that those involved are genuinely interested.

As with any new organization, EWB-USA has encountered some difficulties. Many of these have been a result of unanticipated conditions in the host country. For example, three months after a pump was installed in San Pablo, Belize, a ten-year flood decimated the community and destroyed the pump. A more conventional pump was installed, only to be destroyed by a class IV Hurricane six months

later. EWB-USA again fixed the pump and is currently looking into alternative, longer-term solutions. Another project, this one in Mauritania, also experienced some setbacks. After installing a photovoltaic pump, the community decided that the pump would be more beneficial if connected to a more centrally located well. The well had not been prepared for the pump, and EWB-USA returned to the United States without installing it to the other well. However, one of the villagers had been trained in the installation of the pump and made arrangements to install it after the well had been prepared.

These minor setbacks experienced by the group show that the concepts researched and developed in the classroom are not as easily applied to the outside world, and reinforce the idea that the developing world is the classroom for the 21st century. Engineers Without Borders-USA is helping engineers to become more aware, more involved, and more educated about the challenges posed to them by the developing world. ♦



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Modeling Adventures

Lilly Georgieva

Last February four University of Colorado at Boulder teams buckled their seat belts and plunged into the the Mathematical Contest in Modeling. Three of the teams received "Meritorious Winner" recognition and the team consisting of Stefan Wild, Kevin Leder, and Saverio Spagnolie was designated the recognition of being one of the few Outstanding Papers.

The MCM is a contest in which up to four teams per school consisting of three undergraduates each can compete. The teams have four days to choose one of two problems, solve it using any inanimate objects, and present a solution based on their results. The hundreds of papers written are then graded and placed in four categories – 58% are listed as Successful Participants, 23% are Honorable Mention, 17% receive Meritorious Winner mention, and 2% receive plagues for being an Outstanding Winner.

This year, the team consisting of Stefan Wild, Kevin Leder, and Saverio Spagnolie, was honored with Outstanding Paper recognition. The 2002 MCM began at 8:00 p.m. Eastern Time on Thursday, February 7 2002 when the team was presented with two problems to choose from. The question they chose involved building a mathematical model that examined the effects that different overbooking schemes have on airline revenue with the goal of identifying an optimal strategy. From then

on, the three Applied Mathematics majors had four days to define specifics, and find a mathematical model for the problem.

When choosing between the two questions, Stefan Wild explains, "We knew more about the first problem, but the second one was more interesting." The airline overbooking problem, chosen in light of September 11th, was a highly open-ended question that required a sorting through many variables in order to find a successful approach to the problem. The team specified the question for a flight to New York by Frontier Airlines, a

strategy used to create a "local outlook", as Wild calls it. They considered capacity of the aircraft, reservations, how many cancellations there would be, how many people would have to be bumped to a later flight, and how to bump them based on a complex mathematical model using probability and simulation.

"The contest pushes the students farther than they think they can ever go", comment-

ed Anne Dougherty, the Chair of the Applied Mathematics department, and the advisor for two of this year's teams. The students have to quickly learn to communicate as well as trust the capabilities of each team member. "A lot of people hate each other after the four days", commented Stefan Wild.

At the end, however, the long-term advantages include more than just something to put on a resume. The tremendous boost in confidence that the students walk out with makes them better prepared for

the future. "The contest opened us up to new modeling schemes", said Wild. After completing his Master's degree at CU—Boulder, Wild is planning to get a degree in operations research. He contributes this decision solely to his participation in MCM and hopes to get in the program because everyone in the field is familiar with the contest. Kevin Leder and Saverio Spagnolie contribute their graduate acceptances to Brown University and New York University partly to the contest as well.

The success of this year's MCM CU-Boulder contestants is largely due to a strong Applied Mathematics department where making the students understand the material, instead of just pass the classes, is the main focus. And while many of last year's contestants have now graduated, new students are ready and anxious for next year's Mathematical Contest in Modeling. ♦

"The contest pushes the students farther than they think they can ever go"



Saverio Spagnolie, Kevin Leder, and Stefan Wild at their graduation in May.

Photo Courtesy Anne Dougherty

Micro Machining

Otto Krauss

Most engineering students may have heard of MEMS, but what are they exactly? Micro Electro-Mechanical Systems technology is the integration of electronic components onto a silicon wafer, using micro-machining and fabrication techniques. In the last few years, remarkable strides have been made in this field, as MEMS promise to revolutionize the way we miniaturize electro-mechanical machines. A variety of applications for MEMS include the defense industry, medicine, and micro-satellites for space exploration. A truly revolutionary time lies ahead for MEMS.

The MEMS idea dates back to 1959, when, at the California Institute of Technology, visiting Professor Richard Feynman suggested innovative new fabrication techniques. Feynman's presentation, entitled "There's Plenty of Room at the Bottom", explained some of the possibilities of miniaturization, including putting the information in Encyclopedia Britannica on the head of a pin. The talk failed to generate a fundamentally new technique of fabrication. However, in 1969 Westinghouse Electric Company created a "Resonant Gate FET", which was a mechanical transistor based on a new microelectronics fabrication process. In the 1970s, bulk-etched silicon wafers were employed as pressure sensors, but it was not until the 1980s that widespread experimentation in microelectronics aroused the public's interest. One of the first applications of this technology was the micro-positioning of disk drive heads, as in the hard drives of computers. By the 1990s, the U.S. government, along with a number of research labs and universities around the

world, had active MEMS research and development programs, with many more applications for this new technology.

The benefits of MEMS are numerous. MEMS technology is diverse, so that the boundary between integrated circuitry and complex mechanical devices is nearly indistinguishable. In the past, the most costly components of electronic-actuator systems were the sensors and actuators. With MEMS, these devices are shrunk to a fraction of their size, usually between .1 and 100 microns, but the process itself is cheaper than the macro scale technique it is replacing. The components are fabricated using a batch technique, making them very similar to Integrated Circuits. In fact, the reliability of MEMS systems is also approaching that of ICs, further enhancing their usability. Additionally, MEMS are capable of surviving high g-loads and will not break when dropped, as current accelerometers and sensors often do. The power requirements of MEMS are also a fraction of the value used by the systems that MEMS is replacing. These benefits combine to yield a technology whose importance cannot be understated. In the same way that the integrated circuit revolutionized the microchip industry in the second half of the 20th century, enabling the development of personal computers, digital television, transistor radios, and a host of other

everyday devices, MEMS will revolutionize the electronic sensor-micro machining industry in the coming decades of the 21st century.

There are many developments in the field of MEMS technology. One concept is a micro-propulsion program led by TRW, which has sought to develop a system of micro-thrusters for small satellites. Their design calls for these thrusters to be used for attitude control, station keeping, and orbital correction maneuvers. Recently, the functionality of this system was demonstrated atop a sounding rocket flight, with each thruster providing 10^{-4} seconds of impulse. The small size of the thruster makes it possible to place a large amount on each wafer of silicon, up to an order of 10^6 thrusters, depending on the desired impulse increments. Each of these micro-electromechanical thruster systems is about the size of a poppy seed, with lead



MEMS could provide cost-effective solutions for controlling satellites and rockets with micro thrusters.

Photo courtesy NASA



Photo courtesy Formula 1



Photo courtesy Lockheed Martin

MEMS will miniaturize the size of traditionally large sensors and instruments which will improve performance while cutting cost and maintenance. The possible applications for MEMS are vast, ranging from vehicles and weapons to medical sensors.

stypnate used as propellant. The Defense Advanced Research Projects Agency is funding the program, and the main goals include the characterization of MEMS micro thrusters, along with the verification of their performance in space.

NASA's Jet Propulsion Laboratory is also involved in studying micro thrusters. A task group has been formed in order to see how MEMS could benefit robotic planetary exploration. Besides micro propulsion, other applications for spacecraft include miniature gyroscopes, micro-instruments, micro-valves, and adaptive optics. These advances could lead to smaller planetary spacecraft that can do the same amount of science, but at a fraction of the cost.

In the last few years, the University of Colorado at Boulder has been involved with two MEMS projects, funded by DARPA. The first study, titled "Injectable Ceramic Microcast SiCN MEMS for Extreme Temperature Environments," seeks to improve the fabrication yield from photo polymerization and micro casting, along with fabricating polymer-derived ceramic structures from Silicon CarboNitride alloys. The long-term goals of this project include developing technology for the fabrication of single and multi-layer SiCN MEMS.

The second study, "MEMS and Solder Self-Assembly for 3-D MEMS and MEMS Arrays," looks at developing solder self-assembly technologies. Applications include 3-D corner cube reflectors for optical communications links, 3-D switch arrays, and 3-D MEMS arrays of microbots for automated assembly of microbenches. The principal investigator

for both of these studies is Victor M. Bright.

Already, MEMS have broad applications in the medical field. The most widely used application is for measuring blood pressure. In fact, over 17 million disposable sensor units were sold last year. The sensors are connected to a patient's IV line, and monitor the blood pressure through the solution. Each unit is around \$10, as opposed to \$500-\$600 for silicon-beam transducers, which must be sterilized and recalibrated for the next patient. According to Kurt Petersen of Lucas NovaSensor, maker of the blood-pressure MEMS sensors, "the sensor is the easy part of the project; its packaging takes up most of the development resources." This is critical, since the micron-sized sensors must withstand the human body's harsh environment. The silicon wafers at such small scales have a higher tensile strength than steel, but in the human body, the devices tend to be brittle with the circuitry also being delicate. In addition, there's the issue of compatibility with the body to make sure the sensors are benign. The sensors must be tested over and over to make sure the body will not attack these small devices.

Development of micron-sized accelerometers is also considered important for medical MEMS. Newer pacemaker designs include accelerometer MEMS which determine patient activity. For example, when the patient moves, the sensor measures the movement and causes the pacemaker to adjust its rate.

Even more interesting is the development of instruments small enough to fit on a chip. Several universities and micro

machining companies are pursuing this endeavor. In effect, a single chip will contain a complete blood-analysis system. This is one example of how miniaturization will also reduce costs associated with medical devices by eliminating all the different tools required, such as in blood analysis.

The nation's defense industry is already a major player in the development of MEMS technology. Many of the studies and research efforts currently underway are funded by DARPA, as mentioned previously. However, the commercial sector is not the only one doing research. The government has its own research being conducted at Sandia National Laboratories, and together with DARPA they share about \$200 million in funding annually. As Dr. David Williams, director of Sandia's Microsystems Center, states, "anything that's good for MEMS is good for national defense". He projects that the government's funding will increase at a rate of about 15% to 20% a year. The large government interest in MEMS is due in part to the potential cost savings offered by applying the technology to all aspects of the military.

Some examples include an air-cooled infrared camera using MEMS that will be mounted on everything from a soldier's helmet to provide night vision, to smart munitions providing even greater accuracy. The cameras weigh less than six ounces and cost less than one thousand dollars, providing a cost effective solution to currently mounted cameras.

Raytheon is working with the Air Force in developing a millimeter wave-scanning antenna, whose main feature is

that it only costs 10% of existing antennas. It also has other advantages over current systems, and the telecommunications companies already have built 5000 units for civil use.

Solid free-form fabrication technology promises to save hundreds of millions of dollars to the military each year in producing new and out of production spare parts. As the technology is maturing, Boeing has shown an interest as well, hoping that parts for the 777 will soon be made using this method. The Office of Naval Research is the primary sponsor, and the technique is being proven, with high interest from both the military and commercial sectors.

Currently, there is no mass production of military MEMS systems, just prototypes being tested. However, in the next few years this will change as the technology sees application, with the soldiers and machines of future warfare becoming even smarter and more equipped than they are today.

Currently, the world of MEMS technology is estimated to be worth between

about fifteen and twenty billion dollars, according to Roger Grace Associates. Their forecast calls for that figure to possibly reach thirty billion dollars by 2004, based on market shipments totaling fourteen billion dollars in 2000. Within two years, MEMS will have crept into the telecommunications and health care industries, with the average American using five MEMS

devices per day. Medical uses for the future include chemical sensors and fluid-flow devices. An example is a carbon monoxide detector that will be available for home use. The defense industry is involved in almost every aspect of MEMS, promising to enhance warfare and save costs as well. The space program will have more efficient and more precise attitude control systems for satellites, along with



A 200 micrometer diameter, 45 nanometer thick polymer-derived ceramic SiCN gear with a 50 nanometer diameter hole made by injectable ceramic process.

smaller and more reliable instruments for planetary probes. In addition, the current problems imposed by the packaging of these devices will be solved as well, with the ability to withstand harsh environments, be it the human body, or the far reaches of space. The application of MEMS devices has just begun, and the future promises even more. ♦



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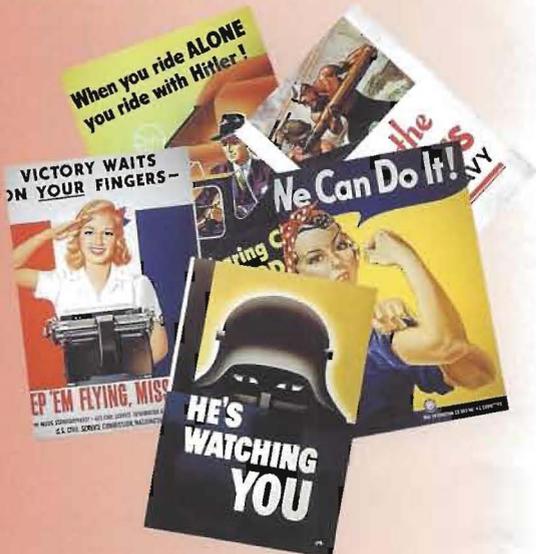
(EL PAGE DEL
AMUSMENTO)

TIPS FOR A HEALTHY LIFE
-THE PARANOIACS VERSION-

Don't trust your neighbor. He's a sly one alright. He always seems to know when you're in your room, always looks at you when you look at him and always wears the same clothes as you. Oh wait, that's just a mirror...this time.

Oh no, they're not going to control you. Don't be a slave of their little lines and blinking lights, today drive anyway you want to...this time.

Sometimes, in the middle of the night you...WHAT'S THAT BEHIND YOU?! It was nothing...this time.



ANAGRAMS

Yessir, nothing beats the zany fun of an anagram game! Try to decode the secret message in this jumble of letters.

Answer on bottom of page

CU BUOLDER

Impress your friends with random facts!

Pogonophobia is the fear of beards.

"Floccinaucinihilipilification" is the longest non-medical word in the English language. It means "the act of estimating as worthless."

The word "nerd" was first coined by Dr. Seuss in "If I Ran the Zoo."

"Go." is the shortest grammatically correct sentence in the English language.

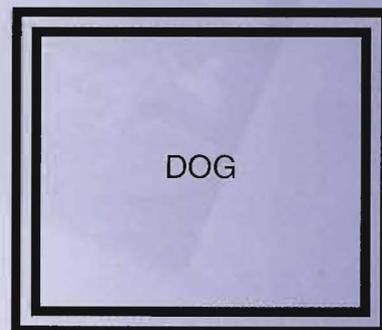
The names of all the continents end with the same letter that they start with.

"Q" is the only letter in the alphabet that does not appear in the name of any of the United States.

The word "trivia" comes from the Latin "trivium" which is the place where three roads meet, a public square. People would gather and talk about all sorts of matters, most of which were trivial.

The sentence "The quick brown fox jumps over the lazy dog." uses every letter in the English language.

WORD SEARCH



DOG	OD
GOD	OG
DO	
GO	



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Answer:
HELP, I'M BEING HELD HOSTAGE.



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