USC Viterbi

FALL 2012

DON'T LOOK NOW

Superposition, mind-bending physics and one very cold computer: USC unveils first operational quantum computing center at a university.

IN MEMORIAM

On April 11, 2012, the USC Viterbi School lost two of its students in a tragic crime. Below, are excerpts from Dean Yannis C. Yortsos' memorial remarks:

Ming Qu, 1988–2012

Ying Wu, 1988–2012

"We honor the memory of Ming Qu and Ying Wu, two bright engineering graduate students in the Ming Hsieh Department of Electrical Engineering.

This is an unprecedented tragedy in our history. Words are not enough to describe how we feel.

However, in this difficult time, we are warmed by the fact that our common bonds and connections are not circumstantial. Rather, they are a strong manifestation of our powerful and enduring association — the Trojan and Viterbi family. It is the cohesiveness of this family that gives us the strength to cope with our loss today.

We, engineers and scientists, are analytical and methodical. We want to know why things happen. When we're confronted with an unexplainable atrocity, we struggle to understand. We can't comprehend how the lives of two young people, full of potential, full of energy, have been taken away from them so cruelly.

As engineers and scientists and as leaders, we have solved a great number of challenges. Ming and Ying were preparing to use their skills and knowledge in electrical engineering to help solve many of these issues — and thus to empower society.

Their sudden loss, however, confronts us with a different challenge. The challenge to make this world a better place, so that the tragic events that took their lives will never happen again. Here or anywhere else.

It is a different challenge than the ones we have been used to address. It is not only technical — and it is complex. But it deserves our commitment, our unwavering commitment. It is a debt we owe to Ying and Ming."

— Dean Yannis C. Yortsos

For more information about the Ming Qu and Ying Wu Memorial Scholarship Fund and to make a donation, contact Jane Ong at (213) 821-2921 or jane.ong@usc.edu.

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SPRING 2012

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Yannis C. Yortsos

Executive Director, Communications and Marketing
Michael Chung

Editor
Adam Smith

Contributing Writers
Modupe Alabi, George Bekey, Jon Campbell, Kathleen Concialdi, Katie Dunham, Eric Mankin, Robert Perkins, Adam Smith, Mabel Tsui

Art Direction and Graphic Design
Pentagram

Photography
Noe Montes, Cody Pickens, Ziva Santop/Steve Cohn Photography, Andrew Stowe, Timo Yates, Adam Voorhes

Graphics / Illustrations
Einar Baldvin, Greer Freshwater Burton, Huan Tran

Cover Photography
Luke Fisher

Volume 11, Issue 1
USC Viterbi magazine is published twice a year for the alumni and friends of the Viterbi School of Engineering at the University of Southern California.

Letters to the editor and

BOARD OF COUNCILORS

BY THE NUMBERS

7
NAE members inducted in last four years

30%
Entering freshmen are women – compared to 18 percent national average

13.8%
Alums that went on to start companies
(Source: USC Stevens Institute for Innovation)

5
MIT TR35 faculty in past three years

436,000,000
Players reached bya video games developed by USC GamePipe Laboratory alums

111
Ph.D.s in C.-C. Jay Kuo's (Ming Hsieh Dept. of Electrical Engineering) teaching genealogy
(Source: The Mathematics Genealogy Project)

25,000
K-12 students over the past 35 years in Larry Lim's USC MESA (Mathematics, Engineering, Science Achievement)

Quantum Power

I would like to discuss a bit on innovation and give you my thoughts about it. And then, I would like to bring in quantum computing.

Fifty or so years ago, innovation was a rather infrequent event, typically the result of laborious, methodical work in research labs, often taking a long gestation time. It was a welcome, but infrequent, supplement to the routine. Today, innovation has supplanted the routine: words such as "disruptive," "out of the box" and "transformational" are the norm.

I may sound discipline-centric, but the truth is that this is because of the technological and scientific advances that sprang from advances in the semiconductor and integrated circuit in the last half century. The constant and reinforcing interplay between science and technology has resulted in Moore's law – the doubling of the capacity of transistors every 18 months. This has brought us what we know as exponential technologies: information technology, biotechnology and nanotechnology. And along with them, the opening of the vast vistas of innovation, everywhere – not only in technology and devices – but in medicine, the arts, the social sciences and communications. Largely and fundamentally because of Moore's law (and where appropriate, the Viterbi algorithm) we have the Internet, iPhones, the Human Genome Project, Facebook, computer games and interactive media, robotic surgery and the unprecedented economic development in China, India and the rest of the world.

Moore's law opens increasingly greater opportunities: capturing them, transforming them and converting them into products and concepts, drive today's innovation-based economy. In the past, the limitation to innovation was the implementation. Today it is the idea – and ideas are now generated everywhere on the planet. This fundamental enabling has been the result of science and technology.

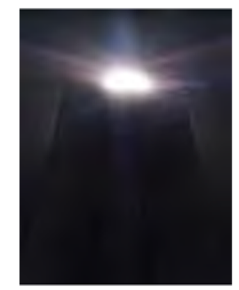
As minimum features on transistors approach nanometer dimensions, however, this inexorable pace will slow down. Unless, that is, we can extend or redefine Moore's law in the realm of the quantum world, with its still vastly unexplored possibilities. Enter quantum computing and quantum information science and technology: the study of the new possibilities quantum mechanics offers for the acquisition, transmission and processing of information.

Quantum computers are predicted to solve classically intractable tasks such as breaking cryptographic codes, efficiently searching large databases and efficiently simulating quantum dynamics. Advances in that area promise to create a Moore's law of their own, even much faster and more enabling. At USC, quantum computing research is leading the world through the Center for Quantum Information Science and Technology (CQIST), and especially the recently established USC-Lockheed Martin Quantum Computing Center at our Information Sciences Institute. This research will lead to advances in quantum computing using solid-state devices and large-scale quantum information processing, capable of outperforming the most powerful classical computers. This quantum universe is mysterious, counterintuitive, but seductive. It gives rise to terms such as quantum adiabatic optimization and quantum entanglement. And it has the potential to dramatically speed up the solution of problems in machine learning, image recognition, software debugging, database searching or drug design. In short, it has the potential to keep Moore's law, or its quantum counterpart, driving innovation to even more unprecedented levels, for the benefit of humanity.

In the past, the limitation to innovation was the implementation. Today, it is the idea—and ideas are now generated everywhere on the planet.

I invite you to read in this issue some of the remarkable work that is going on at USC in this breathtaking area.

Yannis C. Yortsos
Dean, USC Viterbi School of Engineering



To watch the dean's video on quantum computing at USC, visit: viterbi.usc.edu/quantum

NOT A LA-Z-BOY *Christopher McIntosh's "Recliner Roadster" is capable of speeds of 35 to 40 miles per hour. "The fun part was taking something like a chair and figuring out how to build a go kart around it."*

PHOTOGRAPH BY CODY PICKENS

40 MPH in a La-Z-Boy

Student Adds "Recliner Roadster" to Roster of Inventions

While most teenagers resort to sports cars or dirt bikes to satisfy their "need for speed," USC Viterbi mechanical engineering student Christopher McIntosh turned to other, more original measures.

Converting an old, Craigslist red recliner chair into a modified go-kart, McIntosh created what he named the "Recliner Roadster." McIntosh found that developing and building his invention provided him with valuable experience in pursuing a career in engineering.

Inspired by a joystick-controlled mobile sofa chair he saw at a high school robotics competition, McIntosh first equipped his recliner chair with an electric scooter motor and basic go-kart steering in 2010. But after the motor burnt out, McIntosh decided to replace it with something significantly more powerful – a 125cc motorcycle engine that gets the Recliner Roadster to speeds of 35 to 40 miles per hour.

Though his vehicle is not street legal, McIntosh has found plenty of opportunities to drive it on back roads and empty parking lots in his community. He has also driven it in his hometown's annual Fourth of July parade, where he hopes to earn "Most Unusual Means of Transportation" this summer. And though he has fewer opportunities nowadays to use the Recliner Roadster, which remains parked in his garage up in Northern California, he is always eager to take it out for a spin or do some fine-tuning when he travels home.

While McIntosh had technical experience from past projects (from a leaf-blower powered hovercraft to a makeshift moped) as well as from a high school woodshop class, for the most part, he picked up most of the necessary building skills as he went along.

"When I first started out on this project, I thought it was going to be somewhat straightforward," McIntosh said. "I thought I would kind of bolt things on and use primarily wood and steel brackets I bought at a hardware store . . . I just started realizing that it wasn't going to happen unless I could actually weld things together and do a full steel frame."

The knowledge McIntosh has gained from the project has proved helpful so far, particularly in the classroom: "If the teacher is explaining why a bracket is going to shear at a particular location, I can kind of envision how that would happen and why it would happen that way."

But while the physical task of building the chair certainly proved enriching, perhaps even more so was the creative aspect of the project, which McIntosh said was not only most challenging and enjoyable of all, but also that which will continue to motivate him to develop new projects and progress as an engineer. *–MT*

CUE THE SUN *panels assembled by Viterbi students take light and make power in a December 6 demo.*

Here Comes the Sun

USC Viterbi Students Capture Solar Power for Electric Cars

The Global Electric Motorcars (GEM) vehicles that are ubiquitous on the USC campus currently plug into the power grid for a recharge. But someday, they may be plugging into solar charging stations built and designed by USC Viterbi School of Engineering undergraduates.

A preview took place last Dec. 6, when 32 juniors and seniors in the "Alternative Energy Engineering" class set up an array of eight solar panels in brilliant sunshine, generating a 1,200-watt flow of energy into batteries and a waiting GEM vehicle.

To open the demonstration, the group diverted a small trickle of the energy flow into a boombox, which thumped out a rousing solar-powered rendition of "Here Comes the Sun."

The class, taught by professors Alice Parker, Gordon Roesler and Katherine Shing, incorporated many practical issues. During the semester, the class heard from Michael Bass (MS '85, MBA '99), project manager at eSolar, who offered perspectives on the non-engineering issues involved in alternative energy solutions along with an overview of solar thermal technologies, an alternative to the photovoltaic panels used by the class.

Parker noted that the class embodied the vision of USC Viterbi dean, Yannis C. Yortsos: "It is interdisciplinary Engineering+," she said. "It is work on one of the National Academy of Engineering's Grand Challenges; it is entrepreneurial, and it follows a vision of technology leading societal change." *–EM*

USC'S MICHAEL WATERMAN has been elected to the National Academy of Engineering (NAE). Named a Guggenheim Fellow in 1995, Waterman is the USC Associates Chair in Natural Sciences and professor of biological sciences and mathematics in the USC Dornsife College of Letters, Arts and Sciences and a professor of computer science in the USC Viterbi School of Engineering.

Election to the NAE is among the highest professional distinctions accorded to an engineer.

Widely regarded as the founding father of computational biology, Waterman's research concentrates on the creation and application of mathematics, statistics and computer science to molecular biology, particularly to DNA, RNA and protein sequence data. He is co-developer of the Smith-Waterman algorithm for sequence comparison and of the Lander-Waterman formula for physical mapping.

"Michael Waterman's election into the National Academy of Engineering is a resounding confirmation of his remarkable and pioneering work in computational biology," said USC Viterbi Dean Yannis C. Yortsos. "We cannot be more pleased that the academy has bestowed this highest honor upon him."

"Mike is a true trailblazer whose groundbreaking research has enabled countless advances in the computational and life sciences," said USC Dornsife Dean Howard Gillman. "He was central to building USC Dornsife's world-renowned program in molecular and computational biology."

Alongside 65 other new members and ten foreign associates, the NAE recognized Waterman for the development of computational methods for DNA and protein sequence analyses. Other newly elected members include USC trustee and USC Dornsife alumnus Dr. Ray R. Irani, executive chairman of the Occidental Petroleum Corporation and namesake of USC's Ray R. Irani Hall; USC Viterbi alumnus and University of California at Santa Barbara Professor Steven DenBaars; and Professor Richard Miller, president of Franklin W. Olin College of Engineering and former associate dean at USC Viterbi.

Energy Geography @ USC

The USC Viterbi School of Engineering is a powerhouse of research in numerous fields related to all aspects of energy. Here's a visual overview of who is doing what, where.

illustration by Huan Tran

1 Loker Hydrocarbon Research Institute
Nobel Prize winner George Olah and Surya Prakash's contribution to energy-related issues ranges from ways to eliminate lead from gas, methanol fuel cells and a new method to capture CO_2 and possibly recycle it in fuels or even animal feed.

2 Hughes Aircraft Electrical Engineering Center
Viktor Prasanna's USC Center for Energy Informatics connects with the USC Smart Grid, optimizing demand response during peak hours. Petros Ioannou's Center for Advanced Transportation Technologies works with carmakers to make road traffic safer, faster and more fuel-efficient. Massoud Pedram specializes in creating more energy efficient 'green' data centers.

3 Ronald Tutor Hall
Chongwu Zhou's laboratories focus on nanotech: more storage capacity in batteries using bulk silicon nanowires; also a new kind of transparent solar cell material. The USC Energy Institute, directed by Don Paul is here, along with The Center for Interactive Smart Oilfield Technologies (CiSoft) — pioneering new extraction techniques and educating a new generation of petroleum engineers. Hai Wang's Combustion Kinetics lab studies jet fuel combustion and new, ultrathin solar materials, working with Denis Phares.

4 Vivian Hall
P. Daniel Dapkus and Mark Thompson's Center for Energy Nanoscience (CEN), a DOE Frontiers Research Center finds more efficient ways to turn light into electricity and electricity into light; among the researchers on the projects are John O'Brien, Steve Cronin, Michelle Povinelli and Jongseung Yoon. Anupam Madhukar has been working for years on solar power applying quantum dot and nanowires. Steve Nutt's Gill Composites Center has pioneered next-generation composite power cables with greater efficiency. Priya Vashishta uses supercomputing to perform the largest bio-nano simulations.

5 Hedco Building Chemical Engineering
Kristian Jessen is an expert in the subterranean movement of oil and gas and efficient ways to extract it. Iraj Ershaghi, the founding director of CiSOFT, has been leading in the development of smart energy for decades. Fred Aminzadeh leads in the realm of geothermal energy, consulting with practitioners in the U.S. and abroad. Behnam Jafarpour studies rock formations, potential oil and gas reservoirs. Theodore Tsotsis investigates high temperature reactions, while Muhammad Sahimi uses things like fractal geometry to model the geology of rocks.

6 Andrus Gerontology Center
Behrokh Khoshnevis is known for Contour Crafting, a speedy, energy efficient means of 'printing out' buildings; Maged Dessouky has pioneered more efficient transportation methods for California flowers, and Najmedin Meshkati is an international authority on energy safety, from nuclear power to petroleum refining to drilling operations.

7 Olin Hall
Paul Ronney is an expert on combustion, specializing in tiny electrical power generators and flames in space. Fokion Egolfopoulos and his Combustion and Fuels Research lab is working with Hong Kong-based TCC Foundation and Martin Gundersen (Seaver Science Center) on ways to reduce marine diesel emissions.

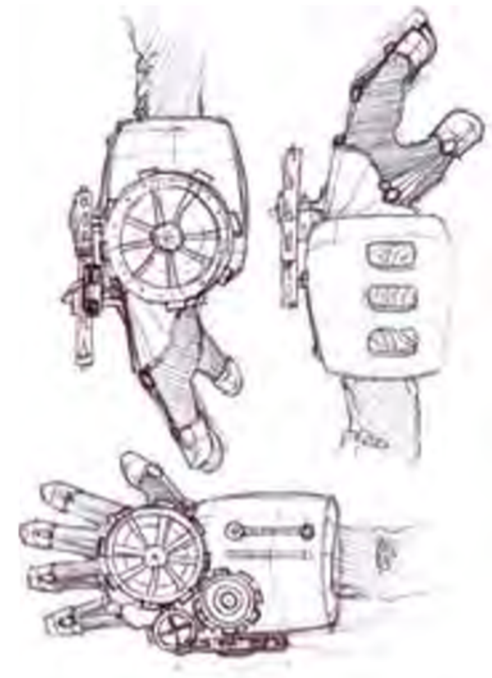
8 Kaprielian Hall
Home to the USC Center on Megacities. Lucio Soibelman looks at appliance specific feedback on electricity consumption in a building; Burcin Becerik-Gerber collaborates with Cyrus Shahabi and Roger Ghanem in imagining new smart buildings that allow users to control energy use (via smart phones) far more effectively than existing designs.

9 Information Sciences Institute
Mike Orosz directs the consumer behavior research efforts in the LADWP/DOE Smart Grid Demonstration project. Clifford Neuman focuses on energy security: protecting personal data about our usage as it's relayed from consumers to utilities.

***CHARGED UP** From a DOE-funded USC Center for Energy Nanoscience (CEN) to the Los Angeles Department of Water and Power Board's $43 Million Smart Grid Demonstration Cooperative Project, USC Viterbi's spans a huge spectrum on energy.*

Anatomy of a Video Game

How to Make a Zombie Game in Five Easy Steps



You play video games on Xbox, Wii, even your cell phone. But how does one get made? In the "Advanced Game Projects" class, eight teams create games that will ultimately be graded and presented to industry representatives. Anthony Ghavami, a junior in computer science and producer of "Benjamin Salisbury and the Clockwork Zombies" illustrates how a video game goes from idea to your game console.

1) A Spark of Genius

The idea for "Clockwork Zombies" was created back in April 2011. Ghavami and classmate Richard Rapp imagined a "puzzle game set on a futuristic space colony where the basic mechanics of rotating gears drove the course of the game." The team worked 12-hour days building on their ideas, perfecting the pitch. Ideas for the video games that will be produced, as well as the actual game play design, must be presented and "green lit" in the spring semester before production begins.

2) Team Building

Once the idea is accepted, a team is built. The "Clockwork Zombie" team was initially made up of Ghavami, Rapp and Jeremy Le and now includes four designers, a producer, a music composer, seven engineers and one sound engineer all from the Computer Science Department and the School of Cinematic Arts, as well as six artists from the Laguna College of Art and Design.

3) Plan and prepare

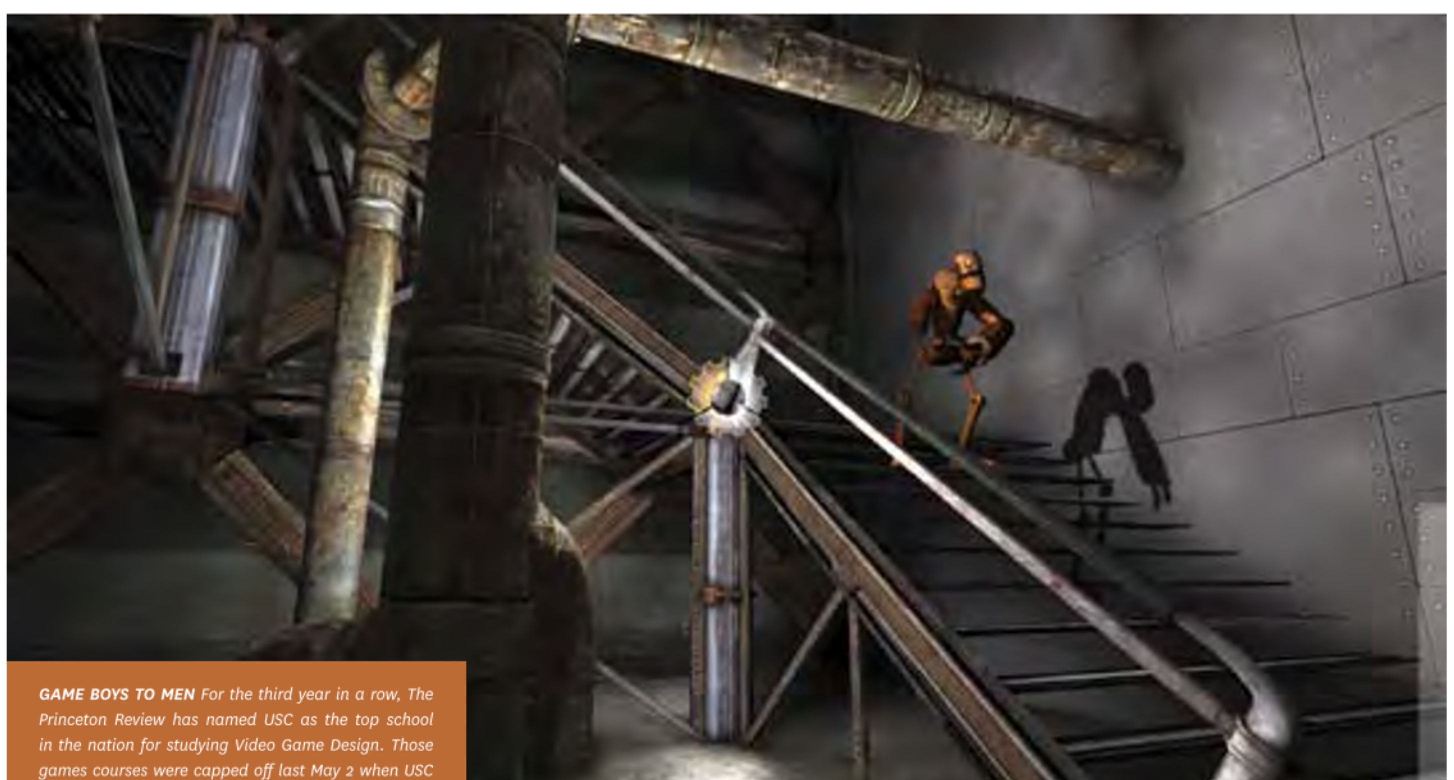
Using large goals and deadlines, each team member is responsible for different game aspects: finishing levels or back end systems by a certain date. As a motivational tool, Ghavami had each designer prototype a level, allowing each member ownership over a specific piece of the game. Each team has a task list with specific deadlines to hit, earning "a red, yellow, or green color for their task based on how well they completed it."

4) Execute

Referencing their goals and original vision, the game is created using a program called UDK, an engine used to help create some of the most successful games. Using the same tools as the big name games, designers develop code using UDK's scripting language and edit the game's cinematography, lighting and animation. Each designer builds the basic geometries such as walls and floors, and then adds images and characters into that landscape. Most of the game's elements are created by the design team; however, zombies and other animations are created by students from the Laguna College of Art and Design.

5) Present!

Execution takes about a year, but once the game is complete, teams present their games to industry representatives at a daylong Demo Day last May. Representatives from companies such as EA and Activision attend to view the games and speak with the teams to either buy the games or offer these students jobs. Backing by such major companies is what allows an original idea and vision to become a reality that anyone can play on their consoles. *–KC*



GAME BOYS TO MEN *For the third year in a row, The Princeton Review has named USC as the top school in the nation for studying Video Game Design. Those games courses were capped off last May 2 when USC Games presented its 14th bi-annual Demo Day.*

Saving Da Vinci's Last Supper from Air Pollution

Air quality monitors show dramatic reduction in air pollution at the painting's location

Having survived long centuries, political upheaval and even bombings during World War II, Leonardo da Vinci's masterpiece "The Last Supper" now faces the risk of damage from air pollution due to its location in one of Western Europe's most polluted cities.

In late 2009, the refectory of Santa Maria Delle Grazie Church, where the painting is located, installed a sophisticated heating, ventilation and air conditioning system to protect the painting from the polluted air of Milan.

To test the effectiveness of their pollution countermeasures, Italian officials called on Constantinos Sioutas, professor of civil and environmental engineering at the USC Viterbi School of Engineering. For his ongoing research, Sioutas has designed unobtrusive air samplers that are compact and quiet.

"These air pollution sampling technologies are ideally suited for use in sensitive facilities such as art galleries and museums. They do not disrupt the day-to-day operations of the facility," Sioutas said.

A multi-national team deployed two sets of air quality monitors for one year at the church, and found that – for the most part – the Italian authority responsible for the facility housing the famous painting (Soprintendenza per i Beni Architettonici e per il Paesaggio di Milano) is winning the war with outdoor air pollution. Fine and coarse particulate matter concentrations were reduced around the painting by 88 and 94 percent, respectively, from their corresponding outdoor levels.

"It's a spectacular reduction," Sioutas said. "It is, frankly, very impressive."

Indoor sources of pollution, however, may still pose a threat. Nancy Daher, USC graduate student and lead author of a journal article on the team's findings, said that fatty lipids from the skin of visitors to the church still appeared in significant quantities around the painting – even with visitor access to the painting strictly regulated.

In addition to aiding in the conservation of "The Last Supper," the team's research can be used as a benchmark for future studies aimed at protecting indoor artworks and antiquities. *–RP and KD*

PRIVATE PARTY *Only a handful of patrons are allowed into the Santa Maria Delle Grazie Church via an airlock-style chamber at any given time and are only allowed to stay for 15 minutes at a stretch. According to USC graduate student, Nancy Daher: "Airborne lipids from visitors' skin can combine with dust in the air and, if they come in contact with the painting, soil it."*

AWARDS

YONG CHEN, assistant professor in the Epstein Department of Industrial and Systems Engineering, has been awarded the NSF Faculty Early Career Development (CAREER) award for his proposal titled "Mask Video Projection Based Additive Manufacturing at the Micro-scale over Large Areas."

AZAD MADNI, professor in the Epstein Department of Industrial and Systems Engineering, and director of Systems Architecting, has been named a fellow of the American Institute of Aeronautics and Astronautics (AIAA).

MALANCHA GUPTA, assistant professor in the Mork Family Department of Chemical Engineering and Materials Science, has been selected to receive the ACS New Investigator Award.

RAMESH GOVINDAN, professor in the Department of Computer Science, has been elected to the Association for Computing Machinery (ACM) Fellows.

MAJA MATARIĆ, Vice Dean for Research, is co-PI on a Yale-lead, $10 million NSF Expeditions in Computing grant; Viterbi collaborators include Fei Sha and Gisele Ragusa.

MILIND TAMBE, professor of Computer Science and Industrial and Systems Engineering, received the IBM Faculty Award for his proposed research, "Towards Smarter Government and Smarter Cities: Computational Game Theory for Public Safety and Welfare."

SOLOMON W. GOLOMB, a university professor who was appointed the first holder of the Viterbi Chair of Communication, has received Sigma Xi's 2012 William Procter Prize for Scientific Achievement, the society's highest honor.

SAMI MASRI, professor in the Sonny Astani Department of Civil and Environmental Engineering, has been selected to be the first recipient of the ASCE George W. Housner Structural Control and Monitoring Medal.

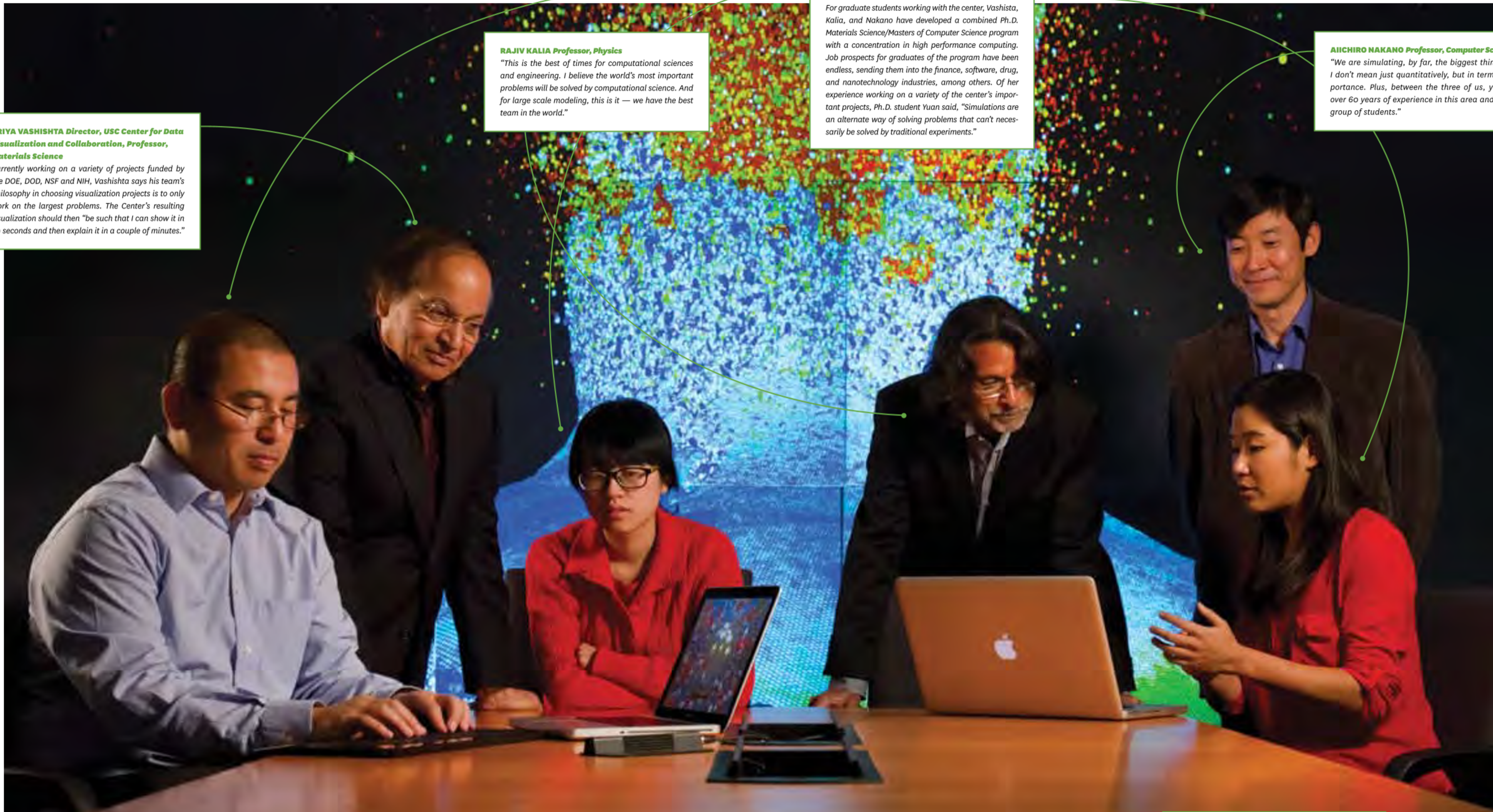
ALAN WILLNER, professor in the Ming Hsieh Department of Electrical Engineering and holder of the Steven and Kathryn Sample Chair in Engineering, has been awarded the John Simon Guggenheim Memorial Foundation Fellowship for 2012-2013.

PRIYA VASHISHTA *Director, USC Center for Data Visualization and Collaboration, Professor, Materials Science*
Currently working on a variety of projects funded by the DOE, DOD, NSF and NIH, Vashishta says his team's philosophy in choosing visualization projects is to only work on the largest problems. The Center's resulting visualization should then "be such that I can show it in 30 seconds and then explain it in a couple of minutes."

RAJIV KALIA *Professor, Physics*
"This is the best of times for computational sciences and engineering. I believe the world's most important problems will be solved by computational science. And for large scale modeling, this is it — we have the best team in the world."

KEN-ICHI NOMURA, *Assistant Research Professor, Physics*, YING LI, *Ph.D., Materials Science '12*, ZAOSHI "AMY" YUAN, *Ph.D., Materials Science '12*
For graduate students working with the center, Vashista, Kalia, and Nakano have developed a combined Ph.D. Materials Science/Masters of Computer Science program with a concentration in high performance computing. Job prospects for graduates of the program have been endless, sending them into the finance, software, drug, and nanotechnology industries, among others. Of her experience working on a variety of the center's important projects, Ph.D. student Yuan said, "Simulations are an alternate way of solving problems that can't necessarily be solved by traditional experiments."

AIICHIRO NAKANO *Professor, Computer Science*
"We are simulating, by far, the biggest things. And I don't mean just quantitatively, but in terms of importance. Plus, between the three of us, you have over 60 years of experience in this area and a great group of students."



Center for Data Visualization and Collaboration (DVC)

Founded in 2002, the center provides the ability to view simulations generated by high-performance computers such as USC's High Performance Computing and Communications facility (the 7th fastest academic supercomputer in the nation).

Housed in a space formerly occupied by the engineering library, the center consists of 12 digital projectors behind the 8'x14' monolithic glass AT&T Tile Wall, upon which 17.5 million pixels are projected. Three 65-inch movable LCD screens and three suspended projectors offer additional projections options for visualizations designed by graduate students. The center is the brainchild of three professors, allies in high performance computing for over two decades: Rajiv Kalia, Aiichiro Nakano and Priya Vashishta.

ABOUT THE SIMULATION SHOWN IN THE PHOTO
Depicted here: the impact of a hypervelocity bullet on a high-performance ceramic plate. Atoms are color-coded according to energy and pressure, with red indicating the highest energy. This simulation research was supported by the National Science Foundation, the Department of Energy and the Department of Defense.

PHOTOGRAPH BY ANDREW STOWE

NEW FACULTY

LUCIO SOIBELMAN

USC Viterbi School of Engineering Dean Yannis C. Yortsos has announced the appointment of Lucio Soibelman as chair of the school's Sonny Astani Department of Civil and Environmental Engineering. The appointment, effective January 1, 2012, has an expected term of three-and-a-half years.

Soibelman joins USC after more than seven years as professor of civil and environmental engineering at Carnegie Mellon University. His academic career began six years previously at the University of Illinois at Urbana-Champaign where he became associate professor. He earned his Ph.D. in Civil Engineering Systems from MIT after 10 years of experience in private industry in his native Brazil.

His research focuses on developing information technologies and knowledge discovery techniques for construction engineering management and sustainable infrastructure design, with emphasis on smart energy-efficient buildings, intelligent water grids and structural-health monitored systems.

Soibelman received the NSF CAREER Award in 2001, the 2010 ASCE Computing in Civil Engineering Award and the American Council on Education Award. He succeeds Erik A. Johnson, who served as interim department chair beginning October 15, 2011.

JULIE HIGLE

USC Viterbi School of Engineering Dean Yannis C. Yortsos has announced the appointment of Julie Higle as chair of the school's Daniel J. Epstein Department of Industrial and Systems Engineering. The appointment, effective January 1, 2012, has an expected term of three and a half years.

Higle comes to USC from The Ohio State University where she served as chair of the Integrated Systems Engineering Department for more than five years. Previously, she was professor of Systems and Industrial Engineering at the University of Arizona where she began her career after earning her Ph.D. in Industrial and Operations Engineering at the University of Michigan, Ann Arbor.

Her research interests include developing stochastic programming models and algorithmic methods for decision making under uncertainty, with a recent focus in the area of stochastic modeling for health care applications. She serves on the editorial board of Operations Research Letters and is Senior Vice President for Academics for the Institute of Industrial Engineers, the largest professional society in the field.

Higle succeeds Stan Settles, who has served as department chair since July 2010.

Dude, Where's My Parking Space?

A mobile laboratory: USC Viterbi's Audi smart car sparks ideas on intelligent parking, outwitting traffic and personalizing the driving experience.

Petros Ioannou had lost the battle with Santa Monica. He and his wife retreated.

"It was the worst experience I had with parking in Los Angeles," Ioannou reflected. "We didn't know there was a farmer's market event happening. Roads were closed. We got lost – we didn't know where the parking structures were. We'd always parked in a particular spot and now the configuration had changed."

"We wandered around, got frustrated and went away."

Now, due to a recent USC Viterbi partnership with Audi and its Electronics Research Laboratory, those sorts of memories may be a thing of the past, a quaint reminder of life before smart cars and "intelligent assist."

Last semester, Ioannou – a professor in the Ming Hsieh Department of Electrical Engineering – and his students in the Center for Advanced Transportation Technologies (CATT), received some new wheels – a black Audi A8 fully equipped with a broad sensor suite that includes radar, lidar (for light detection and ranging), cameras and WiFi. For the next two years, the Audi smart car will be the USC test bed for everything from parking assistance and adaptive driver assistance systems to personalized navigation.

Along with USC, the University of California, Berkeley, the University of California, San Diego and the University of Michigan are also contributing to the three-year project.

With nearly 10 million souls in Los Angeles County alone, the CATT team's research has enormous implications: managing traffic flow, driver comfort, mitigating accidents and, certainly, finding parking at Staples Center on a Friday night.

Imagine a different Santa Monica driving experience, one where the weekend farmer's market is not the death knell of an afternoon. A scenario where the driver can input a destination, and the car will run algorithms to decide – based on the time of day, the driver's cost preferences, scheduled events, the number of available lots – where to park. Indeed, as currently envisioned, the car might even reserve your spot and pay remotely before you've even left the driveway.

Personalized driving is another big driver of the research. For all the smart car's future intelligence, it will remain more of a 300 horsepower personal assistant that caters to the personalities of multiple drivers.

"The car would learn my driving style – acceleration profile, lane usage and level of intervention – and tune its assistance systems to my style," Ioannou said.

What does that mean? It means that the car – whether it's approaching a stop sign, trailing a car or veering dangerously into another lane – knows your reaction times better than you do and will customize an alert accordingly.

In addition, the CATT team's research will go beyond the limited traffic data of say, an iPhone's Sigalert app, to collect data from all possible sources: life data, historical data, unpredictable events, even simulations that can do fast forward events.

So, for example, when the unpredictable does happen – a tanker truck explosion on the eastbound 60 Freeway passing through Montebello – the smart car's simulator will imagine a virtual traffic network, based on real time and historical data to forecast the future. When a massive river of steel is diverted, where does it go?

For Ioannou, a native Cypriot whose first car was a Matador, flash has never been paramount. He loves the dynamics of a motor vehicle. His students' work will likely not be seen in the color and the shape of the new smart cars, but in the underlying algorithms, the unseen presence that solves your parking, predicts the future or saves you from the head-on collision.

Lacking that, in a city like Los Angeles, it may also be your best defense against the scourge of farmer's markets. *–AS*

INTELLIGENCE — AUDI-STYLE *Professor Petros Ioannou and his research students have taken the lead on a four-university research partnership with Audi's Electronics Research Laboratory. The new car, delivered last fall, will be the proving ground of the latest ideas in parking assistance, adaptive cruise control and personalized navigation.*

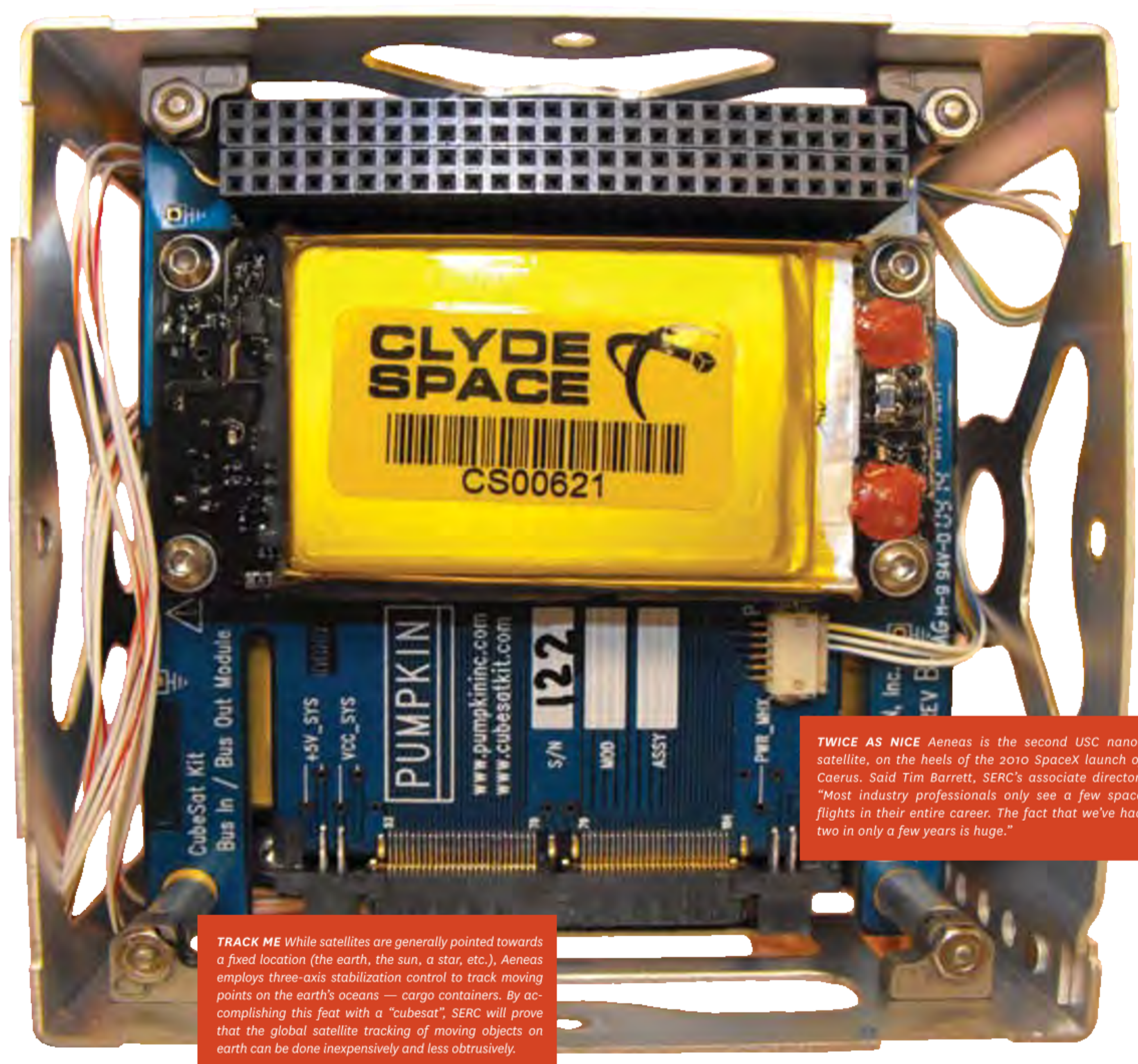
Pirates Beware: Viterbi Mini Satellite Will Be Watching

New Cube Satellite First to Track Cargo Containers Over the World's Oceans

Earlier this August, USC's Space Engineering Research Center (SERC) was slated to launch its newest satellite, a modified Colony I "cubesat" called Aeneas. Launching from Vandenberg Air Force Base near Lompoc, California, Aeneas joins seven other miniaturized satellites on a United Launch Alliance Atlas V rocket.

Built at USC's Information Sciences Institute (ISI) by a rotating team of over fifty students and half a dozen staff members, Aeneas marks two firsts for satellite innovation: it is the first cubesat in history to ground track and the first to deploy a half-meter parabolic dish. A system nearly three years in the making, the dish is a high gain antenna, deployed from a structure not much larger than a loaf of bread. Both features demonstrate that smaller, less expensive satellites are capable of communications usually left up to giant satellites.

Aeneas' mission is to track cargo containers over the open ocean. *–KD*



TWICE AS NICE *Aeneas is the second USC nanosatellite, on the heels of the 2010 SpaceX launch of Caerus. Said Tim Barrett, SERC's associate director, "Most industry professionals only see a few space flights in their entire career. The fact that we've had two in only a few years is huge."*

TRACK ME *While satellites are generally pointed towards a fixed location (the earth, the sun, a star, etc.), Aeneas employs three-axis stabilization control to track moving points on the earth's oceans — cargo containers. By accomplishing this feat with a "cubesat", SERC will prove that the global satellite tracking of moving objects on earth can be done inexpensively and less obtrusively.*

Maseeh Entrepreneurship Prize Competition (MEPC)

An annual business plan competition to help inspire Viterbi student innovators to be at the forefront of the NAE Grand Challenges. Through a generous gift from Fariborz Maseeh, MEPC provides a $50K award in seed funding. Here's a sampling from the 2012 competition: from virtual concerts to water conservation.

Photography by Noe Montes

FREEME

Framework for Runtime Energy Efficient Mobile-App Execution

Company

Murali Annavaram
Asst. Professor, Ming Hsieh Department of Electrical Engineering
Sangwon Lee
Ph.D. candidate, Viterbi Computer Science

Team Mentors

Zaré Baghdasarian
Bill Collins

Creative Impulse

"(On one occasion) we needed to run some mobile apps in a field study and then watched our phone battery indicator literally go from FULL to RED (empty) in 4 hours.

Our idea allows you to do more with your mobile phone and lets FREEME take care of your mobile battery life worries. Patent protected and ready-to-deploy solution."

Club Consortya

Company

Andy Martin
Viterbi M.S., Computer Science for Game Development
Dustin Farris
Viterbi M.S., Computer Science for Game Development
Mike Laflamme
Solutions Developer, Avanade, Inc.
Matthew J. Lucido,
MBA candidate, Marshall School of Business
Ajinkya Waghulde
Viterbi M.S., Computer Science for Game Development

Team Mentors

Robert Flynn
Dimitri Villard

The Pitch

"Club Consortya is a persistent virtual concert environment where people worldwide can participate in a 3D simulation of a real-time, live artist performance. Each participant will be able to customize their own personal avatar for the concerts while earning and purchasing unique ranks, dance-moves, archived performances, and more."

DropOff LLC

Company
Asa Firestone
MBA candidate, Marshall School of Business
Jonathan Beckhardt
MBA candidate, Marshall School of Business
Jay Shah
Viterbi M.S., Ming Hsieh Department of Electrical Engineering

Team Mentors
Ali Fakhari
Ian McGregor

Creative Impulse
"I was driving through a school zone and realized that the real-time radar display system created a feedback loop of information that caused me to slow down. I realized that this feedback loop was so simple and yet such a powerful tool to modify human behavior. It was a logical progression to apply this concept to energy and water conservation.

Dropoff automatically provides real-time water usage information for college dormitory residents in the shower, increasing water conservation behavior and providing efficiency and cost savings."

ClearPath

Company
Cyrus Shahabi
Professor, Viterbi Department of Computer Science
Ugur Demiryurek
Ph.D. candidate, Viterbi Computer Science
Penny Pan
Ph.D. candidate, Viterbi Computer Science
Lian Liu
Ph.D. candidate, Viterbi Computer Science
Christopher O'Connell
MBA candidate, Marshall School of Business

Team Mentor
Tuck Newport

The Pitch
"ClearPath has created a technology that finds the fastest way to get from Point A to Point B, by taking real-time and future traffic congestion into consideration. ClearPath will save commuters time and money, and make delivery businesses more efficient by suggesting more accurate and alternative routes. According to McKinsey Global Institute analysis...using traffic data that help drivers avoid congestion and suggest alternative routes will save consumers worldwide more than $600 billion annually by 2020."

The River and the Sky

Bringing Fresh Water to the People of Two Honduran Villages

By Jon Campbell

DID YOU KNOW?
Some 6,000 children die every day from disease associated with lack of access to safe drinking water, inadequate sanitation and poor hygiene - equivalent to 20 jumbo jets crashing every day.
Source: Blue Planet Network

Augusto "Goose" Alonso stood by the river, exhausted from hard work and the Honduran sun.

His team of student volunteers and local villagers had spent three miserable days fighting La Estanzuela, a wide, lazy river running below the village that shares its name. They had finished building the small levee of sandbags and mud protecting their project site, and the ground had begun to dry. Soon, steel rebar would be laid and concrete poured for a dam that would bring badly needed water to the village above. The team was in country for seven days, and with three already spent on the levee, they were desperately short of time.

For Alonso, a biomedical engineering student and member of the Engineers Without Borders (EWB) chapter at the USC Viterbi School, last December was his fourth trip to Honduras, all as an EWB project manager. He and 10 other Viterbi students are the latest in a half-decade effort to provide freshwater to isolated villages in rural Honduras.

They flew from Los Angeles last winter break to work with local villagers on the small dam, which will power a water wheel pump and force river water up a steep hill into the village above. For this trip, their plan was to build a small, 12-foot portion of the dam while educating locals in the details of its construction.

But the river would not be ignored, and as Alonso watched, a single sand bag began to slide off the levee. Within seconds, bags and mud gave way, flooding the site and setting the team hopelessly behind their tight schedule.

Alonso wondered, "Are we going to be able to do this?"

BUSY BODY *Senior Augusto Alonso, seen here collaborating with local villagers, splits his time between biomedical engineering, Engineers Without Borders (EWB) and maintaining the highest GPA on the USC football team. On EWB: "I wanted to do something that had meaning. We are physically doing something with our lives and free time."*

La Estanzuela is a village of 300, located 10 miles outside the modern city of Marcala. A rough dirt road leads from the city and into the rural countryside, where locals still lack clean water and sewage systems of any kind. They rely on natural springs and ground water, shared with farmers and livestock. Dehydration and gastrointestinal illness plague the villagers, as agricultural runoff, motor oil, and fecal matter contaminate their sole source of water.

If construction of the dam was not completed before spring, the wet season would flood the river and the whole project would be postponed for another year. The night of the levee collapse, Alonso began planning the only solution – start construction on the opposite river bank and build the dam backwards from the original plan. The wisdom of a dozen trips to the village materializes from Alonso in one almost desperate sentence: "You have to be so flexible to do this."

Three miles to the east, co-project leader Kristen Sharer leads another group of EWB students in the village of Corral de Piedra. The village suffers from the same poor quality water as La Estanzuela, but is too far from the river to be a viable source. Instead, they are building a rainwater catchment system that will store several thousand gallons of water collected during the rainy season in massive tanks that were donated by the government in Marcala. Their previous trip focused on building the concrete pads for the heavy tanks and now the system of PVC pipelines that transports the captured water must be finished.

Sharer is excited with the local response: "They were hesitant at first, but with communication and our commitment to the project, they have started to embrace the possibilities the tanks and filters will offer."

At the dam site, Alonso's teams are finishing the first section of the sloping concrete and earthen dam. It's their final day in country, and he is optimistic. "After the sense of hopelessness, I am more confident than ever that the dam will be completed before the wet season in May." While the EWB teams have brought blueprints and schematics, the local villagers, "masters in concrete" according to Alonso and Sharer, have spread plastic sheeting and straw over fresh concrete, allowing it to cure. In the end, the dam's completion will rest with them.

Sharer is especially aware how their experience is altering the idea of charity. "The EWB is about expanding our perception on solutions: what works in the First World could be a disaster in rural Honduras. These projects have to focus on sustainability, on keeping things as simple and low cost as possible. We focused on the right solution for these villages and went with it. What we created here will last."

Story update: As of this printing, EWB-USC has completed both projects in Honduras. The school children of Corral de Piedras are happily enjoying clean water with their school lunch, and the people of La Estanzuela are preparing to open up their distribution system to provide clean water directly from the river to the tap. This fall, EWB-USC eyes a return with all new projects.

PHOTOGRAPHS BY USC ENGINEERS WITHOUT BORDERS

ILLUMIN'S mission is to illustrate the many ways engineering benefits and impacts daily life. Articles are written, edited, and published by undergraduate students at the USC Viterbi School of Engineering.

Books of the Future

The Engineering Behind Electronic Ink Displays

The following is an abridged version of an article published by Illumin Magazine.

The article in its entirety can be found at http://illumin.usc.edu.

Illumin is on Twitter http://twitter.com/#!/illuminmagazine and Facebook http://www.facebook.com/illuminmagazine

Boarding the train to Hogwarts School of Witchcraft and Wizardry, Harry Potter discovers that photos in the wizarding world are not static like they are in the Muggle world. Images move, stirred by magic. Portraits smile and wave; landscapes shift and change over time. Moving photos may now be within reach with a relatively new technology called electronic ink. Thanks to this new development, we may soon be able to enjoy animated magazines, newspapers, and other printed material.

How Does it work?

The most commonly used type of electronic ink works through electrophoretic technology. Electrophoretic ink takes advantage of different colored, oppositely charged particles moving into view to form patterns. Electrophoresis separates particles by their charge by applying voltage via electrodes; positively charged molecules are attracted to negative voltages, and negatively charged molecules are attracted to positive voltages. The ink itself consists of countless solid microcapsules that have three main components: Negatively charged black particles, positively charged white particles, and transparent liquid.

To make an electronic paper display, the ink is bound to a sheet of plastic, forming an evenly distributed film of ink microcapsules. The plastic sheet is laminated to a layer of circuitry, then another transparent plastic layer is then applied on top, sandwiching the microcapsules between the two sheets. The embedded electrodes use negative and positive charges to attract and repel the colored particles, forming text and images.

A Sustainable Alternative

According to the Green Press Initiative, the U.S. uses more than 20 million trees to make paper for books and almost 95 million for newsprint each year. The cost for the Harry Potter book series alone is estimated at 5.8 million trees.

Electronic ink may help in sustainability efforts. One small e-reader can display many different books to a user, saving both landfill space and trees. Electronic ink price labels in retail stores can be reset at any time and reused, saving countless paper slips. A university study estimated that the use of paper books led to four times more greenhouse gas emissions, three times more water usage, and thirty times more water consumption per person than the use of one e-reader. In addition to producing less waste and using fewer resources, electronic ink devices use little power, making them a viable replacement for paper products that produce waste and consume valuable trees.

Reading into the Future

There are known flaws in the current state of electronic ink, and the technology is commonly thought of as highly specialized, mainly limited to use in e-readers.

Though most devices now use the method described above to make an electronic paper display, the ink can be printed on a variety of substances: glass, paper, plastic, and even fabric. Recent breakthroughs in adding color to electronic ink, along side efforts to develop thinner, more flexible, and more durable displays with responsive, touch-screen capability promise a world of applications beyond the range of traditional LCD displays.

Conclusion

Electronic ink is bridging the gap between the brightly lit screens of the digital age and the traditional world of pen and paper. Electronic ink has taken off in the past ten years, and further advancements in the technology will likely revolutionize its application within another decade. Regardless of whether you want to conveniently download and read college textbooks or save the planet by conserving trees, look forward to seeing more and more electronic ink options in the future.

FOR ILLUMIN Michelle Chong is a student at USC majoring in Biomedical Engineering. She participates in research at the Health Sciences Campus and is a certified EMT. In her spare time, she enjoys reading and photography.

More at http://illumin.usc.edu

Thought-Controlled Wheelchair

Spread the Sound: A Brief History of Music Reproduction

Composite Technology and the Hockey Stick Revolution

"Lovers of print are simply confusing the plate for the food."
— Douglas Adams, author, "The Hitchhiker's Guide to the Galaxy"

PHOTOGRAPH COURTESY OF AMAZON.COM, INC.

NASA Funds USC Plan to Print Out Moon Buildings

Viterbi and Architecture Schools partnering on lunar Contour Crafting effort

The natural home for a revolutionary USC Viterbi School of Engineering technique for "printing out" full-scale buildings may be the moon.

Behrokh Khoshnevis, a Viterbi School professor with appointments in three departments, has received funding from the National Aeronautics and Space Administration (NASA) to adapt his Contour Crafting system for lunar construction.

Khoshnevis and collaborators will be designing such items as lunar roads, landing pads and aprons, shade walls, dust barriers, thermal and micrometeorite protection shields and dust-free platforms. The idea is that the machinery will build as much as possible using moon rock and other material.

The technology will have to prove itself in a dress rehearsal on Earth at NASA's Desert Research and Technology Research Studies (D-RATS) facility.

The team hopes to integrate the Contour Crafting units with other equipment for use on the moon under development by NASA, including the Lunar Electric Rover, the Chariot Rover, and an extremely lightweight crane assembly.

According to Khoshnevis: "The CC technology has potential to improve materials handling and schedules, will reduce the need for hard physical labor, assigning humans to a strictly supervisory role, eliminate issues relating to human safety and produce intricate, aesthetically refined designs and structures."

Khoshnevis has been working on Contour Crafting for more than a decade, with support from private sources including Caterpillar Inc., as well as government agencies. Hailed as an imaginative breakthrough by the National Inventors Hall of Fame, Contour Crafting consists of an extremely sophisticated nozzle that moves via a flexible framework, depositing layer after layer of a specially formulated concrete-like material. The current prototype is a unit 13-feet high, 17-feet wide and 20-feet long, incorporating no less than 20 patents in its molding nozzle and other components.

Khoshnevis hopes that on this planet, Contour Crafting can revolutionize construction, reducing waste, saving time, eliminating construction related deaths and injuries, and speeding replacement of housing after disasters.

"The moon," Khoshnevis notes, "offers unique opportunities because it provides for realistic and feasible experimentation with planetary exploration and colonization. It also offers valuable resources such as useful materials, clear view of the heavens, and a stable post for communication platforms."

Collaborators include Madhu Thangavelu, an adjunct professor in astronautics at the Viterbi School, and two faculty members in the USC School of Architecture, Anders Carlson and Neil Leach. *–EM*

MOONRAKER *Khoshnevis' proposal was funded by NASA Advanced Innovative Concept (NIAC) program, one of 800 submitted of which only 30 were accepted. The grant is for one year, with extensions possible depending on demonstrated results.*

PHOTO ILLUSTRATION BY CONNOR WINGFIELD

BRIGHT LIGHTS, BIG CITY *Impressively, the LEDs demonstrated an extremely large range of luminosity, depending on the amount of current applied: a range of some five orders of magnitude.*

THE PROMISE: a new breed of electronic screen — ultrathin, lightweight, energy-efficient and cheap to manufacture.

That glowing promise isn't totally fulfilled by a new process invented by USC scientists, but it's a long step in the right direction. The researchers, led by professors Chongwu Zhou of the USC Viterbi School of Engineering and Mark Thompson of the USC Dornsife College Department of Chemistry, have devised a way to use carbon nanotubes to create Active Matrix Organic Light Emitting Diode (AMOLED) displays.

"Active Matrix" refers to an electronic backplane structure that constructs images by lighting up patterns of individual pixels. "Light Emitting Diodes" (LEDs) are devices that function like solar power cells, but in the opposite direction: rather than converting light to electricity, they convert electricity to light, when energized in patterns by the transistors of the matrix. Organic LEDs are based on carbon chemistry, rather than silicon or other materials. Zhou and Thompson are principals in the USC Center For Energy Nanoscience (CEN), which is researching OLEDs and solar cells intensively.

Active Matrix displays have long been known and are more and widely used — liquid crystal screens are ubiquitous examples. The Zhou lab's non-silicon prototype version is small – a total of 500 pixels, each pixel controlled by two carbon separated nanotube thin-film transistors (SN-TFTs), a switching transistor and a driving transistor, both linking to a charge-holding capacitor.

It is a first-ever effort: "To our knowledge," their paper concludes, "this is the first demonstration of an AMOLED display driven solely by SN-TFTs." And it works. Nearly 350 of the 500 pixels in the first experimental composite assembly lit when energized. — *EM*

Want to Drill Through the Earth's Crust? Try This Glass.

AME's Andrea Hodge and Veronica Eliasson seek to synthesize ultra-hard metallic glass

Imagine a bullet flying at the speed of sound smashing into a hard rock or solid steel plate and not shattering or flattening, but keeping its shape and blasting through. Now imagine a projectile the size of a football or larger doing the same.

Two faculty members from the USC Viterbi School of Engineering received a three-year grant from the Defense Threat Reduction Agency (DTRA) to create an ultra-hard material that can withstand extreme ballistic forces. The possible uses are by no means exclusively military. Mining, manufacturing, and many other areas need tools able quickly to penetrate or cut resistant layers of hard rock or metal.

The materials that PI Andrea Hodge of the Aerospace and Mechanical Engineering Department will focus on are amorphous metal alloys. Unlike the familiar metals seen in everyday life, these so-called metallic glasses lack any crystalline structure.

Crystals fragment and break under extreme impact stress, says Hodge, but some amorphous metals could retain their shape even under extreme conditions.

She is joined by AME colleague Veronica Eliasson, a specialist in shockwaves and fluid-solid interactions. In addition to theoretical contributions, Eliasson will help arrange experimental tests using a plate impact gun located in the Caltech Solid Mechanics Laboratory.

The starting point for their work are variations of substance created by the USC Materials Nanotechnology Research Group called Structural AMorphous alloy (SAM). SAM alloys, according to the research plan submitted to DTRA, "exhibit outstanding corrosion resistance and easy formation of amorphous character," making it a possible beginning in the search for the "next generation structural amorphous metals" DTRA seeks.

Hodge and Eliasson will be working with Alfred University's Olivia Graeve, of the university's Inamori School of Engineering's Nanomaterials Processing Laboratory, a specialist in ceramic engineering. Working closely with Hodge, Graeve's lab will synthesize large samples that will be returned for testing and reformulation. *–EM*

SUPER BULLET *After three years, the group hopes to have developed a new type of alloys that are ultra-hard and can be scaled up for production — and if the effort is successful, these materials can then be used for exploration technologies in land, sea and space.*

Viertbi Start-Ups: Abtum

Maseeh Prize winners target $5.5 billion transceiver chip market

In April 2011, Behnam Analui and Hossein Hashemi won USC Viterbi's inaugural Maseeh Entrepreneurship Prize Competition (MEPC), an annual business plan competition for Viterbi students. As their prize, Analui, a USC researcher, and Hashemi, an associate professor in the Ming Hsieh Department of Electrical Engineering, won $50,000 worth of seed money for their start-up company, Abtum, Inc.

Since then, the team has been working diligently on developing a second generation of their product, a programmable, integrated wide-band transceiver chip.

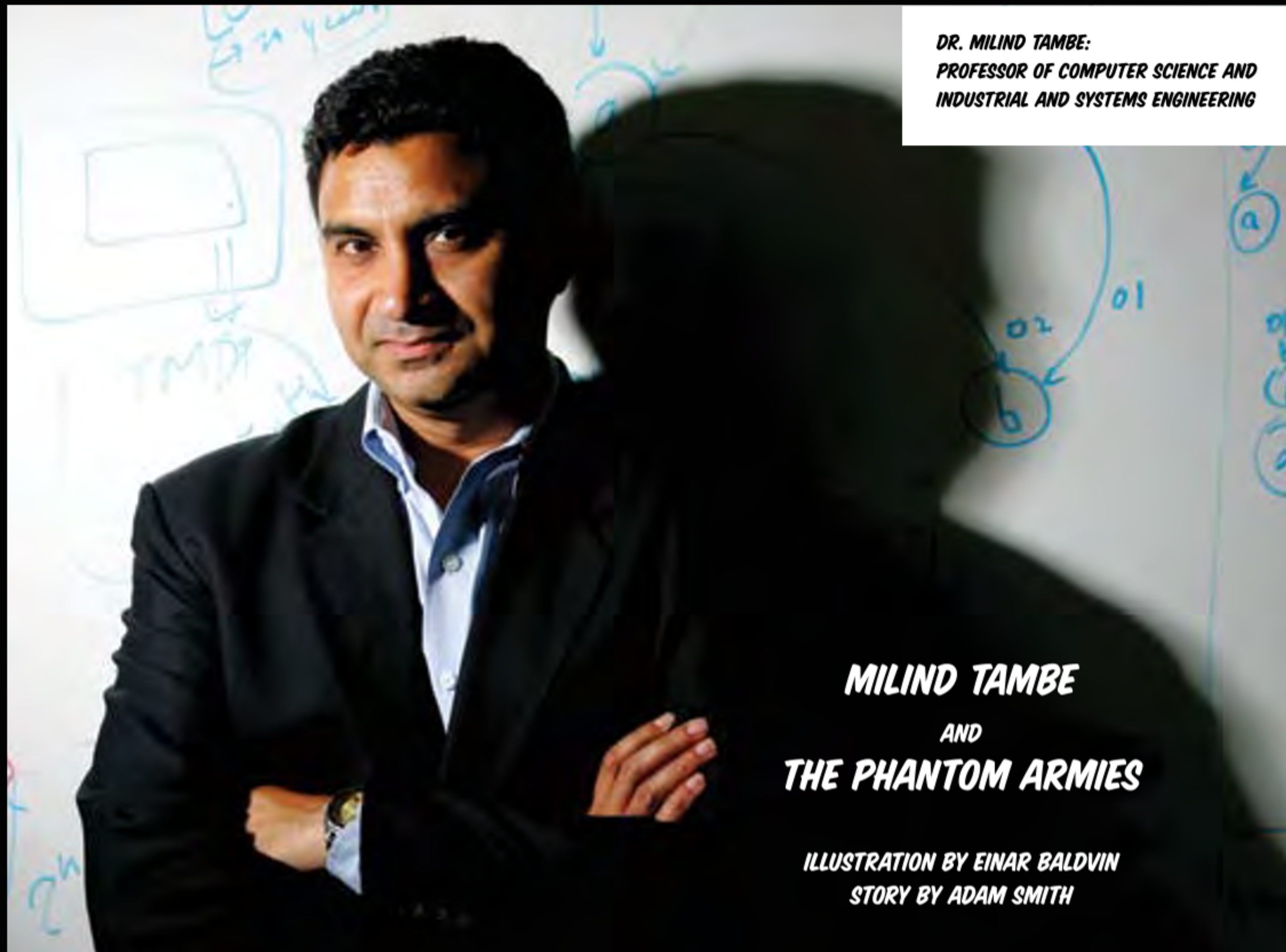
As government regulators continue to auction valuable airwaves – at times for a billion dollars per megahertz – there is an imminent need for wireless devices to work at all levels of the existing and emerging frequency spectrum. The few solutions that do currently exist are expensive, complex, and un-scalable; Abtum hopes to fill the void.

The team had this flood of need in mind when choosing a name for their company. A Persian name, Abtum means "creator of plentiful waters."

Abtum's chip would replace and perform the functions of multiple radio frequency components within current wireless devices, reducing cost, footprint and complexity, while allowing more space for other key components of a mobile device such as displays and batteries. In short, the product would enable users to access a wider variety of media from a smaller device with a longer battery life.

Research and development is currently being funded by the U.S. Department of Defense, so the team doesn't plan to begin actively fundraising until the second or third quarter of 2012. That hasn't stopped them from talking to potential customers, or presenting to a group of venture capitalists in the Bay Area, as arranged by USC's Stevens Institute for Innovation.

Potential customers include telecommunications companies, defense and public safety and mobile device makers. *–KD*



DR. MILIND TAMBE:
PROFESSOR OF COMPUTER SCIENCE AND INDUSTRIAL AND SYSTEMS ENGINEERING

MILIND TAMBE AND THE PHANTOM ARMIES

ILLUSTRATION BY EINAR BALDVIN
STORY BY ADAM SMITH

WHEN I WAS A CHILD IN MUMBAI, MY FATHER TOOK ME TO A CONSTRUCTION SITE. HE SHOWED ME A BRIDGE HE BUILT. I THOUGHT IT WAS EXTRAORDINARY.

I NEVER SAW A REAL COMPUTER UNTIL COLLEGE. BUT I HAD FRIENDS NAMED RODDENBERY AND ASIMOV. THEY TOLD ME ABOUT COMPUTERS THAT COULD PILOT STARSHIPS OR SOLVE THE WORLD'S GREATEST RIDDLES.

COMPUTER SCIENCE WAS A RIDDLE TO MY PARENTS. WHAT WAS IT EXACTLY? YOU CAN'T SEE IT LIKE A 2,000 METER BRIDGE.

TEN YEARS AGO, I STARTED DOING VERY THEORETICAL RESEARCH. ALGORITHMS THAT USED RANDOMNESS TO COORDINATE ROBOTS ON THE SURFACE OF MARS.

TURNS OUT, WE DIDN'T NEED RANDOMNESS ON MARS. WE NEEDED IT HERE ON EARTH.

MY MENTOR ONCE TOLD ME: "YOU DON'T CHOOSE THE PROBLEM; THE PROBLEM CHOOSES YOU."

I DIDN'T KNOW IT THEN – BUT ONE DAY IN SEPTEMBER, THE PROBLEM CHOSE ME.

HOW CAN WE USE RANDOMNESS TO STOP THE TERRORISTS? I TURNED TO SOMETHING CALLED "GAME THEORY."

IMAGINE YOU HAVE EIGHT DOORS YOU NEED TO PROTECT. BUT YOU HAVE ONLY ONE COP. WHAT IF – WHAT IF YOU COULD CREATE THE ILLUSION THAT YOU ACTUALLY HAD EIGHT COPS? IT WOULD BE LIKE YOUR OWN PHANTOM ARMY.

WORKING WITH MY STUDENTS AT THE USC VITERBI SCHOOL OF ENGINEERING, WE CREATED A SOFTWARE PROGRAM CALLED ARMOR.

SINCE 2007, IT'S USED 'INTELLIGENT RANDOMNESS' TO PROTECT EVERYTHING FROM AIRPORTS, PASSENGER JETS, U.S. PORTS AND PUBLIC TRANSPORTATION.

A COUPLE MONTHS AGO, THERE WAS A RASH OF THEFTS IN A NEIGHBORHOOD. LIKE CLOCKWORK, THE THIEVES KNEW EXACTLY WHEN PEOPLE LEFT AND RETURNED HOME.

THE TERRORISTS ARE THE SAME. IN A WORLD OF SCHEDULES, OF PATTERNS, THEY LEARN TO EXPLOIT THEM. THEY LIKE PREDICTABILITY.

THERE ARE SIX INBOUND ROADS TO LAX. NOT ENOUGH POLICE TO MAN CHECKPOINTS ON ALL ROADS AT ALL TIMES. THERE ARE EIGHT TERMINALS. NOT ENOUGH K9 UNITS TO PATROL ALL OF THEM.

FOR THE BAD GUYS, WHAT THEY DON'T KNOW – WHAT GIVES THEM PAUSE – IS WHERE AND WHEN THESE LIMITED SECURITY FORCES WILL BE DEPLOYED ON THE DAY THEY ATTACK.

THAT'S WHAT ARMOR DECIDES.

THERE ARE THOUSANDS OF INTERNATIONAL FLIGHTS EVERYDAY IN THE UNITED STATES. WE DON'T HAVE AN AIR MARSHAL FOR EVERY FLIGHT. THE BAD GUYS KNOW THIS, TOO.

WE CREATED ARMOR IRIS TO KEEP THEM GUESSING.

ARMOR PROTECT IS USED BY THE COAST GUARD OF BOSTON AND NEW YORK CITY. DECIDING PATROL SCHEDULES, LOCATIONS, FREQUENCY, ETC.

SOMEONE ONCE ASKED: "WHERE DID YOU GET ALL THESE EXTRA BOATS?" I HAD TO LAUGH. THE COAST GUARD HAS THE SAME BOATS AS BEFORE.

ARMOR IS NOT LIMITED TO JUST SECURITY. IN A WORLD WHERE COMPUTER ALGORITHMS HELP FIND THE UNDERVALUED BIG LEAGUE PITCHER OR PREDICT THE WEATHER MONTHS IN ADVANCE – IT CAN BE USED FOR ANY PROBLEM WHERE YOU HAVE LIMITED RESOURCES AND CAN'T BE EVERYWHERE AT ONCE.

A PERSONAL FAVORITE: PROTECTING ENDANGERED TIGERS IN THE INDIAN SUBCONTINENT.

I NEVER BUILT A BRIDGE OR A HIGHWAY. MY WORK IS INVISIBLE. I CAN TAKE MY KIDS TO SEE A CHECKPOINT AT LAX. BUT IT'S NOT QUITE THE SAME AS THE TAJ MAHAL OR THE HOWRAH BRIDGE.

MY SUCCESS IS BASED ON A NON-EVENT. I'M OK WITH THIS.

LIFE AFTER

40

1972. The space shuttle program began; the CD, the digital watch, Fortran and C programming languages were invented; and the Atari Company released an explosively popular new product called Pong.

In the midst of this, 40 years ago at USC, three remarkable institutions were born.

Here are the stories from then and now: the **USC Distance Education Network,** the **Signal and Image Processing Institute,** and the **Information Sciences Institute,** all about big promises made – and delivered.

FROM PIONEERING THE INTERNET, SENDING SATELLITE IMAGES THROUGH SPACE OR BRINGING EDUCATION ACROSS CONTINENTS, THREE VITERBI INSTITUTIONS ARE JUST GETTING STARTED. *BY ERIC MANKIN*

Signal and Image Processing Institute (SIPI)

The cover of the December 1972 issue of USC Engineer contains a blurred image of Earth over the line "image processing."

Almost the entire issue that follows is dedicated to the achievements of a remarkable group of researchers who found each other at USC in the 60's – led by alumnus William Pratt (EE M.S. '61 Ph.D. '65) – and went on to history, a history that included embedding the face of a Playboy model as an icon in the literature.

In 1972, a major grant to Pratt led to the founding of the USC Image Processing Institute (IPI), which subsequently transformed the discipline, creating software that remains in daily use today, as the ubiquitous file label JPEG illustrates. IPI was later re-named as the Signal and Image Processing Institute (SIPI) to reflect its expanded research activities.

Pratt, now at Pixelsoft, began as a USC graduate student under Irving Reed, a pioneer in the field of information theory. Reed steered him to research in video coding, which became his Ph.D. thesis, one that opened the field to research.

At the time, simply capturing an image – either video or a still, electronically – had already been solved. Pratt and his backers created SIPI to solve three related problems: "image coding, image restoration and enhancement, and image data extraction." Coding involves reducing the amount of information required to transmit or reproduce video or photos so that, for example, a space satellite could send back volumes of usable images despite severe weight, space and energy limitations.

Lots of the initial work was done on a single image: Lena – half a picture from Playboy, scanned by a student, wound up being propagated around the research community and was the prototype subject for a type of coding that is now ubiquitous: the JPEG.

The invention of JPEG was not an isolated achievement for SIPI. Other outstanding achievements, many by faculty still at the Viterbi School, include:

- MPEG, the moving image equivalent to JPEG in economic recording and transmission of video, with major innovations in fast motion search and rate control contributed by C.-C. Jay Kuo and Antonio Ortega, respectively.
- Image recognition and detection, pioneered by Pratt's close colleague Harry Andrews.
- Medical imaging developments, including the "Brainstorm" software system created by Richard Leahy.

PIN UP *In 1973, Alexander Sawchuk and the SIPI lab manager needed a glossy color image for a conference paper, and just then, he recalls, somebody happened to walk in with a recent issue of Playboy. "Lena" became the international standard test image for image processing algorithms.*

- Development of "fuzzy logic" by Bart Kosko and Jerry Mendel, a technique to avoid over-sensitive, continuous on-off controls by software always hyper-defining yes and no.
- Optical image processing and three-dimensional imaging (holography) brought forward by Alexander "Sandy" Sawchuk and Andrews.
- Sound reproduction, with Chris Kyriakakis developing new systems creating extraordinary fidelity by awareness of listener location.

C.-C. Jay Kuo, SIPI's current director, is enthusiastic about how first-rate work continues to manifest from Pratt's original vision, in all three areas – but in decidedly new forms. "We are moving from image processing to more multimedia signal processing – speech processing, video understanding, biomedical engineering."

And SIPI researchers are now at the forefront in these new areas. Shri Narayanan has attracted international attention for his success in "behavioral informatics," using computational methods to decode nonverbal human communication, including emotional communication, between husbands and wives, for example.

And interpretation of medical images is a major area of image processing – one in which Krishna Nayak has made remarkable advances, most recently with a new technique that allows physicians to track blood flow through heart tissue without dyes.

Additionally, interpretation of images – ability to recognize faces or to follow images in moving video captures, has moved dramatically forward in work done in the laboratory of Gerard Medioni.

Pratt is proud of the legacy he left and the memories. "USC has come miles and miles from when I walked in the door," he recalls. "I got a fellowship from Hughes in '59 . . . and the first person I met was (former dean) Zohrab Kaprielian. He was my mentor. I said, 'I wanted to do a thesis on video coding, and I need some equipment.' He said, 'I have some money set aside from the Air Force – you can have it all; nobody else has any ideas.'"

"I owe so much to USC – it was a golden opportunity; it changed my life for the better."

"(DEN) is no longer just distance learning. It is a system for enabling all students to learn through sophisticated, interactive interfaces. It enhances learning for everyone." — **KELLY GOULIS**, Senior Associate Dean for Graduate and Professional Programs

Distance Education Network (DEN)

In 1972, the expression "distance education" was brand new and widely unknown. Educators had written about the promise of live television for teaching, leading the FCC to license local TV broadcasts by colleges in 1963.

But few real world examples existed when USC Engineering took the lead, boldly creating the Norman Topping Instructional Television Network (ITV) to address the continuing needs of engineers working in the aerospace industry.

The architect of the system was Jack Munushian, who came to USC in 1968 from Hughes Aircraft. "To an extent few people realize, we at the Viterbi School live in a house that Jack built," commented Dean Yannis C. Yortsos following Munushian's passing in 2005. When the IEEE Educational Activities Board awarded the highly coveted Major Educational Innovation Award to Munushian in 1988, the school had already recorded thousands of enrollments in classes via ITV.

The short range, line-of-sight television relays of 1972 survived for 25 years. Then, in 1997, an agreement with Qualcomm to deliver courses to their engineers in San Diego was the catalyst for DEN to invest in the next generation of technology, leading quickly to satellite broadcasts to corporate sites all over California and Arizona.

And then came Internet delivery – *global reach*. President C.L. Max Nikias, while dean of the Viterbi School, was an unflagging exponent of improving and upgrading DEN, working with Herb Schorr of ISI to integrate ISI's skill in network technology with the new model.

As DEN's executive director, Binh Tran took the lead in using ISI's fundamental web technology and building it into a functional, flexible and user-friendly system. "It is no longer just distance learning. It is a system for enabling all students to learn through sophisticated, interactive interfaces. It enhances learning for everyone."

Throughout these changes in technology, the underlying academic structure of a USC Viterbi School of Engineering master's degree has remained constant. DEN students meet the same admission requirements, uphold the same academic standards and fulfill the same rigorous curriculum as on campus students.

Forty-seven M.S. degree programs are now offered online through DEN; the relationship with industry continues to grow, with dozens of major companies here and abroad now providing employees the opportunity to enhance their education. The course offerings have expanded from the initial concentration of aerospace and defense industries to subjects in many other areas – for example, students in Kuwait are studying petroleum engineering and students in South Korea are studying engineering management.

DEN has provided access in some unusual locations. Perhaps the most dramatic instance of this was an Army soldier who completed all of his studies while on active duty: first in Kuwait, then in Afghanistan. Captain Matt Smith received his M.S. in Electrical Engineering in 2010. Attending the commencement ceremonies at the Galen Center "was the first time I ever stepped on campus," Smith said.

Another remarkable DEN student story is taking place right now. Ryan J. Williams was on his way to a Ph.D. under the guidance of Professor Gaurav Sukhatme, when an accident left him a quadriplegic. Williams is now living at his parents' home in Virginia with only limited hand and arm mobility.

And he is still on track for his degree, thanks to DEN. "After my accident, I required three classes to fulfill my course load for the Ph.D."

Stories like Smith and Williams are exceptional, but every day DEN is impacting the landscape: the technology and resources are changing the shape of education at Viterbi and at USC.

One standout example is the iPodia program. With DEN as a platform, iPodia allows undergraduate students in Beijing, Taipei and Los Angeles to collaborate on engineering courses in a real-time, face-to-face format. Discussions for other collaborative programs incorporating DEN are taking place with other international universities including India, Mexico and Germany.

"It is no longer distance learning," said Kelly Goulis, USC Viterbi Senior Associate Dean for Graduate and Professional Programs, who has cultivated DEN from local television relay to global Internet delivery. "It is enabling all students to enhance their learning experience through sophisticated interfaces. It is live content over the web, which is valuable for students everywhere, just as much for on-campus students as for distance learners."

Information Sciences Institute (ISI)

By the time the words you are reading have been printed, the world's first fully programmable quantum computing laboratory will have completed its first actual computations in another Viterbi School body that this year celebrated its 40th birthday.

Dr. Keith W. Uncapher created the University of Southern California Information Sciences Institute (ISI) in April 1972. By 1973, according to Uncapher, ISI had "a staff of 48, including 10 graduate students, and four USC faculty participants," occupying 20,000 square feet in the Marina del Rey building – that remains its campus to this day – working on six projects for the Advanced Projects Research Agency (ARPA) using a state-of-the-art PDP 10 computer connected to ARPA's nascent network then called Arpanet. Now it is known as the Internet.

ISI work was a fundamental driver of Arpanet into the Internet. This role, particularly the contributions of ISI staffers including Paul Mockapetris, Danny Cohen and Jonathan Postel – is perhaps its most widely known research contribution. But major advances in numerous other areas of engineering have come out of the 12-story tower overlooking the harbor, including:

- Natural language programs to translate between human languages: from English to Chinese or Arabic, for example. Kevin Knight and Daniel Marcus' system has repeatedly won national competitions.
- Programs to teach languages to servicemen, including "Tactical Arabic" used in Iraq and "Tactical Pashto" used in Afghanistan, created by W. Lewis Johnson.
- Artificial intelligence, teaching machines to think the way humans do is a primary focus at ISI, with numerous researchers, including Yigal Arens and Yolanda Gil. Jerry Hobbs and Ed Hovy used these techniques to help write the IBM Watson system that won "Jeopardy!"
- Geographical information systems allowing detailed data retrieval, keyed to map coordinates by Craig Knoblock, so that clicking on any point on a map returns detailed data from many sources.
- The MOSIS chip brokerage, used by companies, academics and students everywhere to create affordable chip prototypes.
- Chip design for advanced applications, including 'processor in memory' chips, prosthetic chips that imitate biological functions and more.
- Computer system design to make supercomputers more flexible and user-friendly by Robert Lucas and colleagues, and Robert Crago's parallel computers, which have multiple hardware clusters intelligently cooperating to solve complex problems.
- Grid computing, a resource sharing system co-invented by Carl Kesselman, which has evolved into the now ubiquitous cloud computing systems Kesselman applies medical information.
- Robotics, including Wei-Min Shen's unique modular "transformer" system, in which identical modules reassemble themselves in different shapes for different use – turning from a crawler to a climber to a digger depending or whether it is on the moon or under the sea.

CALCULATED By the time the words you are reading have been printed, the world's first fully programmable quantum computing laboratory will have completed its first actual computations here.

Since 1988, Herb Schorr has been executive director of ISI. He has been witness to many changes, but nothing perhaps as dramatic as the USC Lockheed Quantum Computing Center, which held its official ribbon-cutting ceremony on October 28, 2011 (see story, page 33).

While ISI began with almost exclusively government funding – especially DARPA – Schorr foresaw that a critical factor today is to find auxiliary funding from non-government sources. And ISI is finding promising areas for such funding. The new quantum computing system is a partnership between Lockheed Martin, USC and D-Wave Systems, the manufacturer of the device.

Another increasingly critical area is cybersecurity. Specialists Terry Benzel and B. Clifford Neuman have, in cooperation with UC Berkeley, created a unique, safely sealed off facility – the DETERlab, where researchers and students can study malicious code without endangering other machines. The Department of Homeland Security and National Security Agency have recognized ISI as a National Center of Academic Excellence in Information Assurance Research (CAE-R), and students from numerous institutions are now studying cybersecurity through USC.

Artificial intelligence, teaching machines to think the way humans do is a primary focus at ISI, which has led to using these techniques to help write the IBM Watson system that won "Jeopardy!"

And space travel is no longer a totally government operation. Since 2010, ISI has been working with the Space Engineering Research Center (SERC) on a new generation of satellite vehicles (see story, page 13).

"We are now beginning to witness that ISI and USC are becoming an attractive force to the U.S. computer science community," wrote Uncapher decades ago. "I believe that through the use of ISI's reputation along with that which already exists at USC, that we will be very successful in attracting very, very good computer people."

The decades have proven Uncapher right.

2012: A Quantum Odyssey

How USC Became Home to the World's First Operational Quantum Computing Center at a University and Why It Matters

by Adam Smith, photograph by Adam Voorhes

At noon, on December 23, 2011, the USC Viterbi School of Engineering awakened its first volcano.

Odd thing is, despite its location in Marina Del Rey, this particular "volcano" was situated in one of the coldest places on earth – 100 times colder than intergalactic space.

The crown jewel of the USC Lockheed Martin Quantum Computing Center, the 128 qubit Rainier chip – christened after the massive strato-volcano outside Seattle – became operational two days before Christmas last year. There was no fanfare of trumpets. No banks of coruscating neon lights.

Somewhere in the USC Information Sciences Institute (ISI), inside a 12-foot black box, a tiny quantum processor began to stir. The culmination of 12 years of work by Canadian-based D-WAVE, Rainier had found its first customer in Lockheed Martin, the world's largest defense contractor.

Lockheed Martin, in turn, had found a home for the cold, black box at ISI, the university's storied research institute.

In the years to come, the USC Lockheed Martin center may prove to be the testbed for a whole new generation of quantum engineers. It may begin to solve the sort of optimization problem that outstrip classical computers. Indeed, Rainier's successor – the 512 qubit Vesuvius chip – has the potential to solve problems in 120 milliseconds that would take the world's most powerful supercomputers 320,000 years.

For now, December 23, 2011, may be remembered as the day a payroll tax cut was passed by Congress. Or the first Friday of the Mayan doomsday calendar.

Or something else entirely.

The Conversation

Ned Allen, Lockheed Martin's chief scientist, had a problem.

All sophisticated hardware, from the Chevy Volt to the MAC OS, has lots of code. But when an operating system fails, it's a minor annoyance. When a multi-billion dollar F-35 Joint Strike Fighter has software bugs, it's mission critical.

In January of 2010, Allen requested a meeting with Daniel Lidar, professor of electrical engineering and director of the USC Center for Quantum Information Science & Technology. Lidar thought it was a meeting about potential funding from Lockheed Martin; the talk quickly turned to jet fighters.

As Lidar noted, "Microsoft can release a version of Windows whenever they want, and the worst thing that can happen is customers will complain that the operating system is crashing. But when you talk about an airplane, it won't even get off the ground until you have convinced the people in charge the software runs correctly."

As Allen explained, that means a process called V&V – verification and validation – whereby Lockheed engineers essentially *test to exhaustion*, either of funds or the engineers themselves. Lockheed Martin's F-35 jet fighter has

TO BOLDLY GO . . .
The next quantum chip, D-WAVE's 512 qubit Vesuvius chip, promises to address problems with more variables than all the atoms in the universe.

With quantum computers we should be able to solve problems in a matter of hours, instead of… the age of the universe

millions of lines of code. What's worse, sophisticated jet fighters are only adding more code, not less. The problem is compounded by the fact that Lockheed Martin doesn't write all their own software – they rely on parts from other companies, even those overseas. That raises the specter of not just bugs, but *malicious bugs*.

"He impressed upon me very clearly," said Lidar, "that they were up against the wall, and the problem was only getting worse. This was taking an unreasonable amount of time and money – between 10 to 20 percent of the F-35 project being devoted to V&V. It's in the many billions."

Allen was looking for a radical new solution. Not just a theoretical approach, but a quantum computing solution using real machines. Rather than painstakingly debugging a plane one line of code at a time, could quantum more rapidly detect the anomalies in the code?

Lidar remembered D-WAVE – "the SpaceX of quantum computing." During his time at University of Toronto from 2000 to 2004, a then fairly unknown D-WAVE had been busy amassing intellectual property, including three patents from Lidar on "overcoming quantum decoherence." Since then, they had announced the creation of "the world's first commercially available quantum computer."

He convinced Allen to take a look at the D-WAVE One, the Rainier chip. Nearly a year and a half later, that conversation in Lidar's office blossomed into D-WAVE's first sale.

Five months later – October 28, 2011 – Yannis C. Yortsos, USC Viterbi dean, Ray Johnson, chief technology officer of Lockheed Martin and Vern Brownell, president and CEO of D-WAVE, stood on the 11th floor of ISI and announced the first fully programmable quantum computing system at an academic institution.

Science Fiction vs. Science Reality

Ever since British physicist David Deutsch imagined a quantum computer that could prove the existence of parallel worlds and solve the inscrutable nature of photons, electrons and atoms, quantum computing has mainly existed in the world of theory.

Today, inside the black box, is a small, magnetically shielded realm that goes beyond the laws of classical physics. The Rainier chip's computational power derives from the atomic and subatomic kingdoms of quantum – where the spin of an atom's nucleus can determine how information is stored on a computer.

Whereas classical computers store bits of information as either a "1" or "0", the D-WAVE machine can store "qubits" of information in either state – or both. For the 128 qubit Rainier, that means, at least in theory, it can calculate problems with a lot of different variables, problems so vast they have 3.40282367 × 1038 possible answers.

To put that in perspective, the most state of the art quantum devices today have gotten no further than 14 qubits, and they're largely not scalable. The D-WAVE machine is, and that next volcano – the 512 qubit Vesuvius chip – promises to address problems with more variables than all the atoms in the universe.

The D-WAVE machine cannot solve problems that are impossible for today's classical computer, but it is an accelerator – a device that, in all likelihood, can solve specific optimization problems faster than any processor ever built.

As Lidar told KPFK radio recently: "With quantum computers we should be able to solve such problems [protein folding] in a matter of hours, instead of… the age of the universe."

In addition to optimization problems like V&V (see sidebar, page 37), the new center also means a chance to study the very nature of quantum physics, "the spooky action at a distance" that so befuddled Einstein.

"I try to understand how nature works," said USC ISI's Sergio Boixo. "But that was before we had an actual device. Three years ago, it didn't seem possible."

According to Boixo, what people think is science fiction might actually be science reality. "That's something I realize everyday. Every time I run a new benchmark [on the Rainier] and I get a positive result . . . I remember when I saw the paper by Hartmut Neven of Google, who actually used the chip for image recognition. They managed to outperform, in some metrics, the algorithm that Google is already using."

Boixo, a Spanish born quantum engineer who ran software for the European Central Bank, was brought to ISI specifically to test the new chip. He represents the latest in a continuum going back to 2003, a joint strategy between USC Viterbi and the USC Dornsife College of Letters, Arts and Sciences to hire new faculty in quantum computing and related disciplines. Today, after USC bested several other university suitors for Lockheed's hand, that investment looks strategic, indeed.

But more than anything, at the heart of the new center is a focus on students. Kristen Pudenz, for example, one of four Ph.D.s. working with Lidar, was the co-author of the paper on the F-35 problem: quantum V&V. Nearly four months ago, she was among the very first to remotely access the Rainier chip from her laptop at the USC campus.

"This is fantastic," said Pudenz. "It's not just writing papers – I can actually come up with an algorithm that I think will work and test it right away. I don't have to wait for the results."

Said Dean Yortsos: "Experimenting with this device, I would say it's almost the same as how computer scientists and engineers experimented with the original silicon chip at the dawn of the computing era, which goes back 50 years or so.

"History will show whether this is true or not. But unless you take this adventure, you will never know – and this is what we're doing."

ABOVE (from left to right): *Vern Brownell, president and CEO of D-WAVE; Yannis C. Yortsos, USC Viterbi dean; Ray Johnson, chief technology officer of Lockheed Martin; and Herb Schorr, executive director of the USC Information Sciences Institute, announce the USC Lockheed Martin Quantum Computing Center.*

QUANTUM QUOTABLES

"My career started with programming Von Neumann's original machine. Fortunately or unfortunately, I go back a long ways in this computing racket. **And to me, the best part of [the D-WAVE machine] is – if I go downstairs – it's a real machine, it's hardware.** I can get my hands around it. I think we're at the dawn of a new era of computing in my lifetime."
Herb Schorr
Executive Director, USC Information Sciences Institute

"Sixty years ago, the UNIVAC 1 [the Universal Automatic Computer], the first commercially available computer in the United States was first sold to the U.S. Census Bureau. It was initially conceived for business and administrative use – it could add two 10-digit numbers at a rate of almost 100,000 additions per second. It even predicted the electoral victory of Dwight D. Eisenhower the following year. Few, if any, however, predicted that this 15-ton machine would revolutionize every aspect of how we live our lives.

UNIVAC 1 was the first modern computer in the United States – all subsequent computers have been merely improved versions with more advanced microelectronics, memory and communication technology.

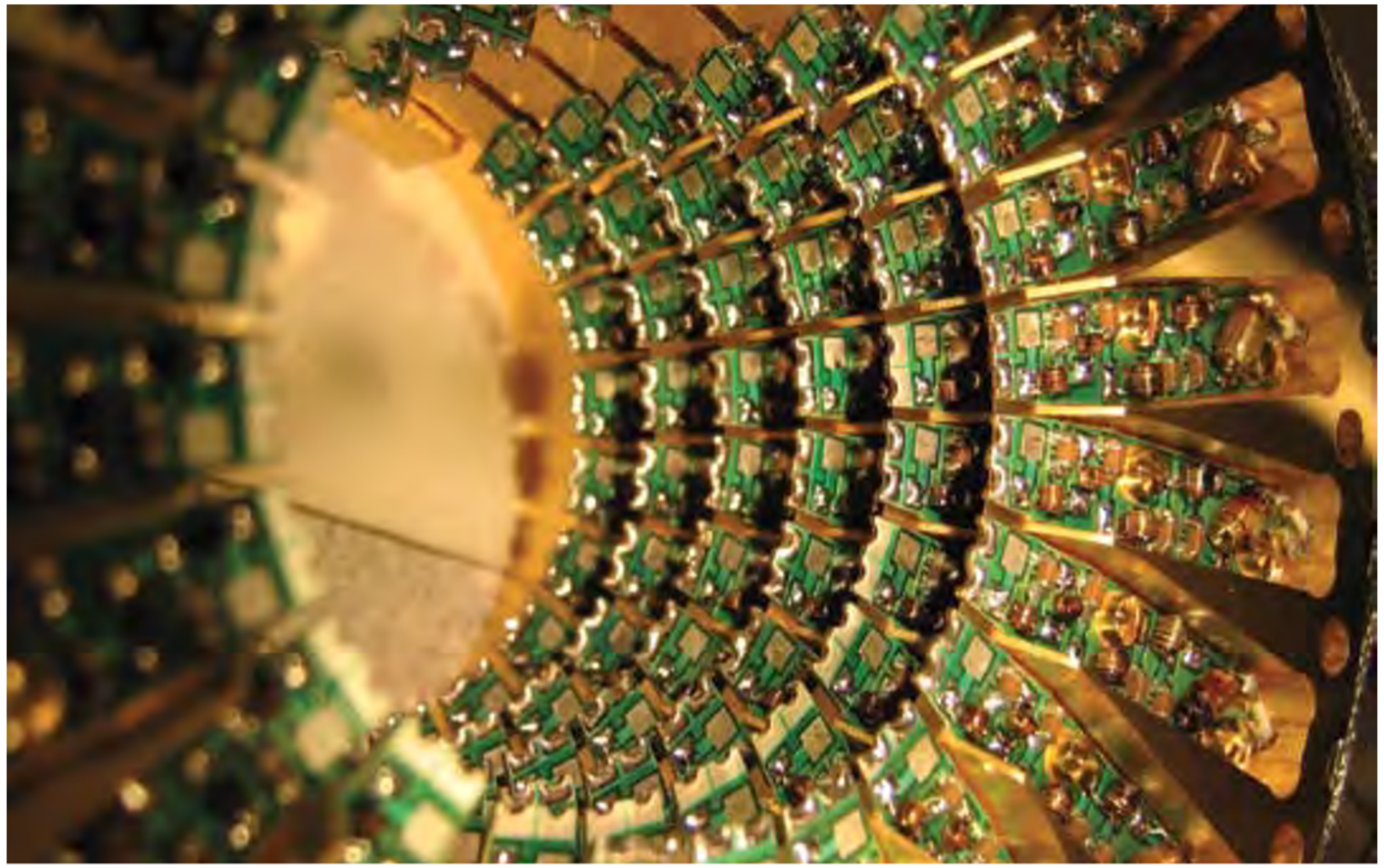
The D-Wave One Adiabatic Quantum Computer represents not merely the latest ancestor of UNIVAC, but the next big leap – the advent of scalable quantum computing."
Yannis C. Yortsos
Dean, USC Viterbi School of Engineering

"This whole enterprise of creating a quantum computer started in the mid-nineties in a very unusual place. A commerce course at UBC [University of British Columbia] taught by a guy named Haig Farris (future co-founder of D-WAVE). I took Haig's course as a Ph.D. student in physics kinda on a whim. I thought it might be cool to see how business things worked. About midway through the course, we had an essay that was due for a significant portion of our grade.

I had a whole bunch of mid-terms, and I was thinking about just not doing it. . . . It occurs to me now, during the subsequent 12 years – If I hadn't written that essay, if I decided to blow it off like I really wanted to, I wouldn't have met Haig, and none of this would've happened . . ."
Geordie Rose
Founder and chief technology officer, D-WAVE

"ISI has always worked in the early development of technology that revolutionizes society. We got involved in the early days of the Internet.

I see [the quantum chip] being similar to the way transistors were in the sixties. I can still remember all the quotes back then – 'Transistors will never work; electronic vacuum tubes will never be replaced.' A few years later, those tubes were out of existence. Transistors today are a $300 billion worldwide industry. That's more than the GDP of Holland or Austria."
John Damoulakis
Deputy Director, USC Information Sciences Institute



SETH LLOYD (SL) is a professor of mechanical engineering and director of the W.M. Keck Center for Extreme Quantum Information Theory (xQIT) at the Massachusetts Institute of Technology. Dr. Lloyd created the first technologically feasible design for a quantum computer and participated in the first experimental demonstrations of quantum computation. His work is the basis for the first commercially available quantum computer, produced by D-Wave.

DANIEL LIDAR (DL) is a professor of electrical engineering and chemistry at USC, where he is scientific and technical director of the USC Lockheed Martin Quantum Computing Center. In addition, he is the founding director of the USC Center for Quantum Information Science & Technology (CQIST). He was elected a Fellow of the American Physical Society and a Senior Member of the IEEE in 2007.

Q & A: SETH LLOYD AND DANIEL LIDAR

SL: Why are you interested in adiabatic quantum computation, and what made you decide to help Lockheed Martin operate their adiabatic quantum computer?

DL: My interest in adiabatic quantum computation (AQC) is driven by my perception that it is likely to be the approach that will lead to the first realization of a truly large scale quantum computer. I am also fascinated by the intrinsic beauty of the idea of gently guiding quantum dynamics to find the solution to hard problems. And, AQC is still relatively unexplored compared to the circuit model, which means that there are still major open questions to be answered... Regarding Lockheed Martin, USC is grateful to the company for its decision to partner with us, and to establish a joint and equal partnership research Center...

SL: Although the jury is still out on whether adiabatic quantum computers can provide an exponential speed-up over classical computation, many quantum computer scientists with whom I have spoken have expressed skepticism that adiabatic quantum computers can provide such a speed up—even in principle, let alone in practice. What do you think?

DL: We know from theoretical work that in principle AQC is "computationally equivalent" to standard, circuit model quantum computing. This means that any computation performed in one model (adiabatic or circuit) can be simulated with modest polynomial overhead using the other model. In this sense, any exponential speed-up over classical computation that is known to exist in the circuit model immediately translates over into an exponential speed-up in the adiabatic model... You are probably referring to the fact that we don't yet know whether adiabatic quantum computers can be made fault-tolerant and thus resistant to decoherence and noise, and that this seems essential to ensure a speedup, at least based on our experience with the circuit model. And here I must agree that the jury is still out... in summary, I do not share the skepticism that there is some fundamental reason that adiabatic quantum computers cannot provide a speedup. Whether we can achieve this in practice is of course a very different question, and one of the reasons we want to explore what can be done with the D-Wave chip.

SL: Are the D-Wave adiabatic quantum computers ending up in their ground state—and so solving the desired problem—after a fully coherent quantum process, or do they end up there after some messy, noisy, quasi-thermal process? If you think that they are operating coherently, what experimental evidence can you adduce that suggests that?

DL: We know that the D-Wave chip doesn't always end up in the ground state. But this is OK; as long as it ends up in the ground state with high probability we can run the computation a few times and amplify our confidence that have obtained the right answer. This is a standard procedure also in classical probabilistic computation, and so doesn't present a problem. The fact that the D-Wave chip doesn't always end up in the ground state also teaches us that the process is to some extent incoherent, noisy, and quasi-thermal. On the one hand we can expect that some of this can be engineered away. On the other hand, perhaps the more interesting question is whether it is really essential to strive for completely coherent adiabatic evolution in order to start to outperform classical computers. There is theoretical evidence that even partly incoherent quantum processes can outdo classical computers in certain tasks... In any case, the question of the "quantumness" of the D-Wave chip is probably at the top our research agenda at USC, and is one we are actively investigating.

SL: What kind of hard problems are you currently posing to the adiabatic quantum computer?

DL: Under the very able leadership of Dr. Sergio Boixo, who was recently hired as our first Quantum Applications Engineer at ISI, we are currently performing very detailed benchmarking of the D-Wave chip. We are studying primarily one-dimensional qubit chains and two-dimensional qubit lattices. The one-dimensional chains are "easy", in the sense that we know right off the bat what the ground state should be, and so we can characterize the actual performance of the processor relative to what is expected... The two-dimensional lattices are more interesting and more challenging, since it can be very hard to find the correct ground state even classically. In fact, the qubit layout and connectivity of the D-Wave processor was designed to enable the chip to solve a problem that is known to be NP-hard: the ground state of the classical Ising model on a bi-partite graph. We don't yet know whether the processor can solve this problem with any speed-up compared to classical computers, and our benchmarking is designed to address this very question...

SL: Are you optimistic about the future of adiabatic quantum computing?

DL: I'm cautiously optimistic. We already have preliminary numerical indications that there is entanglement in the state of the D-Wave chip, and this suggest that some of the required quantum magic is present. Ultimately, I believe that some form of error correction will be necessary in order to ensure continued scaling, and this will probably be the main obstacle... I hope that the work we are doing at USC with the D-Wave chip will serve to inspire others to construct adiabatic quantum computers. If I had to gamble, I'd bet that the first demonstration of a quantum computation that runs faster than any current classical machine will be done using adiabatic quantum computing.

What Quantum Means For You

As Niels Bohr famously said, "Prediction is very difficult, especially about the future." Though the USC Lockheed Quantum Computing Center is still in its infancy, its research has profound implications for aerospace, medical imaging, robotics, finance, web search, bioinformatics and other disciplines. Here's just a sampling of potential applications:

Cheaper, More Efficient Solar Power

More sunlight falls on the surface of the Earth in one hour than is necessary to provide energy for the entire world for a year. The problem is a matter of efficiency – most of that energy is wasted. So what molecules are best at trapping sunlight or converting to electricity? It's an optimization problem with so many variables, only a quantum chip has the processing speed to deal with it effectively. For example, working in concert with Harvard 's Alan Aspuru-Guzik, the D-WAVE machine is now analyzing 10 million molecules that might be perfect candidates for cheap photovoltaic plastics.

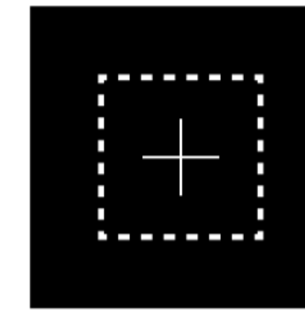
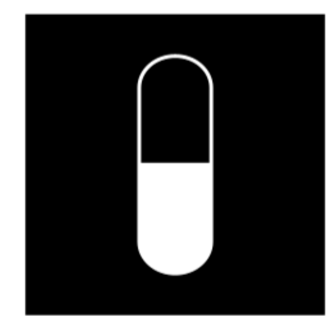


Image recognition

This is essentially an area of machine learning – how do you teach a computer to find a needle in a haystack? With the advent of digital photography, the world produces billions of photographs. Humans, of course, can easily identify objects in a photo, but computers can't. Enter quantum. Imagine a future where you can search Google images and find anyone wearing your high school class colors or the EPA can detect the slightest changes to polar icecaps from a wealth of satellite imagery.



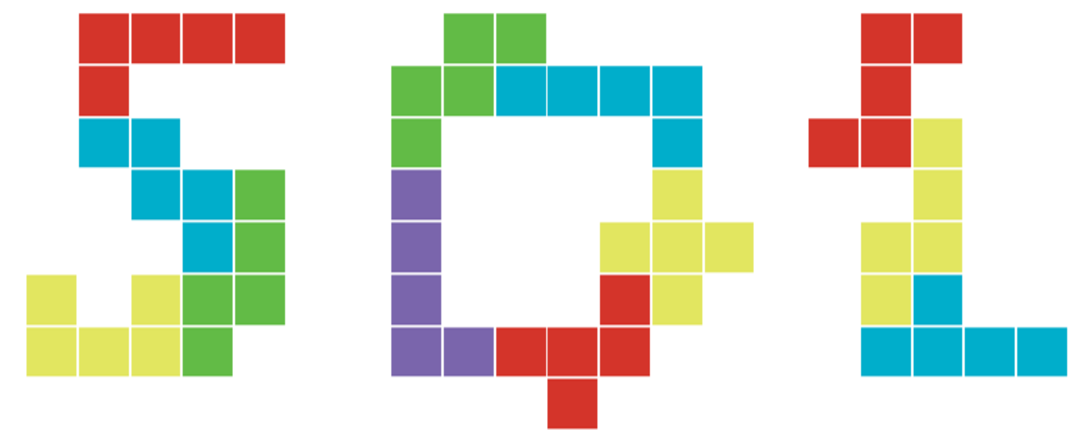
New Designer Drugs

Proteins are the workhorses of the body, taking on a wide variety of tasks. They fight infections, turn food into energy, copy DNA and catalyze chemical reactions. Insulin is a protein, as are antibodies and many hormones. And like a piece of biological origami, the protein folds itself into the form necessary to carry out its job. Without the shape, the protein would be worthless. It's very hard to simulate protein folding, even on giant supercomputers. If you want to make a designer cancer drug, for instance, it's not enough to know which atoms you would use. What shape will they be in? That's a quantum problem.

Web Search

Today's Internet landscape has billions of web pages. Google's Page Rank algorithm must go through all these sites on a routine basis to curate your search results. But this problem quickly becomes one of scale – what happens when there are trillions of web pages? It turns out that Page Rank can actually be mapped to quantum computing and made faster. Though invisible to most of us, this is a huge calculation and will be crucial to how we consume information across an exploding digital universe.

PHOTOGRAPH COURTESY OF D-WAVE SYSTEMS



Digital pioneer **Sol Golomb** celebrates 50 years at USC

by Eric Mankin, photography by Noe Montes

More than six decades ago, a Baltimore-born prodigy graduated from Johns Hopkins University with a B.S. in mathematics before his 19th birthday. That individual remains brilliant in 2012, celebrating his 80th birthday and his 50th year on the faculty of the USC Viterbi School of Engineering – a school named after the young graduate student he mentored many years ago.

Polylingual, a USC leader, an international authority in communications, a celebrity in the world of mathematical games, winner of almost every honor in his multiple fields, Sol Golomb continues to teach (including freshmen seminars), to write (including deeply informed essays on history) and to research as he enters his ninth decade.

And his is the story of a remarkable individual embedded in a remarkable generation. Golomb was a leader in an extraordinary cohort of American thinkers who revolutionized understanding of the longstanding mysteries of mind and thought: breakthroughs as fundamental, or even more so, as the understanding of gravity, or the atom.

It all began in 1948 – three breakthrough IT discoveries at Bell Labs. That year, as Golomb recently wrote, saw the publication of "A Mathematical Theory of Information" by Claude Shannon, a figure Golomb compares to Einstein and Newton; the Allied invention of error correcting codes by Robert Hamming; and the invention of the transistor by John Bardeen, Walter Brattain and William Shockley.

Golomb recalls that as a young scientist working for his Ph.D. at Harvard, he was initially expecting to travel the abstract route of pure mathematics, but a summer job in engineering at Lockheed Martin, along with a Fulbright scholarship that took him to Oslo, Norway, brought his attention to the explosion of consequences of the 1948 revelations.

As a result, in 1956, after completing his Ph.D., he did not proceed directly to academia, but instead went to the Jet Propulsion Laboratory, where a wildly talented and diverse set of minds were working on projects including – four months after the Russian launch of Sputnik – the first U.S. satellite, Explorer.

"Our average age at the time was about 25," Golomb recalled, and the group included Andrew Viterbi (the future naming donor for the USC School), Lloyd Welch, William Lindsey, Thomas Kailath, Robert McEliece and others whose list of honors would fill this entire magazine.

And it was not just space that these minds attacked. At the same time, the information theory implications of the discovery that DNA carried the coding of living things were sinking in. Golomb and one of his JPL colleagues were on that case as well.

As he recently wrote: "It was through Max Delbrück, the acknowledged father of molecular genetics, whom I met in 1956, that I met the others in this field. In 1960, on my first visit to London, I took a side-trip to Cambridge, where I spent the day with Francis Crick. He took me to lunch at the Eagle, the pub where Watson and Crick worked out the double helix structure of DNA, according to legend, on the back of a napkin."

Golomb insights enabled the Mars rovers to send back clear video images of what they saw on the surface of the red planet 100 million miles away.

Perhaps, Golomb's most outstanding contribution to the legacy of this outstanding group of colleagues was his analysis of shift register sequences, random-seeming series of bits that concealed a deep, unmistakable and highly conspicuous order to listeners who knew what to listen for.

Golomb created the mathematics behind them while still a graduate student at Harvard. A digital electronic message, he realized, could be modulated into a shift register sequence produced at a transmitting device. He saw that if the same sequence were built into the receiver, it would be possible to receive much fainter signals than would otherwise be detectable.

The shift register sequence, in effect, repeats the signal over time, so that more total signal energy can be concentrated at the receiver. Over time, the true signal builds while the random noise largely cancels itself out.

When Golomb subsequently came to JPL, he worked with colleagues in turning his insight into a critical tool for space communications, and in 1961, scored a spectacular success. A powerful radio transmitter aimed a specially designed signal at Venus, while a giant radar receiver that had the same sequence programmed in, listened – and detected the echo: clear, despite pervasive noise along its multimillion mile interplanetary journey.

The radar bounce off Venus provided another remarkable scientific benefit. Radar means "radio detection and ranging." Using the received signal for ranging gave the most accurate measurement yet of Venus's exact distance. It also had the unexpected effect of measuring the true value of an "astronomical unit" – the basic distance unit for space travel, the average distance of the earth to the sun. The accepted value, as calculations made with the new tool soon established, was off by 1/1000 – an enormous error for these purposes.

The same radio system, mounted on a space vehicle (Mariner 9, on its way to Mars), provided a test of Einstein's theory of relativity when it sent a signal back to JPL that traveled close to the sun. While the sun's gravity would bend the path of a physical object, general relativity predicted that gravity would instead alter the radar pulse's frequency in specific ways. Analyzing the Mariner signal confirmed Einstein's prediction more completely than any previous test.

The method has become a basic tool for NASA. Decades later, other Golomb insights enabled the Mars rovers to send back clear video images of what they saw on the surface of the red planet 100 million miles away. The system on the Rovers is known as "Low Complexity Lossless Compression for Images," or LOCO-I, and was developed by a three-man team of engineers working at Hewlett-Packard Laboratories in Palo Alto. Golomb's name occurs more than 34 times in their original 2000 paper.

Golomb's close JPL colleague Andrew Viterbi developed a related mathematical technique for encoding messages that worked for terrestrial purposes called Code Division Multiple Access (CDMA), sending out multiple signals simultaneously over a very wide frequency band at low power. The Viterbi algorithm, which allows users to efficiently recognize the signals coming for one receiver, is now at the heart of the systems that permit a cell phone to pick up messages sent to it – and to no other phone – was the foundation of the Qualcomm company.

And USC Engineering plays a key role in the Golomb-Viterbi relationship. After fruitful years at JPL, Golomb decided to pursue a new role as a professor in Southern California. While at JPL, "I taught part time at Caltech, at UCLA and at USC, and I got offers from all three. Some people were surprised I chose USC, but the question I asked myself was the one I ask my students: 'where can you make the most difference?'"

The answer was USC, where his JPL colleague Andrew Viterbi had already been studying as a graduate student, ultimately receiving his Ph.D. in engineering in 1962. Golomb not only mentored him for his degree, Viterbi recollected, but assisted in such things as helping find a place for his parents to live. And it was in Golomb's car, on a drive north to the Bay Area, that he had made his decision to propose to his wife, Erna.

Golomb's own wife is Bo, whom he met in Scandinavia while on his fellowship. From Bo he learned Danish, which he speaks along with varying levels of Norwegian, Swedish, Hebrew, German, French, Russian and Chinese.

At USC, Golomb's pursuits, and those of the school, progressed together–inextricably bound and in tandem. Not long after his arrival at the school, Golomb settled into teaching and researching, followed by a drumbeat of honors, awards and occupation of key USC positions. In 1976, Golomb became the first USC faculty member to achieve the distinction of joining the National Academy of Engineering (NAE) whilst still on staff. In 1985, he received the Shannon Award, the highest honor in IT; in 2000, he was awarded the Richard W. Hamming Gold Medal of the Institute for Electrical and Electronics Engineers (IEEE), followed by his election to the National Academy of Sciences (NAS) in 2003; he is a fellow of: American Academy of Arts and Sciences (AMCAD), the American Association for the Advancement of Science (AAAS) and IEEE.

His colleague, George Bekey was at USC Engineering a year before Golomb's arrival. "I have known Sol Golomb for almost 50 years, since I arrived at USC in 1962, and my admiration for his knowledge, wisdom, and kindness has continued to grow. I have known several geniuses over the years, and Sol outshines them all, because he is so broad in his interests and abilities. He is a true polymathic scholar, with a deep knowledge of mathematics, communication theory, the classics, European history, architecture of Scandinavian churches, the Book of Genesis, multiple languages, wine growing, and puzzle solving."

Golomb has long been thinking broadly about the enterprise of education, both about engineering and in a broader context. One area of interest: the growing dominance of non-U.S. students in engineering, particularly at the postgraduate level, a situation that has changed markedly from when he was a 19 year old.

Demographics are one factor. For a long time in the United States, engineers and scientists were second-generation immigrants, whose parents sacrificed "so their children could have a spectacular education." Golomb's parents and Viterbi's – "Andy himself was born in Italy and came to the U.S. at age 4" – are examples. For the third and fourth generation, there are easier routes.

And the problem, Golomb says, is intensified because now American would-be engineers are faced with students from China and India, where the competition for few slots is extreme, so the top one percent of Americans are facing off against the top one tenth or one-hundredth percent from other places: "It is very hard for even the brightest American students to compete and be standouts in that group."

But beyond this: in the United States, Golomb said, despite the fame and prominence of Steve Jobs, Bill Gates and Mark Zuckerberg, "We have not conveyed the notion that engineering is a glamorous profession. It's sad that for a significant portion of the population, an engineer is someone who drives a train."

"There have been a few attempts to have TV series that would appeal to high school age kids that would glamorize specific incidents in general area of science and technology – these have to be subsidized – and how do you get people to watch – there are no obvious or easy answers."

Which brings up, perhaps, the story of Sol Golomb: not obvious, not easy but certainly an inspiration. "He is also a kind and thoughtful person; truly, a giant of a man. I'm proud to call him a friend and colleague," said Bekey. "USC is indeed fortunate to have him on its faculty."

POLYOMINOES

For Sol Golomb's entire career as a scientist, he has cherished a second love: games, specifically mathematical games. He has invented them, including games now internationally known that have become the inspiration for many others; he has written about them, and obviously he enjoys them. Perhaps his most famous contribution in the field is the open-ended puzzle resource called polyominoes. The name comes from the familiar tile game dominos, in which all the pieces are rectangles made of two squares. Golomb invented the term polyomino as a 22-year-old Harvard student to refer to tiles made of three, four or more squares.

Polyominoes are the shapes that players of the now-ancient computer game Tetris have to assemble into flat layers; they are also a fruitful source of mathematical problems. And Golomb has literally written the book on them: Polyominoes (Princeton University Press, 1996).

THE MANY FACETS OF SOL

IN THE BEGINNING
At 80, teaches freshman seminars — one on puzzles ("Puzzles, Patterns, Games and Illusions"), one on the Book of Genesis.

THE WUNDERKIND
Graduated Johns Hopkins at 18; published a book on space signaling that JPL referred to as its "Bible" at 32.

THE GREAT COMMUNICATOR
Bounced a radio signal off Venus, produced best test yet of Einstein's theory of relativity, work lead to first transmitted images from Mars.

THE LEGEND
"Sol is one of the greatest living American scientists. He has enriched our university and our school immensely."
—Dean Yannis C. Yortsos

THE GAME-MASTER
Analysis and popularization of polyominoes led to world use, and the video game Tetris. Created a hybrid of chess and checkers called "cheskers."

THE POLYGLOT
Speaks English, Hebrew, Danish, Norwegian, Chinese, German, French and Russian. Learned Danish from wife, Bo, whom he met during his Fulbright stay in Scandinavia.

THE ORIGINALIST
Work at the basis of compact discs, wireless including cell phones, secret codes, supersensitive radar and more.

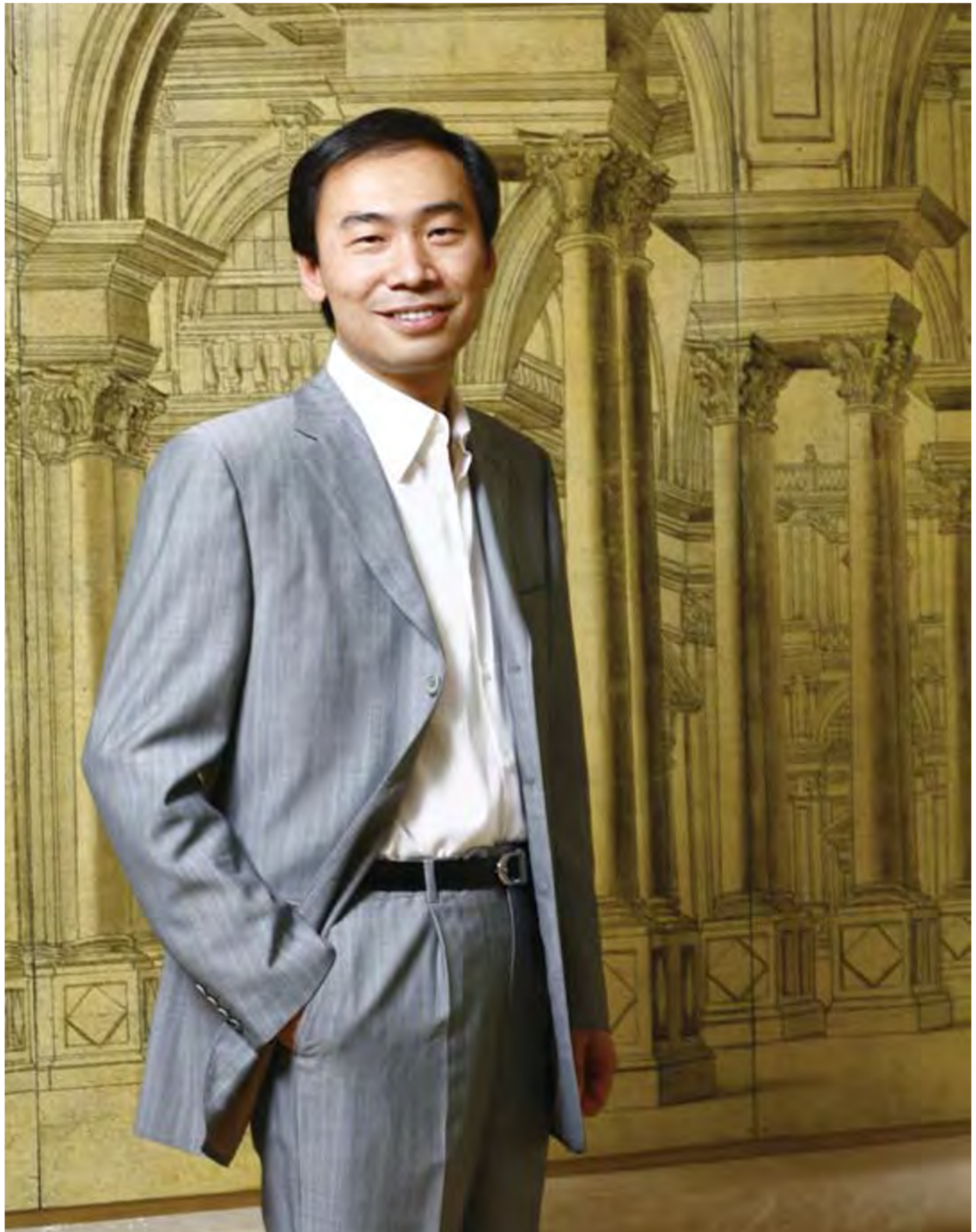
THE HONOREE
Member of the NAE, NAS, American Academy of Arts & Sciences; winner of Shannon Award, Hamming Medal, Procter Prize, USC Presidental Medallin and much more.

CHARIOT RACE

During the '70s and '80s, the E-Week chariot race was among the fondest memories of many USC engineers. According To Raymond Lowe (BSEE '84, BSEMT '93), all manner of engineering clubs, fraternities and societies would compete for Ben-Hur-esque glory, designing and building the perfect chariot or rickshaw-based transport, assigning two runners and a jockey to complete one full lap around the engineering quad.

"The lightest guy was always the jockey," said Lowe, "and that happened to be me. If the handle broke or the two runners lost control, the jockey was in a bad place. Our chariot actually broke, and I ended up flat on my back . . . the mechanical engineers always won."

PHOTOGRAPH COURTESY OF USC ARCHIVES



Fire in Two Valleys

Former Silicon Valley entrepreneur turned V.C., Feng Deng (MS '93), is looking to ignite the Chinese Silicon Valley

by Adam Smith

It was 1985 – nearly 10 years after Chairman Mao's death and the end of the Cultural Revolution.

Twenty-two-year-old Feng Deng sat in his room at Tsinghua University and read stories about another revolution, this one some 11,000 miles away.

His roommate gave him the book, a thin Chinese translation – "Fire in the Valley: The Making of the Personal Computer." The firebrands had names like Jobs, Noyce, Grove and Gates.

It was the first time he'd ever heard of a place called San Jose – "In China, our English wasn't so good, we called it *sanjoze*." It was also the first time he learned another curious word – entrepreneurship. That concept, for Deng and his fellow classmates, simply didn't exist.

"These people changed the world," said Deng. "They created things and changed the world. While in China–the [way] people's lives [were like] at that time–after graduation, you [didn't] look for a job. The government [would] say, 'Hey, your background is in this area; we'll give you a job over there.' They allocated jobs to the graduates of that time."

Deng read "Fire in the Valley" twice, leading to a bit of arson in his own mind, namely to the idea that he couldn't choose his own path.

Half a lifetime later, Deng's path has hopscotched across the Pacific Rim, first as a USC Viterbi student (MS in Computer Engineering, '93), then as a Silicon Valley entrepreneur with Netscreen Technologies and today as the co-founder of Northern Light Venture Capital, one of China's leading investors in Zhongguancun – the Silicon Valley of China.

Today, one of his greatest ambitions is to fashion a bridge between his two alma maters, USC and Tsinghua. Deng imagines a future where highly skilled technical students from China can receive a dual master's degree from both institutions: one year at Tsinghua and one year at USC, where they gain exposure to "state of the art research, innovation and–above all–creativity."

For Deng, gone are the days of *bukang bubei* – the instruction he received from the Chinese state on how to interact with Westerners during the 1971 Nixon visit. *Not too hot, not too cold, not humble, not arrogant. Give as much information as required – politely – and then go.* Deng, the product of a global education, is now among its principal cheerleaders.

In contrast to his time at USC Viterbi, creativity, in Deng's view, remains a challenge for the current Chinese education system. "I feel so much sympathy for the current Chinese students," said Deng. "They study so hard; it's so competitive. For an elementary school student, they start at probably 10-12 hours per day, seven days a week."

Deng considers himself somewhat fortunate that he came of age in a People's Republic of China that, comparatively, was only just beginning to re-embrace rigorous state examinations in the wake of the Cultural Revolution.

One of the defining moments of his childhood, in fact, was the 1969 Sino-Soviet border conflict. Fears of an imminent Soviet invasion prompted a massive state-ordered evacuation of Beijing. Within three to four weeks, all of the city's universities and government officials, including Deng's family, had been re-located south to Hubei Province.

But for Deng, that two-year exodus wasn't exactly a time of terror. It was a time of exploring the Hubei countryside, of learning to swim in the Yangtze River, of exploring the relics of ancient wars and watching movies.

"It was actually [a] pretty happy [time] for me," Deng laughs. "Because we [didn't] have to study hard."

Today's current crop of Chinese students is more than making up for any shortfalls in studiousness. But "indigenous innovation," according to Deng – whose Northern Light has backed over 60 Chinese start-ups – remains a concern.

"If you think about Internet search," said Deng, "companies like Google invented it. Baidu [Chinese search company] makes it localized, but the big idea came from the U.S. Solar PV was invented in the U.S. and other countries. China is not the initial inventor, but they use their lower costs, manufacturing base to make it faster."

However, Deng notes, that's only an incomplete picture. China knows it cannot compete on price forever and is moving at an equally high velocity to embrace true innovation. He sees a landscape where a perfect storm of V.C. money flooding China, Chinese universities flush with state research dollars, and perhaps more importantly, students returning from USC and other premier American research universities might mean more Haiers and Lenovos.

"We have so many overseas students going back to China; they brought back a lot of the research and industry experience to China."

For Deng, that remains among his strongest impressions of USC: "The way we learned is not just from the books. We learned from research that was very close to industry. We learned from the student circles."

Under the tutelage of Alvin Despain, those "student circles" at USC were like a mini United Nations. Over 20 Ph.Ds. from Asia, Europe and the United States gathered together in labs. It was a clearinghouse of ideas and worldviews unlike anything Deng had previously known.

Suddenly, the old ideas of how to talk to foreigners began to falter. Bukang bubei was dead. Another casualty of the fire.

THE EVERLASTING STUDENT *Feng Deng, seen here last May, delivered the keynote address at the 2012 USC Viterbi School Graduate Commencement Ceremony: "When I graduated from this engineering school, nobody even knew words like 'Internet firewall.' Never mind how to build one. A few years later, at Netscreen we built the best firewall in the world simply by continuously learning. Because learning is the engine that drives innovation."*

GLOBETROTTER *Amazed by the Promethean stories of Robert Noyce and Steve Jobs, Feng Deng criss-crossed the Pacific — entrepreneur in Silicon Valley, venture capitalist in China's Zhongguancun.*

PHOTOGRAPHS COURTESY OF FENG DENG

The Quiet Man

Mike Markkula on co-founding Apple and how USC got him to think different

by Adam Smith

At age 33, Armas Clifford "Mike" Markkula Jr. was already retired.

A millionaire from stock options as a marketing manager for Intel, he spent his days teaching himself to read music for guitar – Peter, Paul & Mary and John Denver – and building custom wood furniture for his A-Frame cabin in Lake Tahoe.

Said Markkula, "Every Monday, I'd help people write business plans and find financing to start companies. I thought it was fun. But I only did it Mondays."

One Monday, he pulled into the driveway of Paul and Clara Jobs' home in Los Altos.

Markkula entered the garage, looked past their unkempt 22-year-old son, Steve, and his buddy, Steve Wozniak, and pondered the machine on the workbench.

Markkula, the USC trained engineer, knew it was "a massive achievement."

Garages had always been a bit of a sacred space to Markkula. When he was a kid, growing up in quiet 1950s' Burbank, his father, a former Lockheed engineer turned orthotist, used to hang out in the garage on the weekends. They didn't talk much. They would just invent. The common refrain became: "How are we going to make this thing work?"

Markkula saw something he could make work: the Apple II. The first computer with a color TV display. The first semiconductor random access memory (RAM). First single board computer – everything but the power supply on a single printed circuit board. "The circuit design was absolutely brilliant," said Markkula, "it takes a 'Tommy Techie' like me with years of circuit design experience to appreciate what Woz had done."

He had a vision: "We can make a Fortune 500 company in less than five years. No one had ever done that in the history of American business. And we did it."

As co-founder of Apple alongside Jobs and Wozniak, Markkula wrote Apple's first business plan. He became their first investor, conceived their core values, wrote early software, became arguably one of Jobs' greatest mentors and, as both chairman and CEO, played a critical role for the next 20 years.

"Apple was started with a really huge idea in mind," Markkula said. "We knew we had to grow at an unheard of pace. We had to get big enough so that when IBM finally entered the marketplace, they couldn't squash us."

Though many Apple historians, including Jobs' biographer Walter Isaacson, depict Markkula as a "father figure" to Jobs, he brushes it aside. "No, I did mentor him a bit. I tried to channel his good things and minimize his not so good things. That worked out pretty well for quite a few years."

But despite his bona fides as an investor, entrepreneur and guiding force in one of the most successful tech companies on the planet, in his heart, Markkula remains an engineer. He thinks like an engineer, consumes the world's problems like an engineer, and USC is inextricably bound up in that.

"In the USC Engineering School," said Markkula, "they literally force you to learn how to think. If you don't learn how to frame a problem and think it through – man, you're not going to get through there. That's an extremely valuable talent. I used it all the time in my career from little things to big ones. Know what the variables or the parameters of the problem are. Know exactly what you're trying to solve."

The young man that completed his bachelor's degree in 1964 and master's degree in 1966 – both in electrical engineering – never dreamed about being chairman of a computer empire. "I just wanted to be the greatest engineer I could be, " he reflected 46 years later. "To me, that's fun. That's enjoyable. To have challenging things to engineer and challenging problems to solve."

Even today, by his own admission, he stays awake at night thinking about engineering problems, pondering cosmology, genetic engineering and the latest killer app for the iPad.

"I'm deliberately trying not to start another company," Markkula laughs. "My mind comes up with ideas when I see a problem. It's just my nature. I try to give ideas away to someone, hoping they'll start a company instead. I'll give you an example: I really would like to see someone start a company named Quiet. And the first product they should make is an almost silent leaf blower. The technology is available. The same technology could be used to make a quiet chainsaw or a quiet lawnmower. I think it would make for a huge company. I probably have a half a dozen ideas like that."

ENGINEERING ME

Name: Armas Clifford "Mike" Markkula Jr.

Class Years: B.S. EE '64; M.S. EE '66

Titles: Engineer, entrepreneur, co-founder and chairman of Apple, Inc. (1977-1997)

Toughest USC class: Probably Thermodynamics. The professor said, "If you're not a mechanical engineer, you can't get an A in this class." Of course that piqued my competitive spirit. So I got an A on every exam, an A on every homework — damn if he didn't give me a B!

On selling the Apple II: I wanted people to understand that Apple II was not just a game machine. You could do things worthwhile with it. So I wrote three programs for it: ColorMath, teaching young kids to add and subtract; the second one was CheckBook, and it balanced your checkbook; the third was called Finance; it did loan payment calculation, internal rates of return. *I loved doing that.*

On creating the Apple culture: We created something called Apple values, and there were 10 of them. When people would interview, one of the questions we might ask would be: "Are you the kind of person who if you came in Monday morning and your cubicle shrunk by three feet — would that make you mad?" We were always changing office space because we never quite had enough.

On seeing Apple become ubiquitous: I'm just proud it is what it is. It's been a lot of years since 1977. The time it hit me the most, I was walking down the street in Hong Kong. Must've been 1980. One of those great big buses went by — and on the back of the bus it had this huge, color Apple logo. I went, "Damn! – they even know about us over here in Hong Kong."

Music to engineer by: Diana Krall, Antonio Carlos Jobim, and various jazz artists

Heroes: Go read a book called "As I See it" by J. Paul Getty. Getty's philosophy of dealing with people was spot on. He wouldn't give people a job to do that he couldn't do himself.

I wish I'd invented: An extra hour for every day.

Things I'd save from the fire (most prized possessions): My wife, Linda. Everything else can be replaced.

In the next 10 years . . . Genetics!!!! I think genetic engineering is going to knock our socks off. It's just immense. It wouldn't surprise me if it doubled or tripled our average lifetime.

PHOTOGRAPHS COURTESY OF MIKE MARKKULA

Libya's New PM: A Viterbi Engineer

After 42 years of Col. Muammar el-Qaddafi, electrical engineer Abdurrahim El-Keib (MS EE '76) navigates Libya's future.

by David Lowenstein / Daily Trojan

The interim prime minister of Libya, Abdurrahim El-Keib, received his master's degree in electrical engineering from USC Viterbi School of Engineering in 1976.

Keib was elected as prime minister in October 2011 by the National Transitional Council, the de facto governing body of Libya.

After earning his master's degree, Keib went on to earn his doctorate from North Carolina State University in 1984.

After briefly teaching at the University of Tripoli, Keib was exiled by former Libyan leader Col. Muammar Gaddafi and fled to the United States, where he still holds citizenship.

Keib taught electrical engineering at the University of Alabama and then moved to United Arab Emirates, where he chaired the electrical engineering department at the Petroleum Institute in Abu Dhabi.

When the uprising against Gaddafi began in February, Keib returned to Tripoli where he helped fund and organize the rebel forces. Keib was selected to represent the capital city of Tripoli for the NTC.

Yannis C. Yortsos, dean of the Viterbi School, said he is proud of Keib and hopes his experience at USC helps guide him in his new position.

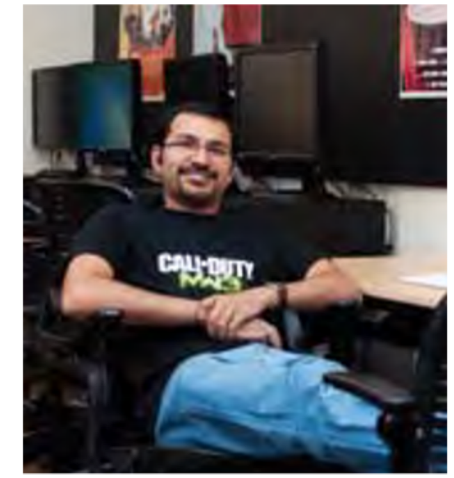
"As Libya enters a new promising chapter in its history, we wish him the best in restoring democracy and bringing a bright future for the Libyan people," Yortsos said in a statement. "We are hopeful that the Trojan spirit and values will guide him in the difficult but exciting path of national rebuilding."

Keib will remain in power until democratic elections are held in Libya, according to the NTC.

Along with unifying Libya, Keib is addressing the increased pressure from human rights group to take action against forces accused of committing inhumane crimes.

PARADISE *Tens of thousands of years ago, the Sahara desert, which now covers roughly 90% of Libya, was lush with green vegetation. It was home to lakes, forests, diverse wildlife and a temperate Mediterranean climate.*

PHOTOGRAPH COURTESY OF CORBIS IMAGES



Engineering "Modern Warfare"

Recent grad has worked on bestselling games

In December of 2011, video game "Call of Duty: Modern Warfare 3" broke industry records, passing $1 billion in sales in just 16 days. By comparison, the popular 3-D movie "Avatar" took 17 days to reach the same milestone.

Basking in the game's meteoric rise was Bharathwaj "Bat" Nandakumar, 27, who served as online engineer on the Activision Blizzard first-person shooter game. A 2007 graduate of USC Viterbi's Masters of Computer Science program, Nandakumar only decided to pursue gaming as a career several years ago. Now, he has five Activision games to his credit, including some of the most popular video games of all time, "Call of Duty: Black Ops" and "Call of Duty: World at War" among others.

Nandakumar arrived at USC from his hometown of Chennai, India in the fall of 2006. A graduate of Hindustan College of Engineering with a bachelor's degree in electronics and communications, he hoped to pursue a Ph.D. in robotics. But when those plans changed, he says USC Gamepipe Director Michael Zyda helped him focus his sights on a gaming career. Having taken several games classes already, Nandakumar enrolled in the Network Games course and did research with Zyda to broaden his knowledge in programming and networking.

HIGHLIGHT REEL *As an online engineer, Nandakumar is responsible for creating and handling multiplayer features. For "Call of Duty: Black Ops" and "Call of Duty: Modern Warfare 3," Nandakumar helped to develop a new game feature called "theater mode," where players can save and record clips of gameplay for playback and sharing in-web and online.*

OBITUARIES

DR. ROBERT "BOB" M. GAGLIARDI, PhD, age 77, Professor Emeritus of Electrical Engineering at the University of Southern California, died Friday, February 3, 2012 of blood cancer at his home in Palm Desert, California. As the sole proprietor of RMG Consultants for over 40 years, he was honored for noteworthy service by both NASA and the IEEE. Bob was also a beloved faculty member of the USC Viterbi School of Engineering, where he taught satellite and optical communications for more than 45 years. Bob is survived by his high school sweetheart and beloved wife of 54 years, Mary Anne (Lynch) of Palm Desert; son Robert Gagliardi, Jr. of Los Angeles; daughter Cinda (Steven) Kemper of San Diego; daughter Sherri (Marco) Flores of Murrieta, California; and four beautiful grandchildren—Sean, Marina and Ryan Kemper and Sayla Flores.

DAVID GAINER, Ret. USAF Chief MSGT, 63, died Thursday, February 2, 2012. David received his B.A. in Financial Management from Texas Lutheran University and his M.S. in Systems Management from University of Southern California. While in the Air Force, David received a Bronze Star for his service. David was also a longtime community activist for gay and human rights, board member of Service Members Legal Defense Network and an active member of Cathedral of Hope. David is survived by his life partner David Guy, daughter Brie Gainer, granddaughter Ilona Sunshine Hawkins, brothers Robert Gainer of Kentucky and Rodney Gainer of Florida, former wife Lilia Gainer of San Antonio, nieces, nephews, cousins and friends.

OTTO ALSTERGREN SANDBERG (BSCE '51), 85, died Thursday, January 26, 2012 at Ollie Steele Burden Manor in Baton Rouge. As the general manager of plant services with Borden Chemical in Geismar, Otto helped oversee an outstanding plant record. He retired in 1991 and became a consulting engineer in European operations. Otto was also a longtime member of Rotary, a member of Sons of Norway, Lief Erikson Lodge 2-001 and a member of American Institute of Chemical Engineers. He is survived by his wife Catherine Daigle Sandberg, daughters Ellen Parr Sandberg, Suzanne Parr Sandberg and Signe Parr Sandberg, son Lars Parr Sandberg and his wife Lynn, six grandchildren, three great-grandchildren, sister Signe Bach-Gansmo and brother Hagbart Alstergren Sandberg.

GEORGE RAYMOND SHEPHERD, 85, died Sunday, January, 15, 2012 at Willow Springs, California. Since becoming a pilot for the United States Navy, aviation was George's greatest passion. He was also recruited by the U.S. Air Force and held a long-time career with Arco, eventually becoming its vice president. George is survived by his children and their families: Kathy and her husband Bob Blankenship; Debby and her husband Rod Green; Ron Shepherd and his wife Donna; Son-in-Law Greg Schneeweiss; eight grandchildren and 12 great-grandchildren.

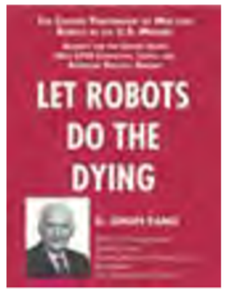
WARREN W. SIMONDS, 84, died Wednesday, January 25, 2012. After graduating from the University of Southern California with a degree in foreign service, Warren served the United States in World War II as a radio operator in the Army Air Corps. Warren later moved to Baton Rouge, where he served as an administrator at Baton Rouge General Hospital and president of the Louisiana Hospital Association. Warren was actively involved with the Boy Scouts of America for over 20 years as well as the Kiwanis Club in Baton Rouge for more than 50 years. He is survived by his beloved wife of 56 years, Elizabeth J. Simonds, of Cumming; three cherished children, William P. Simonds, Carolyn S. Cagle and husband Kenny, and Jonathan R. Simonds and wife Kathy; 10 much loved grandchildren and two great-grandchildren; his brother, Dr. Robert Simonds and wife Betty, of Mercer Island, Washington; and his niece, Monika Simonds.

MANBIR SINGH, 67, Ph.D, died in December 2011 while visiting family in India. A pioneer in biomedical imaging technology and beloved faculty member at the USC Viterbi School of Engineering, Manbir joined the Department of Radiology at USC in 1977 and received a joint appointment in Biomedical Engineering in 1988. He was one of the first investigators to demonstrate the synergism of X-ray CT and nuclear medicine single photon emission computed tomography (SPECT) imaging in detecting and visualizing both the anatomy and function of the heart. Dr. Singh was also the founding director of the graduate program in Biomedical Imaging within the department of Biomedical Engineering. He is survived by wife Heidi and their son, Kabir, 24, of Los Angeles, California.

Robot Warriors

A look at robotic systems in use by the U.S. military

by George A. Bekey, founder, USC robotics program



This is a remarkable book by a remarkable man. It is an almost encyclopedic review of the robotic systems in use by the U.S. military, on the ground, on and under water, in the air and in space. Even more important are Simon Ramo's predictions about the future use of autonomous and semi-autonomous systems. In view of his record in various areas of engineering and science, these predictions should be taken seriously. Among his many achievements, he is the co-founder of Ramo-Wooldridge Corporation (later renamed Space Technology Laboratories). Ramo was one of the founders of the National Academy of Engineering. Now, at age 99, he is the Presidential Chair and Professor of Electrical Engineering at USC.

The basic thesis of the book is that in the future the American military establishment will be characterized by a cooperative partnership between humans and robots. Ramo believes that our future security depends on developing such partnerships, since it will no longer be possible to defend the U.S. (and participate in possible future wars) with an entirely human Army, Navy and Air Force personnel, for three reasons: (1) cost: in view of spiraling costs of defense and the severe national deficit; (2) the increasing reluctance of the American public to accept large numbers of battle casualties; and (3) the need to reduce the number of American forces stationed in other countries. Ramo points out that we have 800 installations in 100 countries, with large contingents of military personnel in such countries as Germany, Japan, Italy and the Republic of Korea, not counting personnel in Afghanistan.

The following four chapters deal with today's robots in air and space, in surface ships and submarines, and on land. Unmanned air vehicles (UAVs), frequently referred to as drones are much in the news. While there were essentially no UAVs a decade ago, there are currently more than 7000 in regular use, and the number is growing. A similar situation exists with respect to unmanned ground vehicles (UGVs), surface water vehicles, and unmanned underwater vehicles. Chapter 8 concentrates on the "Information Problem." Ramo points out that control of large numbers of robots in the air, on land and in the water will require very large allocations of bandwidth and dramatic increases in communication rates. Additional bandwidth will be required to prevent cyber attacks against our robot forces. The issue of jamming and potential attacks against our communication infrastructure is discussed at length. It is not clear that such increases will be possible.

The book emphasizes the author's conviction that any autonomy on the part of the robots will be limited, and that in the coming human-robot partnerships, the ultimate decision to fire a weapon will always rest with the human partner. Many robotics researchers, including myself, are not sure. It is my belief that financial pressures and personnel limitations (i.e., providing a sufficient number of highly trained humans to control the growing number of robots) will lead to increased battlefield autonomy on the part of intelligent robots, capable of learning andmodifying their behavior. Such autonomy will lead to a host of ethical issues as well as new problems in the design of rules of engagement, in addition to those discussed in this book.

LET ROBOTS DO THE DYING by Simon Ramo imagines a future where American security depends upon cooperative partnerships with robots.

How To Prevent The Next Titanic

Shifting our focus from ships to the ocean itself

by Professor Costas Synolakis

This past April marked the 100th anniversary of the sinking of the Titanic. The story keeps enthralling us, despite the fact that so few of us travel by large ocean liners. Recent events provide clues on why ship disasters captivate us. In January's sinking of Costa Concordia off the Isola de Giglio in Italy, 32 died, a surprising number given that the ship was only five years old and the accident occurred within a few hundred feet of the nearest port.

The Costa Concordia captain claimed that the undersea rock formation his ship hit was uncharted – in other words, it was not present in navigational charts. Similar claims have been made in other recent marine disasters. In 2000, MSS Express Samina, a ferry with 534 passengers, sunk off the island of Paros in the eastern Mediterranean. In 2005, the submarine U.S.S San Francisco hit an unmapped seamount about 350 miles south of Guam. In all these disasters, the images are unnervingly similar. Large gashes at the exterior of the ship are suggestive of what the stricken Titanic must have looked like. In all cases, accidents occurred in calm seas, and captains blamed faulty navigational charts and unexpected currents.

The demise of ships has always precipitated design improvements and regulations; we are rapidly getting to the point of diminishing returns in terms of design without huge added costs; to improve marine safety, we need to focus on the sea itself.

The shipping industry should take note. There are Titanic-sized gaps in our knowledge of the details and motions of the seafloor. Rogue waves can appear without warning and can literally break ships in seconds, yet they are elusive and even less understood than tsunamis; they were considered mythical before 1995, when first measured. Floating weather stations in the deep sea (buoys) that transmit real time data for winds, sea surface heights, water temperatures and currents can vastly improve weather forecasts and anticipate rogue waves, yet are sparse. The National Oceanic and Atmospheric Administration operates a large network of buoys in the Pacific, but poor maintenance is an issue: buoys are sacrificed to reduce "big government". As they go offline, the quality of marine forecasts diminishes markedly.

As the cruise and shipping industries expand, they should share the costs of marine-weather forecasts and of high resolution mapping of the seafloor. Well-built ships are no match even for benign sand bars or "perfect storm" waves. Design improvements are without exception addressing lessons learned from the last disaster, but it is hard to anticipate unknowns. A ship-based real time system transmitting measurements of sea surface temperature, salinity and weather information costs less than $50,000 per installation. Yet, even if deployed in 10 percent of the ships industry, it can lead to dramatic improvements in the accuracy of sea-state forecasts and improve safety substantially.

The legacy of Titanic is not only the professionalism of the crew and its orchestra – which kept playing – but that the inconceivable can and does sometimes happen. Improving the odds of survival of ships and passengers relies increasingly on learning more about our waves, winds and seafloors.

We Must Cooperate on Nuclear Safety

Radiation fallout doesn't care about national boundaries.

by Professor Najmedin Meshkati

A nuclear accident anywhere has the potential to be a nuclear accident everywhere. That is why it is encouraging that the United Nations is examining the lessons of the accident at the Fukushima Daiichi power plant in Japan, the worst nuclear disaster since Chernobyl in 1986.

The Chernobyl accident in Ukraine was attributed initially to workers who shut off key emergency equipment during a test and then ignored warnings that the reactor was out of control. The accident in Japan followed a powerful earthquake and tsunami that swept over the northern part of the country. But both disasters were also the result of failures in the safety cultures of Japan and the Soviet Union. Japan's nuclear regulatory agency, for instance, was never really independent from the nuclear industry or the country's powerful Ministry of Economy, Trade and Industry. The plant's operator, Tokyo Electric Power Company, had a long history of disregarding safety concerns and a woefully weak safety culture but was allowed to operate with minimal government oversight.

What we need now are tough, system-oriented safety standards and much closer cooperation between countries and their regulators. The United Nations should also urge its members to forge a balance between national sovereignty and international responsibility, when it comes to nuclear safety. Radiation fallout doesn't discriminate or care about national boundaries.

This approach can begin at a regional level. As a start, Persian Gulf countries should be entitled to know the details of the safety measures for Iran's just-completed nuclear reactor in the coastal city of Bushehr and for the four reactors under construction by the United Arab Emirates in Abu Dhabi. Persian Gulf countries would all be vulnerable to radiation fallout and water contamination from a nuclear accident in either of those countries. The same logic also applies to the Dimona reactor in Israel and ones planned in Egypt and Jordan. All three countries should open their books on the safety of those plants. Such an initiative would force these neighboring countries to engage in a mutually beneficial nuclear diplomacy. One of the consequences might be to build better overall better relations.

The disasters at Chernobyl and Fukushima are sober reminders of what Nobel physicist Richard P. Feynman said in the context of another technological system failure, the space shuttle Challenger explosion in 1986: "When playing Russian roulette, the fact that the first shot got off safely is little comfort for the next."

A full version was originally printed in The New York Times — September 2011.

ILLUSTRATION BY PETER BOLLINGER

PHOTOGRAPH BY COREY ARNOLD

The Many Lives of Engineers

As a nod to the NAE's "Changing the Conversation" initiative, we go outside the laboratory – a look at the myriad talents, interests and dimensions of the USC Viterbi engineer.

Photography by Noe Montes

GEOFF SPEDDING
Chair, Department of Aerospace and Mechanical Engineering

"Ever since lying on my belly on a wooden board in the rough and tumble of cold surf on a pebble beach on family holidays in England, I have enjoyed the idea of surfing. I like the calm and watchful periods with the adrenaline rush and accelerations in between.

"I like the fact that it is its own universe."

CAROLINE WIN
B.S., biomedical engineering '13

WADE YAMAZAKI
B.S., biomedical engineering '12

"I was drawn into the world of Taiko because of the tremendous opportunity for individual growth it involved and encouraged. Boosting my confidence and increasing my passion for Taiko, my first performance allowed me to overcome stage fright. I loved the connection I felt with the group while performing, the power of striking the Taiko drums..."

—Caroline Win

TODD BRUN
Associate Professor, Ming Hsieh Department of Electrical Engineering

"The process of acting is very different than the process of research. This may have helped me find some balance in college and graduate school, and avoid burning out. But my experience on stage has been invaluable in teaching and public speaking."

TERRY BENZEL
Deputy Division Director, Computer Networks USC Information Sciences Institute (ISI)

"Riding a Harley with my husband and the Los Angeles Harley Owner's Group (LA1 HOG) provides me an outlet away from my computer...We ride in a staggered formation, and watching a group of 30 bikes execute maneuvers in unison and following formation is a thing of beauty."

'N SWENC (ALL FEMALE A CAPELLA GROUP)
Members of the Society of Women Engineers (SWE)

"...collaboration is taking on a new level of importance in our ability to create the best technology, structures, and systems out there. In this same way, 'N SWEnc is about taking each of our individual talents and bringing it together to create something better.

"For me, it's a perfect example of Aristotle's belief that 'the whole is greater than the sum of its parts' – a mantra I try to bring to Viterbi every day."

—Brittney Pottenger (USC SWE president)

With Patrick Soon-Shiong

Visionary philanthropist and surgeon on innovation and the

You once said: "The most important advances in medicine would be made not by new knowledge in molecular biology . . . It'll be made by mathematicians, physicists, computer scientists, figuring out a way to get all that information together." What did you mean by that?

The advent of genomic and proteomic sequencing has created the possibility of truly personalized medicine, but to turn that into reality means analyzing terabytes of data, identifying the key information required for a clinical decision and transmitting that information to physicians and patients at the point of care. That is a complex systems engineering challenge and requires complex algorithms, dedicated high performance computing and lots of capacity for transporting and storing massive data sets.

When you were working on diabetes and cancer, when did you first realize the necessity for an engineering solution?

Twenty years ago, when I was developing a way to transplant islet cells for diabetic patients, I needed to create a zero gravity environment, here on earth, to work on those cells. I turned to JPL and NASA for the solution, which turned out to be a brilliant, but simple piece of mechanical engineering.

You have been associated with USC and the Viterbi School for almost four years. Tell us about your impressions.

I'm a fan. I've been impressed by the leadership, both of the university and the school, and I'm delighted that USC has emerged in recent years as a strong national institution and center of excellence.

Let's talk about innovation. As an inventor, where do your ideas come from? For example, what inspired your use of seaweed extract for diabetic patients?

It's hard to generalize. Ideas come in different ways. But many of the really revolutionary ideas in science come when people from different disciplines get together. I have always had a very varied group of friends and contacts, and that keeps me exposed to ideas from many different fields of activity.

Your father was a herbal doctor – what childhood memory of him still lingers in your mind?

As a young child, I would watch him dispense traditional Chinese medicines and I was fascinated by the whole idea of helping the sick. Watching and helping him is what made me decide at an early age that I would be a doctor.

Your recent chair gift funds a professor at "the intersection of engineering and medicine - specifically computer science, mobile vision or robotics." What excites you about that particular intersection?

Everything. There are infinite possibilities, from the systems engineering challenge of creating a completely new, integrated model of healthcare delivery, to the prospects for enhancing individual human capabilities: for example, helping the blind to see through machine vision and object recognition; or helping paraplegics to walk and badly injured people to regain the use of their limbs through robotics and mechanical engineering solutions.

You joined with Bill Gates, Warren Buffet and many others in the Giving Pledge. Describe a scene in the future – how would you like your generosity to manifest itself in our everyday lives?

To take a local example, when the Martin Luther King Hospital in South L.A. reopens, I would like patients there to have access to exactly the same up-to-date genomically-informed medical care and expertise as the well-heeled residents of Beverly Hills.

Every person experiences a couple of game-changing moments that essentially inform who they are today. What are yours?

There are so many. Soon after I qualified as a

GREAT EQUALIZER *Dr. Soon-Shiong, who developed and sold two multibillion-dollar pharmaceutical companies, was raised in South Africa under apartheid. Faced with early discrimination, he has dedicated himself to closing disparity gaps around the world through the vehicle of innovation.*

USC Viterbi
School of Engineering

University of Southern California
1150 S. Olive Street,
Suite 1510
Los Angeles, CA 90015

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Web: viterbi.usc.edu/mork

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213.740.4339

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213.740.0332

Sonny Astani Department of Civil and Environmental Engineering
213.740.0603
Web: viterbi.usc.edu/astani

Computer Science
213.740.4494
Web: Viterbi.usc.edu/cs

Ming Hsieh Department of Electrical Engineering
Web: viterbi.usc.edu/hsieh

Systems
213.740.4447

Electrophysics
213.740.4700

Daniel J. Epstein Department of Industrial and Systems Engineering
213.740.4893
Web: viterbi.usc.edu/epstein

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